Collect. Vol. Sci. Pap. ICCAT, 80(8): 178-191 (2023)

STANDARDIZED CATCH RATES AND SIZE DISTRIBUTION FOR ATLANTIC SAILFISH FROM THE VENEZUELAN PELAGIC LONGLINE FISHERY IN THE CARIBBEAN SEA AND ADJACENT WATERS OF THE WESTERN CENTRAL ATLANTIC (1987-2018)

F. Arocha[1], M. Ortiz[2], M. Narváez[1], J.H. Marcano[3], E. Evaristo[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 (2012-2018). 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 shows 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 except for three peaks that occurred in 1999, 2007, and a smaller in 2016.

RÉSUMÉ

*Un indice standardisé de l'abondance relative du voilier (*Istiophorus albicans*) a été élaboré en combinant trois sources de données : le Programme international sur les istiophoridés (1987-1990), le Programme d'observateurs de la palangre pélagique du Venezuela (1991-2011) et le Programmes d'observateurs nationaux (2012-2018). L'indice a été estimé à l'aide de modèles mixtes linéaires généralisés dans le cadre d'une approche de modèle delta log-normal. La procédure d'analyse de standardisation incluait l'année, le navire, la zone, la saison, l'appât et la profondeur de pêche comme variables catégorielles. Des diagrammes de diagnostics ont été utilisés comme indicateurs de l'ajustement global du modèle. La série temporelle montre que l'abondance relative des voiliers capturés par la flottille palangrière observée du Venezuela reflète une forte réduction au début de la série, par la suite la série reste assez stable à l'exception de trois pics survenant en 1999, 2007 et dans une moindre mesure en 2016.*

RESUMEN

*Se desarrolló un índice 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 (1991-20111) y el* Programa *nacional de observadores (2012-2018). 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. La serie temporal muestra que la abundancia relativa de pez vela capturado por la flota palangrera venezolana observada refleja un fuerte descenso en el periodo inicial de la serie, posteriormente la serie se mantiene algo estable a excepción de tres picos que se produjeron en 1999, 2007 y uno menor en 2016.*

KEYWORDS

Sailfish, Catch rates, Caribbean Sea, Venezuelan longline fishery.

[1] Instituto Oceanográfico de Venezuela, Universidad de Oriente, Cumaná 6101 – VENEZUELA.
[2] ICCAT Secretariat, C. Corazón de Maria 8, Madrid 28002, Spain
[3] MPP Pesca y Acuicultura-Sucre, Cumaná 6101 – VENEZUELA.
* Corresponding author: farochap@gmail.com

Introduction

The present document offers an update since Arocha *et al.* (2016), on the standardized catch rates and size distribution by sex of Atlantic sailfish caught by the Venezuelan longline pelagic fishery. The Venezuelan pelagic longline fleet operates over an important geographical area in the western central Atlantic and its main target species were swordfish and yellowfin tuna through the 1990s, thereafter (in 2000), yellowfin tuna became the main target species (Arocha *et al.,* 2017). However, bycatch species such as billfish, albacore tuna, and sharks have been commonly caught and commercialized locally throughout the history of the fishery (Arocha *et al.,* 2001; Arocha et. al. 2017; SCRS/2023/056). 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 (Ortiz and Arocha, 2004). The present update on standardized catch rates for Atlantic sailfish continues to use the same combination of three sources of observed data (Arocha et. al. 2016), namely, the early international billfish program data 1987-1990, from ICCAT's EPBR in Venezuela for 1991-2011, and from the National Observer Program from 2012 to its termination in 2018.

These time series were used to develop the new updated standardized catch rates of Atlantic sailfish to the last year of the series (2018) 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 an indication of influential observations, as well as size structure by sex caught by the fishery over the period analyzed.

Materials and Methods

The early data from the international billfish program (1987-1990) was combined with ICCAT's EPBR in Venezuela because it was the origin of the ICCAT-sponsored EPBR Venezuelan Pelagic Longline Observer Program (VPLOP); the data was recorded by observers placed on Venezuelan pelagic longline vessels targeting yellowfin and swordfish in the Caribbean Sea and adjacent waters of the Atlantic. The data used in the analysis for the period of 1987 to 2011 was obtained from the billfish research programs through its termination; thereafter, the national agency responsible for collecting fishery statistical data in Venezuela (INSOPESCA) developed the National Observer Program (PNOB) for large pelagic fisheries in 2012 and has recorded observed fishery data through 2018 when it was stopped due to lack of funds and qualified personnel.

The EPBR's VPLOP surveyed between 1.7% and 19.7% of the Venezuelan longline fleet trips during the period of 1991-2011, with an overall average of 10.9% (Arocha et. al., 2013). While the PNOB surveyed <5% during its duration (2012-2018). Of these sets, Atlantic sailfish were reported caught in 31.39% of sets for the period of 1987-2018. The detailed information collected in the EPBR's VPLOP, as well as fishing grounds for the Venezuelan fleet, is the same as described in Ortiz and Arocha (2004), and similar to the information recoded by the PNOB. Factors included in the analyses of catch rates included: bait type and condition (live, frozen), 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). Fishing effort is reported in terms of the total number of hooks per trip and the number of sets per trip, as the number of hooks per set, varied; catch rates were calculated as the number of sailfish caught per 1000 hooks.

