

**STANDARDIZED CATCH RATES FOR NORTHERN ALBACORE (*THUNNUS ALALUNGA*) FROM THE VENEZUELAN PELAGIC LONGLINE FISHERY OFF THE CARIBBEAN SEA AND ADJACENT AREAS OF THE WESTERN CENTRAL ATLANTIC**

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*SUMMARY*

*A standardized index of relative abundance for northern albacore (*Thunnus alalunga*) was developed by the combination of two data sources; the ICCAT/EPBR sponsored Venezuelan Pelagic Longline Observer Program (1991-2011), and the National Observer Program (2012-2014). The index was estimated using Generalized Linear Mixed Models under a delta lognormal model approach due to the by-catch nature of *T. alalunga* in the Venezuelan pelagic longline fishery. The standardization analysis procedure included year, vessel, area, season, bait, and fishing depth as categorical variables. Diagnostic plots were used as indicators of overall model fitting. The time series show that the relative abundance of northern albacore caught by the observed Venezuelan longline fleet reflects a relatively slow increasing trend since the early period reaching its highest value in 2008; thereafter the series drops to a low value in 2011. In the final years of the series, a strong increasing trend in the catch rates is observed, displaying the highest value in the last year.*

*RÉSUMÉ*

*Un indice standardisé de l'abondance relative du germon du Nord (*Thunnus alalunga*) a été élaboré en combinant les deux sources de données, à savoir le programme d'observateurs palangriers pélagiques du Venezuela parrainé par l'ICCAT/EPBR (1991-2011) et le programme d'observateurs nationaux (2012-2014). L'indice a été estimé à l'aide de modèles mixtes linéaires généralisés selon une approche du modèle delta-lognormale en raison de la nature de prise accessoire du *T. alalunga* dans la pêcherie palangrière pélagique vénézuélienne. La procédure d'analyse de la standardisation a inclus l'année, le navire, la zone, la saison, l'appât et la profondeur de la pêche qui ont servi de variables catégoriques. Des diagrammes de diagnostic ont été utilisés comme indicateurs de l'ajustement global du modèle. Les séries temporelles ont montré que l'abondance relative du germon du nord capturé par la flottille palangrière vénézuélienne observée affiche une tendance à la hausse relativement lente depuis le début de la période, atteignant sa plus forte valeur en 2008, puis chutant par la suite à une faible valeur en 2011. Dans les dernières années de la série, une forte tendance à la hausse est observée dans les taux de capture, affichant la valeur la plus élevée au cours de la dernière année.*

*RESUMEN*

*Se desarrolló un índice de abundancia relativa para el atún blanco del norte (*Thunnus alalunga*) mediante la combinación de dos fuentes de datos: el programa de observadores de palangre pelágico de Venezuela (1991-2011) auspiciado por el ICCAT/EPBR y el Programa nacional de observadores (2012-2014). El índice se estimó utilizando modelos lineales mixtos generalizados con un enfoque del modelo delta lognormal debido a la naturaleza de captura fortuita de *T. alalunga* en la pesquería de palangre pelágico venezolana. El procedimiento del análisis de estandarización incluía año, buque, área, temporada, cebo y profundidad de pesca*

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como variables categóricas. Los diagramas de diagnóstico se utilizaron como indicadores del ajuste global del modelo. Las series temporales muestran que la abundancia relativa del atún blanco del norte capturado por la flota de palangre venezolana observada reflejan una tendencia de crecimiento relativamente lento en el periodo inicial de la serie, alcanzando su valor máximo en 2008, para posteriormente descender hasta una valor bajo en 2011. En los años finales de la serie, se observa una fuerte tendencia ascendente en las tasas de captura, presentando el valor más elevado en el último año.

## KEYWORDS

*Northern albacore, Catch rates, Caribbean Sea, Venezuelan longline fishery*

## Introduction

The Venezuelan pelagic longline fleet operates over an important geographical area in the southwestern quadrant of the North Atlantic and its main target species were yellowfin tuna and swordfish since 1986 through the late 1990s, thereafter, yellowfin tuna became the main target species. However, bycatch species such as billfish, albacore tuna, and sharks have been commonly caught and commercialized locally throughout the history of the fishery. In 1991, ICCAT's Enhanced Program for Billfish Research (EPBR) in Venezuela started placing scientific observers on board Venezuelan pelagic longliners targeting tuna and swordfish. The data collected has been instrumental to estimate robust standardized catch rates for several ICCAT species caught by the Venezuelan pelagic longline fleet (e.g., BSH, Arocha et al. 2015; WHM, Arocha et al. 2012; YFT, Arocha et al. 2004); mostly because of persisting difficulties in obtaining non-aggregated pelagic longline log book data by species.

Albacore (*Thunnus alalunga*) is considered a by-catch of the Venezuelan longline fishery, average albacore catches in the longline fishery represents ~13 % of the total tropical tuna (YFT, BET, BLF) catches for the period of 1986-2013. Historically, albacore longline catches since 1986 were below 150 t, until 2009, when a steady increase of over 200 t have been consistent over several years showing a steady increasing trend (ICCAT, 2015). In an effort to contribute to the northern albacore stock assessment, standardized catch rates of northern albacore, as a measure of an abundance index, were estimated for the southwestern quadrant of the North Atlantic from data collected by the Venezuelan pelagic longline observer programs. This document reports on the analytical methods and provides abundance indices for the period of 1991-2014.

## Materials and Methods

The data used in this study came from the database of the ICCAT sponsored EPBR Venezuelan Pelagic Longline Observer Program (VPLOP) for the period 1991-2011 and from INSOPESCA's National Observer Program for the period 2012-2014 (Gassman et al., 2014). Arocha and Marcano (2001) described the main features of the fleet, and Marcano *et al.* (2005, 2007) reviewed the available catch and effort data from the Venezuelan Pelagic Longline fishery covered by the observer program. The VPLOP surveys on average 10,9% of the Venezuela longline fleet trips during the period of 1991-2011 (Arocha et al., 2013), and about 5% from INSOPESCA's 2012-2014 observer program. Of the 6,901 sets observed, northern albacore was reported caught in 3,636 sets (52.69 %). Detailed information collected in the VPLOP, as well as fishing grounds for the Venezuelan fleet is the same as described in Ortiz and Arocha (2004). Factors considered in the analyses of catch rates included: bait type and condition, depth of the hooks, area of fishing, and season, defined to account for seasonal fishery distribution through the year (*i.e.*, Jan-Mar, Apr-Jun, Jul-Sep and Oct-Dec). As in prior CPUE analyses for the Venezuelan pelagic longline fleet, vessels were classified into 3 categories based on the vessel size primarily (Ortiz and Arocha, 2004). Fishing effort is reported in terms of the total number of hooks per trip and number of sets per trip, as the number of hooks per set, varied; catch rates were calculated as number of northern albacore caught per 1000 hooks.

