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STANDARDIZED CATCH RATES FOR BLUE SHARK (*PRIONACE GLAUCA*) FROM THE VENEZUELAN PELAGIC LONGLINE FISHERY IN THE CARIBBEAN SEA AND ADJACENT WATERS OF THE NORTH ATLANTIC OCEAN: PERIOD 1994-2013

Freddy Arocha[1*], Mauricio Ortiz[2], Jesús H. Marcano[3]

SUMMARY

Indices of abundance of blue shark (Prionace glauca) *from the Venezuelan Pelagic Longline fishery are presented for the period 1994-2013. The index of number of fish per thousand hooks was estimated from numbers of blue shark caught and reported in the observer data forms recorded by scientific observers aboard longline (Venezuelan Pelagic Longline Observer Program) vessels since 1994, and from INSOPESCA's Observer Program for 2012-2013. The standardization analysis procedure included the following variables; year, vessel, area, season, bait, and approximate fishing depth. The standardized index was estimated using Generalized Linear Mixed Models under a delta lognormal model approach. The standardized CPUE series show that the relative abundance of blue shark increased in the early part of the series (1997-2000) followed by a decline from 2001 until 2006 with the lowest value in 2005, and some recovery in the latest years of the series.*

RÉSUMÉ

*Les indices d'abondance du requin peau bleue (*Prionace glauca*) des pêcheries palangrières pélagiques du Venezuela sont présentés pour la période 1994-2013. L'indice du nombre de poissons par mille hameçons a été estimé à partir du nombre de requins peau bleue capturés et déclarés dans les formulaires de données d'observateurs remplis par les observateurs scientifiques embarqués à partir des palangriers depuis 1994 du programme d'observateurs palangriers pélagiques du Venezuela et du programme d'observateurs d'INSOPESCA pour la période 2012-2013. La procédure d'analyse de la standardisation a inclus les variables suivantes : année, navire, zone, saison, appât et profondeur approximative de la pêche. L'indice standardisé a été estimé à l'aide de modèles mixtes linéaires généralisés selon une approche du modèle delta-lognormale. Les séries standardisées de la CPUE montrent une augmentation de l'abondance relative du requin peau bleue au cours de la première partie de la série (1997-2000), suivie d'une baisse entre 2001 et 2006, la valeur la plus faible apparaissant en 2005, et un léger rétablissement au cours des dernières années de la série.*

RESUMEN

Se presentan los índices de abundancia de tintorera (Prionace glauca) de las pesquerías de palangre pelágico de Venezuela para el periodo 1994-2013. El índice del número de peces por mil anzuelos se estimó a partir del número de tintoreras capturadas y declaradas en los formularios de datos de observadores consignados por observadores científicos a bordo de palangreros (Programa de observadores de palangre pelágico de Venezuela) desde 1994 y por el Programa de observadores de INSOPESCA para 2012-2013. El procedimiento del análisis de estandarización incluía las siguientes variables: año, buque, área, temporada, cebo y profundidad de pesca aproximada. El índice estandarizado se estimó utilizando modelos lineales mixtos generalizados con un enfoque del modelo delta lognormal. La serie de CPUE estandarizada demuestra que la abundancia relativa de la tintorera aumentó en la primera parte de la serie (1997-2000), y a continuación se produjo un descenso de 2001 a 2006, con el menor valor en 2005, y cierta recuperación en los últimos años de la serie.

KEYWORDS

Blue shark, catch rates, Caribbean Sea, Venezuelan longline fishery

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[1] Instituto Oceanográfico de Venezuela, Universidad de Oriente, Cumaná 6101-Venezuela. Email: farocha@sucre.udo.edu.ve

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

[3] INSOPESCA-Sucre, Cumaná, Venezuela.

1. Introduction

The Venezuelan longline fleet operates over an important geographical area in the western central Atlantic and its main target species is yellowfin tuna and other tropical species, however bycatch species such as billfish and sharks are also commonly caught. In 1994, the Venezuelan Pelagic Longline Observer Program (VPLOP), sponsored by ICCAT's Enhanced Billfish Research Program, started to gather information on the shark species caught by the Venezuelan pelagic longline fishery. The information on shark species composition from the VPLOP's catch, indicated that blue shark (*Prionace glauca*) represented about 35% of the total shark catch (Tavares and Arocha, 2008). Early studies indicated a seasonal occurrence of blue shark in catches, starting high in the first quarter of the year in waters off Guyana and Suriname, and increasing progressively towards Trinidad and the Caribbean during the second and third quarter, and finally concentrating in the Caribbean towards the fourth quarter of the year (Arocha *et al*., 2005). The need to analyze blue shark catch rates and the continuous difficulties in obtaining pelagic longline logbook data by species prompted the use of the data collected from the VPLOP to develop standardized catch rates for blue shark caught by the Venezuelan fleet. This document presents the standardized catch rates of blue shark from this fleet, using a Generalized Linear Random Mixed Model.

