STANDARDIZED CPUE OF BLUE SHARK (*PRIONACE GLAUCA*) CAUGHT BY SANTOS LONGLINER IN SOUTHERN BRAZIL (1984-2005)

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SUMMARY

Catch rate data from commercial fisheries have often been used as a relative index of fish stock abundance. Blue shark catch/effort data (1984-2005) caught off Southern Brazil by the tuna fleet based in Santos were standardized using a Generalized Linear Model (GLM) approach. The modeling procedures assumed a log-normal error distribution. Akaike Information Criterion (AIC) and deviance analysis were used to select the relevant factors. The final model included "year", "quarter" and "target" as main factors. The factor "target" was the most significant followed by "quarter" factor. The variability rate explained by the model was 0.81 (pseudo-R^2). The final standardized index showed an increasing trend until 1988 followed by a strong decreasing trend until 1993. From the 1995 on, the catch rate showed a high fluctuation without a clear trend until 2005. Our result suggests that the blue shark from the South Atlantic stock is not strongly affected by the fishery. However, despite this fleet has target sharks at least half of the period, this interpretation must be carefully analyzed due to the low fishing effort of Santos longliners and the small area where they operate, considering that the mentioned data were the only information used in this paper.

RÉSUMÉ

Les données de taux de capture des pêcheries commerciales ont souvent été utilisées comme indice relatif de l'abondance des stocks de poissons. Les données de capture/d'effort du requin peau bleue (1984-2005), capturé au large du Sud du Brésil par la flottille thonière dont le port d'attache est à Santos, ont été standardisées à l'aide de la méthode du modèle linéaire généralisé (GLM). Les procédures de modélisation ont postulé une distribution d'erreur lognormale. Le critère d'information d'Akaike (AIC) et des analyses de déviance ont été utilisés pour sélectionner les facteurs pertinents. Le modèle final a inclus « année », « trimestre » et « cible » comme facteurs principaux. Le facteur « cible » s'est avéré le plus significatif, suivi par le facteur « trimestre ». Le taux de variabilité expliqué par le modèle était de 0,81 (pseudo-R^2). L'indice standardisé final a dégagé une tendance croissante jusqu'à 1988, suivie par une forte tendance à la baisse jusqu'à 1993. A partir de 1995, le taux de capture a subi une fluctuation élevée, sans qu'une tendance claire ne se dégage jusqu'à 2005. Nos résultats suggèrent que le requin peau bleue du stock de l'Atlantique Sud n'est pas fortement affecté par la pêcherie. Toutefois, bien que cette flottille ait ciblé des requins au moins pendant la moitié de la période, cette interprétation doit être minutieusement analysée en raison du faible effort de pêche des palangriers de Santos et de leur zone réduite d'opération, compte tenu du fait que les données mentionnées constituaient les seules informations utilisées dans le présent document.

RESUMEN

Los datos de tasa de captura de las pesquerías comerciales se han utilizado a menudo como índice de la abundancia relativa del stock. Se estandarizaron los datos de captura/esfuerzo (1984-2005) de la tintorera, capturada en las aguas de la costa meridional de Brasil por la flota atunera con base en Santos, utilizando un enfoque de modelo lineal generalizado (GLM). En los procedimientos de modelación se asumió una distribución de error lognormal. Se utilizaron el criterio de información Akaike (AIC) y el análisis de devianza para seleccionar los factores pertinentes. El modelo final incluía como factores principales los factores "año", "trimestre" y "especie objetivo". El factor "especie objetivo" fue el más significativo, seguido

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por el factor "trimestre". La tasa de variabilidad explicada por el modelo fue 0,81 (pseudo-R^2). El índice estandarizado final mostraba una tendencia creciente hasta 1988, seguida de una fuerte tendencia a la baja hasta 1993. Desde 1995 en adelante, la tasa de captura mostraba una fuerte fluctuación sin una tendencia clara hasta 2005. Nuestros resultados sugieren que el stock de tintorera del Atlántico sur no está muy afectado por la pesquería. Sin embargo, a pesar de que esta flota ha dirigido su actividad hacia los tiburones durante al menos la mitad del periodo, esta interpretación debe ser analizada detenidamente debido al escaso esfuerzo pesquero de los palangreros de Santos y a la pequeña zona en la que operan, y se tiene que tener en cuenta que los datos mencionados fueron la única información que se ha utilizado en este documento.

