STANDARDIZED CATCH RATE OF ALBACORE (*THUNNUS ALALUNGA* BONNATERRE, 1788) CAUGHT BY THE SPANISH SURFACE LONGLINE FISHERY IN THE WESTERN MEDITERRANEAN 2004-2015

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SUMMARY

*Standardized relative abundance indices of albacore (*Thunnus alalunga *Bonnaterre, 1788) caught by the Spanish surface longline, LLALB, in the western Mediterranean Sea were estimated for the period 2004-2015. Standardized CPUEs were estimated through a General Linear Modeling (GLM) approach under a negative binomial error distribution assumption. The main factors in the standardization analysis were fishing area and time of the year. Following a relatively stable trend for the period 2004-2008 and an increase between 2009 and 2010, the index seems to have declined since 2011 onwards.*

RÉSUMÉ

*Les indices standardisés d'abondance relative du germon (*Thunnus alalunga, *Bonnaterre, 1788) capturé par la pêcherie palangrière espagnole de surface (LLALB) dans l'Ouest de la Méditerranée ont été estimés pour la période 2004-2015. Des CPUE standardisées ont été estimées par le biais d'une approche de modélisation linéaire généralisée (GLM) en postulant une distribution d'erreur binomiale négative. Les principaux facteurs de l'analyse de standardisation étaient la zone de pêche et la période de l'année. Après une tendance relativement stable entre 2004 et 2008 et une augmentation entre 2009 et 2010, l'indice semble avoir diminué à partir de 2011.*

RESUMEN

Se estimaron índices de abundancia relativa estandarizada del atún blanco (Thunnus alalunga, Bonnaterre, 1788) capturado por la flota de palangre de superficie española, LLALB, en el Mediterráneo occidental para el periodo 2004-2015. Las CPUE estandarizadas se estimaron mediante un enfoque de modelación lineal generalizado (GLM) con un supuesto de distribución de error binomial negativa. Los factores principales en el análisis de estandarización fueron la zona de pesca y el momento del año. Tras una tendencia relativamente estable para el periodo 2004-2008 y un incremento entre 2009 y 2010, el índice parece haber descendido desde 2011 en adelante.

KEYWORDS

Albacore, Longline, Stock assessment, Catch/effort, Pelagic fisheries, Mediterranean Sea

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1. Introduction

1.1 Description of the fishery

The Spanish longline fishery targets albacore (*Thunnus alalunga*) in the western Mediterranean. The spatial distribution of the fishery has been generally consistent for the period 2004-2015, with catches localized along the Spanish western Mediterranean (**Figure 1**).

The albacore longline, LLALB, is the shallowest longline gear deployed by the Spanish surface longline fishery. The Spanish surface longline fleet uses alternative configurations of the basic gear, depending on the wanted target species, such as the traditional or home-based longline (LLHB), American style longline (LLAM), bottom longline (LLPB), half water or semi-pelagic longline (LLSP), and the bluefin tuna longline (LLJAP). The detailed descriptions of those 5 fisheries can be found in **Table 1**.

LLALB is a drift longline, which operates in high-sea fishing grounds (**Figure 1**) at depths up to 1500 m. Both the size of the hook and the thickness and length of the fishing lines are smaller compared to other drifting longline gears. Between 2000 and 7000 hooks are set by fishing operation. Hook depth ranges from 20 to 50 m. The most commonly used bait is frozen sardine (*Sardina pilchardus*) and round sardinella (*Sardinella aurita*). One single fishing operation (set) is typically carried out per fishing day. The time period for gear setting and hauling is variable, and the time during which the fishing gear is in operation averages at eleven hours. Although active throughout the year, the main fishing season is from May to September (García-Barcelona *et al*., 2010; Saber *et al*., 2015).

The evolution of the LLALB fishery in the western Mediterranean has been fairly stable due to its strongly artisanal nature from its startup in the late nineties. As is the case for all the main fisheries in the western Mediterranean, the LLALB fishery is scientifically monitored by both the Spanish Institute of Oceanography (IEO) Information and Sampling Network, and the IEO On-Board Observer Program.

1.2 Regulation measures

Until now, with the exception of some technical specifications related to the fishing gear characteristics (number of hooks, hook size, line material and length, etc), the Mediterranean albacore fishery has not been subjected to any regulation measures.

