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# STANDARDIZED CATCH RATES OF THE ATLANTIC STOCKS OF SHORTFIN MAKO (*ISURUS OXYRINCHUS*) INFERRED FROM SPANISH SURFACE LONGLINE FISHERY TARGETING SWORDFISH DURING THE 1990-2023 PERIOD

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*SUMMARY*

*Standardized catch rates in number and weight per unit of effort were obtained for the North and South Atlantic shortfin mako stocks using Generalized Linear Models. A total of 17,613 trips (nominal effort 538.4 million hooks) for the North stock and 7,665 trips (nominal effort 316.7 million hooks) for the South stock were available in the analysis between 1991 and 2023. The base case models explained the 33% and 49% of the CPUE variability in number of fish for the North and South Atlantic stock, respectively. The CPUE variability can be mainly attributed to the area factor. The results in number of fish showed a stable slightly increasing trend until 2018, with large fluctuations in the last years after the implementation of the recommendations, probably due to the small amount of data for those years. The results do not show signs of stock depletions during the period analyzed. In general terms, the models suggest overall stable CPUE trend in the North and South stocks.*

*RÉSUMÉ*

*Les taux de capture standardisés en nombre et en poids par unité d'effort ont été obtenus pour les stocks de requins-taupes bleus de l'Atlantique Nord et Sud à l'aide de modèles linéaires généralisés. Un total de 17.613 sorties (effort nominal de 538,4 millions d'hameçons) pour le stock du Nord et de 7.665 sorties (effort nominal de 316,7 millions d'hameçons) pour le stock du Sud étaient disponibles dans l'analyse entre 1991 et 2023. Les modèles du cas de base ont expliqué 33% et 49% de la variabilité de la CPUE en nombre de poissons pour le stock de l'Atlantique Nord et Sud, respectivement. La variabilité de la CPUE peut être principalement attribuée au facteur zone. Les résultats en nombre de poissons ont montré une tendance stable et légèrement croissante jusqu'en 2018, avec d'importantes fluctuations au cours des dernières années après la mise en œuvre des recommandations, probablement en raison de la faible quantité de données pour ces années. Les résultats ne montrent pas de signes d'épuisement des stocks au cours de la période analysée. D'une manière générale, les modèles suggèrent une tendance globale stable de la CPUE dans les stocks du Nord et du Sud.*

*RESUMEN*

*Se obtuvieron tasas de captura estandarizadas en número y en peso por unidad de esfuerzo para los stocks de marrajo dientuso del Atlántico Norte y Sur utilizando Modelos Lineales Generalizados. Se analizaron un total de 17.613 mareas (esfuerzo nominal de 538,4 millones de anzuelos) para el stock del Norte y 7.665 mareas (esfuerzo nominal de 316,7 millones de anzuelos) para el stock del Sur entre 1991 y 2023. El modelo del caso base explicó el 33% y el 49% de la variabilidad de la CPUE en número de peces para el stock del Atlántico Norte y Sur, respectivamente. La variabilidad de la CPUE puede atribuirse principalmente al factor área. Los resultados en número mostraron una tendencia estable ligeramente creciente hasta 2018 mostrando grandes fluctuaciones en los últimos años después de la implementación de las recomendaciones, probablemente debido a la escasez de datos de esos años. Los resultados no muestran signos de agotamiento de las poblaciones durante el período analizado. En términos generales, los modelos sugieren una tendencia global estable de la CPUE en los stocks Norte y Sur.*

*KEYWORDS*
*shortfin mako, sharks, CPUE, GLM, longline, Spanish fleet*

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## 1. Introduction

The shortfin mako (*Isurus oxyrinchus*) is a highly migratory shark species mainly found in tropical, intertropical and temperate seas. It is a common, extremely active species regularly present in oceanic areas with occasional inshore movements from high seas over the continental slopes (Compagno 2001).

The last stock assessment of both shortfin mako stocks, North and South Atlantic, were conducted in 2017. In 2019, the projections of the North Atlantic stock were updated based on the 2017 stock assessment and those parameters selected. Since 2017, several ICCAT recommendations have been implemented for the conservation of the northern stock (Rec. 17-08, Rec. 19-06, and Rec. 21-09) and one recommendation for the southern stock (Rec. 22-11) of the Atlantic shortfin mako. The first recommendations (Rec. 17-08 and Rec. 19-06) required vessels to promptly release North Atlantic shortfin mako in a manner that causes the least harm to the individuals and allowed vessels to retain the dead shortfin makos on board under certain conditions (among others the vessel has either an observer or EMS, etc.).

For the North stock, the currently recommendation in force (Rec. 21-09) is the implementation of a rebuilding program for reducing the total fishing mortality to maintain this at sustainable levels to rebuild the stock. Since 2022 when that Recommendation entered in force, the CPCs are forbidden from retaining on board and landing shortfin mako sharks.

For the South stock, the aim of the Rec. 22-11 is to implement a fishery management plan to counteract overfishing immediately and gradually achieve biomass levels sufficient to support maximum sustainable yield. This Recommendation entered in force in 2023. In the case of the South stock, a maximum retention of 1,295 tons will be allowed but this amount of total mortality will be reviewed in the light of the results of this year´s assessment.

In addition to ICCAT Recommendations, shortfin mako entered in CITES in November 2019 being in some cases the marketing quota more restrictive than the scientific quota recommended and further reducing possible retained catches in the case of southern stock.

The most common method for standardizing catch rates (CPUE) is the application of generalized linear models (GLM) (Robson 1966; Gavaris 1980; Kimura 1981) which removes the effects of factors other than abundance that bias the index. Indirect factors such as operational changes, technological improvements, including changes in the target species or the targeting criteria of the skippers over time, could be a good alternative to be considered in some cases. Modeling approaches should be adapted to each fishery case, data availability and the respective historical circumstances of each fishery.

The aim of this document is to update the Spanish longline fleet targeting swordfish standardized CPUE series previously provided for the Atlantic shortfin mako stocks (Fernández-Costa *et al.* 2017) covering in the present case a 34-years period.

## 2. Material and methods

The data used consisted of trip records of the Spanish longline fleet targeting swordfish voluntarily provided for research covering the 1990-2023 period. Nominal effort per trip was defined by thousands of hooks. The nominal catch per unit of effort was initially obtained as number of fish per thousand hooks. The different recent regulations implemented on Atlantic shortfin mako stocks, the covid-19 pandemic as well as other circumstances have affected the quantity and quality of available scientific data. Therefore different approaches were studied.

