SCRS/2016/092 Collect. Vol. Sci. Pap. ICCAT, 73(5): 1707-1721 (2017)

STANDARDIZED CATCH RATES OF SAILFISH CAUGHT BY THE BRAZILIAN LONGLINE FLEET (1978-2012) USING A GENERALIZED LINEAR MIXED MODEL (GLMM), WITH A DELTA LOG APPROACH

Bruno L. Mourato[1]; Humberto Hazin[2]; Felipe Carvalho[3]; Fábio Hazin[4]

SUMMARY

In the present paper, catch and effort data from 73,810 sets done by the Brazilian tuna longline fleet, including both national and chartered vessels, in the equatorial and southwestern Atlantic Ocean, from 1978 to 2012, were analyzed. The fished area was distributed along a wide area of the equatorial and South Atlantic Ocean, ranging from 3ºW to 52ºW of longitude, and from 011ºN to 40ºS of latitude. The CPUE of the sailfish was standardized by a Generalized Linear Mixed Model (GLMM) using a Delta Lognormal approach. The factors used in the model were: year, fishing strategy, quarter, area, sea surface temperature, and the interactions year:strategy, year:quarter and year:area. The standardized CPUE series of the sailfish showed a gradual decreasing trend, particularly after the year 2000.

RÉSUMÉ

Le présent document analysait les données de prise et d'effort provenant de 73.810 opérations de la flottille palangrière brésilienne (nationale et affrétée) ciblant les thonidés dans l'océan Atlantique équatorial et du Sud-Ouest entre 1978 et 2012. La zone de pêche a été distribuée sur une vaste zone de l'océan Atlantique équatorial et du Sud, s'étendant de 3ºW à 52ºW de longitude et de 11ºN à 40ºS de latitude. La CPUE du voilier a été standardisée en utilisant un modèle mixte linéaire généralisé (GLMM) au moyen d'une approche delta log-normale. Les facteurs utilisés dans le modèle étaient : année, stratégie de pêche, trimestre, zone, température de surface de la mer et les interactions année:stratégie, année:trimestre et année:zone. La série de CPUE standardisée du voilier a montré une tendance descendante progressive, surtout après l'an 2000.

RESUMEN

En este documento se analizan los datos de captura y esfuerzo de 73.810 lances realizados por la flota atunera brasileña de palangre (de buques nacionales y fletados) en el Atlántico suroccidental y ecuatorial entre 1978 y 2012. La zona de pesca se distribuía a lo largo de una amplia zona del Atlántico meridional y ecuatorial, entre 3ºW y 52ºW de longitud y 11ºN y 40ºS de latitud. Se estandarizó la CPUE del pez vela mediante modelos mixtos lineales generalizados (GLMM) utilizando un enfoque delta lognormal. Los factores usados en el modelo fueron: año, estrategia de pesca, trimestre, área, temperatura de la superficie del mar, y las interacciones año:estrategia, año:trimestre y año:área. La serie de CPUE estandarizada de pez vela presentaba una tendencia decreciente gradual, especialmente después del año 2000.

KEYWORDS

Istiophorus platypterus, *CPUE, Atlantic Ocean, By-catch*

[1] Universidade Federal de São Paulo, Departamento de Ciências do Mar. Av. Almirante Saldanha da Gama, 89, 11030-400 Santos, SP, Brazil. Email: mourato.br@gmail.com
[2] Universidade Federal Rural do Semi-Árido (UFERSA). Av. Francisco Mota, 572 – Costa e Silva – CEP: 59625-900 – Mossoró – RN – Brasil. Email: hhazin@gmail.com
[3] NOAA Pacific Islands Fisheries Science Center, 1845 Wasp Boulevard, Honolulu, HI 96818, USA. Email: felipe.carvalho@noaa.gov
[4] Universidade Federal Rural de Pernambuco, Departamento de Pesca e Aquicultura, Laboratório de Oceanografia Pesqueira. Rua Dom Manoel de Medeiros, s/n – Dois Irmãos, 52171-900 Recife, PE, Brazil. Email: fhvhazin@terra.com.br

Introduction

In recent decades, there has been a growing concern with the status of several billfish populations worldwide, mainly because of an increased mortality resulting from fishing. Among the istiophorid, sailfish (*Istiophorus platypterus*) is a highly valued species for the recreational fisheries, as well as for small-scale and artisanal fisheries, particularly in developing countries, where it represents an important source of food and income. It is also often caught, as by-catch, by the pelagic longline fishery, directed to tunas and swordfish, which accounts, by far, for the main impact on its stocks in the Atlantic Ocean.

Stock assessments for large pelagic are commonly based on catch per unit of effort (CPUE) due to the greater availability of such data. Although CPUE has been classically used as an index of relative abundance, the relationship between the CPUE and the actual abundance is not linear, being affected by several factors, which may, therefore, lead to interpretation errors and make its utilization rather complex. As a result of market changes over the years, for instance, a number of fleets have frequently altered their fishing strategies in order to increase their efficiency. Since 1956, when longline fishing operations began in the Southern Atlantic Ocean, a number of changes in fishing operations and strategies have been observed which directly reflect on catch compositions (Amorim e Arfelli, 1984; Hazin et al., 2007; Carvalho et al., 2010; Mourato et al., 2011). Such variations lead to oscillations in catchability which may introduce serious errors in the estimation of abundance indices. The incorporation of these factors in the estimation of CPUE is, therefore, crucial for accurate stock assessments.

Hence, to contribute information for the assessment of the western stock of the sailfish, in the present paper a standardized series of CPUE for the species, caught by the Brazilian fleet, including both national and chartered vessels, was updated, spanning for 35 years, from 1978 to 2012.

Material and Methods

In the present study, catch and effort data from 73,810 tuna longline sets obtained from logbooks reported by the Brazilian tuna longline fleet, including both national and foreign chartered vessels, from 1978 to 2012, were analyzed. The longline sets were distributed along a wide area of the equatorial and South Atlantic Ocean, ranging from 3ºW to 52ºW of longitude, and from 011ºN to 40ºS of latitude **(Figure 1)**. The resolution of 1º x 1º, per fishing set, was used for the analysis of the geographical distribution of fishing effort and catches.