For the Venezuelan longline observer data, relative indices of abundance for northern albacore were estimated by Generalized Linear Modeling approach assuming a delta lognormal model distribution following the same protocol as described in Ortiz and Arocha (2004). A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. Deviance analysis tables are presented for the proportion of positive observations (i.e., positive sets/total sets), and for the positive catch rates. Final selection of explanatory factors was conditional to: a) the relative percent of deviance explained by adding the factor in evaluation and, b) The  $\chi^2$  significance. The vessel factor was evaluated as a categorical grouping (similar to prior analysis of this database) in which 3 groups were defined according to their size, amount of gear deployed, main fishing area, target species, and the spatial distribution of the vessels (see Ortiz and Arocha, 2004; Table 1b).

Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), the Bayesian Information Criterion (BIC), and a  $\chi^2$  test of the difference between the [-2 loglikelihood] statistic of a successive model formulations (Littell et al., 1996). Relative indices for the delta model formulation were calculated as the product of the year effect least square means (LSmeans) from the binomial and the lognormal model components. The LSmeans estimates use a weighted factor of the proportional observed margins in the input data to account for the non-balance characteristics of the data. LSMeans of lognormal positive trips were bias corrected using Lo et al., (1992) algorithms. Analyses were done using the Glimmix and Mixed procedures from the SAS® statistical computer software (SAS Institute Inc. 1997).

## Results and Discussion

The nominal effort of the Venezuelan pelagic longline fleet is mostly distributed in the eastern Caribbean Sea, off the northeastern shelf of South America (the Guyana-Amazon area), and occasionally northeast of the Antillean Arc Chain of Islands. The observed effort of the fleet over the time period is reflected in the annual spatial pattern of the effort in number of hooks deployed over the time series analyzed (**Figure 1**). The effort observed northeast of the Antillean Arc Chain of Islands was mostly attributed to fishing operations directed at northern albacore conducted by three vessels during spring and early summer between 1995 and 2003 (**Figure 2**). Thereafter, those few vessels' operations were re-directed at tropical tunas in the Caribbean Sea. The most important catch rates of northern albacore since 2004 come from the Guyana-Amazon area and caught as by-catch in tropical tuna fishing operations of the Venezuelan longline fleet.

The historic fraction of northern albacore in the Venezuelan longline catch ranged from 0 to 31% over the time series, with a mean catch fraction of approximately 12% (**Figure 3**). However, since the large drop in 1994-1995, the recent historic fraction of northern albacore show an uneven but steady increase reaching over 25% in the last two years of the series.

The deviance analysis for northern albacore from the Venezuelan observer data analyses are presented in **Table 1** based on the numbers of fish as catch rates. For the mean catch rate given that it is a positive set, the factors: *Year*, *Vessel\_Cat*, *Area*, *Season*, and; and the interactions *Year*×*Vessel\_Cat*, *Year*×*Area*, and *Year*×*Season* were the major factors that explained whether or not a set caught at least one fish. For the proportion of positive/total sets; *Year*, *Vessel\_Cat*, *Areas*, *Season*, and *Bait Condition*; and the interactions *Year*×*Area*, *Year*× *Vessel\_Cat*, and *Year*×*Season* were more significant. Once a set of fixed factors were selected, first level random interaction between the year and other effects were evaluated.

The results from the random test analyses for northern albacore and the three-model selection criterion indicate, that for the conditional mean catch rate (i.e., positive observations), the final mixed model included the *Year*, *Vessel\_Cat*, *Season*, *Area*, and *Bait* as fixed factor and the random interactions, *Year*×*Vessel\_Cat*, *Year*×*Season*, *Year*×*Area*, and *Year*×*Bait*. (**Table 2**). For the proportion of positive/total sets, the final model included the *Year*, *Vessel\_Cat*, *Area*, *Season*, and *Bait* as main fixed factors and the random interactions, *Year*×*Season* and *Area*×*Season*.

Once a final model was defined, a set of diagnostics were evaluated to determine; a) deviations from the model assumptions, and b) observations with significant influence or departure from the main trends. The binomial proportion of the positive sub-model include plots (**Figure 4 a-d**) for a check of the link function, the variance function, the check for the error distribution of the model, and the qq-plot (normalized cumulative quartile plot) of the standardized deviance residuals. All diagnostic plots show no indication of departure from the expected or null pattern, the linear trend fit (broken line) and smother (loess) trend (solid line) for all plots fall within the expected pattern. The next set of plots (**Figure 5 a-f**), check for the scale of fixed factors and covariates in the model. Results indicate no strong departures from the expected pattern (i.e., a constant range about the zero line).

A series of plots that check for indication of influential observations in the model are presented in **Figure 6**. The first plot (upper left) is the deviance residuals of each observation, the second plot is the estimates of leverage (diagonal elements of the 'hat' matrix), and they represent the influence of a given observation in the fit. The third plot shows observations with Cook's distances estimated that have greater influence. The next plot is the estimated restricted likelihood distances (RLD) (SAS, 2008), a global measure of the influence of the observations on all parameters. The greater the RLD, the greater their influence in the model overall fit. The fifth plot is a combination of the leverage and Cook's distance estimates, on this plot observations within the upper-right region delimited by the broken lines (cut-off values of leverage and Cook's distance) represent observations with high influence and high leverage overall. Of 491 observations, only three observations showed high influence and leverage; thus no action was taken.

In GLM models with random components in the model fit, a series of plots provide information on the influence of given observations on the overall unconditional predicted values (fixed factor expectation and random assumption influence) (**Figure 6**). First, is the PRESS residuals plot (SAS, 2008), PRESS residual measure influences as the difference between the observed value and the predicted (marginal) mean, where the predicted value is obtained without the observations in question. High PRESS residuals indicate observations with large influence in model fit. Another measure of influence for GLM mixed models is the DFFITS, which is similar to Cook's distances, large values indicate greater changes in the parameter estimates relative to the variability of the variability of the parameter. Finally, the Covariance ratio estimates measure the impact of an observation in the precision of a vector of estimates (SAS, 2008). In general, most observations were within the expected pattern, the few observations that appeared to be influential did not affect the overall model fit.

Model diagnostics for the positive observations of the lognormal sub-model, are the same as for the binomial sub-model; that is, checks for the link function, variance function, error distribution, the normalized cumulative quartile (**Figure 7 a-d**), and check for the scale of fixed factors and covariates in the model (**Figure 8 a-f**). Similarly, checks for indication of influential observations for the positive observations of the lognormal sub-model (**Figure 9**) included, deviance residuals, Leverage, Cook's distance, RLD, PRESS residuals, DFFITS and Covariance ratio plot. No strong variations were observed, thus we can conclude that the model is not grossly wrong.

The distributions of normalized residuals and the diagnostic plots of the distribution of residuals (**Figure 10 a-e**) do not show strong deviations from the expected null pattern.

Standardized CPUE series for northern albacore are shown in **Table 3** and **Figure 11**. Coefficients of variation ranged from 40% to 62% for the selected model fit based on catch rates of numbers of fish and vessel category. The time series show that the relative abundance of northern albacore caught by the observed Venezuelan longline fleet reflects a relatively slow increasing trend since the early period of the series reaching its highest value in 2008, thereafter the series drops to a low value in 2011. In the final years of the series, a strong increasing trend in the catch rates is observed, displaying the highest value in the last year.

Considering that the information that exists in logbooks do not reflect the catch of northern albacore and that there is a potential high degree of under-reporting, the standardized CPUE index based on observer data can be used as a proxy to reflect the overall trend in relative abundance of northern albacore caught by the Venezuelan longline fleet in the southeastern Caribbean Sea and the northeastern area of South America.

