STANDARDIZED CATCH RATES OF SHORTFIN MAKO (*Isurus oxyrinchus*) CAUGHT BY THE SPANISH SURFACE LONGLINE FISHERY TARGETING SWORDFISH IN THE INDIAN OCEAN DURING THE PERIOD 2001-2018

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

ABSTRACT

Standardized catches per unit of effort in number and weight were obtained for the shortfin mako (*Isurus oxyrinchus*) using General Linear Modeling procedures based on trip data from the Spanish surface longline fleet targeting swordfish in the Indian Ocean over the period 2001-2018. Factors such as area, quarter, gear and bait, as well as the fishing strategy were taken into account. The model explained 31% and 24% of CPUE variability in number and weight, respectively.

Key words: shortfin mako, sharks, CPUE, GLM, longline**.**

1. INTRODUCTION

The Spanish surface longline fishery targeting swordfish began to operate in certain areas of the Indian Ocean in 1993, when some of the longliners started experimental surveys. Since the beginning of the fishing activity in the Indian Ocean, the basic data for the scientific monitoring of this fleet have been collected by the Information and Sampling Network (ISN), by the Scientific Observer Program and specific logbooks designed for scientific purposes (García-Cortés and Mejuto 2000, García-Cortés *et al.* 2004, 2008).

Shortfin mako (SMA) is usually the second most prevalent large pelagic shark bycatch species -after the blue shark- of many longlines fishing tuna and tuna-like species in the epipelagic layers of the Indian Ocean. This bycatch species is fully retained and is also much prized as a regular bycatch in the Spanish surface longline fishery targeting swordfish (Buencuerpo *et al.* 1998, Fernández-Costa and Mejuto 2010, Garcés and Rey 1983, Mejuto 1985, Mejuto and González-Garcés 1984, Moreno 1995).

It is well known that in distant longline fleets all over the world, it is difficult to correctly identify all the bycatch species, especially when they present a certain taxonomic difficulty and / or have a low price at the markets. Thanks to years of previous experience of the Spanish fleet in similar fisheries in other oceans and the price of SMA in the markets, the SMA captures reported to IOTC for this fishery is usually reliable (García-Cortés and Mejuto 2005, Ramos-Cartelle *et al.* 2008, 2009).

Full stock assessments commonly require at least catch data series and indices of abundance that should be standardized. The catches per unit of effort (CPUEs) are assumed to be reliable indicators of abundance for most large pelagic species in view of the lack of direct abundance indicators or scarce independent fishery data. CPUE indicators must be evaluated on a case by case basis taking into account -among other factors- the empirical knowledge of each fishery, the quality of the data used, the spatial coverage of each fleet in relation to the stock area-distribution, as well as the biological plausibility of the inter-annual CPUE variability obtained in the analyses for this type of long-span species, since abrupt changes in the total biomass should not be expected during short time scenarios (Ramos-Cartelle *et al.* 2011).

[1] Instituto Español de Oceanografía. P.O. Box 130, 15080 A Coruña. Spain.
tunidos.corunha@co.ieo.es
http://www.co.ieo.es/tunidos

Generalized Linear Modeling techniques (GLM) (Gavaris 1980, Kimura 1981, Robson 1966) have been used to estimate standardized catch rates based on data from commercial fleets with unbalanced spatial-temporal activity as regularly observed, because of the complex migratory behavior of the large pelagic species linked to environment habitats and because of the adaptation of the fleets to the area-time availability of the targeted species.

Spatial-temporal limitations are frequently described in the data from many oceanic longline fleets during the access to new fishing areas or during learning periods, geographical expansions or because of shifts to other fishing species-areas. The regrouping or redefinition of areas-times or the selection of selected time series is frequently implemented to avoid convergence problems in the GLM caused by too many missing cells, to improve fits (Semba and Nishida 2008, Ichinokawa and Brodziak 2010) or for considering more representative periods of relative abundance. The Spanish longline fishery started some prospecting operations in the India Ocean in 1993 using traditional multifilament longline style in some areas which were mostly restricted to the western region over that learning period (García-Cortés *et al.* 2008). However very few observations are available from the first learning period mostly from survey trips testing gear and searching for the target species in unknown new fishing areas. After the preliminary period, this longline fishery was consolidated and later expanded geographically. The geographical expansion since 2001 has resulted in an increase in the spatial coverage, including the accessed to South-central regions and those fishing areas remained very stable since then. Moreover, since 2001, after the initial learning period, the commercial fishing areas of this fleet remained quite constant and the monofilament 'American style' was largely introduced in most boats and it basically became the only existing gear style.

The aim of this document is the standardized CPUE series of shortfin mako (*Isurus oxyrinchus*) for the Spanish longline fishery targeting swordfish in the Indian Ocean.

2. MATERIAL AND METHODS

The data used consisted of trip records voluntarily provided for research covering the 2001-2018 period. Nominal effort per trip was defined by thousands of hooks. The nominal catch per unit of effort was obtained as number of fish and kilograms round weight per thousand hooks.

The standardized log-normal CPUE analyses were performed using GLM procedures (*SAS 9.4*) for the period 2001-2018 assuming a log-normal distribution of catch rates. A base case GLM (in number of fish and in weight) and two sensitivity analyses (in weight) were carried out. The models took into consideration the results of deviance obtained, including the main factors and factor-interactions that reduce the overall deviance ≥ 5.0% of the full model in weight (model with all factors and possible interactions that provided a solution):

$$\text{Ln (CPUE)} = u + Y + Q + A + G + B + R + \text{(interactions)} + e$$

Where: u = overall mean, Y = *year* effect, Q = *quarter* effect (Q1 = January-March; Q2 = April-June; Q3 = July-September; Q4 = October-December), A= *area* effect (**Figure 1**), G = *gear* style effect (traditional multifilament or American-monofilament style), B = *bait* type (mackerel or squid), R= *ratio* effect (defined in order to categorize each type of trip record based on the percentage of swordfish in weight related to the catches of swordfish and blue shark combined, broken down into ten ratio categories at 10% intervals) and e = logarithm of the normally distributed error term.

An alternative run considered as a sensitivity analysis was performed using a GLM MIXED (GLMM) procedure which allows some of the parameters in the linear predictor to be treated as random variables (Maunder and Punt 2004). The standardized CPUE in weight obtained from the sensitivity analysis (GLMM) was scaled for comparison with the also scaled standardized CPUE in weight obtained by the base case GLM. Both series were scaled to their respective mean values.

