SCRS/2023/041 Collect. Vol. Sci. Pap. ICCAT, 80(4): 125-135 (2023)

UPDATED STANDARDIZED CATCH RATES IN BIOMASS FOR THE SOUTH ATLANTIC STOCK OF BLUE SHARK (*PRIONACE GLAUCA*) FROM THE SPANISH SURFACE LONGLINE FLEET FOR THE PERIOD 1997-2021

J. Fernández-Costa[1], A. Ramos-Cartelle, B. García-Cortés, and J. Mejuto

SUMMARY

This paper provides an update of standardized catch rates in weight of blue shark using a Generalized Linear Model (GLM) from a total of 7,139 trips carried out by the Spanish surface longline fleet targeting swordfish in the South Atlantic stock for the period 1997-2021. The criteria used to define explanatory variables were similar to those used in previous papers. The main factors considered in the analysis were year, quarter, area, targeting criteria of skippers, gear and the interaction quarter-area. The results indicate that the target criteria of the skippers was the most important factor which explained the CPUE variability followed by gear and in less extent the other factors analyzed. The GLM results explained 84% of CPUE variability in gutted weight. The results showed an increasing trend reaching a peak in 2017 then a slight decrease until 2020 followed by an increased trend in most recent years.

RÉSUMÉ

Le présent document fournit une mise à jour des taux de capture standardisés en poids du requin peau bleue en utilisant un modèle linéaire généralisé (GLM) à partir d'un total de 7.139 sorties réalisées par la flottille espagnole de palangriers de surface ciblant l'espadon dans l'Atlantique Sud entre 1997 et 2021. Les critères utilisés pour définir les variables explicatives étaient similaires à ceux utilisés dans les documents antérieurs. Les principaux facteurs pris en compte dans l'analyse sont l'année, le trimestre, la zone, les critères de ciblage des capitaines, l'engin et l'interaction trimestre-zone. Les résultats indiquent que le critère de ciblage des capitaines est le facteur le plus important qui explique la variabilité de la CPUE, suivi par l'engin et, dans une moindre mesure, par les autres facteurs analysés. Les résultats du GLM expliquent 84% de la variabilité de la CPUE en poids éviscéré. Les résultats montraient une tendance à la hausse atteignant un pic en 2017, puis une légère baisse jusqu'en 2020, suivie d'une tendance à la hausse dans les années les plus récentes.

RESUMEN

Este artículo proporciona una actualización de las tasas de captura estandarizadas en peso de la tintorera mediante un Modelo Lineal Generalizado (MLG) para un total de 7.139 mareas realizadas por la flota de palangre de superficie española dirigida al pez espada en el stock del Atlántico sur durante el período 1997-2021. Los criterios utilizados para seleccionar las variables explicativas fueron similares a los utilizados en trabajos anteriores. Los principales factores considerados en el análisis fueron el año, el trimestre, la zona, los criterios de direccionamiento de los patrones, el arte y la interacción trimestre-zona. Los resultados indican que el criterio de direccionamiento de los patrones fue el factor más importante en explicar la variabilidad de la CPUE seguido del arte y en menor medida del resto de factores analizados. Los resultados de GLM explicaron el 84 % de la variabilidad de la CPUE en el peso eviscerado. El resultado mostró una tendencia creciente alcanzando un pico en 2017, un ligero descenso hasta 2020 seguido de un incremento en la tendencia en los últimos años.

KEYWORDS

Blue shark, CPUE, GLM, abundance, longline

[1] Instituto Español de Oceanografía (IEO), CSIC, P.O. Box 130, 15080 A Coruña (Spain). E-mail: tunidos.corunha@ieo.csic.es

1. Introduction

Blue shark (*Prionace glauca*) is a highly migratory species of wide ranging in the oceanic-epipelagic ecosystem with high abundance and a broad geographic distribution in different oceans, regularly found between 50ºN and 50ºS (Compagno 1984).