2. 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 1994-2011 and from INSOPESCA's National Observer Program for the period 2012-2013 (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 1994-2011 (Arocha *et al*., 2013), and ~5% from INSOPESCA's 2012-2013 observer program. Since the collection of species-specific shark data in 1994, the data collected comprises a total of 5,683 record-sets from 1994 through 2013. Of these sets, blue shark was reported caught in 605 sets (10.6%). Detailed information collected in the VPLOP, as well fishing grounds for the Venezuelan fleet are 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). Individual vessel identification was also available and used in alternative analysis 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). There were 92 different vessels in the VPLOP database of which 63 had reported catches of blue shark at any time. However, not all were fishing during the 1994-2013 period, actually 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. For example, an autoregressive variance-covariance matrix (AR1) assumes a higher correlation of catch rates for each vessel in adjacent observations in a time frame (i.e., years or months) (Little *et al*., 1996). Another example, compound symmetry (CS) variance-covariance assumes that variability is the result of two components, a constant overall variance and constant covariance between subjects (vessels) (Bishop, 2006). Other variance covariance structures can assume spatial or temporal correlations, or estimate parameters for individual subject. The main objective is to evaluate if variance within vessels is consistent and shows a given pattern. 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 blue shark caught per 1000 hooks.

For the Venezuelan longline observer data, relative indices of abundance for blue shark were estimated by Generalized Linear Modeling approach assuming a delta lognormal model distribution following the same protocol as described in Tavares *et al*., 2012. 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 under two different approaches: 1) 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); and 2) Considering each individual vessel as a sampling unit, and using "repeated measure" approach to estimate variability for each vessel assuming the AR1 and CS variance-covariance matrix structure.

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).

3. Results and discussion

Blue shark 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 southeastern part. 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 that north of Surinam and east of the Orinoco Delta (Venezuela) (=area 2). Very small catch rates were observed in the central Caribbean Sea, and in the southwest of the Sargasso Sea (=area 3). In general, the highest blue shark catch rates were closer to land masses than in open ocean waters.

The frequency distribution of log-transformed nominal CPUE in numbers of blue shark per thousand hooks is presented in **Figure 2**. The distribution is bimodal, with one peak at very low catch rates (about 0.1 sharks per 1000 hooks), and another at about 0.6 sharks per 1000 hooks. A bivariate plot of number of sharks per number hooks show that set/trips with lower number of hooks tend to catch blue shark more frequently than trips with larger number of hooks (**Figure 3**), the number of hooks deployed is directly related to the size category of the vessel. Usually, large size vessels with larger number of hooks deployed still catch blue shark but in lower numbers, and thus, a much lower catch rates. This explains the bimodal distribution of the nominal catch rates observed before. The scatter plot of logCPUE per vessel size category (**Figure 4**), show that small and medium size vessels (category 1 and 2) display the higher rates of blue shark catch, while it is lower for the larger vessels (category 3) but the variability of catch rates are quite large overall. The distribution of catch by areas is shown in **Figure 5**, these included: the Caribbean (area 1), the Guyana-Amazon (area 2), and the southwest of the Sargasso Sea (area 3), it was noted that very few and low catches were reported from area 3. Another factor considered in the analyses was depth; **Figure 6** shows a bivariate plot of catch rates versus depth of hook by set. There is a large variation, but the plot and smoother trend suggests higher catch rates as depth increases, particularly after 45 m. In the model, depth was categorized into shallow sets (<45 m) and deep sets (>45 m). Bait type was also a factor evaluated, in past studies the type of bait was used as a factor, but recently the condition of the bait was identified as live or dead, and added to the input data. **Figure 7** shows the variance component analysis for bait type and by condition of bait in each category. Overall results indicated more variability within groups (78.5%) than among groups (15.7%). Live or dead bait show no difference in relation to blue shark catch rates.

The deviance analysis for blue shark from the Venezuelan longline observer data analyses are presented in **Table 1** for the analysis based on the number of fish as catch rates. For the proportion of positive/total sets; *year*, *vessel-size-group*, *area*, *season* and *bait type*; and the interactions *year*×*depth*, *year*×*bait type*, *year*×*areas*, *year*×*season*, and *year*×*vessel-size-group* were the major factors that explained whether or not a set caught at least one shark. For the mean catch rate given that it is a positive set, the factors: *year*, and *vessel-size-group*; and the interactions *year*×*season* and *year*×*vessel-size-group*, were more significant. Once a set of fixed factors were selected, we evaluated first level random interaction between the year and other effects. **Table 2** shows the results from the random test evaluation for interactions that included the *year* factor. For the proportion of positive sub model, the interaction *year*×*season* was significant, while for the positive observations sub model the interaction *year*×*vessel-size-group* category, *year*×*season* and *year*×*bait* were significant, and included in the final model.