Due to the high proportion of sets with zero catches of sailfish (~80%), a GLMM using a Delta Lognormal approach was used for the standardization of CPUE. In the Delta Lognormal model, the catch rates are assumed to be the result of two dependent processes: a) the probability of catching at least one fish; and b) the conditional expected mean catch rate given that there is a positive probability of capture. In this case, the probability of capture was assumed to follow a binomial distribution, while the mean catch rate was assumed to follow a normal error distribution of the log-transformed CPUE. A GLMM model was applied with the logit function being used as the link between the linear predictor and the binomial error response variable.

GLMM models are generally non-orthogonal and the order of entry of explanatory variables affects the contribution of each variable in the final model. For the final model, the selection of factors and interactions was carried out by analysis of deviance tables (Ortiz and Arocha, 2004). Briefly, main factors and interactions were included in the model if: a) the percent of total deviance explained by a given factor/interaction was 5% or greater; and b) the Chi-square probability was 0.05 or less for the test of deviance explained versus the number of additional parameters estimated for a given factor or interaction. In the case of a statistically significant interaction between the year factor and any other factor, they were considered as random interactions in the final model.

Once the fixed factors and interactions were selected, all interactions involving the factor year and area were evaluated as random variables to obtain the estimated index per year, transforming the GLMs in a GLMMs (Generalized Linear Mixed Models). Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), Schwarz's Bayesian Information Criterion (BIC), and a chi-square test of the difference between the [-2 log likelihood statistic] successive model formulations. Relative indices for the delta model formulation were calculated as the product of the year effect least square means (LSmeans) from the binomial and the lognormal model components. The LSmeans estimates use a weighted factor of the proportional observed margins in the input data to account for the un-balanced characteristics of the data. The factors considered as explanatory variables were "Year" (35), "Quarter" (4), "Area" (A1>20ºS; A2<20ºS), "Fleet strategy" (3). Sea surface temperature (SST) was also considered as a continuous explanatory variable. The fleet strategy was estimated in two steps. In the first step, a multivariate cluster analysis was conducted to identify the different Targeting Strategies (TS) by combining clusters of predominant species that were internally coherent and externally isolated. A total of 73,810 fishing sets with approximately 25 species reported in the observer logbooks were analyzed. The Target Strategy typology was then built using the “K Means” method. This approach is widely applied among non-hierarchical clustering techniques and is well adapted to very large datasets. Each cluster (of fishing sets) can be considered a Target Strategy (Hazin *et al.*, 2007; Mourato *et al.*, 2011). For a given number of clusters, the final value of the criterion is given. Analyses were conducted with different numbers of clusters, among which the most realistic solution was chosen when considering the evolution of the criterion value. The Target Strategy can be described by the mean values obtained (centroids). In the second step, a matrix was constructed considering the frequency of sets conducted by each fishing vessel within each cluster (Target Strategy). Then, a Fuzzy Clustering method with ordination-based Canonical Correspondence Analysis (CCA) was applied to find coherent patterns that may discriminate clusters of vessels (Fishing Fleets) with similar fishing strategies.

Because multiple explanatory variables were used in these models, which may potentially cause multicollinearity problems, Generalized Variance Inflation Factors (GVIF) were calculated for the models main effects (Fox and Monette, 1992). The definition of threshold values for these GVIF seems to be somewhat arbitrary, but as a general rule most authors recommend that values higher than 5 may be cause for concern, while values higher than 10 can indicate serious collinearity problems (O'Brien, 2007).

All statistical and data analyses developed on this study were performed using the software R-3.2.4 (R Core Team, 2016) with the aid of packages *dplyr* (Wickham and Francois, 2015), *ggplot2* (Wickham and Chang, 2016), *lme4* (Bates, 2016), *lsmeans* (Lenth, 2016), *lmerTest* (Kuznetsova et al., 2016).

Results and Discussion

In terms of preliminary analysis of the explanatory variables, the sailfish CPUE had a significant and positive correlation with year, quarter, fishing strategy and sea surface temperature, and a significant negative correlation with area (**Figure 2**). Some of the possible explanatory variables were also correlated between themselves, such as for example SST that was negatively correlated with both area (-0.65) and quarter (-0.36) (**Figure 2**). In this multivariate simple effect model, the Generalized Variance Inflation Factors (GVIFs) were calculated and in all cases the values were < 10, meaning that severe collinearity problems between these explanatory variables were not likely to be occurring. The calculated GVIF factors were: Year=6.73, Quarter=1.72, Area=2.46, Strategy=2.97 and SST=3.95. The proportion of null catches of sailfish for the Brazilian fleet during the period of the present study was ~80%. Positive catches proportion varied during the period of study between 5.9% and 38.8% of the sets (**Table 1**). The number of sets with positive and null catches by factors (**Figures 3**) indicates that the proportion of positive sets was relatively uniform for quarter and area, but different for fishing strategy, as it should be expected, and for different years, since the distribution of the different fishing strategies changed from year to year.