The Spanish surface longline fishery was developed since late 1970's in the North Atlantic targeting mainly swordfish (*Xiphias gladius*). The Spanish longline fleet began working in the south stock (south of 5 degrees North) in 1986. The blue shark has been the most important bycatch of shark species in the Spanish surface longline fleet for decades (García-Cortés *et al.* 2023 in press, Mejuto 1985, 2007; Mejuto *et al.* 2009a) but with the improvement of vessels storage systems together with the increase in the economic value in the markets permitted the skippers retain onboard all the blue shark caught. This supposed an important change in the fishing strategy since mid of 1980´s for the surface longline fleets targeting swordfish. The impact of these changes on the fishing strategy has already been described in abundant literature presented to SCRS and also considered in the recent standardized CPUE analysis of Spanish fleet in the Atlantic (Fernández-Costa *et al.* 2017, Mejuto and De la Serna 2000, Mejuto *et al.* 2001a, 2001b, 2009b, 2017, 2021; García-Cortés *et al.* 2016, Ramos-Cartelle *et al.* 2016, 2021a, 2021b), in the Indian Ocean (Fernández-Costa *et al*. 2021, Ramos-Cartelle *et al.* 2020a, 2020b), and described in the ICCAT literature for many fleets; as well as it has been assessed by the SCRS Methods Working Group (Anon. 2001).

In the early 2000's the monofilament longline "American style" was broadly introduced in the Spanish surface longline fleet in substitution of the traditional style (multifilament). Since then, most vessels have been fishing with this new monofilament (García-Cortés *et al.* 2016, Mejuto and De la Serna 2000, Mejuto *et al.* 2001a, 2001b, 2009b).

Catch-per-unit-effort (CPUE) data from commercial fishing operations have traditionally been used as the main source of information in order to obtain a relative index of abundance and used in the fish stock assessments. This index may be considered in some cases to be an indicator of changes in abundance over time (Maunder and Punt 2004, Maunder *et al.* 2006, Ortiz and Arocha 2004). One of the most common methods for standardizing catch and effort data from commercial longline fleets is the application of the Generalized Linear Model (GLM) (Robson 1966, Gavaris 1980, Kimura, 1981) which removes the effects of factors other than abundance that bias the index and those standardized CPUEs could be used as annual indexes of abundance.

The present document update the standardized CPUE series of the blue shark in the South Atlantic stock previously provided (Ramos-Cartelle *et al.* 2016, Mejuto *et al.* 2009b) for the forthcoming stock assessment.

2. Material and methods

The data used in the present analysis were voluntarily reported for scientific purposes from the Spanish surface longline fleet targeting swordfish and from scientific observes onboard in the South Atlantic stock during the period 1997-2021. The catch per unit of effort (CPUE) was calculated as kilograms of gutted weight caught per thousand hooks and standardized using Generalized Linear Models (GLM). The methodology used in this paper is based on previous research carried out on the Spanish longline fleet in the Atlantic (Fernández-Costa *et al.* 2017, Mejuto and De la Serna 2000, Mejuto *et al*. 2009b, 2017; García-Cortés *et al.* 2016, Ramos-Cartelle *et al.* 2016, 2020a, 2020b, 2021a, 2021b). A sensitive analysis was also carried out using Generalized Linear Mixed Models (GLMM). The analyses were done using the GLM procedures (SAS 9.4).

The spatial areas used on the model were the same as those used in previous analyses for the South Atlantic stock of blue shark (Ramos-Cartelle *et al.* 2016). The hypothetical boundary line between North and South Atlantic stocks was located at 5º N latitude as assumed by ICCAT. Two main gear types were considered in the analysis: the Spanish traditional multifilament style and the American monofilament style.

The fishing strategy for the targeting has changed since early 2000´s. After analyzing the behavior of the Spanish fleet, it was concluded that the percentage in weight of swordfish landed by trip in relation to the amount of combined swordfish and blue shark landed is the best proxy indicator for the skipper targeting criteria to classify trips clearly targeted to swordfish of those trips more diffuses targeted to both species (swordfish and blue shark) (Anon. 2001, Mejuto 2007, Mejuto and De la Serna 2000, Ortiz *et al.* 2010). In this case, the targeting criteria labeled as 'ratio' variable into the model was defined for each trip as the percentage of swordfish related to both the swordfish and blue shark caught (SWO/(SWO+BSH)). The targeting criteria in base case were categorized into ten levels (0.1 quantiles) in order to classify the type of trip. Other lower categorizations of type of trips were also tested. A similar approach to classify the type of trips or sets in multi-specific fisheries is frequently used in the case of other longline fleets where the criteria for target species are diffused or have changed over time (García-Cortés *et al.* 2016).

