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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 the sailfish (*Istiophorus albicans*) were obtained from 10615 trip observations of surface longline fishing targeting swordfish during the period 2001-2014. 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 obtained indicate that the overall trend of the standardized CPUE was similar for the total Atlantic areas and for the East and West stocks. An overall increasing trend was identified for the total Atlantic areas and for the East and West stock for the whole 2001-2014 period with some fluctuations in the most recent years.*

RÉSUMÉ

*Des taux de capture standardisés du voilier (*Istiophorus albicans*) ont été obtenus à partir de 10.615 observations de sorties de palangriers de surface dirigées sur l'espadon, pendant la période 2001-2014. On a trouvé au moins un spécimen de cette espèce dans environ 28% de ces sorties. En raison de la faible prévalence de cette espèce dans cette pêcherie, la standardisation de la CPUE a été réalisée au moyen d'un modèle mixte linéaire généralisé postulant une distribution d'erreur delta-lognormale. Les résultats obtenus indiquent que la tendance globale de la CPUE standardisée était similaire pour toutes les zones de l'Atlantique et pour les stocks de l'Est et de l'Ouest. Une tendance globale à la hausse a été identifiée pour toutes les zones de l'Atlantique et pour les stocks de l'Est et de l'Ouest pour l'ensemble de la période 2001-2014 avec quelques fluctuations au cours de ces dernières années.*

RESUMEN

Fueron obtenidas tasas de capturas estandarizadas del pez vela (Istiophorus albicans) a partir de 10.615 mareas de palangreros de superficie dirigidas al pez espada, observadas entre los años 2001 y 2014. En aproximadamente 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 mixto lineal generalizado, asumiendo una distribución de error delta lognormal. Los resultados sugieren una tendencia de la CPUE estandarizada similar para las áreas del Atlántico total y para los stocks este y oeste. Una tendencia generalmente creciente fue estimada para las áreas del Atlántico total y para los stocks del este y oeste durante el periodo completo 2001-2014, con algunas fluctuaciones durante los años más recientes.

KEYWORDS

Sailfish, catch rates, abundance, GLM

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1. Introduction

Sailfish are an epipelagic species generally found in the upper layers of warm ocean waters (21º to 28ºC). They have often been considered as the most coastal of all the istiophorids in the Atlantic Ocean, with a sporadic presence in the Mediterranean. However, the records of ocean-going fleets indicate that the species can appear, in greater or lesser numbers, over a wide area between the tropical and temperate waters of the Atlantic. Conventional tagging-recovery data suggest that this species usually moves over shorter distances than other istiophorids and rarely enters temperate or cold water areas. It has been postulated that the 25ºC surface isotherm may play an important role in determining its preferred habitat and thus the prevalent areas of distribution. However, the results of this study suggest that they can sporadically go as far as latitudes close to 50ºN and 45ºS.

The sailfish is targeted by recreational fleets in many countries with warm coastal waters. This species is an important attraction for tourism activity related to big-game fishing and high-end charter cruises. The species can also be captured by small-scale coastal fleets using driftnets and artisanal gears, so that this and other species of istiophorids can provide an important source of food for people living near the coast in many countries. The fishing areas where the tuna fisheries operate frequently overlap with the areas where the most common istiophorid species are found for their biological processes (García de los Salmones *et al*. 1989, González and Gaertner 1992, Dickson 1995, Goodyear 2002). The sailfish can thus appear as bycatch in fishing with bottom- and surface-set long lines (Anon. 2005), in purse seine fleets targeting tropical tuna (Delgado de Molina *et al*. 2001, Gaertner *et al*. 2003) and fishing with other gears.

In some fleets it has been possible to estimate –either by direct observation or modelling– the use or destination of the istiophorids captured, the number retained on board, their discard levels (dead), releases (live) and other possible uses (Amorín and Arfelli 2001, García-Cortés *et al*. 2010, Mejuto *et al*. 2007). The Spanish surface longline fleet targeting swordfish, which operates in several oceans takes relatively minor incidental catches of istiophorids (Mejuto *et al*. 2005). Globally, for the oceans as a whole, the percentage of istiophorids landed relative to the total for all species combined landed is considered to be less or around 1% by weight and they would make up roughly 1.5% of the total weight of the bycatch species landed (García-Cortés and Mejuto 2001, 2005; Mejuto *et al*. 2000, 2002, 2006, 2009). So, istiophorids are found to be much less prevalent in the Spanish surface longline fishery than other species such as swordfish, blue shark and shortfin mako, which regularly represent more than 90% of their total catch in weight. Within the istiophorids group, 68.4% was identified as sailfish, 12.7% as white marlin and 12.4% as blue marlin (Mejuto *et al*. 2009).