Table 2 presents a summary of the deviance analysis for the two stages of the Delta model, a description for Lognormal and Binomial models. In both cases, the interactions year:quarter and year:strategy explained more than 5% of the total deviance. Thus, all interactions were tested in the GLMM as random variables. Comparisons of models considering different combinations of interactions were conducted and their summaries are presented in **Table 3**. The selected models for the Lognormal and Binomial components were:

- Lognormal Model: log(CPUE) =

 = Year+Strategy+SST+Area+Quarter+Year:Quarter+Year:Strategy+Year:Area

- Binomial Model: PROP =

= Year+Strategy+SST+Area+Quarter+Year:Quarter+Year:Strategy+Year:Area

Diagnostic plot for the Lognormal model showed that the assumption of the lognormal distribution for the positive dataset seems to be adequate as indicated in the QQ-plots (**Figure 4**). Residuals were homoscedastic at least in the case of the positive dataset. There were no temporal trends in the residuals on a yearly basis, so the assumption of independence of the samples was acceptable (**Figure 4**). The pseudo-R^2 values of the final models explained 30% of the total variance. The value of parameter dispersion was 0.64, indicating that the final model does not show an overdispersion. The main factors were, in order of importance, year (65.3%), fishing strategy (26%), year:strategy (11.7%), quarter (6.3%), year:quarter (5.4%), year:area (3.9%), SST (2.1%), and area (1%). According to Maunder & Punt (2004), the relatively low values of the pseudo-R^2 found in the present work are common in catch and effort data, due to the several factors that influence relative abundance but can't be considered in the model, including environmental, technological and operational factors. Fishing strategy was included as a factor in the present case and it is clearly an oversimplification of the many factors that certainly can't be accounted for, including the targeting behavior of the skipper, which might be reflected in slight operational changes in the fishing operation, which may have a significant impact on the catch composition. The higher importance of the factor year:strategy in sailfish CPUE suggests an important and variable fluctuation in the temporal distribution of the fishing strategy, from one year to the other.

In terms of model interpretation, models coefficients and respective effects presented in **Figure 5**, some interpretations can be taken with regards to the effects of the explanatory variables in the expected sailfish catch rates. In terms of seasonality it is expected for the fishery to have lower catch rates of sailfish during the quarter 2, while higher catch rates are expected during the other quarters, specifically with highest catches during quarter 4. With regards to the environmental variables, higher catch rates are expected with increasing SST. In terms of spatial variables, the expected catch rates increase towards area 1.

The standardized CPUE series shows a gradual decreasing trend, particularly after the year 2000 (**Table 4 and Figure 6**). Mourato et al. (2015) analyzed sailfish catch rate from Brazilian sport fishery and demonstrated a similar trend with a decline between 2005 and 2014. A comparison with the trends shown in recent years by other fleets in this same ocean basin, e.g. Japanese, US, Venezuela and Spanish, might confirm if this is a general trend or a behavior peculiar to the Brazilian fleet. Unfortunately, due to several problems faced by the country with regard to its fisheries statistics, it was not possible to update the Brazilian CPUE series up to more recent years, i.e. 2015 or, at least, 2014. Efforts, however, are on the way and hopefully more recent data will be made available.

References

Amorim, A. F E Arfelli, C. A. 1984. Estudo biológico pesqueiro do espadarte, *Xiphias gladius Linnaeus*, 1758, no sudeste e sul do Brasil (1971 a 1981). B. Inst. Pesca, São Paulo, 11(único):35-62.

Bates, D.; Maechler, M.; Bolker, B.; Walker, S. 2016. lme4: Linear Mixed-Effects Models using 'Eigen' and S4. R package version 1.1-11. https://cran.r-project.org/web/packages/lme4.

Carvalho, F.; Murie, D.; Hazin, F. H. V.; Hazin, H.; Leite-Mourato, B.; Travassos, P.; Burgess, G. Catch rates and size composition of blue sharks (*Prionace glauca*) caught by the Brazilian pelagic longline fleet in the southwestern Atlantic Ocean. Aquat. Living Resour, 23: 373-385, 2010.

Hazin, H. G.; Hazin, F. H. V.; Travassos, P.; Carvalho, F. C.; Erzini, K. 2007. Standardization of Swordfish CPUE series caught by Brazilian longliners in the Atlantic Ocean, by GLM, using the targeting strategy inferred by cluster analysis. Col. Vol. Sci. Pap., ICCAT, Madrid, 60(6): 2039-2047.

Kuznetsova, A.; Brockhoff, P. B.; Christensen, R. H. B. 2016. lmerTest: Tests in Linear Mixed Effects Models. R package version 2.0-30. https://cran.r-project.org/web/packages/lmerTest.

Lenth, R. 2016. lsmeans: Least-Squares Means. R package version 2.23. https://cran.r-project.org/web/packages/lsmeans.

Maunder, M.N. and Punt, A.E. 2004. Standardizing catch and effort data: a review of recent approaches. Fish. Res. 70: 141-159.

Mourato, B., Arfelli, C. Amorim, A., Hazin, H., Carvalho, F. Hazin, F. 2011. Spatio-temporal distribution and target species in a longline fishery off the southeastern coast of Brazil. Braz. j. oceanogr.vol.59**,** no.2, São Paulo.

Mourato, B., Hazin, H., Hazin, F Carvalho, F., Travassos, P and Amorim, A. 2015. Assessing of Atlantic sailfish catch rates based on Brazilian sport fishing tournaments (1996-2014). Collect. Vol. Sci. Pap. ICCAT. Document SCRS/2015/209 (withdrawn).

O'Brien, R. M. 2007. A Caution Regarding Rules of Thumb for Variance Inflation Factors. Quality & Quantity 41 (5): 673.

Ortiz, M. and Arocha, F. 2004. Alternative error distribution models for standardization of catch rates of non target species from a pelagic longline fishery: billfish species in the Venezuelan tuna longline fishery. Fisheries Research 70:275-297.

R Core Team. 2016. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://r-project.org/.

Wickham, H.; Francois, R. 2015. dplyr: A Grammar of Data Manipulation. R package version 0.4.3. https://cran.r-project.org/web/packages/dplyr.

Wickham, H.; Chang, W. 2016. ggplot2: An Implementation of the Grammar of Graphics. R package version 2.1.0. https://cran.r-project.org/web/packages/ggplot2.

Table 1. Catch and effort information of the Brazilian longline fleet from 1978 to 2012.

