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STANDARDIZED NORTH EAST ATLANTIC ALBACORE (*Thunnus alalunga*) CPUE´S FROM THE SPANISH BAIT BOAT FLEET, PERIOD 1981-2014.

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SUMMARY

*Nominal catch of number of fish per unit of effort (CPUE´s) of North Atlantic albacore (Thunnus alalunga) caught by the Spanish bait boat fleet in the North Eastern Atlantic were collected by individual trip for the period 1981-2014. Standardized index was estimated using Generalized Linear Random Effects Model (GLMM) with log-normal error distribution. The year*quarter interaction term and year*zone interaction term were included in the model as random effects to derived the annual standardized catch rates as index of abundance for the time period analysed.*

RESUMEN Las capturas en número de peces por unidad de esfuerzo (CPUE´s) de atún blanco del Atlántico norte capturado por la flota española de cebo vivo fueron recogidas mediante muestreo de mareas individuales durante el período de 1981 a 2014. Se analizaron con un Modelo Generalizado Lineal con Efectos Aleatorios (GLMM). Los factores de interacción año y trimestre y año y zona fueron incluidos como factores aleatorios en el modelo para obtener la serie de CPUE estandarizada en el período analizado. En el modelo empleado se asumió una distribución log-normal del error.

KEYWORDS

Thunnus alalunga, Albacore, standardized CPUE´s, Spanish bait boat fleet, North Atlantic.

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1. Introduction

The North Atlantic albacore stock was assessed in 2013 (ICCAT, 2013a, b) by applying several methods among others: the statistical catch-at-size model MULTIFAN-CL (Fournier *et al.*, 1998) and the stock production model incorporating covariates ASPIC (Prager, 1992). The non-equilibrium production model ASPIC was fitted to the North Atlantic albacore data (Merino *et al.*, 2014) available to the analysis done during the assessment session in 2013 (ICCAT, 2013b). The non-equilibrium production model used time series of standardized catch rates by main commercial fleets and yield (weight) to estimate the status of the stock. Accordingly to the 2016 work plan elaborated for the 2016 North Atlantic stock assessment session it was requested to prepare several statistics and different sets of data derived from the monitoring of the commercial fleet activities targeting this stock.

Therefore the catch per unit of effort (CPUE) series for Spanish bait boat fishery by year had been standardized for the period 1981 to 2014; 2014 was determined as the last input year for the upcoming assessment.

The aim of this paper is to present the information on catch per unit of effort (CPUEn) expressed in number of albacore caught per fishing day by the Spanish bait boat fishery operating in the Bay of Biscay and adjacent Northeast Atlantic area during the time period mentioned. To derive the annual standardized index, the interaction term *year*quarter* and *year*zone*, was modelled by means of the Generalized Linear Mixed Models with Random Effects (GLMMs) assuming the log-normal error distribution in the analysis.

The annual standardized bait boat CPUE´s in numbers of fish from 1981 to 2014 are presented to be examined and considered for use as input for the surplus production model ASPIC to estimate the state of the population of North Atlantic albacore stock during the 2016 assessment session.

2. Materials and Methods

The information used in this analysis was obtained from the monitoring of fishing trips from commercial bait boats randomly sampled and recorded at landing ports through interviews of skippers. Each record contains information on: date of landing, number of fishing days, area of effort, catch in number, likewise information on size of landed catches by commercial categories were obtained through random sampling. Catch in weight (kg) for each trip is obtained from sale market records.

The seasonal migration of immature albacore to the northeast Atlantic waters and the Bay of Biscay during summer months determines the spatial and temporal activity of the fleet according to the species annual behavior and spatial distribution in the Bay of Biscay and North Eastern Atlantic waters. The fishing ground for the bait boat fleet has remained unchanged in a broad temporal scale, however it shows important inter annual variability depending on availability of the resource to the fishing area and gear (Ortiz de Zárate *et al.*, 2015). The stratification of the fishing area concerning trips location, is the same as in previous analyses (Ortiz de Zárate *et al.*, 2014) defined by the explanatory variable ZONE as factor with four levels (1=NE, 2=SE, SW =3 and 4=NW) and considered in the analyses of catch rates (**Figure 1)**.

