SCRS/2015/084 Collect. Vol. Sci. Pap. ICCAT, 72(8): 2090-2101 (2016)

STANDARDIZED CATCH RATES FOR SAILFISH (*ISTIOPHORUS ALBICANS*) FROM THE VENEZUELAN PELAGIC LONGLINE FISHERY OFF THE CARIBBEAN SEA AND ADJACENT AREAS OF THE WESTERN CENTRAL ATLANTIC

F. Arocha[1], M. Ortiz[2] and J.H. Marcano[3]

SUMMARY

A standardized index of relative abundance for sailfish (Istiophorus albicans) *was developed by the combination of three data sources, the international billfish program (1987-1990), the 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. 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 sailfish caught by the observed Venezuelan longline fleet reflects a strong drop in the early period of the series, thereafter the series remains somewhat stable with the exception of two peaks that occurred in 1999 and in 2007. A descending trend in the catch is observed towards the final years of the series.*

RESUMÉ

Un indice standardisé de l'abondance relative du voilier (Istiophorus albicans) *a été élaboré en combinant les trois sources de données, à savoir le programme international sur les istiophoridés (1987-1990), le programme d'observateurs palangriers pélagiques du Venezuela (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. *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 montrent que l'abondance relative des voiliers capturés par la flottille palangrière vénézuélienne observée reflète une forte baisse lors de la première période de la série, par la suite, la série reste à peu près stable à l'exception de deux pics de 1999 et 2007. On observe une tendance descendante de la capture lors des dernières années de la série.*

RESUMEN

*Se desarrolló un índice estandarizado de abundancia relativa para el pez vela (*Istiophorus albicans*) mediante la combinación de tres fuentes de datos, el programa internacional de marlines (1987-1990), el programa de observadores de palangre pelágico de Venezuela (1991-2011) y el Programa nacional de observadores (2012-2014). El índice se estimó utilizando modelos lineales mixtos generalizados con un enfoque del modelo delta lognormal. El procedimiento del análisis de estandarización incluía año, buque, área, temporada, cebo y profundidad de pesca 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 pez vela capturado por la flota de palangre venezolana observada refleja un fuerte descenso en el periodo inicial de la serie, manteniéndose más o menos estable a continuación, con dos excepciones: dos puntos máximos que se produjeron en 1999 y 2007. En los últimos años de la serie se observa una tendencia descendente en la captura.*

KEYWORDS

Sailfish, Catch rates, Caribbean Sea, Venezuelan longline fishery

[1] Instituto Oceanográfico de Venezuela, Universidad de Oriente, Apartado de Correos No. 204, Cumaná 6101 – Venezuela. Corresponding autor: farocha@sucre.udo.edu.ve / farochap@gmail.com

[2] ICCAT Secretariat, C. Corazón de Maria 8, Madrid 28002, Spain

[3] INSOPESCA-Sucre, Cumaná, Venezuela.

Introduction

The Venezuelan pelagic longline fleet operates over an important geographical area in the western central Atlantic and its main target species were yellowfin tuna and swordfish through the mid 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 billfish species caught by the Venezuelan pelagic longline fleet (Arocha *et al*., 2011; Arocha *et al*., 2012); mostly because of persisting difficulties in obtaining non-aggregated pelagic longline log book data by species. Therefore, the data collected by the Venezuelan-EPBR was chosen to develop standardized catch per unit of effort (CPUE) indices of abundance for the billfish caught by the Venezuelan pelagic longline fleet (Ortiz and Arocha, 2004). In earlier estimations of a standardized index of relative abundance for sailfish (*Istiophorus albicans*) (Arocha *et al*., 2008), the data source utilized was entirely from the EPBR, but recently observer data prior to 1991 was recovered, as well as the most recent data (2012-2014) which corresponds to the National Observer Program. Thus, the combination of these three data sources, the international billfish program (1987-1990), the Venezuelan Pelagic Longline Observer Program (1991-2011), and the National Observer Program (2012-2014) were used to develop the new updated standardized catch rates of sailfish to the last year of the series (2014) using a Generalized Linear Mixed Model with random factor interactions particularly for the *year* effect. In addition, graphic diagnostic methods were used to test for overall model fitting and for indication of influential observations.

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 2012-2013 (Gassman *et al*., 2014). The data from the international billfish program (1987-1990) was included in the VPLOP data base because it was the origin of the VPLOP; the data was recorded by observers placed on Venezuelan pelagic longline vessels targeting yellowfin and swordfish in the Caribbean Sea. 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 ~5% from INSOPESCA's 2012-2013 observer program. Of the 6,936 sets observed in those trips, sailfish was reported caught in 2,051 sets (29.57 %). 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 included 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 analyses, vessels were classified into 3 categories based on the vessel size primarily (Ortiz and Arocha, 2004). Factors in the analyses of catch rates included, vessel category, bait type, 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). Like in SCRS/2015/022, individual vessel identification was also available and used in alternative analyses where they were considered as individual sampling units rather than group category. Then, by using repeated measures GLM models is possible to estimate or account for individual vessel variability (Bishop, 2006). Of the different vessels in the VPLOP database not all reported catches of sailfish, nor were all fishing during the 1987-2014 period, when in fact the fleet has completely changed since 2007. The repeated measures GLM models assumed some type of correlation between measurements for each subject (vessel in this case) that can be estimated and separated from the overall variability of the model. The same approach as in SCRS/2015/022 was used to evaluate if variance within vessels is consistent and shows a given pattern, that is, the autoregressive variance-covariance matrix (AR1), and the compound symmetry (CS) variance-covariance. 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 sailfish caught per 1000 hooks.

