

STANDARDIZED CATCH RATES FOR YELLOWFIN TUNA (*Thunnus albacares*) FROM THE OBSERVED VENEZUELAN LONGLINE FLEET IN THE NORTHWESTEN ATLANTIC 1991-2002

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SUMMARY

Indices of abundance of yellowfin tuna from the Venezuelan Pelagic Longline fishery are presented for the period 1991-2002. The index of number of fish per number of hook-hours fished was estimated from numbers of yellowfin tuna caught and reported in the Observer data forms recorded by scientific observers aboard longline (Pelagic Longline Observer Program) vessels since 1991. The standardization analysis procedure included the following variables; year, area, season, fishing time, and fishing depth. The standardized index was estimated using Generalized Linear Mixed Models under a delta lognormal model approach.

RÉSUMÉ

Le présent document fait état des indices d'abondance de l'albacore de la pêcherie palangrière pélagique du Venezuela pour la période 1991-2002. On a estimé l'indice du nombre de poissons pêchés par le nombre d'hameçons-heures à partir du nombre d'albacores capturés et déclarés dans les formulaires de données remplis par les observateurs scientifiques postés à bord de palangriers (Programme d'observateurs à bord de palangriers pélagiques) depuis 1991. La procédure d'analyse de la standardisation a inclus les variables suivantes : année, zone, saison, temps de pêche et profondeur de la pêche. L'indice standardisé a été estimé à l'aide de modèles linéaires généralisés mixtes selon une technique de modèle delta lognormal.

RESUMEN

Se presentan los índices de abundancia de rabil de la pesquería de palangre pelágico de Venezuela para el periodo 1991-2002. Se estimó el índice del número de peces capturados por número de anzuelos-hora a partir del número de rabiles capturados y comunicados en los formularios de datos de observadores registrados por los observadores científicos embarcados en los palangreros (Programa de observadores de palangre pelágico) desde 1991. El procedimiento de análisis de la estandarización incluía las siguientes variables: año, zona, temporada, tiempo de pesca y profundidad de la pesca. El índice estandarizado se estimó utilizando el Modelo Lineal Mixto Generalizado con un enfoque de modelo delta lognormal.

KEY WORDS

Yellowfin tuna, Thunnus albacares, catch rates, longline, Venezuela

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1. Introduction

Information about changes in the abundance of yellowfin tuna, *Thunnus albacares*, is necessary to tune stock assessment models that are required for the management of yellowfin tuna in the Atlantic. The utility of indices of abundance based on catch and effort data can be improved by standardizing them to remove the impact of factors such as changes over time in the efficiency of the fleet. The yellowfin tuna nominal CPUE for the Venezuelan longline fleet has declined steadily since the all time high in 1991 (Marcano, 1999). Since 1991, ICCAT's Enhanced Billfish Research Program (EBRP) started placing scientific observers on board Venezuelan pelagic longliners targeting yellowfin tuna and swordfish. Due to the difficulties in obtaining pelagic longline log book data by species, the data collected from the EBRP from the Venezuelan fleet was chosen to develop standardized catch per unit of effort (CPUE) indices of abundance for the yellowfin tuna caught by the Venezuelan fleet. The Venezuelan longline fleet operates over an important geographical area in the western central Atlantic and its main target species is yellowfin tuna, thus imposing important fishery mortality on the stock fished in the western tropical Atlantic. The present report, review the catch and effort information from 1991 until 2002 and standardize catch rates of yellowfin tuna using a Generalized Linear Mixed Model with random factor interactions particularly for the *year* effect.

2. Materials and Methods

The data used in this paper came from the database of the Venezuelan Pelagic Longline Observer Program (VPLOP) for the period 1991-2002. Arocha and Marcano (1999) described the main features of the fleet and Marcano (1999) and Marcano *et al.* (1999, 2000) reviewed the available catch and effort data from the Venezuelan Pelagic Longline fishery covered by the observer program. Yellowfin tuna has become the main target species for the Venezuelan Pelagic Longline fleet in the past five years, with its fishing grounds extending from northwest of Puerto Rico (22°N-68°W) to off the coast of northeastern Brazil (4°N-44°W) (Fig. 1). Since 1991, trained scientific observers have recorded detailed information on gear characteristics, fishing operations as well morphometric and biological information from a sub-sample of the Venezuelan longline pelagic vessels (Arocha and Marcano, 1999).

