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UPDATE THE STANDARDIZED CATCH RATES OF SAILFISH (*ISTIOPHORUS ALBICANS*) CAUGHT AS BYCATCH OF THE SPANISH SURFACE LONGLINE FISHERY TARGETING SWORDFISH (*XIPHIAS GLADIUS*) IN THE ATLANTIC OCEAN

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SUMMARY

Standardized catch rates of sailfish (Istiophorus albicans) *were obtained from 14,473 trip observations of surface longline fishing targeting swordfish during the period 2001-2019. The nominal effort modelled represented 80.65% of the total effort developed by this fleet during that period. In roughly 28% of these trips at least one individual belonging to this species was found. Because of the low prevalence of this species in this fishery, the standardized CPUE was developed using a Generalized Linear Mixed Model assuming a delta-lognormal error distribution. The results indicate that the overall trend of the standardized CPUE was similar for the Atlantic Ocean and for the East and West stocks. The results showed an increasing trend for the Atlantic Ocean and for the East and West stock reaching a peak in 2015 or 2013, followed by a decreasing trend in the recent years analyzed, although the values remained higher than at the beginning of the series.*

RÉSUMÉ

Des taux de capture standardisés du voilier (Istiophorus albicans) *ont été obtenus de 14.473 observations de sorties en mer de pêcheries palangrières de surface ciblant l'espadon au cours de la période 2001-2019. L'effort nominal modélisé représentait 80,65% de l'effort total exercé par cette flottille pendant cette période. Dans près de 28% de ces sorties en mer, au moins un spécimen appartenant à cette espèce a été rencontré. En raison de la faible prépondérance de cette espèce dans cette pêcherie, la CPUE standardisée a été développée à l'aide d'un modèle mixte linéaire généralisé en supposant une distribution d'erreur delta-lognormale. Les résultats indiquent que la tendance globale de la CPUE standardisée était similaire pour l'océan Atlantique et pour les stocks de l'Est et de l'Ouest. Les résultats indiquaient une tendance à la hausse pour l'océan Atlantique et pour les stocks de l'Est et de l'Ouest, atteignant un maximum en 2015 ou 2013, suivie d'une tendance à la baisse au cours des années récentes analysées même si les valeurs restaient supérieures à celles du début de la série*

RESUMEN

Tasas de capturas estandarizadas del pez vela (Istiophorus albicans) *fueron obtenidas a partir de 14.473 mareas de palangreros de superficie dirigidos al pez espada, observadas entre los años 2001 y 2019. El esfuerzo nominal modelado representó el 80.65% del esfuerzo total desarrollado por esta flota durante ese periodo. En el 28% de las mareas hubo presencia en sus capturas de al menos un individuo de esta especie. Debido a la baja prevalencia de esta especie en esta pesquería, la estandarización de la CPUE fue realizada mediante un modelo del tipo Modelo Lineal Mixto Generalizado asumiendo una distribución de error "delta-lognormal". Los resultados sugieren una tendencia general de la CPUE estandarizada similar para las áreas del Atlántico total y para los stocks Este y Oeste. Los resultados muestran una tendencia creciente alcanzando picos sobre 2015 o 2013 seguida de una tendencia decreciente en los años recientes del análisis, aunque permaneciendo valores más altos que al inicio de la serie.*

KEYWORDS

Sailfish, catch rates, abundance, GLM

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1. Introduction

The sailfish (*Istiophorus albicans*) is an epipelagic and oceanic species usually found in the upper layers of warm ocean waters above the thermocline. It is mainly a pan-tropical species but also distributed throughout subtropical areas and occasionally in temperate waters reaching in some Atlantic sites latitudes near to 50ºN and 45ºS (García-Cortés *et al.,* 2017). They have often been considered as the most coastal of all the istiophorids in the Atlantic Ocean, with a sporadic presence in the Mediterranean Sea (Nakamura, 1985). The current data suggests a very wide distribution within the Atlantic Ocean, making it difficult to identify limits of discontinuity in relation to the areas of occurrence that has been described to date.