For the Venezuelan longline observer data, relative indices of abundance for sailfish were estimated by Generalized Linear Modeling approach assuming a delta lognormal model distribution following the same protocol as described in Arocha et al., 2010. 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 (normally factors that explained more than 5% were selected), and b) The χ^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 χ^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

Sailfish spatial distribution of nominal CPUE from the VPLOP and INSOPESCA's data sets is presented in **Figure 1**. Important catch rates were obtained in the Caribbean Sea area (=area 1), towards the southern part and in the central Caribbean. Although, most of the important catch rates were generally associated in the vicinity of the offshore islands off Venezuela. Another area of important concentration is east of the Orinoco Delta (Venezuela) and north of Surinam (=area 2). Very small catch rates were observed in the southwest of the Sargasso Sea (=area 3). In general, the highest sailfish catch rates were closer to land masses compared to other marlin species, due to the more 'coastal' nature of sailfish.

The deviance analysis for sailfish from the Venezuelan Pelagic Longline 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*, *Vessl_Cat*, and *Areas*; and the interactions *Year*×*Bcondition*, *Year*×*Vessl_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*, *Vessl_Cat*, *Areas*, and *Season*; and the interactions *Areas*×*Season*, *Year*×*Areas*, *Year*× *Vessl_Cat*, and *Year*×*Season* were more significant. Once a set of fixed factors were selected, we evaluated first level random interaction between the year and other effects.

Model diagnostics for the binomial proportion of the positive sub-model include plots (**Figure 2a-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 2 e-i**), 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).

In **Figure 3** are a series of plots that check for indication of influential observations in the model. The first plot (3a) 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 (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 data with high influence and high leverage overall.

In GLM models, like the one presented here, with random components in the model fit, the following plots (**Figure 3**) provide information on the influence of given observations on the overall unconditional predicted values (fixed factor expectation and random assumption influence). 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 several 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, and check for the scale of fixed factors and covariates in the model (**Figure 4a-i**). Similarly, checks for indication of influential observations for the positive observations of the lognormal sub-model (**Figure 5**) 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.

As indicated earlier, alternative models were evaluated, in which individual vessels variability was considered using a GLM with alternative variance-covariance matrix structure, considering catch by each vessel as repeated measures model type. This was done by changing the model structure for the positive observations only, leaving the proportion of positives model the same, and using the same factors (excluding only the vessel size category) and interactions as above. **Table 2** shows the results of the information criteria when using the AR1 variance-covariance structure to estimate individual vessel variability. Using the -2 log likelihood, AIC or BIC as indicators of model fit, the AR1 var-cov model with vessel as repeated sampler unit achieved better fit, the repeated measures model AR1 provided substantially lower AIC values for the fit of the positive observations, compared to the GLMM model that used the vessel category factor instead. The distributions of normalized residuals and the diagnostic plots of the distribution of residuals (**Figures 6 and 7**) do not show strong deviations from the expected null pattern. Therefore, the results from the random test analyses for sailfish 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*, *Vessl_Cat*, *Season*, *Area*, and *Bait* as fixed factor and the random interactions, *Year*×*Vessl_Cat*, *Year*×*Season*, *Year*×*Area*, and *Year*×*Bait* (**Table 2**). For the proportion of positive/total sets, the final model included the *Year*, *Vessl_Cat*, *Area*, *Season*, and *Bait* as main fixed factors and the random interactions, *Year*×*Season* and *Area*×*Season*.

Standardized CPUE series for sailfish are shown in **Table 3** and **Figure 8**. Coefficients of variation ranged from 56.3 to 98.5% for the selected model fit based on catch rates of numbers of fish and individual vessel variability (AR1), the standardized catch rates based on the delta lognormal model using vessel category is shown for comparison (**Figure 8**). The standardized CPUE series show that the relative abundance of sailfish caught by the observed Venezuelan longline fleet reflects a strong drop in the early period of the series, thereafter the series remains somewhat stable with the exception of two peaks that occurred in 1999 and in 2007. A descending trend in the catch is observed towards the final years of the series.

Considering that the information that exists in logbooks do not reflect the catch of sailfish 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 sailfish caught by the Venezuelan longline fleet in the southeastern Caribbean Sea and the upper northeast area of South America.

References

Arocha, F., L. Marcano. 2001. Monitoring large pelagic fishes in the Caribbean Sea and the western central Atlantic by an integrated monitoring program from Venezuela. pp. 557-576. In: *Proceedings of the 52nd GCFI meeting. Key West, Fl. November 1999.*

Arocha, F., M. Ortiz. 2012. Standardized catch rates for white marlin (*Tetrapturus albidus*) from the Venezuelan pelagic longline fishery off the Caribbean Sea and the western central Atlantic: Period 1991-2010. ICCAT, Col. Vol. Sci. Pap., 68: 1408-1421.

Arocha, F. and M. Ortiz. 2011. Standardized catch rates for blue marlin (*Makaira nigricans*) from the Venezuelan pelagic longline fishery off the Caribbean Sea and the western central Atlantic: Period 1991-2009. ICCAT, Col. Vol. Sci. Pap., 66: 1661-1674.