The VPLOP surveys on average 13.3% of the Venezuela longline fleet annual trips (Arocha *et al.*, 2001b). The data collected comprises a total of 3,750 record-sets from 1991 through 2002. Of these sets, yellowfin tuna was reported caught in 2,621 sets (69.8%) with size frequency distribution and estimated weight (converted using current length-weight relationships from Miyake, 1990) per year as shown in **Figures 2 and 3**.

In a prior document Arocha *et al.* (2001a) described the relationship between catch rates for yellowfin tuna and factors that accounted for variability of catch rates by using General Additive Models (GAMs). Boundaries for the geographical regions were defined from the longitude and latitude GAM analysis in 2001. For hook depth, sets were categorized into shallow (= 40 m) and deep (> 40 m) sets. Soaking time observations were categorized into three groups; short sets for 8 or less fishing hours, medium sets for 8 to 12 hours, and long sets for 12 or more hours of fishing time. In addition to the previous factors, a category of boat size (based on the boat total length, horse power and operation characteristics) was included. The Venezuelan Longline fleet was divided into three categories; small boats (less than 20 m), medium boats (between 20 and 26 m), and large boats (26 m or more). The same factors and categories were used in the present analysis.

Fishing effort is reported in terms of the total number of hooks per trip and number of set per trip, as well the number of hours per set. As numbers of hooks per set vary, catch rates were calculated as number of yellowfin tuna caught per hook times hour fished. In addition, biomass catch rates were calculated from average estimated weights of individual fish by year, season and month, where 50 or more fish were measured by strata. If less than 50 size measurements were available in a given strata, the mean size of the upper level (*i.e.* year-season) was applied.

For the Venezuelan longline observer data, relative indices of abundance for yellowfin tuna were estimated by Generalized Linear Modeling approach assuming a delta lognormal model distribution. The delta model estimates separately the proportion of positive sets assuming a binomial error distribution, and the mean catch rate of sets if at least one yellowfin was caught by assuming a lognormal error distribution. The log-transformed frequency distribution of catch rates (lnCPUE) for sets that caught yellowfin tuna is shown in **Figure 4**. The estimated proportion of successful sets per stratum is assumed to be the result of *n* positive sets of a total *r* number of sets, and each one is an independent Bernoulli-type realization. The estimated proportion is a linear function of fixed effects and interactions. The logit function was used as link between the linear factor

component and the binomial error. For sets that caught at least one tuna (positive observations), estimated CPUE rates were assumed to follow a lognormal error distribution (lnCPUE) of a linear function of fixed factors and random effect interactions, particularly when the *year* effect was within the interaction.

A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. The difference of deviance between two consecutive models follows a χ^2 (Chi-square) distribution; this statistic was used to test for the significance of an additional factor in the model. The number of additional parameters associated with the added factor minus one corresponds to the number of degrees of freedom in the χ^2 test (McCullagh and Nelder, 1989, pp 393). Deviance analysis tables are presented for the data series, including the deviance for the proportion of positive observations (*i.e.*, positive sets/total sets), and the deviance 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 or 10% were selected), b) The χ^2 test significance, and c) the type III test significance within the final specified model.

Once a set of fixed factors was specified, possible interactions were evaluated, in particular interactions between the *year* effect and other factors. Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), the Schwarz's Bayesian Criterion (SBC), and a chi-square test of the difference between the -2 loglikelihood statistics 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

The deviance analysis for yellowfin tuna from the Venezuela Longline Observer data analysis is presented in **Table 1**. For the proportion of positive/total sets; *year*, *area*, *season*, *boat category* (=CATBOAT) and the interactions, *year*catboat*, *year*area*, and *year*season* were the major factors that explained whether or not a set caught at least one fish. The explanatory factors selected explained more than 45% of the deviance. For the mean catch rate given that it is a positive set, the factors: *boat category*, *area*, and *fish time*, and the interactions of *year*area*, *year*depth* and *year*catboat* were significant. Once a set of fixed factors were selected, we evaluated first level random interaction between the *year* and other effects. Diagnostic plots of the fitting for the mean catch rate lognormal sub model component and the proportion of positive sets are presented in **Figures 5, 6, 7, and 8**.