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**Table 1.** Deviance analysis table for explanatory variables in the delta lognormal mix model for **northern albacore** catch rates (**in numbers**) from the ICCAT/EPBR Venezuelan Pelagic Longline Observer Program (VPLOP) and INSOPESCA’s Observer Program. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the probability Chi-square test between two nested models. The mean catch rate for positive observations assumed a lognormal error distribution.

*Albacore Vza PLL CPUE Index*

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	<i>p</i>
1	1	4968.326			
Year	23	4270.8278	697.50	23.3%	< 0.001
Year Vc	2	4010.277	260.55	8.7%	< 0.001
Year Vc Area	2	2335.7232	1674.55	55.9%	< 0.001
Year Vc Area Season	3	2266.0269	69.70	2.3%	< 0.001
Year Vc Area Season Depthc	1	2265.0224	1.00	0.0%	0.316
Year Vc Area Season Depthc Btype	3	2234.8286	30.19	1.0%	< 0.001
Year Vc Area Season Depthc Btype Bcond	1	2163.8878	70.94	2.4%	< 0.001
Year Vc Area Season Depthc Btype Bcond Depthc*Bcond	1	2156.7828	7.11	0.2%	0.008
Year Vc Area Season Depthc Btype Bcond Vc*Area	3	2154.4796	9.41	0.3%	0.024
Year Vc Area Season Depthc Btype Bcond Area*Season	5	2152.7826	11.11	0.4%	0.049
Year Vc Area Season Depthc Btype Bcond Area*Bcond	2	2151.9174	11.97	0.4%	0.003
Year Vc Area Season Depthc Btype Bcond Area*Btype	5	2144.4596	19.43	0.6%	0.002
Year Vc Area Season Depthc Btype Bcond Vc*Season	6	2139.643	24.24	0.8%	< 0.001
Year Vc Area Season Depthc Btype Bcond Vc*Bcond	2	2138.9575	24.93	0.8%	< 0.001
Year Vc Area Season Depthc Btype Bcond Area*Depthc	2	2125.1137	38.77	1.3%	< 0.001
Year Vc Area Season Depthc Btype Bcond Vc*Btype	6	2125.1009	38.79	1.3%	< 0.001
Year Vc Area Season Depthc Btype Bcond Vc*Depthc	2	2105.287	58.60	2.0%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Bcond	17	2104.2735	59.61	2.0%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Depthc	15	2082.4844	81.40	2.7%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Btype	35	2044.9361	118.95	4.0%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Season	66	2003.4792	160.41	5.4%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Area	26	2003.17	160.72	5.4%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Vc	29	1971.6984	192.19	6.4%	< 0.001

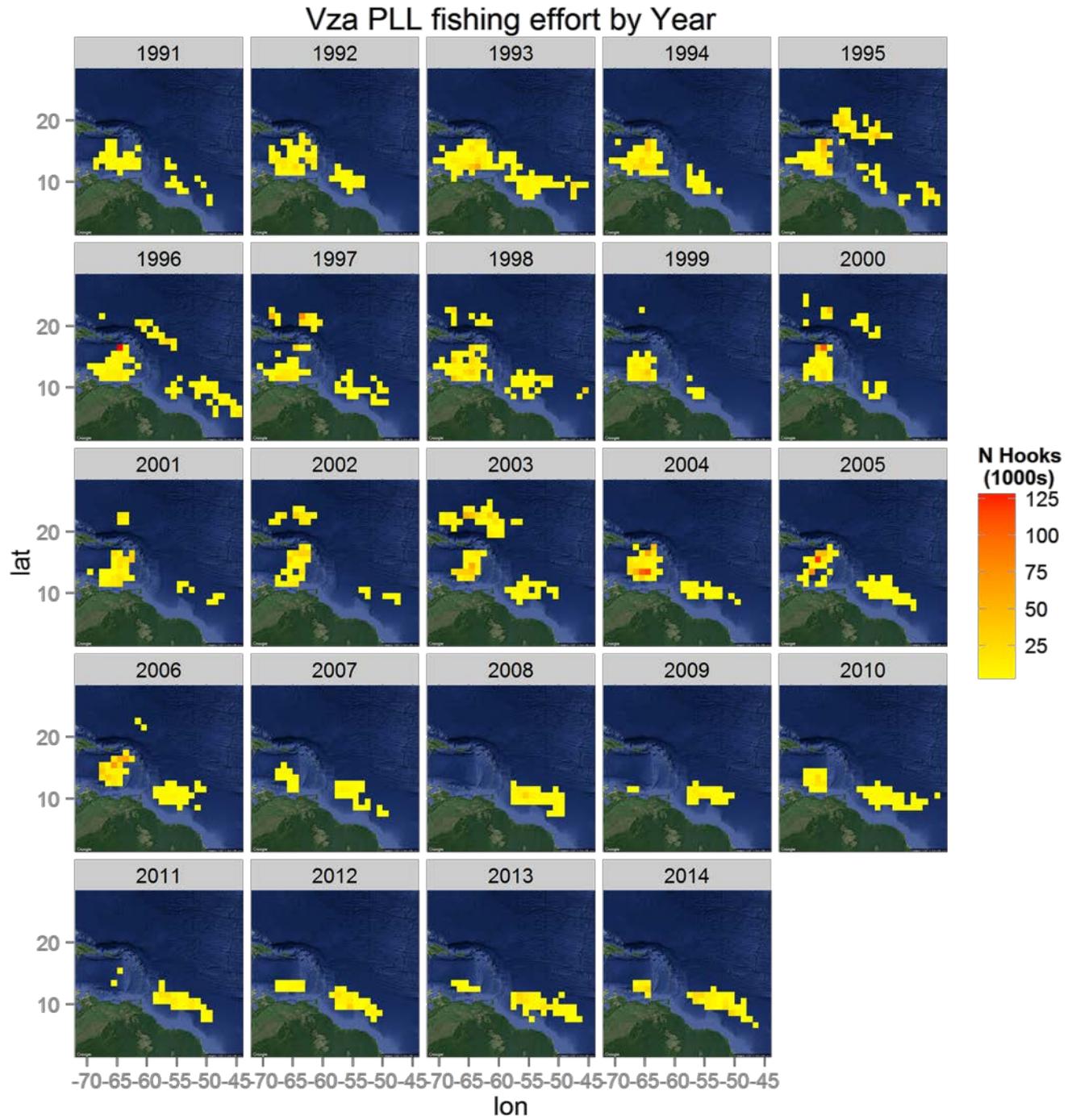
Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	<i>p</i>
1	0	4232.480			
Year	23	2824.952	1407.53	36%	< 0.001
Year Vc	2	2282.349	542.60	14%	< 0.001
Year Vc Area	2	1737.119	545.23	14%	< 0.001
Year Vc Area Season	3	1591.345	145.77	4%	< 0.001
Year Vc Area Season Depthc	1	1584.027	7.32	0%	0.007
Year Vc Area Season Depthc Btype	3	1562.927	21.10	1%	< 0.001
Year Vc Area Season Depthc Btype Bcond	1	1451.047	111.88	3%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Area	29	1230.406	220.64	6%	< 0.001
Year Vc Area Season Depthc Btype Bcond Year*Vc	28	1015.897	214.51	6%	< 0.001
Year Vc Area Season Depthc Btype Bcond Vc*Area	3	1011.910	3.99	0%	0.263
Year Vc Area Season Depthc Btype Bcond Year*Season	69	669.201	342.71	9%	< 0.001
Year Vc Area Season Depthc Btype Bcond Area*Season	5	646.356	22.85	1%	< 0.001
Year Vc Area Season Depthc Btype Bcond Vc*Season	6	627.051	19.30	0%	0.004
Year Vc Area Season Depthc Btype Bcond Year*Depthc	15	596.078	30.97	1%	0.009
Year Vc Area Season Depthc Btype Bcond Area*Depthc	2	590.732	5.35	0%	0.069
Year Vc Area Season Depthc Btype Bcond Vc*Depthc	2	583.909	6.82	0%	0.033
Year Vc Area Season Depthc Btype Bcond Season*Depthc	3	578.420	5.49	0%	0.139
Year Vc Area Season Depthc Btype Bcond Year*Btype	42	475.595	102.82	3%	< 0.001
Year Vc Area Season Depthc Btype Bcond Area*Btype	4	467.959	7.64	0%	0.106
Year Vc Area Season Depthc Btype Bcond Vc*Btype	5	461.974	5.99	0%	0.308
Year Vc Area Season Depthc Btype Bcond Season*Btype	9	438.478	23.50	1%	0.005
Year Vc Area Season Depthc Btype Bcond Depthc*Btype	3	430.644	7.83	0%	0.050
Year Vc Area Season Depthc Btype Bcond Year*Bcond	19	382.202	48.44	1%	< 0.001
Year Vc Area Season Depthc Btype Bcond Area*Bcond	2	376.886	5.32	0%	0.070
Year Vc Area Season Depthc Btype Bcond Vc*Bcond	2	370.834	6.05	0%	0.049
Year Vc Area Season Depthc Btype Bcond Season*Bcond	3	368.373	2.46	0%	0.482
Year Vc Area Season Depthc Btype Bcond Depthc*Bcond	1	364.092	4.28	0%	0.039
Year Vc Area Season Depthc Btype Bcond Btype*Bcond	2	358.218	5.87	0%	0.053