Arocha, F. M. Ortiz. 2010. Standardized catch rates for sailfish (*Istiophorus albicans*) from the Venezuelan pelagic longline fishery off the Caribbean Sea and adjacent areas: An update for 1991-2007. ICCAT-SCRS/2008/039.

Arocha, F., L.A. Marcano, J. Silva. 2013. Description of the Venezuelan pelagic longline observer program (VPLOP) sponsored by the ICCAT Enhanced Research Program for Billfish. ICCAT, Col. Vol. Sci. Pap., 69: 1333-1342.

Bishop, J. 2006. Standardizing fishery-dependent catch and effort data in complex fisheries with technology change. Rev. Fish. Biol. Fisheries 16(1):21-38.

Gassman, J., C. Laurent, J.H. Marcano. 2014. Ejecución del programa nacional de observadores a bordo de la flota industrial atunera venezolana del mar caribe y océano atlántico año 2012. ICCAT-Col. Vol. Sci. Pap.,70:2207-2216.

Littell, R.C., G.A. Milliken, W.W. Stroup, R.D Wolfinger. 1996. SAS® System for Mixed Models, Cary NC:SAS Institute Inc., 1996. 663 pp.

Lo, N.C., L.D. Jacobson, J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-2526.

Marcano, L., F. Arocha, J. Alió, J. Marcano, A. Larez, X. Gutierrez, G. Vizcaino. 2007. Actividades desarrolladas en el Programa expandido de ICCAT para Peces pico en Venezuela: período 2006-2007. ICCAT SCRS/2007/121.

Marcano, L., F. Arocha, J. Alió, J. Marcano, A. Larez. 2005. Actividades desarrolladas en el Programa expandido de ICCAT para Peces pico en Venezuela: período 2003-2004. ICCAT-Col. Vol. Sci. Pap.,58:1603-1615.

Ortiz, M., F. Arocha. 2004. Alternative error distribution models for standardization of catch rates of non-target species from pelagic longline fishery: billfish species in the Venezuelan tuna longline fishery. Fish. Res., 70:275-297.

SAS Institute Inc. 2008, SAS/STAT® 9.2. Cary, NC: SAS Institute Inc.

SAS Institute Inc. 1997, SAS/STAT® Software: Changes and Enhancements through Release 6.12. Cary, NC: SAS Institute Inc. 1167 pp.

Table 1. Deviance analysis table for explanatory variables in the delta lognormal model for **sailfish** catch rates (**in numbers**) from the Venezuelan Pelagic Longline Observer Program (VPLOP). 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.

Sailfish Vza PLL CPUE Index

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	1451.303			
Year	27	1209.9987	241.30	30.6%	< 0.001
Year Vessl_Cat	2	868.483	341.52	43.3%	< 0.001
Year Vessl_Cat Areas	2	821.9345	46.55	5.9%	< 0.001
Year Vessl_Cat Areas Season	3	802.5281	19.41	2.5%	< 0.001
Year Vessl_Cat Areas Season Depth2	1	773.4598	29.07	3.7%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition	1	763.8358	9.62	1.2%	0.002
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Depth2	3	761.0126	2.82	0.4%	0.420
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Depth2	2	755.9468	7.89	1.0%	0.019
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Areas	3	752.6062	11.23	1.4%	0.011
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Season	6	752.3199	11.52	1.5%	0.074
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Bcondition	3	752.2656	11.57	1.5%	0.009
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Depth2	15	734.1623	29.67	3.8%	0.013
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Bcondition	14	728.6775	35.16	4.5%	0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Vessl_Cat	32	726.9728	36.86	4.7%	0.254
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Areas	27	721.3728	42.46	5.4%	0.030
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Season	70	662.3989	101.44	12.9%	0.008

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	2143.455			
Year	27	1489.873	653.58	44%	< 0.001
Year Vessl_Cat	2	1382.750	107.12	7%	< 0.001
Year Vessl_Cat Areas	2	1128.473	254.28	17%	< 0.001
Year Vessl_Cat Areas Season	3	1029.676	98.80	7%	< 0.001
Year Vessl_Cat Areas Season Depth2	1	1029.670	0.01	0%	0.940
Year Vessl_Cat Areas Season Depth2 Bcondition	1	1005.316	24.35	2%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Areas*Bcondition	2	1005.126	0.19	0%	0.909
Year Vessl_Cat Areas Season Depth2 Bcondition Depth2*Bcondition	1	1004.961	0.35	0%	0.552
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Areas	4	1002.357	2.96	0%	0.565
Year Vessl_Cat Areas Season Depth2 Bcondition Areas*Depth2	2	1001.410	3.91	0%	0.142
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Bcondition	3	988.198	17.12	1%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Depth2	3	970.374	34.94	2%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Season	6	967.278	38.04	3%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Bcondition	18	959.981	45.33	3%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Depth2	16	953.762	51.55	3%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Areas*Season	5	937.447	67.87	5%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Areas	35	906.262	99.05	7%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Vessl_Cat	34	820.721	184.59	12%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Season	73	661.631	343.68	23%	< 0.001

