STANDARDIZED CPUE OF BLUE SHARK (*Prionace glauca*) CAUGHT BY INDONESIAN LONGLINE FLEET IN THE EASTERN INDIAN OCEAN

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ABSTRACT

Standardized catch per unit effort (CPUE) as calculated based on commercial catches are the input data to run stock assessment models to gather useful information for decision making in fishery management. In this paper a Generalized Linear Model (GLM) was used to calculate relative abundance indices and effect of longline fishing gear configuration. The parameters used for standardization of CPUE were quarter, year, number of hooks between floats, latitude and longitude. Data were collected by a scientific observer program from August 2005 to December 2018. Most of the boats monitored were based in Benoa Port, Bali. Catches are often equal to zero because blue shark is a bycatch for Indonesian longline fleets. A tweedie model was selected because it has flexibility to the sample distributions. The results showed that the average scaled CPUE was 1.19. The CPUE pattern showed fluctuated during periods and reached the peak on 2006 with 2.09 and the lowest on 0.33 in 2011. The results from this study can demonstrate the catch variation of blue shark by Indonesian tuna longline fleets.

Key Words: Blue shark, standardized CPUE, GLM.

INTRODUCTION

Blue shark (*Prionace glauca*) is one of the shark species that commonly caught by Indonesian longline fishery. As a highly migratory species, this fish stocks and their utilization are carried out by various countries. In the Indian Ocean, managing fish is carried out in countries that are members of the Indian Ocean Tuna Commission on these fish (IOTC, 2018). One of the method used is to calculate the catch per unit effort (CPUE) standardization. Assuming that the fishing effort per unit (CPUE) is calculated based on commercial data it is assumed to be proportional to abundance but also follows the capture power (Quinn & Deriso, 1999).

Nominal changes in CPUE over several years can reflect changes in abundance and capture rate. This happens because of several factors, namely changes in fishing technology and fishing grounds. If there is information about the factors that affect the catch, a statistical model can be used to calculate a standard CPUE value that reflects changes in abundance.

This CPUE standard can be used to evaluate fish supply status, or as input data in estimating fish stocks (Squires & Vestergaard, 2015). CPUE standardization had been applied to assess the stock status for swordfish (*Xiphias gladius*) and tuna (*Thunnus* sp.) on Indonesian longline fishery (Jatmiko *et al*., 2017; Setyadji et al., 2017; Sadiyah *et al*., 2012).

In GLM, the response variable is assumed to follow the probability distribution of the exponential family. In this paper the GLM are used to calculate the standard CPUE of the blue shark captured by the Indonesian longline fleet in the East Indian Ocean (McCullagh & Nelder, 1989). There are four alternative factors that need to be examined: quarter, year, hook between float (HBF) and lattitude-longitude. The results are useful for assessing the stock status of blue sharks, which are important fisheries resources in the Indian Ocean.

MATERIAL AND METHODS

Data and Exploratory Analysis

Tuna long line in Indonesia have gross tonnage between 14 - 149 GT with specifications consisting of main line, branch line, float line, hook, float, radio buoy and others. The material used for the main strap and branch rope is generally monofilament with a diameter of 3 mm and 2 mm. In addition to monofilament, some of the materials used for main and branch ropes are nylon, kuralon, polyamide, polyethylene, kuralon, skyama and longyarn and a combination of these materials. The fishing line used in general is No. 4

In general, longline tuna fishing operations consist of setting and hauling. Between the stocking and drawing of the fishing line there is a time lag usually called the soaking time. The activities of tuna longline fishing based in Benoa Port are generally carried out in the morning at 5:00 a.m. - 10:00 p.m. with a soaking time of about 3-7 hours and fishing hauling activities for 7-13 hours.

The data collection includes the number of captured blue sharks, the number of hooks and the location of the fishing collection, obtained by the Global Positioning System (GPS) device. In addition, scientific observers also noted long line characteristics such as the number of hooks between buoys, the length of the buoy line, the length of the branch line, and the length between the branch lines. Catches per unit of effort are calculated as U = (C / f) × 1,000, where C is the number of fish captured in the fishing set, f is the number of hooks, and U is CPUE in the number of fish caught per 1,000 hooks (Klawe, 1980).

A summary of basic statistics regarding central trends and dispersion is calculated for all variables. Contingency tables and mosaic plots are used to evaluate the balance of database entries at the level of intersection of factors (eg year x quarter). Histograms and dispersion diagrams are used to assess the relationship between variables. Correlation coefficients between continuous variables are also calculated to identify redundant variables.