As mentioned before, 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 or CS 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. Both the repeated measures models AR1 and/or CS provided substantially lower AIC values for the fit of the positive observations, compared to the GLMM model that used the vessel category factor instead. This was corroborated by the diagnostic plots of the distribution of residuals (**Figure 8**) and the qq-plots (**Figure 9**). These results suggest that within a single vessel, the variability of catch rates is smaller compared to the variability of similar size class vessel group. Still smaller/medium size vessels showed the higher catch rates of blue shark in the Venezuelan pelagic longline fishery.

Standardized CPUE series with the vessel size category model for blue shark are shown in **Table 3** and **Figure 10**. Estimated coefficients of variation are large, as indicated by the wide confidence intervals. The standardized CPUE series show that the relative abundance of blue shark increased in the early part of the series (1994-98) followed by a decline from 1998 until 2006 with the lowest value in 2005. Using the vessel individual variability model (AR 1), the trend was similar (**Table 4**, **Figure 11**). A small recovery is observed in the last year of the series. Estimated coefficients of variation in the 'individual vessel model' were similar compared to the model using vessel size category factor.

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Table 1. Deviance analysis table for explanatory variables in the delta lognormal model for blue shark catch rates (in number) from the 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.

Blue shark Vza PLL CPUE Index

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	428.2954			
Year	19	230.5025	197.79	68.2%	< 0.001
Year Vc	2	183.1327	47.37	16.3%	< 0.001
Year Vc Areas	2	182.1531	0.98	0.3%	0.613
Year Vc Areas Season	3	179.5214	2.63	0.9%	0.452
Year Vc Areas Season Depth	1	170.2748	9.25	3.2%	0.002
Year Vc Areas Season Depth Bait_Typ	3	168.0913	2.18	0.8%	0.535
Year Vc Areas Season Depth Bait_Typ Vc*Areas	2	167.3503	0.74	0.3%	0.690
Year Vc Areas Season Depth Bait_Typ Season*Depth	3	165.164	2.93	1.0%	0.403
Year Vc Areas Season Depth Bait_Typ Vc*Depth	2	163.9053	4.19	1.4%	0.123
Year Vc Areas Season Depth Bait_Typ Year*Areas	14	162.9269	5.16	1.8%	0.983
Year Vc Areas Season Depth Bait_Typ Season*Bait_Typ	9	162.6133	5.48	1.9%	0.791
Year Vc Areas Season Depth Bait_Typ Vc*Season	6	162.4349	5.66	1.9%	0.463
Year Vc Areas Season Depth Bait_Typ Year*Depth	7	162.3562	5.74	2.0%	0.571
Year Vc Areas Season Depth Bait_Typ Year*Bait_Typ	20	156.2275	11.86	4.1%	0.921
Year Vc Areas Season Depth Bait_Typ Year*Season	43	153.4523	14.64	5.0%	1.000
Year Vc Areas Season Depth Bait_Typ Year*Vc	17	138.2232	29.87	10.3%	0.027

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	1378.294			
Year	19	1192.665	185.63	30%	< 0.001
Year Vc	2	1140.679	51.99	8%	< 0.001
Year Vc Areas	2	1073.034	67.64	11%	< 0.001
Year Vc Areas Season	3	1038.582	34.45	6%	< 0.001
Year Vc Areas Season Depth	1	1017.973	20.61	3%	< 0.001
Year Vc Areas Season Depth Bait_Typ	3	979.575	38.40	6%	< 0.001
Year Vc Areas Season Depth Bait_Typ Vc*Areas	4	977.926	1.65	0%	0.800
Year Vc Areas Season Depth Bait_Typ Season*Depth	3	968.786	10.79	2%	0.013
Year Vc Areas Season Depth Bait_Typ Vc*Season	6	964.475	15.10	2%	0.019
Year Vc Areas Season Depth Bait_Typ Areas*Depth	2	964.432	15.14	2%	< 0.001
Year Vc Areas Season Depth Bait_Typ Depth*Bait_Typ	3	963.276	16.30	3%	< 0.001
Year Vc Areas Season Depth Bait_Typ Areas*Bait_Typ	5	960.532	19.04	3%	0.002
Year Vc Areas Season Depth Bait_Typ Areas*Season	5	960.457	19.12	3%	0.002
Year Vc Areas Season Depth Bait_Typ Season*Bait_Typ	9	942.267	37.31	6%	< 0.001
Year Vc Areas Season Depth Bait_Typ Year*Depth	12	884.594	94.98	15%	< 0.001
Year Vc Areas Season Depth Bait_Typ Year*Bait_Typ	38	845.088	134.49	22%	< 0.001
Year Vc Areas Season Depth Bait_Typ Year*Areas	27	783.708	195.87	32%	< 0.001
Year Vc Areas Season Depth Bait_Typ Year*Vc	24	780.380	199.20	32%	< 0.001
Year Vc Areas Season Depth Bait_Typ Year*Season	53	759.955	219.62	36%	< 0.001

Table 2. Analyses of delta lognormal mixed model formulations for **blue shark** catch rates (**in number**) from the 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. Repeated measures models statistics are provided for the positive observations model, using a compound-symmetry (CS) and autoregressive (AR1) variance-covariance structures.