Based on seasonality of bait boat fleet, observations were grouped by calendar quarter, using the following description: QUARTER 2 (May-Jun), QUARTER 3 (Jul-Aug-Sep) and QUARTER 4 (Oct-Nov-Dec).

All trip observations from 1981 to 2014 indicated positive catch of albacore, thus nominal catch rates expressed in number of fish per fishing day were log transformed for standardization. In addition to the Zone and Quarter main factors *year*quarter* and *year*zone* interactions were evaluated, and included in the model as random effects to allow estimation of an annual standardized CPUE´s index. Additionally the standardized CPUE´s by quarter were also estimated as was the case in previous standardization analysis of Spanish bait boat fleet (Ortiz de Zárate and Ortiz de Urbina, 2010;2014).

Final models were:

Model formulation

log (CPUEn) = μ + Y_i + $Zone_k$ + $Quarter_l$ + Y_i * $Quarter_l$ + Y_i * $Zone_k$ + ε_{ikl}

Where:

μ= overall mean
Y = year factor; levels: 1981-2014
Zone = area factor; 4 levels: NE (1), SE (2), SW (3), NW (4)
Quarter = time factor; 3 levels: 2, 3, 4
ε_{ikl} = log-normal error distribution

Analyses were done using Generalized Linear Random Effects Model procedure of JMP v.10 (SAS, Institute Inc.) using restricted maximum likelihood (REML) solution algorithm.

Annual index of abundance was calculated as the back-transformed least squares means (LSmeans) of the *Year* factor.

$$CPUE\ \widehat{Y_i} = \exp\,(LSMean\ Y_i + 0.5 * RSE^2)$$

3. Results and Discussion

Data collected from the Spanish bait boat fishery comprised a total of 3117 trips compiled from 1981 through 2014.This data was used to estimate the nominal CPUE´s classified accordingly to the factor time (Quarter) and fishing area (Zone) included in the period modelled (**Table 1**). Due to the low number of trips (n=12) allocated in quarter 2, this level was not included in the model. Therefore, a total of 3105 observations were analysed. Only quarter 3 and quarter 4 level were included in the model. It is observed that mostly the observation came from quarter 3 (summer season) and stratified zone 2 (SE) characterized by being located in the inner part of the Bay of Biscay, closer to the coastal waters. The observed data doesn´t show a balance design. In **Figure 1,** is reflected the annual change in the fishing area detected for the last three years of the time series that had been incorporated to the previous analysis of bait boat quarterly CPUEs standardized (Ortiz de Zárate *et al*., 2014).

The results from the Generalised Linear Model with random effects fitted and the summary statistics of the maximum likelihood function that minimized the iterations search are shown in **Table 2**. The model accounted for 30.81 % of the variability of the observed log-cpue when incorporating the *year*quarter* interaction and *year*zone* interaction terms as random effects. Previous analysis of the bait boat fleet catch rates with fixed effects (GLM) model explained less variance of the data (Ortiz de Zárate *et al.*, 2014).

Thus, the present GLMM model with random components captures better the variability observed in the bait boat log-nominal catch rates used in the last assessment (ICCAT, 2013b; Ortiz de Zárate *et a*l., 2014), in regards temporal and spatial annual distribution of catches per unit of effort.

The quarterly least squares means and their standard error estimated by the GLM model with random components are shown in **Table 3**. The annual least squares means, their standard error and derived coefficient of variation, were estimated by the defined model assuming a log-normal model distribution, likewise the standardized catch rates (CPUEn) were estimated and are presented in **Table 4.** The annual corresponding number of observed trips had been included in the summary **Table 4**.

Density and frequency distribution of the log transformed response variable (CPUEn) for years 1981 to 2014, is shown in **Figure 2 a.** Diagnostics plots of the fitted model were evaluated and shown in **Figure 2 b-c**. Plots of the normalized cumulative residuals (or qq-residual plots), distribution of standardized residuals and standardized residuals by year for the dependent variable are presented. It is appreciate some negative residuals on the tail of the normal distribution, that don´t fit well the normal standard distribution. Those observations represent a number of trips with very low number of fish (i.e.1 or 2 fish) caught.On the other hand, a few large positive residuals are observed in the qq-plot, which represent extremely productive trips, scarce in number. As overall, the distribution of normalized residuals and the distribution of residuals do not exhibit large deviation from the model assumption, for the time series that had been analysed. The annual series of residuals show some deviation around the mean with not clear trend in the variability estimated on the observed data.

