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CPUE AND CATCH TRENDS OF BLUE AND MAKO SHARKS CAUGHT BY BRAZILIAN LONGLINERS IN THE SOUTHWESTERN ATLANTIC OCEAN (1978 - 2007)

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SUMMARY

*In the present study, catch and effort data from 60.645 sets done by the Brazilian tuna longline fleet (national and chartered), in the Southwestern Atlantic Ocean, from 1978 to 2007 (30 years), were analyzed. The CPUE of blue and mako sharks was standardized by a GLM, using 3 different approaches: in the first one, a negative binomial error structure (log link) was assumed, while in the second one, a more traditional delta-lognormal model, assuming a binomial error distribution for the proportion of positive sets and a Gaussian error distribution for the positive blue and mako sharks catches was applied. The last approach was the tweedie distribution, recently proposed to adjust models with high proportion of zero. All models were based on the following factors: quarter, year, area, target, quarter*year and year*area. The results indicated that the tweedie might be a better option for the standardization of CPUE for blue shark and delta-lognormal for mako shark. The blue shark CPUE standardized by the tweedie GLM showed a relatively stable trend, from 1978 to 1995. From 1995 on, however, there was an increasing trend, with a sharp rise between 2000 and 2002, up to a maximum value in 2007, close to 2.0. Like for the blue shark, the mako shark CPUE, both nominal as well as standardized by the delta-lognormal model, was relatively stable up to the middle nineties, increasing then in more recent years.*

KEYWORDS
Blue shark, mako shark catch/ effort, standardized, catchability

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1. Introduction

In 2004, for the first time in its history, ICCAT (International Commission for the Conservation of Atlantic Tunas) carried out an exercise of stock assessment of Atlantic blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*). Although the general conclusion of the assessment was that both shortfin mako and blue shark stocks in the North and South Atlantic seemed to be in an adequate condition, probably at levels above the Maximum Sustainable Yield, the results of the analysis should be interpreted with considerable caution due to data deficiencies and to the fragility of the assessment methods employed. In the following year ICCAT SCRS (Standing Committee of Research and Statistics) decided to address shark issues, in the context of the fisheries managed by the Commission, under a specific group. Finally, during its 2006 meeting, ICCAT recommended that a new stock assessment for the two species be carried out in 2008, emphasizing, though, the acute need for more detailed data, particularly on fishing effort and catches from the main fisheries catching those species in the Atlantic Ocean.

The blue shark is probably the widest ranging chondrichthyian, showing a circumglobal distribution in tropical, subtropical, and warm-temperate seas, including the Mediterranean (Compagno, 1999). For that reason, it is the most abundant elasmobranch caught by the pelagic longline fisheries in oceanic areas. Blue shark movements are strongly influenced by water temperature (Pratt, 1979), with the species undergoing seasonal latitudinal migrations on both sides of the North Atlantic (Casey, 1985), South Atlantic (Hazin *et al*., 1990), and in the North Pacific (Nakano, 1994). It is a common species throughout the Brazilian coast, being frequently caught by the longline fishery targeting tunas and swordfish. Catch rates reported from commercial longlining in the Atlantic Ocean range roughly from 2.9 to 100.0 sharks caught per 1,000 hooks (Stevens and Wayte, 1999), while average catch rates as high as 145.0 have been recorded from research longline cruises. Due to its relatively high abundance, it has been well studied, with a considerable amount of information being available on its biology from the South Atlantic Ocean (Amorim, 1992; Lessa *et al*., 2004; Hazin, 1991; Hazin *et al*., 1990; Hazin *et al*., 1994a, b, c; Hazin *et al*., 1998; Hazin *et al*., 2000).

Although much less abundant than the blue shark, the shortfin mako, *Isurus oxyrinchus*, is also a common epipelagic species found in tropical and warm-temperate seas (Compagno, 1999). In spite of its relatively low catches, because of its high commercial value, together with the blue shark, it is one of the best recorded shark species in commercial operations (Clarke *et al*., 2004).

Since 1956, when the tuna longline fishery began in the South Atlantic, several changes in both gear design and structure, as well as in fishing operation and targeting strategies, have been observed, with a strong influence on catch composition (Amorim and Arfelli, 1984; Arfelli, 1996; Hazin, 1993; Hazin and Hazin, 1999; Menezes de Lima *et al*., 2000). Such changes, together, may lead to strong variations in catchability, which, in turn, can introduce serious errors in the estimation of abundance indices (Fréon and Misund, 1999).

One way to overcome this bias is by standardizing the CPUE series by a Generalized Linear Model (GLM), incorporating the factors that are known to influence catchability (Gulland, 1983). Catch and effort databases, however, often include high proportions of records in which the catch is zero, even though effort is recorded to be non-zero. This is particularly the case for less abundant species and for by-catch species (Maunder and Punt, 2004), like the blue and mako sharks. In such cases, in order to standardize the CPUE by GLM, traditionally, a delta-lognormal model is used, assuming different error distributions for the positive catches and for the proportion of positives. Another, less common, method is to assume a negative binomial distribution, using the CPUE as a discrete variable, rounded to integer values. Recently, Shono (2008) proposed the use of the tweedie distribution in order to try obtaining better results in the adjustment of model with a high proportion of zero.

Thus, the objectives of this paper are: a) to updated a standardized CPUE series from the Brazilian longliners in preparation for the stock assessment of the blue and mako sharks; b) to examine recent trends in relative abundance and c) to contribute information on the methods used to standardize CPUE series of pelagic sharks comparing 3 different approaches: delta-lognormal, negative binomial and tweedie distribution.

2. Material and methods

Data set

In the present study, catch data from about 60,645 longline sets done by the Brazilian tuna longline fleet, including both national and chartered vessels, from 1978 to 2007 (except for 1990, 1993 and 2003) were analyzed. The logbooks were made available by the Special Secretariat of Fisheries and Aquaculture (SEAP), of the Brazilian government. The logbook data included individual records containing the vessel identification, hour of the set, location of fishing ground (latitude and longitude), date, and the number of fish caught in each fishing day. The longline sets were distributed along a wide area of the Southwestern Atlantic Ocean, ranging from 10º to 50ºW of longitude and from 07ºN to 45ºS of latitude (Fig. 1).