For the Venezuelan longline observer data, relative indices of abundance for Atlantic sailfish were estimated by the Generalized Linear Modeling approach assuming a delta lognormal model distribution following the same protocol as described in Arocha *et al.* (2016). 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 the positive catch rates. The 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 □2 significance. The vessel factor was evaluated as a categorical grouping (like 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 Akaike's Information Criterion (AIC), the Bayesian Information Criterion (BIC), and a χ^2 test of the difference between the [–2 loglikelihood] statistic of 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. 2008).

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 with 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 is 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.

Table 2 shows the results of the information criteria when using the random effects for those interaction that included the year factor. Using the -2 log likelihood, AIC or BIC as indicators of model fit. **Figures 6** and **7** provide general diagnostic plots of the final model. 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, Ves_Cat, Season, Area, and Bait as fixed factor and the random interactions, Year×Ves_Cat, Year×Season, Year×Area, and Year×Bait. (**Table 2**). For the proportion of positive/total sets, the final model included the Year, Ves_Cat, Area, and Season, as main fixed factors and the random interactions, Year×Ves_Cat, Year×Season, Year×Area and Year×Bait.

Standardized CPUE series for sailfish are shown in **Table 3** and **Figure 8**. Coefficients of variation ranged from 57 to 108% for the selected model fit based on catch rates of numbers of fish. 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, possibly due to the low number of observed sets during the early years. Since 1991, the standardized catch rates have remained relatively stable except for three peaks that occurred in 1999, 2007, and in 2016. In general, standardized catch rates after the high peak in 2007 have remained higher than before 2007.

A total of 5164 Atlantic sailfish were caught and measured by the scientific observers of the Venezuelan observer programs. The size distributions of the 2110 males and 1864 females, ranged from 80 cm to 224 cm LJFL for males and from 85 cm to 257 cm LJFL for females; a group of 1190 unsexed specimens ranged from 82 cm to 200 cm LJFL (**Table 4**).

Historical annual length distributions show no apparent pattern until 2011where median sizes remain relatively stable; thereafter, a drop in the sizes of Atlantic sailfish is observed for the remaining of the period (**Figure 9**). Although, it appears that the dop in size is mostly attributed to smaller male fish caught after 2011.

References

Arocha F., J.H. Marcano, E. Evaristo and X. Gutiérrez. 2017. Size distributions of swordfish (*Xiphias gladius*) in the Caribbean Sea and adjacent waters of the western central Atlantic, from observer data of the Venezuelan longline fisheries. ICCAT, Col. Vol. Sci. Pap., 74: 1251-1257.

Arocha F., M. Ortiz and J.H. Marcano. 2017. 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. ICCAT, Col. Vol.Sci.Pap. 73:1397-1412.

Arocha, F. M. Ortiz, M. Narváez, J.H. Marcano and E. Evaristo. 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. ICCAT, Col. Vol. Sci. Pap.,.72:2090-2101.

Arocha, F., L.A. Marcano and 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.

Arocha, F., L.A. Marcano, J.S. Marcano, X. Gutiérrez and J. Sayegh. 2001. Captura incidental observada de peces de pico en la pesquería industrial de palangre venezolana en el Mar Caribe y en el Atlántico centro Occidental: 1991-1999. ICCAT, Col. Vol. Sci. Pap., 53:131-140.

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

Lo, N.C., L.D. Jacobson and 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.

Ortiz, M. and 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.

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.

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	1629.1329			
Year	31	1351.3388	277.79	33.0%	< 0.001
Year Vessl_Cat	2	1009.8231	341.52	40.5%	< 0.001
Year Vessl_Cat Areas	2	963.2746	46.55	5.5%	< 0.001
Year Vessl_Cat Areas Season	3	936.7765	26.50	3.1%	< 0.001
Year Vessl_Cat Areas Season Depth2	1	911.87	24.91	3.0%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition	1	903.6149	8.26	1.0%	0.004
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Depth2	3	896.3706	7.24	0.9%	0.065
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Depth2	2	895.4481	8.17	1.0%	0.017
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Bcondition	3	892.4381	11.18	1.3%	0.011
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Season	6	891.8403	11.77	1.4%	0.067
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Areas	3	890.3707	13.24	1.6%	0.004
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Depth2	17	866.482	37.13	4.4%	0.003
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Bcondition	15	865.8561	37.76	4.5%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Vessl_Cat	32	864.4961	39.12	4.6%	0.181
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Areas	27	861.1087	42.51	5.0%	0.029
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Season	77	786.3649	117.25	13.9%	0.002