Standardized CPUEs series, expressed by number of fish per fishing day, for North Atlantic albacore and their respective 95% low and upper confidence intervals are presented in **Figure 3.** As shown, the temporal trend is quite stable, but a decrease from 1999 to 2003 and at the contrary an increase in recent years from 2011 to 2013, followed by a decrease in the latest year 2014, levelling off with the previous years of low catch rates. On the other hand, the quarterly annual time series of least squares means estimated by the GLM with random effects model are display in **Figure 4,** with the purpose of showing the variability explained by seasonality in the bait boat fishery, that corresponds to summer months (quarter 3) and autumn months(quarter 4) on annual bases.

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Table 1. Number of trips (OBS) sampled by quarter, zone and year, period 1981-2014.

Quarter	No.OBS	Zone	No.OBS
2	12	NE	914
3	2605	NW	304
4	500	SE	1857
		SW	42
Total	3117		3117

Table 2. Results of Generalized Linear Random Effects Model with log-normal error distribution.

REML Variance Component Estimates

Random Effect	**Var Ratio**	**Var Component**	**Std Error**	**95% Lower**	**95% Upper**	**Pct of Total**
QUARTER*YearC	0.2913076	0.210775	0.0646657	0.0840325	0.3375176	19.653
ZONE*YearC	0.1909438	0.138157	0.0329306	0.0736142	0.2026997	12.882
Residual		0.7235481	0.0187448	0.6881698	0.7617401	67.465
Total		1.0724801	0.0744591	0.9402931	1.2347982	100.000

-2 LogLikelihood = 8041.621648
Total including negative estimates = 1.0724801

Fixed Effect Tests

Source	**Nparm**	**DF**	**DFDen**	**F Ratio**	**Prob > F**
YearC	33	33	49.41	0.6448	0.9075
QUARTER	1	1	30.94	329.867	<.0001*
ZONE	3	3	85.21	10.672	0.3674

Table 3. Quarterly Standardized CPUEs series (nº of fish/fishing day) for albacore catch rates from Spanish bait boat fleet 1981-2014.

Level Q3	Year	Least Sq Mean	Std Error	Level Q4	Year	Least Sq Mean	Std Error
3	1981	4.8528163	0..32472431	4	1981	4.2042299	0.53125758
3	1982	4.8644218	0.29124451	4	1982	4.5256864	0.51812340
3	1983	5.28996	0.31308659	4	1983	4.8976236	0.34269911
3	1984	4.771186	0.32235983	4	1985	4.9724858	0.39211142
3	1985	4.9676392	0.26696433	4	1986	4.6606756	0.29161056
3	1986	4.7416191	0.24595535	4	1987	4.8519501	0.33149301
3	1987	5.2944981	0.24161733	4	1988	5.0586303	0.27736869
3	1988	5.0926327	0.23592264	4	1989	4.7992929	0.24469776
3	1989	4.9049441	0.21016785	4	1990	4.7515525	0.32149425
3	1990	5.6359451	0.25771717	4	1991	4.5874293	0.32934477
3	1991	5.3006347	0.23204923	4	1992	3.9235076	0.36740130
3	1992	5.4325586	0.27763217	4	1993	4.6438717	0.45785133
3	1993	5.2128496	0.29140073	4	1994	4.9821241	0.34593729
3	1994	5.5240008	0.26322993	4	1995	4.575013	0.40581036
3	1995	5.2816073	0.23580697	4	1997	4.6798126	0.31409376
3	1996	5.4420255	0.27227207	4	1998	5.0365377	0.51735379
3	1997	5.4826519	0.29100524	4	1999	3.7925391	0.38421891
3	1998	5.5882511	0.28275088	4	2000	3.5723845	0.35195727
3	1999	5.4760796	0.25388855	4	2001	3.8226607	0.57375092
3	2000	5.674871	0.24743778	4	2002	3.7236039	0.33719452
3	2001	4.6220003	0.23954028	4	2003	4.322228	0.32273365
3	2002	4.7669821	0.29537707	4	2004	4.440703	0.32141290
3	2003	5.5229645	0.24516897	4	2005	4.4555092	0.27055153
3	2004	5.4675044	0.26344564	4	2006	4.4654538	0.35159198
3	2005	5.4011402	0.22333274	4	2007	4.4217014	0.31655974
3	2006	6.2439123	0.28010271	4	2008	4.0922356	0.37587626
3	2007	5.6947412	0.27107280	4	2009	4.9467962	0.31951089
3	2008	5.4791342	0.28827999	4	2010	4.6757561	0.28229516
3	2009	5.5788387	0.23344964	4	2011	6.1303014	0.26125298
3	2010	5.4076557	0.23838487	4	2012	5.2673893	0.27181301
3	2011	5.4424284	0.22405987				
3	2012	5.8675935	0.23488553				
3	2013	5.7212772	0.24595090				
3	2014	5.025843	0.24684255				