The methodology used in the present paper is based on previous research carried out by the Spanish longline fleet in the Atlantic and Indian Oceans (Mejuto *et al.* 2009, 2013; Fernández-Costa *et al.* 2017, 2024). The response variable catch per unit of effort was measured as number (CPUEn) of fish per fishing effort and it was standardized using Generalized Linear Models (GLM) procedures (*SAS 9.4*).

$$\text{Ln (CPUEn)} = u + Y + Q + A + R + G + Y*Q + e$$

where: u = overall mean, Y = *year* effect, Q = *quarter* effect (1: January-March; 2: April-June; 3: July-September; 4: October-December), A = *area* effect (**Figure 1**), R = *ratio* effect defined for each available trip record as an indicator of the target criteria of the skipper type of trip expressed as the percentage of swordfish by weight related to the catches in weight of swordfish and blue shark combined, classified in ten categories at 10% intervals (Mejuto and De la Serna 2000), G = *gear* effect (1: traditional multifilament; 3: American-style monofilament; 9: modified American-style monofilament), Y*Q = the interaction year-quarter and e = logarithm of the normally distributed error term. Standardized residuals by year were plotted.

GLM procedures were also tested to obtain standardized CPUEw (kg round weight per thousand hooks) per stock.

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 both species combined landed swordfish and blue shark was the best proxy indicator in this fleet for the skipper targeting criteria to classify trips clearly targeted to swordfish of those trips more diffuses targeted to swordfish and/or blue shark (Anon. 2001, Mejuto and De la Serna 2000, Mejuto 2007, Ortiz *et al.* 2007). That approach performed best among different scenarios simulated for this fishery-case (Anon. 2001). The targeting criteria labeled as '*ratio*' variable in the model was defined for each trip as the percentage of swordfish related to both the swordfish and blue shark caught and later categorized in the base case model in ten levels (0.1 quantiles) in order to classify the type of trip into the model. 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 changes for targeting are known but it is diffused or they have changed over time (Carvalho *et al.* 2010, Ortiz *et al.* 2010; García-Cortés *et al.* 2016; Coelho *et al.* 2023). Values of least squared mean predictions, standard error, CPUEn values and 95% confidence intervals and other statistical diagnoses were obtained for each run.

Considering that abrupt changes in the biomasses of swordfish and shortfin mako are not expected over short time periods and given that data coverage for swordfish catches per trip has been consistently maintained from 1990 to 2023, a reconstruction of expected shortfin mako catches per trip was conducted for post-regulations period. This process involved a prior standardization of the swordfish *versus* shortfin mako catch ratio during the pre-regulation period and to implement those ratios for subsequent years as the average of the standardized ratios from the previous five years.

## 3. Results and discussion

The first regulations on shortfin mako were implemented in the northern stock for the Spanish fleet surface longline in year 2018. Subsequent to this, the various regulations (ranging from the allowance for the retention of dead catch on board during observed trips to the complete prohibition of retention) have collectively diminished the quantity and quality of data available with adequate spatial-temporal details, a phenomenon that has been further compounded by the advent of the COVID-19 pandemic among other limitations. The improvement of the on-board observer program since 2020 is making it possible to increase coverage values. Finally, for the whole period 1990-2023 a total of 17,613 trip records (16,945 trips between 1990 and 2017) with a nominal effort of 538.4 million hooks were available in the analysis of the North Atlantic shortfin mako stock.

With regard to the southern stock regulations, it was in year 2021 that a CITES quota was established in 2023 reached the value of zero allowed landings. So, a total of 7,665 trip records (7,566 trips between 1990 and 2019) with a nominal effort of 316.7 million hooks were available for the period 1990-2023 in the analysis of the South Atlantic shortfin mako stock.

Therefore, the coverage of the combined North and South Atlantic stocks by the observations used against the total effort of this fleet (Task II effort data) varies considerably over the period, from around 71% of the total effort until 2015 (Fernández-Costa *et al*. 2017), to a minimum of 3% in 2020, rising to around 20% in the final years.

**Table 1** provides the ANOVA summary obtained from the GLM analysis for each of the Atlantic stocks, including R-square, mean square error (root), F statistics and significance level, as well as the Type III SS for each factor used. The GLM model explained 33% and 49% of the CPUE variability in number of fish for North and South Atlantic stocks, respectively. As with the case of the previous shortfin mako CPUE analyses (Fernández-Costa *et al*. 2017), the CPUE variability (Type III SS) may be mainly attributed to the *area* factor. The interaction *quarter*area*, the *ratio* and *year* in the North, and *year* and *quarter* in the South seem to be also significant, although less important.

As previously described in literature, the type of trip was a significant but less important factor in the case of this bycatch species. However, this factor was relatively more important in the case of the North Atlantic fleet. The results suggest that this factor is also significant but much less important than in the case of the swordfish and blue shark analyses, probably because the shortfin mako was a regular "pure" bycatch throughout the history of this fishery which has been documented since the 1980s (Mejuto and González-Garcés 1984, Mejuto 1985), with quite high occurrence but relatively medium prevalence by the total trip as compared to main species.

**Table 2** provides information on estimated parameters (Lsmean), their standard error, the percentage of coefficient of variation (CV%), standard CPUE in number of fish and upper and lower 95% confidence limits. **Figure 2** provides distribution of standardized residuals and the normal probability *qq*-plot over the 1990-2023 period. The box-plot of the standardized residuals obtained, by main factor, is shown in **Figure 3**. The fit of the model seems not to be biased and residuals are normally distributed.

The CPUEn trends over time and their respective 95% confidence intervals are also plotted in **Figure 5**. The CPUEn models suggest a quite stable, slightly increasing trend in both stocks until the regulations were implemented. After this time, the fluctuations shown in standardized CPUE are unlikely to reflect changes in the stock's abundances. Sudden increases or decreases from one year to the next are not biologically plausible for this type of species. Those large fluctuations in most recent period likely are mainly due to the reduced amount of reliable data on this bycatch species.

After applying the standardized SWO/SMA ratios, new GLM procedures were also tested to obtain standardized CPUEw (kg round weight per thousand hooks) per stock. The GLM models explained 25% and 42% of the CPUE variability in round weight for North and South Atlantic stocks, respectively. The **Figure 6** shows the trend of CPUE in kg-RW during the 1990-2023 period.