From 2017, as a result of the International Commission for the Conservation of Atlantic Tuna Mediterranean swordfish rebuilding plan, a closure period shall apply to longline vessels targeting Mediterranean albacore from the 1 October to 30 November each year (ICCAT Rec [16-05;12]). In addition, by 15 June 2017, Contracting Parties and Cooperating Non-Contracting Parties (CPC) shall provide to the ICCAT Secretariat the list of all catching vessels authorized to fish actively for Mediterranean albacore tuna. For subsequent years the deadline is set at 15 March (ICCAT Rec [16-05;28]).

2. Material and Methods

Data for the analysis was collected from the Spanish pelagic longline fishery targeting albacore in the western Mediterranean. The information, recorded on a trip basis, included: vessel identification, date and geographical location (area 5x5) by fishing operation (set), fishing effort (number of hooks), catch (either biomass in kg or number of fish) and, whenever possible, length composition of the catch.

2.1 Data exclusions

Data inspection basically entailed the elimination of incomplete and erroneus records, such as incorrectly recorded number of fish weight or fishing effort. Whenever possible, incorrect measurement units were corrected. As a result, approximately one per cent (1 %) of the records available for the period 2004-2015 was eliminated for later analysis.

2.2 Analytical approach

An exploratory analysis (results not shown here) of the available data based on a Poisson error distribution pointed to the existence of overdispersion. Thus, indices of abundance were estimated by a generalized linear modeling approach assuming a negative binomial model (NB). For a response variable recording catch in fish number, the negative binomial distribution, like the Poisson distribution, describes the probabilities of the occurrence of numbers greater than or equal to 0. Unlike the Poisson distribution, the variance and the mean are not equivalent. The variance of a negative binomial distribution is a function of its mean and has an additional parameter, the dispersion parameter, θ or k, which might serve as a proper approach for modeling counts with variability different from its mean[1].

The NB generalized linear model was parameterized as a rate model in which the fishing effort (number of hooks) was implemented as an offset, which reflects the total effort by set over which the count response (number of fish) was generated. In fact, the offset is an exposure variable with a coefficient constrained to a value of 1.0 (i.e., enters into the model as a constant). Since the natural log (log_e) is the canonical link for the NB model, the offset was logged prior to entry into the estimating algorithm.

A priori explanatory factors in the model were area and month. Individual factor relevance as well as interactions among them was assessed by means of a step-wise regression procedure. The criterion used to determine the set of factors and interactions that significantly explained the observed variability implied the assumption that the difference in residual deviance (essentially a measure of the variability explained by the model) between two consecutive models follows a Chi-square distribution (χ^2) with degrees of freedom equal to the difference in number of parameters estimated in both models (McCullagh and Nelder, 1989).

The analyses were conducted and the graphs designed using R statistical software (R Core Team, 2017). Among others, packages MASS (Venables and Ripley, 2002), lsmeans (Lenth, 2016) and ggplot2 (Wickham, 2009) were of particular help.

3. Results and Discussion

A total of 895 LLALB fishing sets for the period 2004-2015 were available for analysis. An annual summary of the information available for the analysis (number of sets, fishing effort, nominal catch and observed catch rates) is given in **Table 2**.

Sampling coverage (in terms of annual percentage of weight sampled with respect to total Task I reported to ICCAT) is shown in **Figure 2**. Sampling coverage, around 30 % on average, has remained fairly constant for the time series in the analysis.

Figure 3 shows the distribution of factors (year, month, area) used in the standardization analysis. Except for year 2015, which showed both a reduced number of fishing sets and a remarkable unbalanced distribution, treatment combinations across years was reasonably satisfactory. Note here that albacore fishing in the western Mediterranean in year 2015 was largely influenced by the looming implementation of ICCAT Mediterranean Swordfish Rebuilding Plan. In order to ensure a good position for swordfish quota allocation, a large portion of the fishing effort customary exerted on albacore was switched to swordfish.

Table 3 records the estimated parameters for the final NB model. **Table 4** reports the Deviance analysis results. Table shows the final model after selection conducted by stepwise addition of a single factor each step. Factors year, month, area, and the area*month interaction were statistically significant (α= 0.01). The final model accounted for 21.8 % of the residual deviance in the data.