In 2009 ICCAT carried out a complete assessment of both stocks of sailfish in the Atlantic (Anon. 2010) using various models of production and different combinations of indices for relative abundance. The study of trends in abundance suggested that both eastern and western stocks underwent their largest decrease in biomass before 1990. Since 1990 the different indicators for abundance have given contradictory results, some suggesting declining numbers, others an increase and others showing no clear trend. Although there is uncertainty regarding the situation of both sailfish stocks, the results of the assessment models have suggested overfishing, probably more intensive in the East Atlantic than the West.

Bearing in mind all these limitations and uncertainties, an effort has been made in recent years to retrieve historical information regarding the Spanish longline fishing fleet, based on various sources of information provided voluntarily to help clarify the uncertainty surrounding trends in relative abundance. To this end a data mining exercise was conducted with a view to compiling and analysing historical information on catch and effort for this species in the Spanish surface longline fleet.

This document analyzes scientific records gathered since 2001 in order to obtain the standardized catch rates for sailfish in the Atlantic areas as a whole as well as for the East and West stocks, where this surface longline fleet has traditionally operated.

2. Materials and methods

The traditional surface longline gear of the Spanish fleet in the Atlantic has remained relatively constant over several decades of the past century in terms of general structure and configuration. There have been some technological improvements in traditional fishing gear over that period in the Atlantic Ocean, generally allowing for a greater number of hooks per set, which were appropriately considered as nominal effort in the analysis. However, around the year 2000 the monofilament or so-called “American style” units were suddenly and widely introduced in most fishing areas and boats. The two styles of longline gear were considered and categorized in this analysis: traditional multifilament and the new monofilament.

Data on sailfish catches and effort per trip were recorded. The data used consisted of trip information covering the period 2001-2014 obtained from a research activity. The nominal CPUE was calculated as grams of round weight caught per thousand hooks. The standardized CPUE was obtained based on previous studies carried out on the Spanish longline fleet in the Atlantic and used in the CPUE analysis of different Atlantic longline fleets (e.g. Ortiz and Arocha 2004, Ortiz de Urbina *et al.* 2013).

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

The standardization of the CPUE (in grams of round weight per thousand hooks) for the total Atlantic areas and for the East and West stocks was carried out using a Generalized Linear Mixed Model (MIXED procedure, SAS 9.2) 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 proportion of positive components serves to model the probability of capturing sailfish (at least one) in a trip. The factors tentatively considered were year, zone, quarter, gear, bait and interactions. The final models were selected based on the analysis of deviance obtained for total Atlantic areas, including the main factors and factor-interactions that reduce the overall deviance ≥ 3.5% of the full model (model with all factors and possible interactions that provided a solution). The model selected for the total Atlantic areas was also used for West and East restricted analyses. Since the objective is to provide a relative annual index of abundance, interactions, particularly those involving the year factor, could not be included as a fixed interaction in the model. However, year interactions may be considered as random interactions (Maunder and Punt, 2004) where the estimated variance due to interaction is incorporated into the annual trend along with its estimated standard error. The final models selected in all cases were:

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

These analyses covered a total of 10615 trips (310.9 x10^6 hooks) made in the swordfish fishing grounds of this fleet in the Atlantic Ocean as a whole for the period 2001-2014. In 27.6% of the trips (2929 trips, corresponding to 120.7 x10^6 hooks) at least one sailfish was caught per trip. For the East stock (zones: 1, 2, 4, 5) the analysis covered a total of 7866 trips (192.2 x10^6 hooks) and for the West stock (zones: 0, 3, 6, 7, 8) a total of 2749 trips were covered (118.7 x10^6 hooks). For the East and West stocks, 25.0% of the trips (1970 trips and 73.9 x10^6 hooks) and 34.9 % of the trips (959 trips and 46.7 x10^6 hooks) respectively caught at least one sailfish.

Data confirm the relatively low prevalence of this species in the catch with zero catch records in 72.4%, 75.0% and 65.1% of the available trips, for the total Atlantic areas, East and West stocks, respectively. **Figure 2** shows the distribution of the Spanish longline positive catches of sailfish recorded by year. Despite the low prevalence of the species in this fishery, it suggests a continuous distribution of sailfish among some areas of the Atlantic Ocean. Some positive catches were recorded in squares up to 50ºN and 45ºS, suggesting the potentially broad geographical presence-distribution of this species at least sporadically in some months of the year, as a result of warm currents and the expansion of this species within the respective warm masses. The areas of fishing activity of the Spanish fleet during the combined period 2001-2014 are also mapped.