Models

Generalized linear models (GLM) can be written in matrix notation as the realization vector of the response variable; E is hope, g is a link function, is a parameter vector and is a design matrix of explanatory variables. The probability distribution for, and link functions must be pre-selected to calculate parameter estimates, which represent the effects of explanatory variables (e.g. years) (McCullagh & Nelder, 1989). The model used for the analysis is:

glm(formula = CPUE ~ Year + Quarter + Cat_HBF + LatLon, family = tweedie(var.
power = p, link.power = 0), data = bsh)

The explanatory variables considered in the model for standardizing CPUE are year, quarter, hooks between floats (HBF) and location (latitude and longitude). HBF was categorize into deep (> 10 hooks) and shallow (<= 10 hooks). Latitude and longitude were combined into LatLon. These variables are chosen as factors that influence the catchability level in the longline fleet. There is no separation between the Exclusive Economic Zone (EEZ) inside and outside Indonesia because fishing areas are still in the same area in the

Eastern Indian Ocean. The standard diagnostic plot is used to assess the installation of the selected model. All analyzes are carried out using the R software function.

RESULTS AND DISCUSSION

The fishing ground of tuna longline fishing were spread from coordinates 09°-18° S and 98°-117° E. The average number of hooks between floats tends to be stagnant from year to year with an average of 14 hooks and range from 11-19 hooks. The highest average occurred in 2005 with 19 hooks and the lowest was in 2006 with 11 hooks. The average number of total hooks used in one fishing operation was 1,300 hooks/set with ranges from 1,000-1,500 hooks/set. The highest number occurred in 2007 with more than 1,500 hooks/set and the lowest number occurred in 2011 with only 1,000 hooks/set (Table 1).

Nominal CPUE (N/1,000 hooks) showed very low number with the average of 0.6/1,000 hooks. The highest value occurred in 2018 with 1.2/1,000 hooks and the lowest value occurred in 2011 with less than 0.1/1,000 hooks. The pattern showed fluctuated from 2005-2013 then rose significantly from 2014 and reached the peak on 2018 with around 1.2/1,000 hooks (Figure 1). For the standardized CPUE (N/1,000 hooks) showed the higher average of 1.3/1,000 hooks. The highest value occurred in 2006 with 2.1/1,000 hooks and the lowest value occurred in 2011 with less than 0.3/1,000 hooks. The pattern also showed fluctuated throughout the years and appeared increased in 2018 with around 1.5/1,000 hooks (Figure 4).

Moreover, the proportion of zero catch showed high value from around 0.4 to almost 1.0. The highest value was occurred in 2011 with almost 1.0 and the lowest was around 0.4 occurred in 2018 (Figure 2). Overall, there was around 65% fishing operations did not caught blue shark. The relatively low number of blue shark caught by Indonesian tuna longline vessels showed that this species is bycatch from targeted tuna (Jatmiko *et al.*, 2015).

The summary indicators showed that all variables (Year, Quarter, Cat_HBF and

Latlon) were significantly affect the catch of blue shark ($p<0.05$) (Table 2). The fishing ground (LatLon) had important roles of the fishing operation due to the reducing the residual deviance in substantial value.

Indonesian longline fleets were mainly operated in south and west of Indonesian waters. This area was included in the eastern Indian Ocean. Therefore, the analyzed datasets cover a portion of the Indian Ocean stock and the standardize CPUE can be interpreted as a local alternate. However, the data and information from other spots which covering whole Indian Ocean will provide better assessment for stock status of blue sharks.

It is important to notice that the results of the model indicate that more information is needed to increase the information from the variation of blue shark fishing by Indonesian longline fisheries. The model did not met every time we attempt to adjust it using more parameters regarding the interaction between years and other variables. The lack of convergence often arises when the model is more than a parameter, when the data does not convey sufficient information to allow estimation of all parameters (McCullagh & Nelder, 1989).

The low decrease in proportional deviation shows that fishing ground (LatLon) was the most influence variable that affecting the catch of blue shark in longline fishery. However, other variables and information such as during the day when a longline is deployed in water (day or night), type of bait, size and type of hook, and if fishermen use light sticks to attract fish, it is necessary to better understand catch levels, and increase relative abundance index estimates . Therefore, Indonesian onboard observers are encouraged to collect more detailed data, which is very important for assessing the status of fisheries in the southeast, and the stock of Indian blue sharks.