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	2383.520			
Year	31	1531.895	851.63	50%	< 0.001
Year Vessl_Cat	2	1424.772	107.12	6%	< 0.001
Year Vessl_Cat Areas	2	1170.494	254.28	15%	< 0.001
Year Vessl_Cat Areas Season	3	1066.216	104.28	6%	< 0.001
Year Vessl_Cat Areas Season Depth2	1	1066.170	0.05	0%	0.829
Year Vessl_Cat Areas Season Depth2 Bcondition	1	1044.959	21.21	1%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Depth2*Bcondition	1	1044.958	0.00	0%	0.971
Year Vessl_Cat Areas Season Depth2 Bcondition Areas*Bcondition	2	1044.320	0.64	0%	0.726
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Areas	4	1042.141	2.82	0%	0.589
Year Vessl_Cat Areas Season Depth2 Bcondition Areas*Depth2	2	1042.069	2.89	0%	0.236
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Bcondition	3	1020.754	24.21	1%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Season*Depth2	3	1010.279	34.68	2%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Vessl_Cat*Season	6	1002.568	42.39	2%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Bcondition	19	993.671	51.29	3%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Depth2	18	991.936	53.02	3%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Areas*Season	5	968.793	76.17	4%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Areas	35	945.409	99.55	6%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Vessl_Cat	34	860.380	184.58	11%	< 0.001
Year Vessl_Cat Areas Season Depth2 Bcondition Year*Season	80	673.322	371.64	22%	< 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). The likelihood ratio tests the difference of –2 REM log likelihood between two nested models. The asterisk rows indicate 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		Dispersion
	Proportion Positives						
	Year VesCat Area Season	1303.3	1305.3	1305.3			2.6622
	Year VesCat Area Season *Year*Season*	1290.8	1294.8	1300.3	12.5	0.0004	2.1316
	Year VesCat Area Season *Year*Season Year*VesCat*	1282.5	1288.5	1296.7	8.3	0.0040	1.8539
*	Year VesCat Area Season *Year*Season Year*VesCat Area*Season*	1264.6	1272.6	1283.5	17.9	0.0000	1.6711
	Positives catch rates Vessel Size Category						
	Year VesCat Season Area Bait	4565.3	4567.3	4573			
	Year VesCat Season Area Bait *Year*VesCat*	4504.3	4508.3	4512.7	61	0.0000	
	Year VesCat Season Area Bait *Year*VesCat Year*Season*	4379.7	4385.7	4392.2	124.6	0.0000	
	Year VesCat Season Area Bait *Year*VesCat Year*Season Year*Area*	4333.5	4341.5	4350.2	46.2	0.0000	
*	Year VesCat Season Area Bait *Year*VesCat Year*Season Year*Area Year*Bait*	4285.8	4295.8	4306.8	47.7	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	Lci	Uci	CV	std error	CV	obs
1987	11	2.318	4.675	1.10	19.85	83%	2.026	83%	0.95
1988	6	0.950	1.256	0.22	7.31	108%	0.711	108%	0.39
1989	10	1.098	1.242	0.27	5.78	90%	0.583	90%	0.45
1990	10	1.463	0.707	0.13	3.72	100%	0.368	100%	0.60
1991	46	2.806	0.956	0.25	3.60	74%	0.372	74%	1.15
1992	76	1.730	0.780	0.19	3.22	81%	0.330	81%	0.71
1993	99	3.115	0.271	0.05	1.52	105%	0.149	105%	1.28
1994	84	1.594	0.567	0.13	2.51	86%	0.255	86%	0.65
1995	78	1.544	0.532	0.12	2.35	86%	0.239	86%	0.63
1996	68	1.722	0.554	0.13	2.31	81%	0.236	81%	0.71
1997	77	2.231	0.444	0.09	2.14	92%	0.215	92%	0.91
1998	118	2.178	0.536	0.14	2.03	75%	0.209	75%	0.89
1999	118	3.853	1.530	0.48	4.85	63%	0.503	63%	1.58
2000	72	3.303	0.730	0.20	2.70	73%	0.278	73%	1.35
2001	36	1.554	0.365	0.08	1.76	93%	0.177	93%	0.64
2002	32	1.720	0.461	0.09	2.41	99%	0.239	99%	0.70
2003	57	1.926	0.422	0.09	1.92	88%	0.194	88%	0.79
2004	67	2.557	0.468	0.11	2.06	85%	0.209	85%	1.05
2005	62	2.792	0.497	0.12	2.06	81%	0.210	81%	1.14
2006	85	3.033	0.880	0.26	3.02	68%	0.313	68%	1.24
2007	70	3.825	2.713	0.95	7.78	57%	0.802	57%	1.57
2008	104	2.284	0.877	0.23	3.35	75%	0.346	75%	0.94
2009	75	2.745	0.672	0.14	3.23	92%	0.324	92%	1.12
2010	103	2.336	0.779	0.16	3.72	92%	0.374	92%	0.96
2011	115	2.375	0.909	0.20	4.09	87%	0.414	87%	0.97
2012	162	5.794	1.385	0.33	5.84	82%	0.596	82%	2.37
2013	101	2.422	1.248	0.31	4.95	78%	0.509	78%	0.99
2014	109	2.954	0.675	0.13	3.46	97%	0.344	97%	1.21
2015	99	1.991	0.790	0.15	4.07	98%	0.404	98%	0.82
2016	169	2.806	1.809	0.50	6.52	71%	0.675	71%	1.15
2017	60	2.102	1.130	0.23	5.64	95%	0.563	95%	0.86
2018	50	2.975	1.139	0.22	5.82	97%	0.579	97%	1.22

Table 4. Mean size of Atlantic sailfish (LJFL) caught by the Venezuelan pelagic longline fishery in the Caribbean Sea and adjacent areas of the western central Atlantic.