Figures 4 and **5** show graphical diagnostics for assessing the final NB model fit. Even though the residual patterns show some departures from distributional assumptions at the tails, generally adequate fit the model. Based on the *rootogram* plot, it seems that the final model tends to under predict the observed counts.

Table 5 and **Figures 6** and **7** report estimated standardized relative abundance indices, standard errors and corresponding coefficients of variation.

[1]In R methods glm.nb and glm are unusual in how they define the dispersion parameter. The variance is given as: $\mu + (\mu^2 / \theta)$ rather than $\mu + \alpha \mu^2$, which is the direct parameterization. The latter formulation is the way NB is modeled in SAS, Stata, Limdep, SPSS, Matlab, Genstat, Xplore, and most all software.

Following a relatively stable trend for the period 2004-2008 and an increase between 2009 and 2010, the index seems to have declined since 2011 onwards. Even if the descending trend in the standardized CPUE series seems clear for the most recent period (**Figure 6**), year 2015 might be affected by the fact that in the aim of achieving higher quotas (in the framework of the Mediterranean swordfish rebuilding plan, ICCAT Rec. [16-05]), a significant part of the fishing effort originally targeted at Mediterranean albacore was switched to swordfish. Therefore, it would be worthwhile to undertake further analysis in order to better characterize the aforementioned descending trend since 2011 in the fishery indicator.

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Table 1. Main characteristics of Spanish surface longline fisheries (from (García-Barcelona *et al*., 2010). Fisheries: LLHB, traditional or home-based longline; LLAM, American style longline; LLPB, bottom longline; LLSP, half water or semi-pelagic longline; LLJAP, bluefin tuna longline fishery.

Fishery	**Main characteristics**
LLALB	See Material and Methods section.
LLHB	Drifting longline targeting swordfish. It is of variable length, ranging from 37 to 65 km, which enables working with 1500 to 4000 hooks. The main line hangs from floats and, based on the information recorded by means of depth sensors, the average depth of surface hooks reaches 30 m, with a maximum depth of 50 m. Hook size is 7.5 x 2.5 cm, usually baited with mackerel (*Scomber scombrus*) or chub mackerel (*Scomber japonicus*) ranging in size from 25 to 30 cm (total length). Depending on the fishing season and price of the bait, hooks can also be baited with forage fish such as Atlantic saury (*Belone belone*) or silver scabbardfish (*Lepidopus caudatus*). Chemical and electrical lights are used to attract prey. Setting this gear starts at mid-afternoon and lasts until after sunset. Gear hauling starts early in the morning and lasts until mid-morning. This gear is used throughout the year.
LLAM*	It was originally imported from the Italian and American longliners in the early 2000s. Following a period of widespread use between 2003 and 2005, it has been relegated mainly to the Atlantic fishing grounds. Unlike the traditional longline, this monofilament longline reaches 90 to 100 km in length with a smaller number of hooks (900 to 1100), which implies a greater distance between hooks. Fishing depth is greater, with deepest hooks working at 70 m. Monofilament longline allows the distance between hooks to be varied for each set. Hooks are separated between 70 and 90 m, which allows faster hauling. Furthermore, soaking time is longer than for the traditional longline. Both the mainline and the branch lines are thicker than in the traditional longline, and hooks are equipped with weights of 30 to 70 g, which increases the bait sinking rate. The hook type and bait, both are the same as in the traditional longline. Like the traditional longline, LLAM is used throughout the year.
LLPB	Operated by the longline fleet mainly from July to October. It is also used by artisanal vessels with small Gross Register Tonnage (GRT). It operates in coastal waters or grounds near the home port. LLPB is a variant of the bottom longline targeting silver scabbardfish, consisting of a longline similar to the traditional one, but with shorter distance between hooks, and fixed at the sea bottom by means of weights or stones. Unlike the others, it is not a drifting longline and is usually set close to the continental slope. The number of hooks in each fishing set does not usually exceeds 900, with 600 hooks in many sets. The bait used is mackerel (*Scomber* sp.) or round sardinella (*Sardinella aurita*).
LLSP*	An improved surface longline allows increased hook depth during summer time (when the sea surface temperature is higher). This gear has been in use since 2007. It operates in mesopelagic waters and is similar to the traditional longline, but differs in the number of hooks between floats is larger, and some weights or stones are placed along the mainline. These modifications make the gear more stable against the sea currents, and enhance the depth of hooks in the water column. Because setting speed is lower than for the traditional longline, the number of hooks does not usually exceed 1500. Sea turtles and sharks bycatch at these depths are very small. LLSP is used in a seasonal way, mainly from July to October.
LLJAP	Monofilament longline only used during the months of May, June and the first half of July, when bluefin tuna enters the Mediterranean for breeding. Main differences between this gear and the swordfish monofilament longline include: fishing at greater depth, squid (*Illex* sp.) bigger than 500 g is preferred as bait, gear working for 24 hours. The number of hooks by set does not exceed 1200.