The analysis of deviance (**Table 1**) highlights the main factors and factor-interactions that reduce the overall deviance (≥ 3.5%) of the full models, in both the positive only observations model and the proportion of positive model components for the total Atlantic areas. The results indicate that zone and year are the major factors for both models, but the interactions of year*zone, year*bait and zone*quarter may also contribute to the variability observed for the positive catch rates and year*zone for the proportion of positive catch.

The fact that the zone factor and its interactions explain most of the variations observed, both in positive catch rates and the proportion of positive catches, should not be considered unusual in this type of fishing carried out in areas ranging from tropical to temperate, where one would expect the local distribution and abundance of the species to vary considerably as a result of seasonal migration and the preferred distribution of the species in warm waters. In these circumstances one would expect a high degree of geographical variation, probably greater than the level of inter-annual variation.

Yearly figures for the number of observations, the proportion of positive catch, the nominal CPUE and standardized CPUE obtained by the final models with their confidence levels (95%) are shown in **Table 2** for the total Atlantic and for the East and West stocks during the period analyzed. The scaled nominal and standard CPUE and other diagnostic results are also shown in the table.

Figure 3 shows the residual pattern of log-transformed catch rates, the normal probability *qq*-plots and residuals by year of the positive catches. Standardized deviance residuals of the proportion of positives *versus* explanatory variable are shown in **Figure 4** and standardized deviance residuals of the positive catches *versus* explanatory variable are shown in **Figure 5** for the total Atlantic areas. **Figure 6** shows the nominal CPUE values and the standardized CPUE obtained for the series analyzed as a whole. The estimated standardized CPUEs are similar to the nominal CPUEs obtained. The standardized CPUEs obtained indicate an overall increasing trend for the total Atlantic areas as well as for East and West stock for the whole 2001-2014 period, with some fluctuations in the most recent years.

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Table 1. Deviance table analyses of the factors tested, for positive catch rates and for proportion of positives, respectively. Highlighted are the factors with ≥ 3.5% of deviance explained.

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
Null	_	4711.3398			
Year	13	4589.6652	121.6746	9.3%	< 0.001
Year Zone	8	3721.8769	867.7883	66.5%	< 0.001
Year Zone Quarter	3	3694.7959	27.0810	2.1%	< 0.001
Year Zone Quarter Gear	1	3632.5872	62.2087	4.8%	< 0.001
Year Zone Quarter Gear Bait	3	3628.1538	4.4334	0.3%	0.218
Year Zone Quarter Gear Bait Quarter*Gear	3	3622.3956	5.7582	0.4%	0.124
Year Zone Quarter Gear Bait Gear*Bait	1	3621.1764	6.9774	0.5%	0.008
Year Zone Quarter Gear Bait Year*Gear	6	3617.2065	10.9473	0.8%	0.090
Year Zone Quarter Gear Bait Zone*Bait	18	3611.7574	16.3964	1.3%	0.565
Year Zone Quarter Gear Bait Quarter*Bait	9	3597.9112	30.2426	2.3%	< 0.001
Year Zone Quarter Gear Bait Zone*Gear	6	3580.2284	47.9254	3.7%	< 0.001
Year Zone Quarter Gear Bait Year*Bait	27	3547.9815	80.1723	6.1%	< 0.001
Year Zone Quarter Gear Bait Year*Quarter	39	3547.3001	80.8537	6.2%	< 0.001
Year Zone Quarter Gear Bait Year*Zone	102	3411.8093	216.3445	16.6%	< 0.001
Year Zone Quarter Gear Bait Zone*Quarter	24	3405.6726	222.4812	17.0%	< 0.001