Table 2. Analyses of delta lognormal mixed model formulations for sailfish catch rates (**in numbers**) from the Venezuelan Pelagic Longline Observer Program (VPLOP). Likelihood ratio tests the difference of –2 REM log likelihood between two nested models. The bold lettering and 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	
Proportion Positives					
Year VesCat Area Season	1260	1262	1265.9		
Year VesCat Area Season *Year*Season*	1246.7	1250.7	1256	13.3	0.0003
Year VesCat Area Season *Year*Season Year*VesCat*	1238.3	1244.3	1252.2	8.4	0.0038
Year VesCat Area Season Bait *Year*Season Year*Area*	1240.8	1248.8	1259.4	-2.5	N/A
Year VesCat Area Season Bait *Year*Season Area*Season*	**1221.9**	**1229.9**	**1240.5**	**16.4**	**0.0001**
Positives catch rates Vessel Size Category					
Year VesCat Season Area Bait	3989.9	3991.9	3997.5		
Year VesCat Season Area Bait *Year*VesCat*	3926.2	3930.2	3934.5	63.7	0.0000
Year VesCat Season Area Bait *Year*VesCat Year*Season*	3807.4	3813.4	3819.8	118.8	0.0000
Year VesCat Season Area Bait *Year*VesCat Year*Season Year*Area*	3757.5	3765.5	3774	49.9	0.0000
Year VesCat Season Area Bait *Year*VesCat Year*Season Year*Area Year*Bait*	3704.1	3714.1	3724.8	53.4	0.0000
Positives catch rates AR1 var-cov with Vessel as subject repeated measures					
Year Season Bait	3704.1	3714.1	3724.8		
Year VesCat Season Area Bait *Year*VesCat Year*Season Year*Area Year*Bait*	**1991.7**	**2001.7**	**2012.3**	**1712.4**	**0.0000**

Table 3. Nominal and standardized (Delta lognormal mixed model) CPUE series (**nos.** /1000 hooks) for sailfish catch rates from the Venezuelan Pelagic Longline Observer Program (VPLOP).

Year	N Obs	Nominal CPUE	Standard CPUE	Low CI	Upp CI	CV	std error
1987	11	2.318	5.627	0.870	16.958	85.8%	3.3
1988	6	0.950	2.118	0.278	7.506	98.5%	1.4
1989	10	1.098	1.575	0.235	4.909	88.4%	0.9
1990	10	1.463	0.931	0.140	2.887	87.9%	0.6
1991	46	2.806	0.899	0.181	2.077	67.1%	0.4
1992	76	1.730	0.742	0.148	1.732	67.8%	0.3
1993	99	3.115	0.271	0.052	0.659	70.7%	0.1
1994	84	1.594	0.759	0.152	1.764	67.5%	0.3
1995	78	1.544	0.664	0.136	1.516	66.3%	0.3
1996	68	1.722	0.750	0.161	1.629	63.1%	0.3
1997	77	2.231	0.676	0.132	1.615	69.3%	0.3
1998	118	2.178	0.933	0.203	1.998	62.2%	0.4
1999	118	3.853	2.397	0.548	4.881	59.0%	1.0
2000	72	3.303	0.693	0.145	1.538	64.5%	0.3
2001	36	1.554	0.431	0.082	1.053	70.9%	0.2
2002	32	1.720	0.507	0.086	1.398	79.3%	0.3
2003	57	1.926	0.314	0.061	0.751	69.4%	0.1
2004	67	2.557	0.347	0.070	0.807	67.5%	0.2
2005	62	2.792	0.405	0.081	0.938	67.3%	0.2
2006	85	3.033	0.726	0.159	1.543	61.7%	0.3
2007	70	3.825	1.840	0.440	3.584	56.3%	0.7
2008	104	2.284	0.462	0.093	1.073	67.4%	0.2
2009	75	2.745	0.526	0.097	1.325	72.9%	0.3
2010	103	2.336	0.511	0.095	1.281	72.6%	0.3
2011	115	2.375	0.724	0.132	1.850	73.9%	0.4
2012	162	5.794	0.946	0.184	2.264	69.5%	0.4
2013	101	2.422	0.784	0.153	1.869	69.2%	0.4
2014	109	2.954	0.442	0.076	1.196	77.9%	0.2

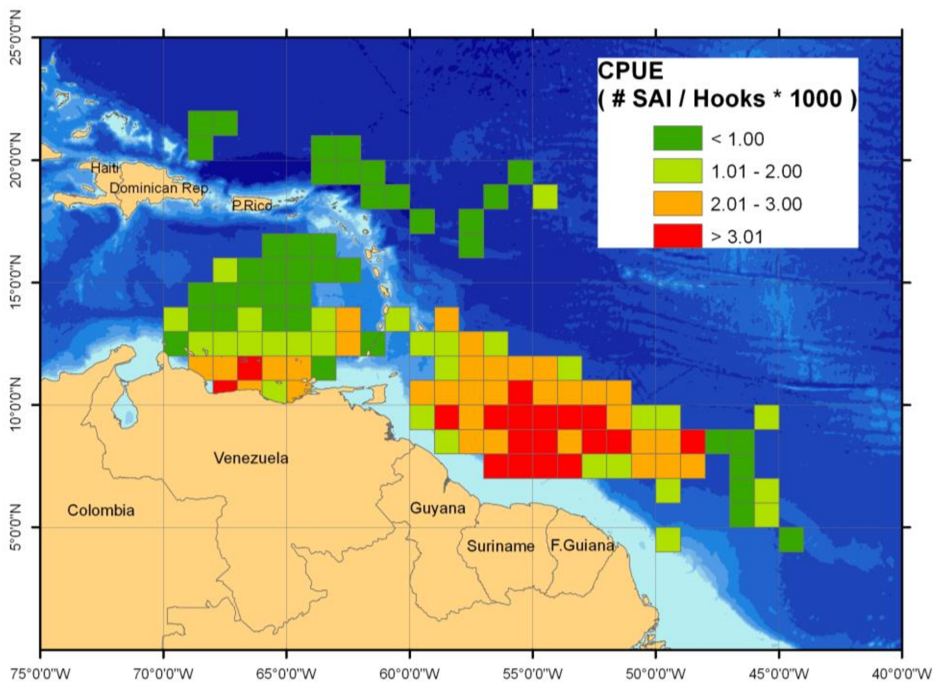

Figure 1. Spatial distribution of nominal CPUE of sailfish (numbers/1000 hooks) caught by the Venezuelan pelagic longline fleet during 1987-2014 and recorded by the VPLOP and PNOB.