3. RESULTS AND DISCUSSION

Shortfin mako is a medium-prevalence bycatch in the Spanish longline fleet target *Xiphias gladius* in the Indian Ocean. During the period 2001-2018 and for this fleet, its catch by weight represents an average of 5.35% (CI95% = ±0.56) of total annual round weight of species combined, being the third most prevalent species by weight after the swordfish (43.35%) and the blue shark (38.84%) (IOTC data[2]). Spanish longline data confirm the presence of this species in 98% (CI95%=±1.72) of trips observed. So, the analyses of the positive catches are recommended, making a total of 2,178 trip (71.1 million hooks) records available.

Figure 1 shows the geographical area distribution defined for the GLM runs for the period analyzed, 2001-2018. The number of observations per spatial-temporal strata may be considered very satisfactory except for area 56, where few observations were available. The final runs thus considered 7 areas (area 56 was joined to area 57).

The analysis of deviance (**Table 1**) highlights the main factors and factor-interactions that reduce the overall deviance (≥ 5.0%) of the full models tested. The deviance results indicate that *year* and *area* and their interaction *year*area* are the major factors, but the type of trip (*ratio)* factor and others interactions may also contribute to some extent to the variability observed. The type of trip was a significant but less important factor in the case of this bycatch species. The significance of the type of trip with regard to the main desirable species has been described for several important oceanic longline fleets fishing in the Atlantic areas (e.g. Chang *et al.* 2007, Hazin *et al.* 2007[a,b], Mejuto and De la Serna 2000, Mourato *et al.* 2007, Ortiz 2007, Ortiz *et al.* 2007, Paul and Neilson 2007, Yokawa 2007) and more recently for the Pacific and Indian Ocean, as well. The results obtained in this case suggest that this factor is significant but much less important than in the case of the swordfish and blue shark analyses, probably because the shortfin mako was and still is a "pure" bycatch with high occurrence but relatively medium prevalence by trip as compared to the main species. The implementation of the type of trip as a factor based on ratios among species was discussed in previous papers vs. other possible approaches with identical results, and it was tested via simulations approaches (Mejuto and De la Serna 2000, Mejuto *et al.* 2000, Anon. 2001). In this particular case, of the different proxies evaluated by the methods working group of ICCAT, 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 necessarily provide the best performance in all cases-fisheries (Anon. 2001).

The final base case model was selected based on the analysis of deviance, including the main factors and factor-interactions that reduce overall deviance ≥ 5.0% of the null model and provide a solution: Ln (CPUE) = u + Y + Q + A + R + e.

The base case model explains the 31% and 24% of the CPUE variability in number and weight, respectively. Frequency distributions of standardized residual as well as the normal probability *qq-plot* for the base case GLM runs are provided (**Figure 2**). **Figures 3** and **4** show the variability box-plot for standardized residuals obtained by the main factors considered in the base case runs, in number and in weight, respectively. Least squared means, standard error and CPUE values obtained and their respective confidence intervals (95%) are shown in **Tables 2 and 3**, in number and in weight, respectively**.** Base case CPUE trends over time and their respective 95% confidence intervals are plotted (**Figure 5**). The standardized mean weight by year and the relevant confidence intervals were also obtained using the same GLM approach (**Figure 5**). The CPUE trend in number and weight are very similar, with an overall upward trend. Regarding the mean weight of the specimens, it remains quite stable during the period.

A sensitivity analysis using a GLMM procedure was run: Ln (CPUEw) = u + Y + Q + A + R + e + random (Y*Q + Y*A + Y*R). The standardized CPUE in weight obtained was scaled to compare it with the scaled standardized CPUEw base case and its 95% confidence intervals (**Figure 6**). GLMM reflects a more pessimistic trend until 2008 and an upward trend similar to that of GLM base case since 2008.

Another sensitivity analysis GLM was done without *ratio* effect: Ln (CPUEw) = u + Y + Q + A + e. As in the previous sensitivity analysis, the result was scaled and compared to the base case (**Figura 7**). The trend in both series is practically identical.

---

[2] IOTC-2020-DATASETS-NCDB_080420.xlsx

Several standardized CPUE were published for different fleet operating in the Indian Ocean, some of them are in number (Mikihiko and Yasuko 2019, Wen-Pei *et al.* 2019) and others in weight (Coelho *et al.* 2017, Brunel *et al.* 2018). This is a limitation for comparison of different CPUE units. All of them were scaled to be compared with those obtained in this study (**Figure 8**). The trend in number obtained in this study is similar to that published for the Taiwanese fleet. Comparing the series in number of the Japanese versus the Spanish fleet since 2001, we see that the Japanese index showed huge fluctuations biologically unlikely and a practically inverse general trend than Spanish index. As for CPUEw, they all have a slight upward trend since 2008.

Acknowledgments

The authors would like to express their warmest thanks to all the members of the team who were involved in the scientific recording of the data over a long period. We would also like to thank the skippers of the Spanish 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.

Brunel, T., Coelho, R., Merino, G., Ortiz de Urbina, J., Rosa, D., Santos, C., Murua, H., Bach, P., Saber, S. and Macías, D. 2018. A preliminary stock assessment for the shortfin mako shark in the Indian ocean using data-limited approaches. IOTC-2018-WPEB14-37.

Buencuerpo, V., Ríos, S. and Morón, J. 1998. Pelagic sharks associated with the swordfish, *Xiphias gladius*, fishery in the Eastern North Atlantic Ocean and Strait of Gibraltar. Fish. Bull. 96:667-685.

Coelho, R., Rosa, D. and Lino, P.G. 2017. Fishery indicators for shortfin mako shark (*Isurus oxyrinchus*) caught by the Portuguese pelagic longline fishery in the Indian Ocean: Catch, effort, size distribution and standardized CPUEs. IOTC-2017-WPEB13-35.

Chang, S. K., Lee, H.H. and Liu, H.I. 2007. Standardization of South Atlantic swordfish by-catch rate for Taiwanese longline fleet. Col. Vol. Sci. Pap. ICCAT, 60(6): 1974-1985.

