Standardized catch rates of small coastal sharks from the United States Gulf of Mexico and south Atlantic gillnet fishery, 1998-2005

Kevin McCarthy

National Marine Fisheries Service, Southeast Fisheries Science Center
Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, FL, 33149-1099
Kevin.J.McCarthy@noaa.gov

Sustainable Fisheries Division Contribution SFD-2007-001

Introduction

Gillnet landings and fishing effort of commercial vessels operating in the Gulf of Mexico and the Atlantic Ocean south of Virginia have been monitored by the National Marine Fisheries Service (NMFS) through the coastal logbook program (conducted by the NMFS Southeast Fisheries Science Center). The program collects data by fishing trip on landings and effort for vessels with permits to fish in a number of fisheries managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. Although the coastal logbook program began in 1990, gillnet effort data collection began in 1998. Previously, only landings data were collected for vessels that reported fishing gillnets.

The available catch per unit effort (CPUE) series, from 1998 - 2005, was used to develop abundance indices for the small coastal shark species complex. In addition, indices were developed for blacknose sharks Atlantic sharpnose sharks, bonnethead sharks, and finetooth sharks.

Prior to 1998, gillnet size was not reported to the coastal logbook program, therefore indices of abundance for small coastal shark species landed from gillnet trips began in 1998. In addition, there is some delay in receiving and entering logbook data such that all data for 2006 were not available for the analysis and the time series ends with 2005 data.

Methods

In many years during the period 1998-2005, a large percentage of landings reported to the coastal logbook program included unclassified sharks (Figure 1). 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 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.

Subsetting data for CPUE analysis using species composition

An objective approach, developed by Stephens and McCall (2004), was used to subset logbook trip records using species composition. This method uses the observed species composition of a fishing trip to infer if that trip's effort occurred in the habitat of the target species. Species composition was examined for the Gulf of Mexico and US south Atlantic gillnet trips. Only those species occurring on at least 1% of all trips were considered. The method is described in detail in Stephens and McCall (2004). A brief summary follows.

The species composition from catch records is used to estimate the parameters of a logistic regression. For example, Let Y_j be a categorical variable describing the presence/absence of the non-target species for trip j. Similarly, let x_{ij} describe the presence/absence of blacknose sharks.

$$Y_j = \begin{cases} 1 & \text{if the target species is caught} \\ 0 & \text{if the target species is not caught} \end{cases}$$

Then a logistic regression is applied to estimate the probability that blacknose sharks would have been encountered on a trip. Using the regression results, a score (S_j) is assigned to each trip j as a function of the species encountered during that trip:

$$S_j = \exp \sum_{i=0}^{k} x_{ij}\beta_i$$

where the coefficients $\beta_1,\beta_2,\ldots\beta_k$ quantify the predictive effect of each species and β_0 is the intercept of the logistic regression.

This score is then converted into the probability of observing blacknose sharks given the vector of presence/absence of the other species observed on the trip (j).

$$\pi_j = \Pr\{Y_j = 1\} = \frac{S_j}{1 + S_j}$$

Given the coefficients $\beta_0, \beta_1, \ldots, \beta_k$ and the presence/absence indicators $x_{1j},\ldots, x_{kj}$, the log-likelihood (excluding constants independent of the parameters) is the sum:

$$L\{Y|\beta_0, \ldots, \beta_k, x_{1j}, \ldots, x_{kj}\} = \sum_{j \in j+} \log(\pi_j) + \sum_{j \in j-} \log(1 - \pi_j)$$

where j+ indicates trips that landed blacknose sharks, and j- indicates trips where blacknose sharks were absent. The log-likelihood was maximized using the statistical package R (Ihaka and Gentleman, 1996). The estimated β coefficients reflect the association (positive or negative) between the non-target species and blacknose sharks, π_j is intended to estimate the probability that trip *j* occurred in the habitat of blacknose sharks.

Trips were selected for CPUE analysis using a critical value. The critical value was determined by examining the relationship between the critical value and the number of incorrect predictions. Both false positives (blacknose sharks predicted to occur when absent) and false negatives (blacknose sharks not expected to occur when present) were considered. The critical value that minimized the number of incorrect predictions was selected. Trips were included in the CPUE analysis if π (as calculated above) was above the critical value.

Six factors were considered as possible influences on the proportion of trips that landed any of the small coastal shark species (SCS). The factors examined included Year, Season, Days (days at sea per trip), Permit (shark permit type), Veslen (vessel length in feet), and Subregion (areas fished). Few gillnet trips (approximate 25 for the period) in the Gulf of Mexico reported landings of small coastal sharks. Only data from the south Atlantic were included in the analyses. The factors are summarized below:

Factor	Levels	Value
YEAR	8	1998 - 2005
SEASON	4	1=January-March, 2=April-June, 3=July-September, 4=October-December
DAYS	5	1, 2, 3-4, 5-6, and 7+ days at sea
PERMIT	3	d = directed shark permit, i = incidental shark permit, n = no shark permit
VESLEN	5	1 = vessel < 32 feet, 2 = vessel 32-41 feet, 3 = vessel 42-54 feet, 4 = vessel 55 or more feet, 5 = length unknown
SUBREGION	4	Areas 2600-2780, 2800-2880, 2900-3081, 3300-3575

Factors examined for index development of individual small coastal shark species varied from the list above only for the factor Subregion.

Species	Levels	Subregion Value
Sharpnose	4	Areas 2600-2780, 2800-2880, 2900-3081, 3300-3575
Blacknose	3	Areas 2600-2780, 2800-2880, 2900-3575
Finetooth	3	Areas 2600-2780, 2800-2880, 2900-3575
Bonnethead	3	Areas 2600-2780, 2800-2880, 2900-3575

The delta lognormal model approach (Lo et al. 1992) was used to develop standardized indices of abundance. This method combines separate generalized linear model (GLM) analyses of the proportion of successful trips (trips that landed large coastal sharks) 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 procedure 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 employed. The linking function selected was "normal", and the response variable was ln(CPUE). The response variable was calculated as: ln(CPUE) = ln(pounds of SCS species/square yards of net fished x hours fished). All 2-way interactions among significant main effects were examined.

A stepwise approach was used to quantify the relative importance of the factors. First a GLM model was fit on year. These results reflect the distribution of the nominal data. Next, 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 ≥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. Higher order interaction terms were not examined.

The final delta-lognormal model was fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute). All factors were modeled as fixed effects except two-way interaction terms containing YEAR which were modeled as random effects. 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 and the lognormal on CPUE of successful trips were:

Small coastal shark (SCS) complex

PPT = YEAR + PERMIT + SUBREGION + SEASON + VESLEN + YEAR*SUBREGION + PERMIT*VESLEN + YEAR*SEASON

LN(CPUE) = YEAR + PERMIT + VESLEN + DAYS + SEASON + SUBREGION + YEAR*SEASON + YEAR*VESLEN + YEAR*SUBREGION + PERMIT*SUBREGION + YEAR*PERMIT + VESLEN*SUBREGION + VESLEN*SEASON

When any of the interactions HKS_SET*VESLEN, PERMIT*HKS_SET, or YEAR*PERMIT 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.

Sharpnose sharks

PPT = YEAR + SUBREGION + VESLEN + DAYS + SUBREGION*DAYS

LN(CPUE) = YEAR + VESLEN + SUBREGION + DAYS + VESLEN*SUBREGION + YEAR*VESLEN + YEAR*SUBREGION

The binomial model failed to converge when any other interaction terms were included in the model.
Blacknose sharks

PPT = YEAR + SEASON + SUBREGION + VESLEN + PERMIT + YEAR*SUBREGION + SEASON*SUBREGION + SUBREGION*PERMIT

LN(CPUE) = YEAR + VESLEN + DAYS + PERMIT + YEAR*VESLEN + YEAR*DAYS + YEAR*PERMIT

The binomial GLM failed to converge when DAYS or any of the two-way interaction terms not listed above was included in the model. Those terms were excluded from further analyses.

Finetooth sharks

PPT = YEAR + VESLEN + PERMIT + VESLEN*PERMIT

LN(CPUE) = YEAR + PERMIT + VESLEN + YEAR*VESLEN

The binomial GLM failed to converge if the interactions YEAR*VESLEN, YEAR*HKS_SET, or VESLEN*HKS_SET were included in the model and those interaction terms were excluded from the analysis.

Bonnethead sharks

PPT = YEAR + PERMIT + SUBREGION + VESLEN + YEAR*PERMIT + YEAR*SUBREGION + PERMIT*VESLEN

LN(CPUE) = YEAR + VESLEN + PERMIT + SUBREGION + SEASON + DAYS + YEAR*VESLEN + SUBREGION*SEASON + YEAR*SEASON + VESLEN*SEASON + YEAR*SUBREGION + SUBREGION*DAYS

Including any of the two-way interaction terms in the model prevented the binomial GLM from converging. Those terms were excluded from further analyses.

Nominal CPUE, relative nominal CPUE, number of trips, proportion positive trips, abundance indices, and relative abundance indices are provided in Tables 1-5 for the SCS complex, sharpnose, blacknose, finetooth, and bonnethead sharks, respectively. In a number of cases, GLMMIX failed to converge when all the significant interaction terms identified in the GLM analyses were included in the GLMMIX model. As with the GLM models that failed to converge, small sample size and inclusion of many factors in the models is likely the cause of lack of convergence in the GLMMIX models.

The CPUE series for the small coastal complex as a whole had no obvious trend over time (Figure 2). Confidence intervals for the index were large. In the SCS complex analysis, the GLMMIX failed to converge when any of the interaction terms PERMIT*VESLEN, VESLEN*SUBREGION, or VESLEN*SEASON were included. Those terms were excluded from the analysis. Proportion positive trips, QQ plots of residuals for successful catch rates, and plots of chi-square residuals for the delta lognormal model on proportion successful trips by each main effect are provided in Figures 3-9. Frequency distributions of ln(CPUE) for positive catches and plots of residuals for lognormal models on successful catch rates by each main effect are shown in Figures 10-16. These data appear to have met the assumptions for the analysis.

The sharpnose index of abundance also had no clear trend over the time series (Figure 17). The large confidence intervals are likely due to few observations in the large matrix resulting from the numerous factors in the GLMMIX model. In this analysis, GLMMIX failed to converge when DAYS, SUBREGION*DAYS, VESLEN*SUBREGION, YEAR*VESLEN, or YEAR*SUBREGION were included in the model and the terms were excluded from the analysis. Diagnostic plots of proportion positive trips, QQ plots of residuals for successful catch rates, and plots of chi-square residuals for the delta lognormal model on proportion successful trips by each main effect are provided in Figures 18-23. Frequency distributions of ln(CPUE) for positive catches and plots of residuals for lognormal models on successful catch rates by each main effect are shown in Figures 24-29. These data appear to have met the assumptions for the analysis.

The CPUE series developed from blacknose shark data had generally increasing CPUEs over time (Figure 30). The confidence intervals also increased over the time series. In developing the blacknose shark index, GLMMIX failed to converge with any of the interactions SEASON*SUBREGION, SUBREGION*PERMTI, VESLEN*PERMIT, YEAR*DAYS, or YEAR*PERMIT included in the model, and those interaction terms were excluded from the model. Proportion positive trips, QQ plots of residuals for successful catch rates, and plots of chi-square residuals for the delta lognormal model on proportion successful trips by each main effect are provided in Figures 31-37. Frequency distributions of ln(CPUE) for positive catches and plots of residuals for lognormal models on successful catch rates by each main effect are shown in Figures 38-42. A few years of the time series have high proportion positive trips, however, overall these data appear to have met the assumptions for the analysis.

The finetooth shark index of abundance had no clear trend over time (Figure 43). Confidence intervals of this index were very large, probably due to a combination of many factors included in the model and relatively few observations. Proportion positive trips, QQ plots of residuals for successful catch rates, and plots of chi-square residuals for the delta lognormal model on proportion successful trips by each main effect are provided in Figures 44-48. Frequency distributions of ln(CPUE) for positive catches and plots of residuals for lognormal models on successful catch rates by each main effect are shown in Figures 49-52. The proportion positive finetooth shark trips were low for some years of the time series, but these data generally appear to have met the assumptions for the analysis.