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Table 1. Summary of observed fishing effort from Indonesian tuna longline fishery during 2005–2018. Results are pooled and also presented by year of observation.

Year	Trip	Sets	Total hooks	Hooks per set	Mean hooks per float	Mean Lat (S)	Mean Lon (E)
2005	9	108	157,065	1,454	19	14.3	111.8
2006	13	401	577,243	1,440	11	16.9	113.4
2007	13	265	406,135	1,533	14	17.0	103.5
2008	15	370	483,662	1,307	13	14.2	107.3
2009	13	283	323,042	1,142	12	11.4	113.2
2010	6	165	220,394	1,336	14	12.0	113.3
2011	3	105	110,384	1,051	12	13.7	117.4
2012	8	198	290,265	1,466	14	18.9	104.5
2013	7	210	231,994	1,105	13	12.3	114.9
2014	6	182	214,665	1,180	15	11.2	106.1
2015	5	148	172,463	1,165	14	10.8	103.8
2016	3	130	175,868	1,353	11	9.2	106.0
2017	4	139	192,188	1,383	15	14.9	98.3
2018	6	195	262,856	1,348	15	14.5	105.3

Table 2. Summary of indicators as calculated using Tweedie model. Number of predicted zero catches (zero), and *p* values as calculated using a Kolmogorov-Smirnov test.

```
        Df Deviance Resid. Df Resid. Dev       F    Pr(>F)
NULL                     2898     5727.0
Year    13   807.36      2885     4919.7 35.7542 < 2.2e-16 ***
Quarter  3    31.05      2882     4888.6  5.9589 0.0004782 ***
Cat_HBF  1   137.94      2881     4750.7 79.4150 < 2.2e-16 ***
LatLon  40  1629.58      2841     3121.1 23.4541 < 2.2e-16 ***
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 3. Summary of parameter estimations of Tweedie model. Terms: SE – standard error, p – p values as calculated using Z test to assess difference from zero.

```
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)       0.09364    0.31963   0.293 0.769569
Year2006          0.75450    0.22340   3.377 0.000742 ***
Year2007          0.68697    0.22065   3.113 0.001868 **
Year2008          0.51004    0.21792   2.341 0.019326 *
Year2009         -0.12099    0.26484  -0.457 0.647824
Year2010          0.55813    0.25654   2.176 0.029666 *
Year2011         -1.20562    0.66269  -1.819 0.068973 .
Year2012         -0.30194    0.26970  -1.120 0.262995
Year2013         -0.69414    0.32681  -2.124 0.033758 *
Year2014         -1.04238    0.30762  -3.389 0.000712 ***
Year2015         -0.36576    0.32005  -1.143 0.253213
Year2016          0.70284    0.27329   2.572 0.010168 *
Year2017         -0.24048    0.25792  -0.932 0.351219
Year2018          0.55172    0.22471   2.455 0.014137 *
Quarter2          0.51561    0.13546   3.806 0.000144 ***
Quarter3          0.41145    0.14554   2.827 0.004732 **
Quarter4         -0.01094    0.14752  -0.074 0.940868
```

