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STANDARDIZED CATCH RATES OF ALBACORE (*THUNNUS ALALUNGA*) CAUGHT BY THE BRAZILIAN FLEET (1978-2011)

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SUMMARY

The present study analyzed catch and effort data from 88.423 sets done by the Brazilian tuna longline fleet (national and chartered) in the equatorial and southwestern Atlantic Ocean, from 1978 to 2011 (35 years). The CPUE of albacore was standardized by a GLM, assuming a delta lognormal distribution. The factors used in the model were: quarter, year, area, and fishing strategy. The standardized CPUE series obtained for albacore was not much different from the one done in 2010; except for one peak in 1993 that was apparent in 2010 but which is no longer apparent (Table 3 and Figure 4). The standardized CPUE series shows a significant oscillation over time, with a general increasing trend from the early 1980s to the mid-1990s, then a sharp decrease until 2003, remaining low until 2010, and then increasing again in the two last years of the series (2011 and 2012).

RÉSUMÉ

Cette étude analyse les données de prise et d'effort provenant de 88.423 opérations à la palangre de la flottille brésilienne (nationale et affrétée) ciblant les thonidés dans l'océan Atlantique équatorial et du Sud-Ouest entre 1978 et 2011 (35 ans). La CPUE du germon a été standardisée au moyen d'un GLM postulant une distribution delta lognormale. Les facteurs utilisés dans le modèle étaient les suivants : trimestre, année, zone et stratégie de pêche. La série de CPUE standardisée obtenue pour le germon ne différait pas beaucoup de celle obtenue en 2010, à l'exception d'un niveau record en 1993 qui apparaissait en 2010, mais qui a désormais disparu (Tableau 3 et Figure 4). La série de CPUE standardisée présente une oscillation importante au cours du temps, avec une tendance générale à la hausse à partir du début des années 80 jusqu'à la moitié des années 90 avant de connaître une forte diminution jusqu'en 2003, de rester faible jusqu'en 2010 avant d'augmenter à nouveau pendant les deux dernières années de la série (2011 et 2012).

RESUMEN

En este estudio se analizan los datos de captura y esfuerzo de 88.423 lances realizados por la flota atunera de palangre brasileña (nacional y fletada) en el Atlántico suroccidental y ecuatorial entre 1978 y 2011 (35 años). Se estandarizó la CPUE del atún blanco mediante un GLM asumiendo una distribución delta lognormal. Los factores utilizados en el modelo fueron trimestre, año, área y estrategia de pesca. La serie de CPUE estandarizada obtenida para el atún blanco no era muy diferente de la realizada en 2010, excepto por un pico en 1993 que estaba claro en 2010 pero ya no lo está (Tabla 3 y Figura 4). La serie de CPUE estandarizada muestra una oscilación importante en el tiempo, con una tendencia creciente general desde principios de los ochenta hasta mediados de los noventa y posteriormente un marcado descenso hasta 2003, permaneciendo baja hasta 2010 y luego aumentando de nuevo en los dos últimos años de la serie (2011 y 2012).

KEYWORDS

Catch rates, Standardized CPUE, Abundance indices, Longline

1. Introduction

Stock assessments for large pelagics are commonly based on catch per unit of effort (CPUE) due to the greater availability of such data. However, the use of CPUE as an index of relative abundance has been debated by a number of authors. 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, making 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, 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 (Fréon e Misund, 1999). The incorporation of these factors in the estimation of CPUE is, therefore, important for accurate stock assessments. The main objective of the present paper was, therefore, to generate a standardized CPUE series for albacore tuna caught by Brazilian longliners in the Atlantic Ocean, which may be utilized in the next albacore stock assessment, scheduled for June, 2013.

2. Material and Methods

In the present study, catch and effort data from 88,423 tuna longline sets reported by the Brazilian tuna longline fleet, including both national and foreign chartered vessels, from 1978 to 2012 (35 years) were analyzed. All the data were obtained from the logbooks filled in by the skippers of the vessels. The longline sets were distributed along a wide area of the equatorial and South Atlantic Ocean, ranging from 10ºE to 52ºW of longitude, and from 010ºN to 50ºS of latitude **(Figure 1)**. The resolution of 1º latitude x 1º longitude, per fishing day, was used for the analysis of the geographical distribution of catches.