The standardized CPUE series of bonnethead sharks showed an increase in CPUE over time (Figure 53). Again, the large confidence intervals are probably due to many factors included in the model and few observations. The GLMMIX model for bonnethead sharks failed to converge with any of the terms YEAR*VESLEN, VESLEN*SUBREGION, YEAR*SEASON, VESLEN*SEASON, YEAR*SUBREGION, or SUBREGION*DAYS included in the model. Only main effects were included in the final model. Proportion positive trips, QQ plots of residuals for successful catch rates, and plots of chi-square residuals for the delta lognormal model on proportion successful trips by each main effect are provided in Figures 54-59. Frequency distributions of ln(CPUE) for positive catches and plots of residuals for lognormal models on successful catch rates by each main effect are shown in Figures 60-66. These data appear to have met the assumptions for the analysis.

No clear trends in CPUE were apparent in the SCS complex, sharpnose shark, and finetooth shark indices. The blacknose shark and bonnethead shark indices did have increasing CPUEs over time, however. In all cases, relatively few observations and many significant factors included in the GLMMIX models were likely the cause of very large confidence intervals in the CPUE series.

Literature Cited

Ihaka, R., Gentleman, R., 1996. R: a language for data analysis and graphics. J. Comput. Graph. Statist. 5, 299–314.

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.

Acknowledgements

Thanks to John Carlson and Julie Neer for providing gillnet observer data and to Guillermo Diaz for help with subsetting the data.

Table 1. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for SCS complex in the US south Atlantic developed from coastal logbook gillnet trip data.

YEAR	Nominal CPUE	Relative Nominal CPUE	Trips	Proportion Successful Trips	Index	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.043	0.233	535	0.411	0.058	0.780	0.174	3.500	0.870
1999	0.762	4.141	478	0.529	0.074	0.995	0.238	4.163	0.818
2000	0.316	1.717	620	0.550	0.063	0.847	0.217	3.310	0.769
2001	0.059	0.322	658	0.584	0.068	0.922	0.242	3.516	0.752
2002	0.046	0.248	513	0.528	0.100	1.356	0.367	5.014	0.731
2003	0.032	0.175	459	0.636	0.053	0.710	0.172	2.927	0.807
2004	0.120	0.650	391	0.455	0.054	0.727	0.152	3.468	0.917
2005	0.095	0.514	552	0.500	0.123	1.664	0.505	5.477	0.653

Table 2. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for sharpnose sharks in the US south Atlantic developed from coastal logbook gillnet trip data.

YEAR	Nominal CPUE	Relative Nominal CPUE	Trips	Proportion Successful Trips	Index	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.012	0.904	327	0.615	0.016	0.873	0.523	1.459	0.261
1999	0.011	0.854	285	0.789	0.023	1.216	0.762	1.942	0.237
2000	0.011	0.811	359	0.652	0.018	0.956	0.600	1.522	0.236
2001	0.014	1.063	326	0.647	0.017	0.922	0.571	1.487	0.243
2002	0.009	0.707	210	0.567	0.013	0.721	0.413	1.259	0.284
2003	0.009	0.688	219	0.699	0.015	0.832	0.494	1.400	0.265
2004	0.012	0.875	255	0.604	0.016	0.871	0.523	1.449	0.259
2005	0.028	2.098	256	0.625	0.030	1.610	0.978	2.651	0.253

Table.3 Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for blacknose sharks in the US south Atlantic developed from coastal logbook gillnet trip data.

YEAR	Nominal CPUE	Relative Nominal CPUE	Trips	Proportion Successful Trips	Index	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.003	0.095	146	0.808	0.001	0.124	0.007	2.095	2.524
1999	0.002	0.055	145	0.862	0.001	0.144	0.006	3.348	3.298
2000	0.002	0.065	168	0.935	0.001	0.139	0.019	1.011	1.293
2001	0.006	0.207	177	0.876	0.004	0.400	0.060	2.674	1.210
2002	0.040	1.441	150	0.847	0.011	1.203	0.275	5.255	0.850
2003	0.027	0.993	142	0.803	0.015	1.615	0.320	8.158	0.963
2004	0.061	2.199	133	0.789	0.014	1.499	0.205	10.974	1.301
2005	0.081	2.944	117	0.761	0.026	2.875	0.556	14.862	0.981

Table 4. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for finetooth sharks in the US south Atlantic developed from coastal logbook gillnet trip data.

YEAR	Nominal CPUE	Relative Nominal CPUE	Trips	Proportion Successful Trips	Index	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.001	0.336	509	0.106	0.002	0.842	0.020	36.344	5.796
1999	0.000	0.113	459	0.148	0.000	0.141	0.002	12.743	12.628
2000	0.001	0.423	594	0.202	0.001	0.410	0.010	17.571	5.755
2001	0.003	0.883	636	0.186	0.001	0.674	0.021	22.078	4.470
2002	0.003	0.920	490	0.086	0.001	0.413	0.006	28.005	9.181
2003	0.003	0.775	448	0.143	0.003	1.193	0.036	39.713	4.535
2004	0.004	1.316	377	0.042	0.002	0.844	0.012	58.318	9.364
2005	0.011	3.234	533	0.101	0.008	3.483	0.180	67.387	2.823

Table 5. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for bonnethead sharks in the US south Atlantic developed from coastal logbook gillnet trip data.

YEAR	Nominal CPUE	Relative Nominal CPUE	Trips	Proportion Successful Trips	Index	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.003	0.180	226	0.425	0.001	0.316	0.007	14.090	5.975
1999	0.002	0.155	229	0.489	0.001	0.269	0.005	14.412	7.179
2000	0.005	0.373	384	0.521	0.002	0.439	0.012	16.676	5.128
2001	0.008	0.574	326	0.528	0.003	0.617	0.019	20.100	4.448
2002	0.019	1.347	262	0.408	0.003	0.720	0.019	27.188	5.102
2003	0.008	0.567	164	0.384	0.004	0.865	0.021	35.669	5.547
2004	0.058	4.053	161	0.410	0.014	3.165	0.218	45.937	2.233
2005	0.011	0.750	342	0.398	0.007	1.609	0.076	34.271	3.061

Figure 1. Small coastal shark and unclassified shark landings reported to the coastal logbook program from Gulf of Mexico and U.S. south Atlantic gillnet vessels.

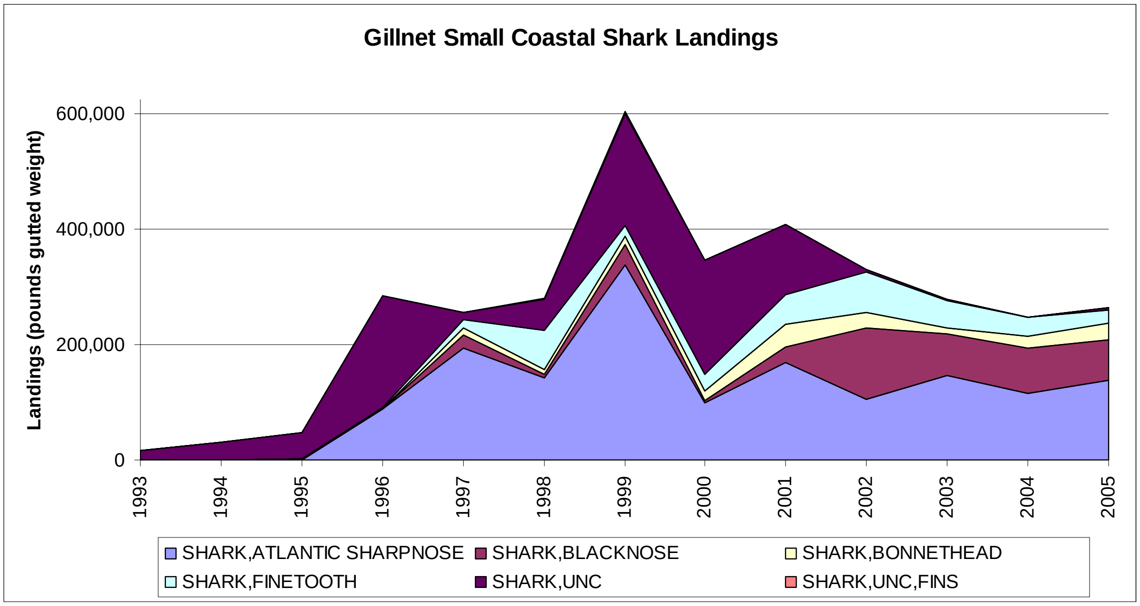

Figure 2. SCS complex nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing gillnets in the US south Atlantic.

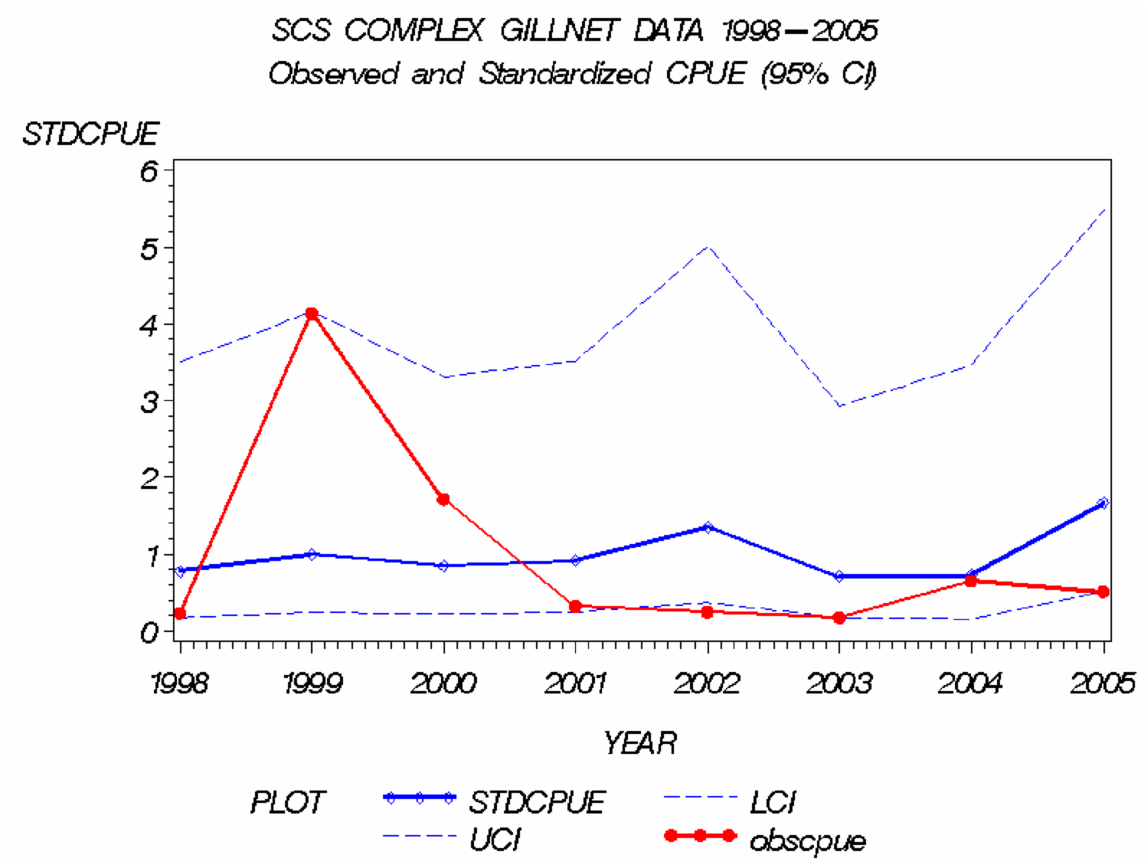

Figure 3. Observed proportion positive SCS complex trips in the US south Atlantic.

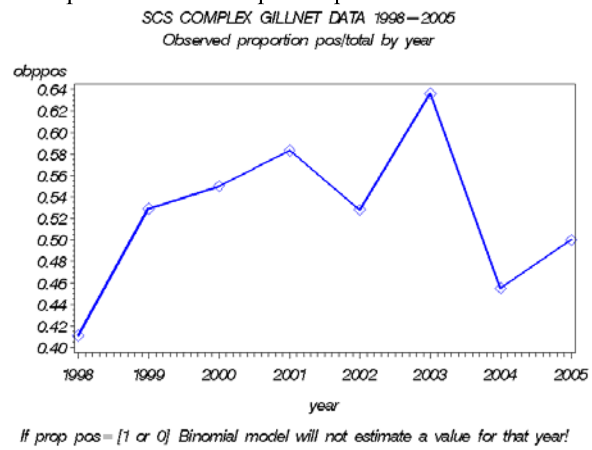

Figure 4. QQ plots of residuals for successful catch rates of the SCS complex from vessels fishing gillnets in the US south Atlantic where CPUE=pounds landed/(net area*hours fished).