*Under LLHB GearCode in ICCAT database.

Table 2. Summary table. Spanish ALB surface longline, western Mediterranean, 2004-2015.

Year	Sets (number)	Effort (1000 h^{-1})	Catch (number)	Catch (kg)	CPUE (n*1000 h^{-1})	CPUE (kg*1000 h^{-1})
2004	68	764.60	5987	29422	7.83	38.48
2005	48	765.00	8347	49236	10.91	64.36
2006	58	666.09	6488	44172	9.74	66.32
2007	101	1093.20	9865	76269	9.02	69.77
2008	38	415.12	6187	41224	14.90	99.31
2009	82	619.66	12314	97562	19.87	157.45
2010	32	482.10	9601	78092	19.91	161.98
2011	38	321.35	5360	41341	16.68	128.65
2012	108	1415.25	16828	143232	11.89	101.21
2013	188	2651.28	28244	235164	10.65	88.70
2014	131	1492.86	12879	102784	8.63	68.85
2015	3	18.48	162	1692	8.77	91.56

Table 3. Summary of estimated parameters for the final NB model. Spanish ALB surface longline, western Mediterranean, 2004-2015.

Parameters	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	3.0172	1.4003	2.15	0.0312
year2005	0.3847	0.1452	2.65	0.0081
year2006	0.2714	0.1414	1.92	0.0550
year2007	-0.0776	0.1208	-0.64	0.5205
year2008	0.2286	0.1590	1.44	0.1505
year2009	0.1857	0.1384	1.34	0.1795
year2010	0.9588	0.1614	5.94	0.0000
year2011	0.4768	0.1654	2.88	0.0039
year2012	0.1904	0.1305	1.46	0.1447
year2013	0.4454	0.1165	3.82	0.0001
year2014	-0.1608	0.1225	-1.31	0.1895
year2015	-1.2161	0.4935	-2.46	0.0137
month2	1.5233	1.3147	1.16	0.2466
month3	0.2046	1.4535	0.14	0.8880
month4	0.6313	1.4393	0.44	0.6609
month5	1.0750	1.4026	0.77	0.4434
month6	2.1363	1.3996	1.53	0.1269
month7	2.4836	1.3989	1.78	0.0758
month8	1.8389	1.4010	1.31	0.1893
month9	2.1872	1.4095	1.55	0.1207
month10	1.3282	1.4103	0.94	0.3463
month11	0.4768	1.4178	0.34	0.7367
month12	-1.0155	1.3409	-0.76	0.4489
area40000	-1.8410	1.1843	-1.55	0.1201
month4:area40000	-1.1543	1.4469	-0.80	0.4250
month5:area40000	0.8497	1.2091	0.70	0.4822
month6:area40000	0.9063	1.1947	0.76	0.4481
month7:area40000	1.0358	1.1896	0.87	0.3839
month8:area40000	1.3310	1.1914	1.12	0.2639
month9:area40000	1.0765	1.2025	0.90	0.3707
month10:area40000	2.1947	1.2039	1.82	0.0683
month11:area40000	1.5806	1.2439	1.27	0.2038

Table 4. Deviance analysis results. Albacore catch in number, Spanish surface longline, western Mediterranean, 2004-2015. Deviance refers to change in deviance; % Dev: percent of deviance explained with respect to the null model; Pr(>Chi): χ^2 probability between consecutive models.

	Df	Deviance	Resid. Df	Resid. Dev	% Dev.	Pr(>Chi)
NULL			894	2863.64		
Year	11	175.20	883	2688.45	6.12	0.0000
Month	11	305.72	872	2382.73	10.68	0.0000
Area	1	106.47	871	2276.26	3.72	0.0000
month:area	8	30.95	863	2245.31	1.08	0.0001

Table 5. Estimated standardized relative abundance indices, standard errors and coefficient of variation. Albacore catch in number, Spanish surface longline, western Mediterranean, 2004-2015.