The factors considered as explanatory variables were “Year” (35), “Quarter” (4), “Area” (A1>25ºS; A2<25ºS), and “Fishing strategy” (4). Due to the moderate proportion of sets with zero catches of Albacore (45.5%), the Delta Lognormal model was used for the standardized CPUE series. In the Delta Lognormal model, the catch rates were assumed to be the result of two dependent processes: a) the probability of catching at least one fish, times 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 observed CPUE. A GLM model was applied with the logit function being used as the link between the linear predictor and the binomial error response variable. The fleet strategy was estimated in two steps (Hazin, et al, in preparation, ANNEX 01): in the first step, a cluster analysis was done to identify the different targeting strategies by combining groups that are internally coherent and externally isolated. Accordingly, based on the 88,423 fishing sets done, with about 25 species reported on the observer log-books, 6 clusters were identified, with the following species being predominant in the catches: 1) YFT; 2) BET; 3) BSH; 4) Others; 5) ALB; and 6) SWO. In the second step, a matrix was constructed considering the percentage of sets done by each fishing boat, within each cluster. Then, a MDS (Multidimensional Scaling) method (Kaufman and Rousseeuw 2005) was applied to find coherent patterns that may discriminate groups of boats with similar fishing strategies, with four different strategies being identified. These four different "fishing strategies" were then used as a factor in the CPUE standardization by GLM. This methodology has been used in several other instances, such as during the last assessments of yellowfin tuna and both mako and blue sharks.

A stepwise approach was initially used to identify the variables to be included in the model. The distribution of residuals was used to verify the assumption of the lognormal distribution of the positive catches. The diagnostic plots were run to evaluate the fitness of the models. Deviance analysis tables for the proportion of positive observations and for the positive catch rates were provided. The indices of abundance were estimated then as the product of the least squares means (LS means) of the factor year for the selected Lognormal and Binomial models (Lo *et al.* 1992; Stefánsson 1996).

3. Results

The proportion of null captures of albacore for the study area was 45,5% for the entire period. In most cases, the proportion of positive captures of albacore was between 20% and 78% of the total of sets with the exception of the period 1993, 2002-2003 where it was lower (**Figure 2**). The independent variables considered in the standardization model, as main factors, are summarized in **Table 1.**

The delta lognormal models explained 27% of the total variance of the model and it is slightly under-dispersed (φ= 0.53). The deviance analyses for the Lognormal and for the Binomial models (**Table 2**) show that "Year" and "Fishing Fleet" variables explained most of the model deviance, with 94.0% and close to 5% for the positive catches, respectively, and about 77% and 20%, for the proportion of positive catches.

Main diagnostic plots, show that, although every leverage point identified on the Cook's distance plots was scrutinized, there was no evidence for their exclusion. The assumption of the lognormal distribution for the positive dataset seems to be adequate as indicated in the QQ-plots for all models (**Figure 3**). 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 3**). The standardized CPUE series obtained for albacore was not much different from the one done in 2010, except for one peak in 1993 that was apparent in 2010 but it's no longer apparent (**Table 3 and Figure 4**).

The standardized CPUE series shows a significant oscillation over time, with a general increasing trend from the early eighties to the middle nineties, then a sharp decrease until 2003, remaining low until 2010, and then increasing again in the two last years of the series (2011 and 2012).

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Table 1. Selection variables to model delta log. A=area; Q=quarter; S= fleet strategy and Y=Year.

Positive sets

Models	(Intrc)	A	Q	S	Y	df	logLik	AIC	delta	weight	Select models
16	**0.91**	**+**	**+**	**+**	**+**	**43**	**-75367**	**68339**	**0**	**1**	**All variables**
14	0.958	+		+	+	40	-75433	68523	184	0	
15	1.017		+	+	+	42	-75439	68547	208	0	
13	1.061			+	+	39	-75488	68682	343	0	
12	0.98	+	+		+	40	-75695	69292	953	0	
11	1.116		+		+	39	-75789	69567	1229	0	
10	1.02	+			+	37	-75802	69602	1263	0	
9	1.145				+	36	-75867	69793	1454	0	
8	0.741	+	+	+		9	-79145	80196	11857	0	
6	0.793	+		+		6	-79213	80422	12083	0	
7	0.75		+	+		8	-79239	80515	12176	0	
5	0.807			+		5	-79284	80666	12327	0	
4	1.413	+	+			6	-82165	91205	22866	0	
3	1.478		+			5	-82317	91798	23459	0	
2	1.421	+				3	-82411	92161	23822	0	
1	1.474					2	-82494	92487	24148	0	

