Draft

Standardization of catch rate for blue marlin (*Makaira mazara*) exploited by the Japanese tuna longline fisheries in the Indian Ocean from 1971 to 2015

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1. Introduction

We updated the standardized CPUE (catch number per 1,000 hooks) of blue marlin (*Makaira mazara*) caught by the Japanese tuna longline vessel between 1971 and 2015. In past, standardization of CPUE of this stock was conducted three times (Uozumi 1998; Nishida et al. 2012; Nishida and Wang 2013). In this document, we followed the approach common (log normal GLM) with the past work.

In this analysis, we focused on the period between 1971 and 2015 and did not include the data before 1970, considering the shift of target species around 1970s. In the 1950s and 60s some of the Japanese longline fishery targeted billfishes (mainly striped and black marlins) in the Indian Ocean, while after the early 1970s, it has targeted mainly bigeye, yellowfin, and southern bluefin (Uozumi 1998, Nishida and Wang 2013). It is suggested that this shift would accompany with the change of pattern of operation such as gear configurations (i.e., gear depth) and area of fishing, and would affect the analysis of standardization.
The aim of this study is to provide abundance index for blue marlin in the Indian Ocean as input data for stock assessment by IOTC working party on billfishes in 2016.

2. Materials and methods

Data filtering

The Japanese longline catch and effort statistics from 1971 to 2015 were used. Total number of all operational level data is 1269199 and zero catch ratio of blue marlin is 85%. Since the proportion of zero catch is large, the Japanese longline catch and effort data was filtered using the hot spot (1-degree area) and the core area approaches, which is applied in previous study (Nishida and Wang 2013). The hot spots and the core area were defined as follows;

A) Hot spot is defined as the grid at 1 by 1 degree with positive catch more than 6 years in all of the quarter. The 6 year is not necessarily consecutive
B) Core area is the area with high density of hot spot judged by the eye

The total number of 1 by 1 degree compartment is 4892 in the whole Indian Ocean. As a result of the application of the procedures and criteria above, 277 hot spots and three core area, i.e. Southwest (SW; between 15°S and 40°S and between 20°E and 41°E), Northwest (NW; between 11°S and 11°N and between 51°E and 69°E) and Central east (CE; between 14°S and 3°N and between 89°E and 119°E) were defined (Figure 1). The core-areas include 243 hot spots, which were used for the further analyses. As result of filtering above, total number of set used in the analysis is 33394 and zero catch ratio is 36%.

GLM analysis

Explanatory variables

In the standardization procedure, we evaluated the effect of year, season (quarter), core area, materials of main line, materials of branch line, gear (number of hooks between floats :NHBF), and effect of area of 1 by 1 degree (1×1: Hot spot).

The core area is defined in Figure 1. Regarding gear effect, NHBF from 1971 to 1974 is not available from logbook, therefore the NHBF was assumed to be 5 for these years because the dominant NHBF in 1975 is five. The number of hooks between float (NHBF) were categorized into 6 classes (1: <=7, 2: 8-10, 3: 11-13, 4: 14-16, 5: 17-19, 6:>=20).The materials of main and branch lines composed of Nylon and others, which are available since 1994. The materials before 1993 was assumed as “others”. All of the explanatory variables are categorical variables.

Response variable

The effects of factors were assessed using GLM procedure (log normal error structure model, R ver. 3.3.1, R Development Core Team.). To stabilize the variance and satisfy the assumption of normality, natural log-transformations were conducted for dependent variables, which is catch number per 1000 hooks. In order to avoid to be unable to calculate natural logarithm for the set with zero catch of blue marlin, the 1/10 of the average catch for whole period was added to all catch.