The response variable was the lnCPUE measured in kg gutted weight per 1000 hooks and the following explanatory variables were considered in the base case analysis: year, quarter (January-March, April-June, July-September, and October-December), area, ratio and gear and the quarter*area interaction.

$$Ln\ (CPUE) = u + Y + Q + A + R + G + Q * A + e.$$

Where, u= overall mean, Y= year effect, Q= quarter effect, A= area effect, R= ratio effect, G= gear effect, e= normally distributed error term A sensitivity analysis was done using Generalized Linear Mixed Models (GLMM) procedure in which the year interactions were included in the model as random effect.

$$Ln(CPUE) = Y + Q + A + G + R + Q*A + \text{random}\ (Y*A + Y*R)$$

Take into consideration the suggestion of the Working Group about to explore reducing the number of ratio categories another sensitivity analysis was also carried out to test the influence of the ratio variable. In this sensitivity analysis the ratio levels were broken down in 5 categories (0.2 quantiles) instead of 10 categories (0.1 quantiles) as used in the base case model. More information about methods tested can be found in documents previously referenced.

3. Results and discussion

The spatial and temporal coverage of the observations were highly representative of the activity of Spanish feet during the period analyzed. For the analysis, a total of 7,139 trip records were available between 1997 and 2021. The percentage of catch covered was the 94% of blue shark catch-task I data of this fleet. **Figure 1** shows the geographical areas stratification used in the GLM models. For consistence, they were the same as used in previous contributions for the South Atlantic stock of blue shark (Ramos-Cartelle *et al.* 2016).

Table 1 provides the ANOVA summary obtained from the GLM base case analysis, including R-square, mean square error (root), F statistics and significance level, as well as the Type III SS for each factor used. The base case model explained the 84% of the CPUE variability in biomass (gutted weight). All the explanatory variables tested contributed significantly to explaining part of the deviance. The CPUE variability (Type III SS) may be mainly attributed to the targeting criteria (*ratio*) followed by *gear*. The *area*, *year* were also significant, although less important. The factor *quarter* was the lowest in significance.

Table 2 provides information on estimated base case parameters (lsmeans), their standard error, coefficient of variation, standard CPUE in biomass and upper and lower 95% confidence intervals obtained for the base case model. The mean CPUE in biomass (CPUEw) and their 95% confidence intervals are plotted in **Figure 4**. The results showed an increasing trend reaching a peak in 2017, later a change in the trend with a slight decrease until 2020 followed by an increased trend in the most recent years.

Figure 2 provides distribution of standardized residuals and the normal probability *qq*-plot over the 1997-2021 period. The box-plot of the standardized residuals obtained by year is shown in **Figure 3**. The fit of the model seems not to be biased and residuals are normally distributed.

A sensitivity analysis carried out with GLMM procedure also showed that all the explanatory variables tested contributed significantly to explaining part of the deviance. The results obtained were very similar to the base case GLM model. Another sensitivity analysis was run to view the effect of reducing the number of categories in the targeting criteria. The analysis was performed reducing the ratio factor to five categories (0.2 quantiles). The model explained the 80% of the CPUE variability in biomass. All the explanatory variables tested also contributed significantly to explaining part of the deviance. The CPUE variability (Type III SS) may be mainly attributed to the targeting criteria (*ratio*) followed by *year*, *gear* and *area*. The *quarter* and the interaction *quarter*area* were also significant, although less important. The results obtained were very similar to the base case GLM model.

Figure 5 shows a comparative between standardized CPUE performed in the base case and sensitivity analyzes. The CPUEs were scaled to maximum values to be compared. The trends achieved were similar in the three analyzes.

In 2000 the Methods Working Group assessed the targeting criteria using simulations for different fisheries-scenarios and the results suggested that there is no clear best methods that could be generally applied to all fleets and that any one proxy could still produce some bias results (Anon 2001). The conclusions of the Group was: *Of the proxy methods evaluated, the use of the ratio of catch of the target species to total catch, performed best on average and remains the preferred proxy, although this method may not provide the best performance in all cases.* The results of the Methods Working Group should at least be consulted and considered when discussing the targeting criteria used by different fleets.