The results from the random test analyses for yellowfin tuna and the three-model selection criterion are shown in **Table 2**. For the proportion of positive/total sets, the final model included the *year*, *area*, *season*, and *boat category* as main fixed factors and the random interactions between *year*season* and *year*boat category*. For the conditional mean catch rate (*i.e.*, positive observations), the final mixed model included the *year*, *area*, *boat category*, and *fish time* as fixed factor and the random interaction of *year*area*, *year*boat category*, and *area*depth*.

Standardized CPUE series for yellowfin tuna are shown in **Table 3** and **4**, and **Figure 9**. Overall, the final models explained about 42% of the variability within the proportion of positive /total sets for the observer yellowfin tuna data, and 41% of the variability within the mean CPUE rates of positive catch sets. Coefficients of variation range from 63 to 87% when catch rates were numbers of fish, and 70 to 84% when catch rates were based in biomass units. The standardized CPUE series show that the relative abundance of yellowfin tuna caught by the observed Venezuelan longline fleet reflects a stable trend from 1991-2002, with a noticeable increase in 2001.

The standardized CPUE series based on the delta lognormal model approach estimated large confidence intervals, but the resulting standardized series from the VPLOP show an overall similar trend (sharp decline in the first years and an fairly even trend afterwards) to the nominal CPUE of the overall Venezuelan longline fleet through 2002 (Fig. 10). Therefore, the standardized CPUE index based on the VPLOP data reflects the overall trend in relative abundance of yellowfin tuna caught by the longline fleet in the southeastern Caribbean Sea and adjacent waters.

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Table 1. Deviance analysis table for yellowfin catch rates using a delta lognormal model. Proportion of positive/total trip-sets assumed a binomial error distribution; *p* value refers to the chi-square test between two consecutive models. The mean catch rate for positive observations assumed a lognormal error distribution.

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	<i>p</i>
1	1	3033.51			
Year	11	2838.91	194.6	15.3%	< 0.001
Year Area	2	2713.22	125.7	9.9%	< 0.001
Year Area Season	2	2688.48	24.7	1.9%	< 0.001
Year Area Season Catboat	2	2626.14	62.3	4.9%	< 0.001
Year Area Season Catboat Depth	1	2625.36	0.8	0.1%	0.378
Year Area Season Catboat Depth Fishtime	2	2510.92	114.4	9.0%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area	15	2150.15	360.8	28.3%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat	15	2063.61	86.5	6.8%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat	3	1999.30	64.3	5.0%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat Year*Depth	11	1829.29	170.0	13.3%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat Year*Depth Area*Depth	2	1820.36	8.9	0.7%	0.011
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat Year*Depth Area*Depth Catboat*Depth	2	1801.40	19.0	1.5%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat Year*Depth Area*Depth Catboat*Depth Year*Fishtime	22	1773.68	27.7	2.2%	0.185
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat Year*Depth Area*Depth Catboat*Depth Year*Fishtime Area*Fishtime	4	1771.66	2.0	0.2%	0.733
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat Year*Depth Area*Depth Catboat*Depth Year*Fishtime Area*Fishtime	4	1761.09	10.6	0.8%	0.032
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat Area*Catboat Year*Depth Area*Depth Catboat*Depth Year*Fishtime Area*Fishtime	2	1758.61	2.5	0.2%	0.291

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	<i>p</i>
1	1	1656.95			
Year	11	1499.92	157.0	23.0%	< 0.001
Year Area	2	1355.98	143.9	21.1%	< 0.001
Year Area Season	2	1268.83	87.1	12.8%	< 0.001
Year Area Season Catboat	2	1215.64	53.2	7.8%	< 0.001
Year Area Season Catboat Depth	1	1211.12	4.5	0.7%	0.033
Year Area Season Catboat Depth Fishtime	2	1192.77	18.3	2.7%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Depth	11	1077.58	115.2	16.9%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Season	21	987.58	205.2	30.1%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area	15	986.57	206.2	30.2%	< 0.001
Year Area Season Catboat Depth Fishtime Year*Area Year*Catboat	16	974.14	218.6	32.0%	< 0.001

Table 2. Delta lognormal mixed models and corresponding random interactions evaluation for both the proportion of positive/total trip-set sub model and the mean catch rate of positive observations sub model. Likelihood ratio test is the Chi-square test for the difference of deviance between two nested models.