The present results in number and weight do not show signs of stock depletion during the period analyzed. In general terms, the models suggest overall stable CPUE trends in the North and South stocks during the 34-year period analyzed.

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## 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.

Carvalho, F.C., Murie, D. J., Hazin, F. H., Hazin, H. G., Leite-Mourato, B., Travassos, P., and Burgess, G. H. 2010. Catch rates and size composition of blue sharks (*Prionace glauca*) caught by the Brazilian pelagic longline fleet in the southwestern Atlantic Ocean. Aquatic Living Resources, 23: 373–385.

Coelho, R., Rosa, D., Santos, C.C., and Lino, P.G. 2023. Updated standardized CPUEs of blue shark in the Portuguese pelagic longline fleet operating in the North Atlantic (1997-2021). Collect. Vol. Sci. Pap. ICCAT, 80(4): 147-177

Compagno, L.J.V. 2001. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Volume 2. Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes). FAO Species Catalogue for Fishery Purposes. No. 1, Vol. 2. Rome, FAO.

Fernández-Costa, J., García-Cortés, B., Ramos-Cartelle, A., and Mejuto, J. 2017. Updated 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., García-Cortés, B., and Mejuto, J. 2024. Updated standardized catch rates of shortfin mako (*Isurus oxyrinchus*) inferred from the Spanish surface longline fishery in the Indian Ocean during the period 2001-2022. IOTC-2024-WPEB20(DP)-21.

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.

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.

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.

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. 265pp.

Mejuto, J. and González-Garcés, A. 1984. Shortfin mako, *Isurus oxyrinchus*, and porbeagle, Lamna nasus, associated with longline swordfish fishery in the NW and N Spain. ICES C.M. 1984/G:72.

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., Ramos-Cartelle, A. and De la Serna, J.M. 2009. 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., De la Serna, J.M., González-González, I., and Fernández-Costa, J. 2013. Standardized catch rates of shortfin mako (*Isurus oxyrinchus*) caught by the Spanish surface longline fishery targeting swordfish in the Atlantic Ocean during the period 1990-2010. Collect. Vol. Sci. Pap. ICCAT, 69(4): 1657-1669.

Ortiz, M. 2007. Update of standardized catch rates by sex and age for swordfish (*Xiphias gladius*) from the U.S. longline fleet 1981-2005 Collect. Vol. Sci. Pap. ICCAT, 60(6): 1994-2017.

Robson, D. S. 1966. Estimation of relative fishing power of individual ships. Res. Bull. Int. Comm. N.W. Atl. Fish. 3: 5-14.

**Table 1.** Summary of ANOVA for CPUE analyses in number of fish for shortfin mako in the Atlantic stocks: R-square, mean square error (root) and F statistics. Dependent variable: ln (CPUEn).

**North Atlantic stock. SMA CPUE in number of fish**

Dependent variable: ln (CPUEn)

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 63 | 10350.22376 | 164.28927 | 136.81 | <.0001 |
| Error | 17549 | 21073.12335 | 1.20082 | | |
| Corrected Total | 17612 | 31423.34711 | | | |

| R-Square | Coef. Var | Root MSE | Cpue1 Mean |
|---|---|---|---|
| **0.329380** | 530.7370 | 1.095818 | 0.206471 |

| Source | DF | Tipo III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Year | 33 | 789.529847 | 23.925147 | 19.92 | <.0001 |
| Quarter | 3 | 133.704164 | 44.568055 | 37.11 | <.0001 |
| Area | 4 | 3599.111765 | 899.777941 | 749.31 | <.0001 |
| Ratio | 9 | 1111.248850 | 123.472094 | 102.82 | <.0001 |
| Gear | 2 | 11.284931 | 5.642465 | 4.70 | 0.0091 |
| Quarter*Area | 12 | 1173.535939 | 97.794662 | 81.44 | <.0001 |

**South Atlantic stock. SMA CPUE in number of fish**

Dependent variable: ln (CPUEn)

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 66 | 5009.66991 | 75.90409 | 111.72 | <.0001 |
| Error | 7598 | 5162.25251 | 0.67942 | | |
| Corrected Total | 7664 | 10171.92242 | | | |

| R-Square | Coef. Var | Root MSE | Cpue1 Mean |
|---|---|---|---|
| **0.492500** | -260.5500 | 0.824271 | -0.316358 |

| Source | DF | Tipo III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Year | 33 | 369.687804 | 11.202661 | 16.49 | <.0001 |
| Quarter | 3 | 194.257394 | 64.752465 | 95.31 | <.0001 |
| Area | 5 | 1233.997488 | 246.799498 | 363.25 | <.0001 |
| Ratio | 9 | 185.957471 | 20.661941 | 30.41 | <.0001 |
| Gear | 1 | 39.056990 | 39.056990 | 57.49 | <.0001 |
| Quarter*Area | 15 | 170.336072 | 11.355738 | 16.71 | <.0001 |

**Table 2.** Least squared mean, standard error, predicted CPUE in number of fish, the 95% confidence intervals and %CV by year, for the Atlantic stocks of the shortfin mako during the 1990-2023 period.