Take into account the empirical knowledge and the behavior (e.g. changes from only targeting swordfish to a diffuse strategy to swordfish and blue shark and no substantial changes in the fishing areas through the years analyzed) of the Spanish fleet the ratio categorized as the percentage in weight of swordfish landed per trip in relation to the amount of the two species swordfish and blue shark landed per trip is the best available proxy as indicator of the targeting criteria of the skippers in the Spanish fleet (Mejuto and De la Serna 2000, Mejuto *et al.* 2023, Ortiz *et al.* 2000). A more in deep discussion about the targeting criteria and other matters as coefficients of variation is given in Mejuto *el al.* (2023).

Acknowledgments

The authors would like to give their sincere thanks to all the members of the team who were involved in the scientific recording and processing of the basic data used in the analysis. We would also like to thank the scientific observers and skippers of the Spanish surface longline fleet involved in this voluntary scientific collaboration.

References

Anonymous. 2001. Report of the ICCAT working group on stock assessment methods (Madrid, Spain –May 8 to 11, 2000). Collect. Vol. Sci. Pap. ICCAT, 52(5): 1569-1662.

Compagno L.J.V. 1984. Sharks of the world. FAO species catalogue. Carcharhiniformes. FAO Fisheries Synopsis, N 125. Vol 4. Part 2.

Fernández-Costa, J., García-Cortés, B., Ramos-Cartelle, A., and Mejuto, J. 2017. Update standardized catch rates of shortfin mako (*Isurus oxyrinchus*) caught by the Spanish surface longline fishery targeting swordfish in the Atlantic Ocean during the period 1990-2015. Collect. Vol. Sci. Pap. ICCAT, 74(4):1730-1745.

Fernández-Costa, J., Ramos-Cartelle, A., and Mejuto, J. 2021. Updated standardized catch rates in biomass for the blue shark (*Prionace glauca*) caught by the Spanish surface longline fleet in the Indian Ocean during the 2001-2019 period. IOTC-2021-WPEB17(DP)-09.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

García-Cortés, B., Ramos-Cartelle, A., Fernández-Costa, J., and Mejuto J. 2016. Standardized catch rates in biomass for the stock of the North Atlantic blue shark (*Prionace glauca*) caught by the Spanish surface longline fleet in the period 1997-2013. Collect. Vol. Sci. Pap. ICCAT, 72(5): 1083-1091.

García-Cortés, B., Ramos-Cartelle, A., Fernández-Costa J., and Mejuto J. 2023 *in press*. Mining of blue shark length data of North and South Atlantic stocks from the Spanish surface longline 1997-2021. Collect. Vol. Sci. Pap. ICCAT. *in press.*

Kimura, D.K. 1981. Standardized measures of relative abundance based on modeling log (CPUE) and their application to Pacific Ocean. Perch. J. Cons. Int. Explor. Mer. 39: 211-218.

Maunder, M. and Punt, A.E. 2004. Standardizing catch and effort data: A review of recent approaches. Fisheries Research 70(2-3): 141-159.

Maunder, M.N., Sibert, J.R., Fonteneau, A., Hampton, J., Kleiber, P., and Harley, S.J. 2006. Interpreting catch per unit effort data to assess the status of individual stocks and communities. ICES Journal of Marine Science, 63: 1373 – 1385.

Mejuto, J. 1985. Associated catches of sharks, *Prionace glauca*, *Isurus oxyrinchus*, and *Lamna nasus*, with NW and N Spanish swordfish fishery, in 1984. I.C.E.S., CM 1985/H: 42.

Mejuto, J. 2007. Aspectos biológicos y pesqueros del pez espada (*Xiphias gladius*, Linnaeus, 1758) del océano Atlántico, con especial referencia a las áreas de actividad de la flota española. Tesis doctoral 265 pp.

Mejuto, J. and De la Serna, J.M. 2000. Standardized catch rates by age and biomass for the North Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-1998 and bias produced by changes in the fishing strategy. Collect. Vol. Sci. Pap. ICCAT, 51(5): 1387-1410.

Mejuto, J., García-Cortés, B., and De la Serna, J.M. 2001a. Brief note on the activity of the Spanish longline fleet catching swordfish (*Xiphias gladius*) in the Atlantic and Mediterranean during the year 1999. Collect. Vol. Sci. Pap. ICCAT, 52(4): 1259-1263.

Mejuto, J., García-Cortés, B., and De la Serna, J.M. 2001b. Standardized catch rates for the North and South Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-1999. Collect. Vol. Sci. Pap. ICCAT, 52(4): 1264-1274.