**Table 2.** Analyses of delta lognormal mixed model formulations for **northern albacore** catch rates (**in numbers**) from the ICCAT/EPBR Venezuelan Pelagic Longline Observer Program (VPLOP) and INSOPESCA’s Observer Program. Likelihood ratio tests the difference of  $-2$  REM log likelihood between two nested models. The highlighted model indicates the selected model for each component of the delta mixed model.

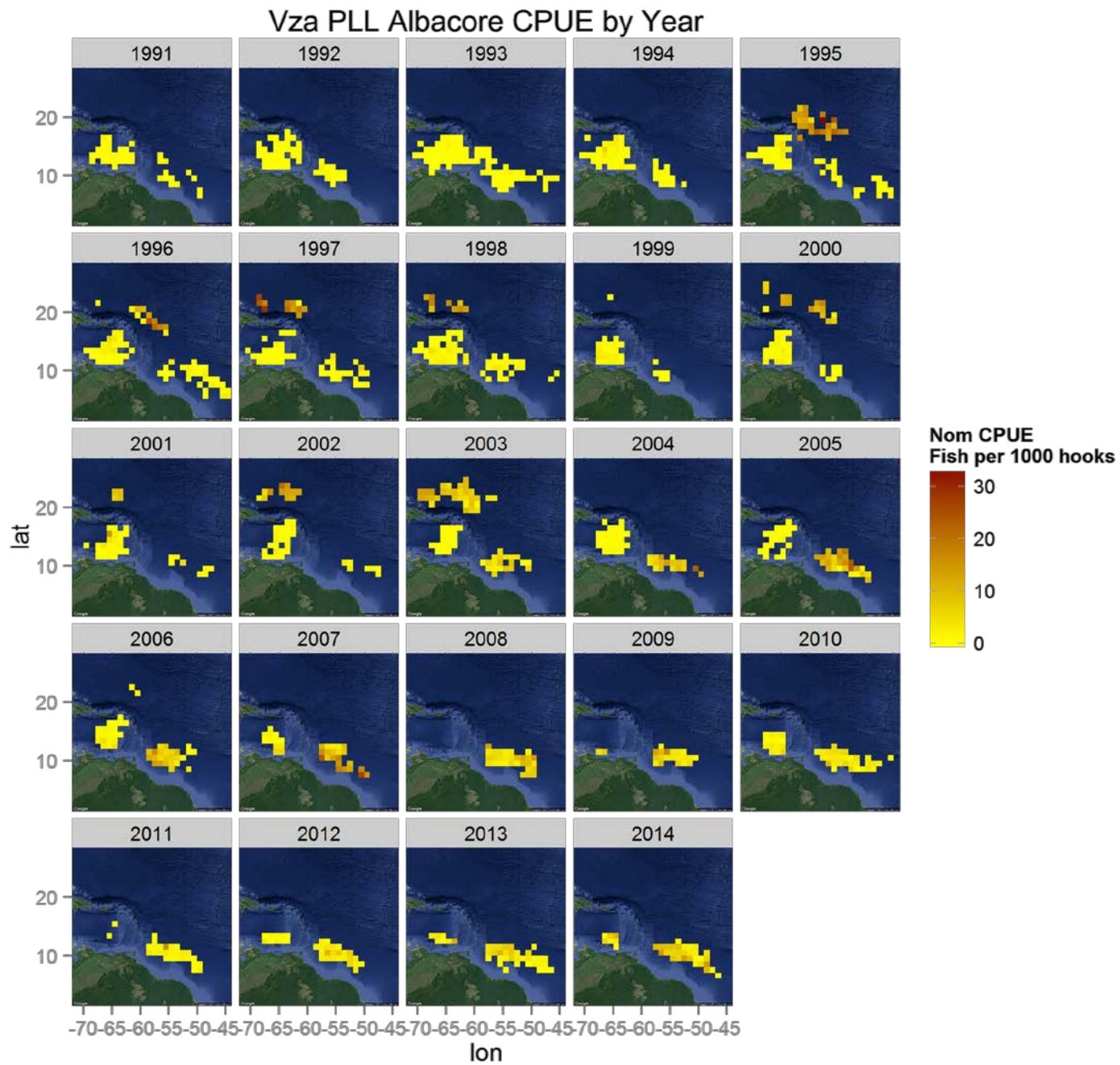
GLMixed Model	-2 REM Log likelihood	Akaike's Information Criterion	Bayesian Information Criterion	Likelihood Ratio Test	
<b>Proportion Positives</b>					
Year VesCat Area Season Bait	1924.7	1926.7	1930.8		
Year VesCat Area Season Bait <i>Year*Season</i>	1919.4	1923.4	1928.6	5.3	0.0213
<b>Year VesCat Area Season Bait <i>Year*Season Year*VesCat</i></b>	1879.7	1885.7	1893.4	39.7	0.0000
Year VesCat Area Season Bait <i>Year*Season Year*Area</i>	1877.8	1885.9	1896	1.9	0.1681
<b>Positives catch rates</b>					
Year VesCat Area Season Bait	8769.5	8771.5	8777.7		
Year VesCat Area Season Bait <i>Year*VesCat</i>	8541.6	8545.6	8549.6	227.9	0.0000
Year VesCat Area Season Bait <i>Year*VesCat Year*season</i>	8471.9	8477.9	8483.9	69.7	0.0000
Year VesCat Area Season Bait <i>Year*VesCat Year*season Year*Area</i>	8445.5	8453.5	8461.6	26.4	0.0000
<b>Year VesCat Area Season Bait <i>Year*VesCat Year*season Year*Area Year*Bait</i></b>	8399.1	8409.1	8419.1	46.4	0.0000

**Table 3.** Nominal and standardized (Delta lognormal mixed model) CPUE series (nos. of fish/1000 hooks) for **northern albacore** catch rates from the ICCAT/EPBR Venezuelan Pelagic Longline Observer Program (VPLOP) and INSOPESCA's Observer Program.