Initial model is as follows;

ln (CPUE + constant) = mean + year + quarter + core-area + ML + BL + NHBF + [1×1] + year*quarter + quarter*area + err

where
ln: natural logarithm,
CPUE: catch in number of blue marlin per 1,000 hooks,
constant: 10% of overall mean of CPUE
mean: overall mean,
year: effect of year,
quarter: effect of fishing season (1; Jan.-Mar., 2; Apr.-Jun., 3; Jul.-Sep., 4; Oct.-Dec.),
core-area: effect of sub-area (Figure 1;SW, NW,CE),
ML: effect of material of main line (0; unknown, 1; others, 2; Nylon),
BL: effect of material of branch line (0; unknown, 1; others, 2; Nylon),
NHBF: effect of gear depth (category of the number of hooks between floats),
[1×1]: effect of area of 1 by 1 degree (Hot spot),
err: error term, ~ Normal (0, σ^2).

We intended to select the final model after variable selection with backward stepwise test with a criterion of the smallest AIC. In the cases in which the factor is not significant as main factor but is significant as interaction with other factors, the main factor was kept in the model.

3. Result and discussion

Annual CPUE standardized by GLM were shown in Figure 2 in relative scale with nominal CPUE. In the relative scaled CPUE, average CPUE during the period analyzed was regarded as 1.0. Quarterly CPUE standardized by GLM were shown in Figure 3 in relative scale with nominal CPUE. Trend of estimated CPUE did not show a large difference with the past results (Uozumi 1998; Nishida et al. 2012; Nishida and Wang 2013) (Figure 4). Residual trend (residual histogram, Q-Q plots and residual plots) were shown in Figure 5, which suggested that the assumption of error structure is not largely violated, although the histogram showed skewed left slightly.

In order to develop more objective criteria defining core-area, the effects of the alternative core-area definition on the abundance index should be explored in future. The two spatial factors, the core-area and the box, might present similar effect on the index, thus the interaction of the two factors are needed to be investigated.

4. References

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real scale (number/1000 hooks) (point and 80% CI)			
Year	lower	point	upper
1971	0.150	0.183	0.217
1972	0.193	0.228	0.266
1973	0.202	0.240	0.279
1974	0.210	0.248	0.288
1975	0.144	0.173	0.203
1976	0.158	0.201	0.247
1977	0.210	0.268	0.329
1978	0.183	0.217	0.254
1979	0.150	0.182	0.215
1980	0.176	0.208	0.241
1981	0.154	0.181	0.209
1982	0.160	0.187	0.216
1983	0.173	0.201	0.230
1984	0.181	0.210	0.241
1985	0.173	0.200	0.228
1986	0.130	0.153	0.178
1987	0.135	0.159	0.185
1988	0.108	0.130	0.155
1989	0.083	0.104	0.126
1990	0.083	0.103	0.124
1991	0.089	0.110	0.132
1992	0.096	0.118	0.142
1993	0.101	0.124	0.147
1994	0.115	0.137	0.161
1995	0.088	0.108	0.129
1996	0.074	0.091	0.110
1997	0.097	0.117	0.138
1998	0.088	0.107	0.127
1999	0.089	0.108	0.128
2000	0.086	0.105	0.125
2001	0.065	0.082	0.099
2002	0.057	0.073	0.091
2003	0.054	0.070	0.087
2004	0.051	0.066	0.083
2005	0.047	0.063	0.079
2006	0.053	0.069	0.086
2007	0.048	0.064	0.079
2008	0.046	0.061	0.076
2009	0.051	0.067	0.084
2010	0.078	0.099	0.121
2011	0.075	0.095	0.115
2012	0.060	0.080	0.100
2013	0.066	0.087	0.109
2014	0.067	0.087	0.107
2015	0.071	0.091	0.113

Table 1. Standardized CPUE for annual CPUE of blue marlin caught by Japanese longline vessels in the Indian Ocean expressed in real scale.

