CONTRADICTORY CATCH RATES OF BLUE SHARK CAUGHT IN ATLANTIC OCEAN BY BRAZILIAN LONG-LINE FLEET AS ESTIMATED USING GENERALIZED LINEAR MODELS

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SUMMARY

Brazilian long-line fleet include national and leased boats. Despite those fleets fishes over the same areas, they probably do not aim at the same species. Hence catch rates of a given species may show different time trend according to the fleet (national or leased). Standardized catch rates of blue shark (Prionace glauca) caught from 2000 to 2006 by national and leased boats from Spain were compared. In order to calculate standardized indices I have analyzed Task II – ICCAT database using gamma and binomial distributions to model positive catch rates and proportion of positive catches respectively. Factors included in the models were year, quarter and area. Catch rates of national and leased boats showed contradictory time trends probably due to different fishing strategies adopted by those two fleets. Therefore, it is doubtful if standardized catch rates are useful as relative abundance indices. When factors accounting for fishing strategies were not included in models, catch rate estimations are not reasonable relative abundance indices.

KEYWORDS

Catch/effort, Fishery Statistics, Abundance, Long lining

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1. Introduction

Catch rate may be affected by the stock biomass and by the fishing gear and strategy adopted by fishermen. If fishermen aims at one particular species the catch rate may be large even if the abundance is not large. Fisherman may select to fish in an area and a month. Besides space and time, there are several other factors the fishermen may select. For example, in the long-line fisheries they can choose the number of hooks per basket, they can control the velocity of the boat when setting the long-line, and so on. Hereafter I will call all operational options that fishermen adopt to catch or avoid catching some species.

Brazilian long-line fleet includes national boats as well leased boats from several countries. Fishermen of national and leased fleets may adopt different fishing strategies according to their goals. Therefore catch rates of one species (*e.g.* blue shark – *Prionace glauca*) caught by the national and leased boats may be quite different even if those fleets fished in the same area and month. In this paper I have analyzed catch and effort data of Brazilian fleet as reported in Task II – ICCAT database. The objective was to verify if catch rate time series of blue shark (BSH) caught by national and leased boats shows different trend.

Catch rates are of major importance in fisheries science because they have been often used as relative abundance indices in stock assessment models. Generalized linear models (GLM) are often used to analyze catch and effort data in order to obtain those "standardized" catch rates (Maunder and Punt, 2004). In spite of the importance of estimating relative abundance indices, the primary objective in this paper was to compare standardized catch rates of different fleets. There is not the pretension of building a valid relative abundance indice. In opposition, I argue that analyses similar to those presented here do not allow for estimating acceptable relative abundance indices.

This paper has six sections. Description and exploratory analysis of data are in the next two sections. Models I have used and diagnostics of the fittings are in sections four and five. In the final section the standardized catch rate estimations are presented and discussed.

2. Database Overview

Although blue shark (BSH) have been caught by Brazilian long line decades ago, catches were not reported until 2000. Hence, positive catches in weight appear just from 2000 to 2006 as reported in Task II database (ICCAT, 2008). Number of reports for each year and fleet are in table 1. Notice that there are information in all years of period 2000-2006 only for national and leased boats from Spain, Honduras and Panama. As a matter of fact the amount of report is large just for two fleets, national and leased boats from Spain. Hence those two fleets were selected and hereafter I will denominate them BR and BR.ESP fleets respectively.

In most of the Task II database entries the catch was reported in weight, while the effort measurement is number of hooks. Hence, nominal catch rate measurement is ton/1000 hooks. Usually the long-line of BR and BR.ESP fleets has up to 1100 hooks, though in most of the database entries effort is larger than that value. Hereafter, database entries in which effort is larger than 1200 hooks are denominated aggregated data.

Proportion of catches equal to zero in the database are expected to decrease as far as the data is aggregated. As a matter of fact overall proportion of aggregated data increased across the last years, while the proportion of catches equal to zero decreased (Figure 1). Proportion of aggregated data is usually large (> 0.7). In opposition, proportions of catches equal to zero are usually small (< 0.2).