Sailfish is a primary target of recreational, charters and tournament fisheries and it is also caught as by-catch in the pelagic longline, in purse-seine fleets targeting tunas –free schools and FADs– (Delgado de Molina *et al*., 2001; Gaertner *et al*., 2003) and with other gears in the Atlantic Ocean (García-Cortés *et al.,* 2017). Artisanal and coastal fisheries with gillnets have been described in some countries on the west coast of Africa with catches representing around 25-44% of the total billfish landings, including the swordfish (Anon., 2016). This data suggests that the artisanal gillnet fisheries in those African coasts could be an important component of the total Atlantic catches and for the East stock in particular.

The Spanish surface longline fishery was developed since late 1970's in the North Atlantic targeting mainly swordfish (*Xiphias gladius*). During the 1980s, this fleet had a geographic expansion westward as well as southward (Mejuto, 2007; Mejuto *et al.,* 2017) and it began working in the southern stock (south of 5 degrees North) in 1986. In 1997, as a consequence of the start of ICCAT recommendations on shark species caught in association with the fisheries of tuna or tuna-like specie in this convention area, a research project was started with the following purposes: 1) to carry out a study on the specific composition of the bycatch of this fishery; 2) to carry out scientific estimations of the catch levels; 3) to identify possible data deficiencies and 4) to propose actions to improve the statistics on these species. This scientific monitoring program was later ongoing and it allowed for improving the estimates of the Task 1 of billfish reported. The Spanish surface longline fleet targeting swordfish has a relatively low incidental catch of istiophorids (García-Cortés *et al.* 2017, Mejuto *et al.* 2005). An important change in the gear style was introduced in the early 2000's when 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*., 2014; Mejuto and De la Serna, 2000; Mejuto *et al.,* 2001, 2003, 2017; Ramos-Cartelle *et al.,* 2017). The available information suggests that the new style in combination with the bait regularly used in this style could have increased catches of this species.

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 as 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 when quantitative, qualitative and representativeness merits achieved. The present document updates the standardized CPUE series of the sailfish in the Atlantic stocks previously provided (García-Cortés *et al.,* 2017) for the forthcoming stock assessment.

2. Material and methods

The data used in the analysis were voluntarily reported for scientific purposes from the Spanish surface longline fleet and from scientific observers on board in the Atlantic during the period 2001-2019. The catch per unit effort (CPUE) was calculated as kilograms of round weight caught per thousand hooks.

The spatial definition considered nine zones taking into account the ICCAT stock boundaries (**Figure 1**). The temporal definition of quarters was as follows: Q1= January, February, March; Q2= April, May, June; Q3= July, August, September; Q4= October, November and December. Two levels of gear were categorized (traditional multifilament and 'American style' monofilament). The bait factor considered four types: squid, mackerel, a combination of squid and mackerel, and others.

The standardization of the CPUE for the entire Atlantic and for the East and West stocks was carried out using a Generalized Linear Mixed Model (GLMM) procedure (SAS 9.4) assuming a delta-lognormal model error distribution. Under this model, both the catch rates of positive records and the proportion of positive records were fitted separately (Lo *et al.,* 1992; Ortiz and Arocha, 2004). The factors considered in the analysis were year, zone, quarter, gear, bait and interactions. The year interactions were considered as random effect. The final models were selected followed the methodology previously described (García-Cortés *et al.,* 2017):

Model positive catch rates = year + zone + quarter + gear + bait + zone*quarter + zone*gear and random interactions year*zone + year*quarter + year*bait, assuming a lognormal error distribution.

Model proportion of positives = year + zone + quarter + bait + zone*quarter and random interactions year*zone + year*bait, assuming a binomial error distribution.

3. Results and discussion

A total of 14,473 trip records were available for the analysis (10,950 trips for East stock and 3,523 trips for West stock) between 2001 and 2019. The spatial and temporal coverage of the observations were highly representative of the whole activity of Spanish longline fleet during the period analyzed. The nominal effort modeled represented 80.65% of the total effort developed by this fleet (task 2-effort) during that period, both for observations with positive catch and null catch of this species reported. **Figure 1** shows the geographical zones stratification used in the GLMM analysis. It was the same zones used in previous analyses for the sailfish Atlantic stocks (García-Cortés *et al.,* 2017). The data is representing a broad distribution of effort modeled. Previous SCRS papers summarize information, but it is updated in the present paper. The areas covered with positive nominal catch rates (kg RW/1000 hooks) by 5ºx5º grid is represented for the combined period analyzed (**Figure 1**). The sailfish is a bycatch specie with a relative low prevalence in this fishery. Nevertheless, at least one sailfish was caught on 28.1% of the available trips observed in the Atlantic Ocean. The proportion of positive catches (averaged over all years) was 25.5% and 37.1% of the trips for the East and West stocks, respectively.