Proportion sets

Models	(Intrc)	A	Q	S	Y	df	logLik	AIC	delta	weight	Select models
16	**3.481**	**+**	**+**	**+**	**+**	**42**	**-8898**	**15536**	**0**	**1**	**All variables**
15	3.432		+	+	+	41	-8911	15559	23.9	0	
14	3.233	+		+	+	39	-9010	15753	217.7	0	
13	3.195			+	+	38	-9019	15769	233.3	0	
12	3.284	+	+		+	39	-9497	16727	1191.9	0	
11	3.247		+		+	38	-9507	16745	1209.6	0	
10	3.042	+			+	36	-9654	17036	1500.3	0	
9	3.02				+	35	-9658	17042	1506.2	0	
8	0.404	+	+	+		8	-10554	18779	3243.5	0	
7	0.355		+	+		7	-10561	18792	3256.8	0	
6	0.212	+		+		5	-10690	19046	3510.9	0	
5	0.173			+		4	-10696	19056	3520.6	0	
4	0.4	+	+			5	-11978	21622	6086.4	0	
3	0.354		+			4	-11985	21634	6098.9	0	
2	0.152	+				2	-12192	22043	6507.3	0	
1	0.131					1	-12194	22045	6509.2	0	

Table 2. Deviance analysis of explanatory variables used to standardize the CPUE series of albacore caught by the Brazilian tuna longline fleet, from 1978 to 2012. A=area; Q=quarter; S= fleet strategy and Y=Year.

Models/Variables	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)	PercDevExp (%)
Positive						
NULL			46917	92484.8		
Y	34	22761.6	46883	69723.2	0.00	93.9
S	3	1117.4	46880	68605.7	0.00	4.6
Q	3	141.0	46877	68464.8	0.00	0.6
A	1	209.9	46876	68254.9	0.00	0.9
Proportions						
NULL1			599	22042.7		
Y	34	5071.1	565	16971.6	0.00	76.9
S	3	1278.9	562	15692.7	0.00	19.4
Q	3	215.4	559	15477.4	0.00	3.3
A	1	25.9	558	15451.5	0.00	0.4

Table 3. Standardized CPUE albacore CPUE caught by the Brazilian tuna longline fleet, 1978-2012.

Year	index	CV_index	CPUEnominal
1978	4.64	12%	6.61
1979	6.76	11%	7.15
1980	2.74	17%	2.97
1981	1.85	23%	2.81
1982	1.82	19%	2.27
1983	3.07	14%	3.27
1984	4.94	11%	5.76
1985	2.66	19%	3.75
1986	4.76	11%	6.23
1987	9.44	8%	10.23
1988	4.76	9%	7.67
1989	9.44	7%	11.07
1990	7.87	13%	7.02
1991	4.18	11%	7.08
1992	5.31	10%	6.05
1993	2.40	39%	1.93
1994	13.90	7%	17.36
1995	6.25	8%	10.66
1996	16.36	6%	16.25
1997	12.26	6%	11.67
1998	11.41	5%	12.77
1999	9.42	5%	11.63
2000	11.62	4%	12.83
2001	9.30	4%	8.42
2002	3.87	8%	3.94
2003	1.52	23%	1.01
2004	2.78	7%	1.71
2005	2.40	8%	1.37
2006	2.45	8%	1.60
2007	2.12	12%	1.30
2008	1.56	17%	0.74
2009	2.23	12%	1.20
2010	2.02	15%	1.04
2011	4.26	7%	4.23
2012	6.22	22%	3.46