Table 4. Nominal and Standardized CPUEs series (nº of fish/fishing day) for albacore catch rates from Spanish bait boat fleet. Years 1981-2014.

Year	**N Obs**	**Least Sq Mean**	**Std Error**	**CV(%)**	**Standard CPUE**	**Nominal CPUE**
1981	24	4.5285231	0.49642204	10.96	120.3355	121.4292693
1982	36	4.6950541	0.48283814	10.28	142.1404	127.4914918
1983	50	5.0937918	0.44069331	8.65	211.7810	168.7823284
1984	26	4.3969701	0.56499824	12.85	105.5021	107.1277137
1985	51	4.9700625	0.43666916	8.79	187.1337	143.6071434
1986	60	4.7011473	0.40713395	8.66	143.0091	133.0910272
1987	42	5.0732241	0.41051024	8.09	207.4696	184.8711294
1988	73	5.0756315	0.4018882	7.92	207.9697	179.5739725
1989	152	4.8521185	0.38866282	8.01	166.3143	144.5084434
1990	66	5.1937488	0.41942947	8.08	234.0441	242.162589
1991	66	4.944032	0.41179352	8.33	182.3254	178.7733803
1992	70	4.6780331	0.43934884	9.39	139.7415	161.7395635
1993	68	4.9283607	0.47011602	9.54	179.4904	213.8317414
1994	58	5.2530624	0.41722354	7.94	248.3461	227.0906829
1995	65	4.9283101	0.43209909	8.77	179.4813	209.4969042
1996	79	5.0678097	0.53820771	10.62	206.3494	235.881895
1997	61	5.0812322	0.43122842	8.49	209.1378	170.1862516
1998	60	5.3123944	0.48048349	9.04	263.5269	273.4039845
1999	88	4.6343094	0.43506255	9.39	133.7631	213.9485909
2000	118	4.6236277	0.42496877	9.19	132.3419	282.7576192
2001	118	4.2223305	0.48276325	11.43	88.5964	121.3417902
2002	119	4.245293	0.4440766	10.46	90.6544	94.88866142
2003	118	4.9225963	0.41845878	8.50	178.4587	209.3178811
2004	130	4.9541037	0.42352195	8.55	184.1710	203.9663919
2005	176	4.9283247	0.39947037	8.11	179.4839	186.30666
2006	154	5.3546831	0.4398092	8.21	274.9101	400.0069196
2007	146	5.0582213	0.4272679	8.45	204.3802	239.684974
2008	83	4.7856849	0.44484985	9.30	155.6245	205.4459361
2009	89	5.2628175	0.41127811	7.81	250.7806	205.4899811
2010	118	5.0417059	0.40450519	8.02	201.0325	166.1402948
2011	159	5.7863649	0.3983128	6.88	423.3189	270.9291372
2012	147	5.5674914	0.40429296	7.26	340.1043	326.8489622
2013	166	5.537182	0.41347689	7.47	329.9506	174.6188025
2014	81	4.6516271	0.52544766	11.30	136.0997	193.2818039