Year	fit	Se.ftt	UL	LL	CPUE	cv	CPUE Nominal
2004	5.50	0.12	308.91	194.14	244.89	2.15	416.50
2005	5.89	0.11	450.67	287.23	359.79	1.95	270.25
2006	5.77	0.12	407.81	253.05	321.24	2.11	200.50
2007	5.42	0.10	275.38	186.47	226.60	1.83	204.88
2008	5.73	0.14	402.06	235.63	307.80	2.38	301.86
2009	5.69	0.11	362.83	239.64	294.87	1.86	276.67
2010	6.46	0.14	836.94	487.60	638.82	2.13	778.86
2011	5.98	0.14	522.42	297.89	394.49	2.40	175.67
2012	5.69	0.09	354.98	247.23	296.24	1.62	266.24
2013	5.95	0.07	442.09	330.58	382.29	1.25	291.98
2014	5.34	0.09	248.35	175.08	208.53	1.67	177.39

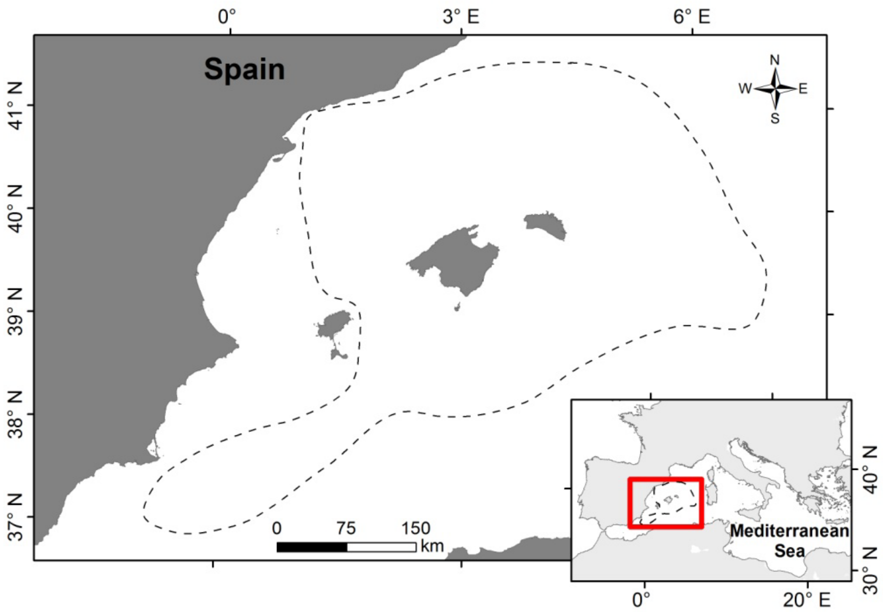

Figure 1. The western Mediterranean Sea showing the fishing grounds of albacore longline fishery (dashed line).