```
Cat_HBFShallow   -0.74378    0.18562  -4.007 6.31e-05 ***
LatLon-10,105    -0.90981    0.23754  -3.830 0.000131 ***
LatLon-10,110    -1.47890    0.23273  -6.355 2.43e-10 ***
LatLon-10,115    -3.58519    0.25420 -14.104  < 2e-16 ***
LatLon-10,120    -3.46709    0.63296  -5.478 4.69e-08 ***
LatLon-15,100    -0.32532    0.44565  -0.730 0.465461
LatLon-15,105    -0.76151    0.25546  -2.981 0.002899 **
LatLon-15,110    -1.02590    0.24033  -4.269 2.03e-05 ***
LatLon-15,115    -1.89642    0.69763  -2.718 0.006600 **
LatLon-15,75     -2.13068    0.34547  -6.167 7.93e-10 ***
LatLon-15,80     -1.72388    0.78046  -2.209 0.027268 *
LatLon-15,85     -0.82131    0.56872  -1.444 0.148811
LatLon-15,90     -0.74115    0.90824  -0.816 0.414549
LatLon-15,95     -1.27720    0.73959  -1.727 0.084296 .
LatLon-20,100    -0.23075    0.34620  -0.667 0.505125
LatLon-20,105    -1.32125    0.28471  -4.641 3.63e-06 ***
LatLon-20,110   -21.56217 1889.54075  -0.011 0.990896
LatLon-20,85     -0.08893    0.37850  -0.235 0.814257
LatLon-20,90      0.18884    0.87190   0.217 0.828551
LatLon-20,95      0.51649    0.34980   1.477 0.139913
LatLon-25,100    -0.89388    0.36394  -2.456 0.014105 *
LatLon-25,105    -0.56386    0.72689  -0.776 0.437982
LatLon-25,85     -1.14306    0.91467  -1.250 0.211511
LatLon-30,100     0.94518    0.23213   4.072 4.79e-05 ***
LatLon-30,80     -1.08683    0.35291  -3.080 0.002093 **
LatLon-30,85      0.96676    0.29660   3.259 0.001129 **
LatLon-30,90      0.16612    0.42332   0.392 0.694772
LatLon-30,95      0.30768    1.12265   0.274 0.784056
LatLon-5,100     -1.01336    0.34197  -2.963 0.003069 **
LatLon-5,105     -2.00143    0.49752  -4.023 5.90e-05 ***
LatLon-5,110     -2.96645    0.60348  -4.916 9.36e-07 ***
LatLon-5,115     -2.15049    0.45124  -4.766 1.98e-06 ***
LatLon-5,120    -21.66633 1889.54075  -0.011 0.990852
LatLon-5,125    -21.37131  408.74995  -0.052 0.958306
LatLon-5,85     -20.01953 1889.54075  -0.011 0.991547
LatLon-5,90      -1.41187    0.28615  -4.934 8.52e-07 ***
LatLon-5,95      -0.63926    0.24281  -2.633 0.008515 **
LatLon0,100     -20.27524 1889.54077  -0.011 0.991439
LatLon0,85      -20.01953 1889.54075  -0.011 0.991547
LatLon0,90       -2.29557    0.45099  -5.090 3.81e-07 ***
LatLon0,95       -2.89881    0.55278  -5.244 1.69e-07 ***
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

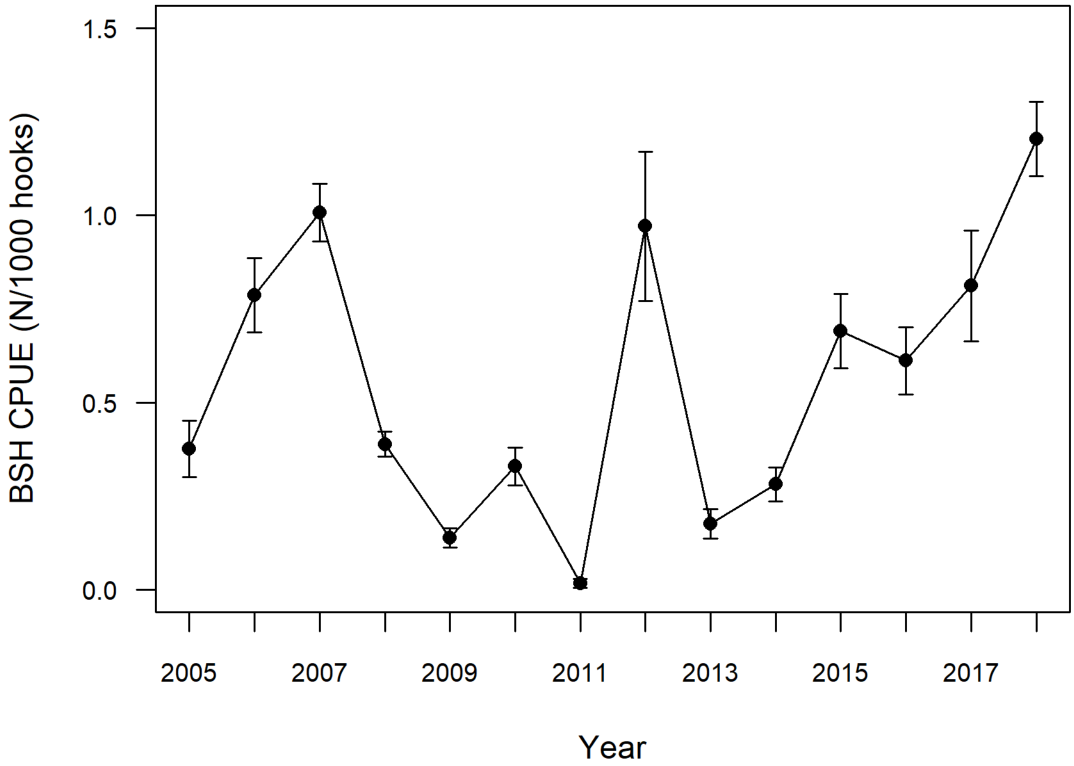

Figure 1. Nominal CPUE series (N/1,000 hooks) for BSH from 2005 to 2018. The error bars refer to the standard errors.

