Standardized catch rates of the blacknose shark (*Carcharhinus acronotus*) from the United States south Atlantic gillnet fishery, 1998-2009

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Introduction

Commercial fishing effort and landings for handline, electric reel (bandit rig), longline and gillnet vessels operating in the U.S. south Atlantic have been reported to the National Marine Fisheries Service (NMFS) through the Coastal Fisheries Logbook Program (CFLP, conducted by the NMFS Southeast Fisheries Science Center). The program collects landings and effort data by fishing trip from vessels that are federally permitted to fish in a number of fisheries managed by the South Atlantic Fishery Management Councils. The coastal logbook program began in 1992 with the objective of a complete census of coastal fisheries permitted vessel activity, with the exception of Florida, where a 20% sample of vessels was selected to report. Beginning in 1993, reporting in Florida was increased to include all vessels permitted for federally managed coastal fisheries.

The CFLP available catch per unit effort (CPUE) data were used to construct a standardized abundance index for blacknose shark. Prior to 1998, gillnet size was not reported to the coastal logbook program; therefore data from all years before 1998 were excluded from the analysis. Few gillnet trips (approximate 25 for the period) reported landings of small coastal sharks in the Gulf of Mexico and an index for blacknose shark in this region could not be produced. However, a standardized abundance index was constructed using data reported from commercial gillnet trips in the U.S. south Atlantic (south of Virginia) for the years 1998-2009.

Methods

In many years during the period 1998-2009, a large percentage of landings reported to the coastal logbook program included unclassified sharks. Only a portion of the unclassified sharks were small coastal shark species. The proportion of unclassified sharks assumed to be small coastal sharks was estimated from NMFS shark gillnet observer data as the observed proportion of small coastal species to all other identified sharks in each area fished. The area specific proportion of small costal shark landings to other shark landings was applied to the unclassified landings reported from each area. Landings of each small coastal shark species were then calculated by applying observed proportions of small coastal shark species reported in the NMFS gillnet observer program to the small coastal shark portion of unclassified shark landings.

Available Data

For each fishing trip, the coastal logbook database included a unique trip identifier, the landing date, fishing gear deployed, areas fished (Figure 1), number of days at sea, number of crew, gear specific fishing effort, species caught and weight of the landings. Fishing effort data available for gillnet gear included depth of net in yards, length of net in yards, and soak time in hours. Multiple areas fished and multiple gears fished may be recorded for a single fishing trip. In such cases, assigning catch and effort to specific locations or gears was not possible; therefore, only trips which reported one area (i.e. subregion, as defined below) and one gear fished were included in these analyses.

Data were further restricted to include only those trips with landings and effort data reported within 45 days of the completion of the trip. Reporting delays beyond 45 days (some reporting delays were longer than one year) likely resulted in less reliable effort data. Landings data may be reliable even with lengthy reporting delays if trip ticket reports were referenced by the reporting fisher.

Clear outliers in the data (i.e., values falling outside the 99.5 percentile), were excluded from the analyses. These included data from trips reporting fishing more than 24 hours, crews of more than 6, gillnet length less than 4 or greater than 2800 yards, and gillnet depth of net less than 2 or greater than 250 yards.

Management measures, specifically closed seasons, required that additional data be excluded from the analyses. The small coast shark complex in the south Atlantic has never had management restriction applied due to quota restrictions. Closed seasons have occurred only once for small coast sharks due to quota restrictions and it was in the Gulf of Mexico (Jan 1- March 18, 2004) not the south Atlantic. No minimum size or trip limit restrictions were in effect for blacknose shark during the years of 1998-2009 for directed permits. A trip limit of 16 small coastal or pelagic sharks for indirect permits began in 1999. Coastal logbook landings were reported in pounds. No size information was available in those data, therefore it was not possible to account for a trip limit measured in total number of sharks landed.