Yellowfin Tuna	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Season Catboat	1381.8	1383.8	1387.5		
Year Area Season Catboat <i>Year*Season</i>	1375.2	1379.2	1382.3	6.6	0.0102
Year Area Season Catboat <i>Year*Season Year*Area</i>	1375.4	1381.4	1386.1	-0.2	#NUM!
Year Area Season Catboat <i>Year*Season Year*Area Year*Catboat</i>	1328.3	1336.3	1342.6	47.1	0.0000
Positive Catch					
Year Area Catboat Fishtime	7417.5	7419.5	7425.3		
Year Area Catboat Fishtime <i>Year*Aea</i>	7107.7	7111.7	7114.4	309.8	0.0000
Year Area Catboat Fishtime <i>Year*Area Year*Catboat</i>	7053.5	7059.5	7063.6	54.2	0.0000
Year Area Catboat Fishtime <i>Year*Area Year*Catboat Year*Depth</i>	6839.7	6847.7	6853.2	213.8	0.0000

Table 3. Nominal and standardized CPUE (Number of fish / hook*hour fished) series for yellowfin tuna catch rates from the Venezuelan Pelagic Longline fishery.

Year	N obs	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1991	98	0.861	0.658	73.6%	0.505	1.885	0.136
1992	266	0.649	0.717	78.9%	0.551	2.216	0.137
1993	461	0.493	1.056	77.0%	0.811	3.175	0.207
1994	136	0.141	0.395	87.0%	0.304	1.364	0.068
1995	455	0.370	0.437	77.0%	0.336	1.314	0.086
1996	364	0.457	0.570	68.9%	0.438	1.525	0.126
1997	378	0.307	0.315	83.5%	0.242	1.036	0.056
1998	424	0.437	0.548	66.5%	0.421	1.412	0.126
1999	357	0.834	0.535	71.6%	0.411	1.487	0.113
2000	332	0.514	0.396	68.3%	0.304	1.049	0.088
2001	259	0.384	1.302	72.1%	1.000	3.645	0.274
2002	218	0.490	0.852	70.6%	0.654	2.336	0.183

Table 4. Nominal and standardized CPUE (kgr of fish / hook*hour fished) series for yellowfin tuna catch rates from the Venezuelan Pelagic Longline fishery.

Year	N obs	Nominal	Standard	Coeff Var	Index	95% confidence intervals	
1991	98	37.707	28.179	72.6%	0.453	0.123	1.665
1992	266	29.913	34.095	77.4%	0.548	0.139	2.159
1993	461	23.466	48.821	76.0%	0.785	0.203	3.030
1994	136	7.052	20.683	84.0%	0.333	0.077	1.435
1995	455	16.809	19.119	74.7%	0.307	0.081	1.164
1996	364	23.901	31.050	67.6%	0.499	0.146	1.704
1997	378	17.751	17.473	79.9%	0.281	0.069	1.146
1998	424	25.675	32.136	65.4%	0.517	0.157	1.705
1999	357	53.113	34.597	70.4%	0.556	0.156	1.980
2000	332	24.856	18.867	67.7%	0.303	0.089	1.036
2001	259	19.089	62.178	71.5%	1.000	0.277	3.614
2002	218	24.611	41.471	70.2%	0.667	0.188	2.364