Model factors proportion of positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
Null	_	5570.7835			
Year	13	5213.1869	357.5966	10.0%	< 0.001
Year Zone	8	2544.3030	2668.8839	74.7%	< 0.001
Year Zone Quarter	3	2473.1558	71.1472	2.0%	< 0.001
Year Zone Quarter Gear	1	2450.0335	23.1223	0.6%	< 0.001
Year Zone Quarter Gear Bait	3	2339.7907	110.2428	3.1%	< 0.001
Year Zone Quarter Gear Bait Quarter*Gear	3	2336.6397	3.1510	0.1%	0.369
Year Zone Quarter Gear Bait Gear*Bait	3	2324.3352	15.4555	0.4%	0.001
Year Zone Quarter Gear Bait Zone*Gear	8	2321.1008	18.6899	0.5%	0.017
Year Zone Quarter Gear Bait Quarter*Bait	9	2320.6570	19.1337	0.5%	0.024
Year Zone Quarter Gear Bait Year*Gear	13	2294.5217	45.2690	1.3%	< 0.001
Year Zone Quarter Gear Bait Year*Quarter	39	2234.6378	105.1529	2.9%	< 0.001
Year Zone Quarter Gear Bait Year*Bait	39	2213.5036	126.2871	3.5%	< 0.001
Year Zone Quarter Gear Bait Zone*Quarter	24	2197.1900	142.6007	4.0%	< 0.001
Year Zone Quarter Gear Bait Year*Zone	103	1998.6465	341.1442	9.6%	< 0.001

Table 2. Number of trips, probability of positive catch, observed mean CPUE (gr/1000 hooks), estimated standardized CPUE, confidence intervals (95%) CPUE, CV and scaled CPUEs of sailfish for total Atlantic areas and for East and West stocks, by year.

Total Atlantic

year	nobs	obppos	obCPUE	stCPUE	LCI	UCI	CV	obsCPUE	stsCPUE
2001	1084	0.121	1376.22	903.65	0.14184	0.53541	0.34145	0.34594	0.27558
2002	1083	0.272	3214.15	2496.46	0.43599	1.32942	0.28422	0.80793	0.76132
2003	836	0.221	2609.52	1911.48	0.31747	1.07034	0.31098	0.65595	0.58293
2004	807	0.213	2417.52	1270.36	0.20280	0.74006	0.33229	0.60769	0.38741
2005	678	0.227	2519.87	1946.63	0.30744	1.14630	0.33811	0.63341	0.59364
2006	631	0.233	2416.38	2132.94	0.35072	1.20639	0.31636	0.60740	0.65046
2007	580	0.233	2341.82	2742.02	0.45946	1.52188	0.30625	0.58866	0.83620
2008	633	0.368	4253.35	3779.74	0.66385	2.00142	0.28122	1.06915	1.15267
2009	711	0.401	5567.64	4498.46	0.81142	2.31934	0.26715	1.39952	1.37185
2010	708	0.364	4879.67	3725.55	0.66523	1.94041	0.27249	1.22659	1.13614
2011	751	0.344	3710.69	3336.35	0.59056	1.75292	0.27710	0.93275	1.01745
2012	704	0.341	5922.94	4246.86	0.74753	2.24384	0.28006	1.48883	1.29512
2013	638	0.357	8022.17	7183.54	1.28840	3.72489	0.27015	2.01651	2.19069
2014	771	0.270	6443.42	5733.63	1.01327	3.01729	0.27795	1.61967	1.74853

East stock

year	nobs	obppos	obCPUE	stCPUE	LCI	UCI	CV	obsCPUE	stsCPUE
2001	882	0.088	670.88	274.51	0.05915	0.31399	0.4362	0.19471	0.13628
2002	835	0.226	2472.41	1460.30	0.35466	1.48181	0.3692	0.71759	0.72494
2003	637	0.198	2039.61	973.54	0.22669	1.03040	0.3925	0.59197	0.48330
2004	595	0.203	2389.75	947.93	0.21669	1.02200	0.4028	0.69360	0.47059
2005	501	0.218	2327.43	1155.62	0.25881	1.27165	0.4143	0.67551	0.57369
2006	452	0.228	2224.27	1354.38	0.31823	1.42058	0.3875	0.64557	0.67236
2007	409	0.220	1941.43	1635.69	0.38909	1.69462	0.3807	0.56348	0.81201
2008	418	0.352	3970.26	2146.90	0.52957	2.14498	0.3607	1.15232	1.06580
2009	487	0.378	4364.13	2392.04	0.60385	2.33524	0.3480	1.26664	1.18749
2010	525	0.328	3411.19	1760.70	0.43890	1.74072	0.3549	0.99006	0.87407
2011	543	0.320	2780.69	1556.86	0.39069	1.52895	0.3513	0.80706	0.77288
2012	495	0.321	6117.88	2836.61	0.71014	2.79240	0.3526	1.77564	1.40819
2013	471	0.350	7938.37	4711.32	1.20471	4.54075	0.3411	2.30402	2.33886
2014	616	0.248	5587.90	4994.68	1.28417	4.78760	0.3381	1.62182	2.47953