Fernández-Costa, J. and Mejuto, J. 2010. A short note on the FAO statistics for porbeagle shark (*Lamna nasus*) in the Atlantic and its relation to other Lamnid. Collect. Vol. Sci. Pap. ICCAT, 65(6): 2031-2050.

García-Cortés, B. and Mejuto, J. 2000. A general overview on the activity of the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean for the period 1993-1999. WPB00-01 IOTC Proceedings no. 3 (2000) page 140-153.

García-Cortés, B. and Mejuto, J. 2005. Scientific estimations of bycatch landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean: 2001 – 2003 period. IOTC-2005-WPBy-14.

García-Cortés, B., Ramos-Cartelle, A., Mejuto, J. 2004. A general overview of the activity of the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean during the year 2002. IOTC-2004-WPB-05.

García-Cortés, B., Ramos-Cartelle, A., Mejuto, J. 2008. Activity of the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean for the period 2003-2006. IOTC-2008-WPB-05.

Garcés, A.G. and Rey J.C. 1983. Análisis de la pesquería española de pez espada, *Xiphias gladius*, entre los años 1978 y 1981. Collect. Vol. Sci. Pap. ICCAT, 18(3):622-628.

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.

Hazin, H.G., Hazin, F., Travassos, P., Carvalho, F.C. and Erzini, K. 2007[a]. Fishing strategy and target species of the Brazilian tuna longline fishery, from 1978 to 2005, inferred from cluster analysis. Collect. Vol. Sci. Pap. ICCAT, 60(6): 2029-2038.

Hazin, H.G., Hazin, F., Travassos, P., Carvalho, F.C. and Erzini, K. 2007[b]. Standardization of swordfish CPUE series caught by Brazilian longliners in the Atlantic Ocean, by GLM, using the targeting strategy inferred by cluster analysis. Collect. Vol. Sci. Pap. ICCAT, 60(6): 2039-2047.

Ichinokawa, M. and Brodziak, J. 2010. Using adaptive area stratification to standardize catch rates with application to North Pacific swordfish (Xiphias gladius). Fisheries Research 106: 249-260

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(2004):141-159.

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. 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., García, B. and De la Serna, J.M. 2000. Preliminary standardized catch rates, in biomass, for the swordfish (*Xiphias gladius*) caught by the Spanish longline fleet in the South Atlantic stock, for the period 1989-1998. Collect Vol. Sci. Pap. ICCAT, 51(4):1293-1311.

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.

Mikihiko, K. and Yasuko, S. 2019. Estimation of annual catch rates and catches for shortfin mako (*Isurus oxyrinchus*) caught by Japanese longline fishery operated in the Indian Ocean from 1993 to 2018. IOTC-2019-WPEB15-21.

Moreno. J.A. 1995. Guía de los tiburones de aguas ibéricas, Atlántico Nororiental y Mediterráneo. Ediciones Pirámide, S.A.:310pp.

Mourato B.L., Andrade, H.A., Amorim, A.F. and Arfelli, C.A. 2007. Standardized catch rate of swordfish (*Xiphias gladius*) caught by Santos longliners off southern Brazil (1971-2005). Collect. Vol. Sci. Pap. ICCAT, 60(6): 1943-1952.

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.

Ortiz, M., Mejuto, J., Paul, S., Yokawa, K., Neves, M. and Hoey, J. 2007. An updated biomass index of abundance for North Atlantic swordfish 1963-2005. Collect. Vol. Sci. Pap. ICCAT, 60(6): 2048-2058.

Paul, S. D. and Neilson, J. D. 2007. Updated sex- and age-specific CPUE from the Canadian swordfish longline fishery, 1988-2005. Collect. Vol. Sci. Pap. ICCAT, 60(6): 1914-1942.

Ramos-Cartelle, A., García-Cortés, B., and Mejuto, J. 2008. Scientific estimates of bycatch landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean with special reference to the 2004 – 2006 period. IOTC-2008-WPEB-03.

Ramos-Cartelle, A., García-Cortés, B., Fernández-Costa, J., and Mejuto, J. 2009. Scientific catch estimations of bycatch species landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Indian Ocean with special reference to the years 2007 and 2008. IOTC-2009-WPEB-03.

Ramos-Cartelle, A., García-Cortés, B., Fernández-Costa, J. and Mejuto, J. 2011. Standardized catch rates for the swordfish (*Xiphias gladius*) caught by the Spanish longline in the Indian Ocean during the period 2001-2010. IOTC-2011-WPB09-23.

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

Semba, Y., and Nishida, T. 2008. Standardization of swordfish CPUE of the Japanese tuna longline fisheries in the Indian Ocean (1980-2006). IOTC-2008-WPB-06: 6pp.

Wen-Pei, T., Xing-Han, W., Kwang-Ming, L. 2019. Standardized CPUE of shortfin mako sharks by the Taiwanese large-scale tuna longline fishery in the Indian Ocean. IOTC–2019–WPEB15-22

Yokawa, K. 2007. Update of standardized CPUE of swordfish caught by Japanese longliners. Collect. Vol. Sci. Pap. ICCAT, 60(6): 1986-1993.

Table 1. Deviance table of the factors tested for log CPUE (in weight) for the shortfin mako of the Indian Ocean. Highlighted are the factors with ≥ 5.0% of deviance explained.