| | CPUE SMA - number of fish / 1000 hooks | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Atlantic stock | | | | | | South Atlantic stock | | | | | |
| Year | Lsmean | Stderr | UCPUE | CPUE | LCPUE | %CV | Lsmean | Stderr | UCPUE | CPUE | LCPUE | %CV |
| 1990 | -0.1696 | 0.1019 | 1.0361 | 0.8484 | 0.6948 | 10.22 | -0.2742 | 0.0788 | 0.8899 | 0.7626 | 0.6535 | 7.89 |
| 1991 | -0.2173 | 0.1019 | 0.9876 | 0.8089 | 0.6625 | 10.21 | -0.5267 | 0.0732 | 0.6835 | 0.5921 | 0.5130 | 7.33 |
| 1992 | -0.0272 | 0.1026 | 1.1962 | 0.9783 | 0.8002 | 10.28 | -0.3018 | 0.0642 | 0.8405 | 0.7410 | 0.6534 | 6.43 |
| 1993 | -0.1353 | 0.1013 | 1.0708 | 0.8780 | 0.7198 | 10.16 | -0.2637 | 0.0550 | 0.8569 | 0.7694 | 0.6908 | 5.50 |
| 1994 | -0.2027 | 0.1010 | 1.0004 | 0.8207 | 0.6733 | 10.13 | -0.2450 | 0.0574 | 0.8774 | 0.7840 | 0.7006 | 5.74 |
| 1995 | -0.3399 | 0.0994 | 0.8692 | 0.7154 | 0.5888 | 9.96 | -0.0557 | 0.0545 | 1.0539 | 0.9472 | 0.8513 | 5.45 |
| 1996 | -0.0734 | 0.0983 | 1.1322 | 0.9337 | 0.7701 | 9.86 | 0.1240 | 0.0520 | 1.2553 | 1.1336 | 1.0237 | 5.21 |
| 1997 | -0.5655 | 0.0983 | 0.6921 | 0.5708 | 0.4708 | 9.86 | -0.1802 | 0.0454 | 0.9137 | 0.8359 | 0.7648 | 4.54 |
| 1998 | -0.4570 | 0.0987 | 0.7721 | 0.6363 | 0.5244 | 9.89 | -0.4258 | 0.0505 | 0.7222 | 0.6541 | 0.5924 | 5.05 |
| 1999 | -0.5825 | 0.1006 | 0.6837 | 0.5614 | 0.4609 | 10.09 | -0.6178 | 0.0541 | 0.6004 | 0.5399 | 0.4856 | 5.42 |
| 2000 | -0.4112 | 0.0994 | 0.8093 | 0.6661 | 0.5483 | 9.96 | -0.0372 | 0.0593 | 1.0842 | 0.9652 | 0.8592 | 5.94 |
| 2001 | -0.3358 | 0.0984 | 0.8710 | 0.7182 | 0.5923 | 9.86 | 0.2286 | 0.0485 | 1.3837 | 1.2583 | 1.1443 | 4.85 |
| 2002 | -0.0468 | 0.0978 | 1.1615 | 0.9588 | 0.7915 | 9.81 | 0.1722 | 0.0512 | 1.3150 | 1.1894 | 1.0758 | 5.13 |
| 2003 | 0.1483 | 0.0997 | 1.4171 | 1.1656 | 0.9588 | 9.99 | 0.1406 | 0.0551 | 1.2843 | 1.1528 | 1.0347 | 5.52 |
| 2004 | 0.2195 | 0.0999 | 1.5226 | 1.2517 | 1.0291 | 10.02 | 0.0576 | 0.0599 | 1.1934 | 1.0612 | 0.9437 | 5.99 |
| 2005 | 0.1408 | 0.1015 | 1.4118 | 1.1571 | 0.9483 | 10.18 | 0.1837 | 0.0680 | 1.3762 | 1.2045 | 1.0542 | 6.81 |
| 2006 | 0.0381 | 0.1040 | 1.2807 | 1.0445 | 0.8518 | 10.43 | 0.0479 | 0.0638 | 1.1912 | 1.0512 | 0.9277 | 6.38 |
| 2007 | 0.3152 | 0.1057 | 1.6954 | 1.3782 | 1.1203 | 10.60 | 0.0025 | 0.0687 | 1.1497 | 1.0049 | 0.8783 | 6.88 |
| 2008 | 0.3451 | 0.1052 | 1.7452 | 1.4200 | 1.1554 | 10.55 | -0.1009 | 0.0602 | 1.0191 | 0.9056 | 0.8048 | 6.03 |
| 2009 | 0.2519 | 0.1040 | 1.5858 | 1.2935 | 1.0550 | 10.43 | 0.1116 | 0.0574 | 1.2533 | 1.1199 | 1.0008 | 5.74 |
| 2010 | 0.1309 | 0.1030 | 1.4024 | 1.1459 | 0.9364 | 10.33 | 0.2102 | 0.0605 | 1.3918 | 1.2362 | 1.0980 | 6.05 |
| 2011 | -0.1040 | 0.1029 | 1.1084 | 0.9060 | 0.7406 | 10.31 | 0.4519 | 0.0587 | 1.7659 | 1.5740 | 1.4030 | 5.87 |
| 2012 | 0.1571 | 0.1027 | 1.4385 | 1.1763 | 0.9619 | 10.29 | 0.4226 | 0.0649 | 1.7363 | 1.5291 | 1.3466 | 6.49 |
| 2013 | -0.1443 | 0.1045 | 1.0683 | 0.8704 | 0.7092 | 10.48 | 0.5105 | 0.0672 | 1.9051 | 1.6699 | 1.4638 | 6.73 |
| 2014 | -0.1072 | 0.1024 | 1.1037 | 0.9031 | 0.7389 | 10.26 | 0.4617 | 0.0703 | 1.8256 | 1.5906 | 1.3859 | 7.04 |
| 2015 | 0.0957 | 0.1024 | 1.3522 | 1.1062 | 0.9050 | 10.27 | 0.3433 | 0.0711 | 1.6246 | 1.4132 | 1.2293 | 7.12 |
| 2016 | -0.0534 | 0.1030 | 1.1663 | 0.9530 | 0.7788 | 10.33 | 0.5758 | 0.0775 | 2.0765 | 1.7839 | 1.5326 | 7.76 |
| 2017 | -0.0248 | 0.1032 | 1.2006 | 0.9807 | 0.8011 | 10.35 | 0.5081 | 0.0751 | 1.9312 | 1.6669 | 1.4387 | 7.52 |
| 2018 | 0.4200 | 0.4564 | 4.1319 | 1.6891 | 0.6905 | 48.12 | 0.5296 | 0.0684 | 1.9464 | 1.7022 | 1.4886 | 6.85 |
| 2019 | 0.7813 | 0.2809 | 3.9403 | 2.2722 | 1.3103 | 28.65 | 0.5509 | 0.0584 | 1.9485 | 1.7377 | 1.5497 | 5.85 |
| 2020 | 1.1781 | 0.1849 | 4.7480 | 3.3044 | 2.2997 | 18.65 | -0.3469 | 0.2510 | 1.1931 | 0.7295 | 0.4460 | 25.50 |
| 2021 | -0.1886 | 0.1120 | 1.0379 | 0.8333 | 0.6691 | 11.24 | 0.5692 | 0.2031 | 2.6856 | 1.8037 | 1.2114 | 20.52 |
| 2022 | 0.4265 | 0.1234 | 1.9660 | 1.5436 | 1.2119 | 12.39 | 0.3438 | 0.1927 | 2.0959 | 1.4367 | 0.9849 | 19.45 |
| 2023 | 0.5819 | 0.1028 | 2.2008 | 1.7990 | 1.4706 | 10.31 | 0.1047 | 0.1188 | 1.4115 | 1.1182 | 0.8859 | 11.93 |