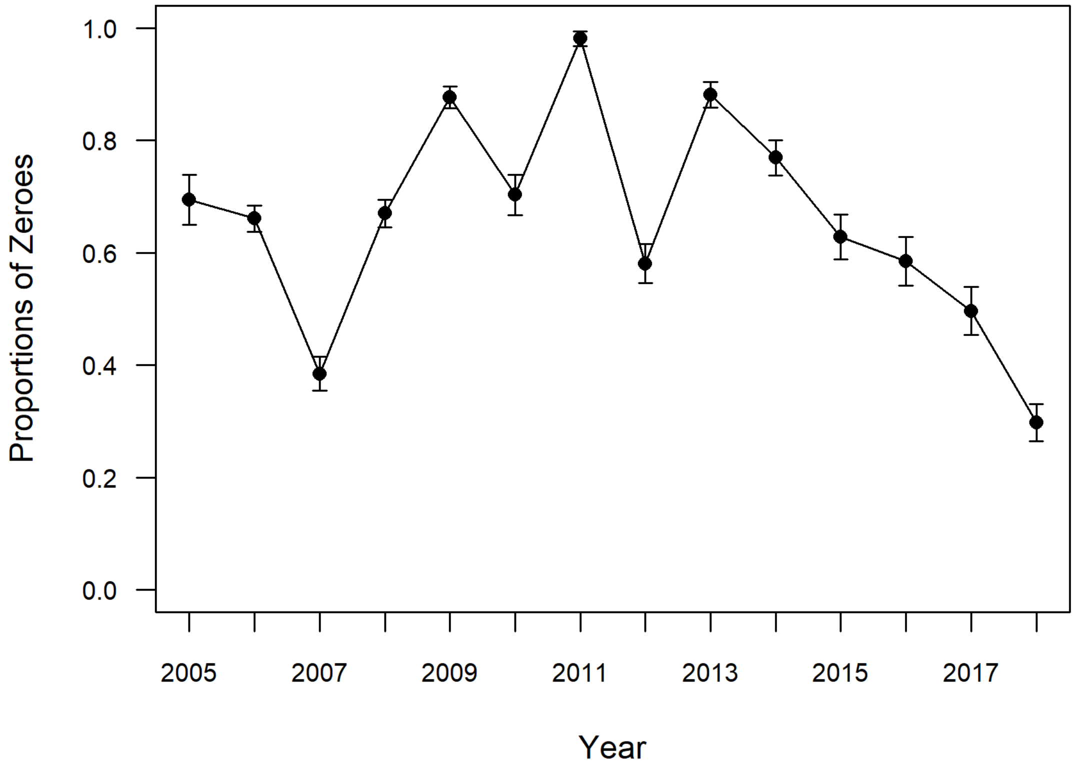

Figure 2. Proportion of zero BSH catches from 2005 to 2018. The error bars refer to the standard errors.