Blacknose shark trips were identified using a data subsetting technique (modified from Stephens and MacCall, 2004) intended to restrict the data set to trips with fishing effort in blacknose shark habitat. Such an approach was necessary because fishing location was not reported to the CFLP at a spatial scale adequate to identify targeting based upon the habitat where the fishing occurred. The modified Stephens and MacCall (2004) method was an objective approach in which a logistic regression was applied to estimate the likelihood that blacknose shark could have been encountered given the presence or absence of other species reported from the trip. As a function of the species reported from a trip, a score was assigned to the trip and that score was converted into the probability of observing blacknose sharks. Trips with scores above a critical value were included in the CPUE analysis. That critical value was set at the score that minimized the number of predictions of blacknose shark occurring when the species was actually absent (false positives) while also minimizing incorrect predictions of blacknose shark absence when the species was actually present (false negatives). For the south Atlantic region those species that were reported from one percent or more of all gillnet trips were included in the data subsetting analyses. Figure 2 provides species-specific regression coefficients. The magnitude of the coefficients indicates the predictive impact of each species.

Index Development

Gillnet catch rate was calculated as weight of blacknose shark per area of net (square yards) per hour fished:

CPUE = total lbs of blacknose/(depth of net in yards*length of net in yards*soak time in hours**)**

Six factors were considered as possible influences on gillnet proportion of trips that landed blacknose shark and on the catch rate of blacknose shark. Days at sea was dropped as a factor due to the fact that 96% of the trips were only one day in duration. In order to develop a well balanced sample design it was necessary to define categories within some of the factors examined:

Factor	**Levels**	**Value**
Year	11	1998-2009
Season	4	1 (Jan-Mar), 2 (Apr-Jun), 3 (Jul-Sep), 4 (Oct-Dec)
Subregion	4	Stat areas 2600-2780, 2800-2900, 2901-2999, 3000-3575 (Figure 1)
Crew (crew_num)*	3	1, 2, 3+ crew members
Vessel length (ves_len)*	5	Unk, <28, 28-35, 36-47, >47 feet
Permit	2	Permit, no permit

* Names in parentheses appear in some figures and tables.

The delta lognormal model approach (Lo et al. 1992) was used to construct a standardized index of abundance. This method combines separate general linear model (GLM) analyses of the proportion of successful trips (trips that landed blacknose shark) and the catch rates on successful trips to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM procedure (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc., Cary, NC, USA).

For each GLM analysis of proportion positive trips, a type-3 model was fit, a binomial error distribution was assumed, and the logit link was selected. The response variable was proportion successful trips. During the analysis of catch rates on successful trips, a type-3 model assuming lognormal error distribution was examined. The linking function selected was "normal", and the response variable was log(CPUE). The response variable was calculated as: log(CPUE)=ln(pounds of blacknose shark/(depth of net in yards*length of net in yards *soak time in hours)). All 2-way interactions among significant main effects were examined. Higher order interaction terms were not examined.

A forward stepwise regression procedure was used to determine the set of fixed factors and interaction terms that explained a significant portion of the observed variability. Each potential factor was added to the null model sequentially and the resulting reduction in deviance per degree of freedom was examined. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$), and the reduction in deviance per degree of freedom was $\geq 1\%$. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model.

The influence of the YEAR*FACTOR interactions were also examined and included in the model as random effects. Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion (BIC), and a chi-square test of the difference between the –2 log likelihood statistics between successive model formulations (Littell et al. 1996).

The final delta-lognormal model was fit using a SAS macro, GLIMMIX (Russ Wolfinger, SAS Institute). To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean value of the series.

Results and Discussion

The final models for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips for each species were:

PPT = CREW_NUM + VES_LEN + SEASON + YEAR + SEASON*YEAR

LOG(CPUE) = YEAR + SUBREGION + YEAR*SUBREGION

When the interactions year*ves_len and crew_num*ves_len were included in the binomial GLM, the model failed to converge, therefore those interaction terms were excluded from later analyses. Failure of the model to converge was likely due to insufficient sample size given the large number of terms included in the model.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index are provided in Table 2 for the blacknose shark model. The delta-lognormal abundance index, with 95% confidence intervals, is shown in Figure 3.

Plots of the proportion of positive trips per year, nominal CPUE, frequency distributions of the proportion of positive trips, frequency distributions of log(CPUE) for positive catch, cumulative normalized residuals, and plots of chi-square residuals by each main effect for the binomial and lognormal models are shown in Figures 4-7. Those diagnostic plots indicate that the fit of the data to the lognormal and binomial models was acceptable. There were some outliers among these data. Those variations from the expected fit of the data were not sufficient to violate assumptions of the analyses. The observed positive blacknose shark trips ranged from approximately 4 to 16% and, although low, were acceptable for the analysis.