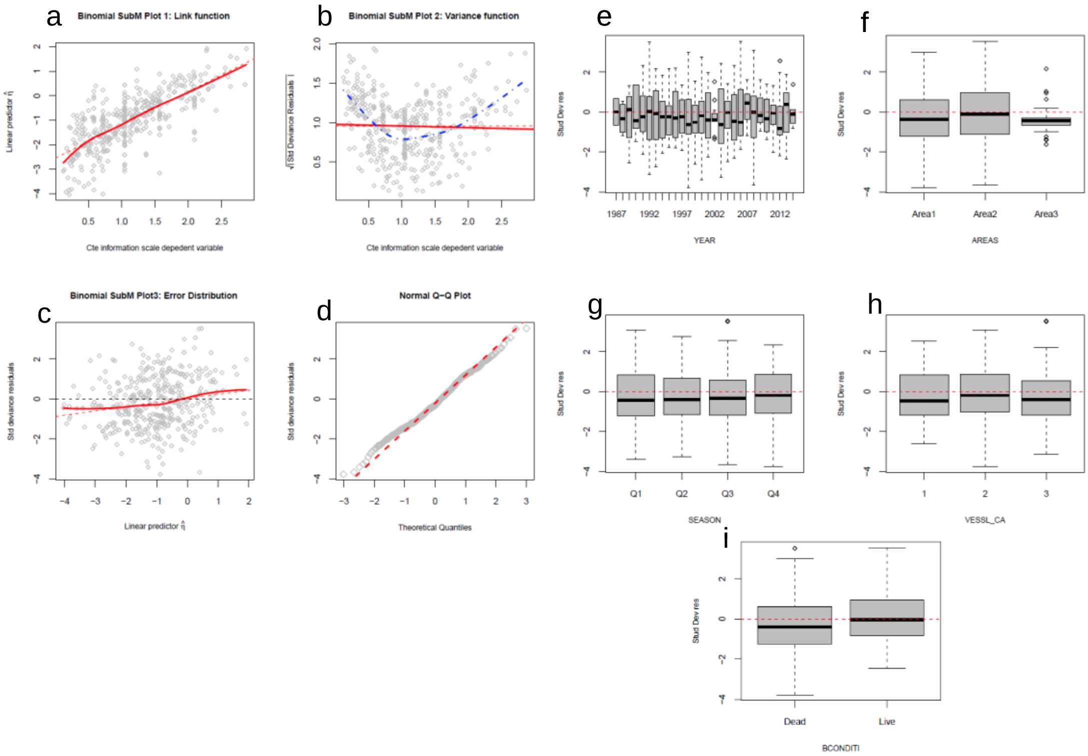

Figure 2. Diagnostic plots for the binomial proportion of the positive sub-model, a) for a check of the link function, b) the variance function, c) the check for the error distribution of the model, d) the qq-plot of the standardized deviance residuals, e-i) check for the scale of fixed factors and covariates in the model.