Statistical analyses

The factors used as explanatory variables were: year (30), quarter (4), area (2) (<15^{o}S and >15^{o}S) and the target species (6; Table 1), as inferred from a cluster analysis, using the K-means method (FASTCLUS, Johnson and Wichern, 1988; SAS Institute Inc, 1989), to identify the number of ideal clusters. The main advantage of such method, instead of using the percentage of a single species as an expression of the targeting strategy, rely in the fact that they consider the frequency distribution of all species in each set, thus providing a more reliable estimation (Hazin *et al*., 2007).

Relative abundance indices were estimated by a Generalized Linear Models (GLM), by 3 different approaches: a more traditional delta-lognormal model, a negative binomial error structure (log link), and a tweedie distribution. For all models, four main effects (Year, Target, Area, Quarter) and their interactions (Year*Quarter and Year*Area) were considered.

In the delta-lognormal model, a binomial error distribution was assumed for the proportion of positive sets and a Gaussian error distribution for the positive blue and mako sharks catches.

The negative binomial error structure is a discrete probability distribution which indicates the number of trials that are necessary to obtain k successes of equal probability θ at the ending of n fishing sets. As the negative binomial distribution requires integer values, the CPUE was transformed to a discrete variable. Since the effort variance was less than 10%, the CPUE was obtained based on the number of fish caught by the mean effort (1,929 hooks per fishing set), rounded to the nearest integer.

The family tweedie is derived from a broader class of probabilistic models, called Models of Dispersion (MD) following Jorgensen (1997). In the tweedie model the response variable was the CPUE calculated as number of fish/ 100 hooks. Because the tweedie model is expressed as the Poisson distribution if the power-parameter (p) of the probability density function is between 1 and 2, then it seems to be appropriate for the analysis (Shono, 2008). In the present study, for both blue and mako sharks, the best value of p was 1.2, assuming a Gamma-Poisson distribution.

The variables were selected using a stepwise approach with forward entry from null model. The decision on entry or exclusion of the predictors was based on the lower value of Akaike Information Criterion (AIC) (Akaike, 1974). Pearson's correlation coefficient was used to measure the strength between the corresponding and predicted values

Results and Discussion

The cluster analysis grouped the data in 6 different strata, according to the target species, as follows: C1= albacore (74.3%); C2= yellowfin tuna, together with albacore and the bigeye tuna (44.8%, 13.4%, and 13.6%, respectively); C3= mixed species; C4= swordfish (54.3%); C5= blue shark (68.4%); and C6= bigeye tuna (72.1%) (Table 1).

The overall proportion of zero catch in the study period was equal to 57.2 and 89.0%, for blue and mako sharks, respectively (Fig. 2). The "stepwise" analysis did not result in the reduction of any variable in the model.

The delta log-normal distribution model explained 64.7% (blue shark) and 41.6% (mako shark) of the variance for the positive catches and about 75.0% (blue shark) and 60.8% (mako shark) for the proportion of positives. The main factor explaining the variance for both the positive catches and the proportion of positives for the blue shark was the target species (cluster), accounting for 52.2% and 47.5%, respectively. However, for the mako shark, year was the main factor, accounting for 48.6% and 29.6 % of the variance for positive catches and proportion of positives, respectively (Table 2 A, B, C, and D).

The negative binomial model explained 33.4% and 40.4% of the variance, for blue and mako sharks, respectively. Similarly to a previous work (Hazin *et al*., 2007), target was the most important factor, explaining 73.1 % and 37.3% of the variance, for blue and mako sharks CPUE, respectively (Tables 3 A and B).

The tweedie model explained 60.1% and 33.2% of the catch rate variability, for blue and mako sharks respectively. Similarly to the delta log-normal model, the target species was again the main factor explaining the variance for blue shark (46.8%), while for the mako shark, the year was the most important factor (27.2%) (Table 4 A and B).

Table 5 shows the overall values of Pearson's correlation coefficient between the observed and predicted CPUE values for blue shark. The distribution of residuals appeared to be quite close to normal (Fig. 3). These results indicate that good fits were obtained for all distribution and assumed errors were quite satisfactory for all models. The tweedie model obtained the smallest coefficient of variance (CV) of blue shark standardized CPUE values (Table 6). Judging from the present results, the tweedie distribution seems to be the best option to standardize de blue shark CPUE.

The analysis of the mako shark Pearson's correlation coefficient (Table 7), distribution of residuals (Fig. 4), and coefficient of variance (Table 8) indicated that the delta-lognormal is probably the best option to perform the standardization of mako shark CPUE. The distribution of residuals of the tweedie and the negative binomial models for mako shark standardized CPUE did not presented characteristics of normality. According to Shono (2008), however, this probably happens because some predicted values obtained from the model corresponding to the zero-catch observations became positive.

The blue shark CPUE standardized by the tweedie GLM (Fig. 5) showed a relatively stable trend, from 1978 to 1995, oscillating from 0.5 to 1.0. From 1995 on, however, there was an increasing trend, with a sharp rise between 2000 and 2002, up to a maximum value in 2007, close to 2.0. One of the possible reasons for this rise was the introduction of the monofilament gear, targeting swordfish, in 1995-1996, followed by a gradual increase in the market value of the blue shark along time. The cluster analysis shows that the blue shark was the second species most caught in the swordfish cluster (Cluster 4; SWO= 54.3%; BSH= 10.7%), while the swordfish was the second species most caught in the blue shark cluster (Cluster 5; BSH= 68.4%; SWO= 8.3%) (Table 1). These results indicate that both species are commonly caught together in the longline fishery, probably due to similarities of habitat use and feeding habits. Therefore, the change of the longline gear to monofilament, from 1995 on, aiming at higher swordfish catches, might have influenced the blue shark CPUE upward. The yearly frequency distribution of the 6 clusters, from 1978 to 2007 (Fig. 6), shows that the relative participation of clusters 4 (swordfish) and 5 (blue shark) lumped together, equal to 9.4%, in 1996, almost doubled in 2001, reaching 18.4%, jumping then to almost 50%, in 2003, and to 73.3%, in 2007. These figures show that after the introduction of the fishing gear, in 1995-96, the change in the targeting strategy was gradual, with a significant increase from the year 2000 on. Furthermore, as the fishery progressed, the realization by fishermen that blue shark catches might be greater than those of swordfish, in a proportion big enough to compensate the price gap between them, might have turned the blue shark increasingly into a target species. In addition, the steady supply of blue shark meat in the local market gradually helped to build a market for the species, thereby driving the prices upward. A similar trend in price rise was also observed in the fins, largely exported to Asian markets.