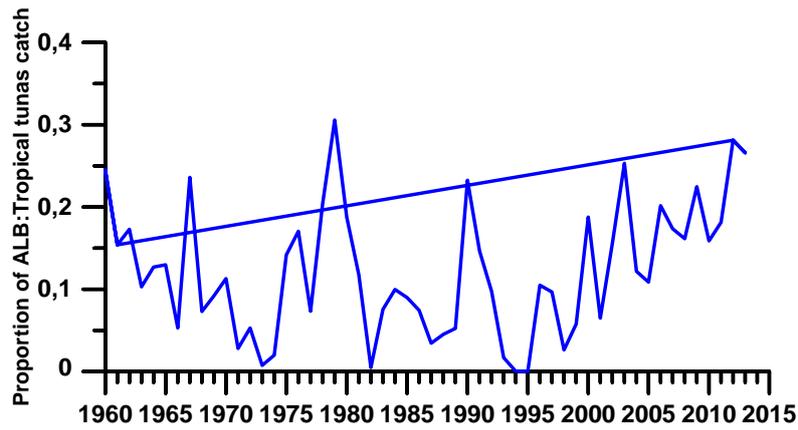
<b>Year</b>	<b>N Obs</b>	<b>Nominal Cpue</b>	<b>Standard CPUE</b>	<b>Low CI</b>	<b>Upp CI</b>	<b>CV</b>	<b>std error</b>
1991	108	0.322	0.354	0.12	1.07	60%	0.628
1992	270	0.228	0.407	0.13	1.26	62%	0.739
1993	470	0.184	0.341	0.11	1.07	62%	0.626
1994	340	0.691	0.667	0.26	1.74	51%	1.001
1995	483	5.494	0.787	0.31	2.03	50%	1.164
1996	395	2.756	0.795	0.34	1.87	45%	1.053
1997	367	5.019	0.856	0.33	2.22	51%	1.280
1998	457	2.021	1.082	0.49	2.40	42%	1.328
1999	356	1.509	1.054	0.40	2.78	52%	1.605
2000	334	2.805	1.154	0.51	2.63	43%	1.464
2001	280	1.441	0.672	0.29	1.54	43%	0.863
2002	221	3.470	0.840	0.32	2.22	52%	1.284
2003	326	5.054	1.040	0.47	2.32	42%	1.281
2004	332	2.502	1.089	0.47	2.55	45%	1.433
2005	266	4.521	1.150	0.50	2.65	44%	1.481
2006	313	4.576	1.177	0.54	2.55	40%	1.394
2007	98	9.273	1.958	0.88	4.37	42%	2.417
2008	180	5.722	2.031	0.79	5.24	50%	3.014
2009	147	6.440	1.085	0.42	2.81	50%	1.614
2010	230	2.580	0.910	0.33	2.50	54%	1.450
2011	227	2.285	0.521	0.17	1.61	61%	0.943
2012	198	3.310	0.785	0.29	2.09	52%	1.207
2013	287	4.382	1.366	0.47	3.93	57%	2.292
2014	414	6.909	1.881	0.66	5.35	56%	3.117



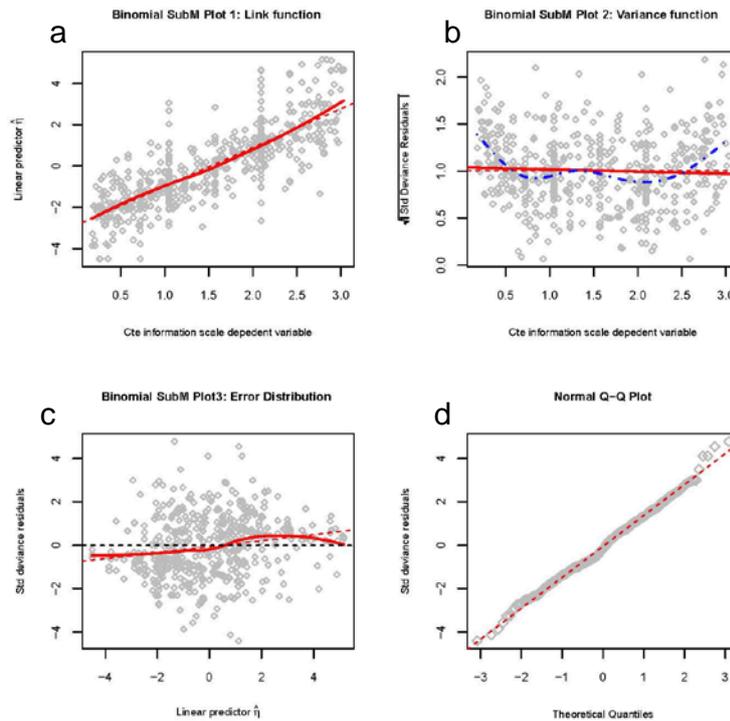
**Figure 1.** Annual spatial distribution of nominal effort (nos. of hooks) of the observed Venezuelan pelagic longline fleet during 1991-2014 and recorded by the VPLOP and PNOB.