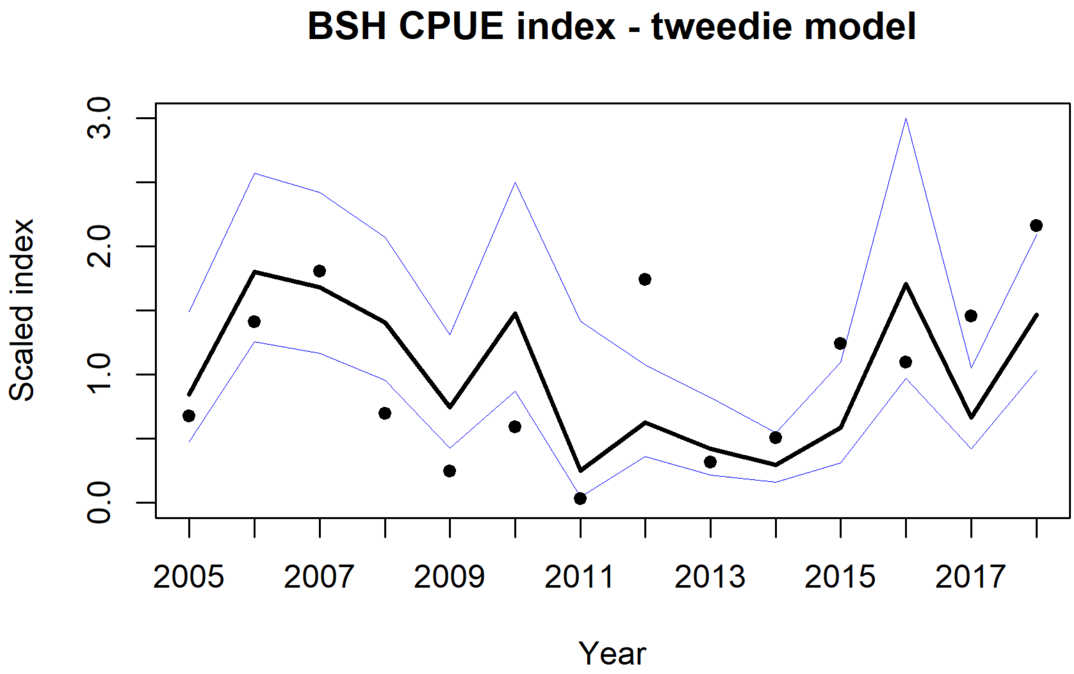

Figure 3. Standardize catch per unit effort (CPUE) calculated using Tweedie model. Values were scaled by dividing them by their means.

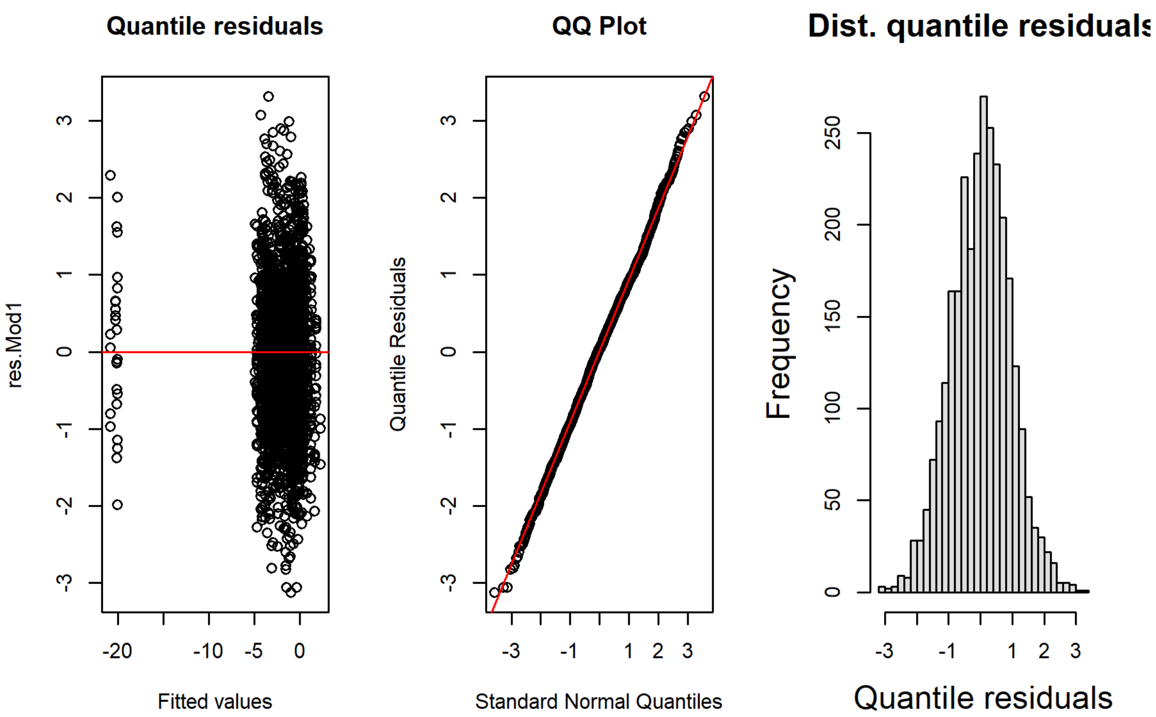

Figure 4. Residual analysis for the Indonesian longline fishery blue shark CPUE standardization of the 2005-2018 datasets.