Like for the blue shark, the mako shark CPUE, both nominal as well as standardized by the delta log-normal model, was relatively stable up to the middle 1990's, increasing then in more recent years, although with a much stronger variance than for the blue shark, certainly due to its much rarer occurrence in catches (Fig. 7). Since the highest frequency of mako shark catches happened in Clusters 3 (mixed species), 4 (swordfish) and 5 (blue shark), its CPUE might have been influenced by the same factors as discussed for the blue shark, above described.

4. Acknowledgments

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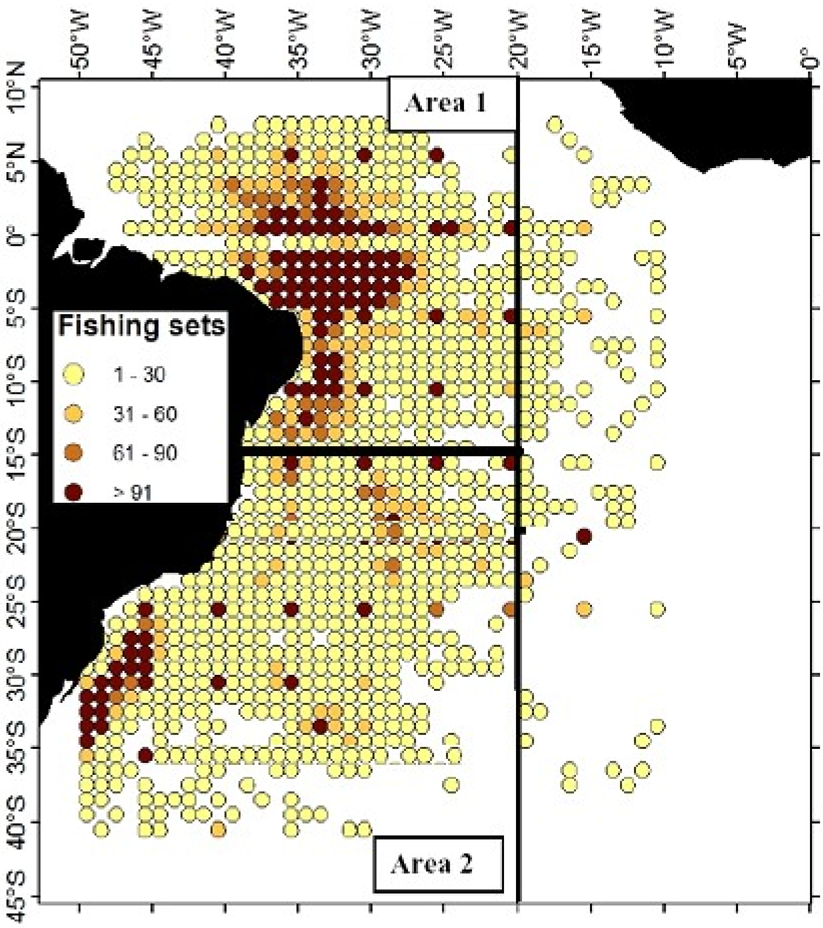
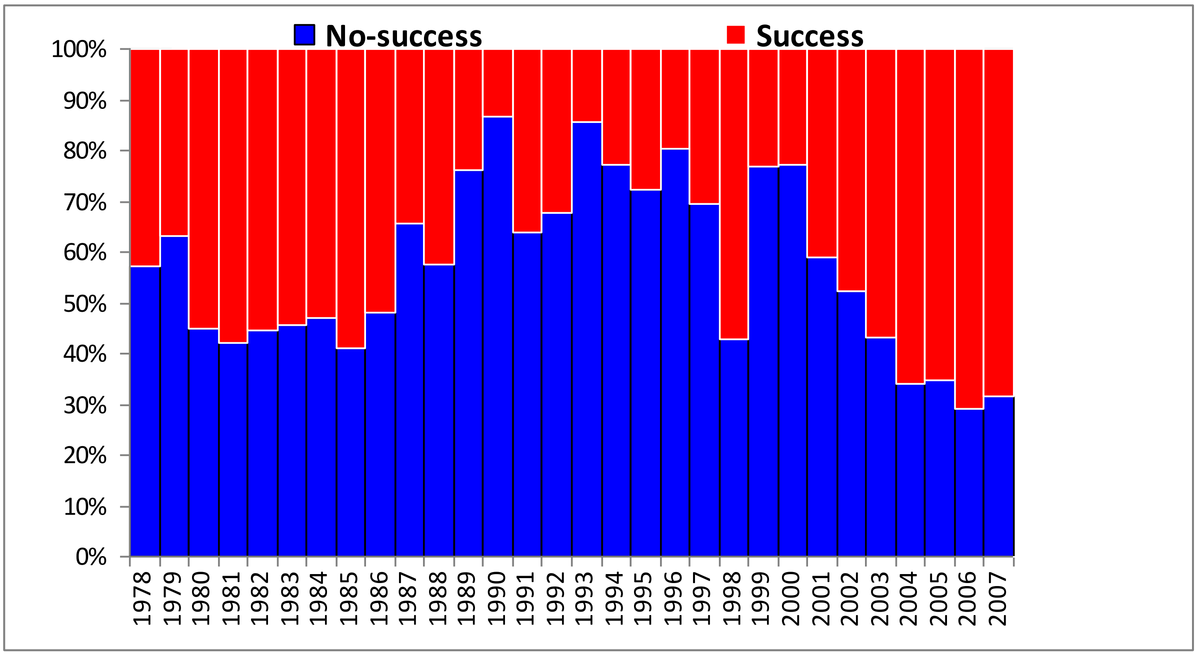


Figure 1. Distribution of the longline sets done by the Brazilian tuna longline fishery in the Atlantic Ocean, from 1978 to 2007

Table 1- Distribution of 60,645 longline sets done by the Brazilian tuna longline fishery in the Atlantic Ocean, from 1978 to 2005, by cluster (values over 10% are in red).