Mejuto, J., García-Cortés, B., Ramos-Cartelle, A., and De la Serna, J.M. 2009a. Scientific estimations of bycatch landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Atlantic Ocean with special reference to the years 2005 and 2006. Collect. Vol. Sci. Pap. ICCAT, 64(7): 2455-2468.

Mejuto, J., García-Cortés, B., Ramos-Cartelle, A., and De la Serna, J. M. 2009b. Standardized catch rates for the blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) caught by the Spanish surface longline fleet in the Atlantic Ocean during the period 1990-2007. Collect. Vol. Sci. Pap. ICCAT, 64(5): 1509-1521.

Mejuto, J., García-Cortés, B., Ramos-Cartelle, A., and Fernández-Costa, J. 2017. Standardized catch rates in number of fish by age for the North Atlantic swordfish (*Xiphias gladius*) inferred from the Spanish longline fleet for the period 1982-2015 and environmental considerations. Collect. Vol. Sci. Pap. ICCAT, 74(3): 1208-1234.

Mejuto J., García-Cortés, B., Ramos-Cartelle, A., and Fernández-Costa, J. 2021. Standardized age-specific catch rates in number of fish for the North Atlantic swordfish (*Xiphias gladius*) inferred from data of the Spanish longline fleet during the period 1982-2019. Collect. Vol. Sci. Pap. ICCAT, 78(7): 122-141.

Mejuto, J., Ramos-Cartelle, A., García-Cortés, B., and Fernández-Costa, J. 2023 *in press*. Update standardized catch rates in biomass for the North Atlantic stock of blue shark (*Prionace glauca*) from the Spanish surface longline fleet for the period 1997-2021. Paper submitted at the ICCAT blue shark preparatory meeting (Olhao, Portugal 12-13 April 2023), SCRS/2023/040.

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

Ortiz, M., Mejuto, J., Paul, S., Yokawa, K., Neves, M., and Idrissi, M. 2010. An updated biomass index of abundance for the North Atlantic swordfish (*Xiphias gladius*) for the period 1963-2008. Collect. Vol. Sci. Pap. ICCAT, 65(1): 171-184.

Ramos-Cartelle, A., García-Cortés, B., Fernández-Costa, J., and Mejuto J. 2016. Standardized catch rates in biomass for the blue shark (*Prionace glauca*) caught by the Spanish longline fleet in the South Atlantic during the period 1997-2013. Collect. Vol. Sci. Pap. ICCAT, 72(5): 1092-1100.

Ramos-Cartelle, A., Fernández-Costa, J., and Mejuto, J. 2020a. Updated catch rate of swordfish (*Xiphias gladius*) caught by the Spanish surface longline fleet in the Indian Ocean during the 2001-2018 period. IOTC-2020-WPEB18-12.

Ramos-Cartelle, A., Fernández-Costa, J., and Mejuto, J. 2020b. Standardized catch rates of shortfin mako (*Isurus oxyrinchus*) caught by the Spanish surface longline fishery targeting swordfish in the Indian Ocean during the 2001-2018 period. IOTC-2020-WPEB16-16.

Ramos-Cartelle, A., Fernández-Costa, J., García-Cortés, B., and Mejuto J. 2021a. Updated standardized catch rates for the North Atlantic stock of swordfish (*Xiphias gladius*) from the Spanish surface longline fleet for the period 1986-2019. Collect. Vol. Sci. Pap. ICCAT, 78(7): 94-108.

Ramos-Cartelle, A., Fernández-Costa, J., García-Cortés, B., and Mejuto J. 2021b. Updated standardized catch rates for the South Atlantic stock of swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1989-2019. Collect. Vol. Sci. Pap. ICCAT, 78(7): 109-121.

Robson, D.S. 1966. Estimation of relative fishing power of individual ships. Res. Bull. Int. Comm. N.W. Atl. Fish.

Table 1. Summary of ANOVA for the GLM base-case procedure: R square, Root MSE and F statistics. Response variable: ln (CPUEw) of blue shark in gutted weight. Spanish longline fleet in the South Atlantic for 1997-2021 period.