GLMixed Model	-2 REM Log likelihood	Akaike's Information Criterion	Bayesian Information Criterion	Likelihood Ratio Test		Dispersion
Proportion Positives						
Year VesCat Area Season Bait	1689.3	1691.3	1695.2			3.3012
Year VesCat Area Season Bait *Year*Season*	1668.1	1672.1	1676.7	21.2	0.0000	2.9062
Year VesCat Area Season Bait *Year*Season Year*VesCat*	1698.4	1704.4	1711.4	-30.3	N/A	2.4459
Year VesCat Area Season Bait *Year*Season Year*Area*	1671.8	1677.8	1684.7	-3.7	N/A	2.2944
Year VesCat Area Season Bait *Year*Season Year*Area Year*Bait*	1675.5	1683.6	1692.8	-7.4	N/A	2.1116
Positives catch rates Vessel Size Category						
Year VesCat Season Bait	1049	1051	1055.4			
Year VesCat Season Bait *Year*VesCat*	974.3	978.3	981.6	74.7	0.0000	
Year Vessel Season Depth *Year*Vessel Year*season*	971	977	982	3.3	0.0693	
Year Vessel Season Depth *Year*Vessel Year*season Year*Bait*	967.2	975.2	981.8	3.8	0.0513	
Positives catch rates AR1 var-cov with Vessel as subject repeated measures						
Year Season Bait	558.6	562.6	568.9			
Year Season Bait *Year*season Year*Bait*	505.8	513.8	522.5	52.8	0.0000	
Positives catch rates CS var-cov with Vessel as subject repeated measures						
Year Season Bait	597.6	601.6	608			
Year Season Bait *Year*season Year*Bait*	570.1	578.1	586.9	27.5	0.0000	

Table 3. Nominal and standardized (Delta lognormal mixed model) CPUE series (number of fish /1000 hooks) for blue shark catch rates from the Venezuelan Pelagic Longline Observer Program (VPLOP) and INSOPESCA's observer program using the vessel size category factor.

Year	*N Obs*	*Nominal CPUE*	*Standard CPUE*	*Low*	*Upp*	*coeff var %*	*std error*
1994	348	0.195	0.047	0.008	0.269	108%	0.0501
1995	506	0.193	0.073	0.016	0.326	87%	0.0633
1996	383	0.045	0.017	0.001	0.205	190%	0.0329
1997	374	0.393	0.154	0.044	0.532	69%	0.1054
1998	442	0.583	0.216	0.064	0.728	67%	0.1442
1999	358	0.444	0.117	0.027	0.509	84%	0.0991
2000	334	0.504	0.151	0.040	0.562	74%	0.1110
2001	282	0.508	0.133	0.034	0.522	77%	0.1027
2002	221	0.367	0.074	0.013	0.404	103%	0.0760
2003	327	0.050	0.044	0.006	0.312	126%	0.0558
2004	329	0.046	0.034	0.004	0.302	153%	0.0514
2005	273	0.012	0.006	0.000	0.181	388%	0.0250
2006	314	0.030	0.013	0.001	0.183	224%	0.0282
2007	98	0.154	0.060	0.008	0.462	135%	0.0812
2008	181	0.205	0.088	0.014	0.560	116%	0.1024
2009	147	0.145	0.045	0.005	0.416	156%	0.0704
2010	231	0.109	0.040	0.004	0.359	154%	0.0610
2011	227	0.147	0.044	0.005	0.394	151%	0.0671
2012	253	0.453	0.107	0.020	0.564	100%	0.1067
2013	55	0.166	0.044	0.004	0.500	184%	0.0808

Table 4. Nominal and standardized (Delta lognormal mixed model) CPUE series (number of fish /1000 hooks) for blue shark catch rates from the Venezuelan Pelagic Longline Observer Program (VPLOP) and INSOPESCA's observer program using the repeated measures model with a auto regressive 1 (AR1) variance-covariance structure where individual vessel were assumed as subjects