KEYWORDS

Blue shark, catch-per- unit of effort, longliner, tuna fishery, standardized, catchability

1. Introduction

Blue shark (*Prionace glauca*) was discussed in the ICCAT Data Preparatory Meeting for Atlantic Shark Stock Assessment (Halifax, September 2001), with emphasis on blue, porbeagle and shortfin mako sharks. The group conclusions were that priority must be given to compiling more complete fishery statistics. It was suggested that some national scientist could examine published reports and any other type of relevant information to come up with scientific estimates of catches (Anon, 2002). Japanese leased longliners were based in Santos City, São Paulo State, Brazil, from 1958 to 1961 (Moraes, 1962; Morais, 1963). Sharks were probably caught by this fleet, nevertheless they were not recorded (Amorim *et al*., 1998). The national longliners settled in Santos (SP) and fishing in the Southern Brazil since 1965/1966 (Arfelli and Amorim, 1988), catch many shark species (Sadowsky and Amorim, 1977; Amorim and Arfelli, 1992; Arfelli and Amorim, 1994; Amorim *et al.*, 1998). In the whole period the Santos longliners targeted different species (Mourato *et al*. 2004). From the mid of 70's on the amount of sharks (blue shark, mako shark, other Carcharhinidae, bigeye thresher and hammerhead) landed by this fleet increased (Amorim, 1992; Amorim *et al*., 2002). Catch rates of commercial fleet must be standardized in order to gather estimations that potentially could be used as indexes of relative abundance. Such indexes can help on the task of assessing the stock biomass. Generalized linear models (GLM) have been often used to standardize catch rate data. In this paper GLM is used in an attempt to estimate indexes of relative abundance of blue shark for the Southern Brazil. The reliability of the estimates and their potential usefulness for assessment analyses is discussed.

2. Material and methods

2.1 Catch and effort data

Data from Santos longline fleet operating off Southern Brazil from 1984 (when the Santos fleet was fully targeting sharks) to 2005 were analyzed. Commercial sheets of fishing companies were used to estimate the weight (kg) of blue shark landed. Fishing effort in number of hooks was estimated using information recorded in logbooks collected by the Instituto de Pesca. The data were aggregated for each year and quarter resulting in 264 records and the catch rate in the d^{th} time strata (U_d) is:

$$U_d = \left(\sum C_d \Big/ \sum f_d \right) \cdot 1000 \qquad (1)$$

where C is the catch (kg) and f is the nominal effort (number of hooks) in the aggregated data set.

According to Arfelli (1996) Santos longline fleet has been fishing off the southeasterrn coast of South America in the subtropical area (17-35° S / 27-52° W) (**Figure 1**). However, detailed information about the area were the longlines were deployed by set was not available for the whole period, hence area was not taken into account in the analysis.

2.2 Model and explanatory variables

Models were built using the software package S-Plus. The approach used to standardize the catch rate is in line with that described by Gavaris (1980), hence we assumed that catch rate follows a lognormal distribution. Explanatory variables were "year", "quarter" and "target". This last factor was based on the proportion of blue shark in the total catch per month. Quartiles of the proportions were used to code four levels.

Generalized linear model (McCullagh and Nelder, 1989) can be used to separate effects of factors that affect the catch rate. The notation we use in the remaining text is based on Andrade *et al.* (2005). The response variable is the expected value of $y_d \equiv \log(U_d)$.

$$\mu_d = \theta_0 + \sum_{j=1}^{p}\sum_{k=1}^{m_j}\theta_{jk}\cdot x_{jk}^{(i)} + \sum_{j=1}^{p-1}\sum_{j'=j+1}^{p}\sum_{k=1}^{m_j}\sum_{k'=1}^{m_{j'}}\gamma_{(j,k),(j',k')}\cdot x_{jk}^{(i)}\cdot x_{j'k'}^{(i)} + \varepsilon_i \quad (2)$$

where the explanatory components are:

θ_0 - expected value of $\log(U_d)$ when all factors are taken at their baseline

θ_{jk} - effect of level k (k = 2, ..., m_j) of factor j on μ_d with respect to the baseline $\theta_{j1} \equiv 0$

$\gamma_{(j,k),(j',k')}$ - interaction effect between θ_{jk} and $\theta_{j'k'}$ with respect to the baseline

$$\begin{cases}\gamma_{(j,1),(j',k')} \equiv 0 & k' = 1,...,m_{j'} \\ \gamma_{(j,k),(j',1)} \equiv 0 & k = 1,...,m_j\end{cases}$$

$$x_{jk}^{(i)} = \begin{cases}1, \text{ if level } k \text{ of factor } j \text{ is present in observation } i \\ 0, \text{ otherwise}\end{cases}$$

ε_d ~ independent identically distributed (i.i.d) random variables with Normal distribution $N(0, \sigma^2)$.