Table 1 provides the standardized mean CPUE in biomass (kilograms of round weight) and the CV for the Atlantic Ocean and for the East and West stocks during the period analyzed. **Figure 2** shows the frequency distribution of the standardized residuals, the normal probability *qq*-plots and the residuals of positive CPUE by year for the Atlantic Ocean and for East and West stocks during the period 2001-2019. The fit of the model seems not to be biased and residuals are normally distributed.

Figure 3 shows the estimated standardized relative abundance indices of sailfish and their 95% confidence intervals obtained for the Atlantic Ocean and for the East and West stocks, during the period 2001-2019. The results obtained indicate that the overall trend of the standardized CPUE was similar for the Atlantic Ocean and for the East and West stocks. The results for the Atlantic Ocean and for the East stock show an increasing trend reaching a peak in 2015 followed by a decreasing in 2016 following with a stable trend for the East stock and a slightly decrease in the case of Atlantic Ocean for the last years of the series analyzed. The West stock shows an increasing trend reaching a peak in 2013 following by a slight decrease in the last years analyzed. In all cases, the most recent mean values remained higher than those obtained at the beginning of the series.

Figure 4 show a comparative of the standardized scaled CPUEs for the Atlantic Ocean and by stock (East and West). **Figure 5** and **Figure 6** show the standardized deviance residuals box-plots of the explanatory variables for the proportion of positives and for the positives catches respectively.

The CPUE series was modeled since 2001 when data improvement already occurred in scientific records. That was one of the reasons why the series have been considered in the present and in previous contributions as more reliable since year 2001. Additionally, our scientific monitoring program was suspended during 2020 due to COVID and it has had some collateral effects on data for 2021. Consequently, the data for 2020 and 2021 have been omitted from our analysis as we do not consider them reliable for the sailfish.

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Table 1. Estimated annual standardized CPUEw (kg RW) and CV of sailfish for the Atlantic Ocean and for East and West stocks.

	Atlantic Ocean		*East stock*		*West stock*	
Year	*CPUEw*	*CV*	*CPUEw*	*CV*	*CPUEw*	*CV*
2001	0.8296	0.3242	0.2340	0.4629	4.4220	0.3762
2002	2.4094	0.2730	1.2450	0.3965	5.7118	0.3063
2003	1.7093	0.3004	0.8079	0.4218	4.7981	0.3572
2004	1.2333	0.3140	0.7911	0.4288	2.6770	0.4011
2005	1.9475	0.3186	0.9940	0.4401	5.0719	0.3865
2006	2.0186	0.3013	1.1699	0.4117	4.5038	0.3643
2007	2.5994	0.2975	1.3971	0.4077	5.9347	0.3611
2008	3.6328	0.2715	1.8370	0.3863	8.5540	0.3027
2009	4.1235	0.2617	1.9948	0.3767	9.7651	0.2865
2010	3.7190	0.2625	1.5862	0.3785	9.7008	0.2800
2011	3.1051	0.2696	1.3367	0.3774	8.7517	0.3021
2012	4.2544	0.2700	2.4863	0.3774	8.6309	0.3153
2013	7.2058	0.2640	4.2217	0.3657	13.7668	0.3069
2014	6.0811	0.2700	4.6229	0.3646	8.5949	0.3356
2015	8.2937	0.2603	6.1047	0.3568	10.9709	0.3072
2016	4.5212	0.2722	2.8287	0.3827	8.0542	0.3073
2017	4.9747	0.2675	3.1049	0.3722	9.6567	0.3069
2018	4.7748	0.2673	2.4218	0.3883	9.9274	0.2888
2019	4.1125	0.2696	2.4222	0.3839	7.3877	0.3024