CLUSTER	**1**	**2**	**3**	**4**	**5**	**6**
YFT	5.6	44.8	9.4	8.2	2.4	6.3
ALB	74.3	13.4	6.8	5.4	4.8	3.1
BET	5.8	13.6	5.2	9.8	1.4	72.1
SWO	3.1	7.5	10.4	54.3	8.3	9.0
SAI	1.3	2.4	2.1	1.9	0.8	1.0
WHM	0.7	1.2	1.4	0.9	0.5	0.5
BUM	0.5	1.3	0.7	2.3	0.4	0.9
OTH.BIL	0.1	0.1	2.4	0.3	0.3	0.0
WAH	0.7	2.9	2.1	0.4	0.3	0.3
DOL	0.4	0.7	5.7	1.3	3.3	0.4
BSH	1.3	2.8	8.2	10.7	68.4	1.9
SPL	0.0	0.2	2.1	0.4	1.6	0.0
BTH	0.0	0.1	0.1	0.1	0.3	0.0
MAK	0.3	0.3	1.8	0.8	2.8	0.1
FAL	0.0	0.1	5.8	0.1	0.2	0.1
OCS	0.0	0.0	0.1	0.0	0.0	0.0
Other Sharks	2.0	1.5	11.7	1.2	2.5	2.7
Other Teleosts	3.9	7.1	24.1	1.9	1.8	1.7
Number of Sets	12.098	16.445	9.786	13.951	3.601	4.764
% of Sets	19.9	27.1	16.1	23.0	5.9	7.9

Blue shark



Mako shark

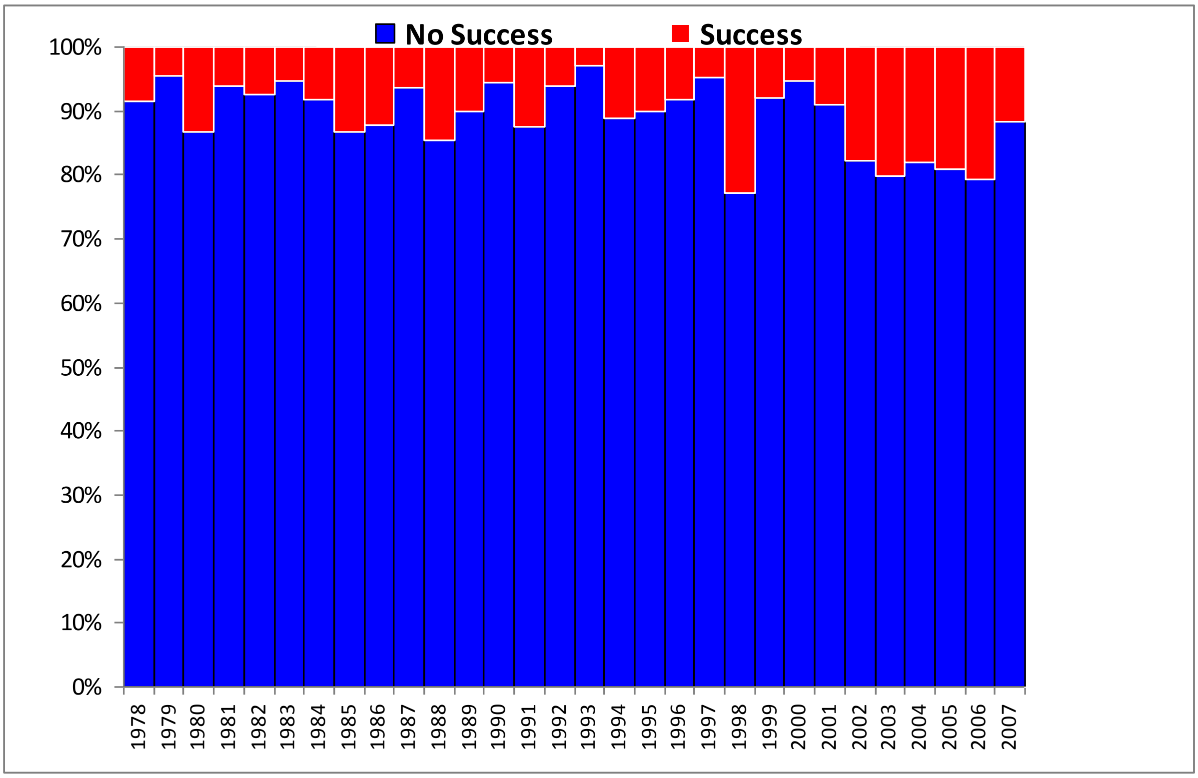


Figure 2. Proportion of positive catches of blue and mako sharks caught by the Brazilian tuna longline fishery in the Atlantic Ocean, from 1978 to 2007

Table 2- Deviance analysis of explanatory variables in the delta-log normal model of blue and mako sharks caught by Brazilian longline fleet, from 1978 to 2007.