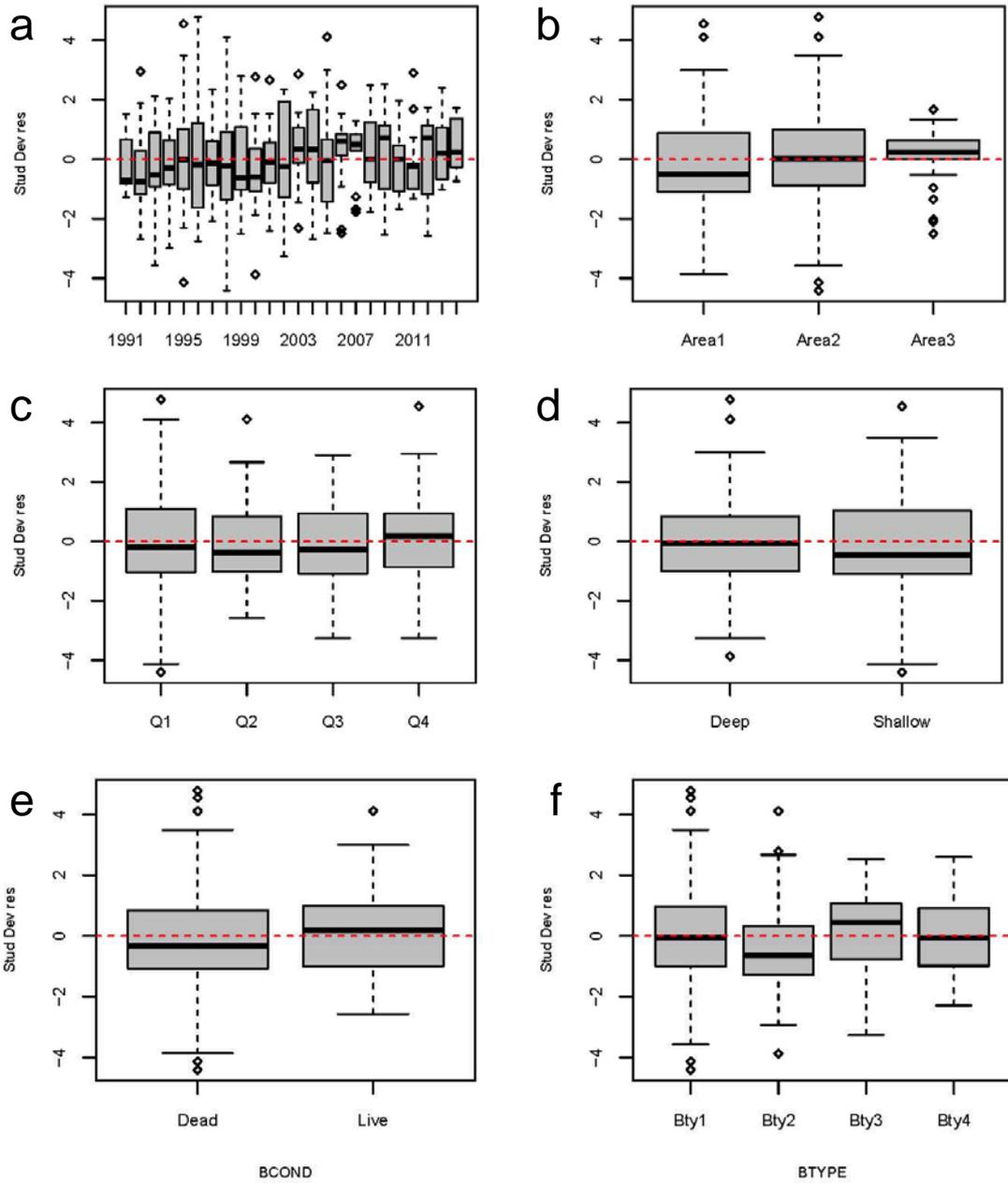
**Figure 2.** Annual spatial distribution of nominal CPUE of **northern albacore** (no. of fish/1000 hooks) caught by the Venezuelan pelagic longline fleet during 1991-2014 and recorded by the VPLOP and PNOB.



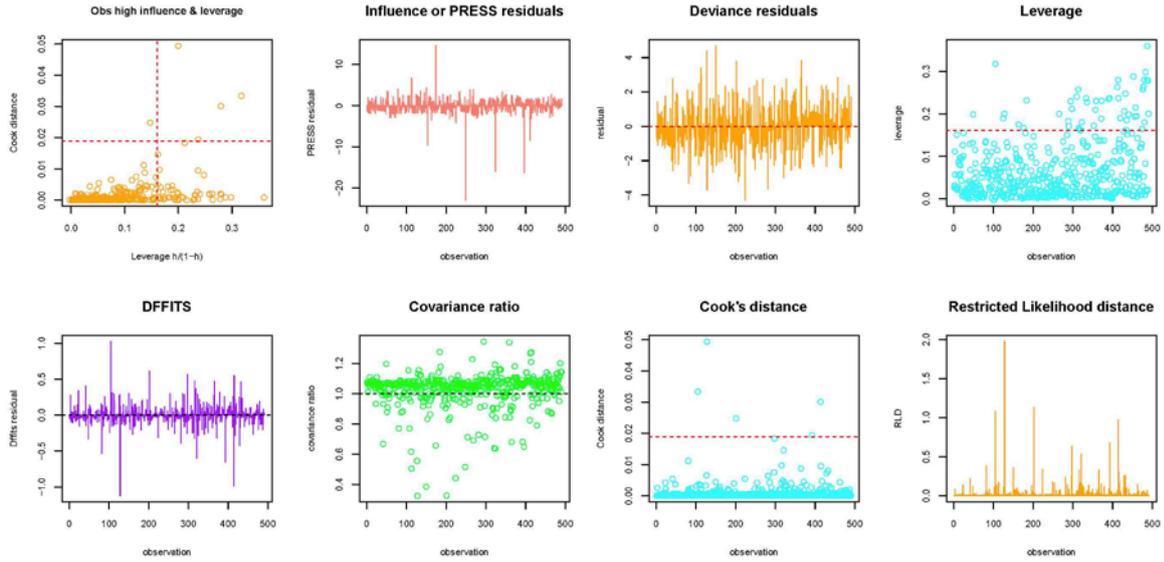
**Figure 3.** Historical fraction of **northern albacore** catch in the Venezuelan pelagic longline fishery.



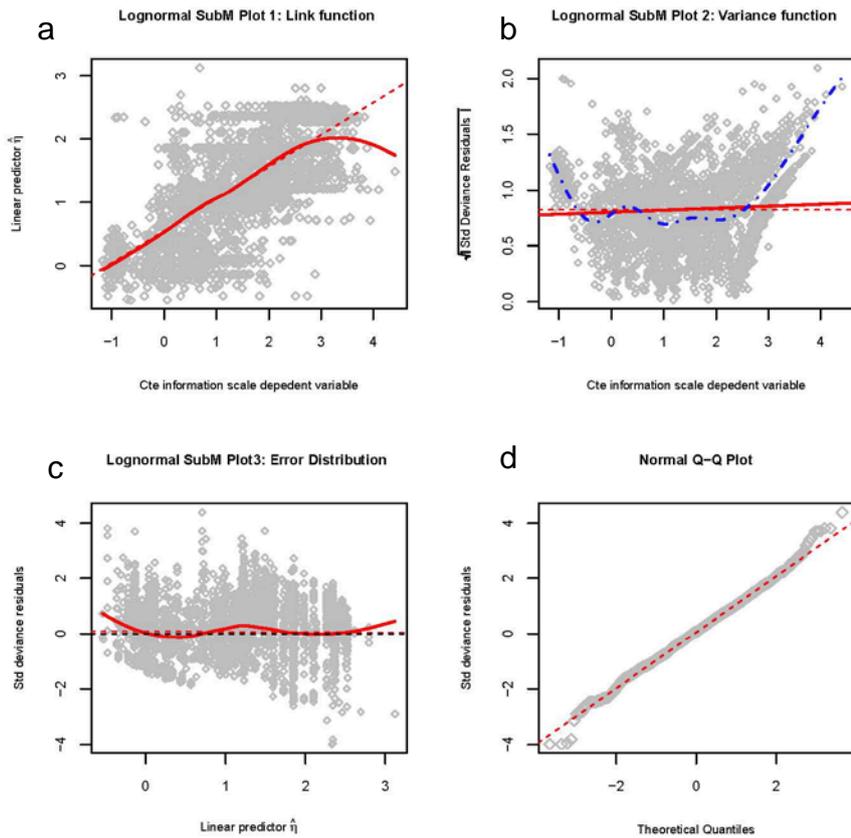
**Figure 4.** Diagnostic plots for the binomial proportion of the positive sub-model, a) for a check of the link function, b) the variance function, c) the check for the error distribution of the model, d) the qq-plot of the standardized deviance residuals.