Atlantic sailfish	n	Mean ± sd (cm)	Range (cm)
Males	2110	167.08±12.78	80-224
Females	1864	168.07±11.15	85-257
Unknown sex	1190	162.66±15.67	82-200

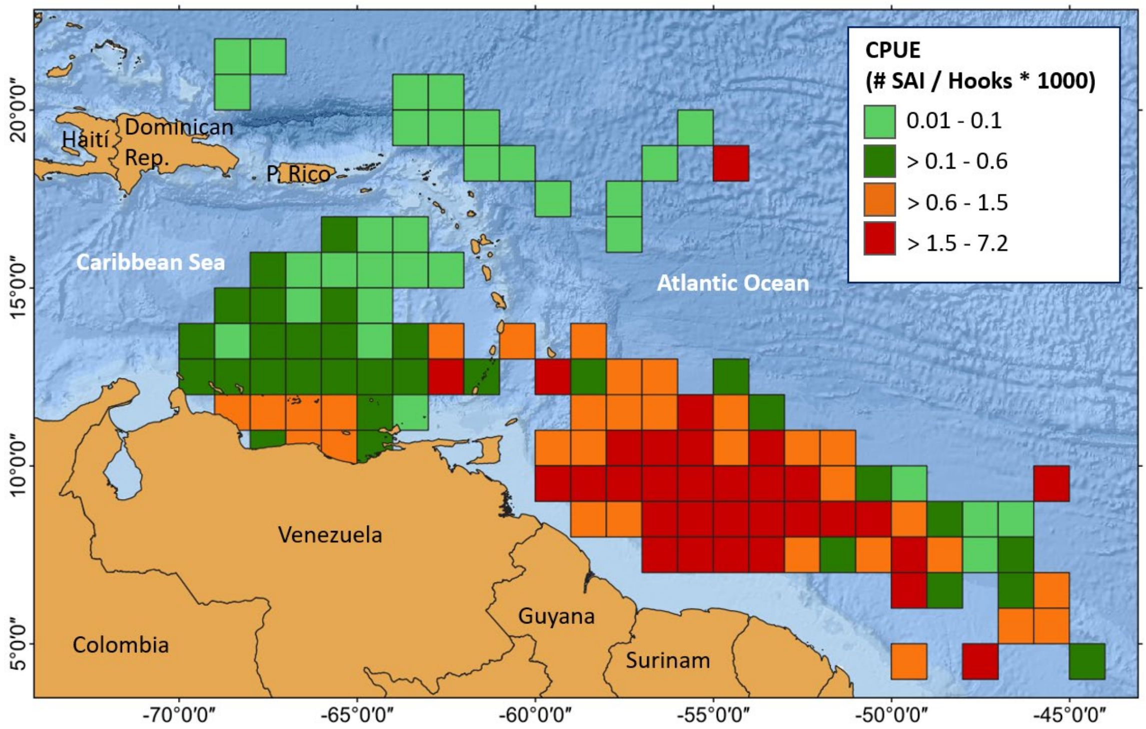

Figure 1. Spatial distribution of nominal CPUE of Atlantic sailfish (numbers/1000 hooks) caught by the Venezuelan pelagic longline fleet during 1987-2018 and recorded by the VPLOP and PNOB.