West stock

year	nobs	obppos	obCPUE	stCPUE	LCI	UCI	CV	obsCPUE	stsCPUE
2001	202	0.262	4456.00	3687.05	0.29482	1.27691	0.3791	0.79832	0.61356
2002	248	0.427	5711.52	4720.18	0.43077	1.43230	0.3073	1.02325	0.78549
2003	199	0.296	4433.83	4091.19	0.33950	1.36527	0.3587	0.79434	0.68082
2004	212	0.241	2495.48	2126.34	0.16009	0.78209	0.4127	0.44708	0.35385
2005	177	0.254	3064.56	4016.64	0.31097	1.43671	0.3970	0.54903	0.66841
2006	179	0.246	2901.47	3726.89	0.30200	1.27365	0.3718	0.51981	0.62019
2007	171	0.263	3299.47	4884.62	0.39922	1.65504	0.3671	0.59112	0.81285
2008	215	0.400	4803.74	7132.04	0.65192	2.16072	0.3064	0.86061	1.18685
2009	224	0.451	8184.21	8422.08	0.79854	2.45983	0.2869	1.46624	1.40152
2010	183	0.470	9092.50	8376.55	0.80273	2.42061	0.2813	1.62897	1.39395
2011	208	0.404	6138.54	7439.42	0.68427	2.23981	0.3031	1.09975	1.23800
2012	209	0.388	5461.24	7337.64	0.66084	2.25620	0.3144	0.97841	1.22106
2013	167	0.377	8258.52	11224.39	1.02720	3.39650	0.3058	1.47956	1.86786
2014	155	0.355	9843.46	6944.18	0.59823	2.23221	0.3383	1.76351	1.15559

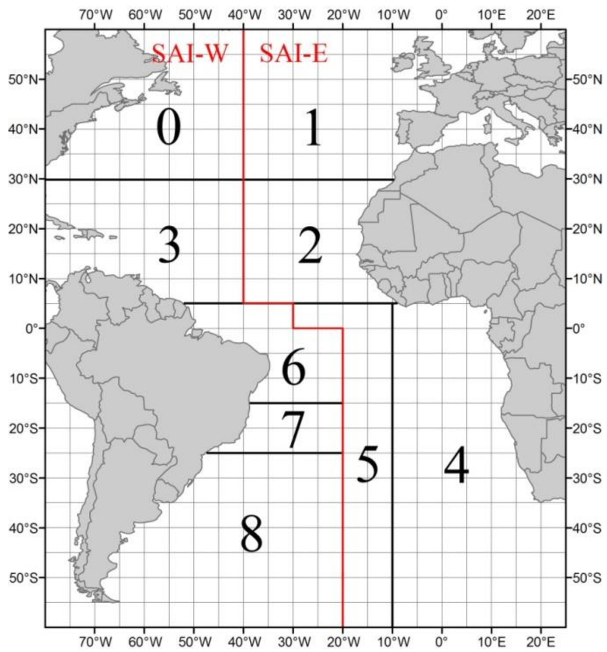

Figure 1. Stratification of geographic zones used for the analysis of sailfish in the Atlantic Ocean.