Year	Positive	Zero	% of zero
1978	113	335	74.8
1979	105	305	74.4
1980	146	374	71.9
1981	99	366	78.7
1982	102	775	88.4
1983	113	494	81.4
1984	86	548	86.4
1985	34	423	92.6
1986	165	722	81.4
1987	104	698	87.0
1988	147	936	86.4
1989	201	776	79.4
1990	21	250	92.3
1991	143	748	84.0
1992	136	923	87.2
1993	63	200	76.0
1994	63	1009	94.1
1995	297	1579	84.2
1996	150	782	83.9
1997	295	1382	82.4
1998	555	2049	78.7
1999	737	4495	85.9
2000	1240	6498	84.0
2001	1778	7889	81.6
2002	644	5851	90.1
2003	584	2642	81.9
2004	1232	3957	76.3
2005	994	2853	74.2
2006	723	2130	74.7
2007	517	1939	78.9
2008	213	1306	86.0
2009	651	1293	66.5
2010	137	624	82.0
2011	407	641	61.2
2012	311	2712	89.7

Table 2. Deviance analysis table of positive catch rates (Lognormal) and proportion of positive sets (Binomial) models.

Model	*Deviance*	*Change in deviance*	*% of total deviance*
Positive catch rates			
Null	10852.8	NA	NA
Y	9970.5	882.4	37.9
Y +S	9619.7	350.8	15.1
Y + S + SST	9590.9	28.9	1.2
Y + S + SST + A	9588.1	2.8	0.1
Y + S + SST + A + Q	9502.4	85.6	3.7
Y + S + SST + A + Q + Y:Q	9012.8	489.6	21.0
Y + S + SST + A + Q + Y:A	9361.3	-348.5	-15.0
Y + S + SST + A + Q + Y:S	9124.2	237.2	10.2
Y + S + SST + A + Q + Y:Q + Y:S	8663.8	460.3	19.8
Y + S + SST + A + Q + Y:Q + Y:A	8901.5	-237.7	-10.2
Y + S + SST + A + Q + Y:A + Y:S	8953.5	-52.0	-2.2
Y + S + SST + A + Q + Y:Q + Y:A + Y:S	8523.9	429.6	18.4
Proportion of positive			
Null	32050.2	NA	NA
Y	30206.7	1843.5	23.3
Y +S	29932.9	273.8	3.5
Y + S + SST	28457.2	1475.7	18.6
Y + S + SST + A	28268.4	188.8	2.4
Y + S + SST + A + Q	28162.4	106.0	1.3
Y + S + SST + A + Q + Y:Q	26855.8	1306.6	16.5
Y + S + SST + A + Q + Y:A	26680.0	175.8	2.2
Y + S + SST + A + Q + Y:S	26468.6	211.4	2.7
Y + S + SST + A + Q + Y:Q + Y:S	25239.2	1229.4	15.5
Y + S + SST + A + Q + Y:Q + Y:A	25606.0	-366.8	-4.6
Y + S + SST + A + Q + Y:A + Y:S	25176.2	429.7	5.4
Y + S + SST + A + Q + Y:Q + Y:A + Y:S	24121.9	1054.4	13.3

Table 3. Summary table of analyses of Delta Lognormal Mixed Model formulations for sailfish catch rates from Brazilian pelagic longline fisheries from 1978 to 2012.

Model	**AIC**	**BIC**	**logLik**	**LRT**
Positive catch rates				
Y + S + SST + A + Q + (1 | Y:Q)	32985.23	33315.0	-16448.6	NA
Y + S + SST + A + Q + (1 | Y:A)	33299.31	33629.1	-16605.7	1.00
Y + S + SST + A + Q + (1 | Y:S)	33061.32	33391.1	-16486.7	0.00
Y + S + SST + A + Q + (1 | Y:Q) + (1 | Y:S)	32654.16	32991.5	-16282.1	0.00
Y + S + SST + A + Q + (1 | Y:Q) + (1 | Y:A)	32910.93	33248.2	-16410.5	1.00
Y + S + SST + A + Q + (1 | Y:A) + (1 | Y:S)	32908.42	33245.7	-16409.2	0.00
Y + S + SST + A + Q + (1 | Y:Q) + (1 | Y:S) + (1 | Y:A)	32519.04	32863.9	-16213.5	0.00
Proportion of positive				
Y + S + SST + A + Q + (1 | Y:Q)	34719.52	35044.3	-17316.8	NA
Y + S + SST + A + Q + (1 | Y:A)	34394.14	34718.9	-17154.1	0.00
Y + S + SST + A + Q + (1 | Y:S)	34236.78	34561.6	-17075.4	0.00
Y + S + SST + A + Q + (1 | Y:Q) + (1 | Y:S)	33376.62	33709.0	-16644.3	0.00
Y + S + SST + A + Q + (1 | Y:Q) + (1 | Y:A)	33658.35	33990.7	-16785.2	1.00
Y + S + SST + A + Q + (1 | Y:A) + (1 | Y:S)	33125.36	33457.7	-16518.7	0.00
Y + S + SST + A + Q + (1 | Y:Q) + (1 | Y:S) + (1 | Y:A)	32405.97	32745.9	-16158.0	0.00

Table 4. Nominal and standardized index of relative abundance of sailfish caught by Brazilian pelagic longline fishery fleet between the years of 1978 to 2012.