Nominal catch rate as calculated for national and leased boats showed contradictory trend from 2000 to 2003 (Figure 1). Catch rate of BSH landed by national fleet increase in the early 2000's, though there is a decreasing trend since 2003. In opposition, catch rate of leased fleet decrease in the early 2000's but, it increases after 2004. Overall catch rates of BSH as calculated for BR fleet were close to 0.2 t/1000 hooks after 2002. Catch rates for BR.ESP fleet were always smaller than 0.2 t/1000 hooks. It is not apparent that the relationships between catch rate and the proportions of aggregated data, or zero catches, are strong.

3. Overall Effort, Catch and Catch Rates

Geographic distributions of catch, effort and nominal catch rate are in figure 2. Database entries unreliable (*e.g.* catches placed over continent) or even improbable (*e.g.* fishing activity too far from home harbors) were discarded. Areas considered in the estimation models (see bellow) are “N” (north) and “S” (south) as displayed figure 2. Thresholds between those two areas are 15^o S and 20^o S for leased and national boats respectively. Those latitudes were selected in order to assure some balance between number of reports in each area.

Both fleets, national and leased boats from Spain, have been fishing over tropical and subtropical waters in the west of Atlantic Ocean. Nevertheless some differences are evident in the maps of effort distributions (Figure 2). National boats have concentrated effort in extremes of the north (N) and south (S) areas, while leased boats from Spain have been fishing mainly close the continent in the north and in the mid of Atlantic in the south area. Most of blue shark landed by national fleet was caught in the southern edge of the fishing ground. Catches of national boats in the north are small. Map of effort and of catche of BSH landed by leased boats from Spain are similar.

Overall catch rates of BSH landed by leased boats are low in squares were the effort was large and vice versa (Figure 2). However, that inverse relationship pattern is not apparent for national fleet database. Although the effort in the south was large, the catch rate was large as well. Hence, half of national fleet effort was concentrated in areas where catch rate of BSH was large.

4. Selection of Models

Generalized linear models were fitted to positive catch rates and proportion of positive catches of the national (BR) and leased boats (BR.ESP) databases. Factors considered were “year”, “quarter” and “area”. I have tried out the binomial distribution and three link functions (logit, probit and cauchit) when modeling the proportion of positive catch rates. Normal and gamma distributions and three link functions (identity, log, inverse) were used to analyze positive catch rates. In order to select a model among those fitted to the same response variable I have relied in Akaike and Bayesian information criteria (Akaike, 1974; Schwarz, 1978).

In order to select the explanatory factors I have started with a saturated model and I have used hypotheses tests to verify if dropping each term results in significant increase of deviance. Interactions were dropped and tested first. Main effect of a factor (*e.g.* area) was discarded only if all interactions including that factor were already discarded.

Models and deviance analyses for them are in tables 2 and 3 respectively. Binomial distribution and logit link function were selected to model the proportion of positive catch rates as reported in the two databases (BR and BR.ESP). Gamma distribution and log link function were selected to model positive catch rates. Therefore delta-gamma models are the alternative to standardize blue shark catch rates. Overall both, AIC and BIC, were smaller for those models showed in table 1 if compared to all other models I have evaluated. The binominal-logit model fitted to BR.ESP database was exception. In this case the BIC was the smallest but the AIC was larger than that calculated when using cauchit link function. Nevertheless, I have relied in BIC to select the logit link function.

Factors I have considered can explain most of the deviance for the proportion of positive catch rates, but they are not efficient explanatory variables for the positive catch database. Pseudo-R^2 as calculated for the models fitted to positive catches are small, while those calculated for proportion databases were close to 0.9. In fact, large R^2 calculations for proportion of positive catches were expected because the sample size is small. Hence models for proportion data are somewhat overfitted if compared to those fitted to positive catch rate databases.