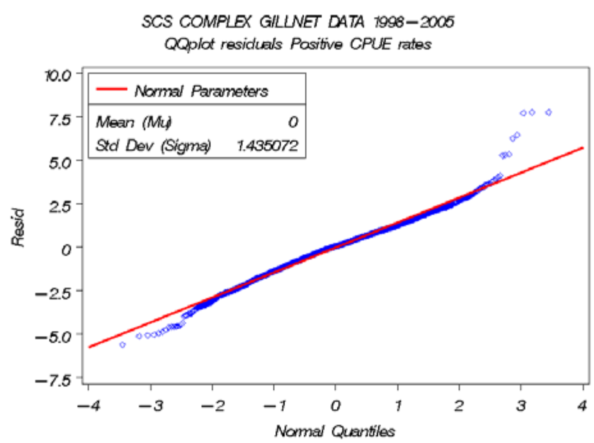

Figure 5. Chi-square residuals for delta lognormal model on proportion successful SCS complex trips, by year, for vessels fishing gillnets in the US south Atlantic.

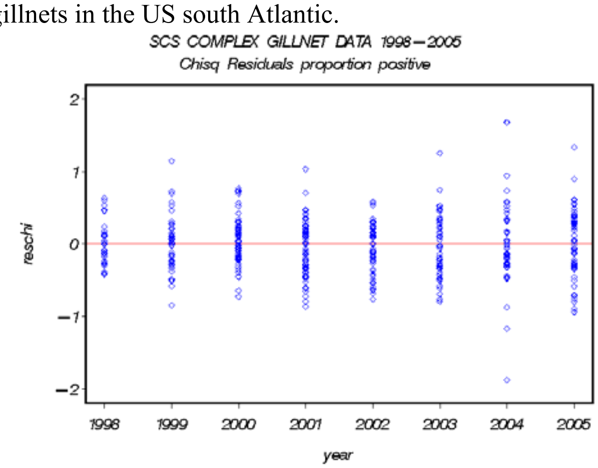

Figure 6. Chi-square residuals for delta lognormal model on proportion successful SCS complex trips, by permit type, for vessels fishing gillnets in the US south Atlantic.

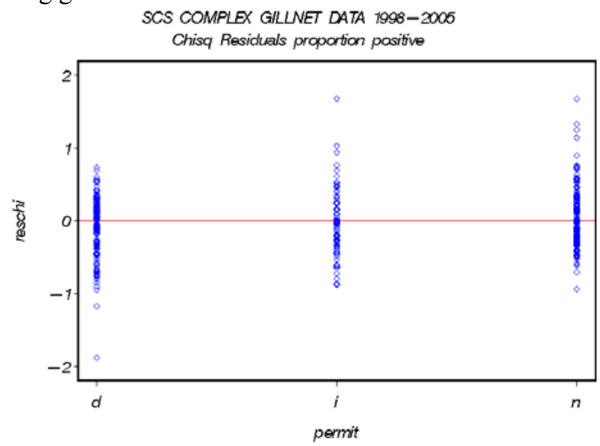

Figure 7. Chi-square residuals for delta lognormal model on proportion successful SCS complex trips, by season, for vessels fishing gillnets in the US south Atlantic.

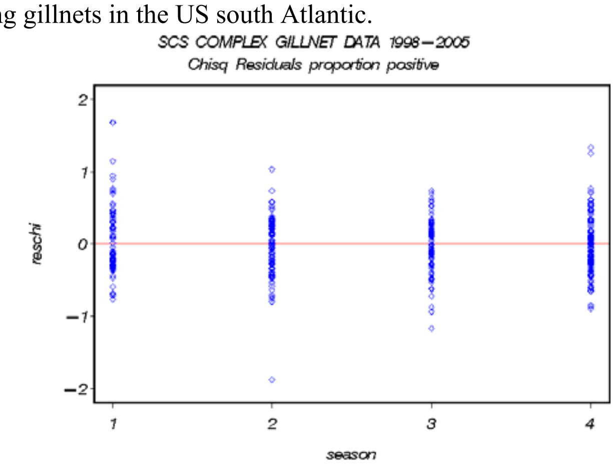

Figure 8. Chi-square residuals for delta lognormal model on proportion successful SCS complex trips, by vessel length, for vessels fishing gillnets in the US south Atlantic.

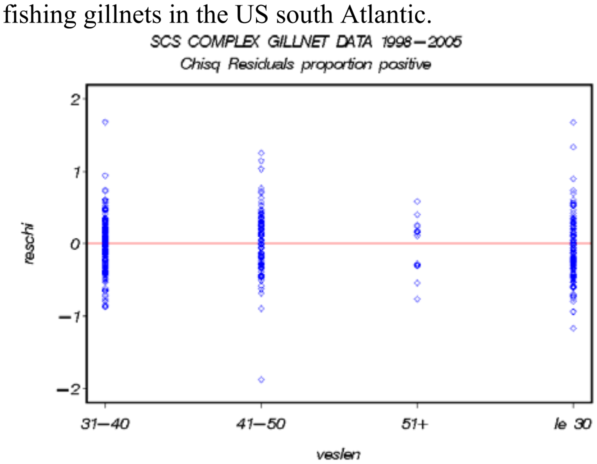

Figure 9. Chi-square residuals for delta lognormal model on proportion successful SCS complex trips, by subregion, for vessels fishing gillnets in the US south Atlantic.

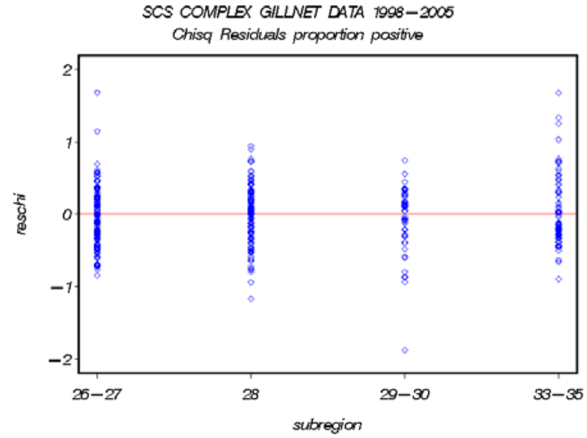

Figure 10. Frequency distribution of ln(CPUE) for positive catches of SCS complex reported from vessels fishing gillnets in the US south Atlantic. The solid line is the expected normal distribution.

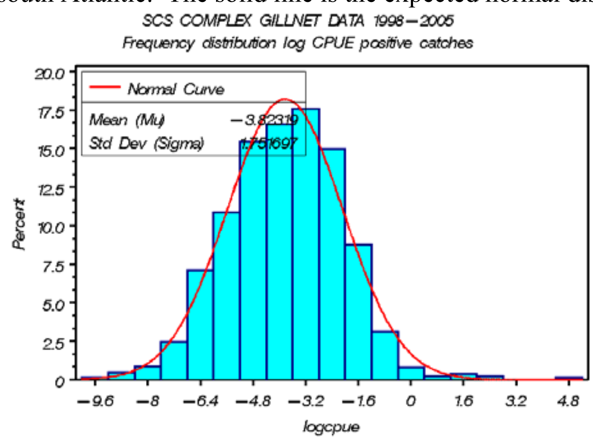

Figure 11. Residuals for the lognormal model on successful catch rates for SCS complex from vessels fishing gillnets, by year, in the US south Atlantic.

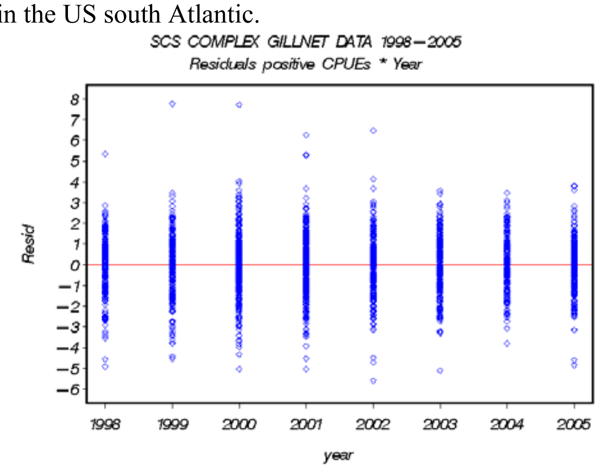

Figure 12. Residuals for the lognormal model on successful catch rates for SCS complex from vessels fishing gillnets, by permit type, in the US south Atlantic.

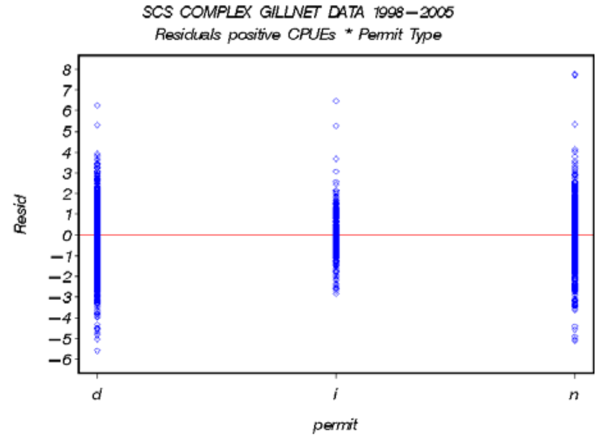

Figure 13. Residuals for the lognormal model on successful catch rates for SCS complex from vessels fishing gillnets, by season, in the US south Atlantic.

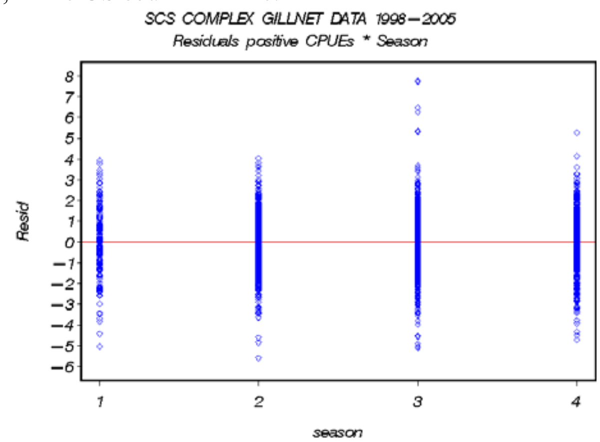

Figure 14. Residuals for the lognormal model on successful catch rates for SCS complex from vessels fishing gillnets, by vessel length, in the US south Atlantic.

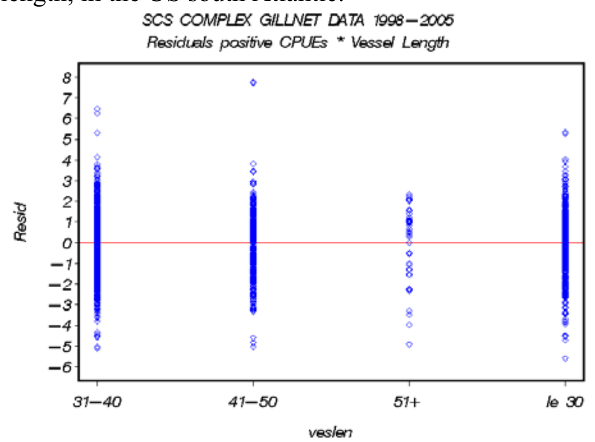

Figure 15. Residuals for the lognormal model on successful catch rates for SCS complex from vessels fishing gillnets, by days at sea, in the US south Atlantic.