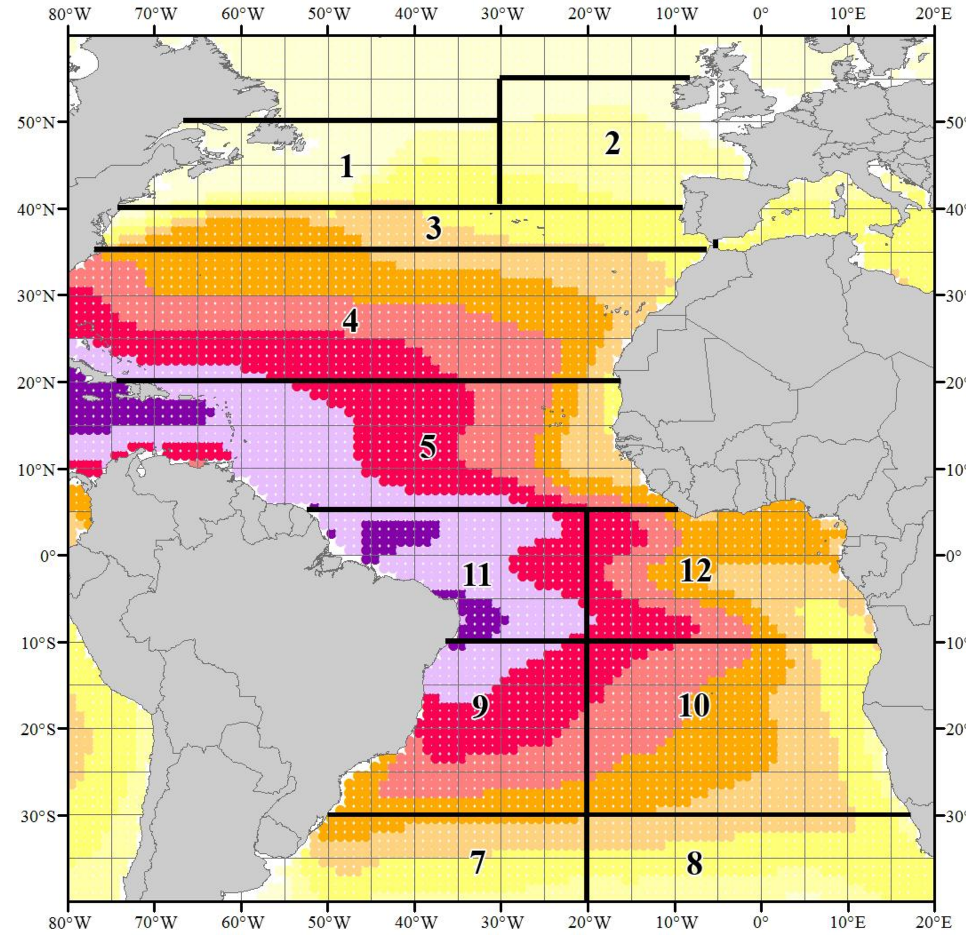



**Figure 1.** Geographical area stratification used for the GLM runs of the shortfin mako, for the North Atlantic stock (areas 1-5) and South Atlantic stock (areas 7-12). The area stratification was kept as in previous analyses. Areas are superimposed on average sea temperature ºC at 50m depth.

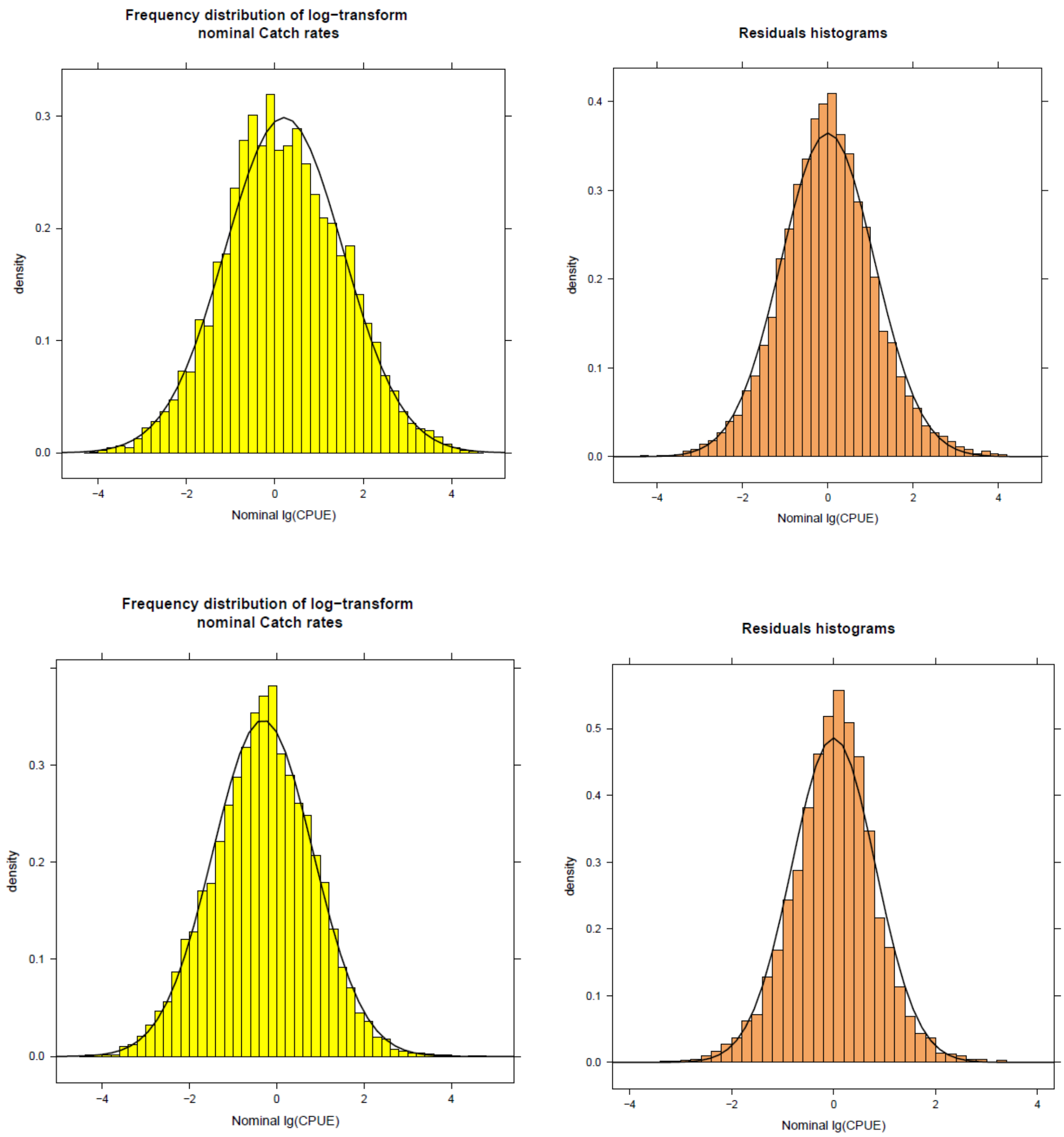



**Figure 2.** Frequency distribution of the log-transformed nominal catch rates (left panels) and residual histograms (right panels) obtained for the GLM runs (in number of fish) of the shortfin mako. North Atlantic stock (upper panels). South Atlantic stock (lower panels).