Blacknose shark standardized catch rates for gillnet vessels had no clear trend over much of the time series (Figure 3). Yearly standardized CPUEs were low during the initial seven years of the period. The highest yearly standardized CPUEs occurred during four of the final five years of the series. The 2008 CPUE was more than three times higher than the CPUE in 2009 (the second highest value). That result may have been driven by a few trips with very high (>2 pounds per hook fished) CPUEs. Coefficients of variation (CV) were fairly high, ranging from 0.64 to 0.72. Confidence intervals were also large, particularly in 2008, perhaps due to the small proportion of positive trips.

Literature Cited

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

Lo, N.C., L.D. Jackson, 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.

Stephens, A. and A. McCall. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fisheries Research 70:299-310.

Table 1. Linear regression statistics for the GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for blacknose shark in the U.S. south Atlantic for vessels reporting gillnet gear landings 1998-2009. Analysis of the mixed model formulations of the positive trip model (**C**) and proportion positive trips (**D**), the likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final model is indicated with gray shading. See text for factor (effect) definitions.

A.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	11	33	27.59	2.51	0.0037	0.0203
crew_num	2	522	136.97	68.48	<.0001	<.0001
ves_len	4	522	136.94	34.24	<.0001	<.0001
season	3	33	60.92	20.31	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	11	32	37.77	3.43	<.0001	0.0031
subregion	3	32	243.66	81.22	<.0001	<.0001

C.

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
year + subregion	6258.8	6260.8	6266.1	-	-
year + subregion + subregion*year	6248.4	6252.4	6256.1	10.4	0.0013

D.

Catch Rates Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
crew_num + ves_len + season + year	2655.1	2657.1	2661.5	-	-
crew_num + ves_len + season + year + crew_num*year	2687.1	2691.1	2694.3	-32.0	-
crew_num + ves_len + season + year + season*year	2632.2	2636.2	2640.0	22.9	<0.0001

Table 2. Gillnet relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index for blacknose shark (1998-2009) in the U.S. south Atlantic.

YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.2859905	1731	0.067591	0.4195176	0.1192861	1.4754027	0.6963795
1999	0.388343	1266	0.0939968	0.4351346	0.122512	1.5454994	0.7030089
2000	0.5402699	1410	0.106383	0.7320708	0.2171098	2.4684634	0.6684202
2001	0.5764651	1330	0.0977444	0.3700855	0.1077726	1.2708542	0.6804639
2002	0.5518122	1333	0.0885221	0.4499281	0.1286479	1.5735608	0.6926486
2003	0.416456	1092	0.0943223	0.7631273	0.2191896	2.6568929	0.6896288
2004	0.1716817	1124	0.0862989	0.2831113	0.0783711	1.0227238	0.7144613
2005	1.5906758	1251	0.0767386	0.9027371	0.2520723	3.2329377	0.7085882
2006	0.7320872	1501	0.0892738	1.046612	0.308942	3.5456388	0.6715055
2007	0.3160589	1582	0.051201	0.5578606	0.1529693	2.03445	0.720916
2008	4.1889296	1322	0.1588502	4.5763714	1.4185155	14.764149	0.6396446
2009	2.2412302	1461	0.1047228	1.4634437	0.431057	4.9684095	0.6729216

Figure 1. Coastal Logbook defined fishing areas.