Year	***N obs***	***Nominal Cpue***	***Standard CPUE***	***Low CI***	***Upper CI***	***CV***	***std error***
1994	348	0.195	0.561	0.008	0.262	105.6%	0.0
1995	506	0.193	0.825	0.015	0.312	88.4%	0.1
1996	383	0.045	0.193	0.001	0.213	209.1%	0.0
1997	374	0.393	1.752	0.044	0.479	65.5%	0.1
1998	442	0.583	2.181	0.057	0.574	63.0%	0.1
1999	358	0.444	1.622	0.036	0.498	73.3%	0.1
2000	334	0.504	2.230	0.058	0.582	62.6%	0.1
2001	282	0.508	1.505	0.033	0.472	74.7%	0.1
2002	221	0.367	0.847	0.013	0.383	102.9%	0.1
2003	327	0.050	0.242	0.002	0.208	171.6%	0.0
2004	329	0.046	0.251	0.002	0.195	158.6%	0.0
2005	273	0.012	0.055	0.000	0.158	474.3%	0.0
2006	314	0.030	0.156	0.001	0.196	230.8%	0.0
2007	98	0.154	0.651	0.007	0.413	135.0%	0.1
2008	181	0.205	1.660	0.030	0.630	88.7%	0.1
2009	147	0.145	0.924	0.013	0.458	110.8%	0.1
2010	231	0.109	0.761	0.011	0.366	108.1%	0.1
2011	227	0.147	0.721	0.009	0.375	115.3%	0.1
2012	253	0.453	2.012	0.047	0.595	70.7%	0.1
2013	55	0.166	0.851	0.008	0.603	147.3%	0.1

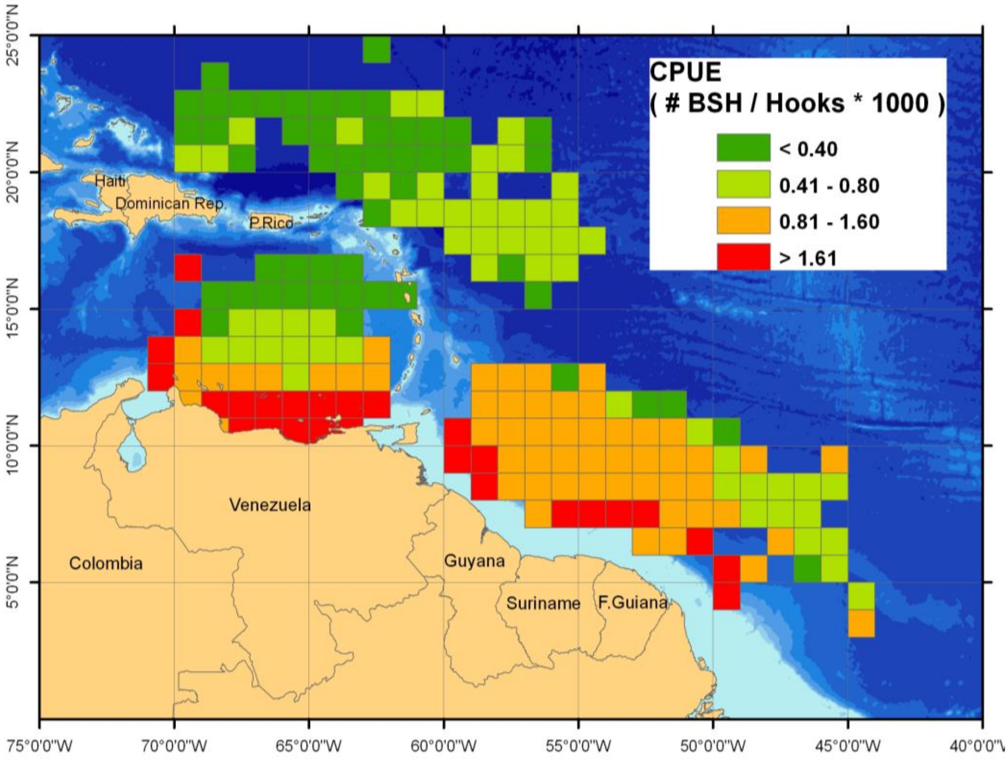

Figure 1. Spatial distribution of nominal CPUE of **blue shark** (numbers/1000 hooks) caught by the Venezuelan pelagic longline fleet during the period of 1994-2013, recorded by the VPLOP and INSOPESCA's Observer Program.