Interaction between area and quarter proved to be not important in two cases: a) models for the proportion of positive catches as reported in BR database; and b) models for positive catch rates as reported in BR.ESP database. Factor “year” is usually the more important followed by “area” and “quarter” (Table 2). Actually the main effect of “quarter” proved to be not significant in some models. Nevertheless, that factor was not discarded because quarter was in interactions selected in hypotheses tests.

5. Diagnostics of the Fittings

Diagnostic plots for residuals of models fitted to national database are in figure 3. Diagnostic plots for the model fitted to positive catch rates shows that there was not biases or outliers of concern. Nevertheless, some comments about the model fitted to the proportion of positive catches is warranted. Leverage power and standard deviance residual were large for several data. Cook's distance calculations for those data were larger than one (see circles outside the bell shaped curve in the graph at right – figure 3). Perhaps deleting each of those data and trying out another fit (sensitivity analysis) would be valuable. Nevertheless, the proportion of positive catch dataset is small and I opted to consider all data and to not shrink the database.

Those comments above about residuals of models fitted to BR database showed in figure 3, are also valid for residuals of models fitted to leased boat database (BR.ESP) as displayed in figure 4. There are not strong evidence of biases but some data are of concern as indicated by Cook's distance calculations. Again I have opted to not drop those data because the proportion of positive catches database is small. Nevertheless, carefully inspection of those data may be requested in the future as far as the intention is to use the estimations as relative abundance indices. Here the objective is to compare standardized catch rates of different fleets.

6. Standardized Catch Rates

In order to calculate standardized catch rates the estimations gathered with binomial and gamma models might be combined. In addition, the effects of the factors that are not of interest (*e.g.* area) should be eliminated in order to estimate an standardized catch rate for each year. There are several approaches to achieve that objective but, I have used the solutions showed in this issue by Andrade (2008).

Scales of catch rates are very different, hence score Z were calculated to allow comparisons between national and leased boat database (Figure 5). Overall standardized calculations fitted well the nominal catch rates. Exceptions are in 2004 for national boats database, and in 2001 and 2005 for leased boats database. Standardized and nominal catch rate time trends for national and leased boats are contradictory. Catch rates as calculated for national boats database increase, while catch rates of leased boats decrease in the early 2000's.

Coefficient of variations (CV) were usually large for small standardized catch rate and vice versa (Figure 5). Overall, all CV calculations were high (≥ 0.5), hence standardized calculations might be careful considered. In particular, standardized catch rate of 2004 as calculated for leased boats database is unreliable.

Follow comments two issues: a) Standardized catch rate fits well the nominal catch rate, at least in the analysis of national boats database; and b) Despite the two fleets fish mainly over the same population the catch rates trend are contradictory. When standardized calculations fit well the nominal catch rate we should be worried. Standardization procedures are usually used to fix nominal catch rates in order to obtain a relative abundance indice. That agreement between the two time series means that standardization procedure did not work out or, that the nominal catch rates are reasonable abundance indices. In my opinion the first explanation seems more probable in most of the analyses.

Failure of standardization procedure is probably caused by the lack of information about fishing strategies adopted by fishermen and about environmental variables. As a matter of fact the models I have used are poor in the sense only year, quarter and area were included as explanatory factors. Other factors like velocity of boat when setting the long-line, or mixed layer depth, would probably improve the estimation model.

Because several important factors were not included in the model, standardized catch rates are not reliable as relative abundance indices. Those contradictory time trends between time series calculated for national and leased boats database do not means that fleets are fishing over two stocks with different biomass. That contradictory time trends means that we do not know what is happening blue shark biomass. In which catch rate time series we should rely? Some could argue that national boat time series should be discarded because that fleet seem to aim at blue shark. Nevertheless, perhaps catch rates of leased boats decreased because those fishermen were avoiding blue shark catch since it was not the target. Whatever the option the point is that we do not have one relative abundance indice we trust in. Assigning equal weights to two catch rate time series is like assuming we are ignorant about which of them is close to the truth. Nevertheless, the truth is that both are probably wrong.

Standardized catch rates as calculated using models missing important explanatory factors should be not straightforward used in assessment models. We should go over better relative abundance indices and/or go over assessment model formulations that are not too sensitive to those indices. I believe that reliability of relative abundance indices is the Achilles tendon of fish stock assessments nowadays.