Year	CPUE nominal	index	LCI index	UCI index	CV	Scaled index	LCI index scaled	UCI index scaled	Scaled CPUE
1978	0.449	0.350	1.336	0.062	0.743	1.426	5.446	0.252	1.136
1979	0.432	0.501	1.831	0.073	0.763	2.042	7.465	0.298	1.093
1980	0.352	0.411	1.418	0.063	0.734	1.675	5.781	0.258	0.891
1981	0.257	0.389	1.825	0.039	0.884	1.586	7.440	0.157	0.649
1982	0.133	0.232	1.486	0.020	1.029	0.945	6.056	0.080	0.338
1983	0.323	0.435	2.211	0.042	0.918	1.772	9.013	0.173	0.817
1984	0.212	0.153	0.847	0.022	0.898	0.623	3.452	0.091	0.536
1985	0.074	0.089	0.561	0.011	0.940	0.362	2.287	0.046	0.188
1986	0.211	0.130	0.596	0.023	0.818	0.529	2.429	0.094	0.534
1987	0.354	0.334	1.323	0.064	0.762	1.363	5.393	0.262	0.897
1988	0.255	0.277	1.122	0.053	0.772	1.129	4.575	0.218	0.647
1989	0.486	0.483	1.687	0.102	0.707	1.967	6.875	0.415	1.231
1990	0.141	0.094	0.718	0.010	1.063	0.382	2.925	0.039	0.356
1991	0.306	0.296	1.202	0.057	0.773	1.206	4.899	0.233	0.775
1992	0.331	0.213	1.086	0.035	0.857	0.868	4.429	0.143	0.838
1993	0.533	0.476	1.867	0.079	0.765	1.940	7.610	0.322	1.348
1994	0.118	0.081	0.438	0.014	0.878	0.331	1.787	0.055	0.300
1995	0.290	0.258	1.267	0.044	0.845	1.050	5.166	0.177	0.735
1996	0.475	0.236	1.274	0.036	0.892	0.962	5.194	0.146	1.201
1997	0.553	0.246	1.063	0.047	0.800	1.004	4.334	0.191	1.399
1998	0.489	0.225	0.982	0.043	0.805	0.918	4.001	0.175	1.237
1999	0.277	0.160	0.713	0.030	0.814	0.651	2.906	0.123	0.702
2000	0.322	0.218	0.910	0.043	0.789	0.888	3.709	0.174	0.816
2001	0.499	0.304	1.256	0.060	0.785	1.237	5.119	0.243	1.263
2002	0.401	0.154	0.780	0.028	0.861	0.628	3.178	0.113	1.016
2003	0.523	0.241	1.211	0.038	0.868	0.982	4.937	0.156	1.323
2004	0.731	0.213	1.021	0.035	0.849	0.870	4.163	0.142	1.851
2005	0.785	0.443	1.653	0.082	0.741	1.807	6.737	0.335	1.987
2006	0.593	0.186	0.846	0.031	0.828	0.759	3.447	0.126	1.500
2007	0.505	0.152	0.825	0.023	0.892	0.619	3.362	0.093	1.279
2008	0.342	0.077	0.480	0.011	0.937	0.313	1.957	0.044	0.865
2009	0.841	0.271	1.175	0.046	0.809	1.103	4.791	0.187	2.128
2010	0.360	0.050	0.373	0.006	1.007	0.204	1.521	0.025	0.911
2011	0.699	0.179	0.756	0.033	0.790	0.728	3.083	0.133	1.770
2012	0.175	0.033	0.206	0.005	0.926	0.133	0.840	0.020	0.442

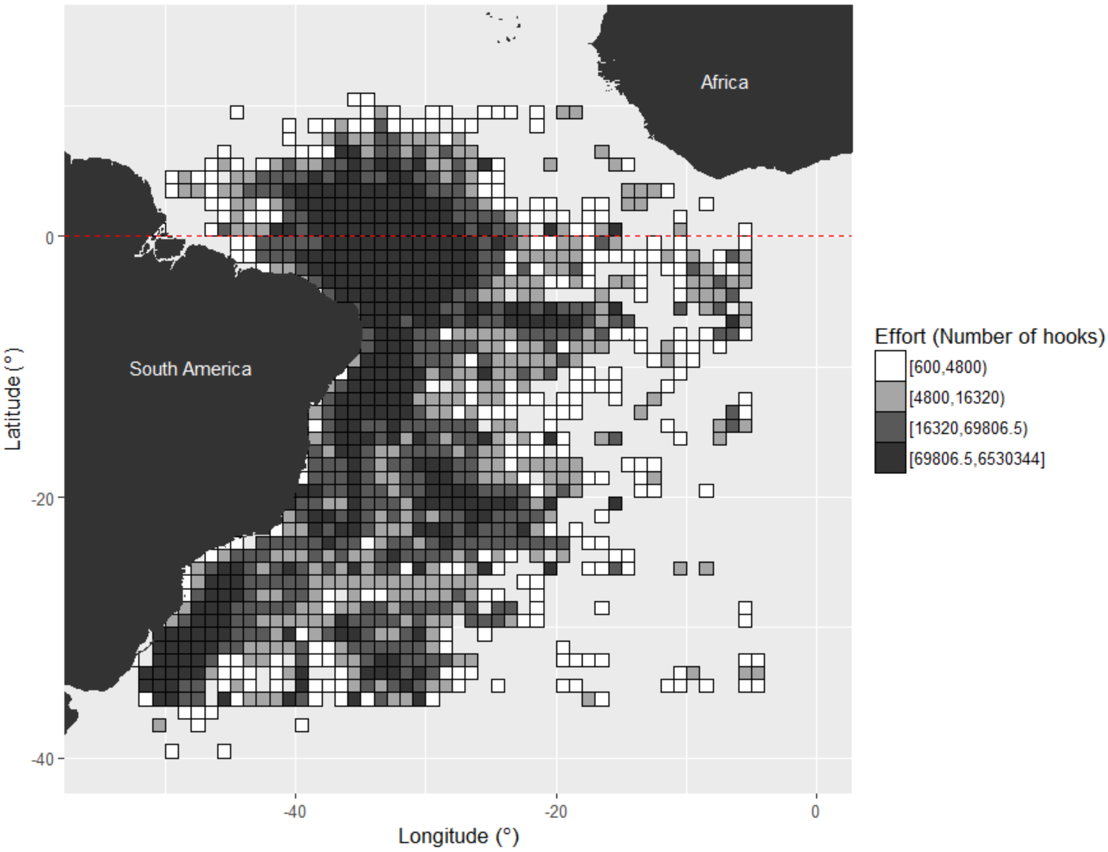

Figure 1. Distribution of the effort done by the Brazilian tuna longline fishery in the Atlantic Ocean from 1978 to 2012 (35 years).