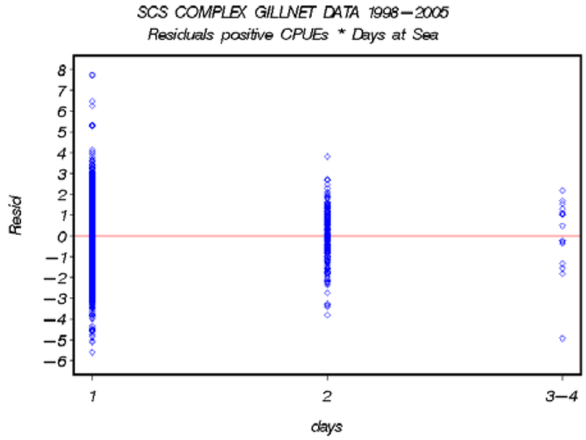

Figure 16. Residuals for the lognormal model on successful catch rates for SCS complex from vessels fishing gillnets, by subregion, in the US south Atlantic.

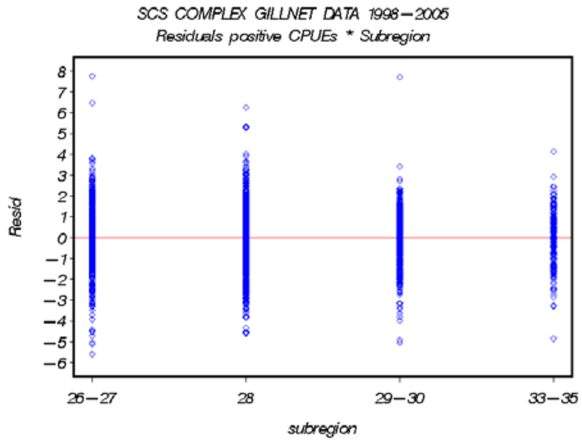

Figure 17. Sharpnose shark nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing gillnets in the US south Atlantic.

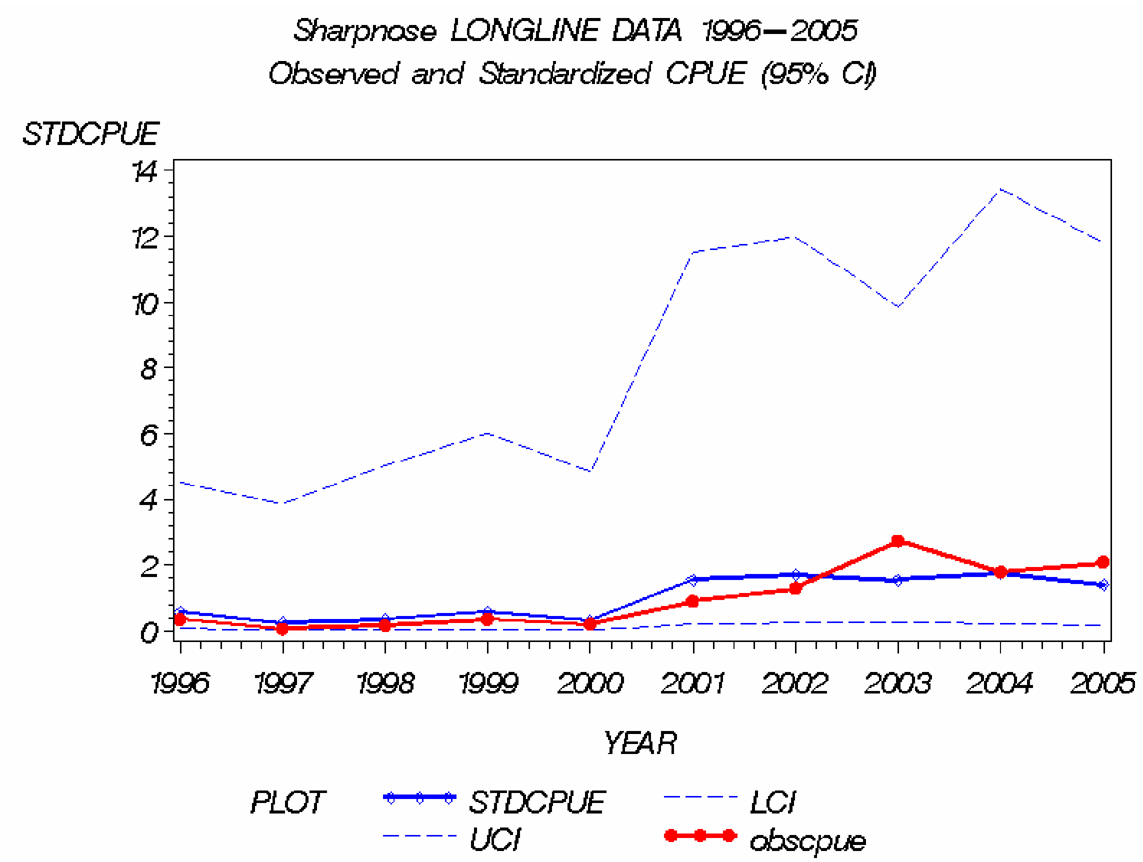

Figure 18. Observed proportion positive sharpnose shark trips in the US south Atlantic.

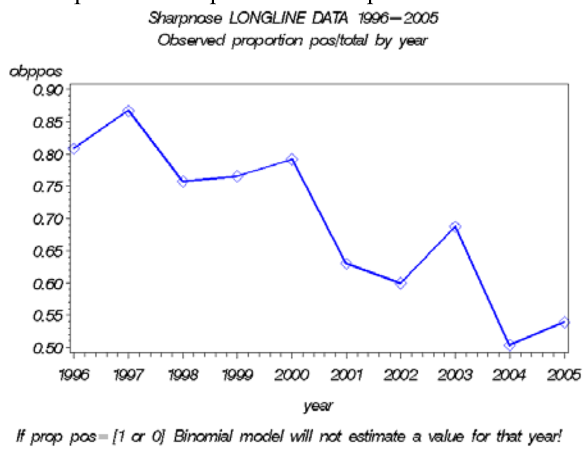

Figure 19. QQ plots of residuals for successful catch rates of sharpnose sharks from vessels fishing gillnets in the US south Atlantic where CPUE=pounds landed/(net area*hours fished).

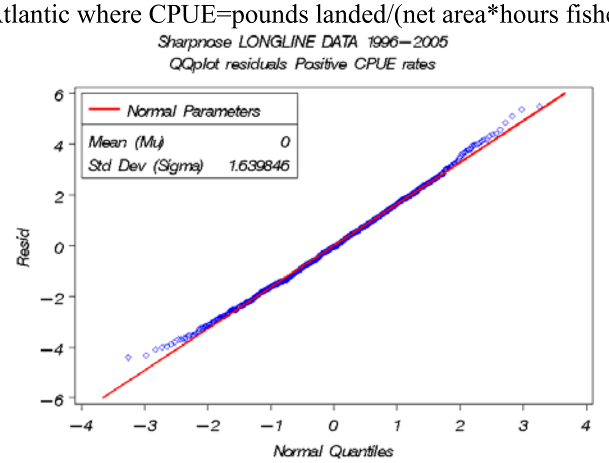

Figure 20. Chi-square residuals for delta lognormal model on proportion successful sharpnose shark trips, by year, for vessels fishing gillnets in the US south Atlantic.

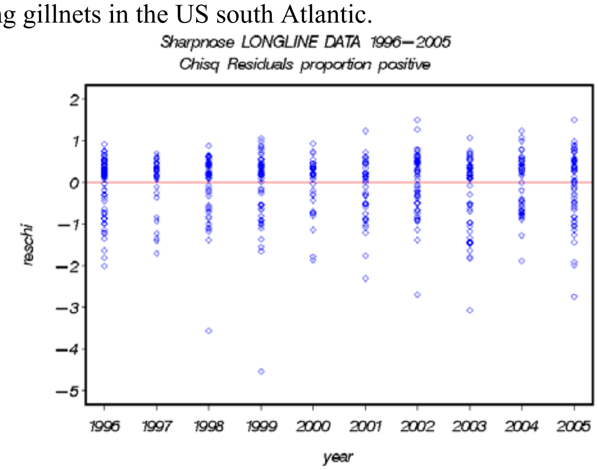

Figure 21. Chi-square residuals for delta lognormal model on proportion successful sharpnose shark trips, by subregion, for vessels fishing gillnets in the US south Atlantic.

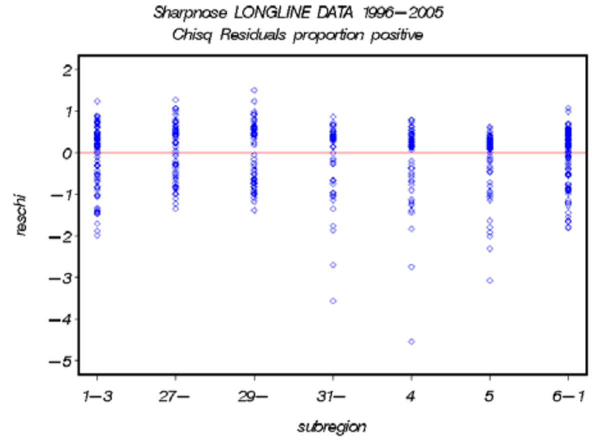

Figure 22. Chi-square residuals for delta lognormal model on proportion successful sharpnose shark trips, by days at sea, for vessels fishing gillnets in the US south Atlantic.

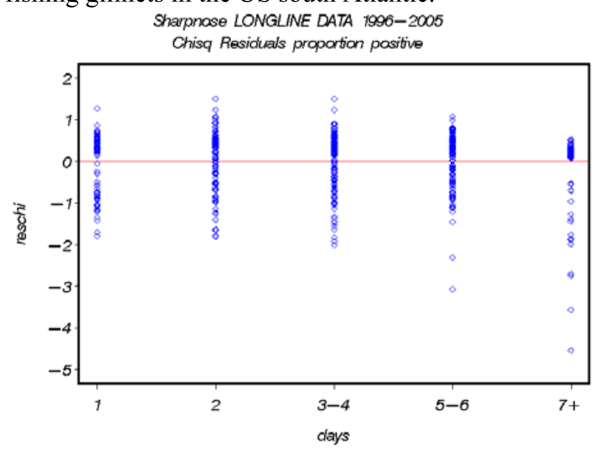

Figure 23. Chi-square residuals for delta lognormal model on proportion successful sharpnose shark trips, by season, for vessels fishing gillnets in the US south Atlantic.

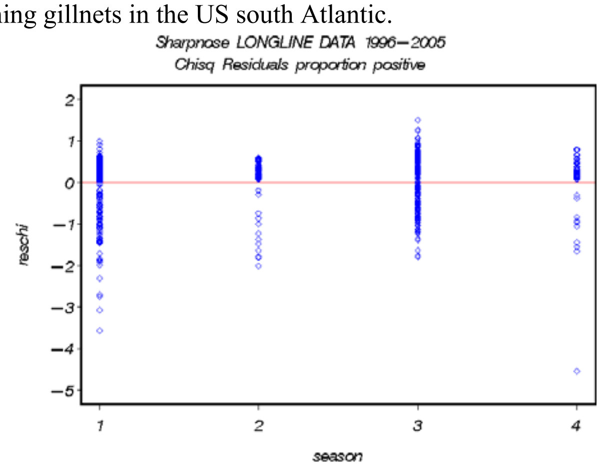

Figure 24. Frequency distribution of ln(CPUE) for positive catches of sharpnose sharks reported from vessels fishing gillnets in the US south Atlantic. The solid line is the expected normal distribution.

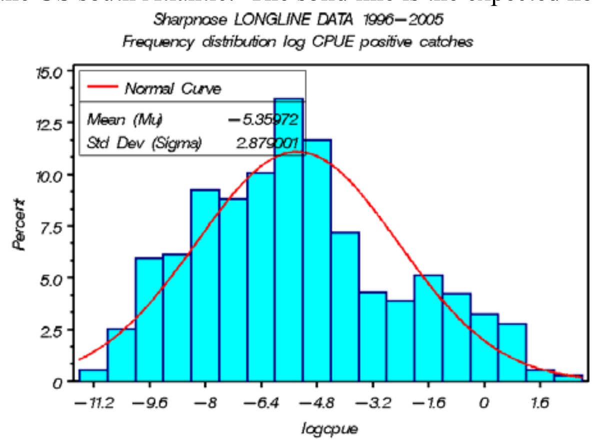

Figure 25. Residuals for the lognormal model on successful catch rates of sharpnose sharks from vessels fishing gillnets, by year, in the US south Atlantic.