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Tables

Table 1 – Number of reports about Brazilian long-line fleet from 2000 to 2006 in the Task II database. Boats based in Brazil are indicated by "national" in the first column at left. Otherwise there is the country of the leased boat. Source: ICCAT (2008).

Origin of the Boat	2000	2001	2002	2003	2004	2005	2006	Total
national	106	62	143	164	216	299	199	1189
Bolivia	0	0	0	10	9	0	0	19
Belize	0	0	40	0	0	0	0	40
Canada	0	0	8	3	11	0	0	22
Spain	165	198	106	129	80	158	207	1043
United Kingdom	0	0	0	0	0	7	31	38
Equatorial Guinea	109	65	0	0	0	0	0	174
Guyana	0	0	15	0	0	0	0	15
Honduras	28	43	85	33	53	75	48	365
Iceland	0	0	20	1	0	0	0	21
Japan	0	6	0	0	0	0	0	6
Saint Kitts & Nevis	0	0	0	0	0	2	14	16
Marroco	0	0	0	0	0	13	42	55
Panama	8	7	62	54	86	121	21	359
Portugal	34	0	35	17	0	15	38	139
Chinese Taipei	91	113	44	0	0	0	0	248
United States	18	39	9	8	14	0	0	88
Uruguay	36	30	2	35	0	0	0	103
Saint Vincent	32	45	38	0	0	0	0	115
Vanuatu	0	0	12	0	0	0	0	12
Total	627	608	619	454	469	690	600	4067

Table 2 – Generalized linear models fitted to positive and to proportion of positive catch rates of blue shark. Factors: A – area; Q – quarter; Y – year. Interactions are indicated by ":". The symbol "^2" means that the model includes all main effects and first order interactions. AIC – Akaike Information Criteria (Akaike, 1974); BIC – Bayesian Information Criteria (Schwarz, 1978).

Database	Response Variables	Explanatory Variables	Distribution	Link Function	AIC	BIC	pseudo-R^2
National	Positive	(A+Q+Y)^2	gamma	log	- 838.18	- 718.61	23.82

boats	Proportion	A+Q+Y+A:Y+Q:Y	binominal	logit	70.14	112.65	89.15
Leased boats	Positive	A+Q+Y+A:Y+Q:Y	gamma	log	- 1457.87	- 1289.32	16.84
from Spain	proportion	(A+Q+Y)^2	binomial	logit	175.77	251.35	91.56

Table 3 – Analysis of deviance tables for the models fitted to positive and to proportion of positive catch rates. Df – Degrees of freedom. Results of Fisher and chi-square tests are in the column at right.

Database	Factor	Df	Resid. Df	Resid. Dev	Pr(>F)
National boats			1022	2346.51	
Positive catches	A	1	1021	1865.31	2.64E-64
	Y	6	1015	1710.21	9.36E-20
	Q	3	1012	1703.54	2.03E-01
	A:Y	5	1007	1582.79	7.24E-16
	A:Q	3	1004	1561.85	2.42E-03
	Y:Q	18	986	1510.73	9.39E-03
Leased boats			911	1021.70	
Positive catches	Y	6	905	920.11	4.47E-17
	A	1	904	906.96	5.22E-04
	Q	3	901	897.43	3.28E-02
	Y:Q	18	883	864.16	3.36E-02
	Y:A	6	877	849.62	3.80E-02
Database	Factor	Df	Resid. Df	Resid. Dev	P(>|Chi|)
National boats			51	231.51	
Proportion of	Y	6	45	161.49	4.04E-13
positive catches	A	1	44	116.04	1.57E-11
	Q	3	41	97.90	4.12E-04
	Y:Q	18	23	46.88	5.27E-05
	Y:A	5	18	24.86	5.19E-04
Leased boats			53	156.10	
Proportion of	Y	6	47	106.74	6.30E-09
positive catches	A	1	46	101.10	1.75E-02
	Q	3	43	94.39	8.21E-02
	Y:A	6	37	71.62	8.76E-04
	Y:Q	18	19	24.66	2.15E-04
	A:Q	3	16	13.17	9.33E-03