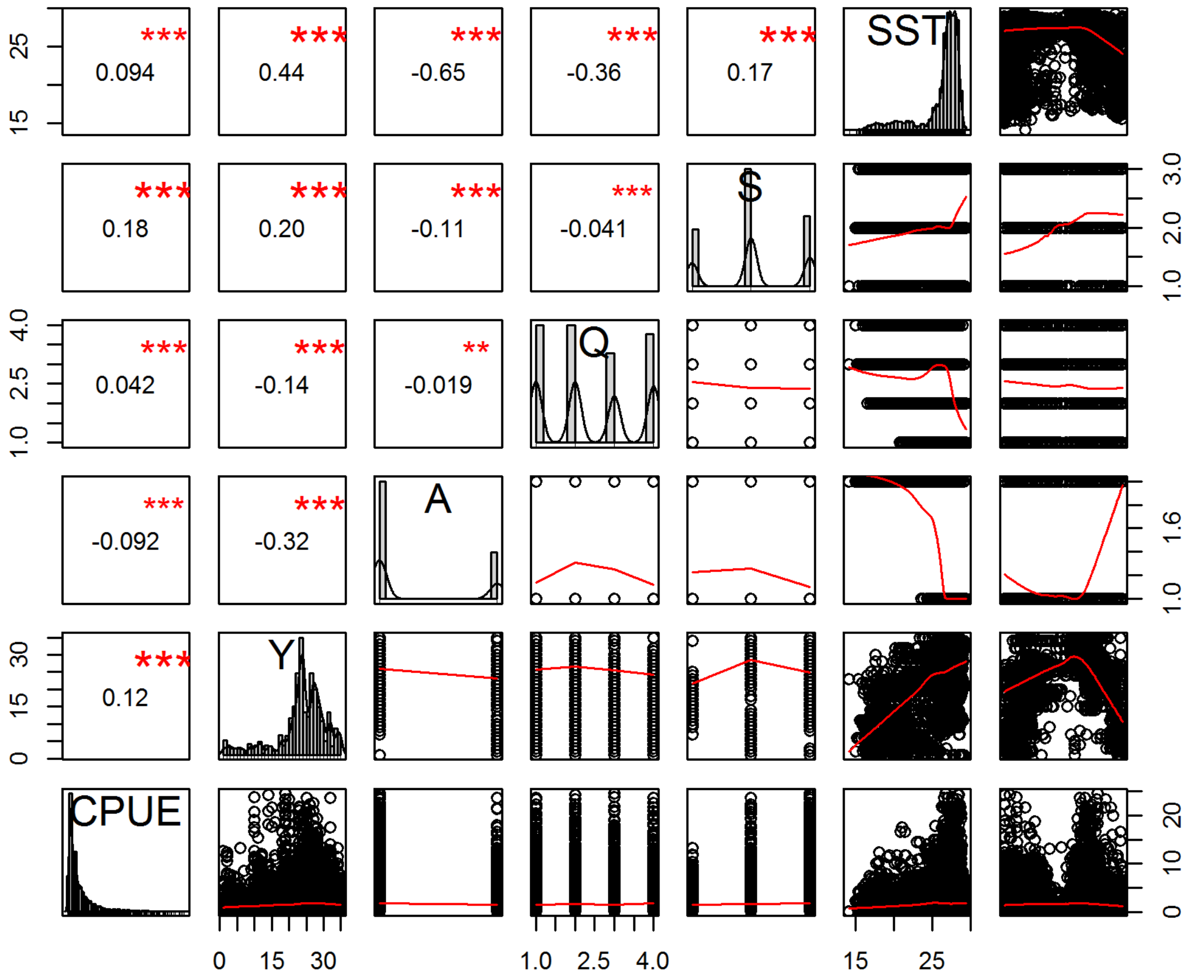

Figure 2. Scatterplots matrices with the relationships between sailfish CPUE and the candidate continuous explanatory variables used diagonal panels show the scatterplots with smooth loess regression lines.

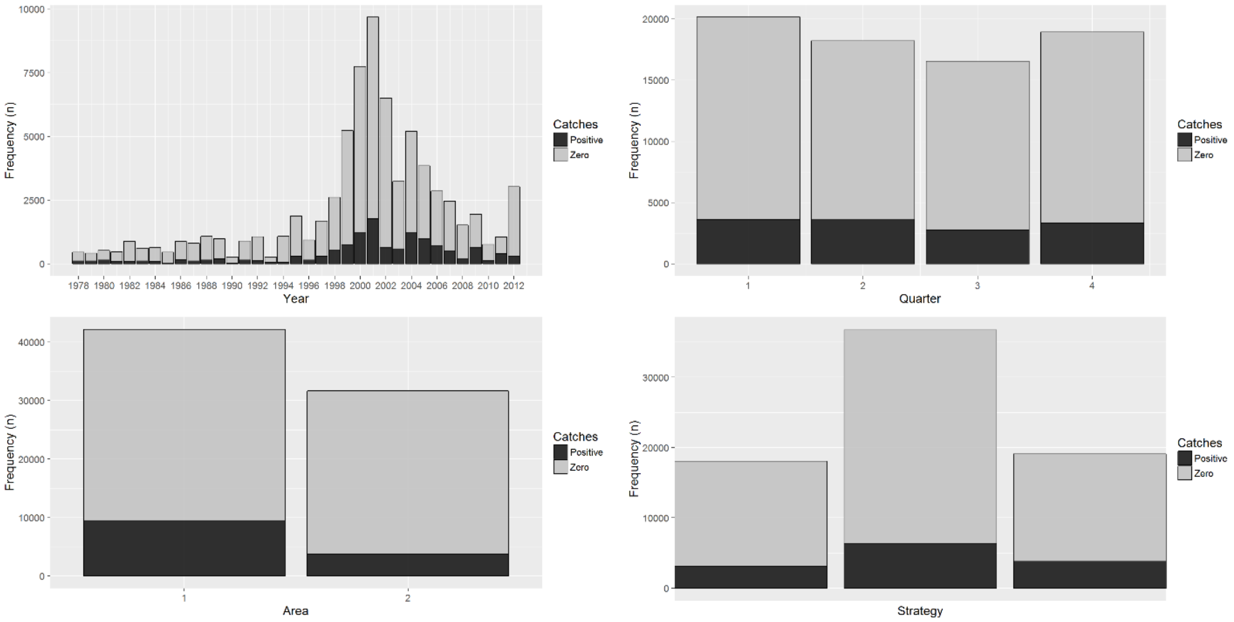

Figure 3. Proportion of positive captures and negative sets by year, quarter, area and strategy.