Blue shark

A)

Delta-log Model positive catches

	Df	Deviance	Resid.Df	Resid.Dev	Pr (Chi)	Explained Deviance	Explained Model
NULL			24403	16567.0			
Year	26	2829.2	24377	13737.9	0.0000	26.4%	17.1%
Quarter	3	74.9	24374	13663.0	0.0000	0.7%	17.5%
Area	1	1979.7	24373	11683.2	0.0000	18.5%	29.5%
Target	5	5591.6	24368	6091.6	0.0000	52.2%	63.2%
Year:Quarter	77	179.3	24291	5912.4	0.0000	1.7%	64.3%
Quarter:Area	3	61.7	24288	5850.7	0.0000	0.6%	64.7%

B)

Delta-log Model Proportion of positives

	Df	Deviance	Resid.Df	Resid.Dev	Pr (Chi)	Explained Deviance	Explained Model
NULL			1038	28792.5			
Year	26	7360.1	1012	21432.4	0.0000	34.1%	25.6%
Quarter	3	705.3	1009	20727.1	0.0000	3.3%	28.0%
Area	1	1464.0	1008	19263.1	0.0000	6.8%	33.1%
Target	5	10255.4	1003	9007.7	0.0000	47.5%	68.7%
Year:Quarter	78	1559.2	925	7448.5	0.0000	7.2%	74.1%
Quarter:Area	3	255.7	922	7192.8	0.0000	1.2%	75.0%

Mako shark

C)

Delta-log Model positive catches

	Df	Deviance	Resid.Df	Resid.Dev	Pr (Chi)	Explained Deviance	Explained Model
NULL			5853	2326.8			
Year	26	470.2	5827	1856.7	0.0000	48.6%	20.2%
Quarter	3	98.8	5824	1757.8	0.0000	10.2%	24.5%
Area	1	118.9	5823	1638.9	0.0000	12.3%	29.6%
Target	5	117.5	5818	1521.4	0.0000	12.1%	34.6%
Year:Quarter	76	153.8	5742	1367.6	0.0000	15.9%	41.2%
Quarter:Area	3	9.1	5739	1358.5	0.0276	0.9%	41.6%

D)

Delta-log Model Proportion of positives

	Df	Deviance	Resid.Df	Resid.Dev	Pr (Chi)	Explained Deviance	Explained Model
NULL			1042	11125.5			
Year	26	2003.4	1016	9122.1	0.0000	29.6%	18.0%
Quarter	3	623.8	1013	8498.3	0.0000	9.2%	23.6%
Area	1	1293.7	1012	7204.6	0.0000	19.1%	35.2%
Target	5	1911.9	1007	5292.7	0.0000	28.2%	52.4%
Year:Quarter	78	628.8	929	4663.9	0.0000	9.3%	58.1%
Quarter:Area	3	308.1	926	4355.8	0.0000	4.6%	60.8%

Table 3- Deviance analysis of explanatory variables in the negative binomial model of blue and mako sharks caught by Brazilian longline fleet, from 1978 to 2007.

Blue shark
A)

Negative Binomial

	Df	Deviance	Resid..Df	Resid..Dev	Pr.Chi.	Explained Deviance	Explained Model
NULL			57561	67219.7			
Year	26	1337.8	57535	65881.8	0.0000	6.0%	2.0%
Quarter	3	464.9	57532	65416.9	0.0000	2.1%	2.7%
Area	1	2787.6	57531	62629.3	0.0000	12.4%	6.8%
Target	5	16394.9	57526	46234.4	0.0000	73.1%	31.2%
Year:Quarter	78	1200.7	57448	45033.8	0.0000	5.4%	33.0%
Quarter:Area	3	238.3	57445	44795.5	0.0000	1.1%	33.4%

Mako shark

B)

Negative Binomial

	Df	Deviance	Resid.Df	Resid.Dev	Pr (Chi)	Explained Deviance	Explained Model
NULL			57518	14337.6			
Year	26	1299.0	57492	13038.5	0.0000	22.4%	9.1%
Quarter	3	627.4	57489	12411.2	0.0000	10.8%	13.4%
Area	1	921.6	57488	11489.6	0.0000	15.9%	19.9%
Target	5	2160.8	57483	9328.7	0.0000	37.3%	34.9%
Year:Quarter	78	662.7	57405	8666.1	0.0000	11.4%	39.6%
Quarter:Area	3	121.6	57402	8544.4	0.0000	2.1%	40.4%

Table 4- Deviance analysis of explanatory variables in tweedie model of blue and mako sharks caught by Brazilian longline fleet, from 1978 to 2007.

Blue shark
A)

Tweedie

	Df	Deviance	Resid. Df	Resid. Dev	Pr(Chi)	Explained Deviance	Explained Model
NULL			57561	51121.8			
Year	26	8864.4	57535	42257.4	0.0000	28.9%	17.3%
Quarter	3	699.7	57532	41557.7	0.0000	2.3%	18.7%
Area	1	5980.3	57531	35577.5	0.0000	19.5%	30.4%
Target	5	14383.6	57526	21193.8	0.0000	46.8%	58.5%
Year:Quarter	78	335.2	57448	20858.6	0.0000	1.1%	59.2%
Quarter:Area	3	439.3	57445	20419.4	0.0000	1.4%	60.1%

Mako shark

B)

Tweedie

	Df	Deviance	Resid. Df	Resid. Dev	Pr(Chi)	Explained Deviance	Explained Model
NULL			57518	7806.5			
Year	26	705.0	57492	7101.5	0.0000	27.2%	9.0%
Quarter	3	366.8	57489	6734.7	0.0000	14.1%	13.7%
Area	1	671.7	57488	6063.0	0.0000	25.9%	22.3%
Target	5	573.6	57483	5489.4	0.0000	22.1%	29.7%
Year:Quarter	78	234.5	57405	5254.9	0.0000	9.0%	32.7%
Quarter:Area	3	41.6	57402	5213.3	0.0000	1.6%	33.2%

Table 5- Model comparison based on the results of Pearson´s Correlation.