Figures

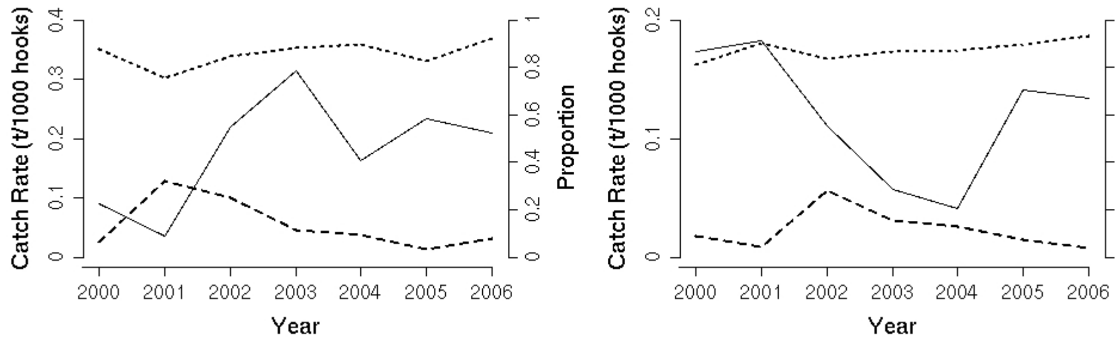
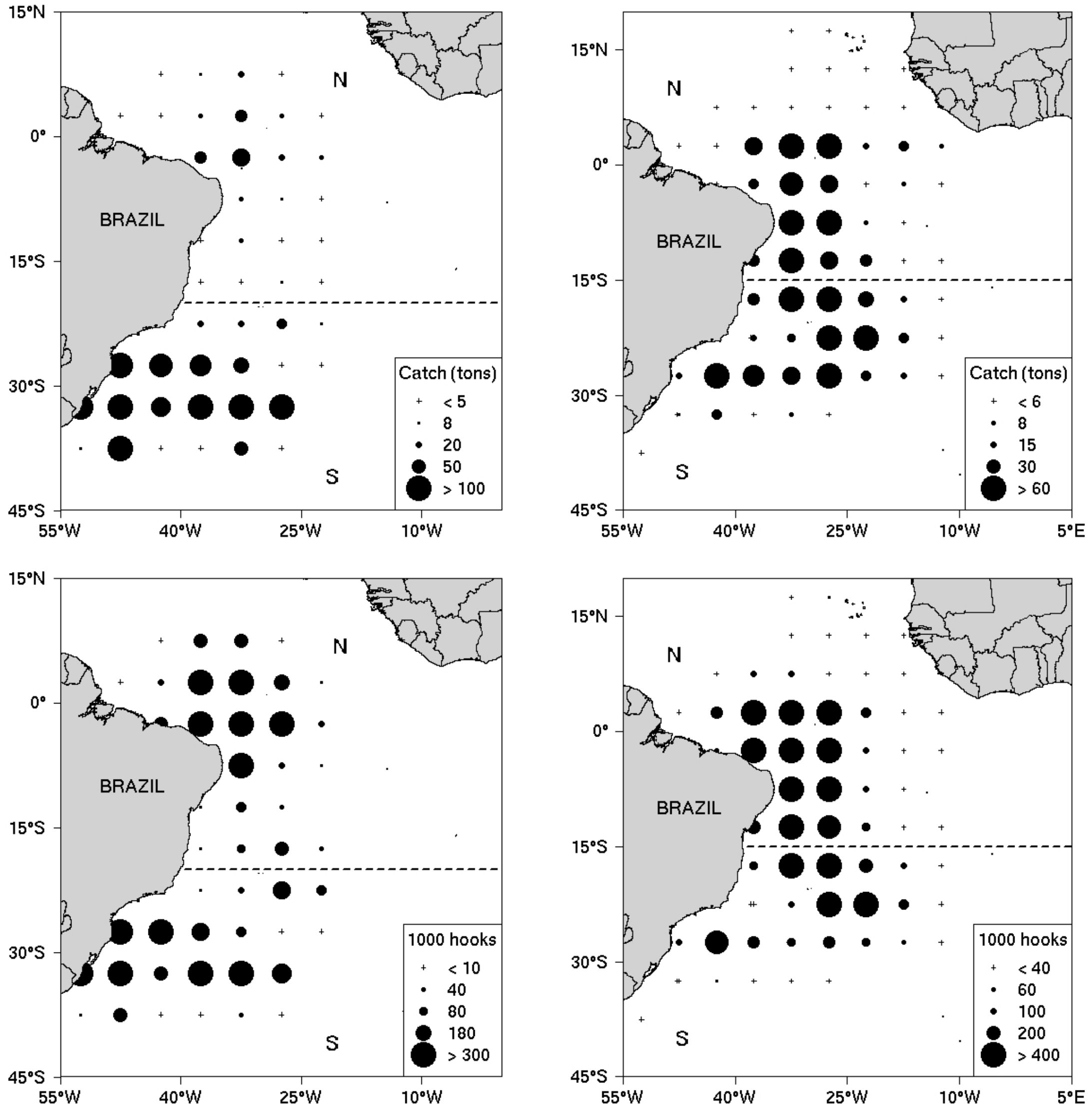