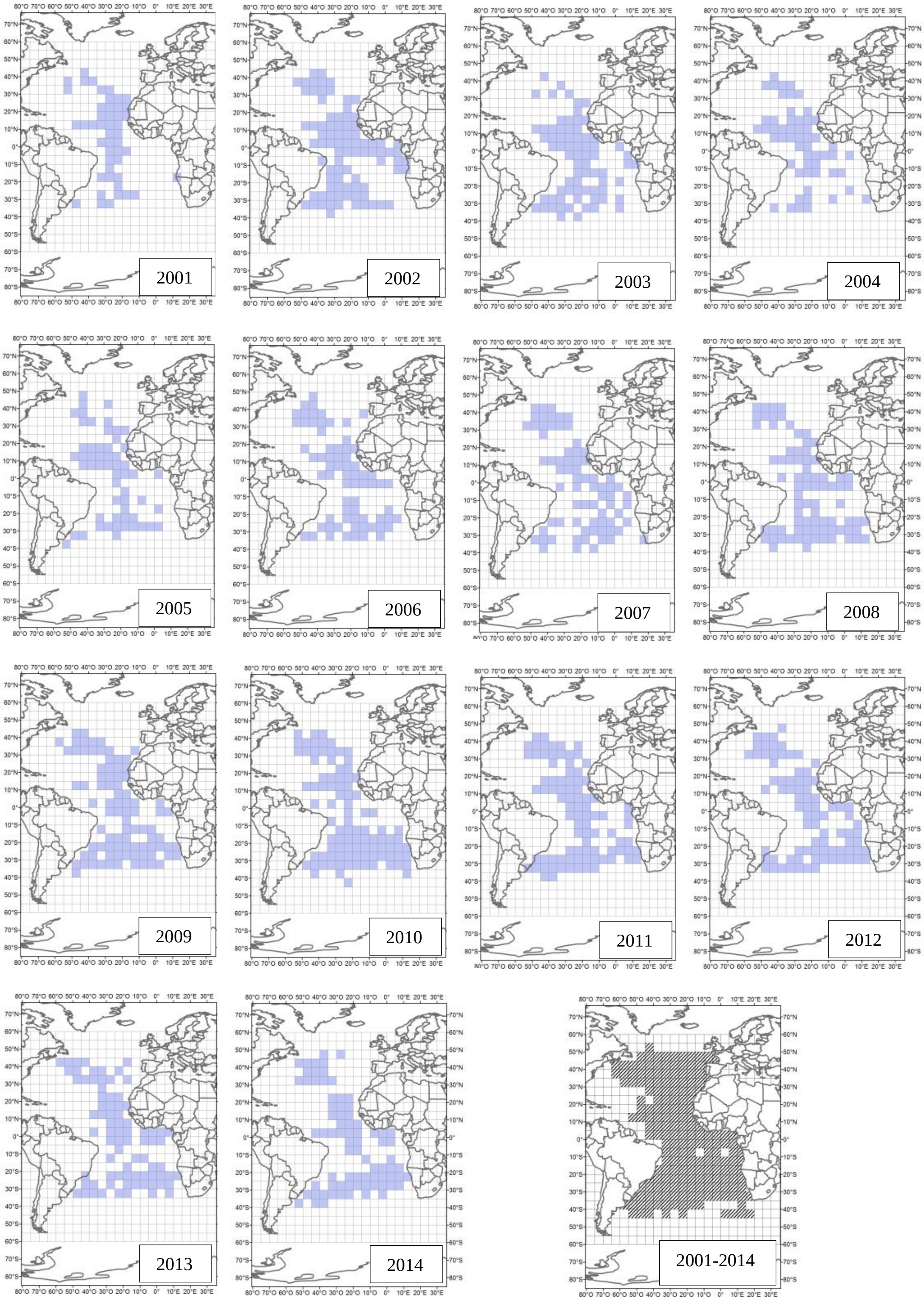

Figure 2. Maps of positive sailfish catch trips by year (blue 5ºx5º squares) and map of the areas where the Spanish surface longline fleet operated in the Atlantic Ocean during the combined 2001-2014 period.