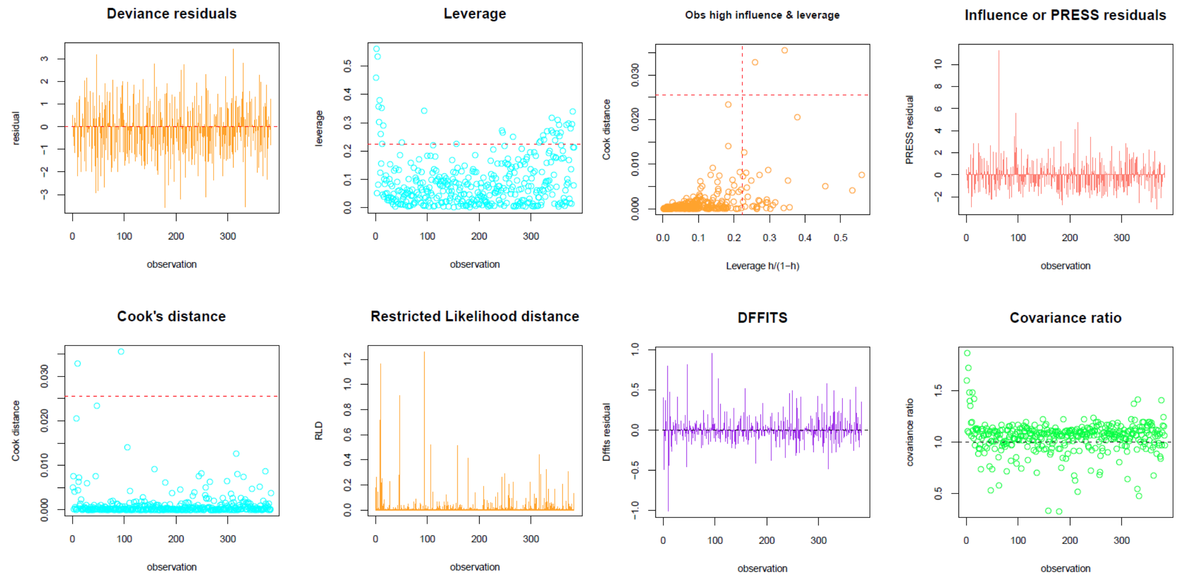

Figure 3. Diagnostic plots for indication of influential observations in the binomial proportion of the positive sub-model model: Deviance residuals, Leverage, Cook's distance, Restricted Likelihood distance (RLD), Cook's/Leverage, PRESS residuals, DFFITS, and Covariance ratio plot.

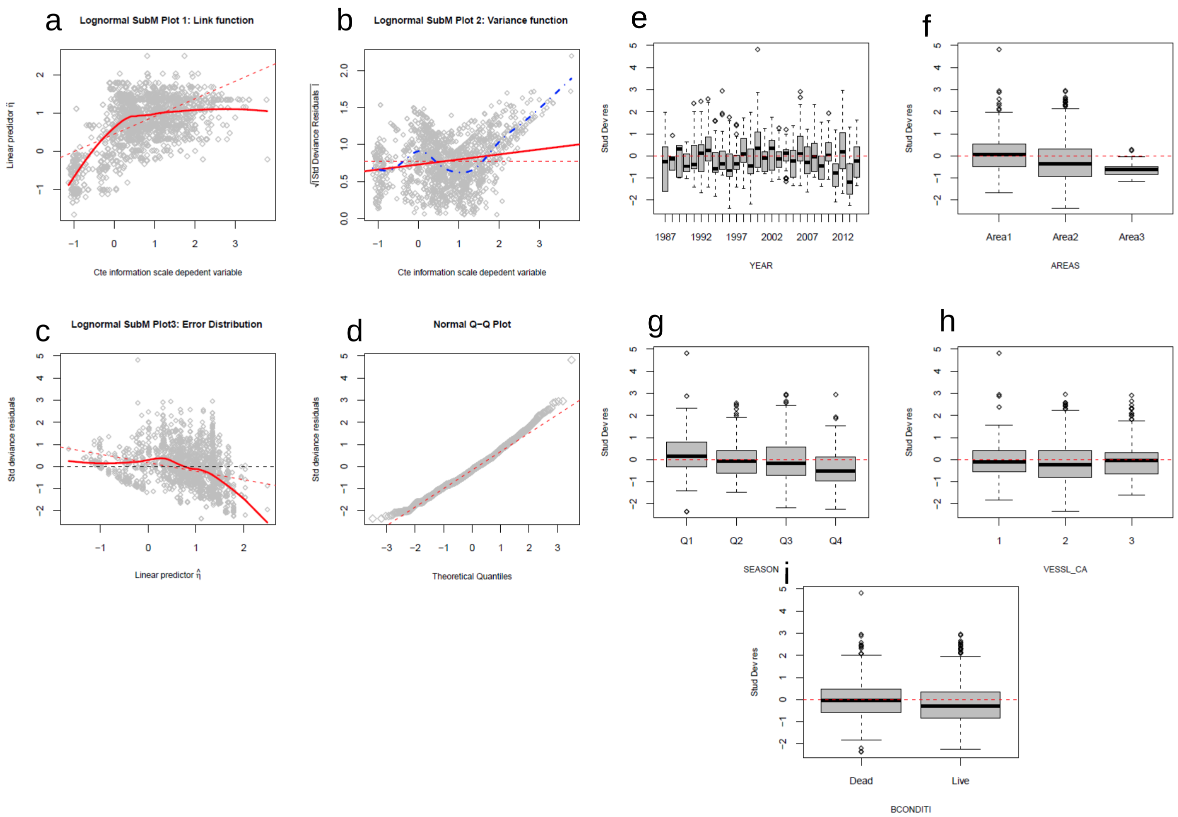

Figure 4. Diagnostic plots for the positive observations sub-model, a) for a check of the link function, b) the variance function, c) the check for the error distribution of the model, d) the qq-plot of the standardized deviance residuals, e-i) check for the scale of fixed factors and covariates in the model.