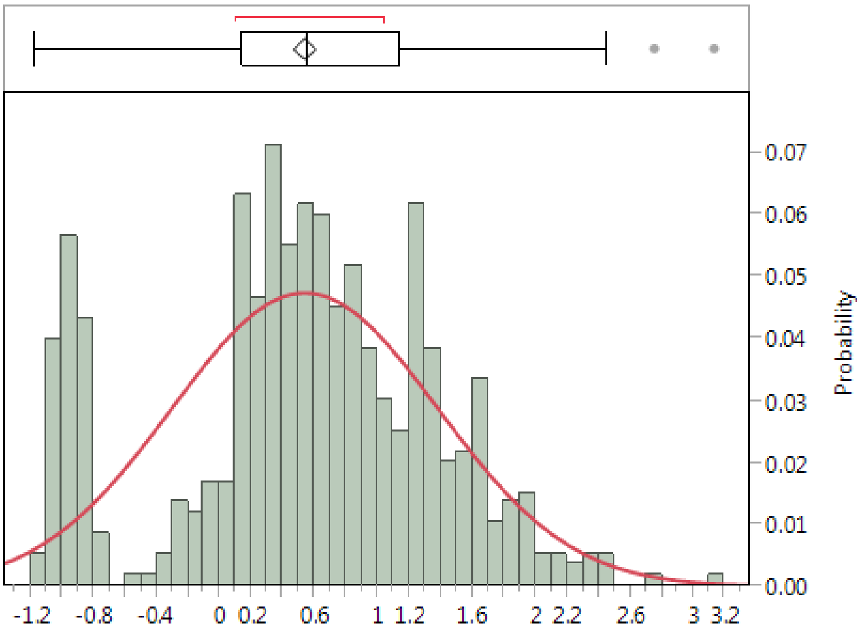

Figure 2. Distribution of positive trips catch rates (number of fish per thousand hooks) for blue shark from the Venezuela pelagic fisheries observer program data, all vessels 1994-2013.

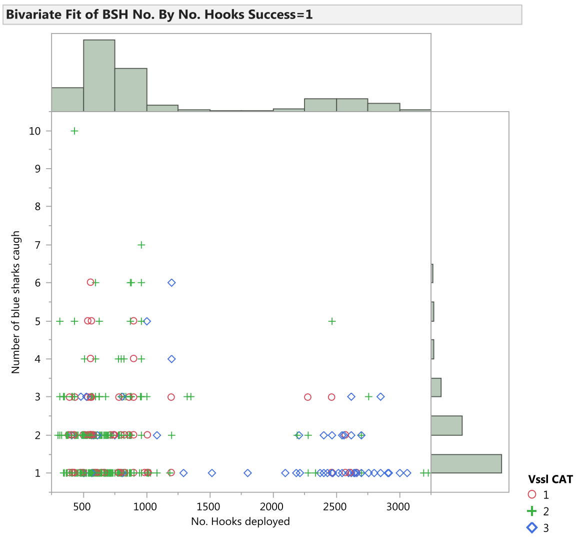

Figure 3. Bivariate plot of numbers blue shark per number of total hooks deployed by vessel category. Only observations with positive catch. Red circles represent vessel of category 1, green plus sign vessels category 2 and blue diamond vessels category 3 (larger size).

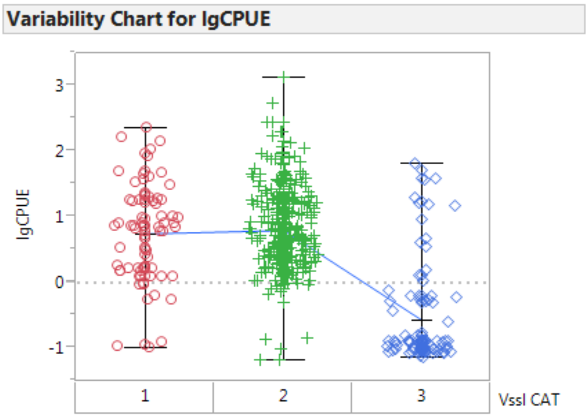

Figure 4. Variability chart of nominal lgCPUE blue shark by vessel size category (1=smaller vessels).

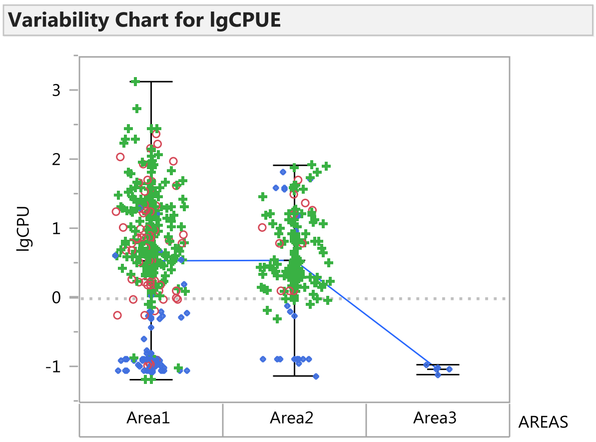

Figure 5. Variability plots for nominal lgCPUE blue shark by geographical area.