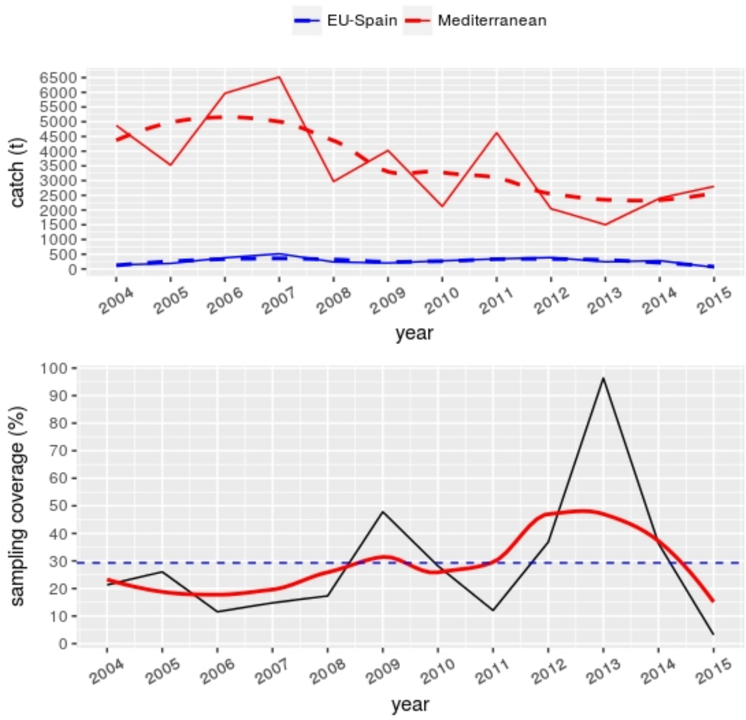

Figure 2. Reported catch (top) and Sampling coverage (bottom). Spanish ALB surface longline, western Mediterranean, 2004-2015 (29.32%, on average for the period covered).

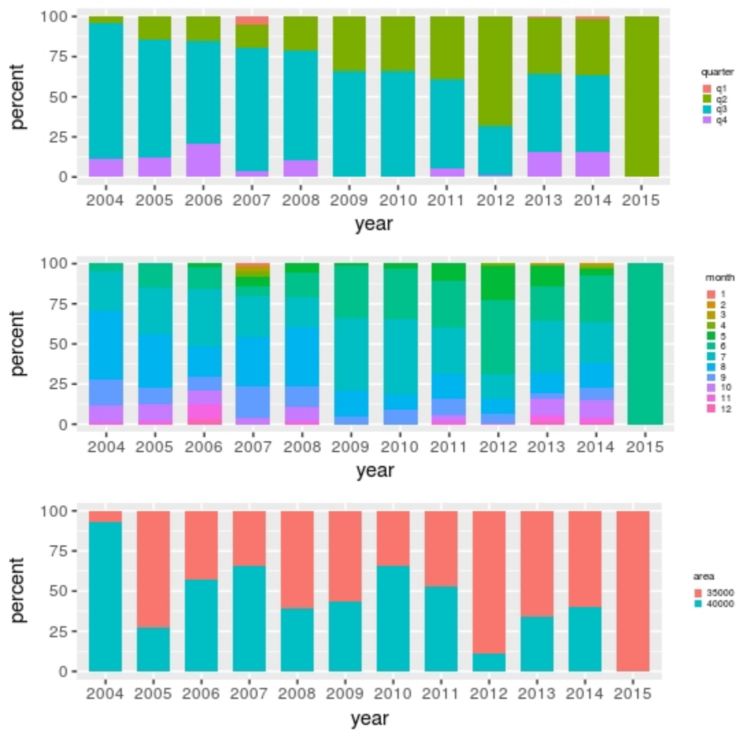

Figure 3. Distribution of relevant factors in the data analyzed. Spanish ALB surface longline, western Mediterranean, 2004-2015.

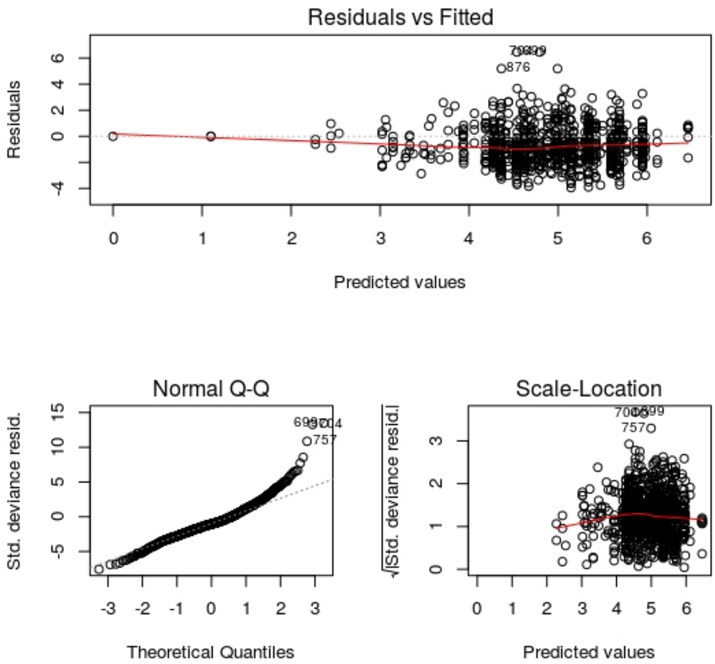

Figure 4. Diagnostics. Spanish ALB surface longline, western Mediterranean, 2004-2015.