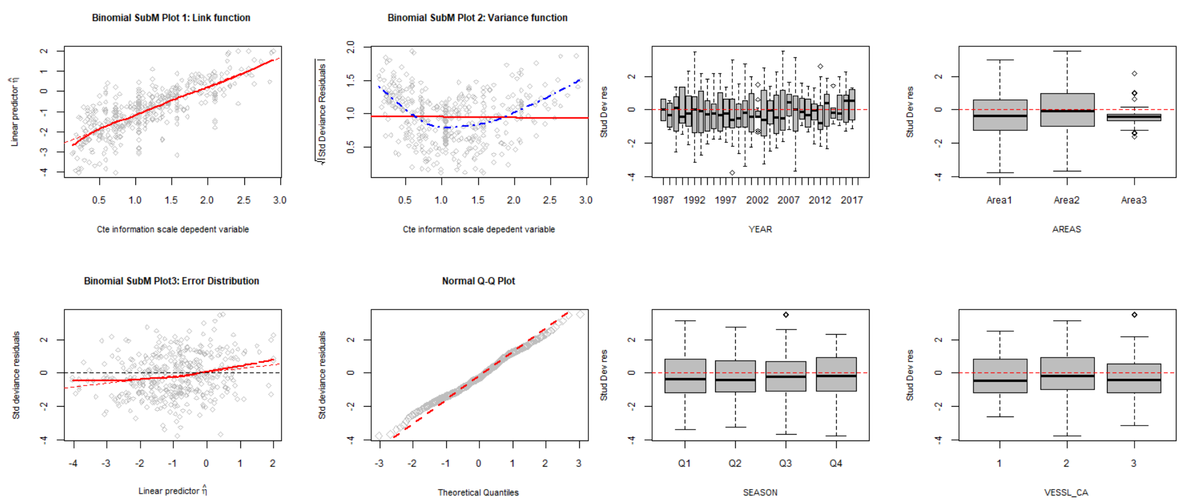

Figure 2. Diagnostic plots for the binomial proportion of the positive sub-model, a) for a check of the link function, b) the variance function, c) the check for the error distribution of the model, d) the qq-plot of the standardized deviance residuals, e-i) check for the scale of fixed factors and covariates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

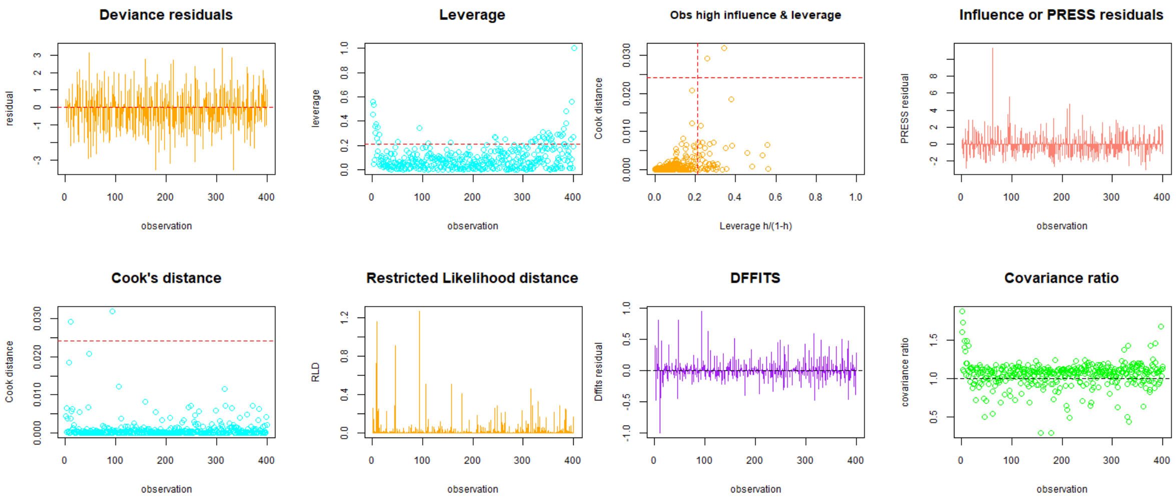

Figure 3. Diagnostic plots for indication of influential observations in the binomial proportion of the positive sub-model model: Deviance residuals, Leverage, Cook's distance, Restricted Likelihood distance (RLD), Cook's/Leverage, PRESS residuals, DFFITS, and Covariance ratio plot.

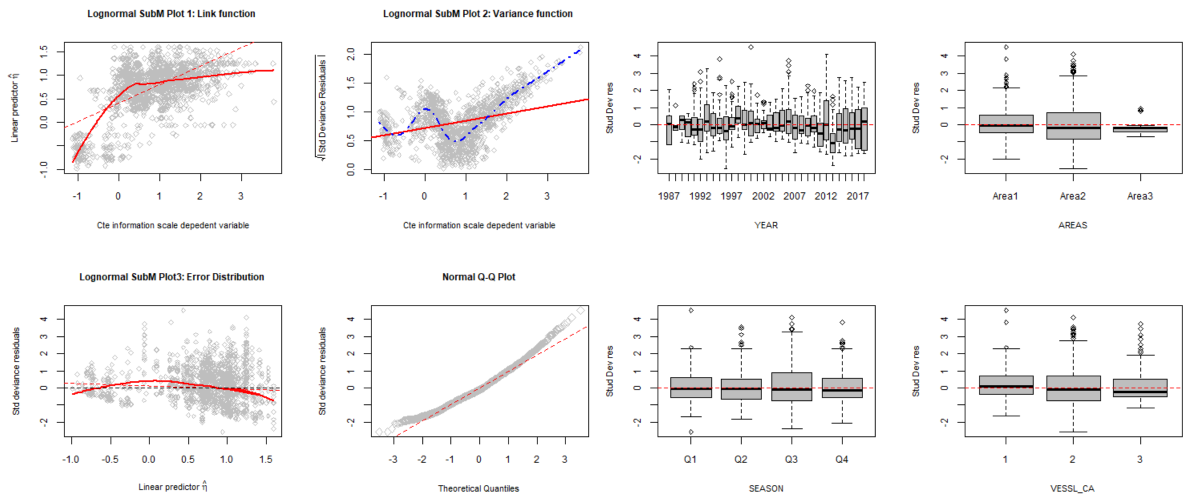

Figure 4. Diagnostic plots for the positive observations sub-model, a) for a check of the link function, b) the variance function, c) the check for the error distribution of the model, d) the qq-plot of the standardized deviance residuals, e-i) check for the scale of fixed factors and covariates in the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