Source	*DF*	*Sum of Squares*	*Mean squared*	*F value*	*Pr>F*
Model	57	7477.288405	131.180498	675.00	<.0001
Error	7081	1376.138499	0.194342		
Corrected Total	7138	8853.426904			

R-Squared	*Coeff. Var.*	*Root MSE*	*Mean CPUE*
0.844564	6.860532	0.440843	6.425782

Source	*DF*	*Type III SS*	*Mean squared*	*F value*	*Pr>F*
yr	24	72.10468	3.004362	15.46	<.0001
qtr	3	1.303069	0.434356	2.24	0.082
area	5	84.718908	16.943782	87.19	<.0001
ratio	9	3361.802248	373.533583	1922.04	<.0001
gear	1	110.94596	110.94596	570.88	<.0001
qtr*area	15	11.956751	0.797117	4.10	<.0001

Table 2. Estimated parameters (lsmeans), standard error (stderr), mean CPUEw in biomass (gutted weight) of blue shark, upper and lower 95% confidence limits and coefficient of variation (CV%) for the Spanish longline fleet in the South Atlantic between 1997 and 2021.

YR	*LSMEAN*	*STDERR*	*UCPUEw*	*CPUEw*	*LCPUEw*	*CV%*
1997	5.73786	0.025365	326.325	310.498	295.439	2.54
1998	5.78171	0.028200	342.878	324.441	306.995	2.82
1999	5.82663	0.028332	358.728	339.351	321.020	2.83
2000	6.08367	0.030093	465.497	438.835	413.700	3.01
2001	6.00056	0.025399	424.396	403.786	384.177	2.54
2002	5.93927	0.026304	399.881	379.787	360.703	2.63
2003	5.84676	0.028609	366.223	346.252	327.371	2.86
2004	5.88099	0.031312	381.019	358.338	337.008	3.13
2005	6.01119	0.036081	438.151	408.236	380.363	3.61
2006	5.99831	0.035182	431.768	402.998	376.145	3.52
2007	5.99407	0.037215	431.686	401.320	373.089	3.72
2008	5.97037	0.031912	417.141	391.849	368.091	3.19
2009	6.08701	0.030626	467.548	440.309	414.656	3.06
2010	6.06128	0.031962	456.888	429.144	403.084	3.20
2011	6.02143	0.031137	438.318	412.368	387.954	3.11
2012	6.09487	0.034782	475.156	443.843	414.594	3.48
2013	6.09843	0.036345	478.342	445.452	414.824	3.64
2014	6.15625	0.037199	507.681	471.983	438.795	3.72
2015	6.17643	0.038163	519.026	481.620	446.909	3.82
2016	6.33163	0.041995	610.831	562.566	518.115	4.20
2017	6.27933	0.040250	577.684	533.862	493.364	4.03
2018	6.16697	0.036256	512.189	477.055	444.331	3.63
2019	6.22719	0.030937	538.238	506.571	476.767	3.09
2020	6.05100	0.020609	442.129	424.626	407.815	2.06
2021	6.17972	0.028001	510.299	483.047	457.251	2.80

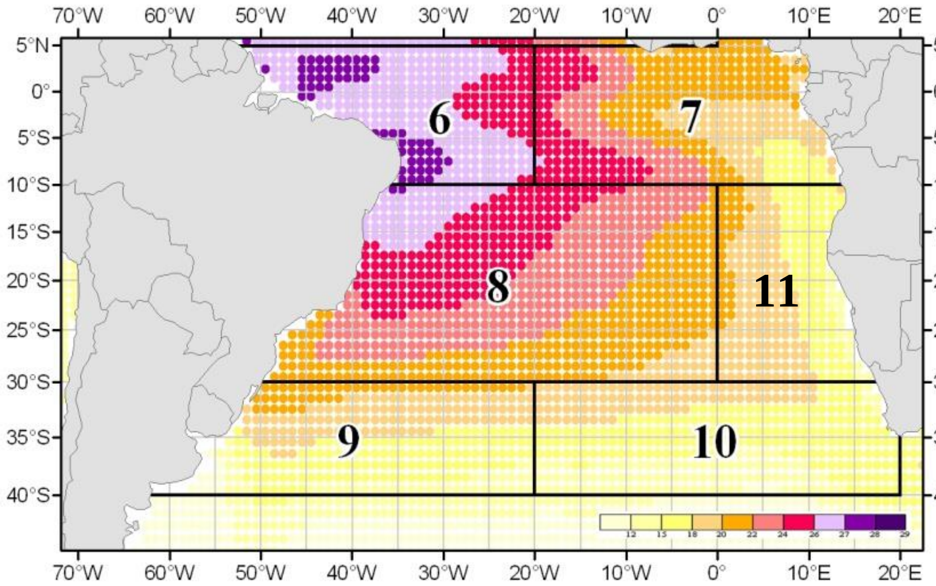

Figure 1. Geographical area stratification used in the GLM for blue shark. The areas were kept as in previous analyses. Areas are superimposed on average sea temperature (ºC) at 50 meters depth.