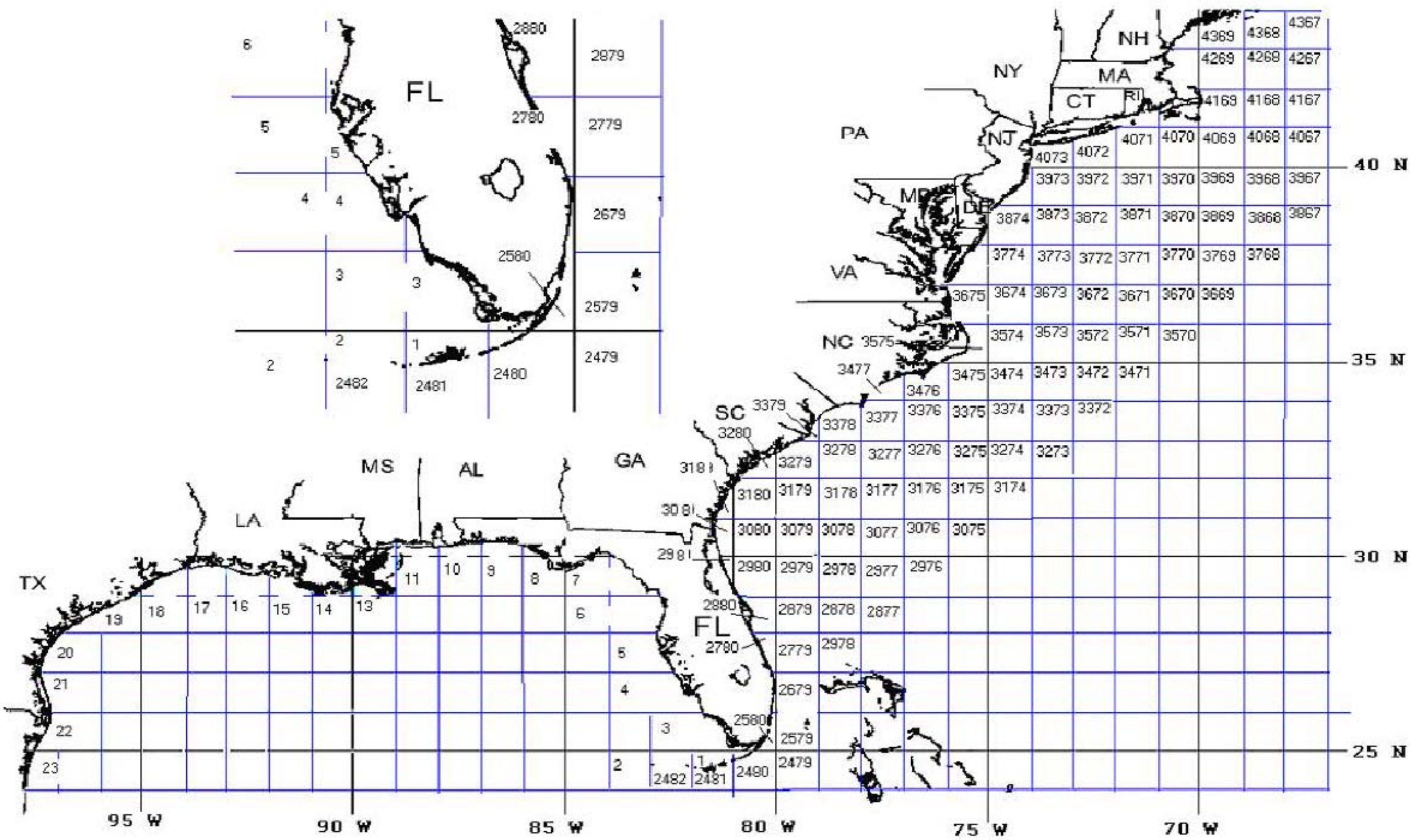


Figure 2. Regression coefficients from the Stephens & MacCall analyses for blacknose shark in the U.S. south Atlantic gillnet data. Positive coefficients signify species that had positive associations with the target species. The magnitude of the coefficients indicates the predictive impact of each species. The value for the regression intercept denotes the probability a trip was fishing in the target species' habitat, but did not report any of the listed species. Species included were reported on at least one percent of gillnet trips in the U.S. south Atlantic.