Model factors	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*	chi-sq
1	_	1330.2505				
Year	17	1193.0327	137.2178	30.1%	< 0.001	7.56E-21
Year Quarter	3	1175.3059	17.7268	3.9%	< 0.001	5.01E-04
Year Quarter Area	6	1080.1007	95.2052	20.9%	< 0.001	2.51E-18
Year Quarter Area Gear	1	1073.6604	6.4403	1.4%	0.011156	1.12E-02
Year Quarter Area Gear Bait	1	1059.8005	13.8599	3.0%	< 0.001	1.97E-04
Year Quarter Area Gear Bait Ratio	9	986.625	73.1755	16.1%	< 0.001	3.62E-12
Year Quarter Area Gear Bait Ratio Year*Gear	1	986.2809	0.3441	0.1%	0.557	5.57E-01
Year Quarter Area Gear Bait Ratio Gear*Ratio	3	985.4004	1.2246	0.3%	0.747	7.47E-01
Year Quarter Area Gear Bait Ratio Quarter*Gear	2	983.9817	2.6433	0.6%	0.267	2.67E-01
Year Quarter Area Gear Bait Ratio Quarter*Bait	3	983.4383	3.1867	0.7%	0.364	3.64E-01
Year Quarter Area Gear Bait Ratio Area*Bait	6	978.5552	8.0698	1.8%	0.233	2.33E-01
Year Quarter Area Gear Bait Ratio Year*Bait	15	978.4785	8.1465	1.8%	0.918	9.18E-01
Year Quarter Area Gear Bait Ratio Area*Gear	4	978.2564	8.3686	1.8%	0.079	7.90E-02
Year Quarter Area Gear Bait Ratio Bait*Ratio	9	977.1872	9.4378	2.1%	0.398	3.98E-01
Year Quarter Area Gear Bait Ratio Quarter*Ratio	26	952.5803	34.0447	7.5%	0.134	1.34E-01
Year Quarter Area Gear Bait Ratio Area*Ratio	41	937.3896	49.2354	10.8%	0.177	1.77E-01
Year Quarter Area Gear Bait Ratio Year*Quarter	51	930.8739	55.7511	12.2%	0.301	3.01E-01
Year Quarter Area Gear Bait Ratio Quarter*Area	17	925.4587	61.1663	13.4%	< 0.001	6.74E-07
Year Quarter Area Gear Bait Ratio Year*Ratio	120	924.5758	62.0492	13.6%	1.000	1.00E+00
Year Quarter Area Gear Bait Ratio Year*Area	73	874.8243	111.8007	24.5%	0.002	2.36E-03

Table 2. Estimated parameters (lsmean), standard error (stderr), standardized CPUE in number (CPUEn) of shortfin mako and upper and lower 95% confidence limits for the Spanish longline fleet in the Indian Ocean during the period analyzed 2001-2018.

YEAR	LSMEAN	STDERR	UCPUEn	CPUEn	LCPUEn
2001	-0.3668	0.0863	0.824	0.696	0.587
2002	-0.2413	0.0616	0.888	0.787	0.698
2003	-0.3317	0.0577	0.805	0.719	0.642
2004	-0.3974	0.0598	0.757	0.673	0.599
2005	-0.3351	0.0673	0.818	0.717	0.628
2006	-0.4704	0.0562	0.699	0.626	0.561
2007	-0.3816	0.0690	0.784	0.684	0.598
2008	-0.4433	0.0727	0.742	0.644	0.558
2009	-0.3708	0.0728	0.798	0.692	0.600
2010	-0.1167	0.0924	1.071	0.894	0.746
2011	-0.0470	0.0846	1.130	0.957	0.811
2012	0.0255	0.0759	1.194	1.029	0.887
2013	-0.1946	0.0703	0.947	0.825	0.719
2014	-0.0545	0.0694	1.088	0.949	0.829
2015	-0.2086	0.0878	0.968	0.815	0.686
2016	-0.0499	0.0933	1.147	0.955	0.796
2017	0.1532	0.0971	1.416	1.171	0.968
2018	0.0119	0.1033	1.246	1.017	0.831

Table 3. Estimated parameters (lsmean), standard error (stderr), standardized CPUE in weight (CPUEw) of shortfin mako and upper and lower 95% confidence limits for the Spanish longline fleet in the Indian Ocean during the period analyzed 2001-2018.

YEAR	LSMEAN	STDERR	UCPUEw	CPUEw	LCPUEw
2001	3.8684	0.0898	57.307	48.059	40.304
2002	3.9686	0.0640	60.105	53.018	46.766
2003	3.9707	0.0600	59.750	53.119	47.223
2004	3.8396	0.0622	52.640	46.598	41.249
2005	3.8337	0.0700	53.165	46.346	40.401
2006	3.7091	0.0584	45.845	40.886	36.464
2007	3.7532	0.0718	49.231	42.769	37.154
2008	3.6864	0.0756	46.407	40.017	34.506
2009	3.7931	0.0757	51.640	44.520	38.382
2010	4.0073	0.0961	66.698	55.253	45.772
2011	4.0589	0.0880	69.071	58.132	48.926
2012	4.1508	0.0789	74.333	63.680	54.554
2013	4.0154	0.0731	64.158	55.595	48.175
2014	4.1495	0.0722	73.227	63.566	55.181
2015	4.0166	0.0913	66.664	55.745	46.614
2016	4.0804	0.0970	71.897	59.449	49.156
2017	4.2770	0.1010	88.231	72.388	59.391
2018	4.1799	0.1075	81.154	65.739	53.253

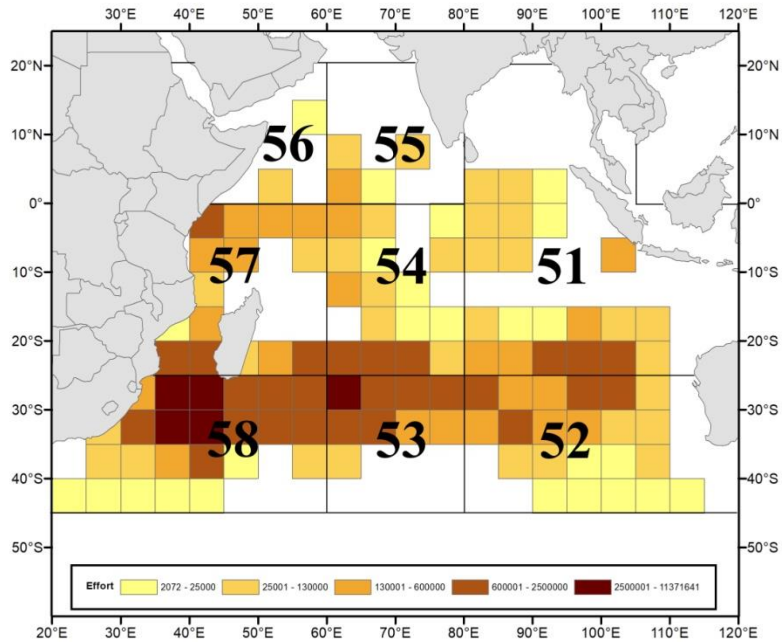


Figure 1. Area definition used for the GLM runs. Color scale represents the total nominal effort of this fleet (thousand of hooks) per 5x5 squares during the combined period 2001-2018.