Model	Obs vs Pred	Dispersion
Delta-log (model positive)	0.70	0.55
Tweedie	0.77	0.45
Negative Binomial	0.56	1.44

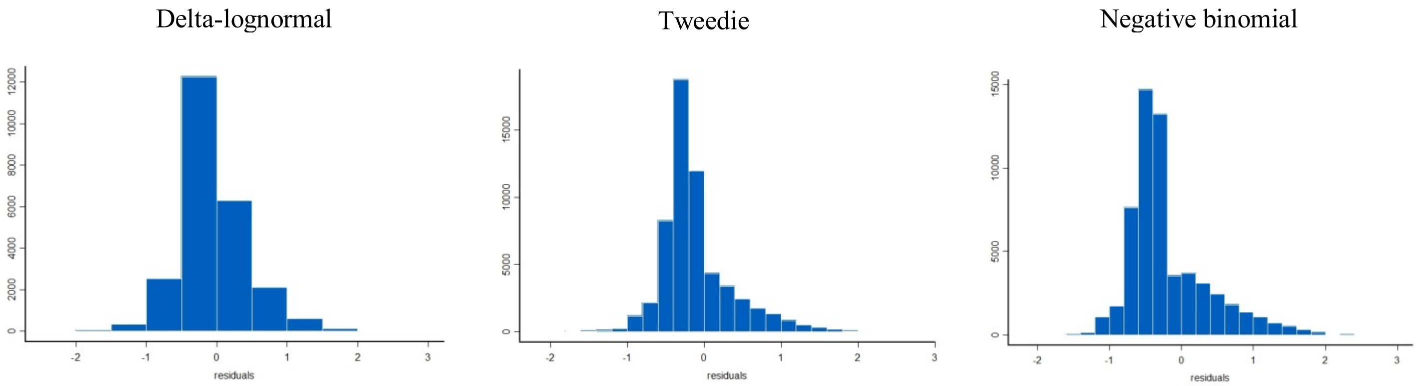


Figure 3- Residual analysis of the models fitting for blue shark catches.

Table 6- Nominal and standardized CPUE for blue shark caught by Brazilian longliners, from 1978 to 2007.

	Nominal CPUE	Tweedie	SE	CV	Negative binomial	SE	CV	Delta-log	SE	CV
1978	0.11	0.03	0.004	11%	2.71	0.477	18%	0.11	0.028	26%
1979	0.08	0.02	0.003	17%	1.19	0.045	4%	0.09	0.022	25%
1980	0.19	0.04	0.003	8%	1.58	0.123	8%	0.16	0.027	17%
1981	0.12	0.02	0.003	12%	1.98	0.254	13%	0.08	0.019	23%
1982	0.12	0.03	0.002	7%	1.47	0.072	5%	0.08	0.016	20%
1983	0.13	0.03	0.003	8%	1.48	0.092	6%	0.08	0.019	22%
1984	0.12	0.04	0.002	7%	2.48	0.308	12%	0.11	0.028	25%
1985	0.10	0.03	0.003	12%	2.11	0.283	13%	0.15	0.034	23%
1986	0.11	0.04	0.003	9%	2.10	0.216	10%	0.13	0.023	18%
1987	0.10	0.04	0.003	8%	1.96	0.167	9%	0.16	0.040	25%
1988	0.12	0.04	0.002	5%	1.79	0.118	7%	0.10	0.024	25%
1989	0.09	0.03	0.003	12%	1.86	0.145	8%	0.10	0.022	22%
1990	0.05									
1991	0.11	0.04	0.003	9%	1.75	0.152	9%	0.10	0.016	15%
1992	0.06	0.02	0.004	17%	2.54	0.382	15%	0.09	0.021	24%
1993	0.02									
1994	0.08	0.02	0.003	14%	1.35	0.070	5%	0.07	0.019	28%
1995	0.07	0.04	0.003	7%	3.18	0.372	12%	0.09	0.015	16%
1996	0.06	0.05	0.004	7%	1.00	0.000	0%	0.11	0.017	15%
1997	0.12	0.04	0.003	8%	1.62	0.084	5%	0.17	0.025	15%
1998	0.15	0.06	0.003	5%	4.43	0.574	13%	0.16	0.018	11%
1999	0.07	0.03	0.002	7%	1.52	0.048	3%	0.07	0.012	17%
2000	0.08	0.03	0.001	4%	1.38	0.028	2%	0.07	0.008	12%
2001	0.16	0.07	0.002	3%	1.97	0.079	4%	0.37	0.021	6%
2002	0.37	0.06	0.002	3%	1.67	0.066	4%	0.30	0.019	6%
2003	0.30									
2004	0.26	0.07	0.002	3%	2.31	0.122	5%	0.29	0.015	5%
2005	0.36	0.07	0.002	3%	2.16	0.095	4%	0.37	0.021	6%
2006	0.41	0.06	0.002	3%	1.64	0.069	4%	0.37	0.021	6%
2007	0.27	0.07	0.003	4%	1.93	0.112	6%	0.38	0.065	17%
Average		0.04	0.003	7%	1.97	0.17	9%	0.16	0.023	14%

Table 7- Model comparison based on the results of Pearson´s Correlation.

Model	Obs vs Pred	Dispersion
Delta-log (model positive)	0.63	0.24
Tweedie	0.46	0.23
Negative Binomial	0.23	1.24