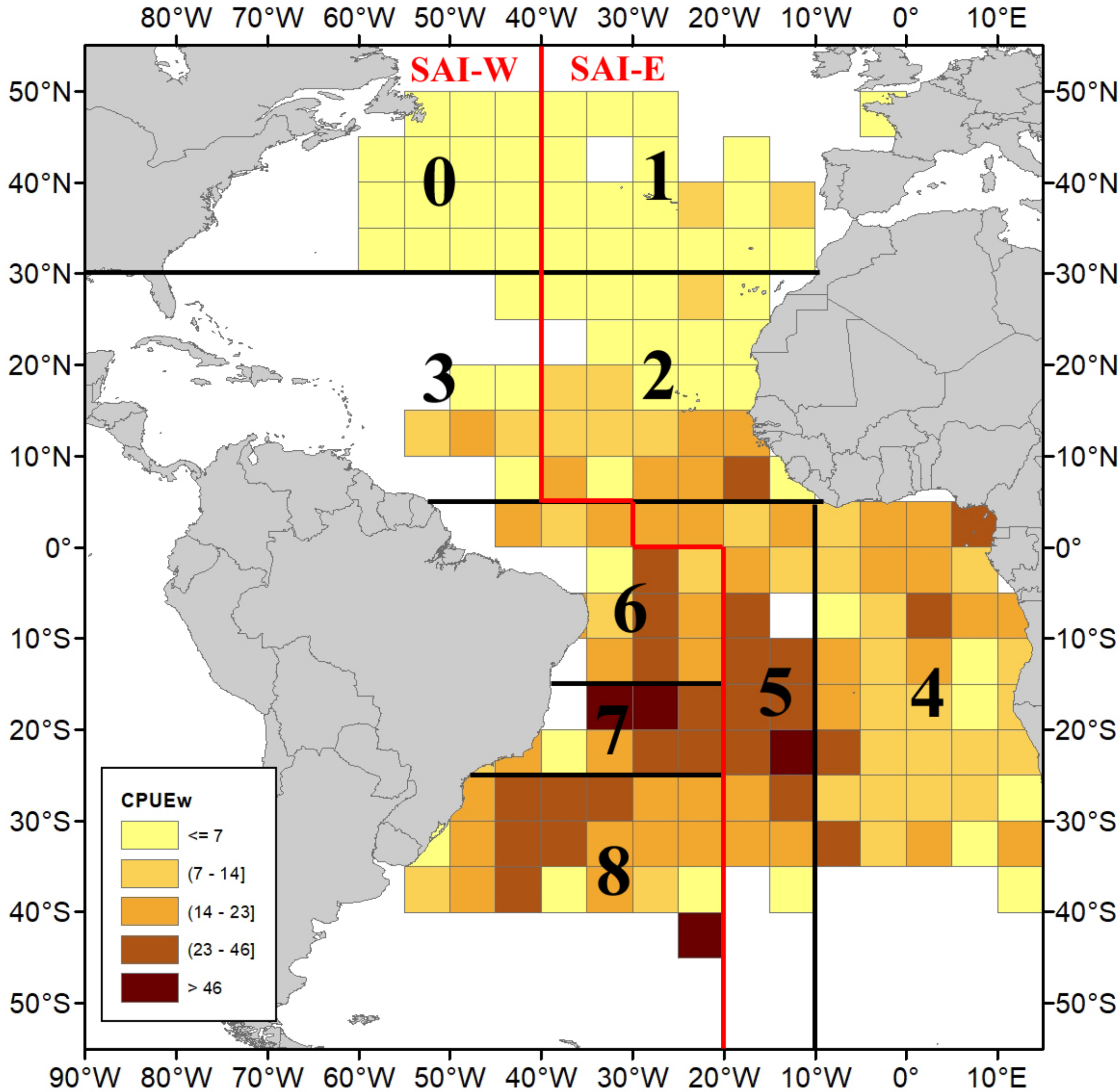

Figure 1. Geographical zones stratification used in the analysis and positive nominal catch rates in round weight (kg/1000 hooks), by 5ºx5º grid during the combined 2001-2019 period.