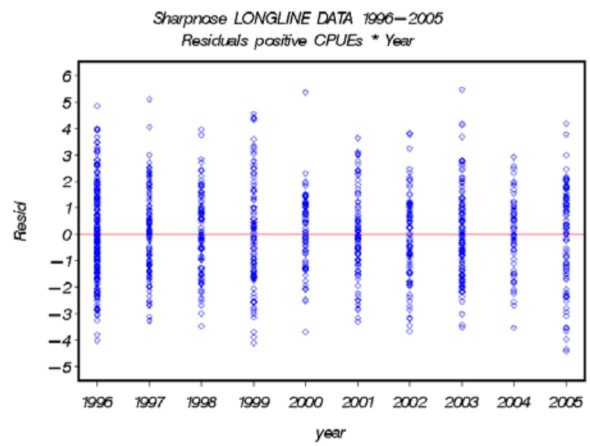

Figure 26. Residuals for the lognormal model on successful catch rates of sharpnose sharks from vessels fishing gillnets, by days at sea, in the US south Atlantic.

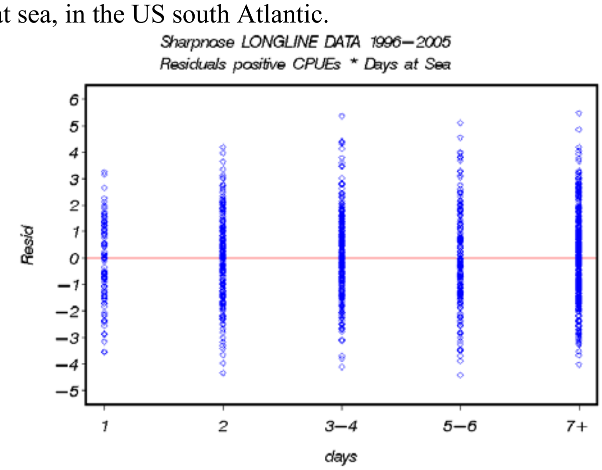

Figure 27. Residuals for the lognormal model on successful catch rates of sharpnose sharks from vessels fishing gillnets, by subregion, in the US south Atlantic.

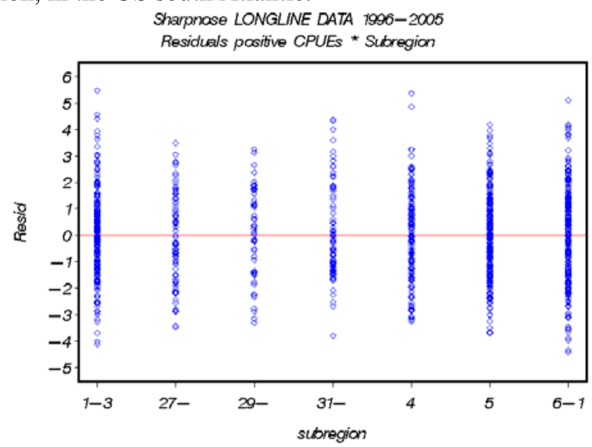

Figure 28. Residuals for the lognormal model on successful catch rates of sharpnose sharks from vessels fishing gillnets, by vessel length, in the US south Atlantic.

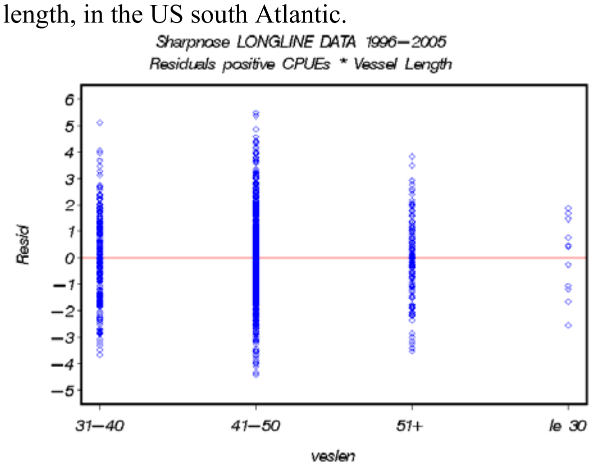

Figure 29. Residuals for the lognormal model on successful catch rates of sharpnose sharks from vessels fishing gillnets, by type of permit, in the US south Atlantic.

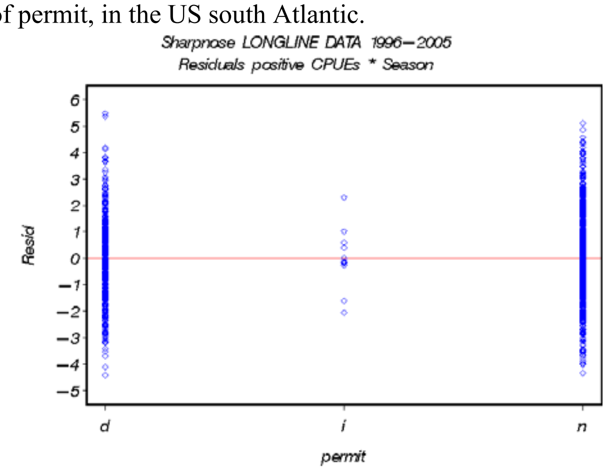

Figure 30. Blacknose shark nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing gillnets in the US south Atlantic.

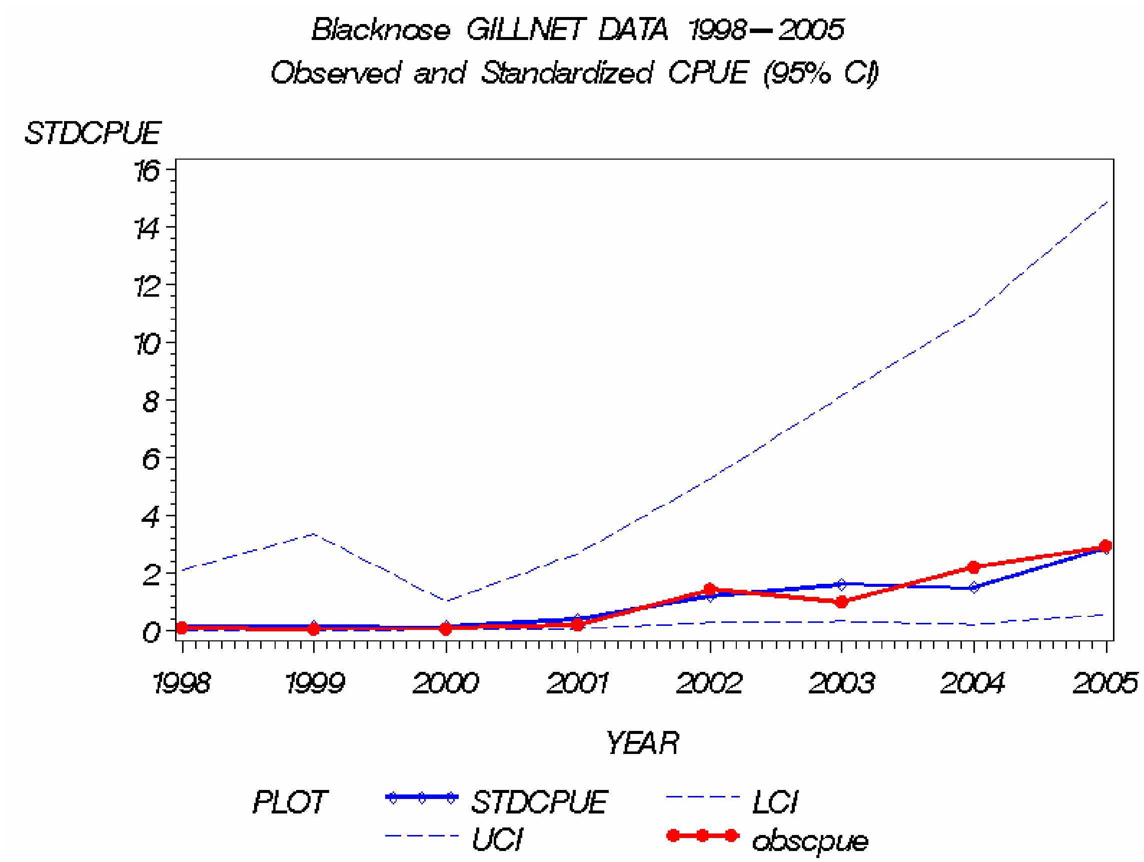

Figure 31. Observed proportion positive blacknose shark trips in the US south Atlantic.

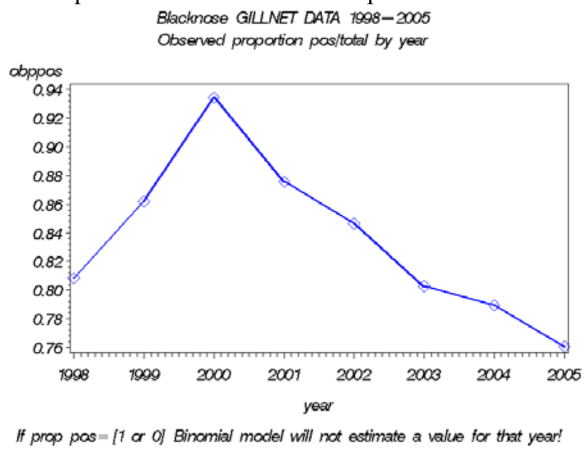

Figure 32. QQ plots of residuals for successful catch rates of blacknose sharks from vessels fishing gillnets in the US south Atlantic where CPUE=pounds landed/(net area*hours fished).

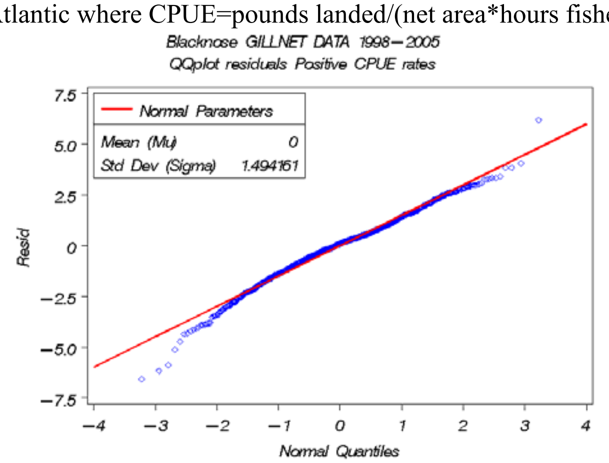

Figure 33. Chi-square residuals for delta lognormal model on proportion successful blacknose shark trips, by year, for vessels fishing gillnets in the US south Atlantic.

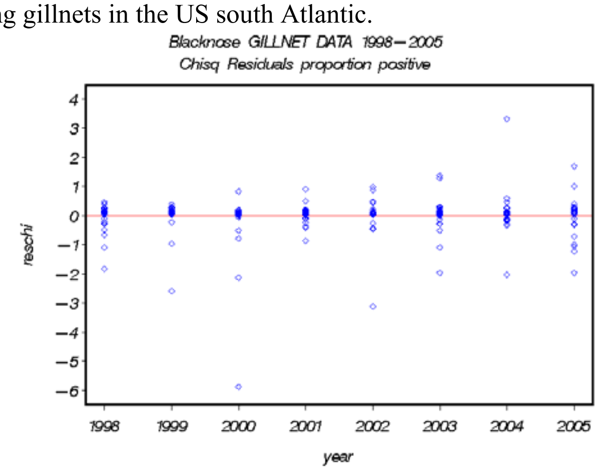

Figure 34. Chi-square residuals for delta lognormal model on proportion successful blacknose shark trips, by subregion, for vessels fishing gillnets in the US south Atlantic.

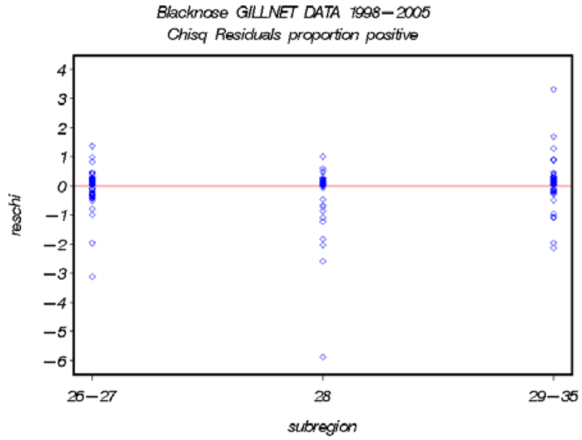

Figure 35. Chi-square residuals for delta lognormal model on proportion successful blacknose shark trips, by vessel length, for vessels fishing gillnets in the US south Atlantic.