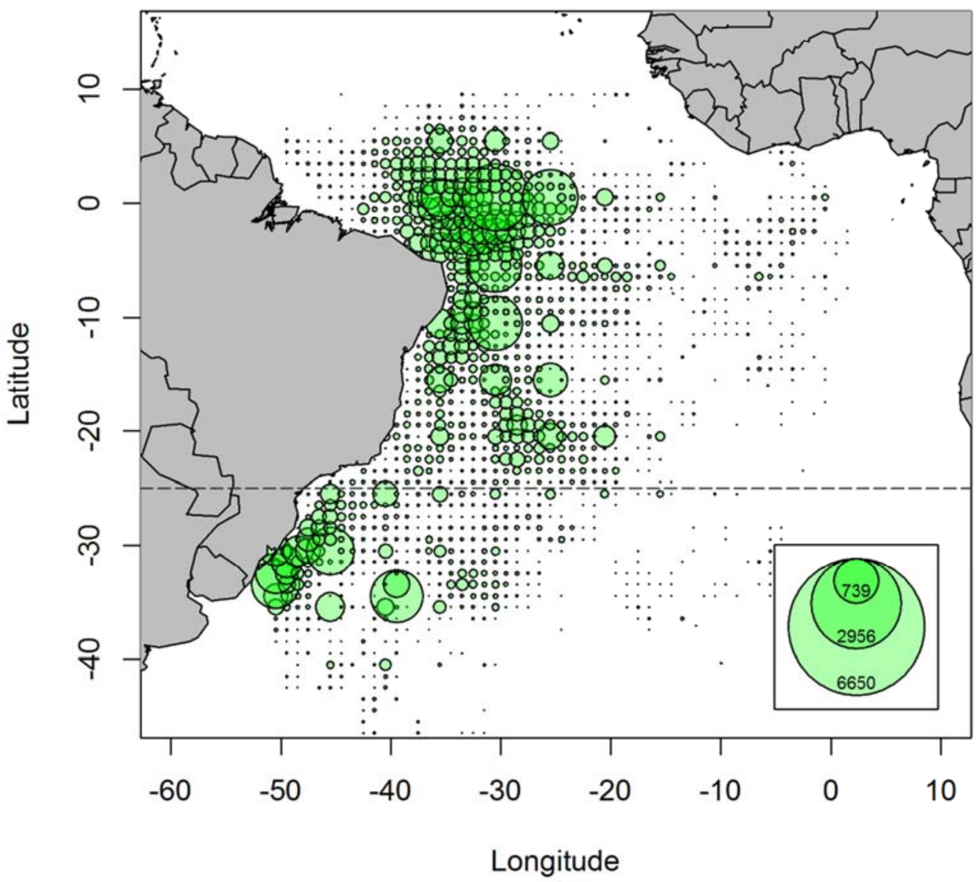

Figure 1. Distribution of the effort done by the Brazilian tuna longline fishery in the Atlantic Ocean, from 1978 to 2012 (35 years).