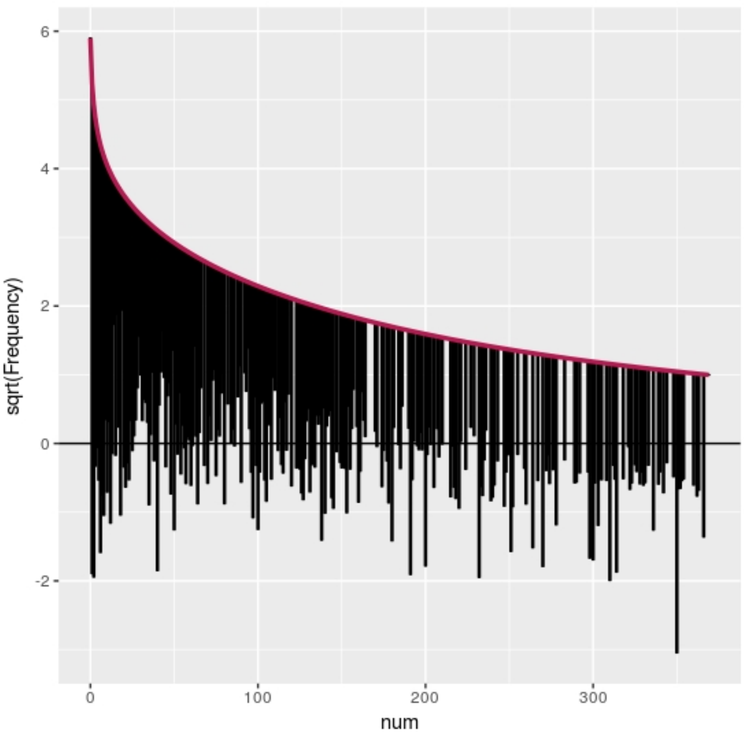

Figure 5. Model fit assessment. Rootplot. Spanish ALB surface longline, western Mediterranean, 2004-2015.

Figure 6. Estimated standardized relative abundance index and corresponding 95% confidence limits (normal approximation). Spanish ALB surface longline, western Mediterranean, 2004-2015 (black, standardized CPUE; red, loess fit.)

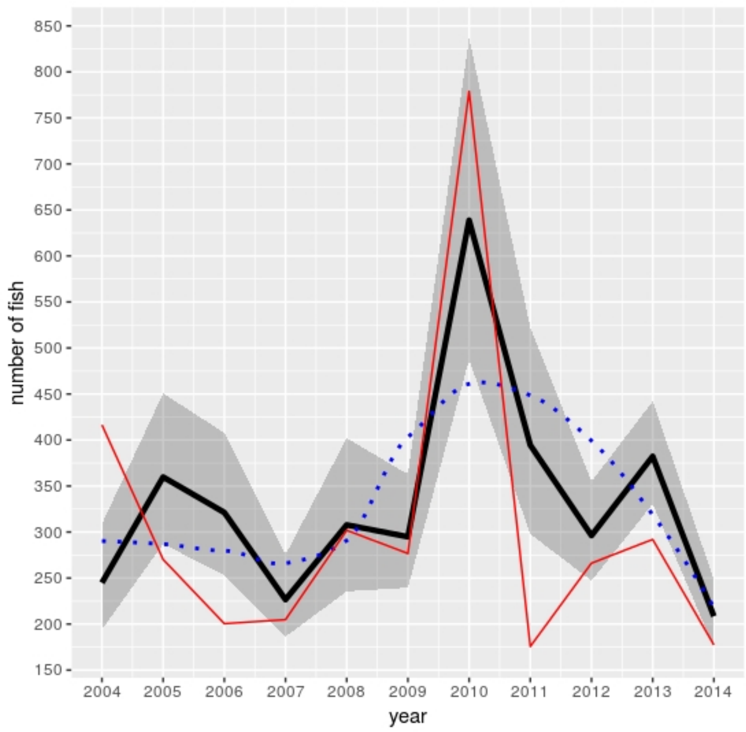

Figure 7. Estimated standardized relative abundance index and corresponding 95% confidence limits (normal approximation). Spanish ALB surface longline, western Mediterranean, 2004-2014 (black, standardized CPUE; red, nominal CPUE; blue, dotted, loess fit).