Only categorical (*i.e.* factors) variables were considered in the model. The baselines of all factors were always the first level to show up in the dataset. A stepwise approach was used to identify variables that affect the catch rate of blue shark. We started with a saturated model with all variables and second level interactions among them, but the model was simplified by excluding terms that were not statistically significant. Akaike Information Criterion-AIC (Akaike, 1974) and the deviances as evaluate with Fisher tests (α = 0,05) were used to select the terms. Finally the distribution of residuals was analyzed to verify if the lognormal distribution was a suitable choice. Diagnostics methods described in McCullagh and Nelder (1989) and Ortiz e Arocha (2004) were also used to verify the goodness of the model fitting. A pseudo-R^2 coefficient was calculated as the fraction of the total deviance explained by the model. This is a measure of the explanatory power of the model.

Assuming that the coefficients estimated for the levels of the factor "year" reflects the annual changes of the biomass they can be used to estimate indexes of relative abundance. Than the standardized catch rate was calculate using the back-transformed calculation of year coefficients by the inverse of the link function.

3. Results and discussion

The data about blue shark landings in the Santos harbor is reliable. The overall catches of blue shark of Santos longliners were largest than catches of any other shark.

The means of catch rates for each factor and level are presented in **Figure 2**. There is a high number of mean values for the years of 2002 and 2003. In 1997 the mean of nominal CPUE were lower than others years. In this year all fleet had yet changed the multfilament longline gear to monofilament longline in order to catch swordfish (Arfelli *et al.* 1997). Differences among means of nominal catch rates are large for the factor "target", hence this factor may has important explanatory effect. For the "quarter" factor the catch rates were usually larger in second than in other quarters, which corroborates the results of Amorim *et al.* (1998). The **Figure 3** shows the distribution of the levels of the "target" factor by "year". The level 4 is most representative in 80's and the beginning of 90's. In this period the tuna catch decreased and blue shark was still very abundant, hence the blue shark was the target species (Amorim, 1992). The same happened to the tuna catches in the northeast (3-7ºS

e 32-38ºW) from July 1983 to December 1988, with the increase of shark catches (Hazin *et al*., 1990). In the period 1995-1999 the level 4 was practically absent due the gear changes in order to catch swordfish. After in the beginning of 2000's the Santos fleet returned to direct at sharks, mainly the blue shark (Mourato *et al*., 2004).

The result of stepwise approach in the choice of the best model pointed that all factors are significant and among the interactions, only that between "year" and "quarter" proved to be significant. However the estimation of indexes of relative abundance may be complex if the factor "year" is included in the interactions. Maunder and Punt (2004) reviewed the approaches for dealing interactions when constructing an index of abundance and one of the methods is to explicitly ignore any interactions between "year" and other variable (*e.g*., Vignaux, 1994). In our analysis the model without the interaction between "year" and "quarter" factors were more satisfactory.

Table 1 shows the deviance analyses of the selected model. All the main factors are significant. The "target" factor explained a large amount of the variation of the catch rate (44%), followed by the "quarter" and the "year". The proportion of the deviance explained by the model is about 0.81, as indicated by the pseudo-R^2 calculation. However this value was expected because the data were agreggated by year and quarter, hence a large part of catch rate variation was lost, what could explain the great value of pseudo-R^2 in our analysis. This situation is not common. Most GLM analyses frequently result in low coefficients of determination (*eg*. Punt *et al*., 2000).

Residuals are approximately normally distributed, hence the log-normality error was an acceptable choice (**Figure 4).** The residuals distributions are homoscedastic and the fitting of the model seems to be not biased (**Figure 5**). The **Figure 6** points some discrepancies between residual and standard normal distributions are small and seem only in the tails being about some extreme values. Therefore error and link function used are acceptable.