relative scale (average=1) (point and with 80% CI)			
Year	lower	point	upper
1971	1.357	1.358	1.358
1972	1.750	1.696	1.662
1973	1.834	1.785	1.745
1974	1.903	1.845	1.801
1975	1.303	1.283	1.266
1976	1.431	1.492	1.545
1977	1.904	1.991	2.059
1978	1.653	1.615	1.586
1979	1.361	1.354	1.344
1980	1.598	1.548	1.507
1981	1.394	1.344	1.307
1982	1.450	1.391	1.353
1983	1.569	1.492	1.438
1984	1.637	1.560	1.506
1985	1.563	1.484	1.427
1986	1.174	1.138	1.114
1987	1.220	1.184	1.158
1988	0.976	0.968	0.966
1989	0.755	0.773	0.786
1990	0.753	0.764	0.773
1991	0.803	0.816	0.824
1992	0.872	0.880	0.885
1993	0.911	0.918	0.920
1994	1.039	1.021	1.008
1995	0.799	0.803	0.804
1996	0.666	0.679	0.687
1997	0.883	0.872	0.865
1998	0.799	0.796	0.793
1999	0.803	0.800	0.799
2000	0.780	0.780	0.783
2001	0.585	0.607	0.622
2002	0.518	0.545	0.567
2003	0.490	0.520	0.541
2004	0.458	0.493	0.518
2005	0.427	0.467	0.494
2006	0.483	0.514	0.535
2007	0.439	0.473	0.496
2008	0.413	0.450	0.478
2009	0.464	0.501	0.525
2010	0.711	0.737	0.757
2011	0.680	0.702	0.719
2012	0.547	0.593	0.624
2013	0.599	0.647	0.680
2014	0.607	0.645	0.671
2015	0.639	0.677	0.706

Table 2. Standardized CPUE for annual CPUE of blue marlin caught by Japanese longline vessels in the Indian Ocean expressed in relative scale in which the average from 1971 to 2015 is 1.0.

nominal (number/1000 hooks) (point and 80% CI)		
Year	real scale	relative scale (Average=1)
1971	0.522	1.492
1972	0.732	2.093
1973	0.746	2.131
1974	0.679	1.941
1975	0.429	1.226
1976	0.541	1.547
1977	0.698	1.996
1978	0.648	1.851
1979	0.605	1.729
1980	0.510	1.457
1981	0.491	1.403
1982	0.618	1.767
1983	0.628	1.796
1984	0.651	1.859
1985	0.603	1.724
1986	0.457	1.306
1987	0.483	1.379
1988	0.413	1.181
1989	0.261	0.747
1990	0.260	0.742
1991	0.263	0.752
1992	0.259	0.739
1993	0.360	1.028
1994	0.375	1.071
1995	0.254	0.727
1996	0.244	0.697
1997	0.456	1.304
1998	0.312	0.891
1999	0.243	0.695
2000	0.263	0.750
2001	0.146	0.416
2002	0.186	0.532
2003	0.108	0.308
2004	0.125	0.358
2005	0.113	0.323
2006	0.151	0.431
2007	0.146	0.416
2008	0.132	0.378
2009	0.099	0.282
2010	0.128	0.366
2011	0.081	0.232
2012	0.084	0.241
2013	0.082	0.236
2014	0.088	0.252
2015	0.073	0.209

Table 3. Nominal CPUE for annual CPUE of blue marlin caught by Japanese longline vessels in the Indian Ocean expressed in real scale and relative scale in which the average from 1971 to 2015 is 1.0.