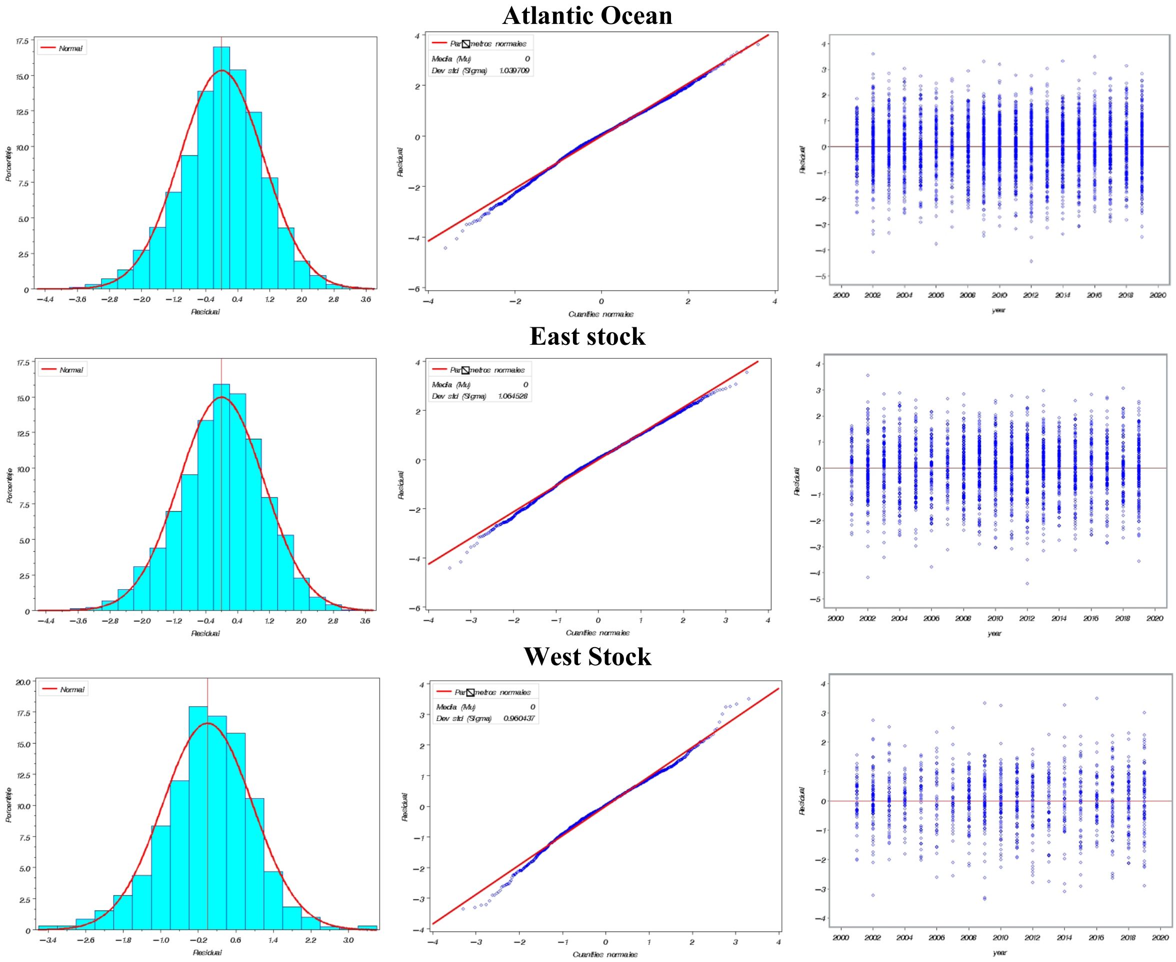

Figure 2. Distribution of the standardized residuals of sailfish CPUE (on the left), normal probability *qq*-plots (on the middle) and residuals of positive CPUE by year (on the right) for the Atlantic Ocean (top) and for East (middle) and West (bottom) stocks, during the period 2001-2019.