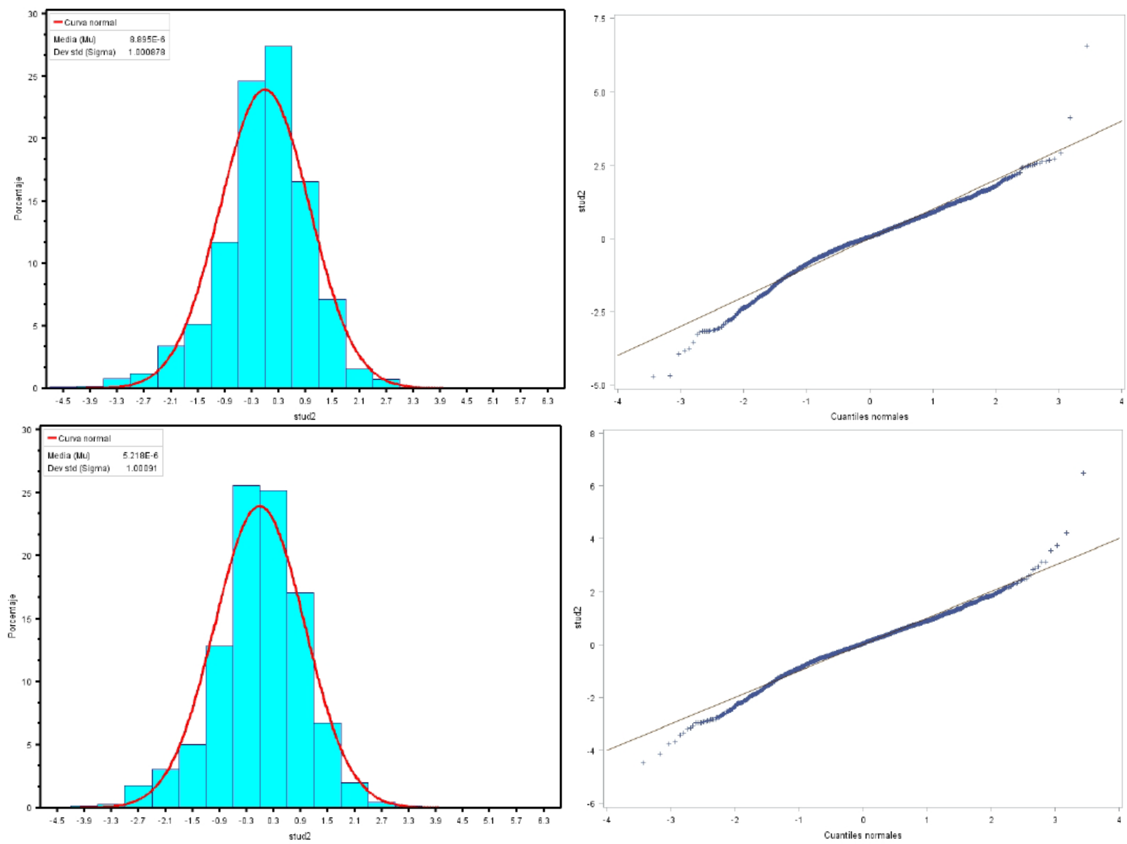


Figure 2. Diagnosis of the GLM runs for standardized CPUE in number of shortfin mako (upper) and in round weight (lower) for Indian Ocean: frequency distribution of the standardized residuals years combined (left panels) and normal probability qq-plot (right panels).

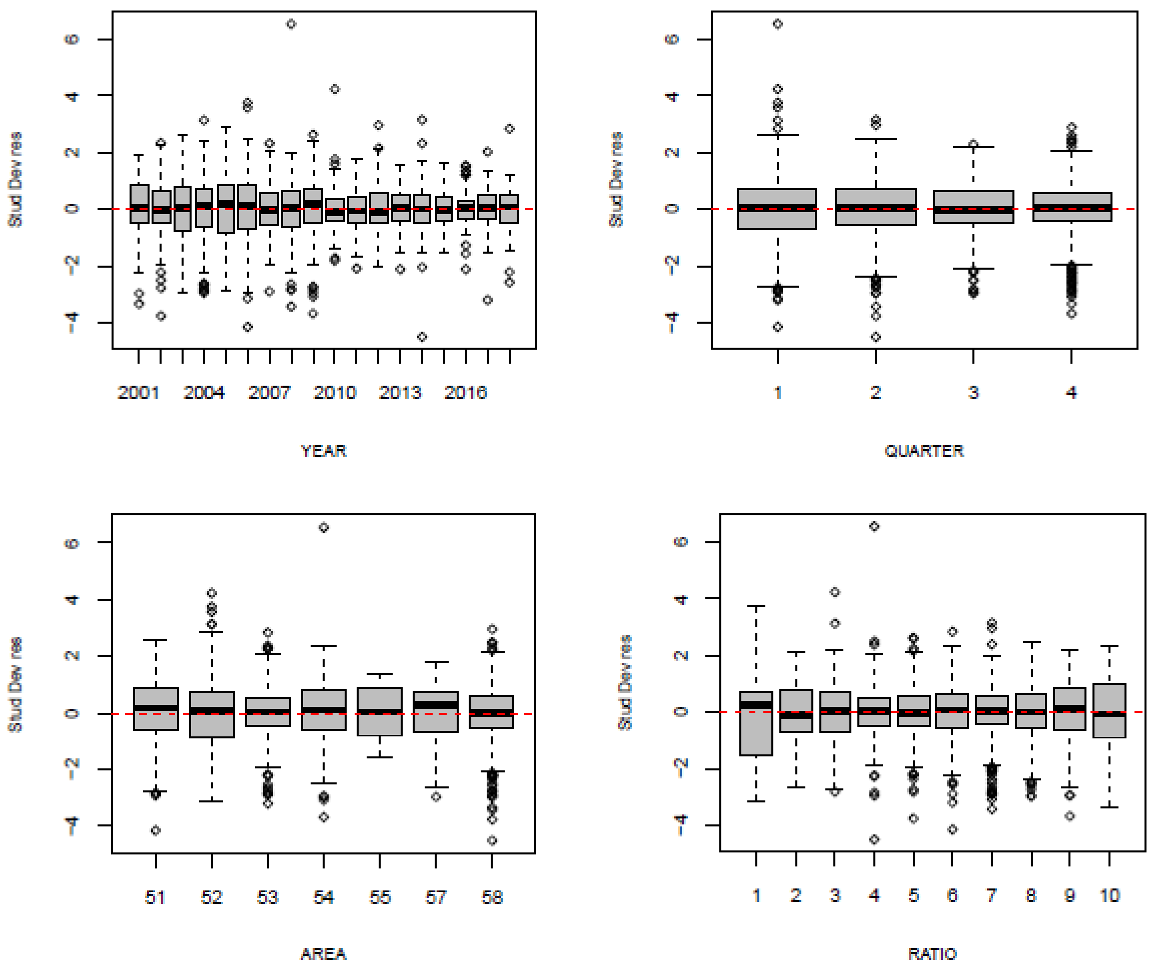


Figure 3. Box-plots of the standardized deviance residuals by explanatory variables obtained from the GLM base case in number of shortfin mako for the Indian Ocean.