Coefficient estimations are in **Table 2**. The year coefficients for the years 93 and 2004 were negatives. All others year coefficients were positive. Estimations for quarter factor were positive. Notice that the coefficients for third and second quarters were usually higher than other quarters, indicating that this is the most productive time for fishing blue shark off the Southern Brazil.

The standardized catch rate oscillated without a clear trend although across the year's seems stable (**Figure 7)**. The **Table 3** shows the estimated values of standardized catch rate and the respective standard errors. Notice that the standard errors of estimates are reasonable small representing that our estimates are relative dependable. According to Nakano and Clarke (2005) the stock status of blue sharks in the Atlantic Ocean has not changed drastically over the past three decades. These authors found based in the Japanese longline fishery a moderate decline in 1996-2000 for the North stock, regarding the South stock this decreasing trend was from 2000. Our result suggests that the blue shark from the South Atlantic stock is not strongly affected by the fishery. However this interpretation must be carefully analyzed due to the low fishing effort of Santos longliners and the small area where they operate. Although the results are speculative because the data is not the ideal, they might be taken into account when discussing the assessment of the South Atlantic stock of the blue shark.

Acknowledgements

The authors wish to especially thank to Dr. Humber A. Andrade and Dr. Humberto Hazin, for the suggestions on the analysis, Roberta Schmidt, for statistical data processing, Mrs. Christina Amorim for our English review, the Santos longliner companies Imaipesca Ind. Com. Pesc. Ltda., Irmãos Ono, Akama Com. Pesc. Ltda., Coop. Mista de Pesca Nipo-Brasileira and Taiyo Ind. Pesca S.A., and the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for the M.Sc. schorlarship.

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Table 1. Deviance analysis table of explanatory variables for the log-normal model for blue shark catch rate. Percent of total deviance refers to the deviance explained by the full model.

	Df	*Resid.Dev*	*Deviance*	*% of total deviance*	*Pr (>F)*
NULL		190.25			
Year	21	168.85	21.41	13.75	0.0000
Year Quarter	3	103.13	65.72	42.22	0.0000
Year Quarter Target	3	34.60	68.53	44.03	0.0000

Table 2. Estimations of regression coefficients, standard error (SE), t statistics values.

	Estimate	*Std.Error*	*t value*
1984	4,037	0,132	30,675
1985	0,243	0,157	1,549
1986	0,073	0,158	0,460
1987	0,284	0,157	1,802
1988	0,577	0,159	3,637
1989	0,507	0,159	3,188
1990	0,608	0,158	3,858
1991	0,370	0,156	2,367
1992	0,138	0,158	0,875
1993	-0,039	0,157	-0,250
1994	0,120	0,157	0,769
1995	0,493	0,158	3,118
1996	0,820	0,159	5,165
1997	0,451	0,165	2,741
1998	0,832	0,158	5,253
1999	0,747	0,159	4,693
2000	0,474	0,158	3,006
2001	0,244	0,162	1,502
2002	0,417	0,157	2,655
2003	0,645	0,162	3,979
2004	-0,024	0,158	-0,149
2005	0,220	0,162	1,358
Quarter2	0,292	0,071	4,129
Quarter3	0,373	0,068	5,518
Quarter4	0,030	0,073	0,407
Target2	0,773	0,078	9,893
Target3	1,374	0,088	15,637
Target4	1,942	0,092	21,159

Table 3. Standardized catch rate (Index) and respective standard error (SE).

Year	*Index*	*SE*
1984	56.68	22.34
1985	72.27	22.68
1986	60.95	22.44
1987	75.28	22.12
1988	100.94	22.31
1989	94.09	22.44
1990	104.16	22.15
1991	82.09	22.92
1992	65.08	22.92
1993	54.51	22.29
1994	63.94	22.21
1995	92.78	22.31
1996	128.73	22.88
1997	89.03	22.44
1998	130.27	22.40
1999	119.70	22.78
2000	91.07	22.87
2001	72.33	23.02
2002	86.05	22.44
2003	108.09	22.72
2004	55.37	22.36
2005	70.65	22.70