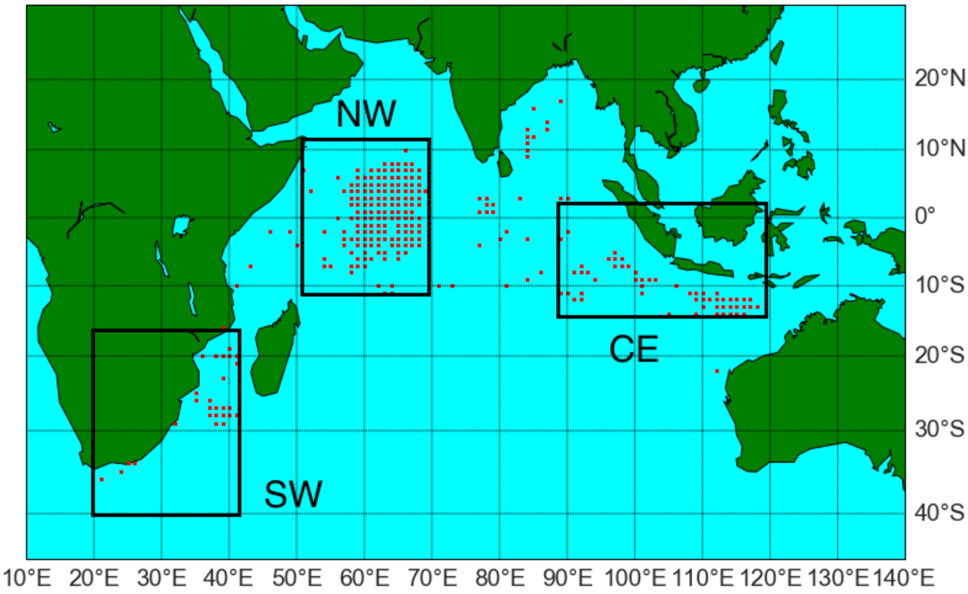

Figure 1. Three core area (SW, NW and CE) and hot spots (red square) used in CPUE standardization of blue marlin caught by Japanese longline vessel in the Indian Ocean.