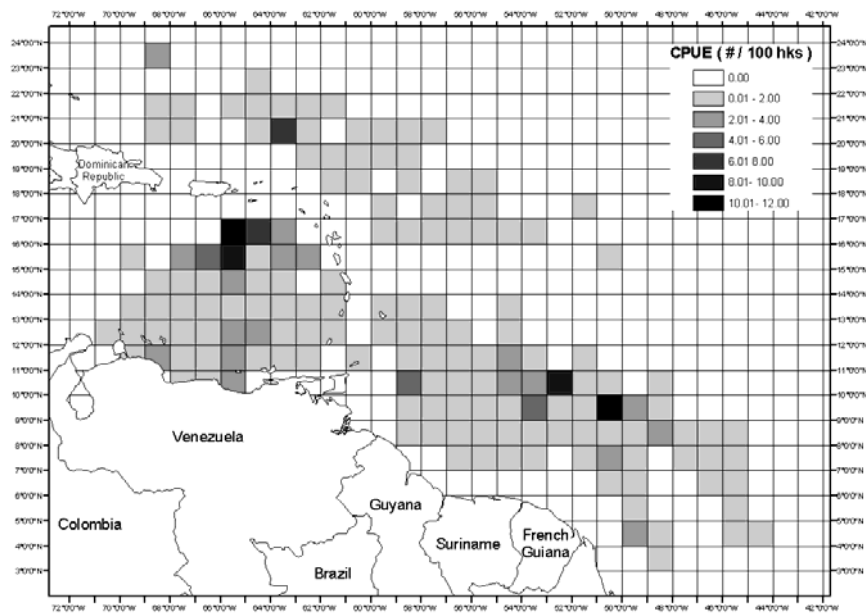


Figure 1. Spatial distribution of nominal CPUE of YFT (numbers/100 hooks) caught by the Veneluelan longline fleet during 1991-2002 and recorded by the Venezuelan Pelagic Longline Observer Program (VPLOP).

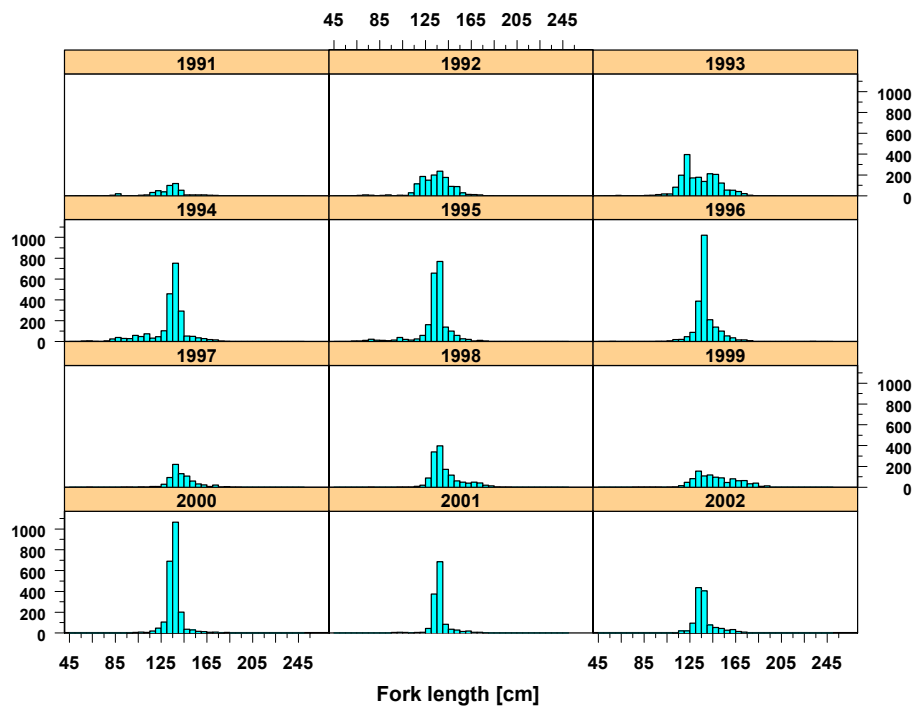


Figure 2. Size frequency distribution of yellowfin tuna by year from the VPLOP.

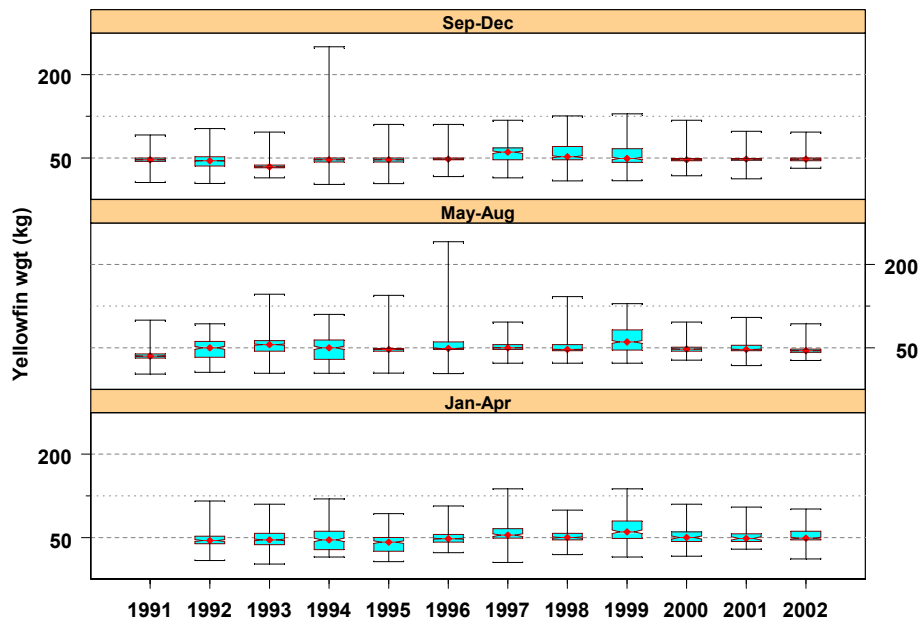


Figure 3. Box plot by year and season of yellowfin tuna estimated weight from the VPLOP.