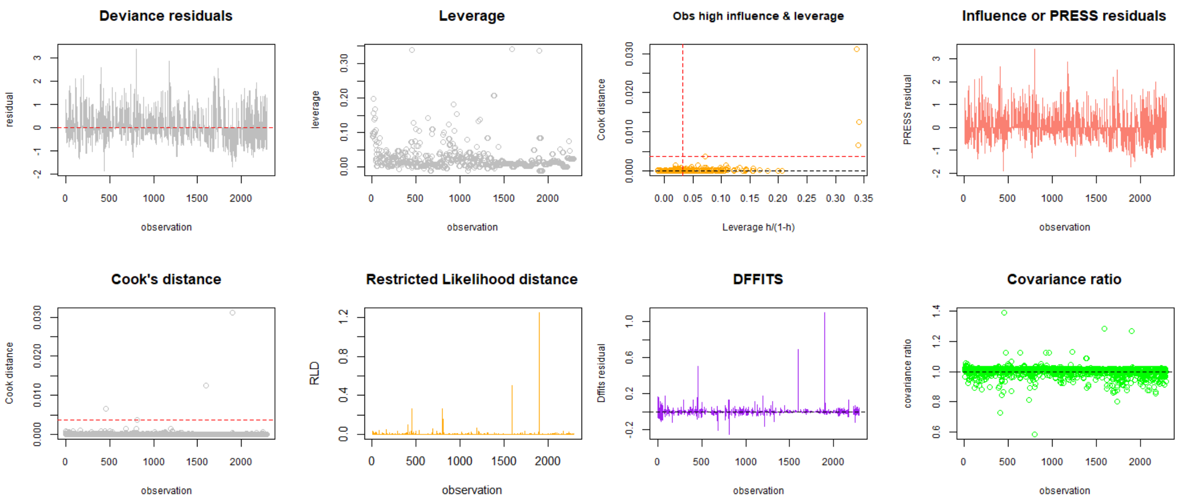

Figure 5. Diagnostic plots for indication of influential observations in the positive observations sub-model: Deviance residuals, Leverage, Cook's distance, Restricted Likelihood distance (RLD), Cook's/Leverage, PRESS residuals, DFFITS, and Covariance ratio plot.