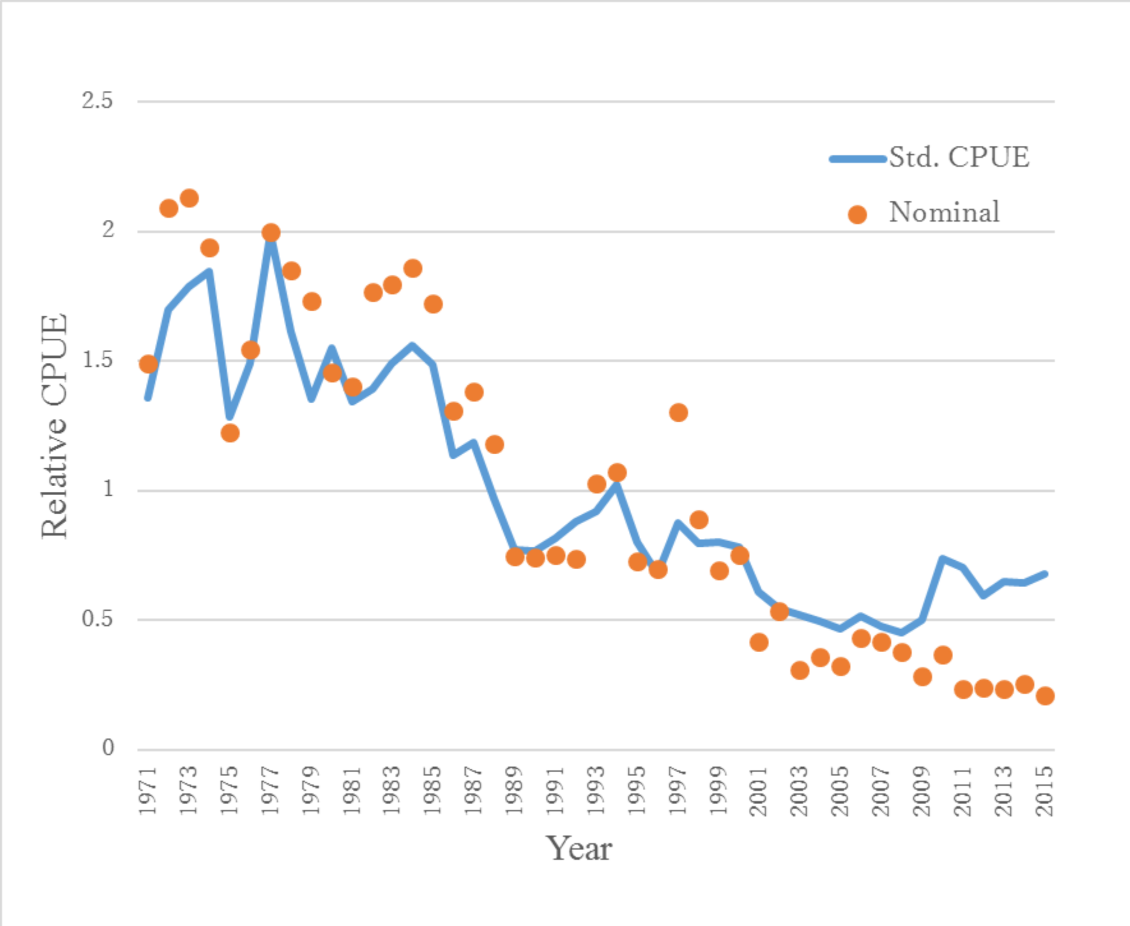

Figure 2. Standardized (solid line) and nominal (solid circle) CPUEs for annual CPUE of blue marlin caught by Japanese longline vessels in the Indian Ocean expressed in relative scale in which the average from 1971 to 2015 is 1.0.

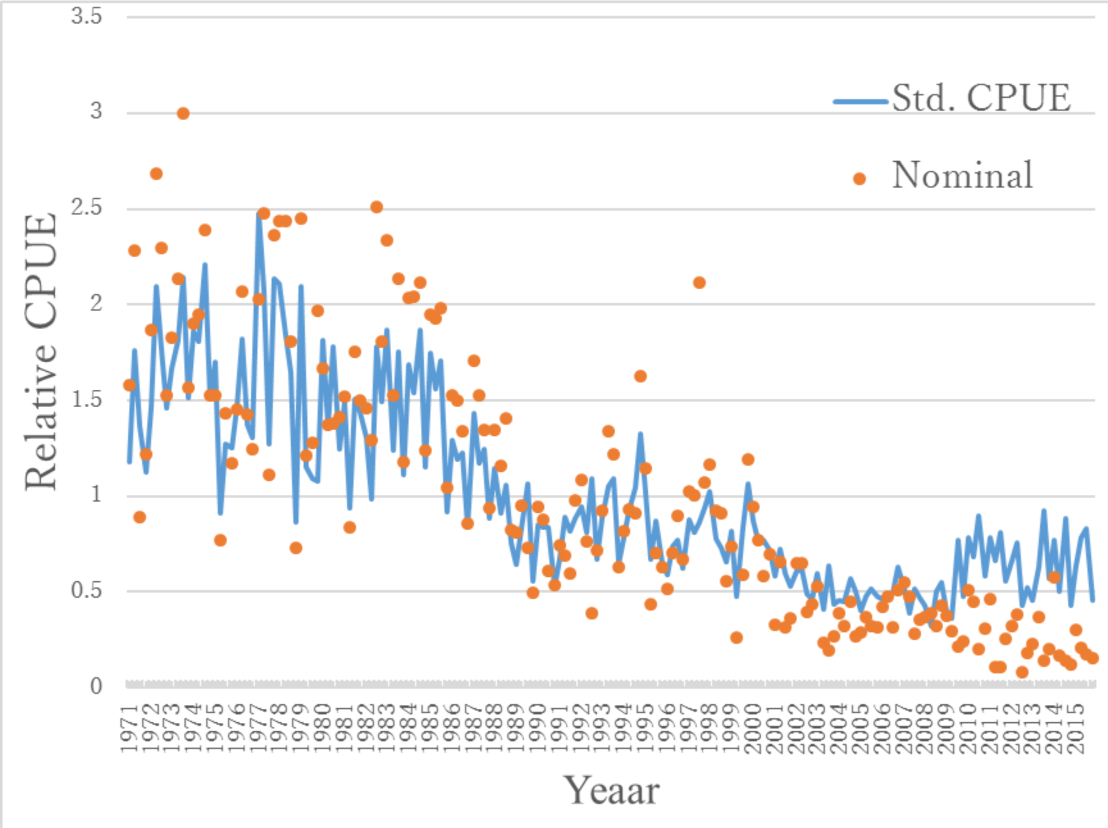

Figure 3. Standardized (solid line) and nominal (solid circle) CPUEs for quarterly CPUE of blue marlin caught by Japanese longline vessels in the Indian Ocean expressed in relative scale in which the average from 1971 to 2015 is 1.0.