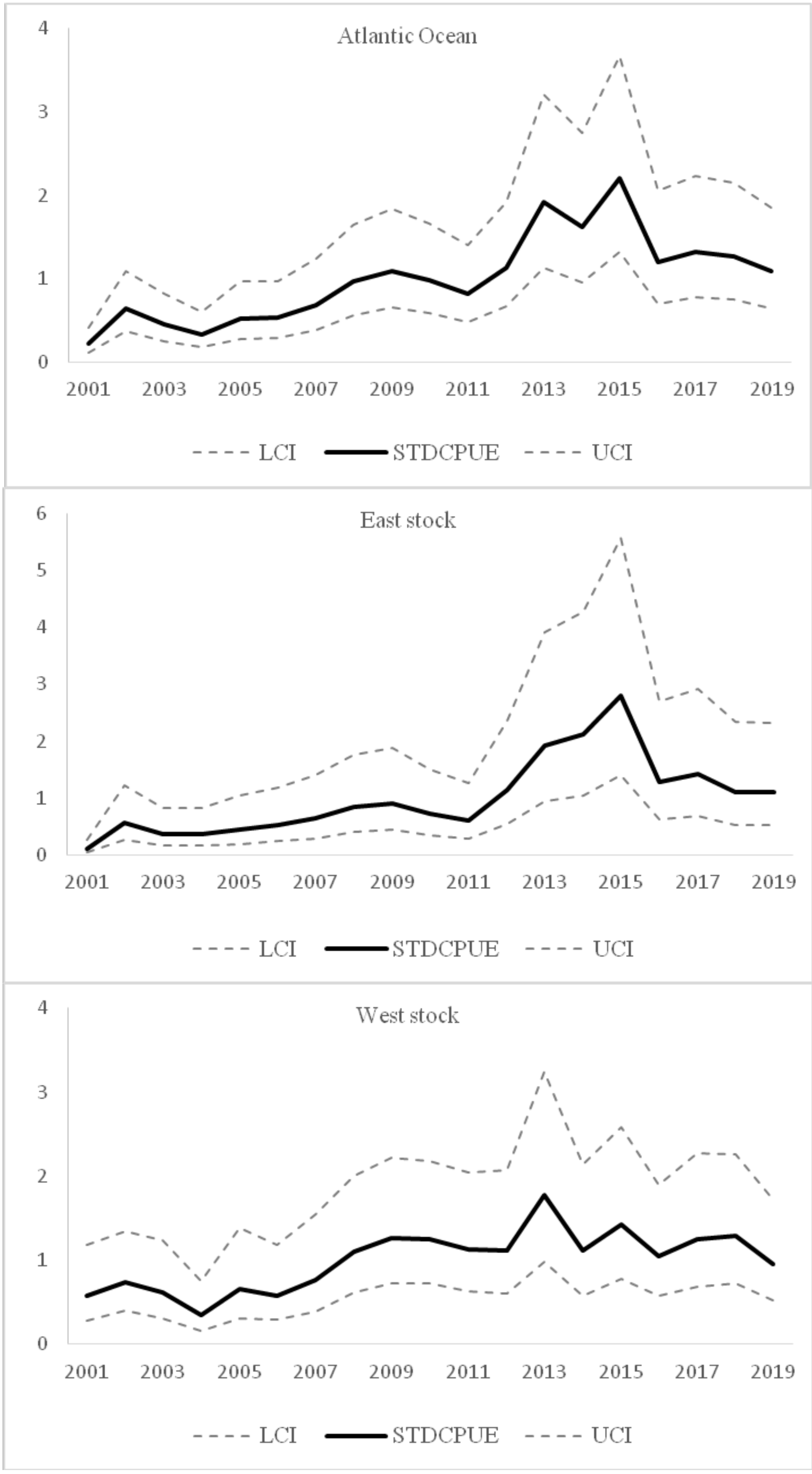

Figure 3. Estimated standardized relative abundance indices of sailfish and their corresponding 95% confidence limits, for the Atlantic Ocean (top) and for the East (middle) and West stocks (bottom), during the period 2001-2019.