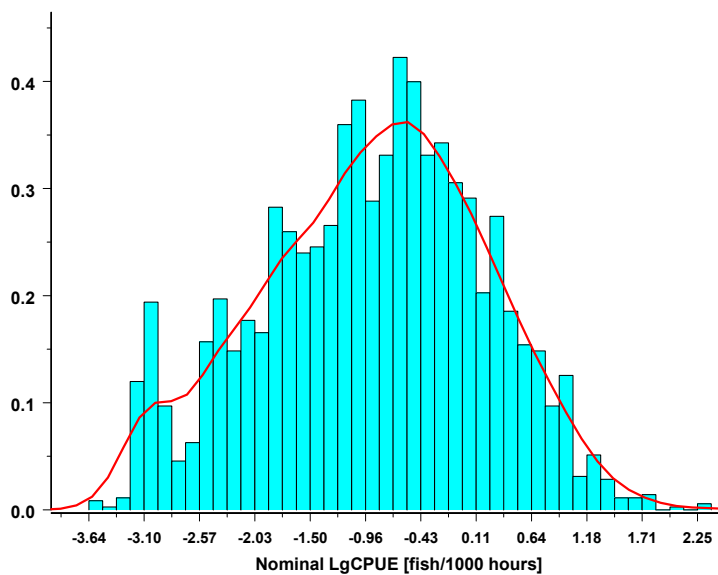


Figure 4. Frequency distribution of log-transformed nominal CPUE of positive set/trip for yellowfin tuna from the Venezuelan Pelagic Longline Observer Program data.

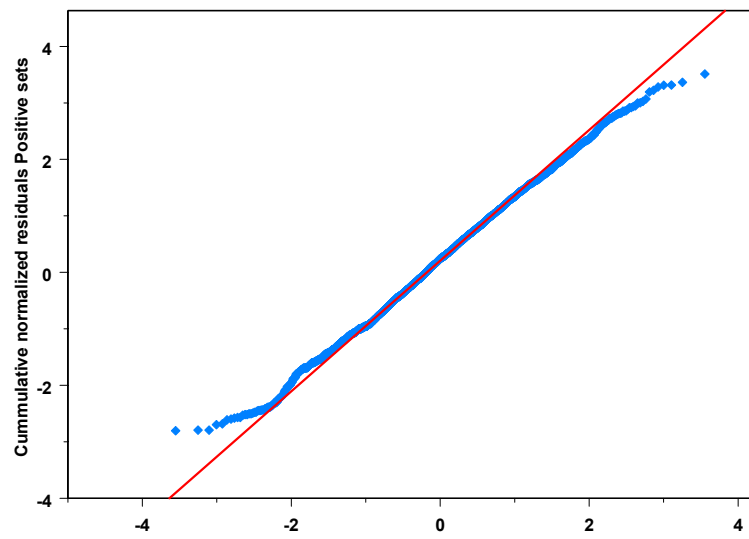


Figure 5. Diagnostic Plot: Cumulative normalized residual (qq-plot) of the positive sets fit in the delta lognormal model.