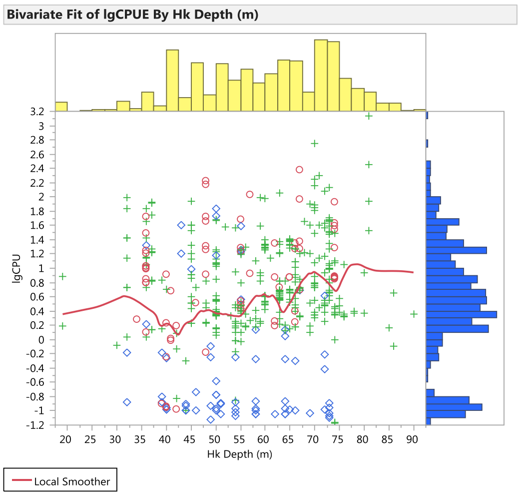

Figure 6. Bivariate plot of nominal catch rate (lgCPUE) versus depth of hook setting by set, the red line is a smoother applied to the data.

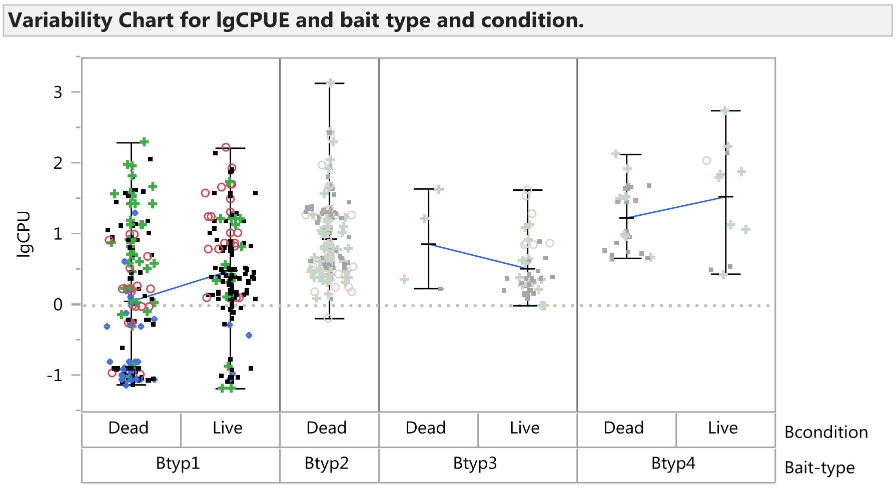

Figure 7. Variability plot for bait type categories and catch rates of blue shark. Variance component analysis indicated a larger variance within each bait type group (78.5%) than among groups (15.7%), also a small difference between live or dead bait within each group, excluding perhaps bait type 2, but low number of samples prevent any further conclusion.

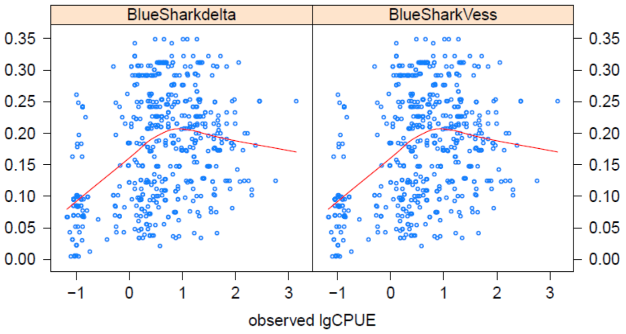

Figure 8. Residual distribution by year of the fit by the model with vessel size category factor (left) and the repeated measures auto-regressive variance-covariance structure (AR1) (right).