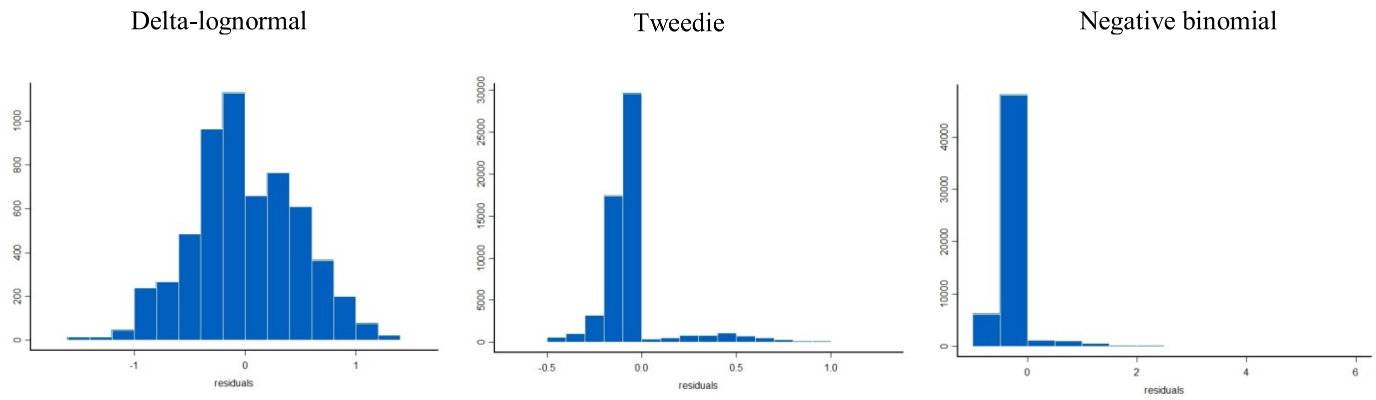


Figure 4- Residual analysis of the models fitting for mako shark catches.

Table 8- Nominal and standardized CPUE for mako sharks caught by Brazilian longliners, from 1978 to 2007.

	Nominal CPUE	DeltaLog	SE	CV	Tweedie	SE	CV	NegativeBinomial	SE	CV
1978	0.00	0.01	0.002	26%	0.001	0.000	16%	0.01	0.008	93%
1979	0.00	0.00	0.002	39%	0.000	0.000	13%	0.01	0.012	91%
1980	0.01	0.01	0.002	23%	0.004	0.001	22%	0.02	0.010	52%
1981	0.00	0.00	0.002	40%	0.002	0.001	35%	0.00	0.000	39%
1982	0.00	0.00	0.001	26%	0.001	0.000	29%	0.02	0.011	63%
1983	0.00	0.00	0.001	43%	0.000	0.000	10%	0.00	0.000	16%
1984	0.01	0.00	0.001	47%	0.002	0.001	41%	0.08	0.042	55%
1985	0.01	0.01	0.002	39%	0.001	0.000	30%	0.03	0.027	85%
1986	0.01	0.01	0.002	20%	0.002	0.000	19%	0.02	0.009	52%
1987	0.00	0.01	0.002	32%	0.007	0.002	23%	0.04	0.023	59%
1988	0.01	0.01	0.002	17%	0.003	0.001	18%	0.02	0.009	54%
1989	0.01	0.01	0.002	20%	0.008	0.002	22%	0.16	0.068	41%
1990										
1991	0.01	0.01	0.003	20%	0.008	0.002	22%	0.13	0.065	52%
1992	0.00	0.02	0.004	24%	0.001	0.000	10%	0.04	0.000	0%
1993										
1994	0.01	0.02	0.004	22%	0.003	0.001	24%	0.03	0.011	39%
1995	0.01	0.01	0.002	17%	0.004	0.001	15%	0.08	0.030	39%
1996	0.01	0.01	0.004	38%	0.006	0.002	30%	0.09	0.047	50%
1997	0.00	0.00	0.001	37%	0.001	0.000	32%	0.01	0.007	48%
1998	0.02	0.04	0.008	23%	0.003	0.001	15%	0.10	0.023	23%
1999	0.01	0.00	0.001	19%	0.004	0.000	10%	0.04	0.008	18%
2000	0.01	0.01	0.001	11%	0.000	0.000	12%	0.00	0.001	30%
2001	0.01	0.02	0.002	11%	0.002	0.000	10%	0.01	0.002	19%
2002	0.02	0.04	0.003	8%	0.004	0.000	7%	0.01	0.002	18%
2003										
2004	0.02	0.03	0.003	9%	0.004	0.000	8%	0.03	0.007	24%
2005	0.02	0.04	0.003	8%	0.005	0.000	7%	0.02	0.004	16%
2006	0.02	0.04	0.004	9%	0.004	0.000	11%	0.01	0.002	38%
2007	0.01	0.02	0.004	18%	0.003	0.001	17%	0.00	0.000	73%
Average		0.01	0.00	17%	0.00	0.00	19%	0.04	0.02	42%