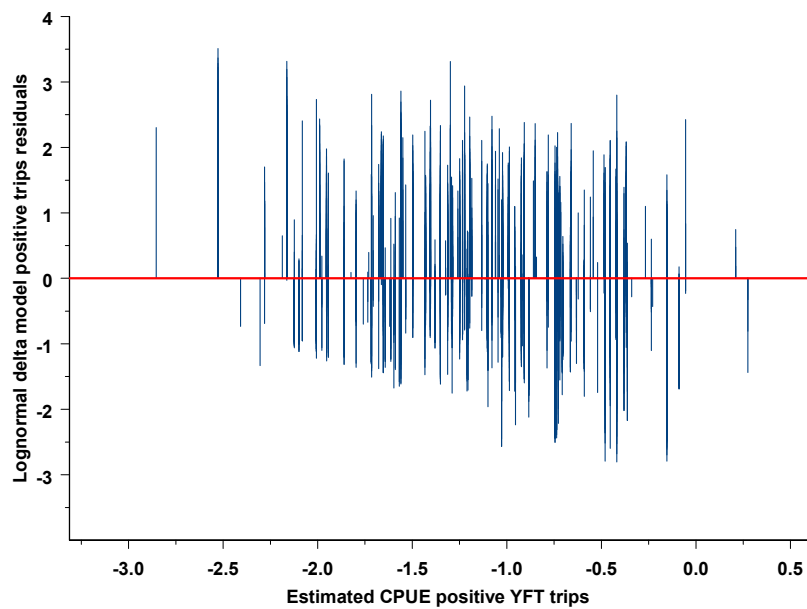


Figure 6. Residuals of the positive sets fit plotted against the predicted catch rates of yellowfin tuna from the VPLOP.

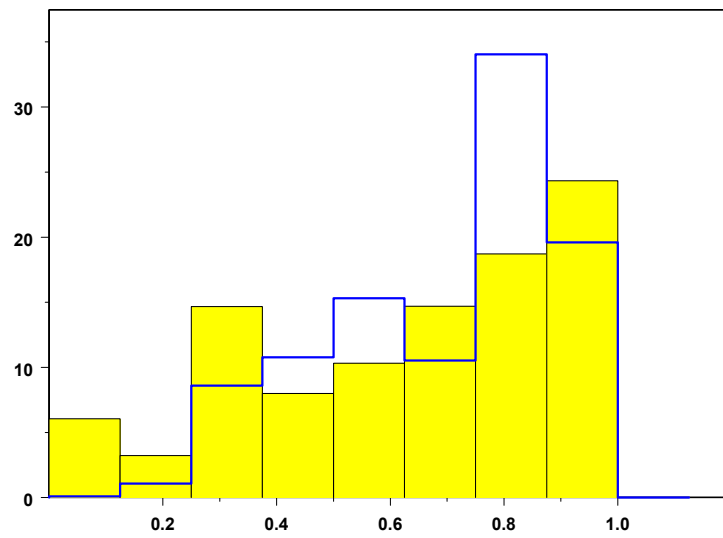


Figure 7. Frequency distribution of observed (solid bars) and predicted (open bars) proportions of positive sets from the VPLOP for yellowfin tuna catch.

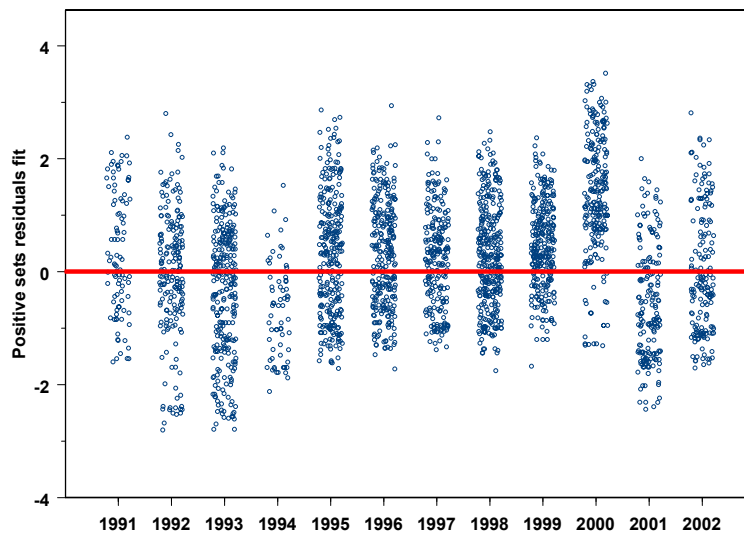


Figure 8. Diagnostic plot: Residuals of positive observations from the lognormal fit by year.