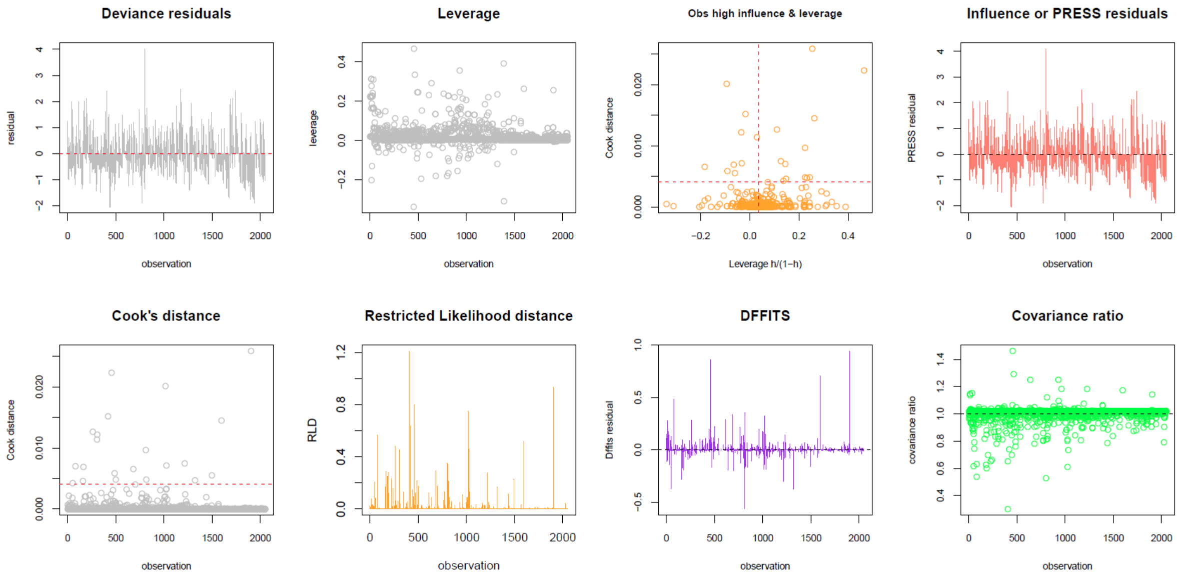

Figure 5. Diagnostic plots for indication of influential observations in the positive observations sub-model: Deviance residuals, Leverage, Cook's distance, Restricted Likelihood distance (RLD), Cook's/Leverage, PRESS residuals, DFFITS, and Covariance ratio plot.

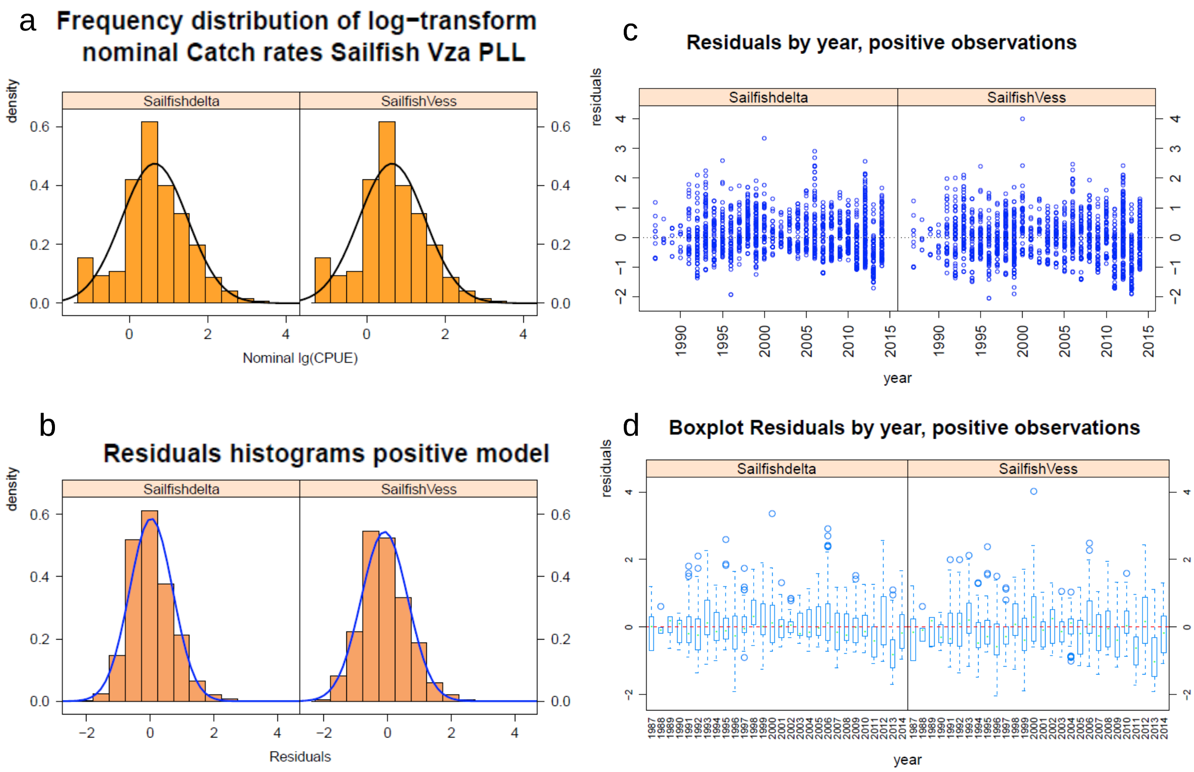

Figure 6. Distributions of nominal logCPUE and normalized residuals plots for positive observations under both model approaches, the standardized catch rates based on the delta lognormal model using vessel category (Sailfishdelta) and model fit based on catch rates of numbers of fish and individual vessel variability (AR1) (SailfishVess). a) Histogram and frequency density distribution of the log-transformed nominal CPUE, b) histogram of the residuals for the positive observations, c-d) Residuals and boxplot residuals by year for positive observations.