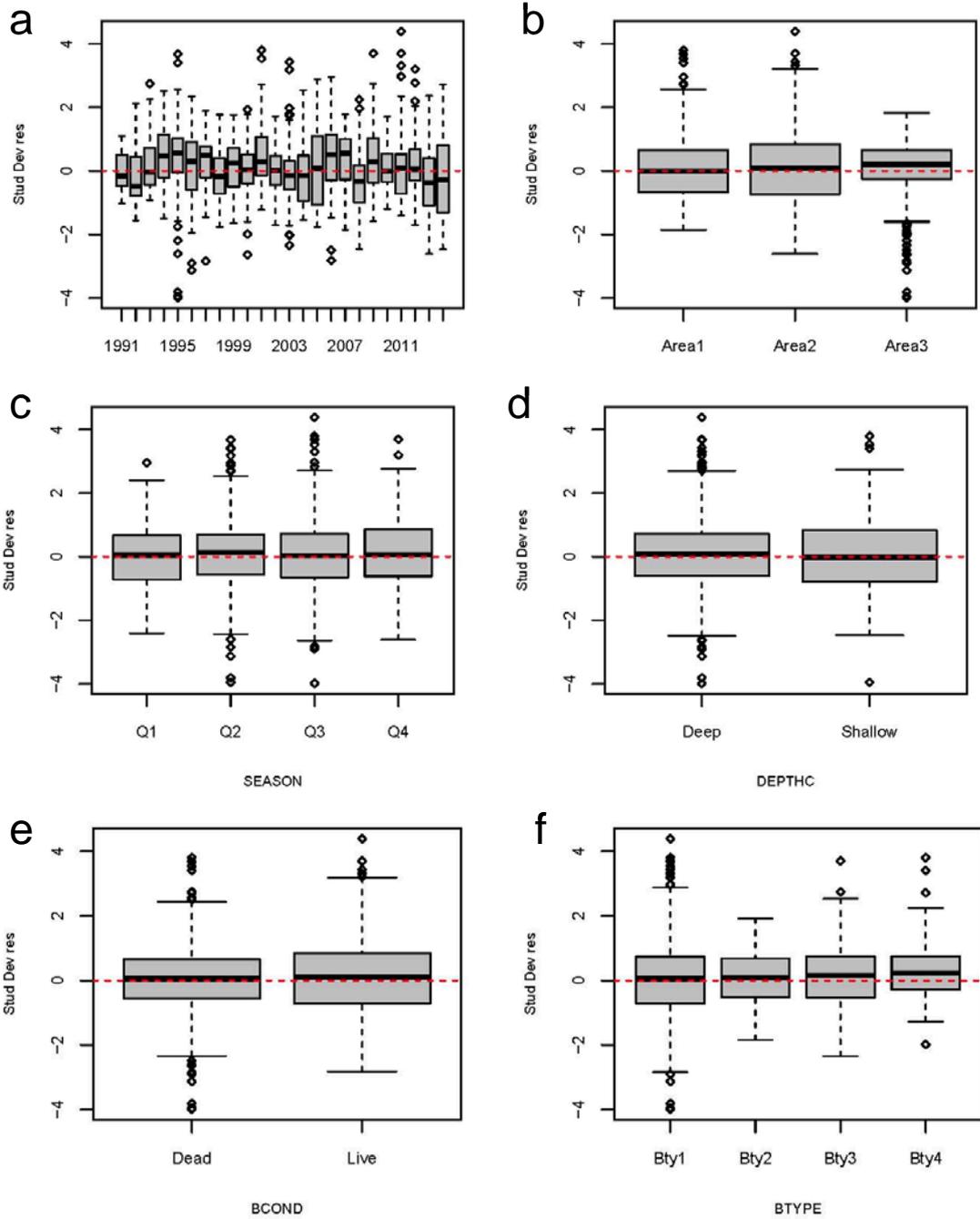
**Figure 5.** a-f) Check for the scale of fixed factors and covariates in the binomial proportion of the positive sub-model.



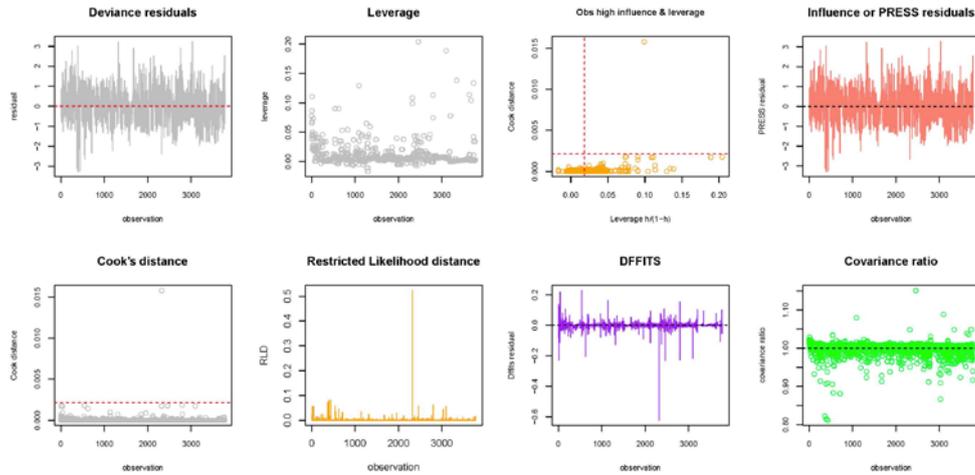
**Figure 6.** Diagnostic plots for indication of influential observations in the binomial proportion of the positive sub-model model: Deviance residuals, Leverage, Cook's distance, Restricted Likelihood distance (RLD), Cook's/Leverage, PRESS residuals, DFFITS, and Covariance ratio plot.