Figure 1 – Catch rate (solid lines), proportions of aggregated information (dotted lines) and of catches equal zero (dashed lines) in the databases. Left panel stands for national fleet (BR) dataset, while information about leased boats from Spain (BR.ESP) is in the right panel.



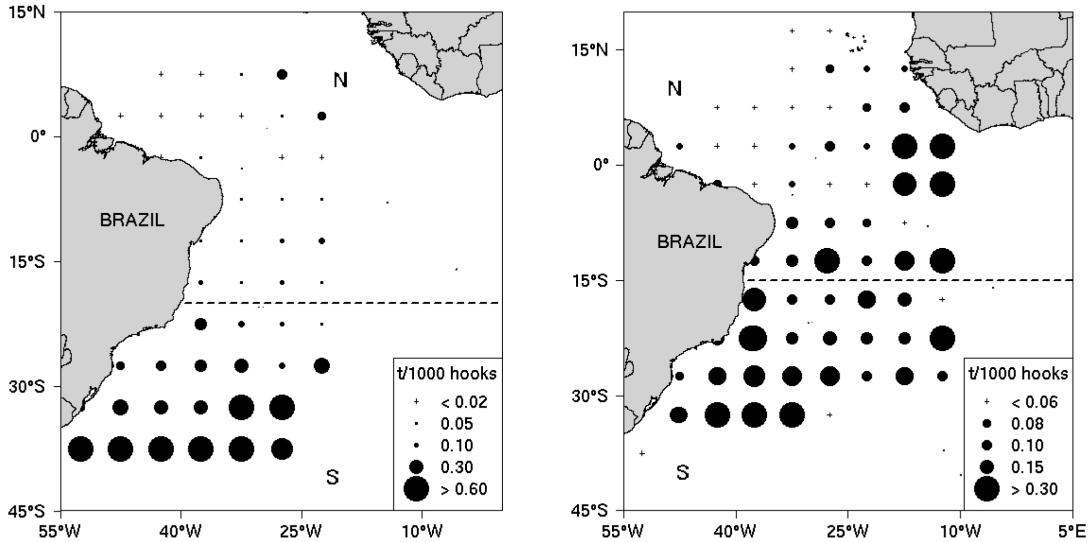


Figure 2 – Catch (t) and catch rate (t/1000 hooks) of blue shark (*Prionace glauca*) and effort (1000 hooks) of Brazilian long-line fleet. Panels in the left column show information about national boats, while information about leased boats from Spain is in the other three panels. Areas considered in the analysis are indicated by N (north) and S (south). Source: Task II database (ICCAT, 2008).