Yellowfin Tuna Standardized Cpue Delta-Lognormal Model Vza PLOP

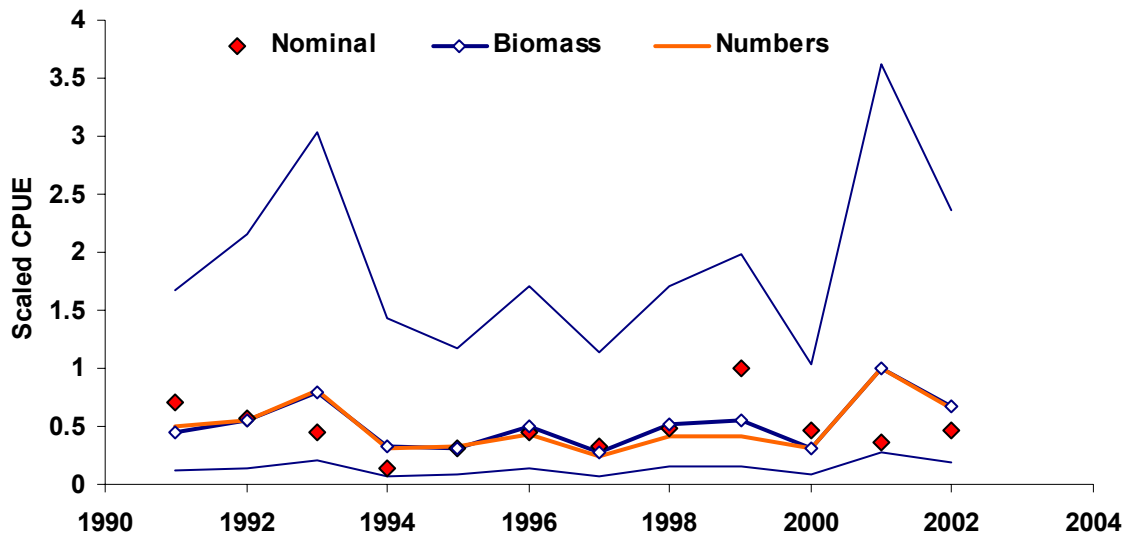


Figure 9. Nominal and standardized catch rates (in biomass units and numbers of fish) for yellowfin tuna from the Venezuelan Pelagic Longline Observer Program. Standardized catch rates were estimated by a delta lognormal mixed model showing 95% confidence intervals (dashed lines).

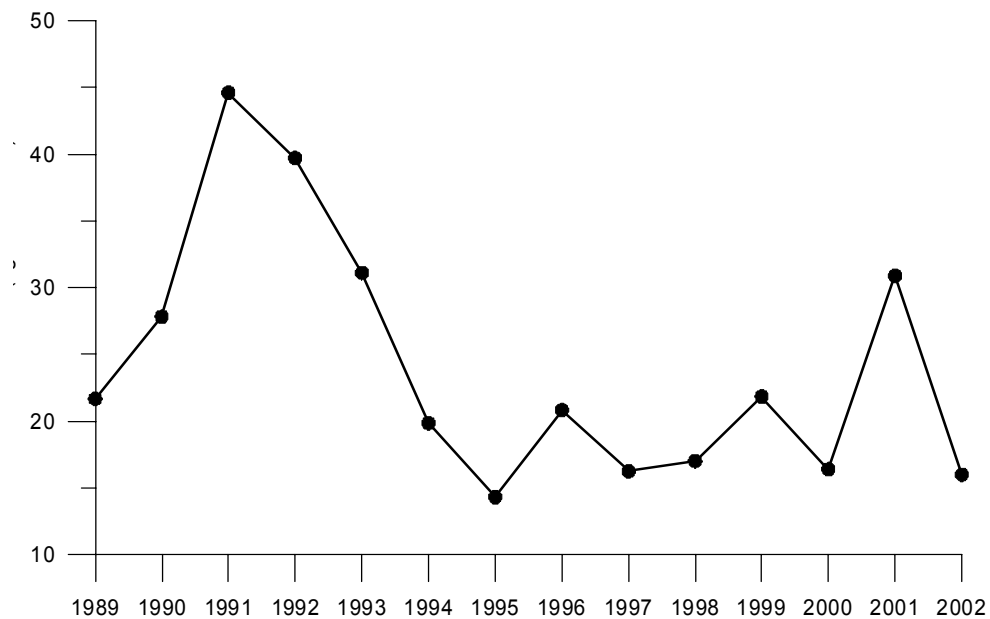


Figure 10. Nominal catch rates in biomass units (kg fish/100 hooks) for yellowfin tuna from the Venezuelan Pelagic Longline fleet obtained from reported logbook information from 1989-2002.