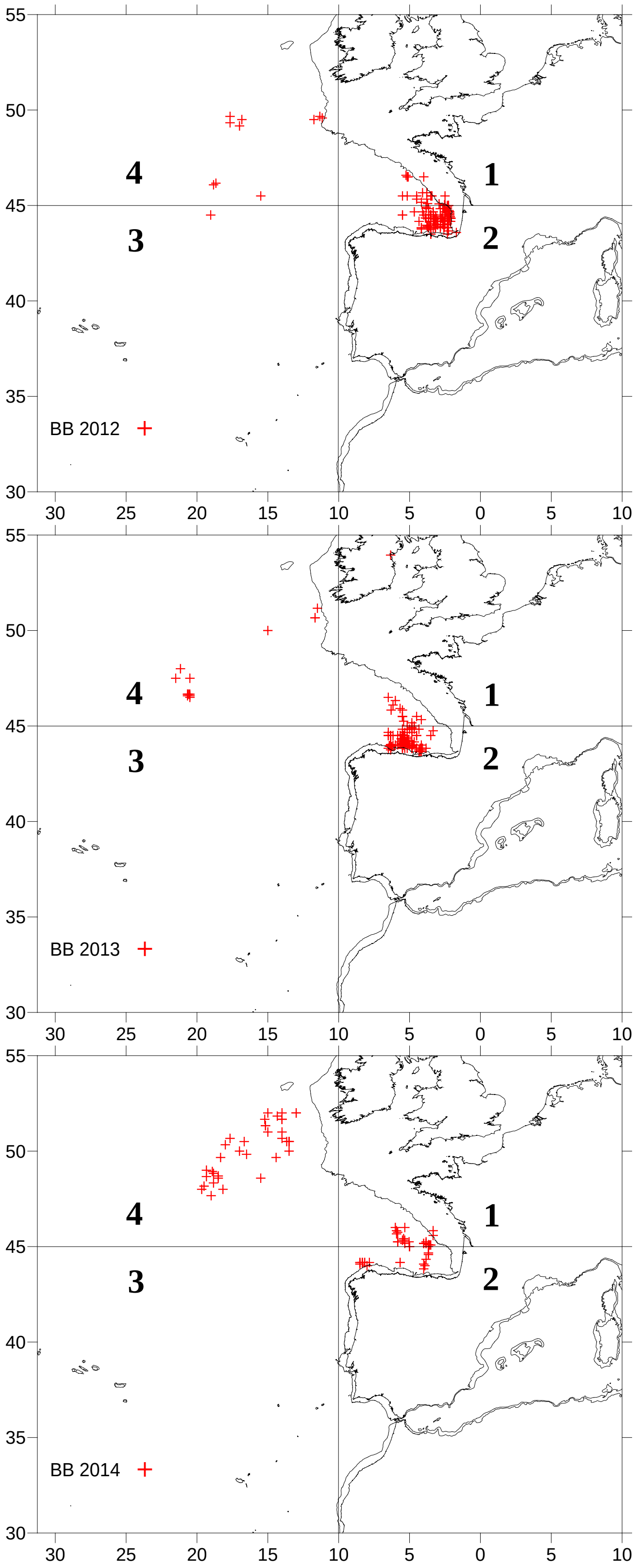

Figure 1. Annual spatial distribution of bait boat trips sampled to collect nominal CPUE´s information during 2012-2014. Levels of spatial factor Zone (1,2,3,4) used in the model are shown.