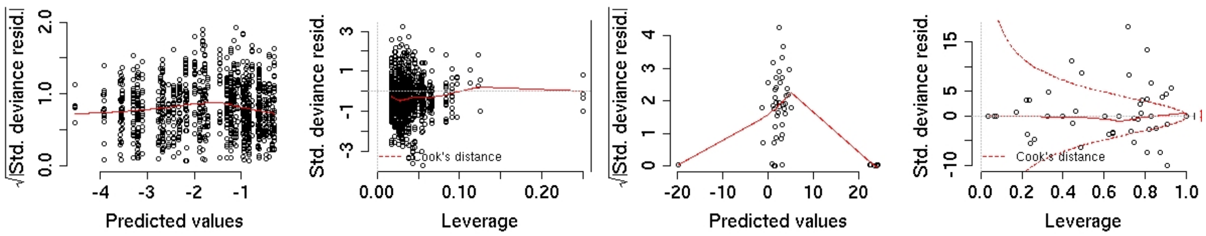


Figure 3 – Diagnostic plots for the models fitted to national boat database. Results gathered when modeling the positive catch rates are in the two panels at left, while information about the model fitted to the proportion of positive catches are in the two other panels. Curve indicated by dashed line curve in the graph at right stand for Cook's distance calculations equal to one.

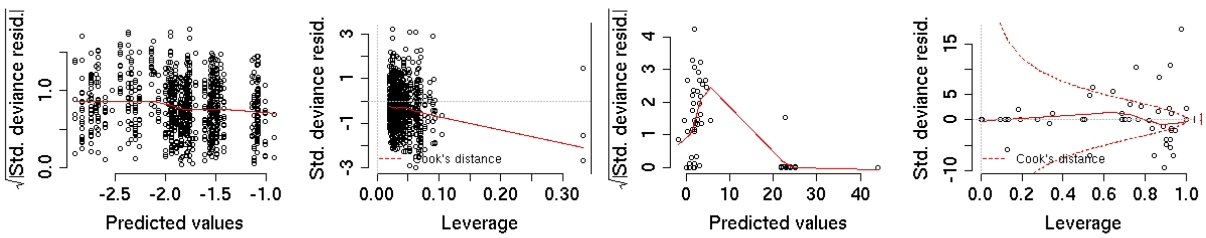


Figure 4 – Diagnostic plots for the models fitted to data of leased boats from Spain. Results gathered when modeling the positive catch rates are in the two panels at left, while information about the model fitted to the proportion of positive catches are in the two other panels. Curve indicated by dashed line curve in the graph at right stand for Cook's distance calculations equal to one.

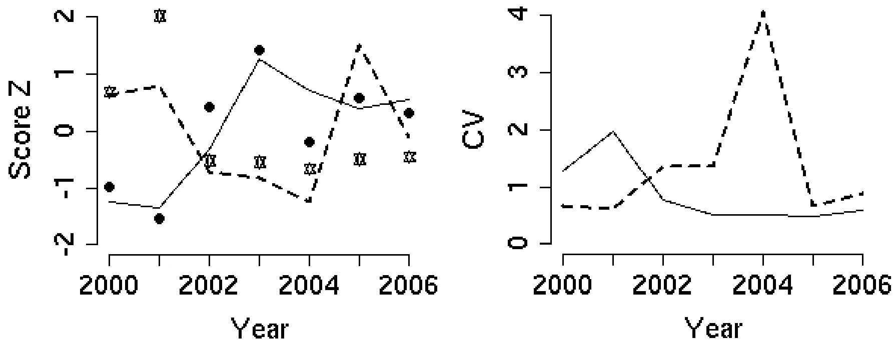


Figure 5 – Scores Z [(value-amean)/standard deviation] for nominal and standardized catch rates (left panel) and coefficients of variation for the predictions of standardized catch rates. Solid lines and black circles stand for standardized and nominal catch rates respectively, as calculated for the national boat database. Similarly, dashed lines and stars stand for standardized and nominal catch rates respectively, as calculated for leased boats from Spain database.