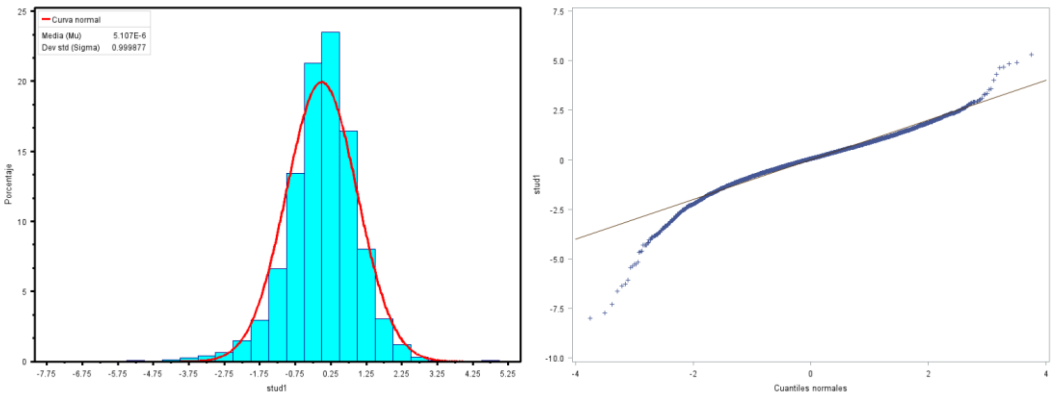

Figure 2. Distribution of the standardized residuals in gutted weight (left) and normal probability qq-plot (right) of blue shark in the South Atlantic stock for years 1997-2021 combined.

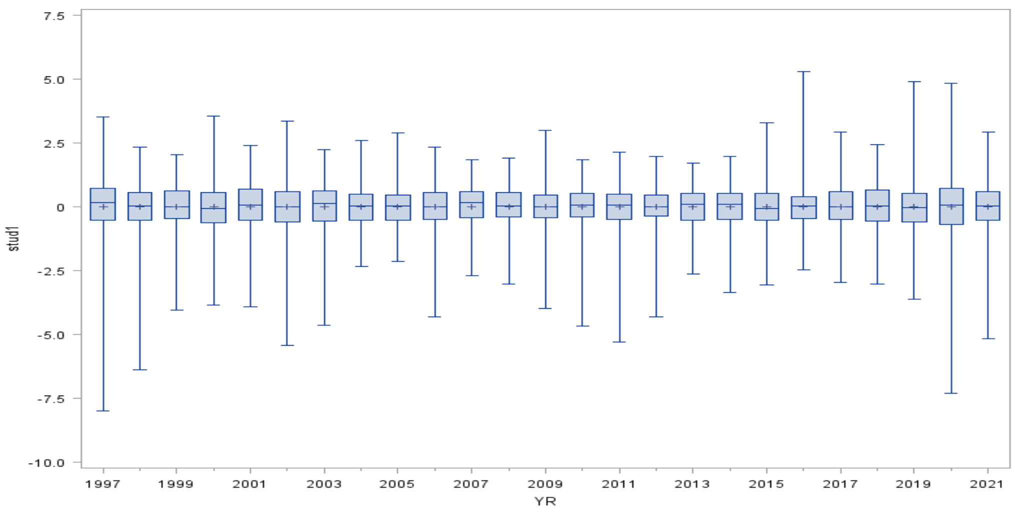

Figure 3. Box-plot of the standardized residuals *vs.* year for the South Atlantic stock of blue shark between 1997 and 2021.