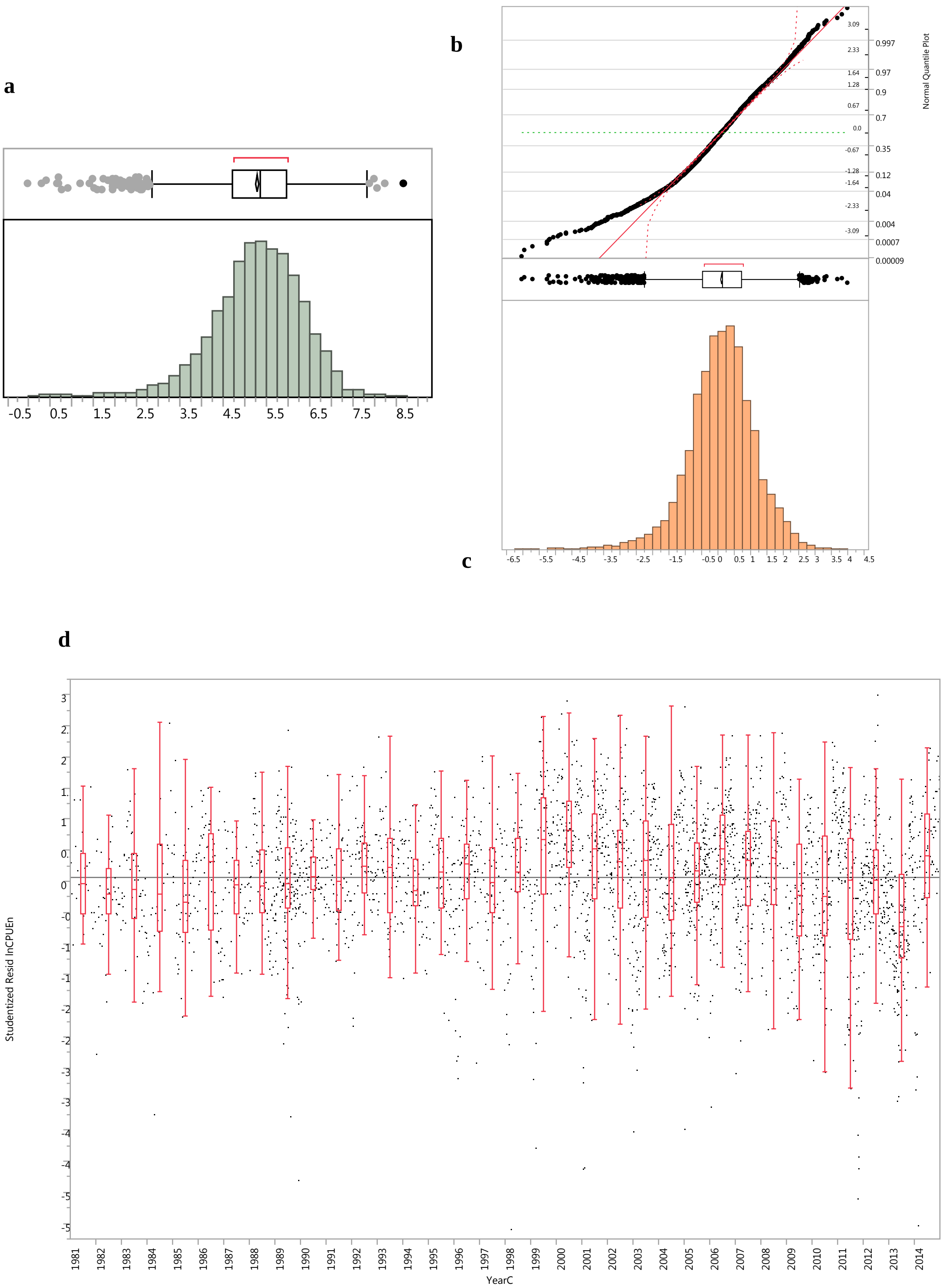

Figure 2. Model diagnostics plots from lognormal error distribution with main effects of Year, Quarter, Zone categories and Year by Quarter and Year by Zone random effects interaction, a) density and frequency distribution of log nominal CPUE bait boat 1981-2014, b) quantiles of standardized residuals, c) histogram of standardized residuals, d) Standardized residuals by year.