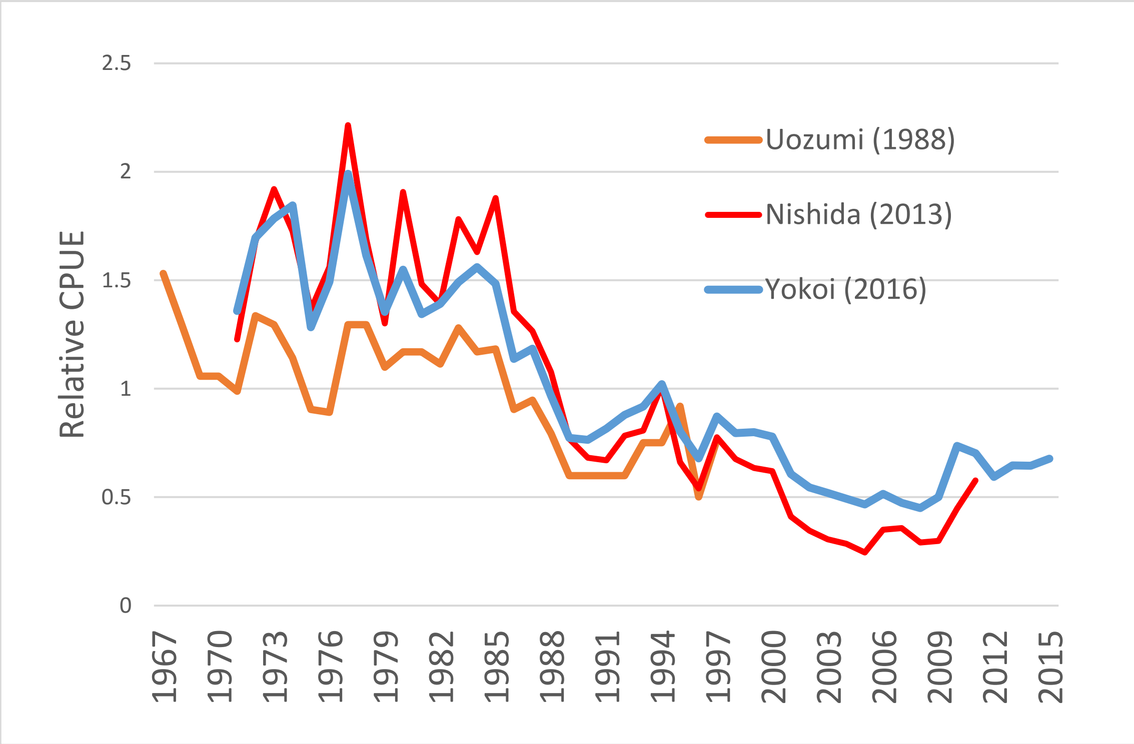

Figure 4. Comparison with past results. Annual CPUE of blue marlin caught by Japanese longline vessels in the Indian Ocean. Uozumi 1998 using a normal sub-area approach. Nishida 2013 and this study are using a core-area approach.