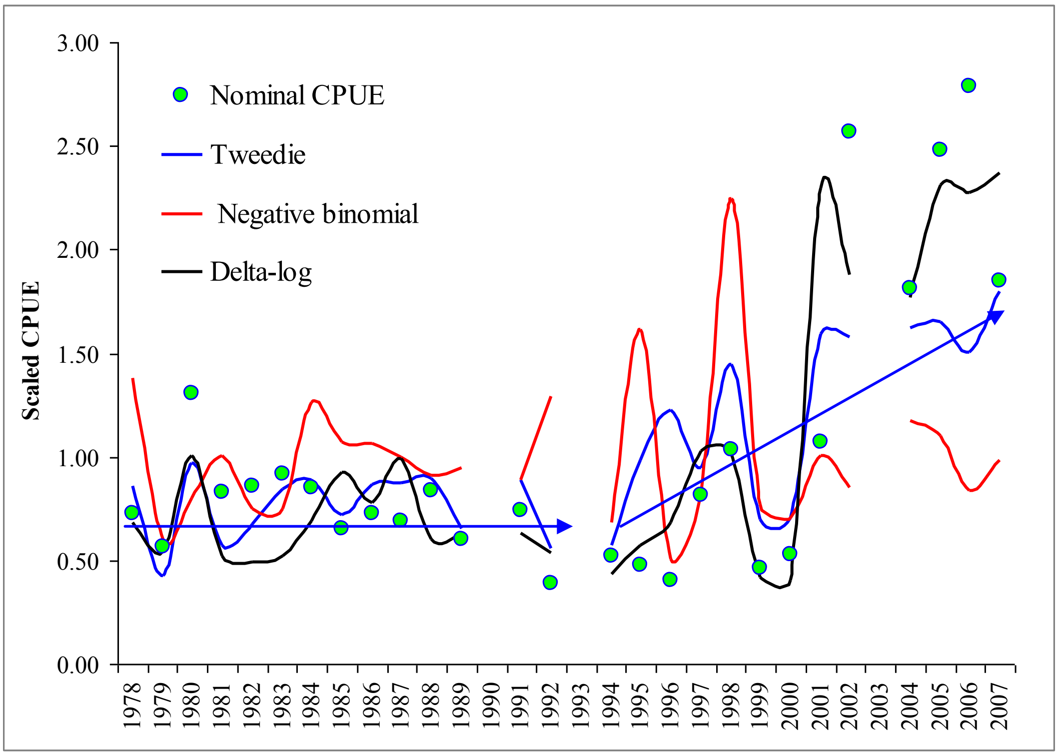


Figure 5- Scaled nominal and standardized CPUE, by delta-lognormal, tweedie, and negative binomial of blue shark for Brazilian tuna longliners, from 1978 to 2007. Blue arrows show the overall trend of the standardized CPUE based on the tweedie distribution.

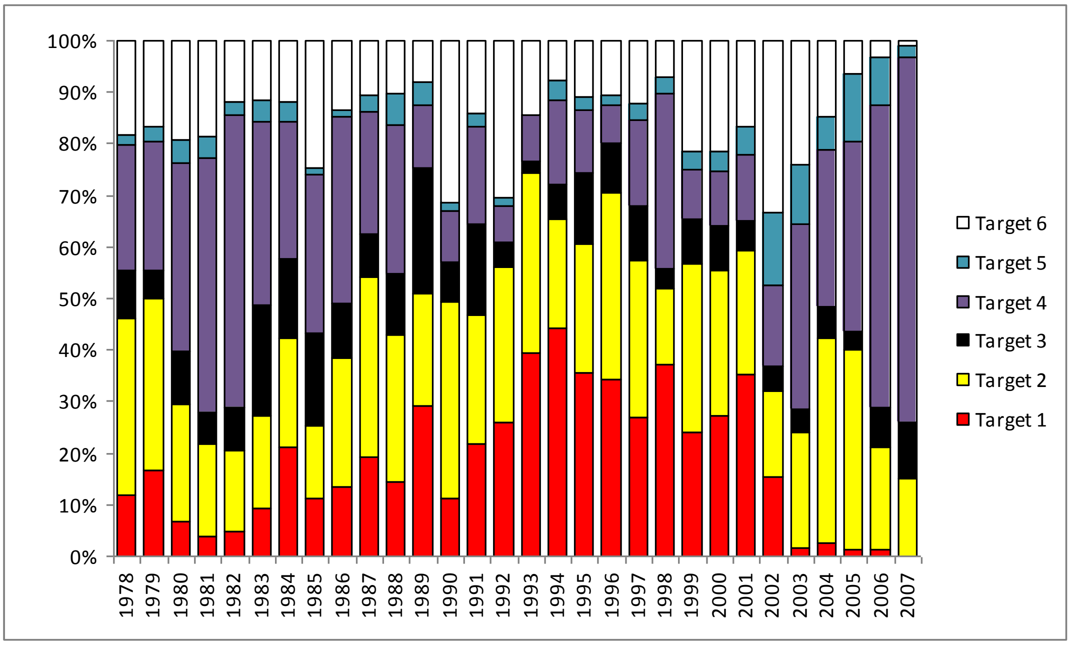


Figure 6- Yearly frequency distribution of the 6 clusters reflecting the targeting strategy, for Brazilian longliners, from 1978 to 2007.

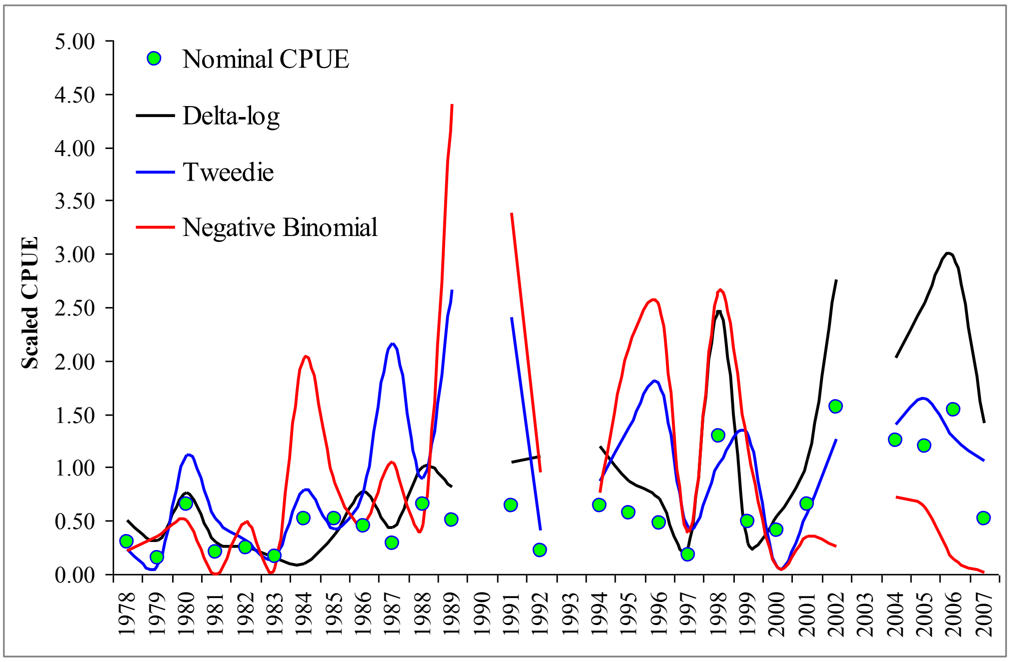


Figure 7- Scaled nominal and standardized CPUE, by delta-lognormal, tweedie, and negative binomial of mako shark for Brazilian tuna longliners, from 1978 to 2007