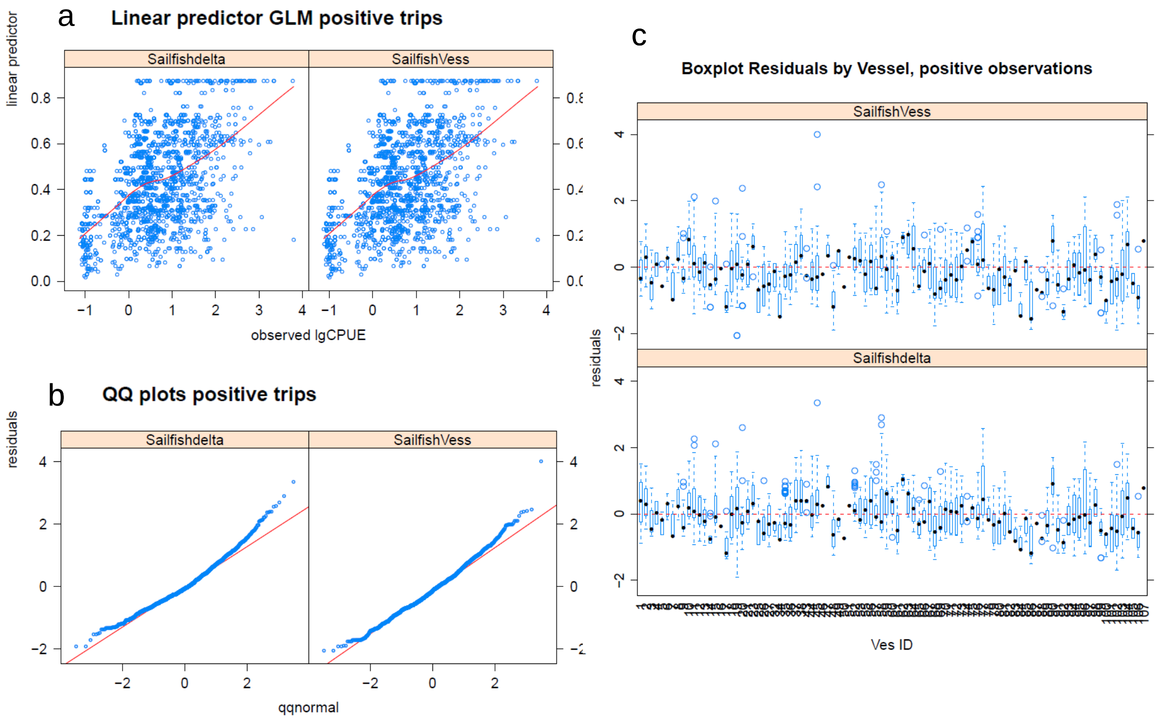

Figure 7. Diagnostic plots for positive observations under both model approaches, the standardized catch rates based on the delta lognormal model using vessel category (Sailfishdelta) and model fit based on catch rates of numbers of fish and individual vessel variability (AR1) (SailfishVess). a) Linear predicted versus nominal logCPUE scatter plot with loess smother trend. b) QQ-normal plot of positive observations, and c) Boxplot residuals by Vessel.

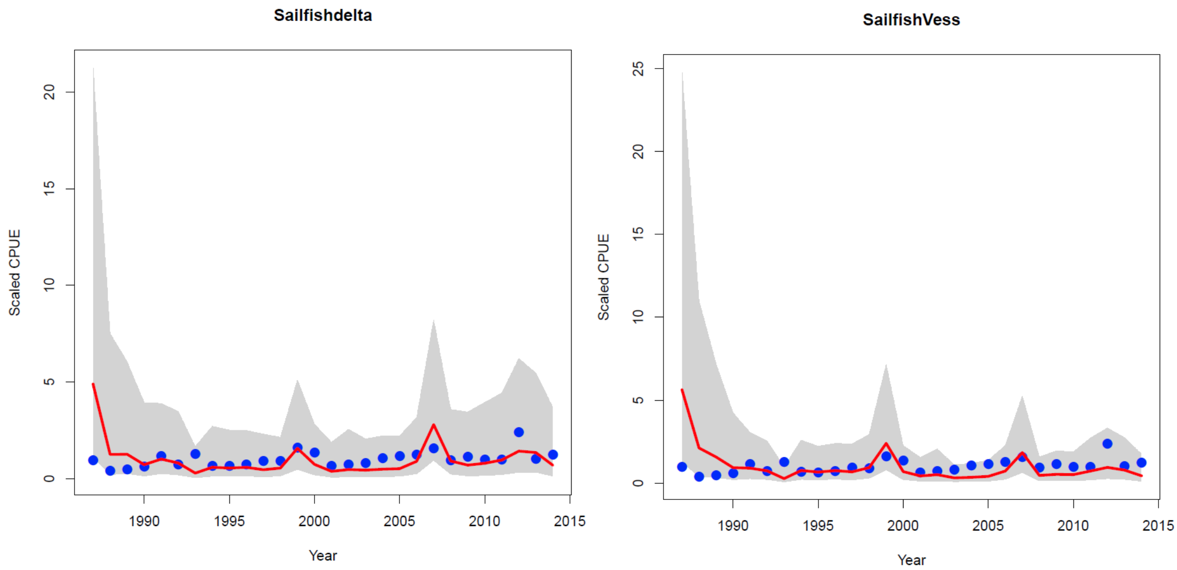

Figure 8. Estimated nominal (circles) and standardized (line) CPUE in numbers of sailfish from the Venezuelan Pelagic Longline Observer Program data set. “Sailfishdelta” represents the standardized catch rates based on the delta lognormal model using vessel category, and “SailfishVess” is the selected model which represents the model fit based on catch rates of numbers of fish and individual vessel variability (AR1). The grey shaded area corresponds to 95% confidence intervals of the standardized CPUE.