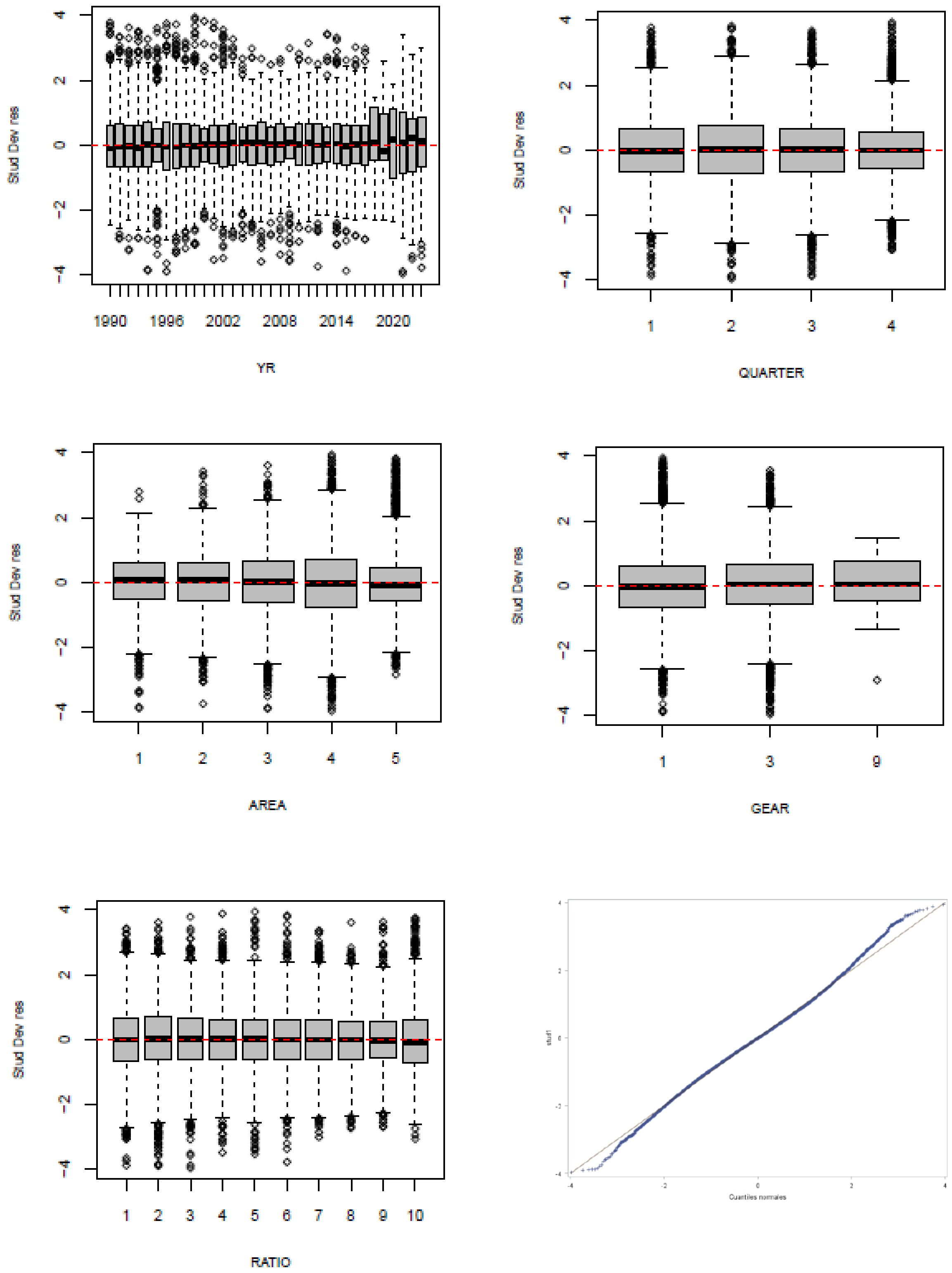



**Figure 3.** Standardized deviance residuals *versus* explanatory variables and qq-plot obtained from the GLM analyses in number of fish of the North Atlantic stock.