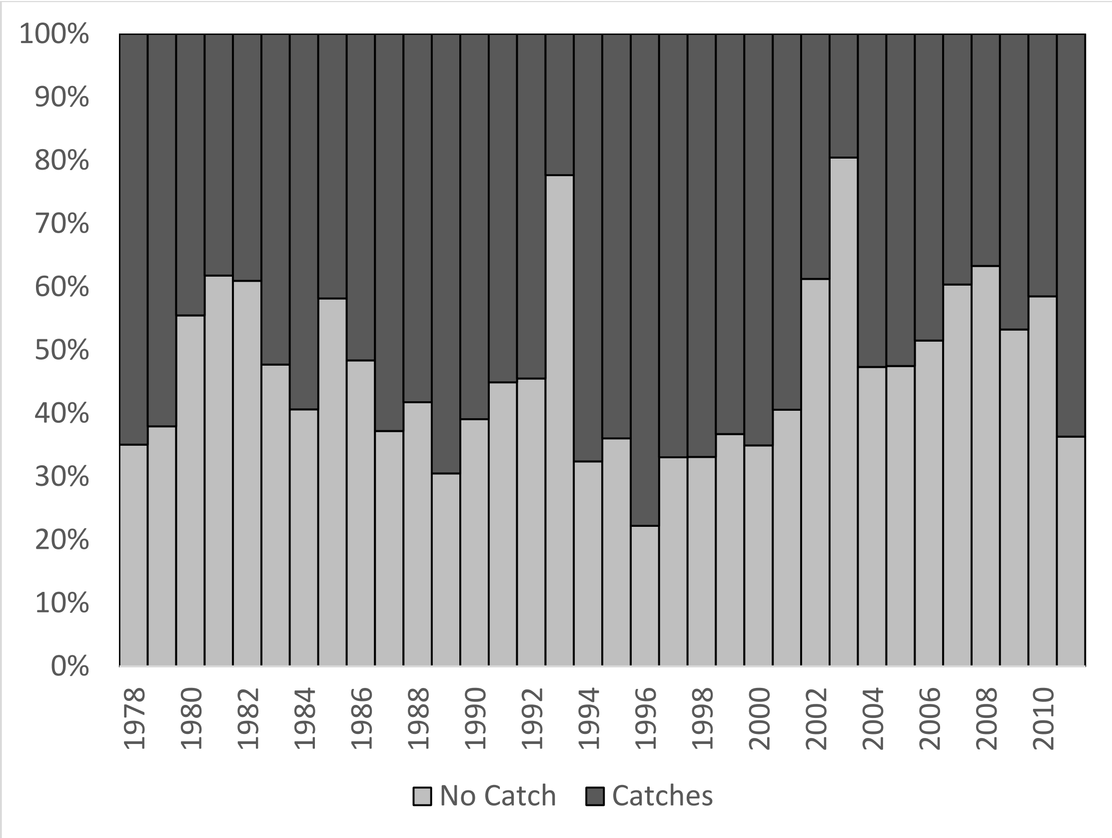

Figure 2. Proportion of positive captures and negative sets.

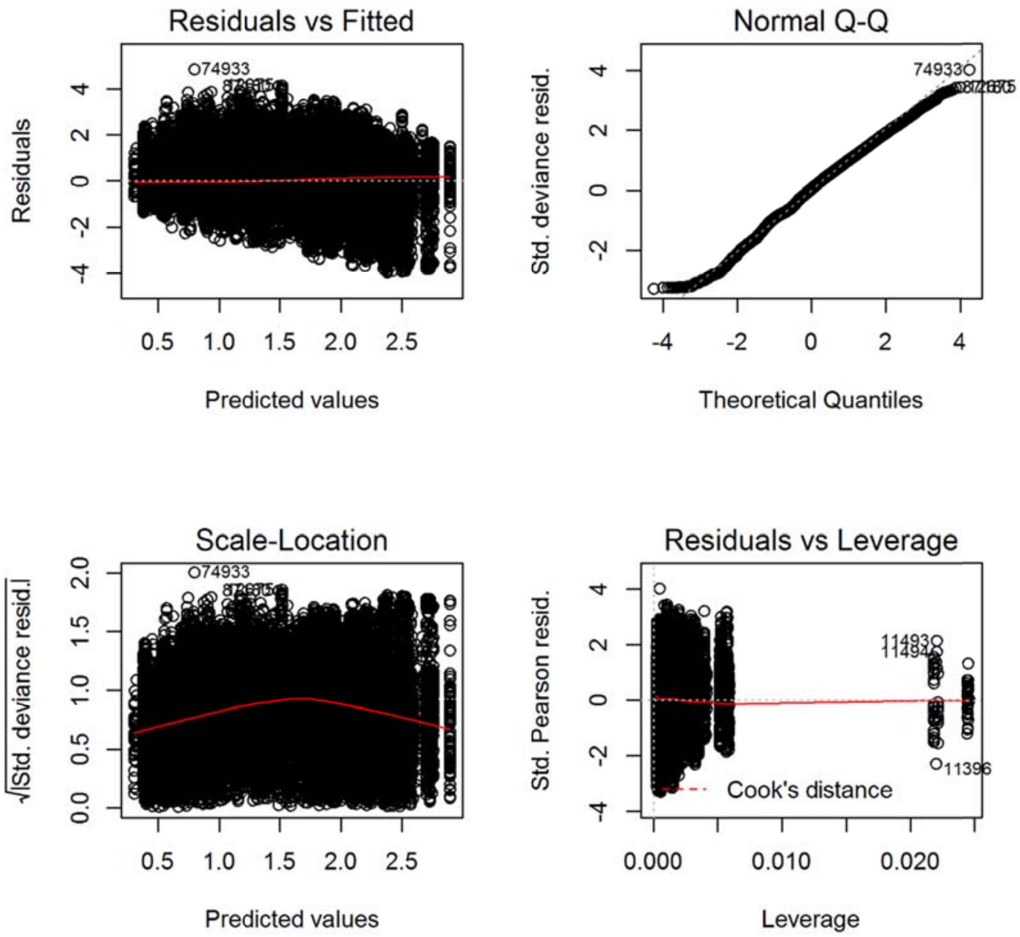

Figure 3. Residual analysis of the log-normal model fitting of albacore caught by the Brazilian tuna longline fleet, 1978 to 2012.