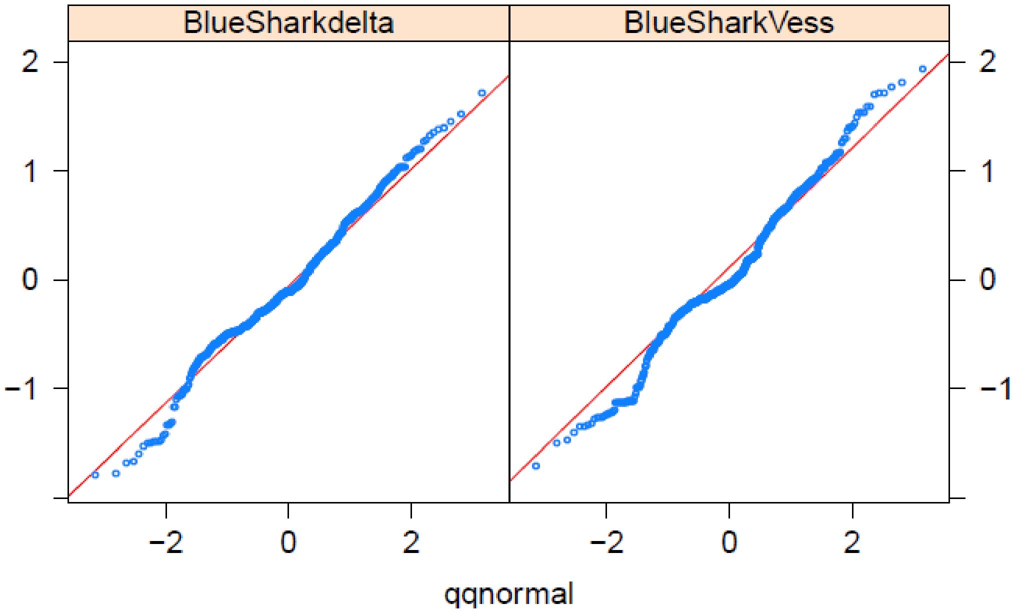

Figure 9. Qq-plots (cumulative normalized residuals) for the positive models with vessel size category factor (left) and the repeated measures auto-regressive variance-covariance structure (AR1) (right).

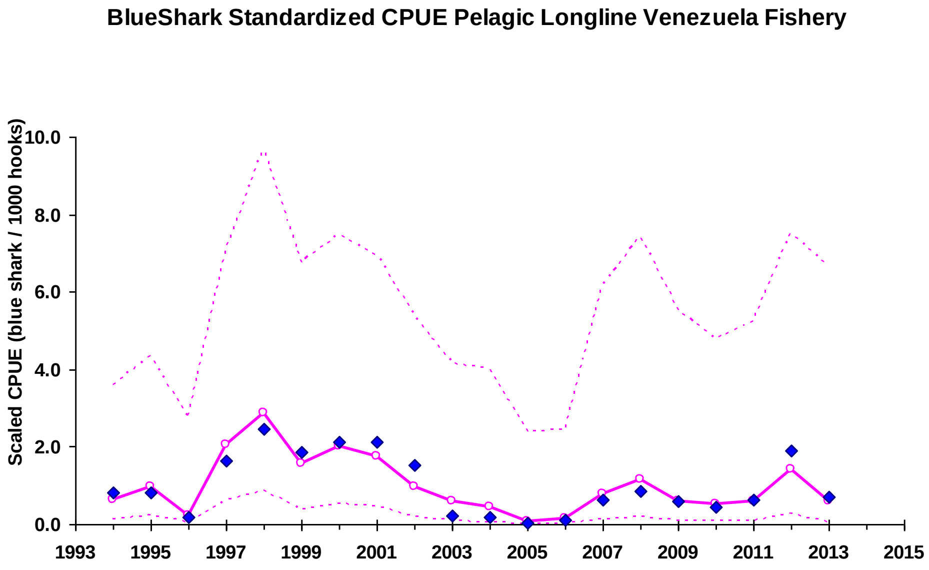

Figure 10. Scaled standard CPUE (filled circles) and nominal CPUE (solid diamonds) for blue shark from the Venezuelan Pelagic Longline Observer Program and INSOPESCA's observer program data sets. Dotted lines correspond to estimated 95% confidence intervals of the standardized CPUE. This model included the vessel size category as a factor.

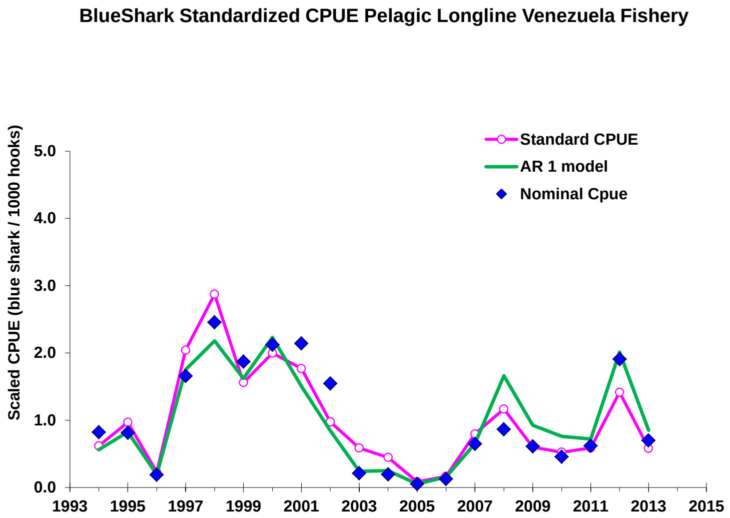

Figure 11. Scaled standard CPUE (circles) and nominal CPUE (solid diamonds) for blue shark from the Venezuelan Pelagic Longline Observer Program and INSOPESCA's observer program data sets. This model included the vessel as subject in a repeated measures model with an auto-regresive (AR1) variance-covariance matix.