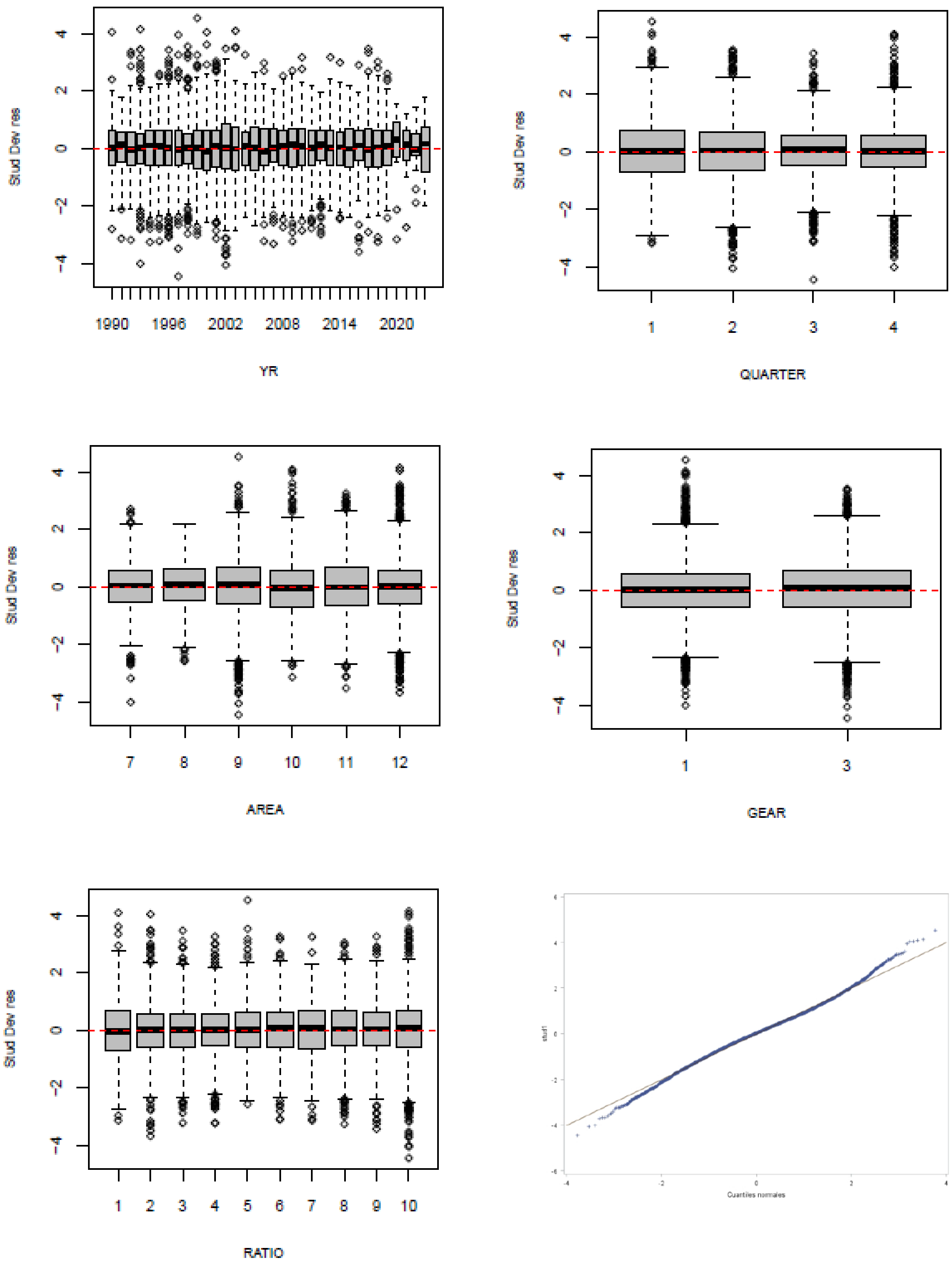
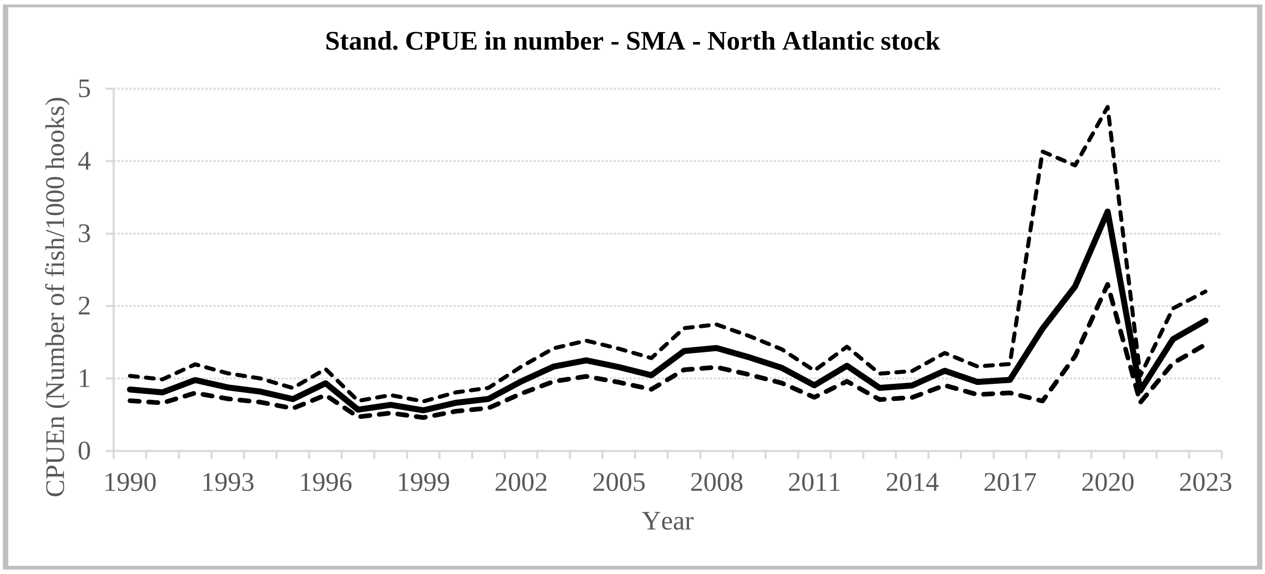



**Figure 4.** Standardized deviance residuals *versus* explanatory variables and qq-plot obtained from the GLM analyses in number of fish of the South Atlantic stock.