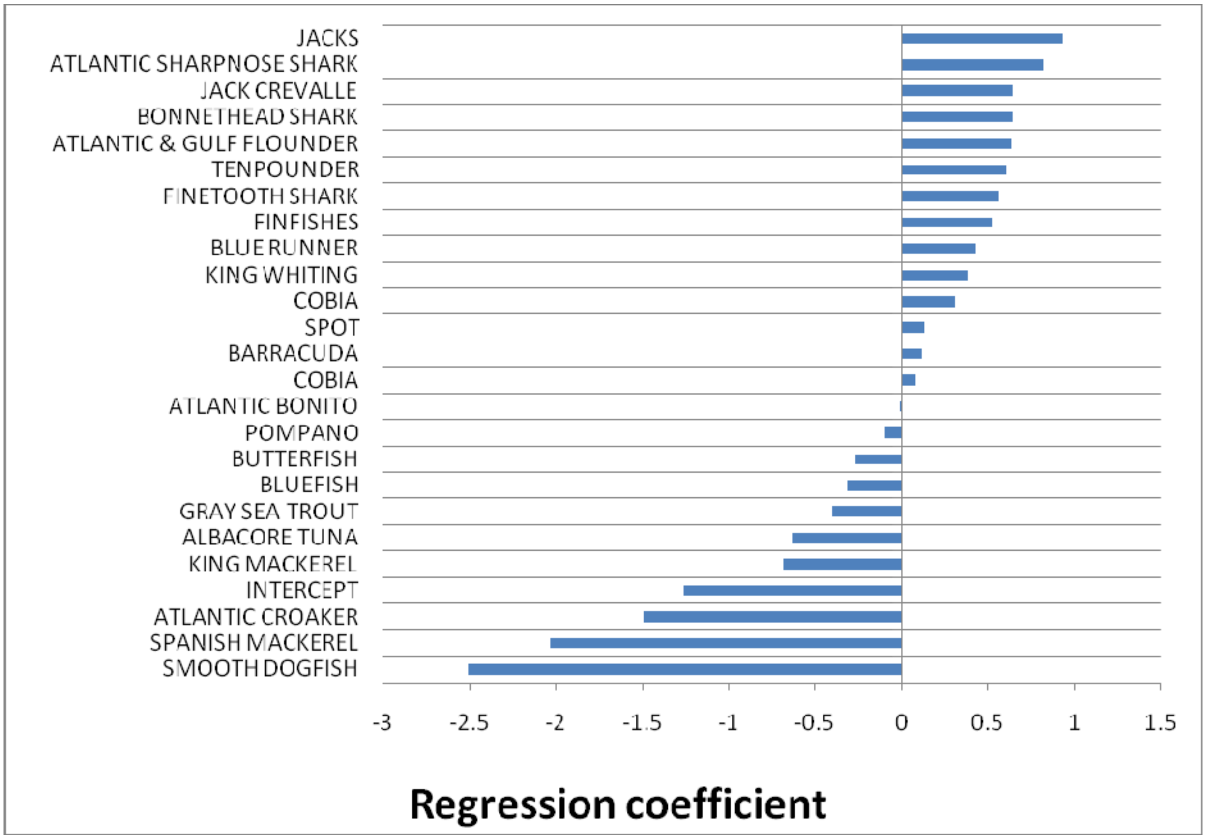


Figure 3. Blacknose shark nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing gillnet gear in the U.S. south Atlantic.