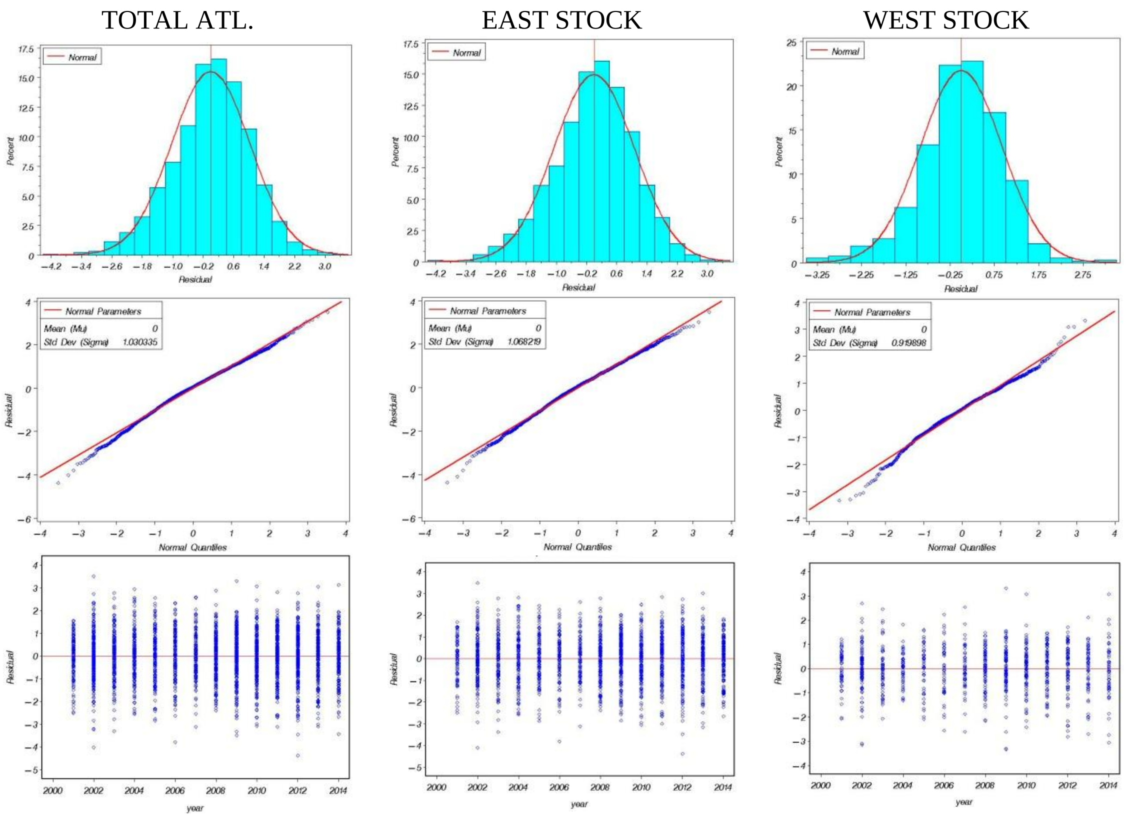

Figure 3. Distribution of the standardized residual of sailfish CPUE, normal probability *qq*-plots and residuals of positive CPUE by year, for the total Atlantic areas, East and West stocks, during the period 2001-2014.

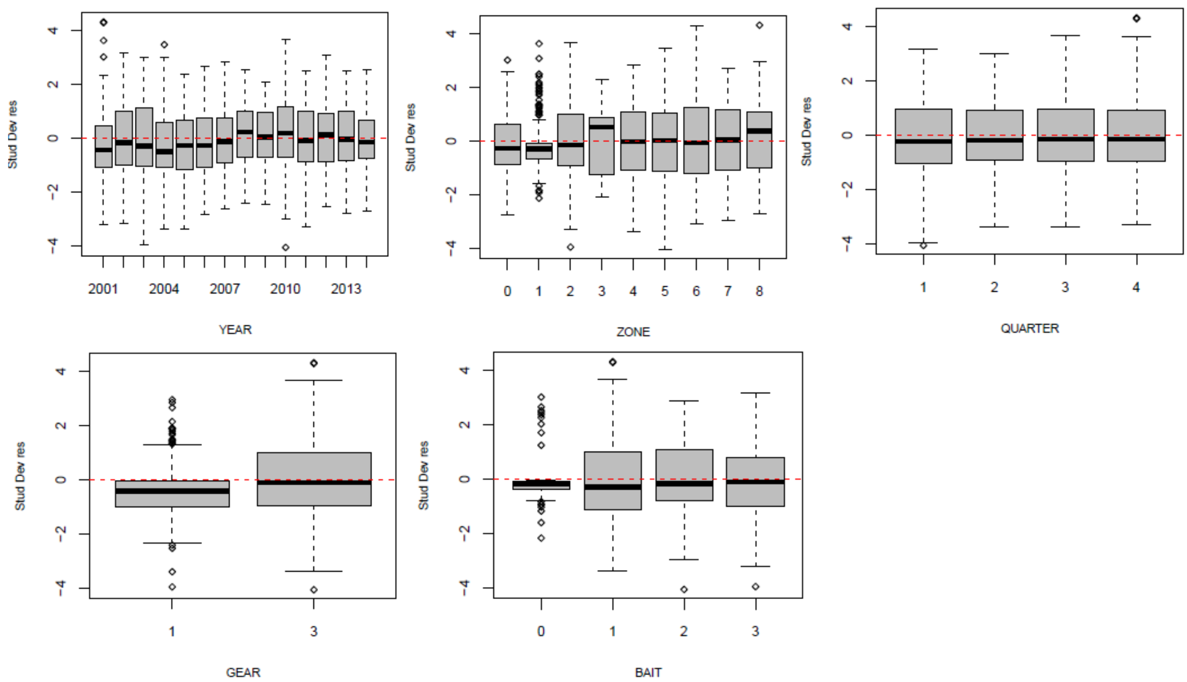

Figure 4. Standardized deviance residuals of the proportion of positives *versus* explanatory variable, for the total Atlantic areas.