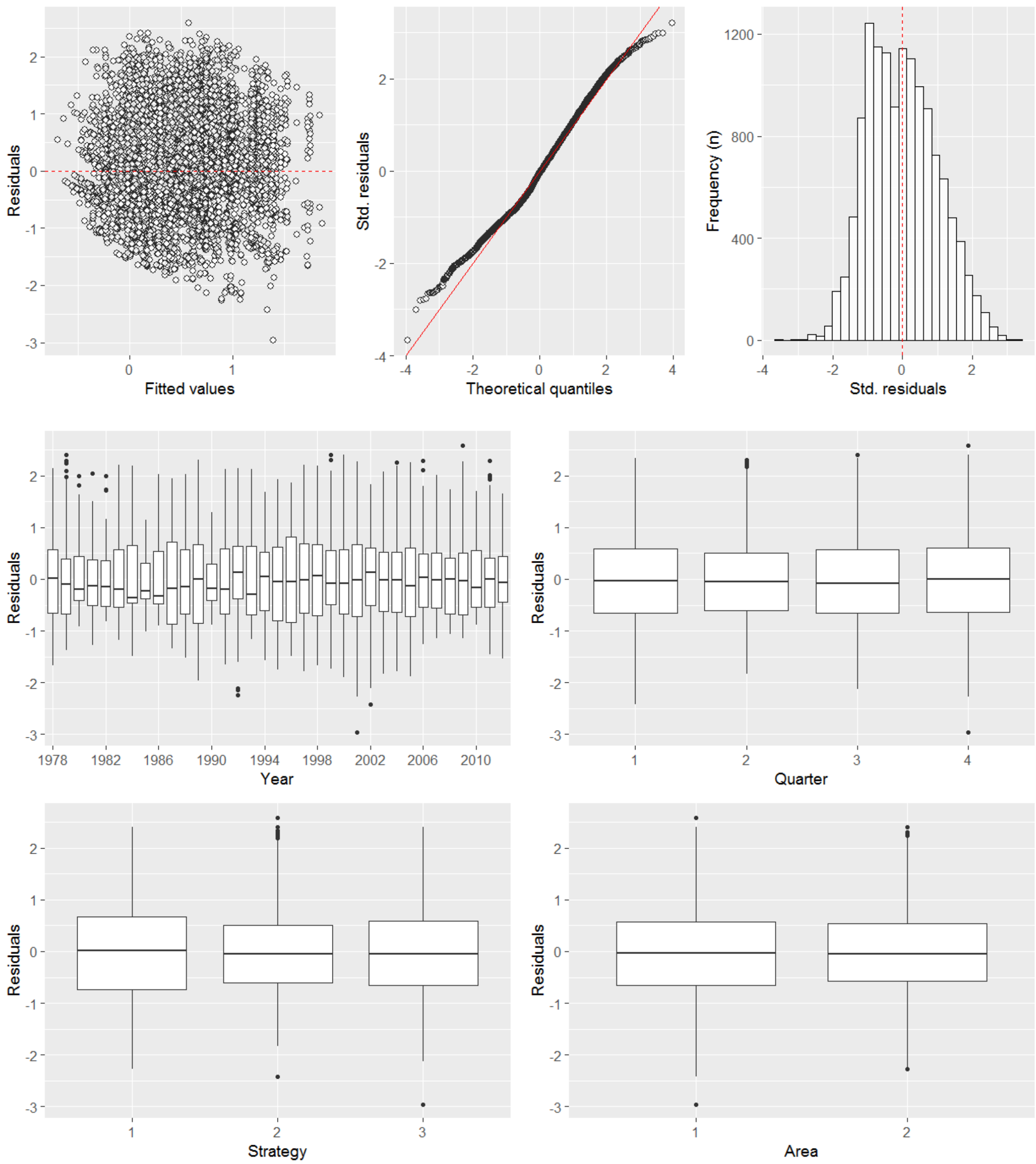

Figure 4. Residual analysis of the Lognormal model fitting of sailfish caught by the Brazilian tuna longline fleet 1978 to 2012.