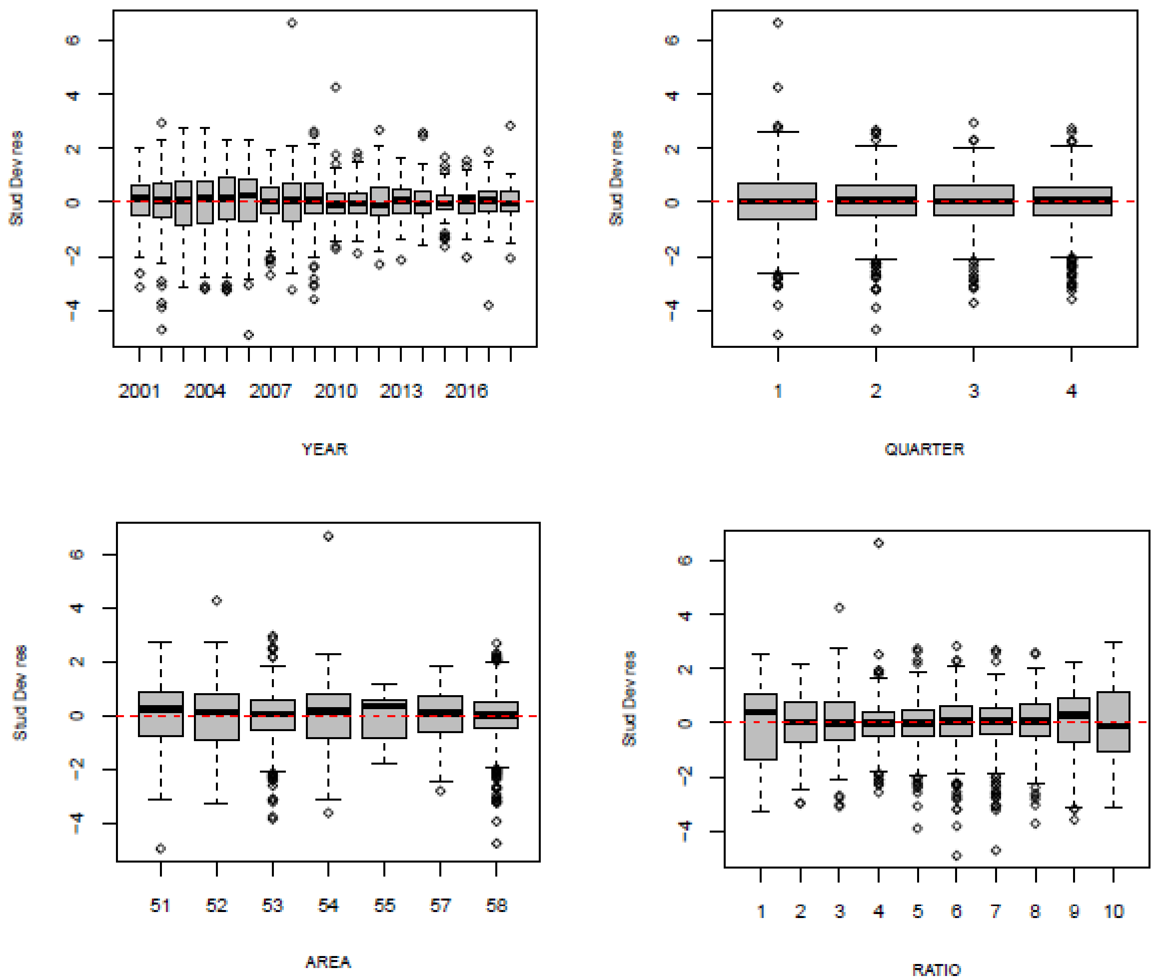


Figure 4. Box-plots of the standardized deviance residuals by explanatory variables obtained from the GLM base case in weight of shortfin mako for the Indian Ocean.