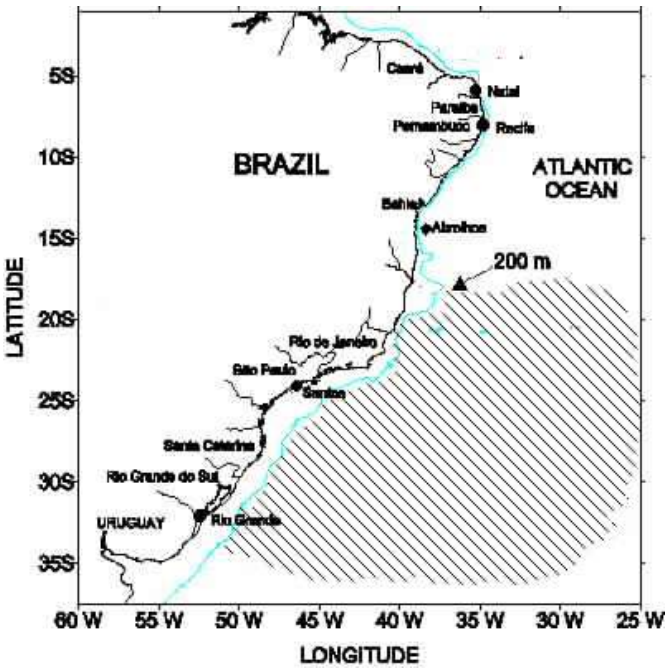

Figure 1. Fishing area of longliners of Santos (SP).

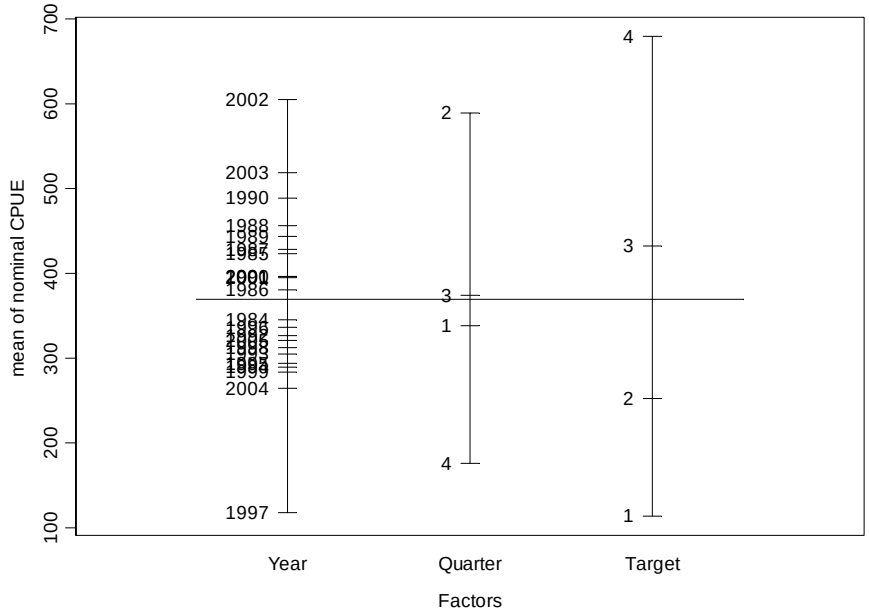

Figure 2. Mean of blue shark catch rate (kg/1,000 hooks) for each factor and level.

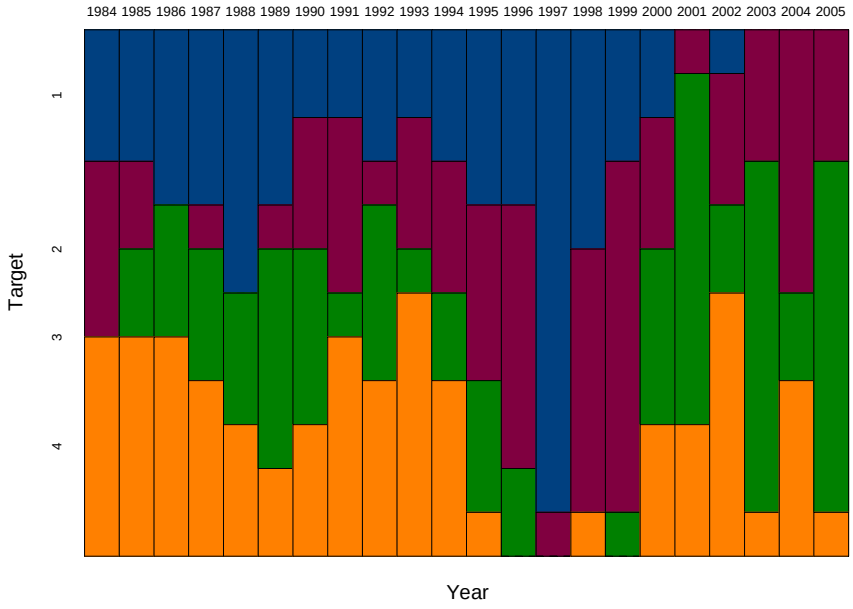

Figure 3. Mosaic-plot of distribution of the levels of the target factor by year from 1984 to 2005.