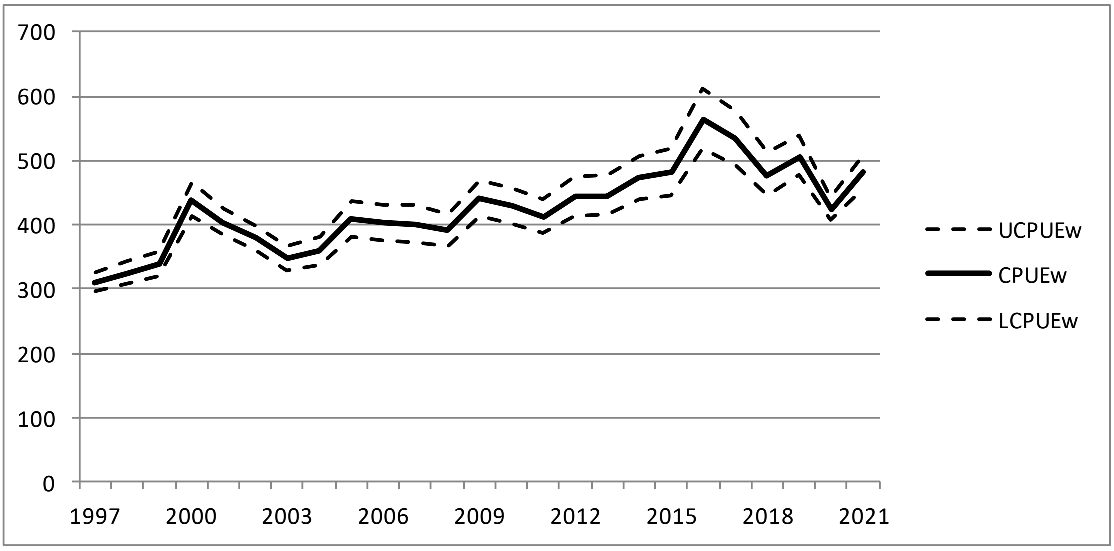

Figure 4. Standardized CPUEw for blue shark and 95% confidence intervals for South Atlantic stock between 1997 and 2021.

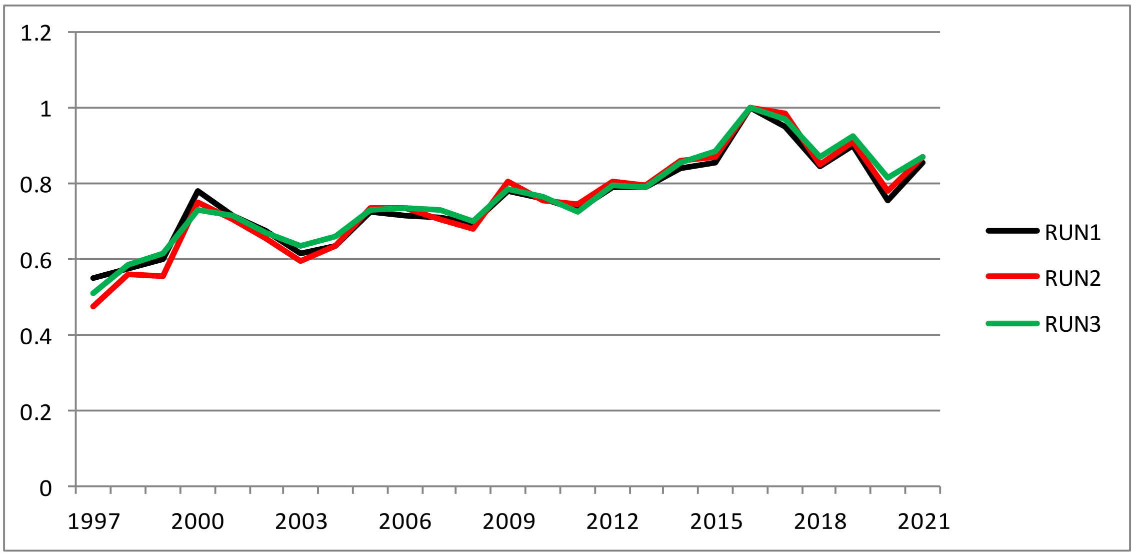

Figure 5. Comparative scaled standardized CPUEw (in gutted weight per thousand hooks) runs carried out for blue shark in the South Atlantic stock between 1997 and 2021. RUN1= base case; RUN2= base case with 5 categories on ratio factor; RUN3= GLMM procedure.