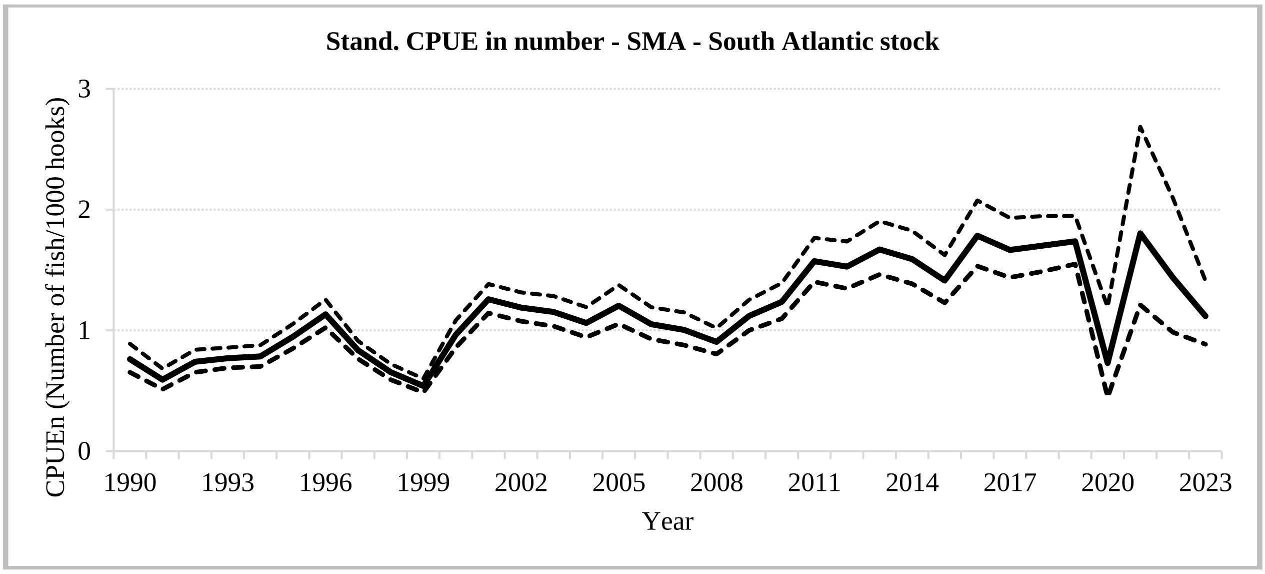
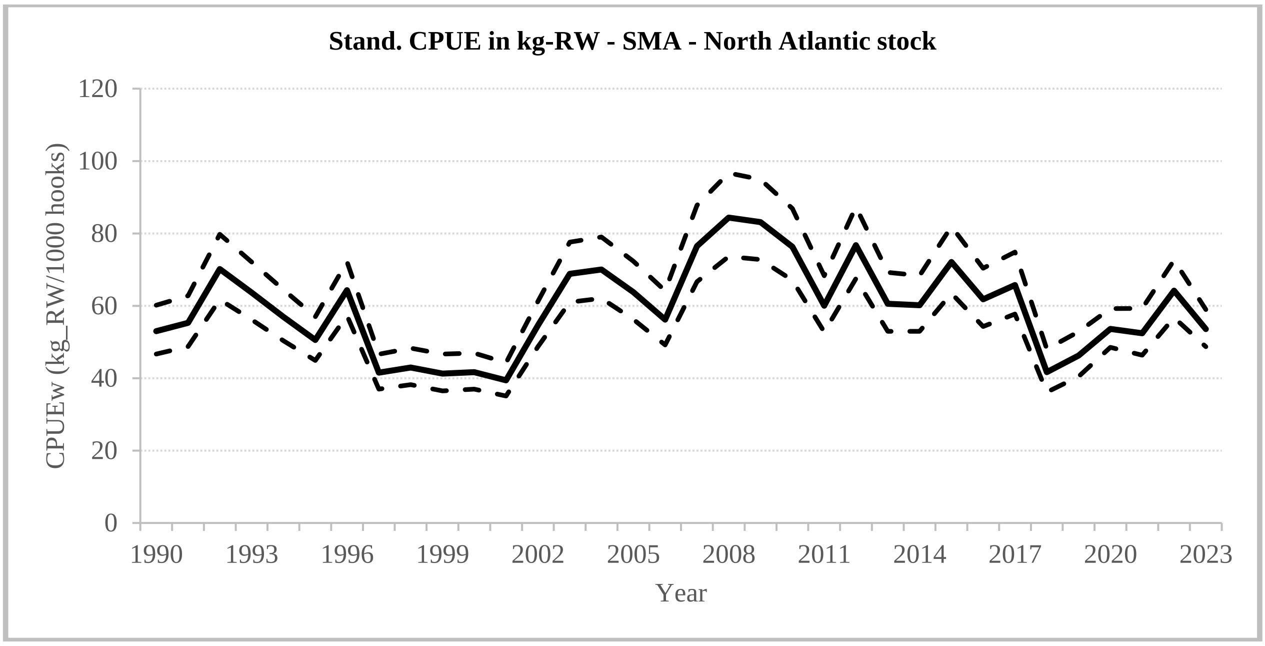




**Figure 5.** Standardized CPUE by year, in number of fish (CPUEn) and confidence intervals (95%) of the North and South Atlantic stocks of the shortfin mako during the 1990-2023 period.



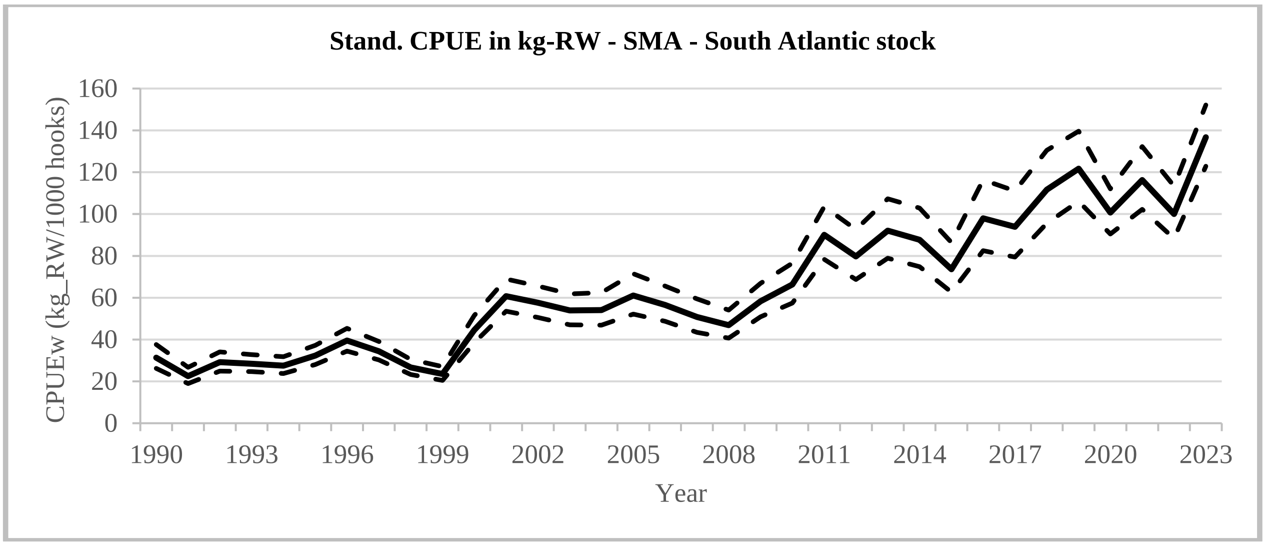




**Figure 6.** Standardized CPUE by year, in kilograms round weight (CPUEw) and confidence intervals (95%) of the North and South Atlantic stocks of the shortfin mako during the 1990-2023 period.