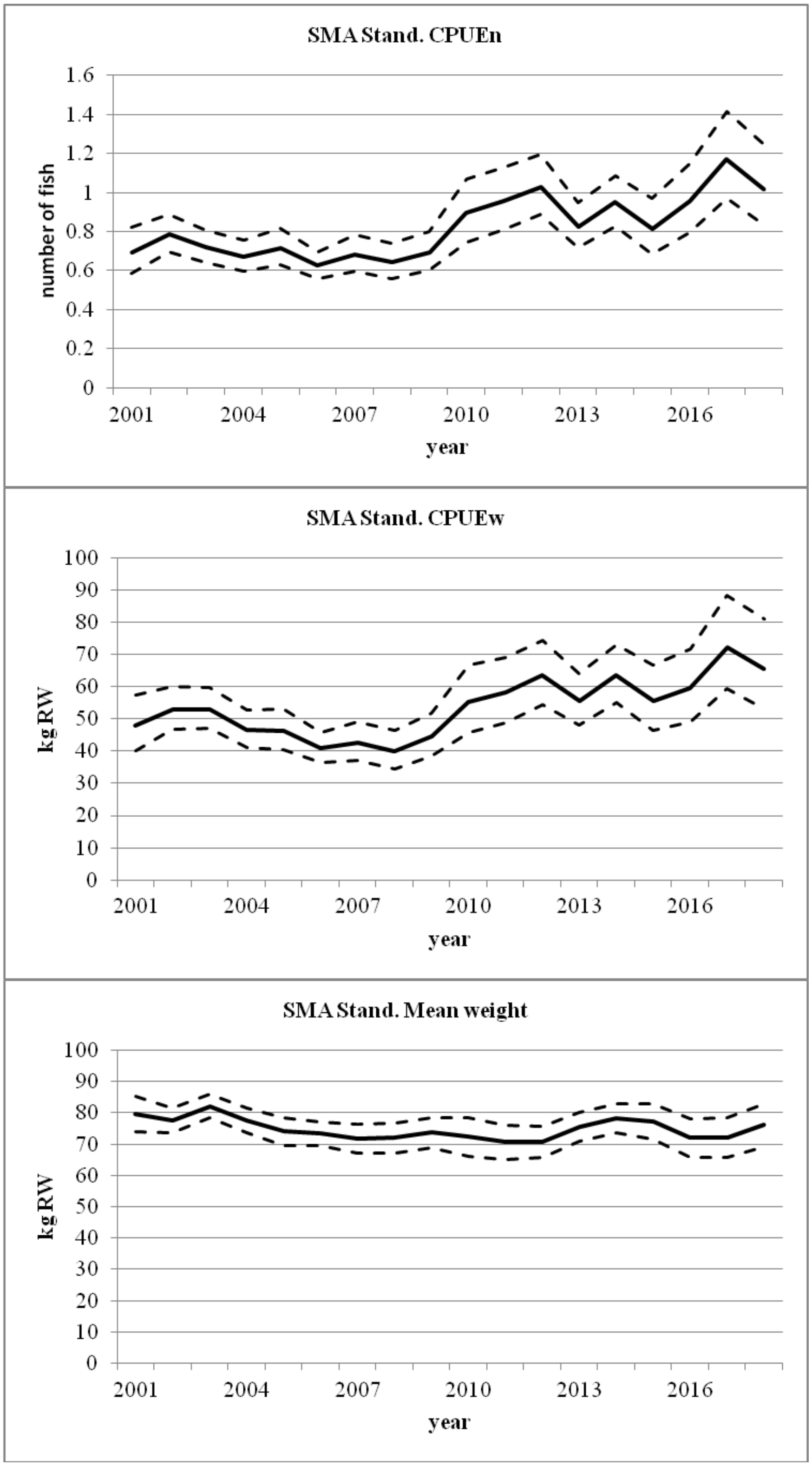


Figure 5. Standardized CPUEs per thousand hooks, in number of fish (upper), in kilograms round weight (middle) and standardized mean round weight in kilograms (lower) of shortfin mako and their respective confidence intervals (95%) observed in the Spanish surface longline fleet during the period analyzed (2001-2018) in the Indian Ocean.

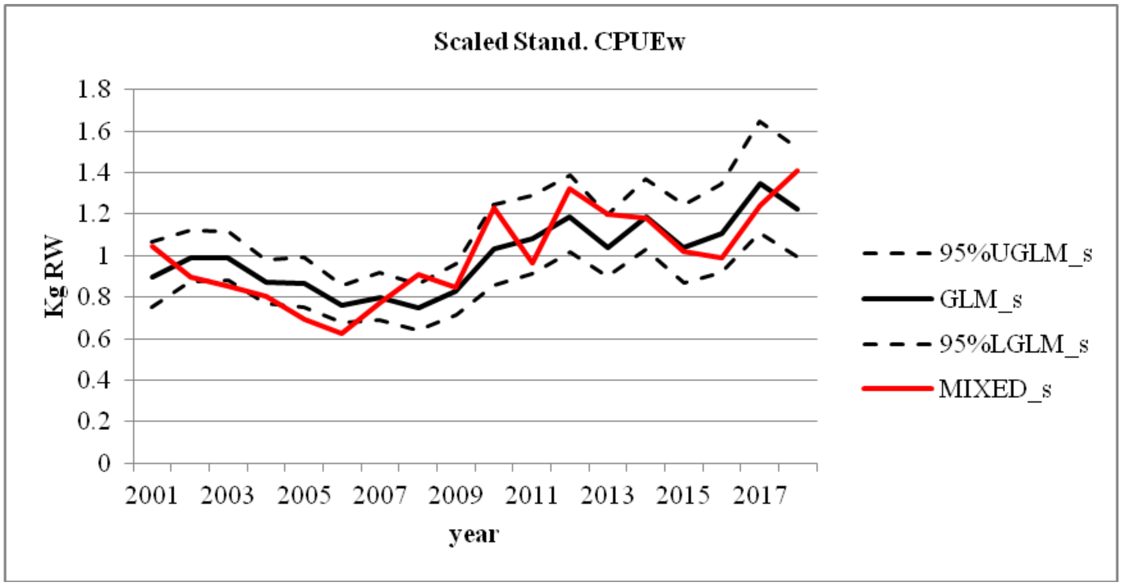


Figure 6. Comparative scaled standardized CPUE in weight, GLM *versus* GLMM (MIXED), obtained in the Indian Ocean for the period 2001-2018. Both series are scaled from their respective mean value.