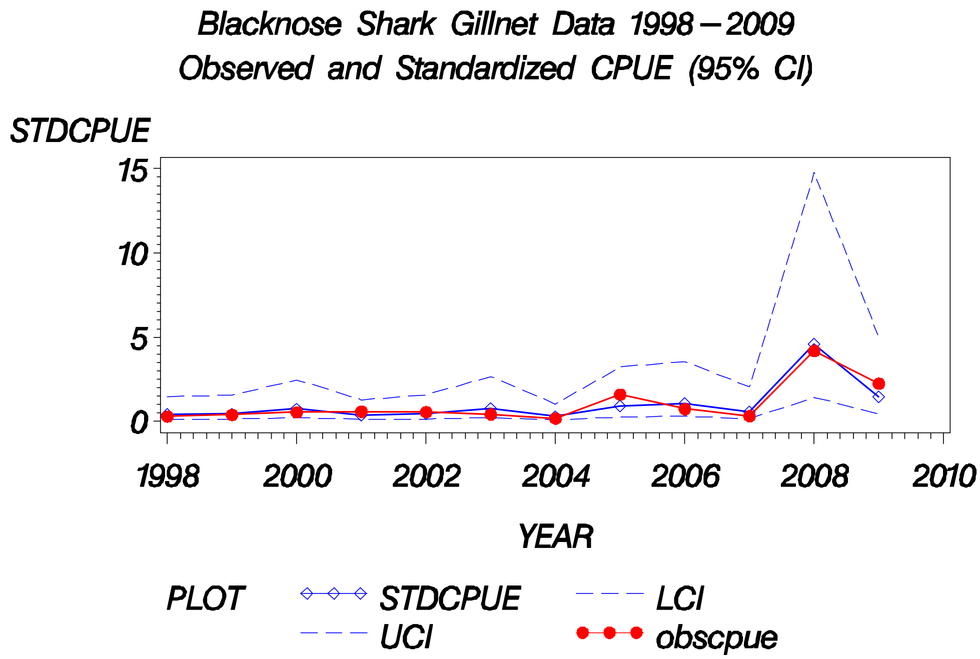
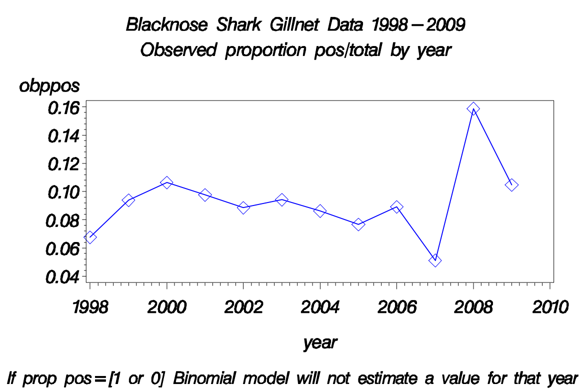


Figure 4. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE of the U.S. south Atlantic 1998-2009 blacknose shark commercial gillnet gear data.

A.



B.

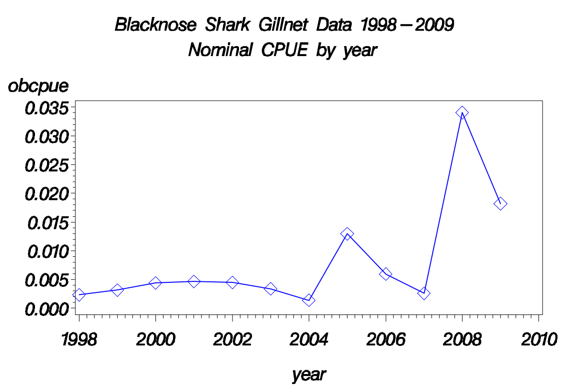
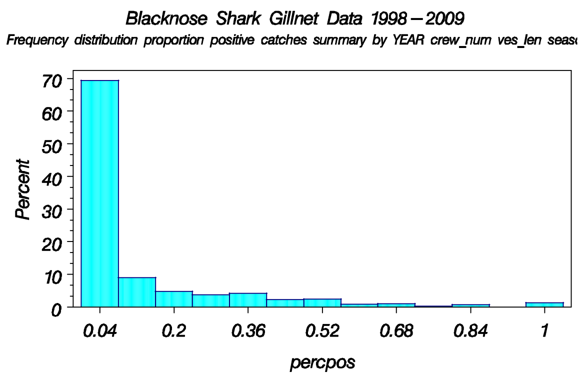
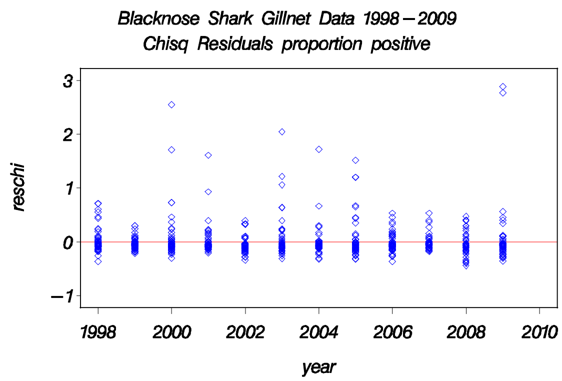


Figure 5. Diagnostic plots for the binomial component of the U.S. south Atlantic 1998-2009 blacknose shark commercial gillnet gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by subregion; **D**. the Chi-Square residuals by days at sea; **E**. the Chi-Square residuals by season.