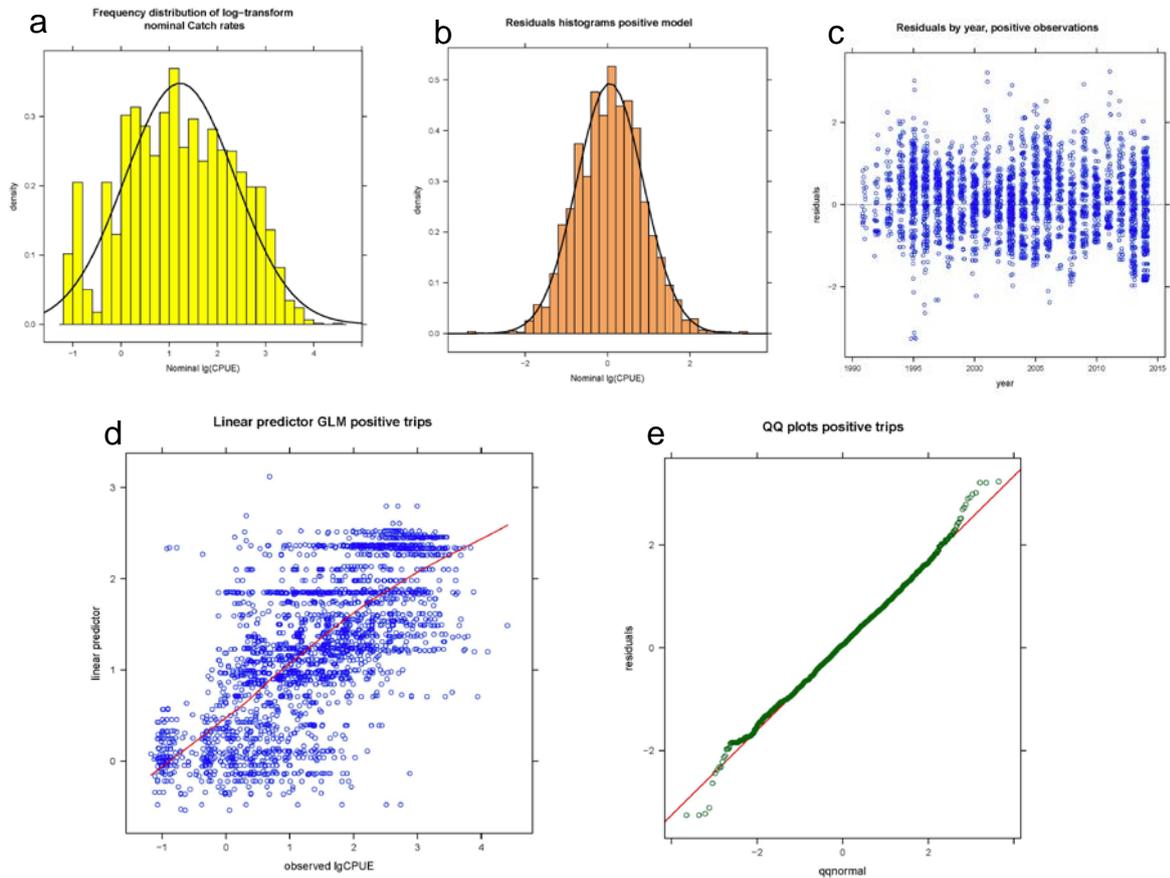
**Figure 7.** Diagnostic plots for the positive observations sub-model, a) for a check of the link function, b) the variance function, c) the check for the error distribution of the model, d) the qq-plot of the standardized deviance residuals.



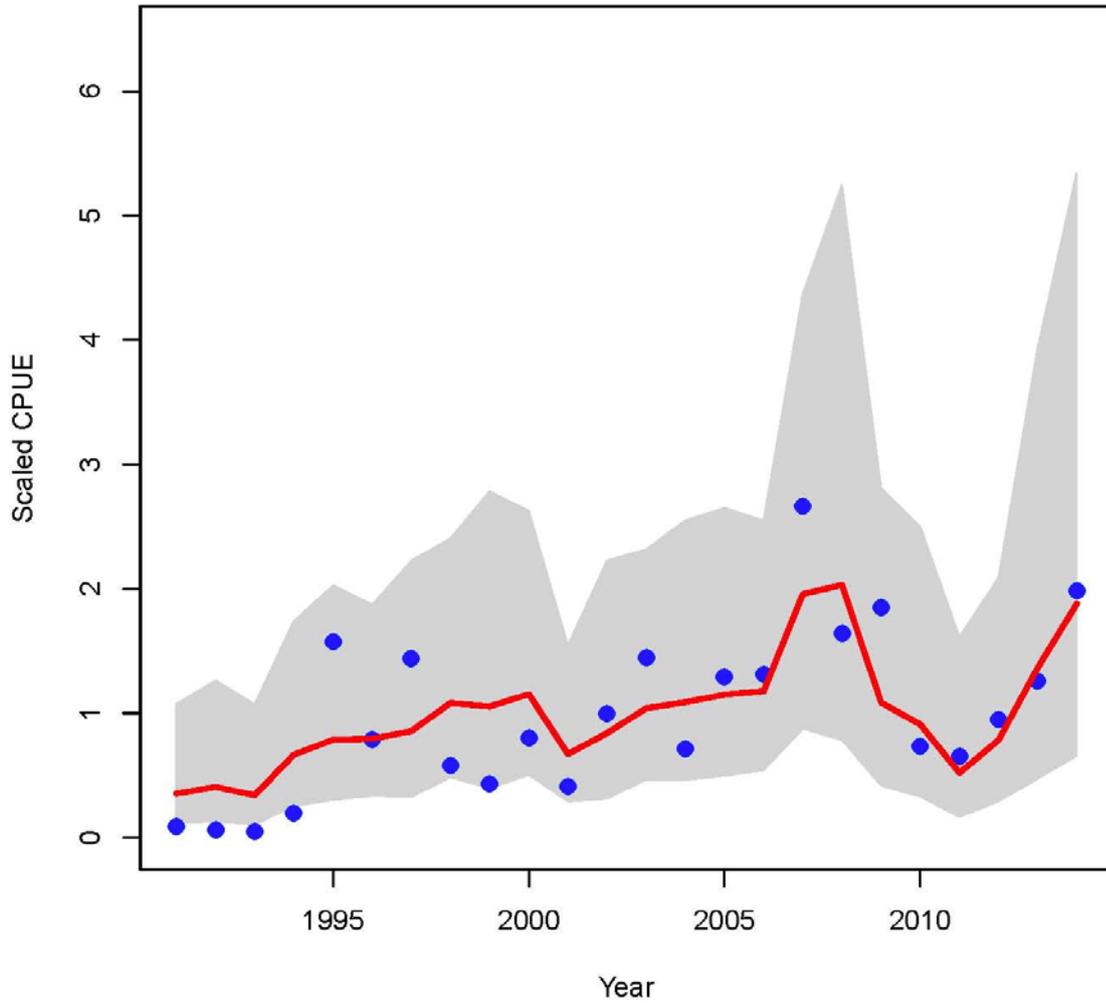
**Figure 8.** e-i) Check for the scale of fixed factors and covariates in the positive observations sub-model.



**Figure 9.** Diagnostic plots for indication of influential observations in the positive observations sub-model: Deviance residuals, Leverage, Cook's distance, Restricted Likelihood distance (RLD), Cook's/Leverage, PRESS residuals, DFFITS, and Covariance ratio plot.



**Figure 10.** Distributions of nominal logCPUE and normalized residuals plots for positive observations and diagnostic plots for positive observations of **northern albacore**. a) Density distribution of the log-transformed nominal CPUE, b) Histogram of the residuals for the positive observations, c) Residuals by year for positive observations, c) Linear predicted versus nominal logCPUE scatter plot with loess smoother trend, and d) QQ-normal plot of positive observations.



**Figure 11.** Estimated nominal (circles) and standardized (line) CPUE in numbers of **northern albacore** from the Venezuelan Pelagic Longline Observer Program data set for the period of 1991-2014. The grey shaded area corresponds to 95% confidence intervals of the standardized CPUE.