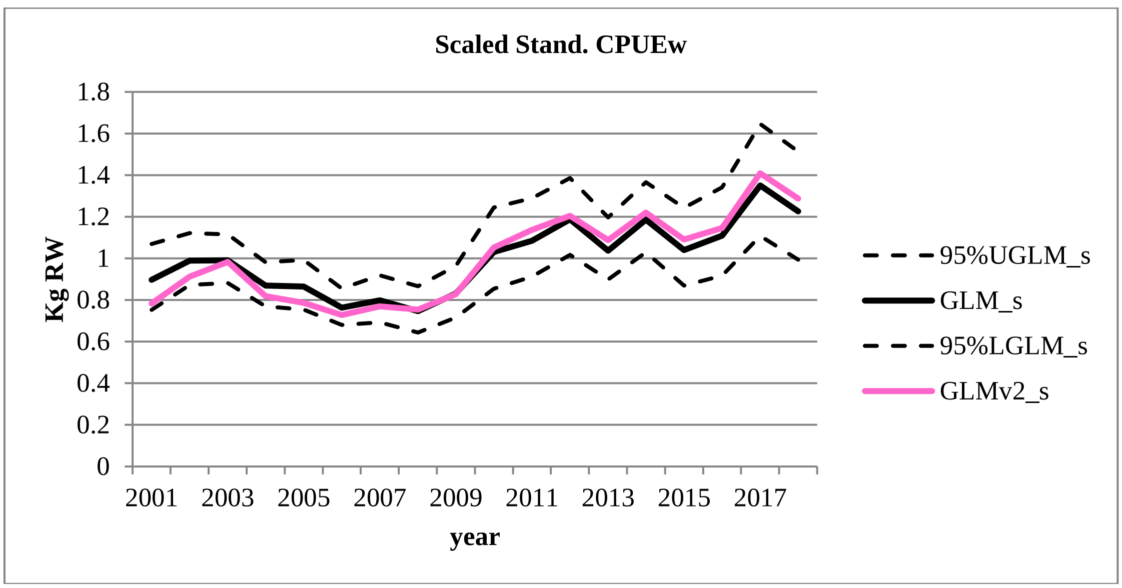
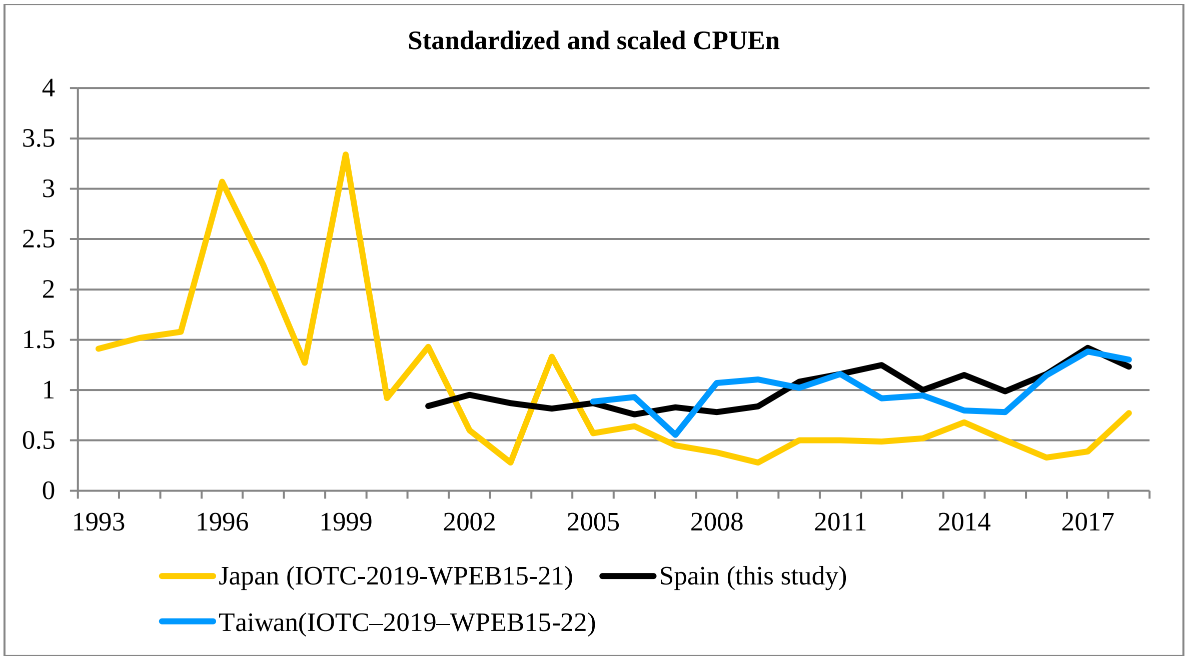


Figure 7. Comparative scaled standardized GLMs (GLM_s: base case, GLMv2_s: without *ratio* factor) CPUE in weight obtained in the Indian Ocean for the period 2001-2018.



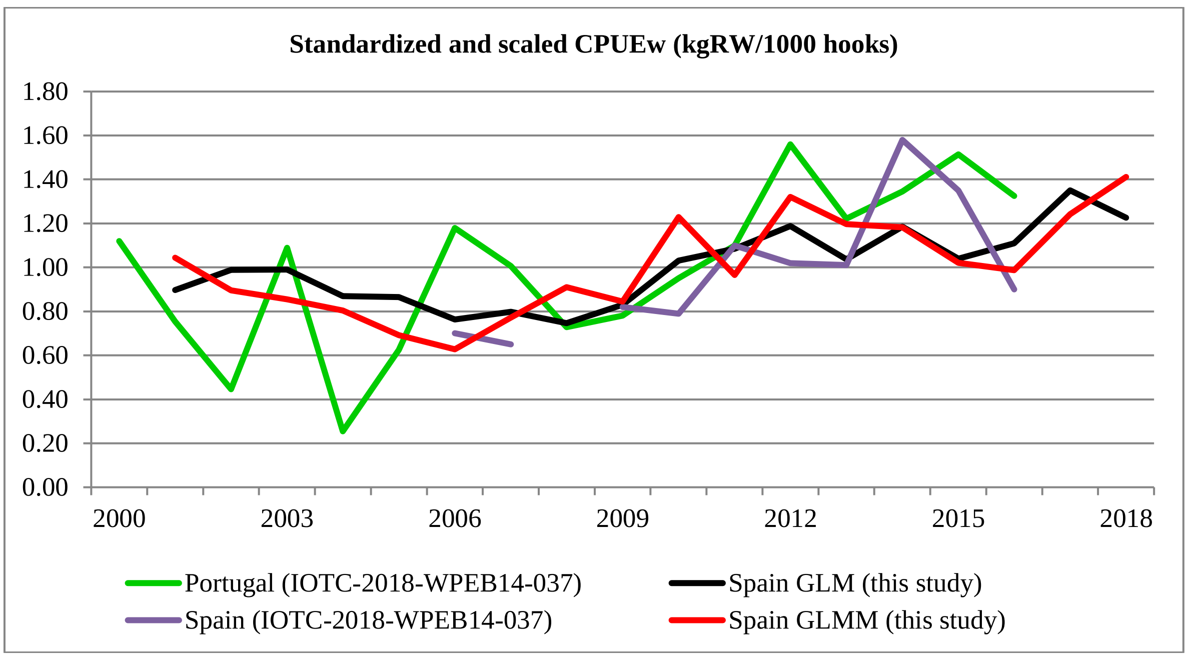


Figure 8. Comparative scaled standardized CPUE in number (upper) and in weight (lower) by different studies published in IOTC and this study.