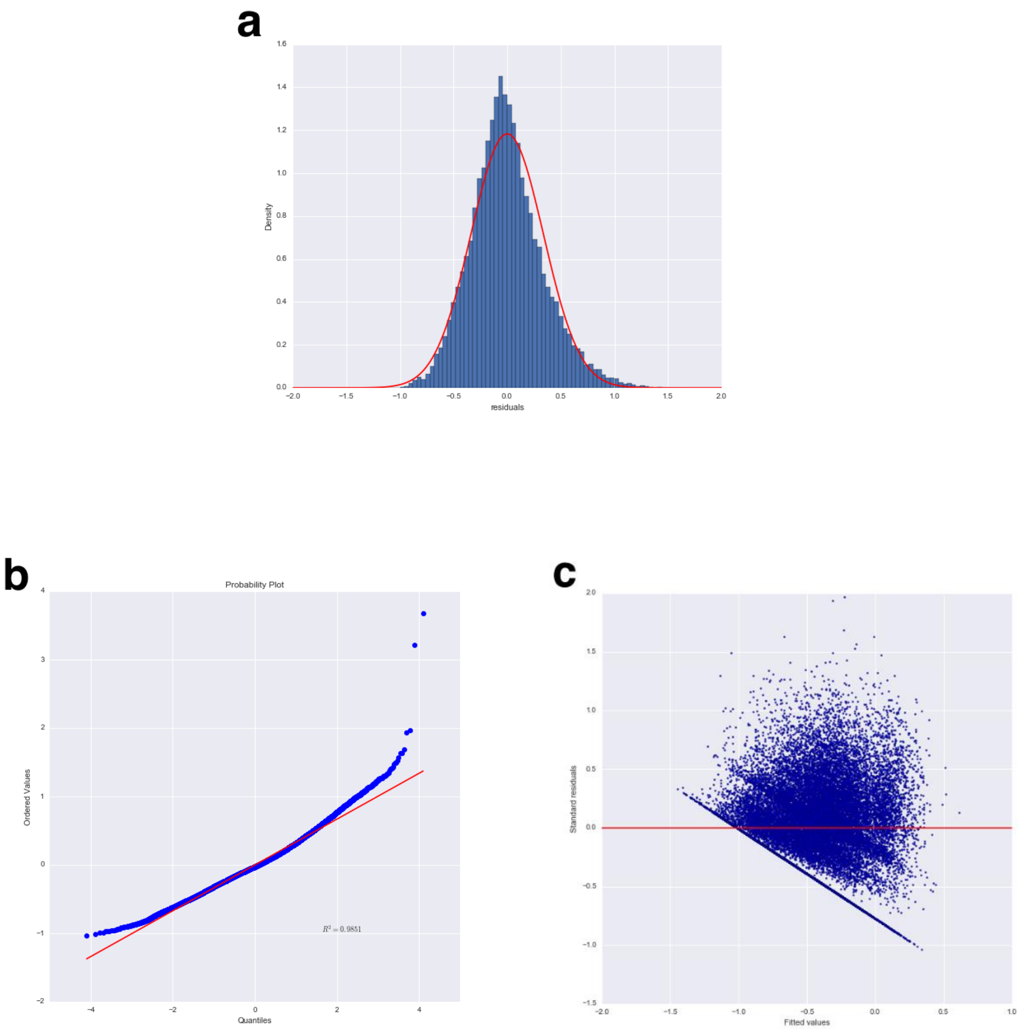

Figure 5. Diagnosis of standardized CPUE. a: Residual histogram, b: Q-Q plot and c: residual plot for CPUE of blue marlin caught by Japanese longline vessels in the Indian Ocean

Appendix1. Result of ANOVA table for CPUE of blue marlin.

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Analysis of Deviance Table (Type III tests)

Response: logCPUE
Error estimate based on Pearson residuals

                                            SS    Df       F    Pr(>F)
as.factor(year)                          394.8    44 45.6153 < 2.2e-16 ***
as.factor(quarter)                         2.3     3  3.8413  0.009214 **
as.factor(1×1)                           366.7   240  7.7684 < 2.2e-16 ***
as.factor(ML)                              8.0     2 20.2549 1.617e-09 ***
as.factor(BL)                              2.6     2  6.6424  0.001306 **
as.factor(NHBF)                           14.5     5 14.7381 1.813e-14 ***
as.factor(year):as.factor(quarter)       228.7   132  8.8068 < 2.2e-16 ***
as.factor(quarter):as.factor(core-area)  112.0     6 94.9215 < 2.2e-16 ***
Residuals                               6482.7 32957
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
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