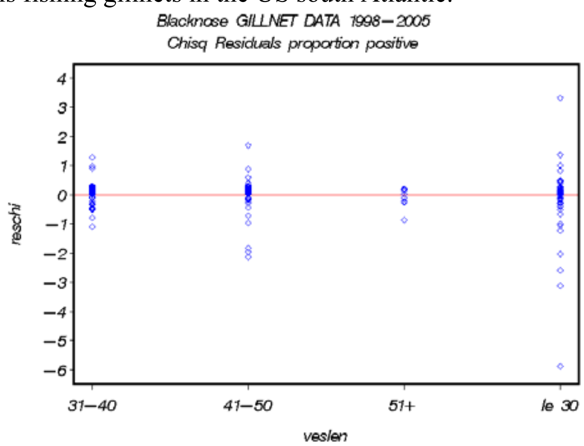

Figure 36. Chi-square residuals for delta lognormal model on proportion successful blacknose shark trips, by season, for vessels fishing gillnets in the US south Atlantic.

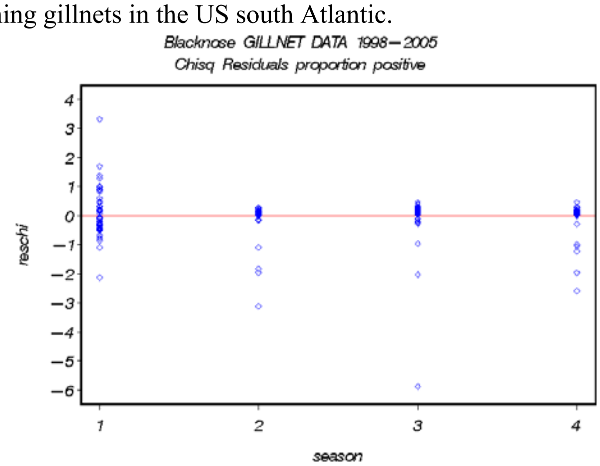

Figure 37. Chi-square residuals for delta lognormal model on proportion successful blacknose shark trips, by permit type, for vessels fishing gillnets in the US south Atlantic.

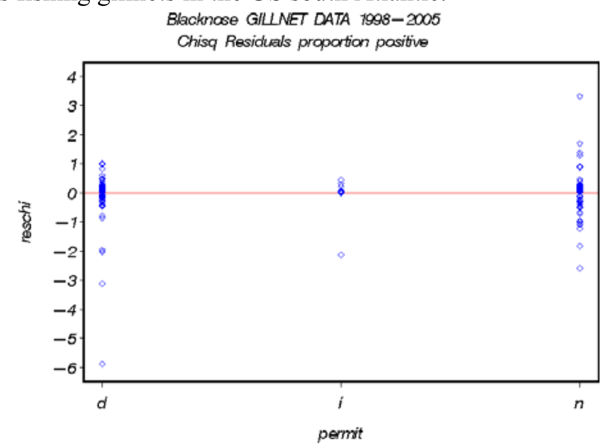

Figure 38. Frequency distribution of ln(CPUE) for positive catches of blacknose sharks reported from vessels fishing gillnets in the US south Atlantic. The solid line is the expected normal distribution.

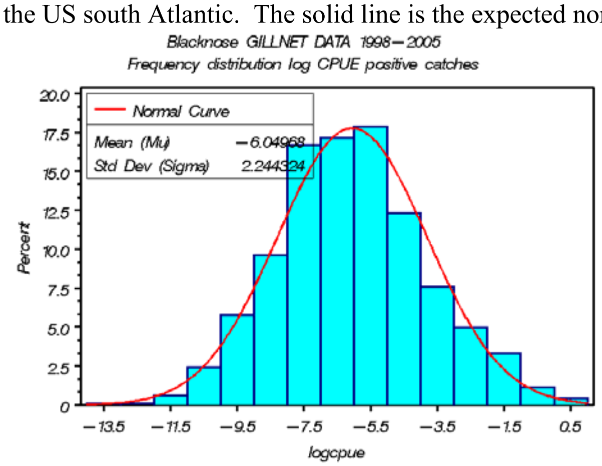

Figure 39. Residuals for the lognormal model on successful catch rates of blacknose sharks from vessels fishing gillnets, by year, in the US south Atlantic.

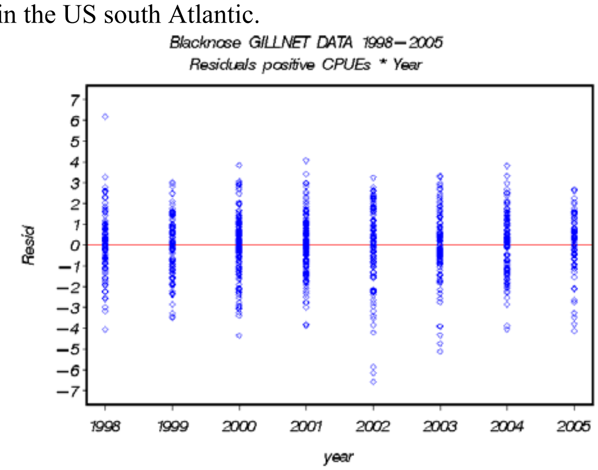

Figure 40. Residuals for the lognormal model on successful catch rates of blacknose sharks from vessels fishing gillnets, by permit type, in the US south Atlantic.

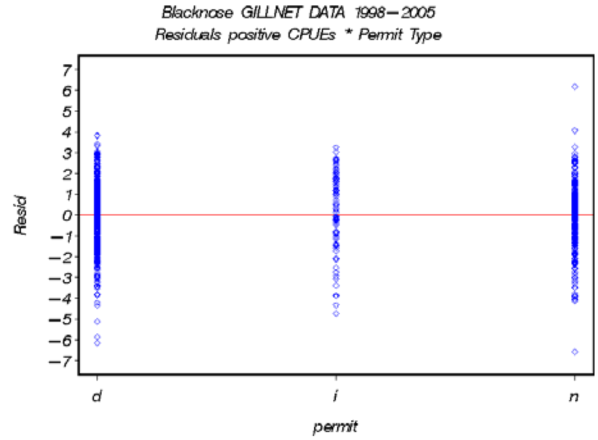

Figure 41. Residuals for the lognormal model on successful catch rates of blacknose sharks from vessels fishing gillnets, by vessel length, in the US south Atlantic.

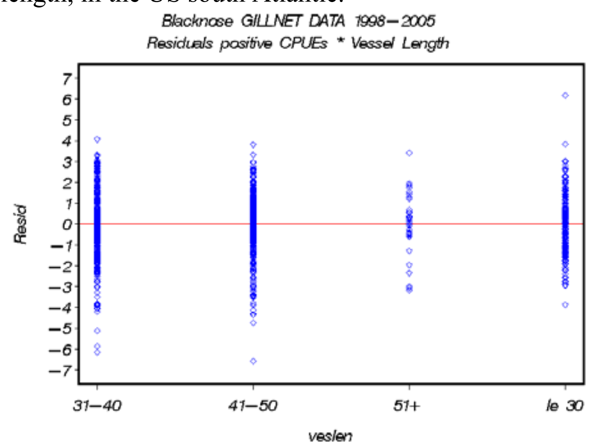

Figure 42. Residuals for the lognormal model on successful catch rates of blacknose sharks from vessels fishing gillnets, by days at sea, in the US south Atlantic.

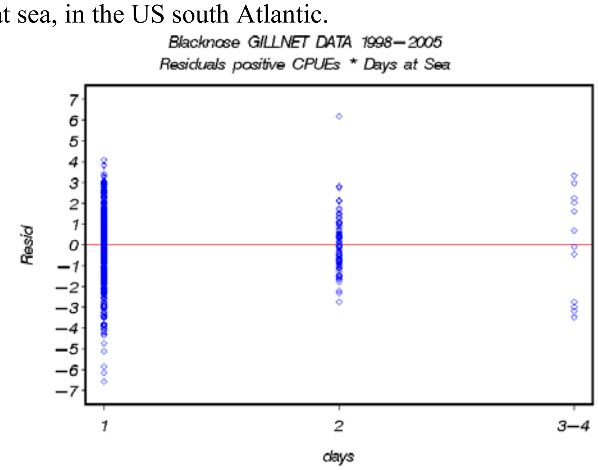

Figure 43. Finetooth shark nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing gillnets in the US south Atlantic.

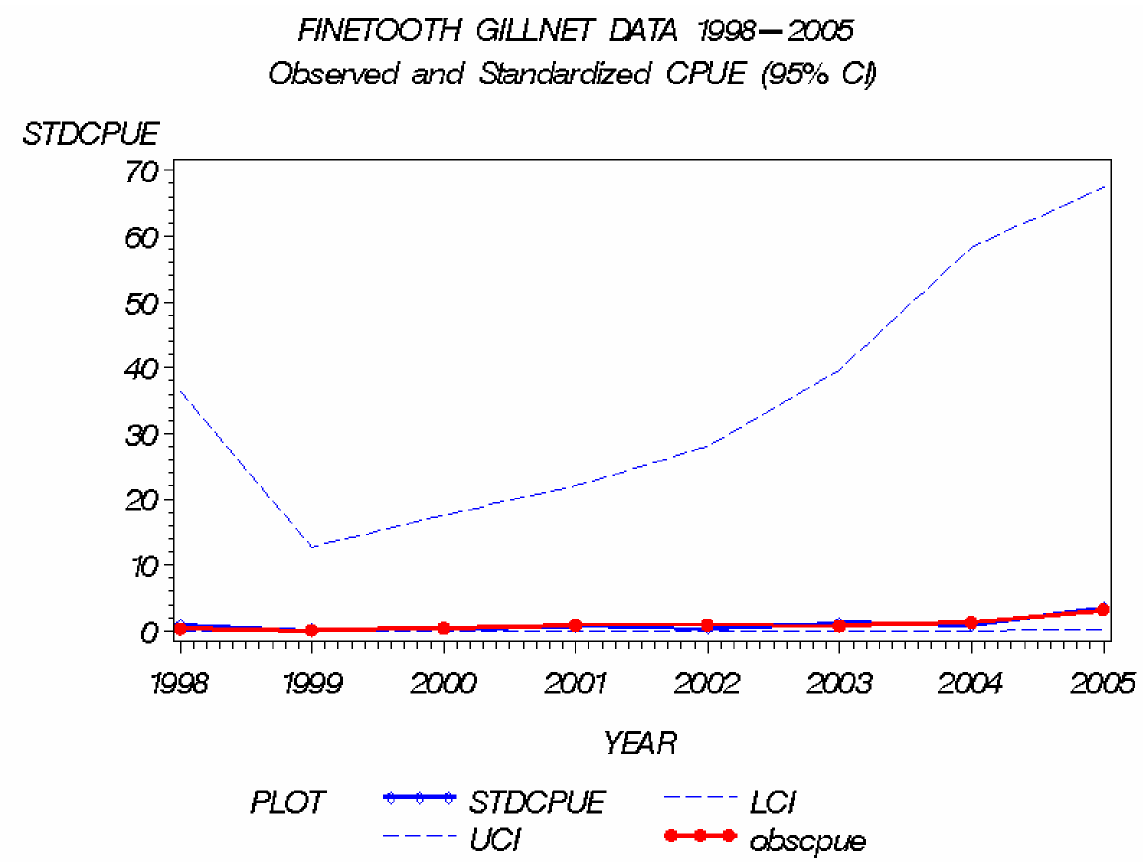

Figure 44. Observed proportion positive finetooth shark trips in the US south Atlantic.

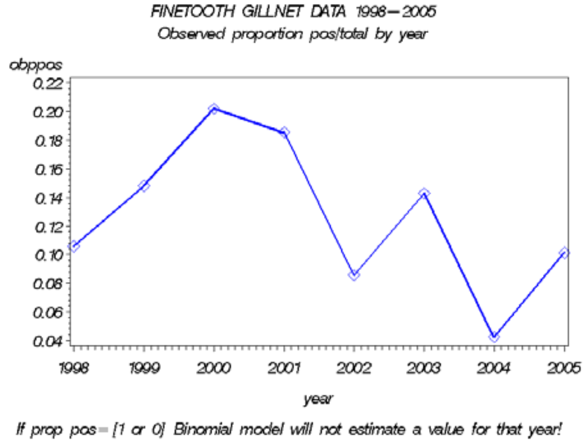

Figure 45. QQ plots of residuals for successful catch rates of finetooth sharks from vessels fishing gillnets in the US south Atlantic where CPUE=pounds landed/(net area*hours fished).