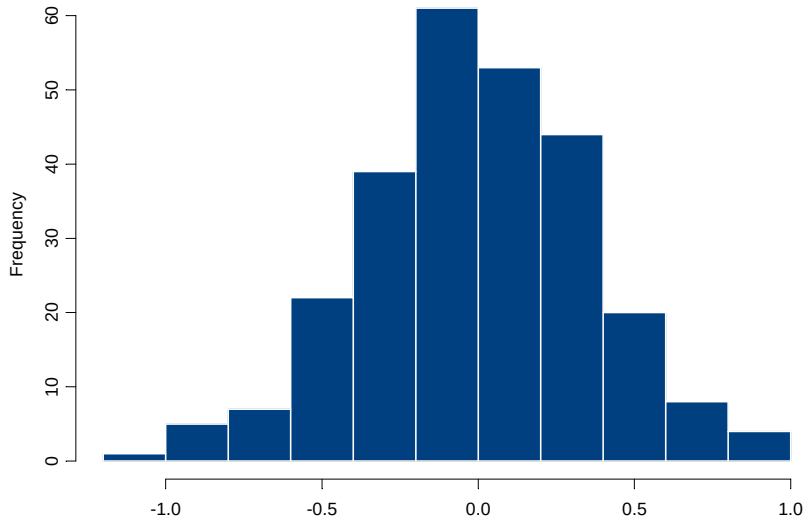

Figure 4. Histogram of residuals.

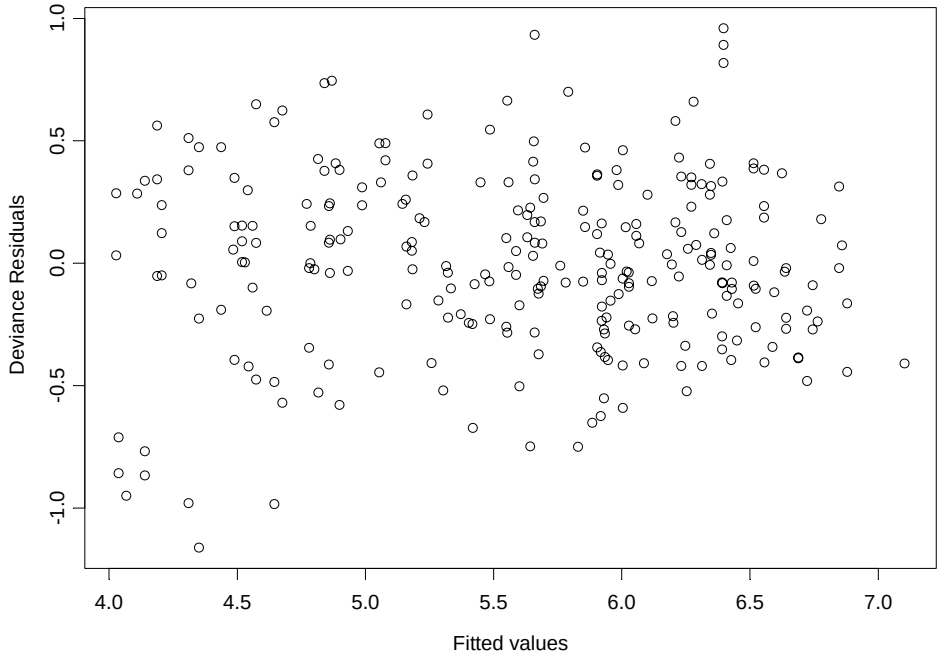

Figure 5. Residual analysis of the log-normal model fitting.