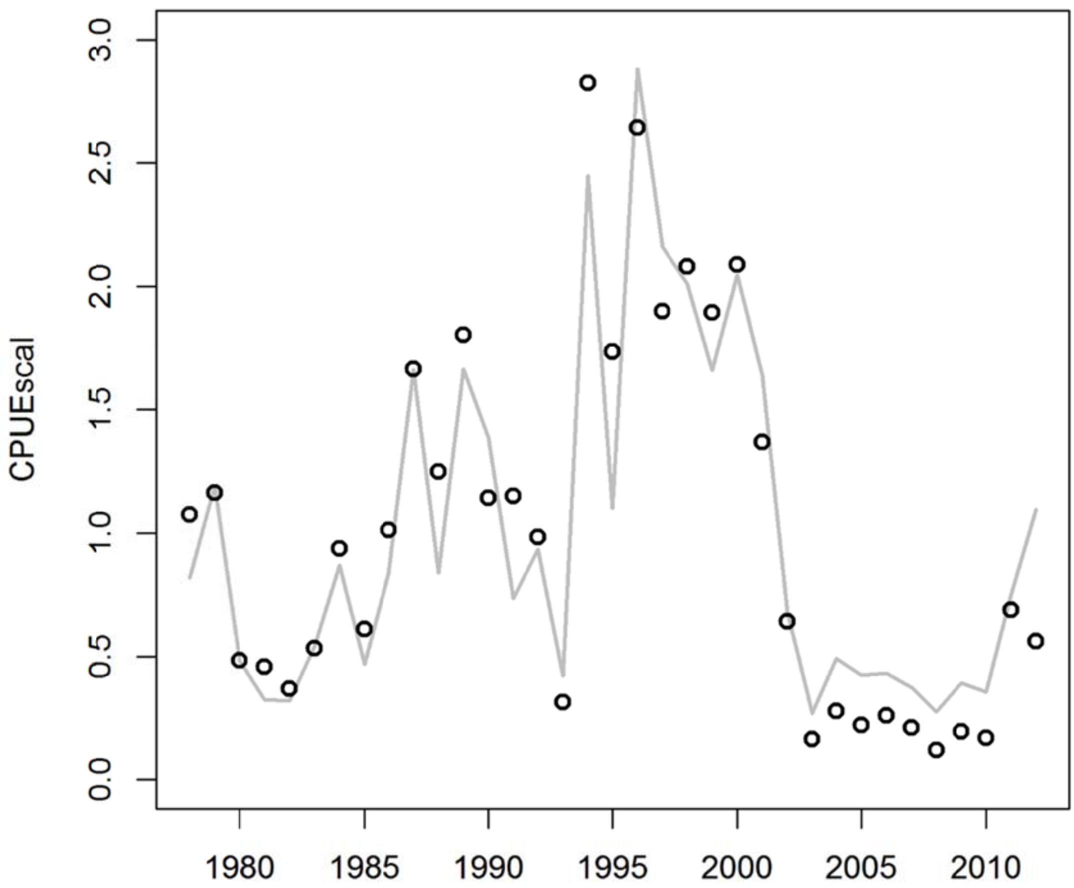

Figure 4. Nominal and standardized CPUE of albacore for Brazilian tuna longliners, from 1978 to 2012.

Annex

A detailed explanation of the CPUE standardization done on the Brazilian tuna longline data

During previous meetings, various SCRS working groups recognized the complex nature of the Brazilian tuna longline fleet, particularly the fact that it presents a large variety of vessels, flags and consequently operational characteristics. Because of that, the standardization methods commonly used by the SCRS might not be appropriate to standardize the Brazilian CPUE, as it has already been argued by the authors. Recently, cluster analyses have been applied to Brazilian tuna longline fishing data, aiming at categorizing fishing effort based on the proportion of the several species in the catches, as a way to detect changes in fishing strategy (target species). Presented for the first time in 2007, this approach has generated a lively discussion. The main advantage of such method, instead of using the percentage of a single species as an expression of the targeting strategy, relies in the fact that it considers the frequency distribution of all species in each set, thus providing, at least in principle, a much more reliable estimation of targeting (catch profile). However, it may have the caveat of overestimating the indices of abundance since the fishing sets with low catches of the target species may not be included in its respective cluster, thus potentially resulting in an artificially higher CPUE. On the other hand, however, the use of aggregated data by fleet, not considering the proportion of each species caught in each set, may cause an opposite bias, since a variable part of the fishing effort deployed might not have been directed to the expected target species, thus artificially lowering its relative abundance. In order to mitigate such bias, for the last yellowfin tuna assessment, done in 2011, the different fishing strategies applied by different fleets operating in Brazil were incorporated as a factor in the standardization process by an alternative methodology hereby explained.