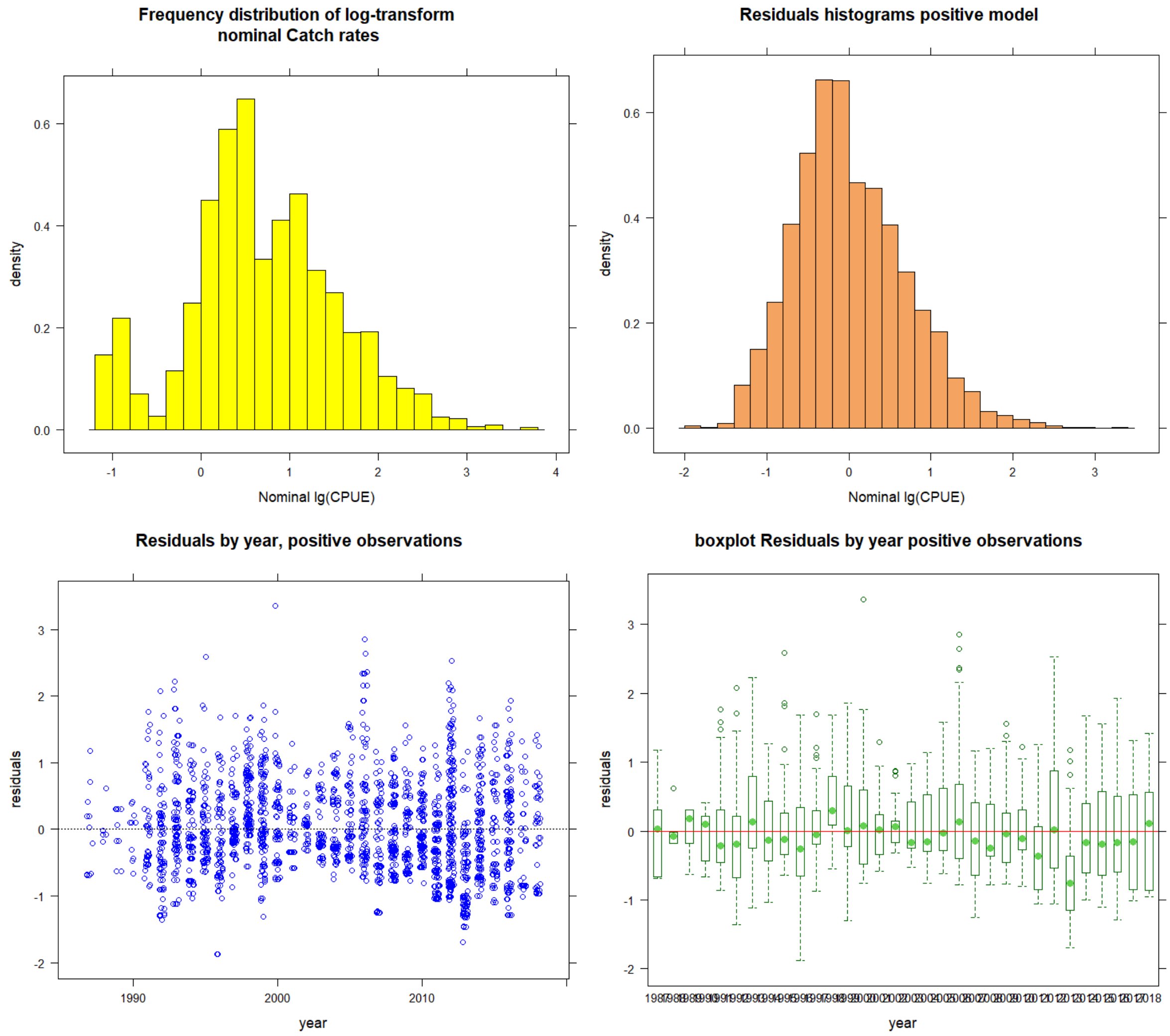

Figure 6. Traditional diagnostic plots for positive observations. a) Histogram and frequency density distribution of the log-transformed nominal CPUE, b) histogram of the residuals for the positive observations, c-d) Residuals and boxplot residuals by year for positive observations.

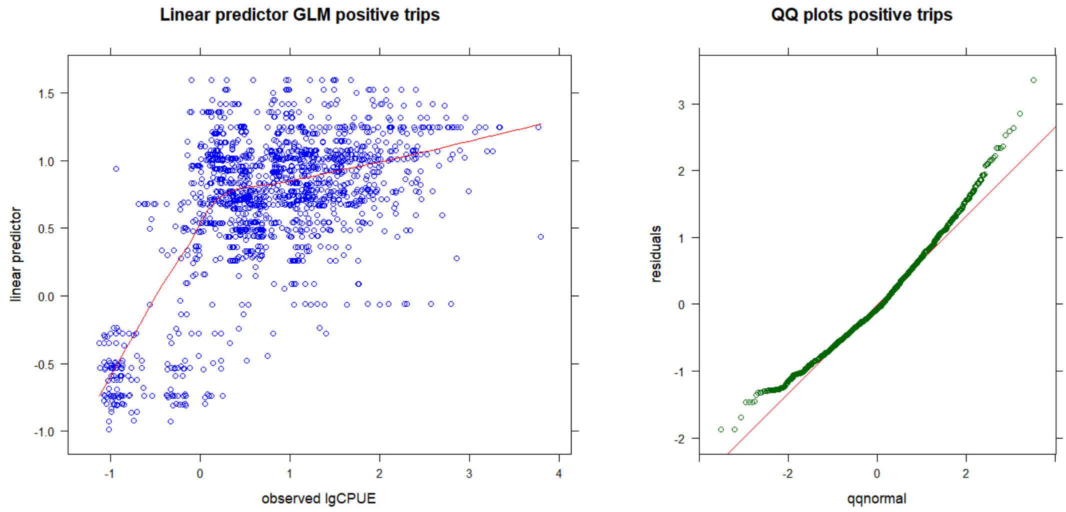

Figure 7. Diagnostic plots for positive observations. a) Linear predicted versus nominal logCPUE scatter plot with loess smother trend. b) QQ-normal plot of positive observations, and c) Boxplot residuals by Vessel.