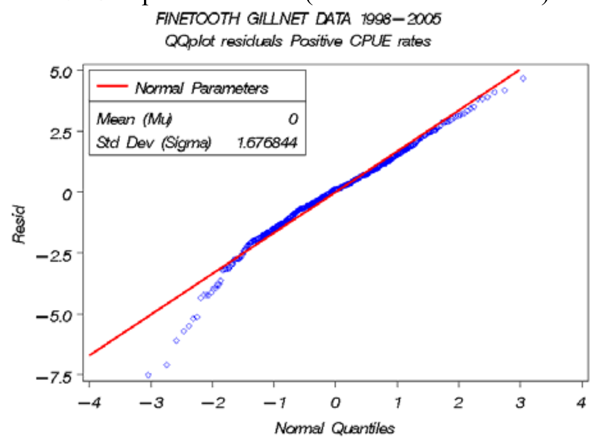

Figure 46. Chi-square residuals for delta lognormal model on proportion successful finetooth shark trips, by year, for vessels fishing gillnets in the US south Atlantic.

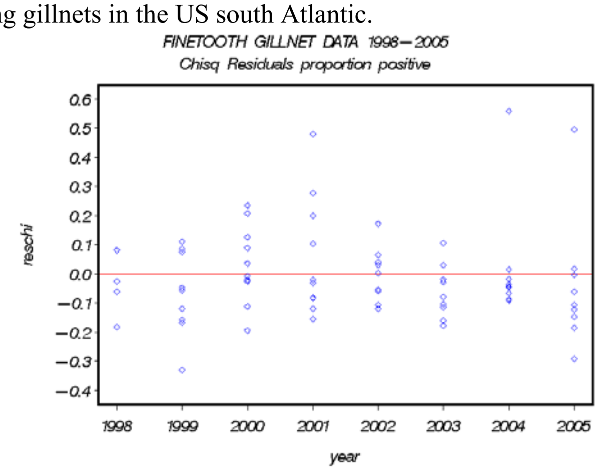

Figure 47. Chi-square residuals for delta lognormal model on proportion successful finetooth shark trips, by vessel length, for vessels fishing gillnets in the US south Atlantic.

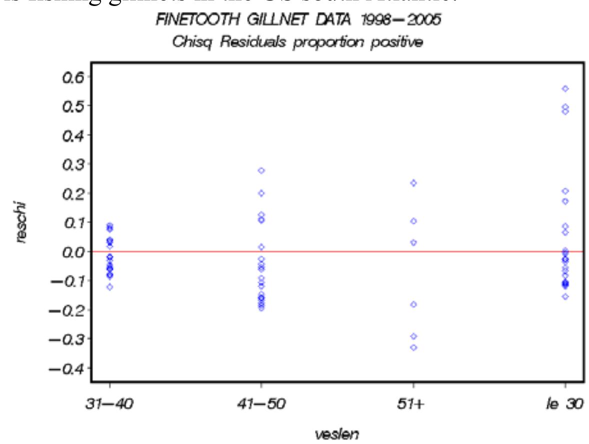

Figure 48. Chi-square residuals for delta lognormal model on proportion successful finetooth shark trips, by permit type, for vessels fishing gillnets in the US south Atlantic.

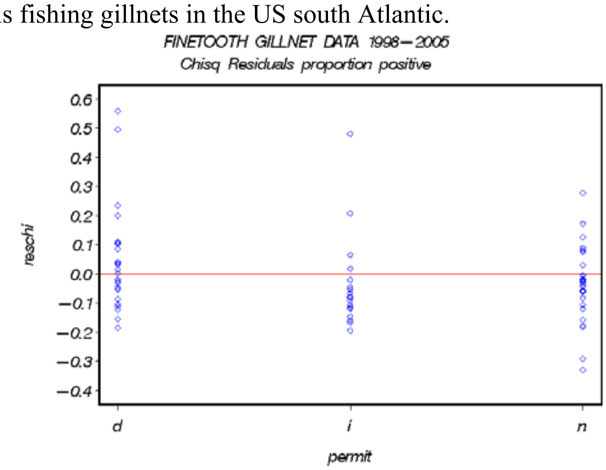

Figure 49. Frequency distribution of ln(CPUE) for positive catches of finetooth sharks reported from vessels fishing gillnets in the US south Atlantic. The solid line is the expected normal distribution.

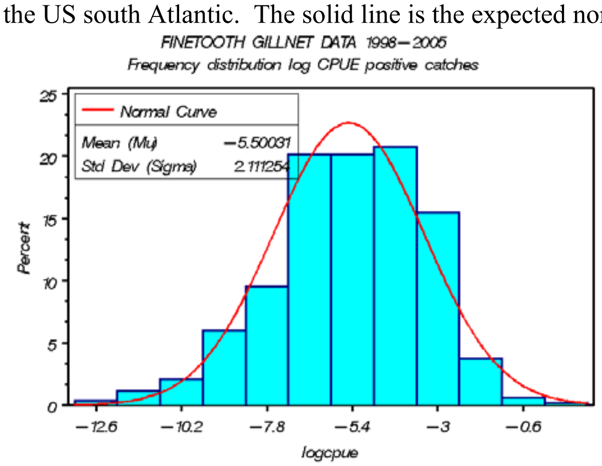

Figure 50. Residuals for the lognormal model on successful catch rates of finetooth sharks from vessels fishing gillnets, by year, in the US south Atlantic.

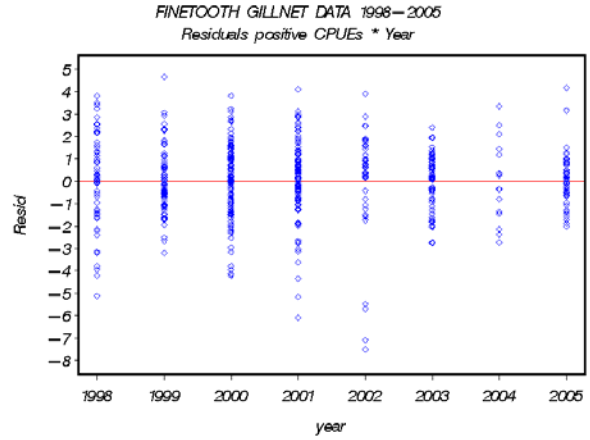

Figure 51. Residuals for the lognormal model on successful catch rates of finetooth sharks from vessels fishing gillnets, by permit type, in the US south Atlantic.

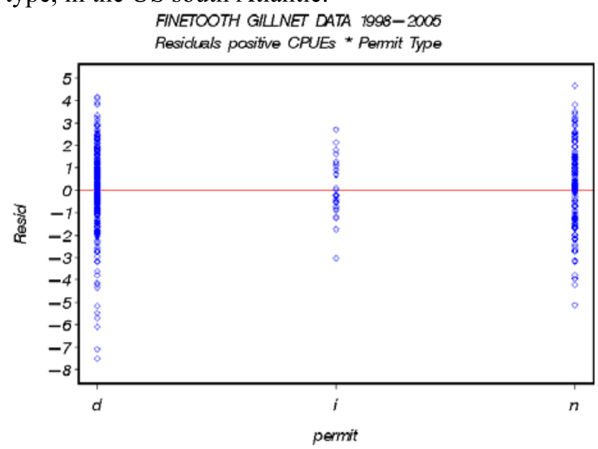

Figure 52. Residuals for the lognormal model on successful catch rates of finetooth sharks from vessels fishing gillnets, by vessel length, in the US south Atlantic.

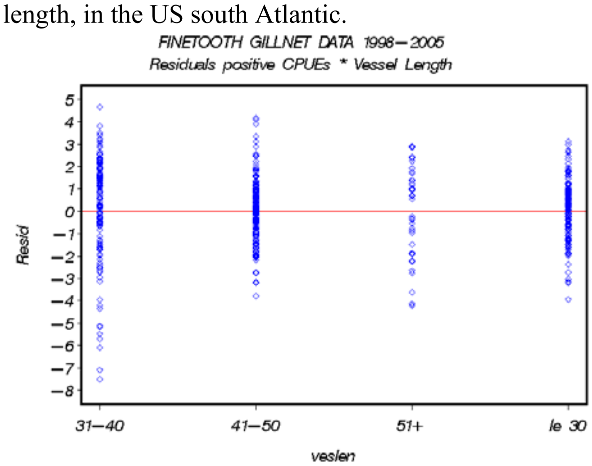

Figure 53. Bonnethead shark nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing gillnets in the US south Atlantic.

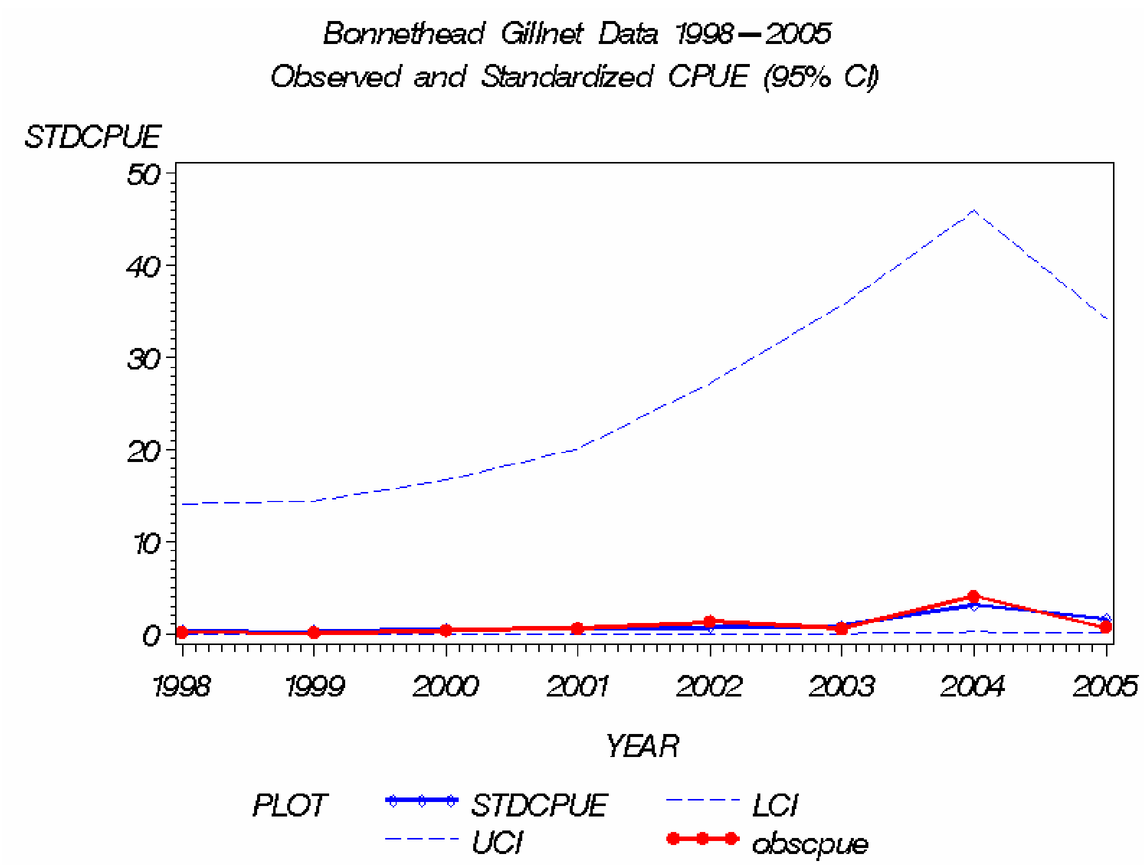

Figure 54. Observed proportion positive bonnethead shark trips in the US south Atlantic.