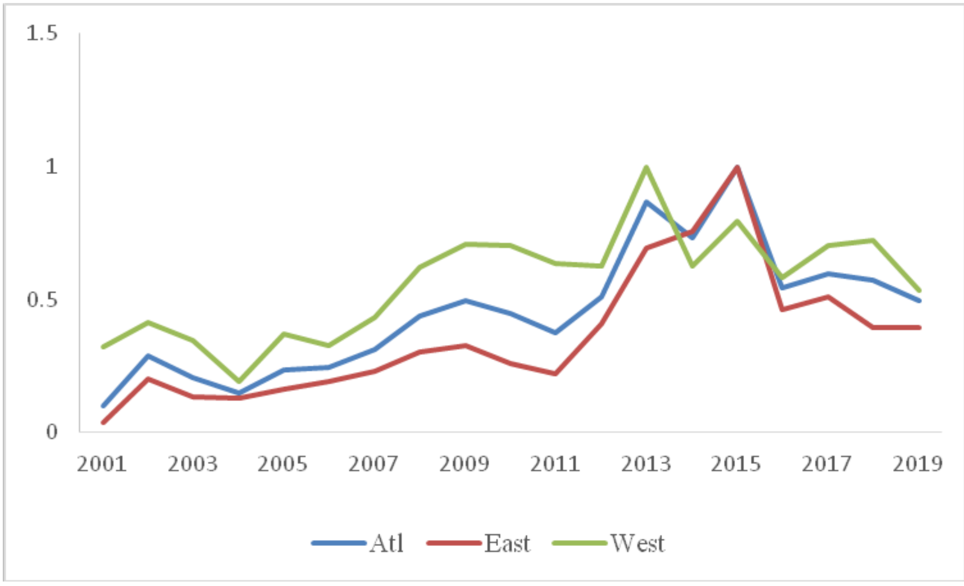

Figure 4. Comparative scaled standardized CPUE of sailfish for the Atlantic Ocean and by stock.

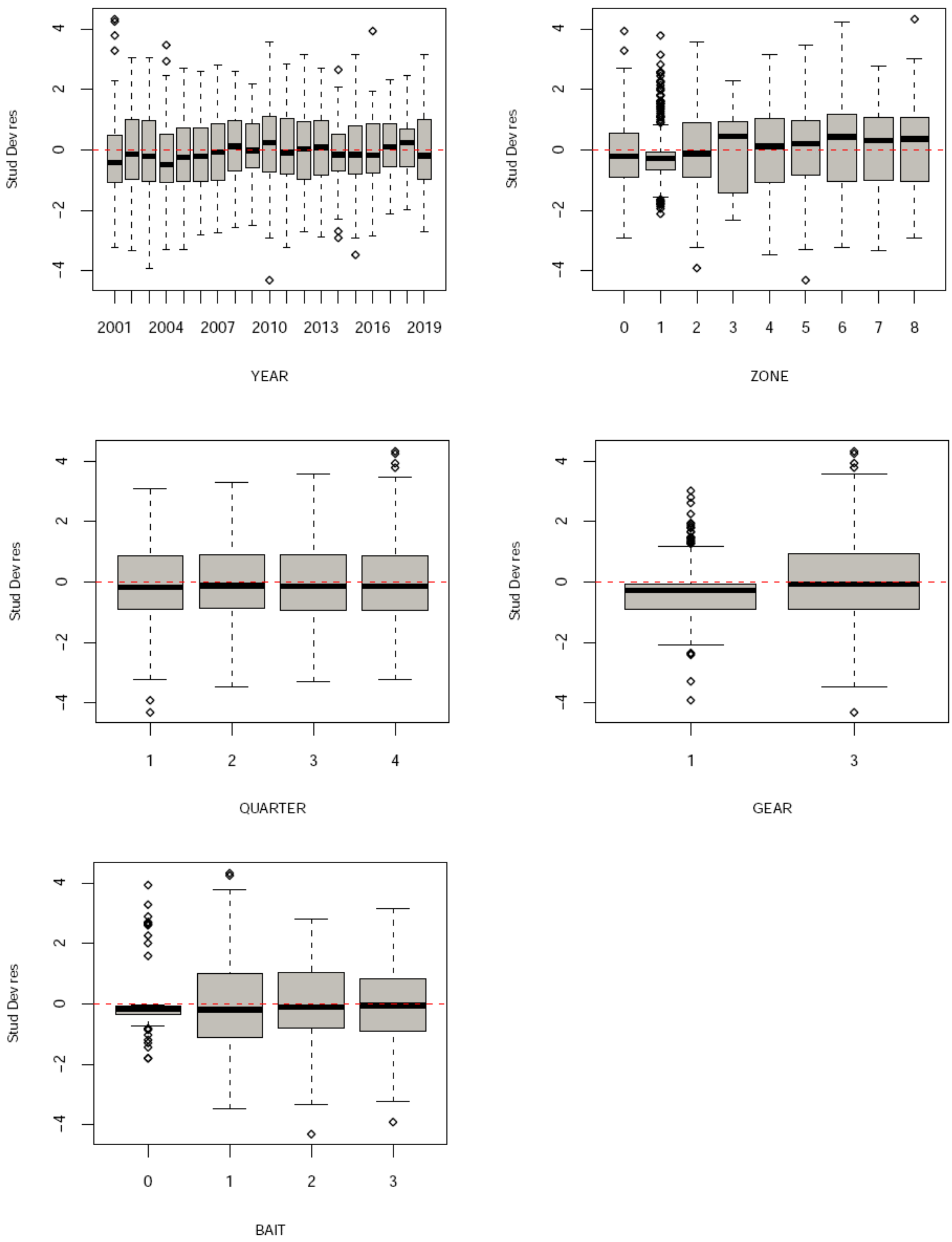

Figure 5. Standardized deviance residuals of the proportion of positives *versus* explanatory variables.