Since 1956, when longline operations in the Southern Atlantic begun, several changes in fishing technology and strategies have occurred, strongly influencing catch composition and relative abundance of the target species. A number of models, such as GLM (General Linear Model), have been applied to minimize the effects of operational variables (fishing tactics) on the estimation of CPUE, through standardization processes. However, information on fishing tactics and even on significant technological changes is often not available, leading to serious errors in the estimation of abundance indices.

Previous analyses of the Brazilian longline fishery (Hazin, 2006, Carvalho *et al*., 2011) have clearly indicated that the different fleets operating in the Southwestern Atlantic Ocean choose different fishing tactics, targeting different resources (catch profile), from time to time. It is very important, therefore, to take this factor into consideration, in any attempt to standardize the CPUE of the species caught. In the approach hereby proposed, the analysis is done in two steps: (*i*) identifying the different clusters of sets with similar species composition from the catch data; and (*ii*) identifying the different fishing fleets that have similar fishing strategies and are consequently associated to the different clusters.

In the first step, a cluster analysis was done to identify the different targeting strategies by combining groups that are internally coherent and externally isolated (MathSoft, 1995). Accordingly, a total of 57,365 fishing sets were thus analyzed, with about 25 species reported on the observer log-books, and 6 clusters were identified (**Table 1**), with the following species being predominant in the catches: 1) YFT; 2) BET; 3) BSH; 4) Others; 5) ALB; and 6) SWO.

In the second step, a matrix was constructed considering the percentage of sets done by each fishing boat, within each cluster. Then, a MDS (Multidimensional Scaling) method was applied to find coherent patterns that may discriminate groups of boats with similar fishing strategies (**Table 2**). These “fishing fleets” were then used as a factor in the CPUE standardization by GLM.

Table 1. Distribution of longline sets from the Brazilian tuna longline fishery in the Atlantic Ocean, between 1980 and 2010, by clusters of main species caught (Target Strategies-TS).

Species	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6
YFT	**54%**	13%	2%	13%	6%	8%
ALB	9%	5%	3%	7%	**75%**	5%
BET	8%	**53%**	2%	5%	4%	7%
SWO	10%	15%	16%	9%	3%	**56%**
SAI	3%	1%	1%	5%	2%	3%
WHM	1%	1%	0%	2%	1%	1%
BUM	2%	1%	1%	1%	1%	2%
SPF	0%	0%	0%	0%	0%	0%
OTH.BIL	0%	0%	1%	1%	0%	1%
SPG.n	0%	0%	0%	0%	0%	0%
BSH	4%	4%	**59%**	6%	2%	10%
SPL	0%	0%	2%	1%	0%	0%
BTH	0%	0%	0%	0%	0%	0%
MAK	0%	0%	4%	2%	0%	1%
FAL	0%	0%	0%	3%	0%	1%
OCS	0%	0%	0%	0%	0%	0%
OTH.SHARKS	3%	3%	2%	6%	2%	2%
OTH.TEL	6%	3%	6%	**40%**	4%	4%

Table 2. General characteristics of fishery operations and strategies of the Brazilian longline fleet obtained from cluster analysis, from 1980 to 2010.

Strategy	Fishing fleet 1	Fishing fleet 2	Fishing fleet 3	Fishing fleet 4
Fleet	6	9	8	16
Boats	41	72	53	97
LOA	24	32	39	33
TBA	84	212	281	257
Setting time (h)	13	16	7	13
Setting duration (h)	5	5	6	5
Hook per basket	7	5	13	7
Effort (n)	1481	1282	2981	1639
Day	18%	11%	72%	23%
Night	82%	89%	28%	77%
Total of the sets (n)	7789	15263	8490	21648
Sets (%)	15%	29%	16%	41%
Target Strategies	Target strategie 1	Target strategie 3-6	Target strategie 5	Target strategie 2-4