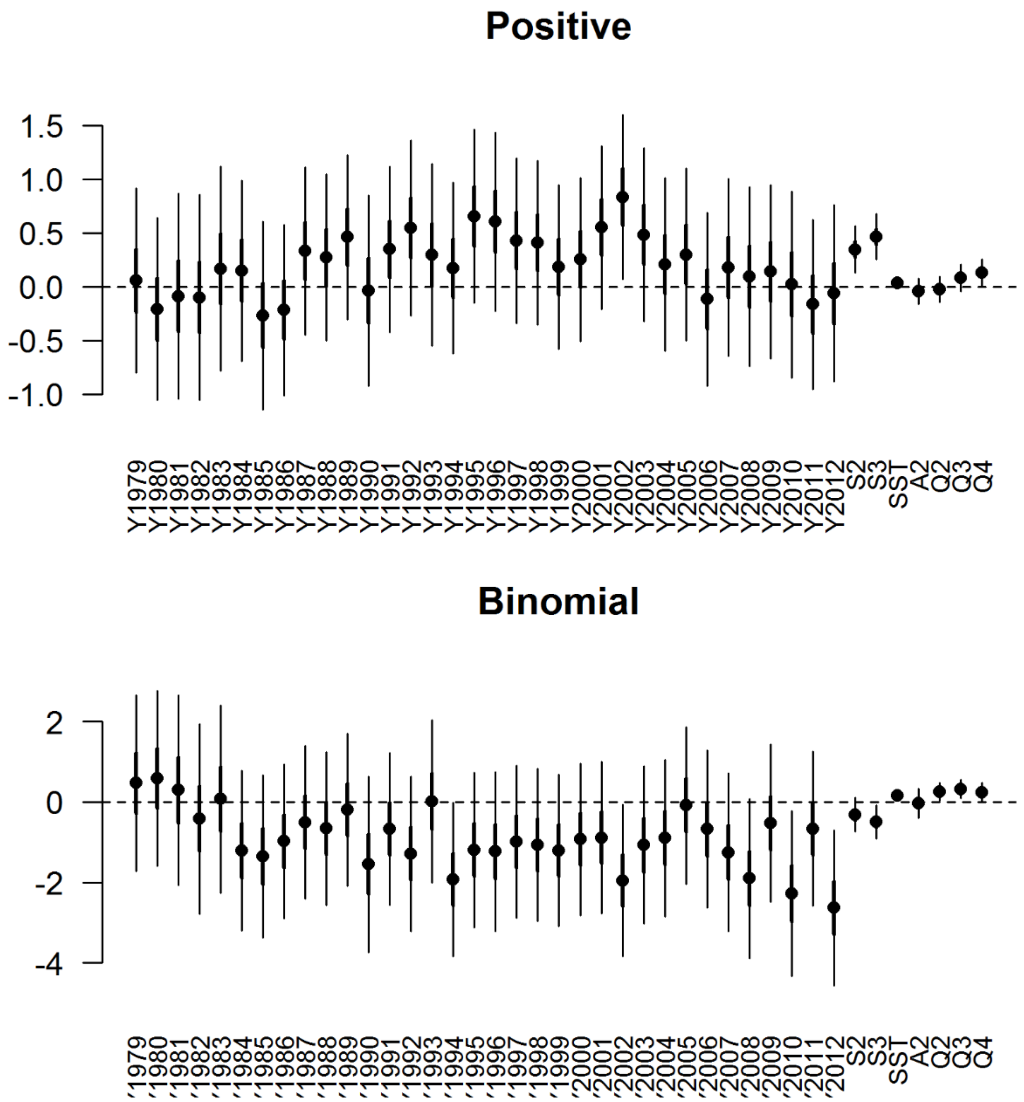

Figure 5. Parameter estimates for predicting sailfish catch rates in the Atlantic Ocean. For each parameter it is indicated the point estimate, the 50% (thick lines) and the 95% (thin lines) confidence intervals.

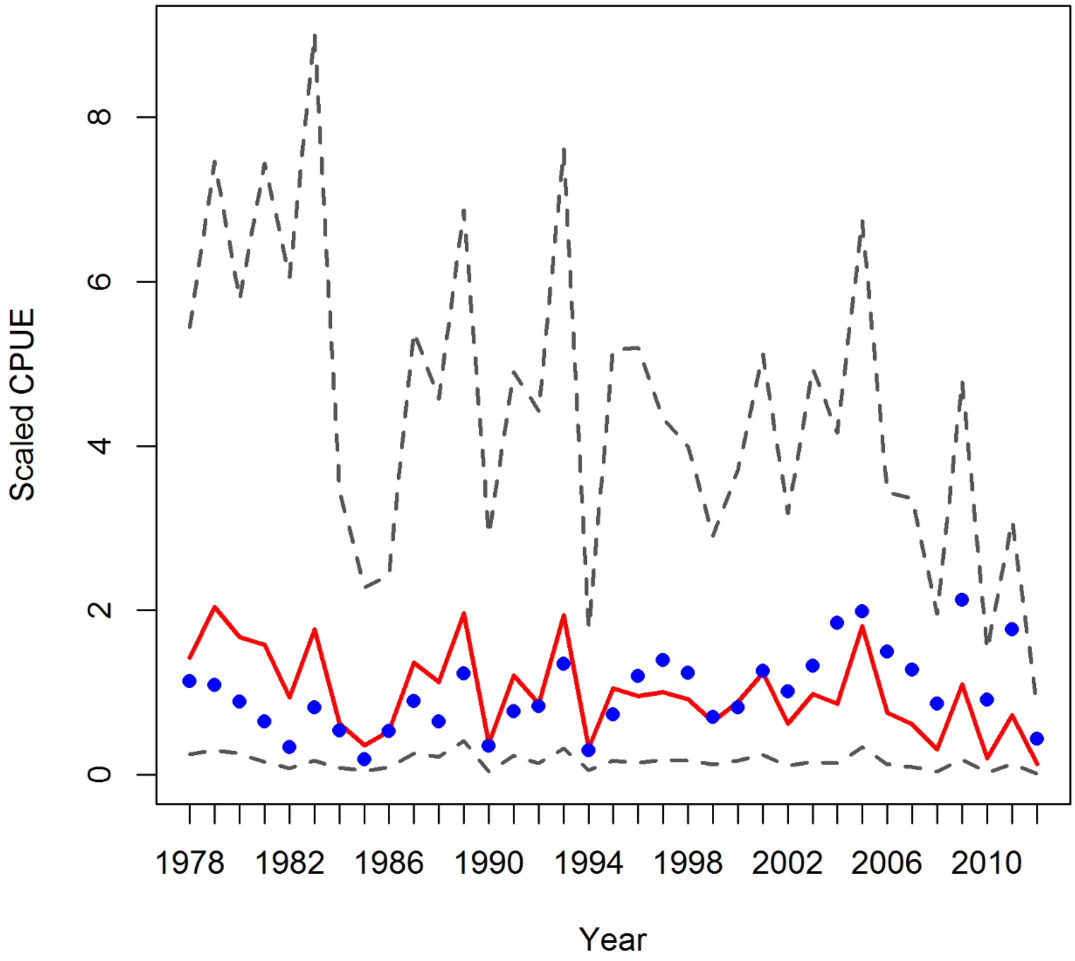

Figure 6. Nominal and standardized scaled CPUE of sailfish for Brazilian tuna longliners from 1978 to 2012.