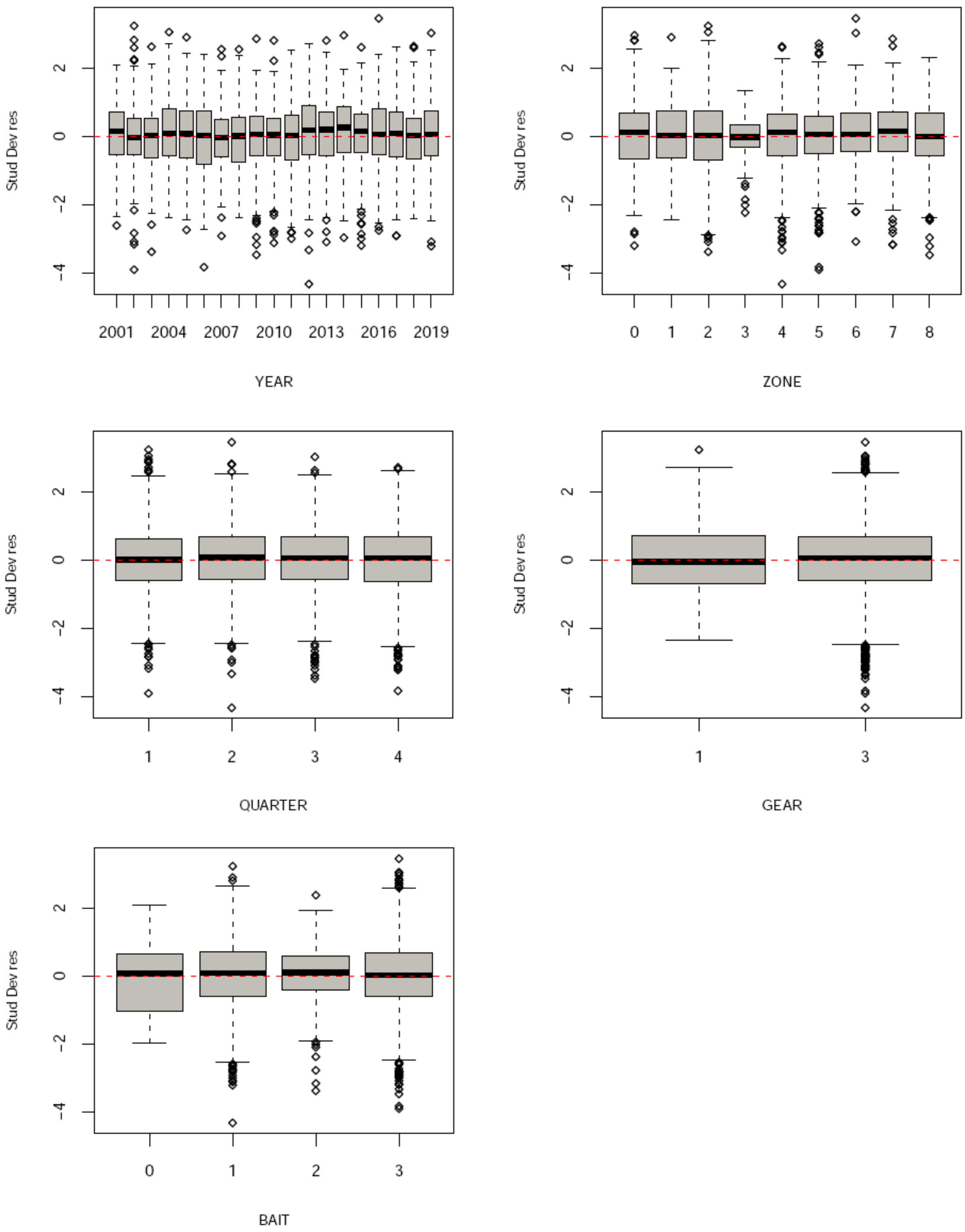

Figure 6. Standardized deviance residuals of the positives catches *versus* explanatory variables.