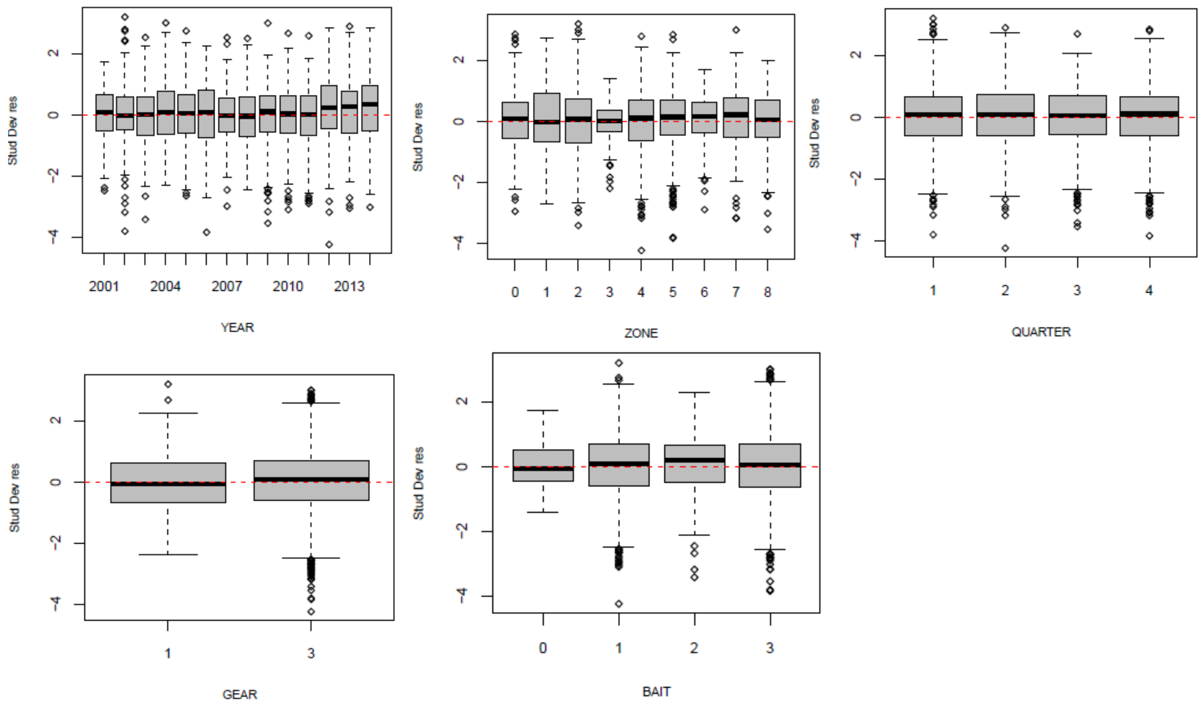

Figure 5. Standardized deviance residuals of the positive catches *versus* explanatory variable, for the total Atlantic areas.

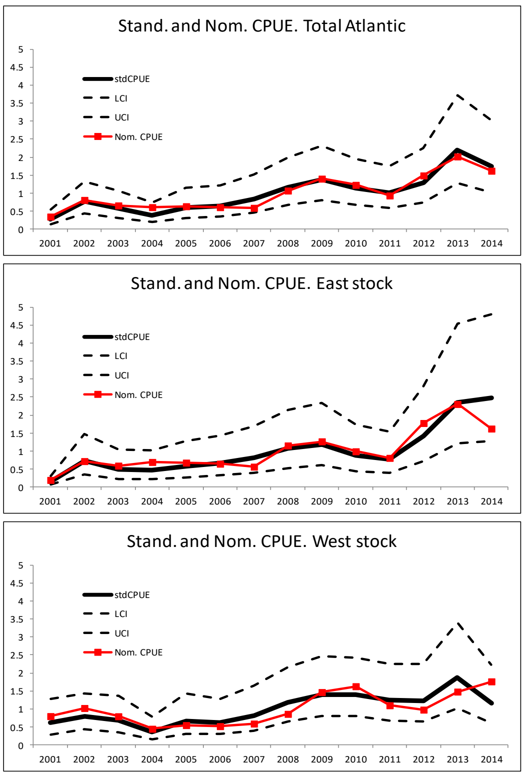

Figure 6. Estimated standardized relative abundance indices of sailfish and their corresponding 95% confidence limits, for the total Atlantic areas and for the East and West stocks, during the period 2001-2014.