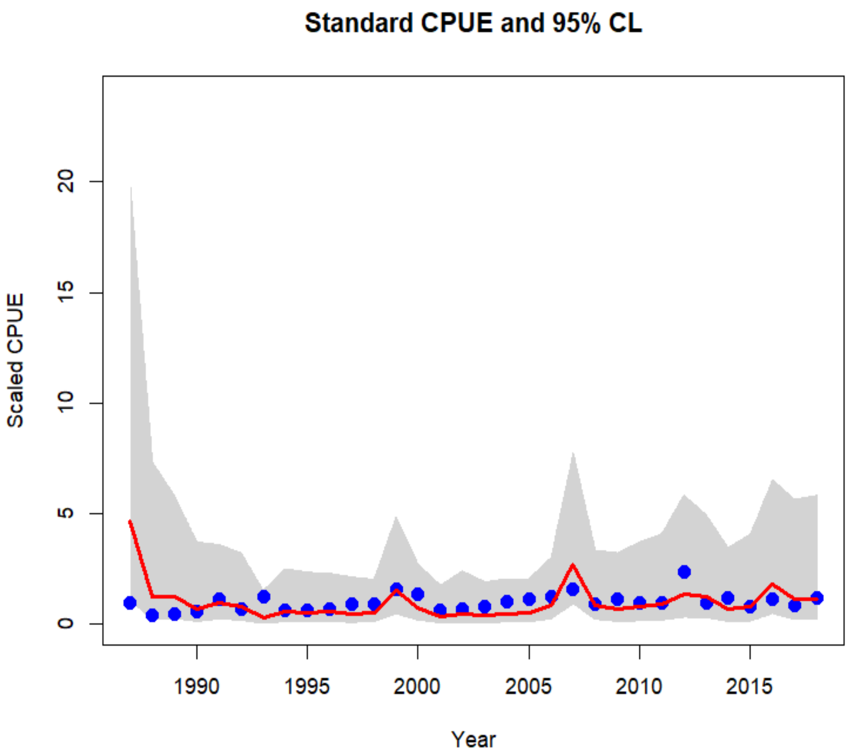

Figure 8. Estimated nominal (circles) and standardized (line) CPUE in numbers of sailfish from the Venezuelan Pelagic Longline Observer Program data set. The grey shaded area corresponds to 95% confidence intervals of the standardized CPUE.

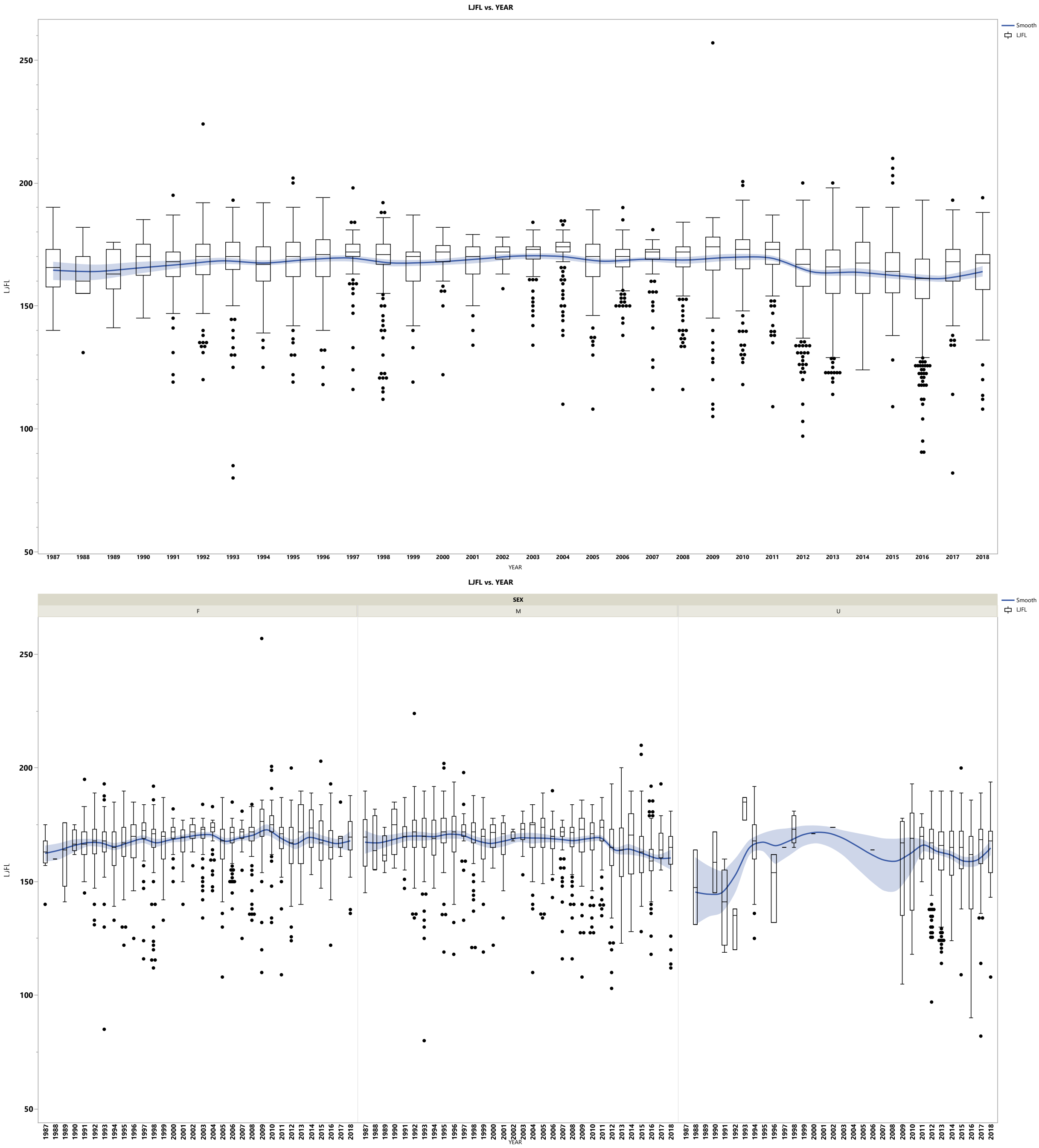

Figure 9. Atlantic sailfish annual length distributions expressed as median with the interquartile range (25% qt–75% qt) from fish caught in 1987-2018 and recorded by the Venezuelan LL observer programs. Top panel is for all sexes combined, bottom panel is by sex (F, females, M, males, U, unknown sex). Smoother spline is with 0.05 lambda and shaded area around are CI.