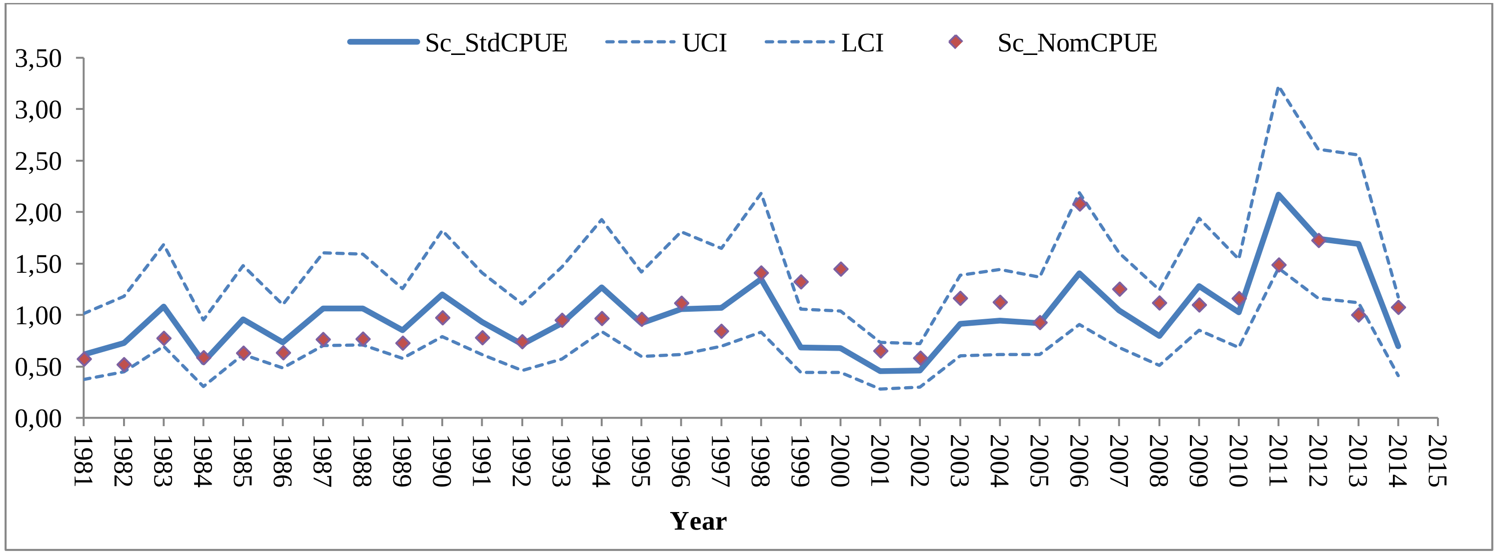

Figure 3. Estimated CPUEn (log-scale), low and upper confidence intervals of response variable from Spanish bait boat fleet, 1981-2014.

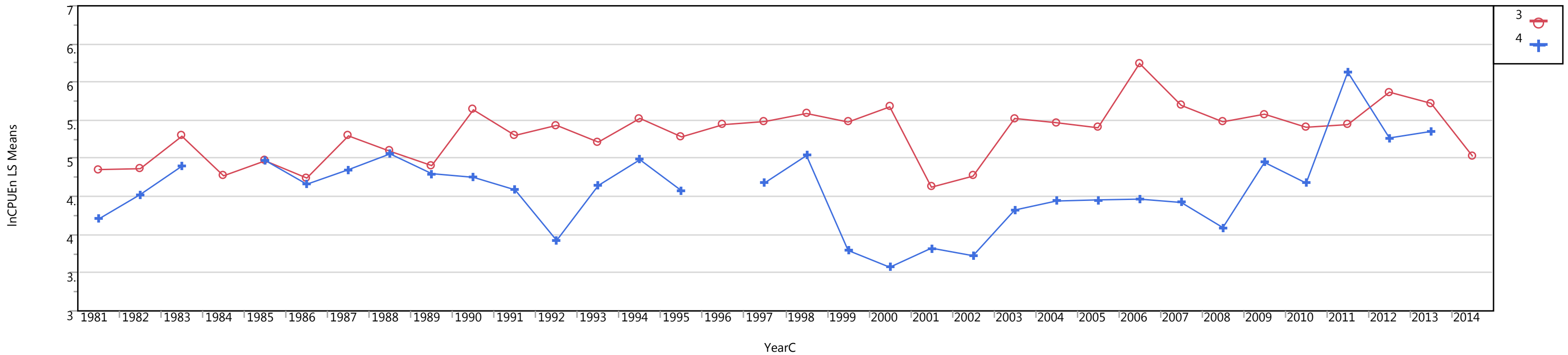

Figure 4. Estimated CPUEn (log-scale) by quarter from Spanish bait boat fleet, 1981-2014.