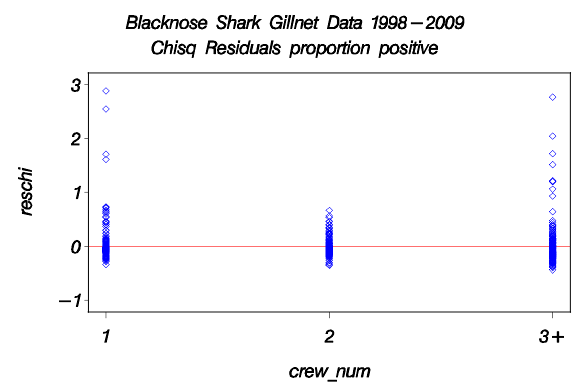
A.



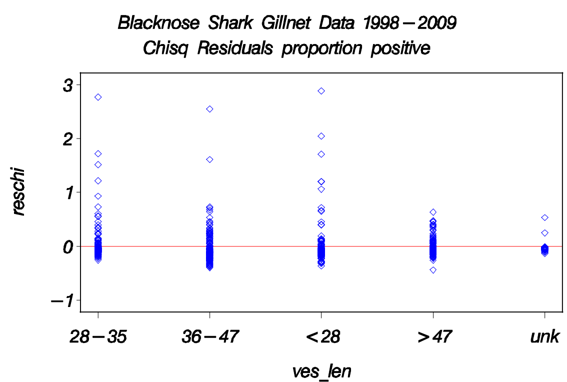
B.



C.



D.



E.

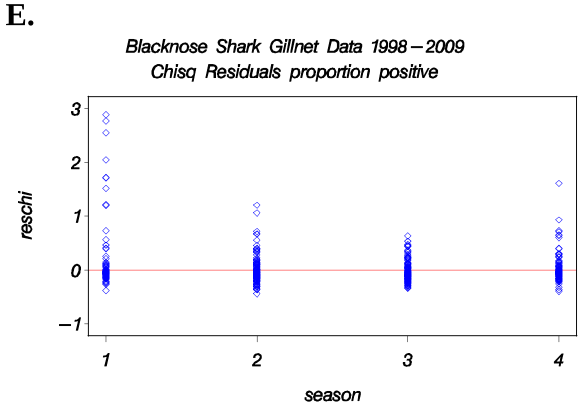


Figure 6. Diagnostic plots for the lognormal component of the U.S. south Atlantic 1998-2009 blacknose shark commercial gillnet gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

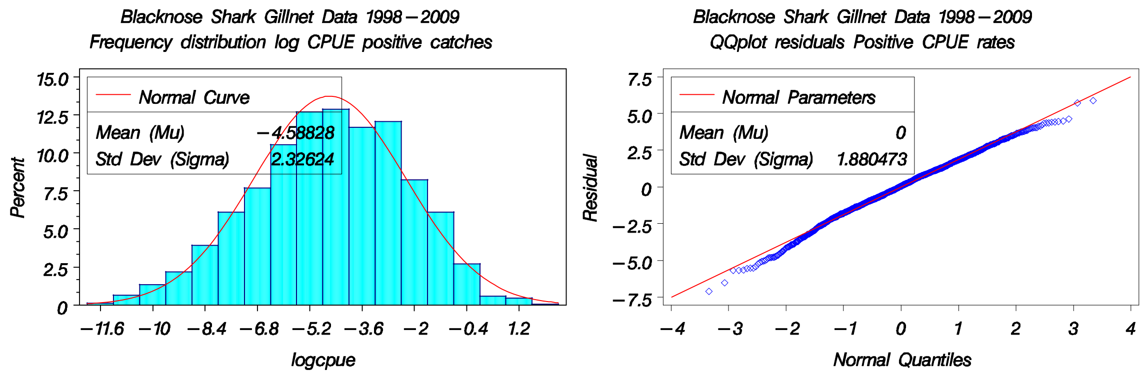


Figure 7. Diagnostic plots for the lognormal component of the U.S. south Atlantic 1998-2009 blacknose shark commercial gillnet gear model: **A**. the Chi-Square residuals by year; and **B**. the Chi-Square residuals by subregion.

A. **B.**