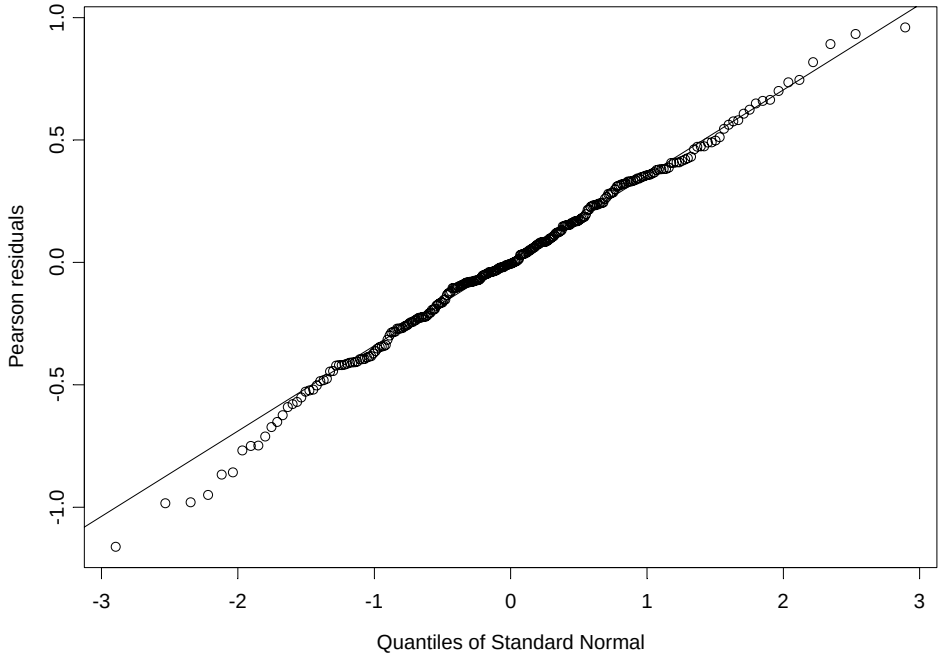

Figure 6. Comparison between residuals and standard normal distributions of the lognormal fitting.

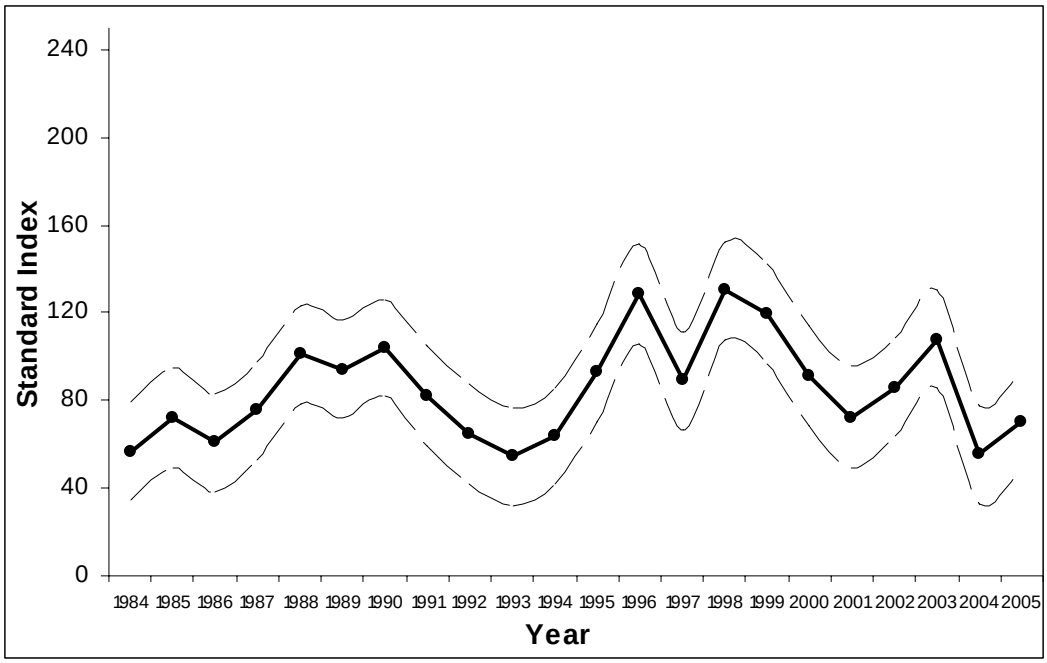

Figure 7. Standardized catch rate of blue shark in the South Occidental Atlantic. Dashed lines stand for the standard errors around the estimations.