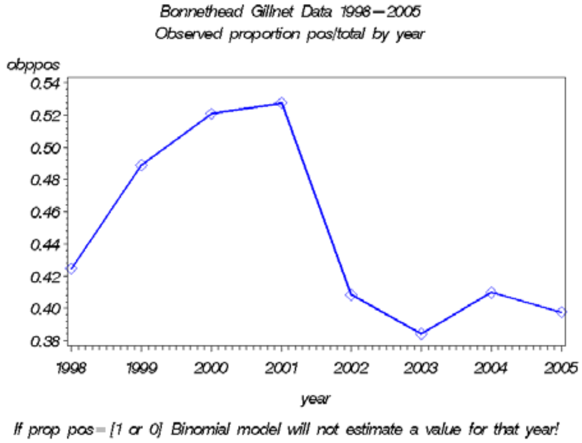

Figure 55. QQ plots of residuals for successful catch rates of bonnethead sharks from vessels fishing gillnets in the US south Atlantic where CPUE=pounds landed/(net area*hours fished).

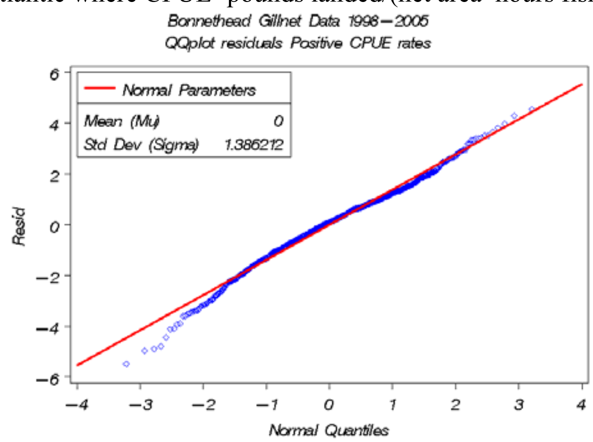

Figure 56. Chi-square residuals for delta lognormal model on proportion successful bonnethead shark trips, by year, for vessels fishing gillnets in the US south Atlantic.

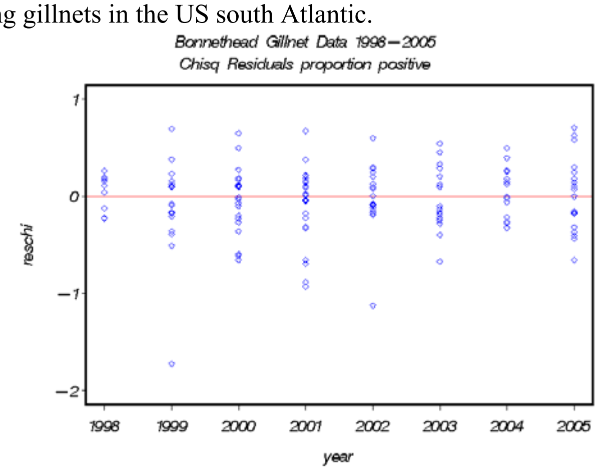

Figure 57. Chi-square residuals for delta lognormal model on proportion successful bonnethead shark trips, by subregion, for vessels fishing gillnets in the US south Atlantic.

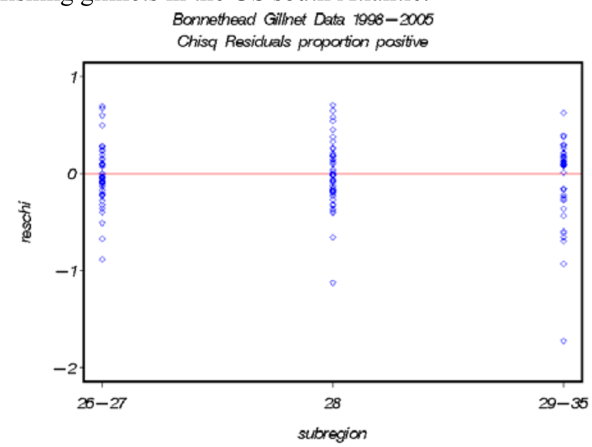

Figure 58. Chi-square residuals for delta lognormal model on proportion successful bonnethead shark trips, by permit type, for vessels fishing gillnets in the US south Atlantic.

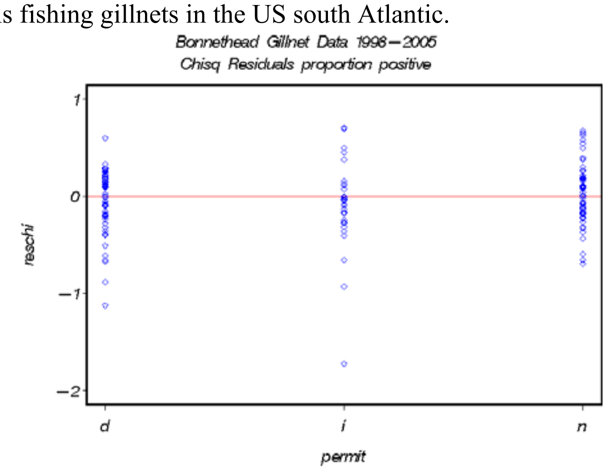

Figure 59. Chi-square residuals for delta lognormal model on proportion successful bonnethead shark trips, by vessel length, for vessels fishing gillnets in the US south Atlantic.

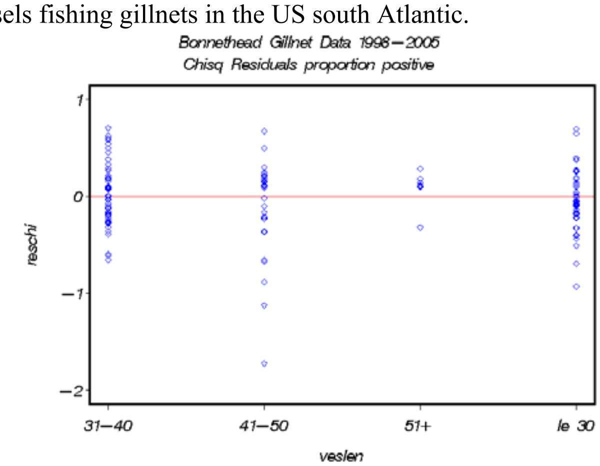

Figure 60. Frequency distribution of ln(CPUE) for positive catches of bonnethead sharks reported from vessels fishing gillnets in the US south Atlantic. The solid line is the expected normal distribution.

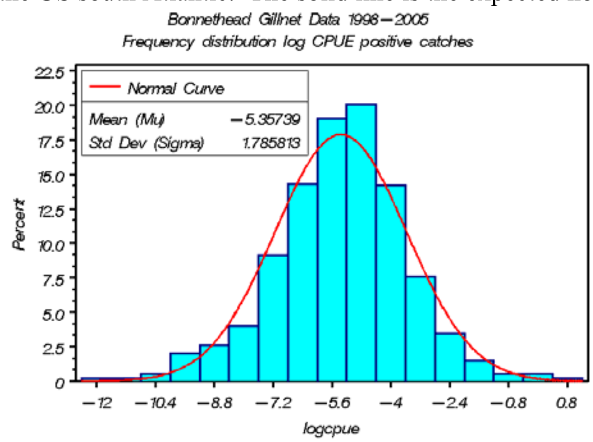

Figure 61. Residuals for the lognormal model on successful catch rates of bonnethead sharks from vessels fishing gillnets, by year, in the US south Atlantic.

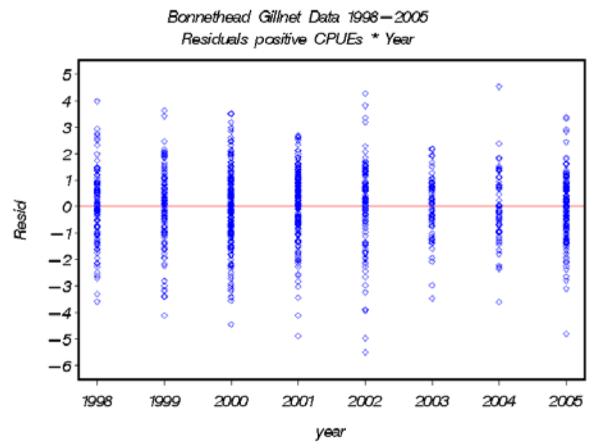

Figure 62. Residuals for the lognormal model on successful catch rates of bonnethead sharks from vessels fishing gillnets, by subregion, in the US south Atlantic.

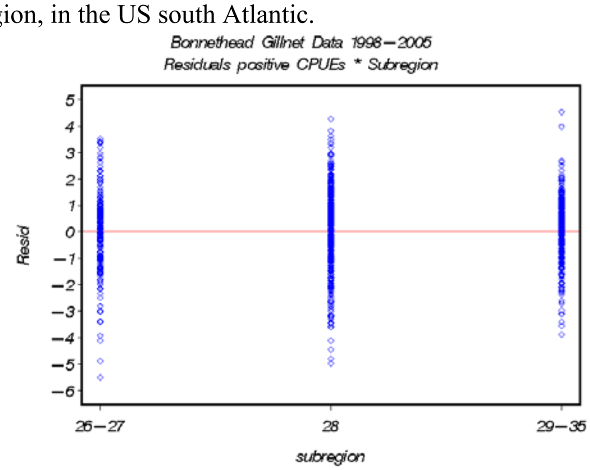

Figure 63. Residuals for the lognormal model on successful catch rates of bonnethead sharks from vessels fishing gillnets, by days at sea, in the US south Atlantic.

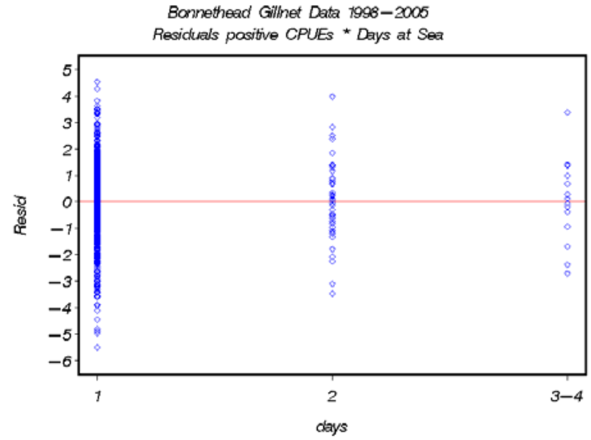

Figure 64. Residuals for the lognormal model on successful catch rates of bonnethead sharks from vessels fishing gillnets, by vessel length, in the US south Atlantic.

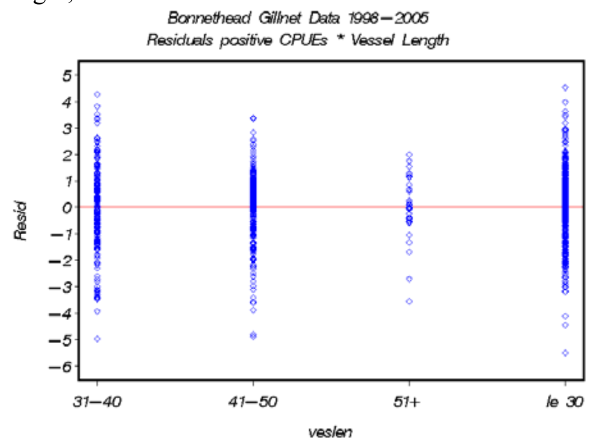

Figure 65. Residuals for the lognormal model on successful catch rates of bonnethead sharks from vessels fishing gillnets, by permit type, in the US south Atlantic.

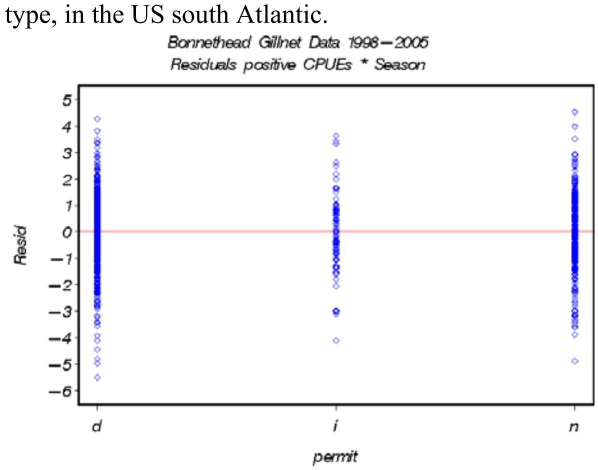

Figure 66. Residuals for the lognormal model on successful catch rates of bonnethead sharks from vessels fishing gillnets, by season, in the US south Atlantic.