United States Commercial Vertical Line Vessel Standardized Catch Rates of Red Grouper in the US South Atlantic, 1993-2008

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Introduction

Handline and electric reel (bandit rig) landings and fishing effort of commercial vessels operating in the U.S. South Atlantic have been monitored by 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 Gulf of Mexico and South Atlantic Fishery Management Councils. The coastal logbook program began in 1990 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 targeted. Beginning in 1993, the sampling in Florida was increased to require reports from all vessels permitted in coastal fisheries.

The available catch per unit effort (CPUE) series was used to develop an abundance index for red grouper landed using vertical line gear (handline and electric reel). Landings and effort data reported to the CFLP were not required for vessels landing red grouper prior to 1992 in the South Atlantic. Given that during 1992 only a 20% subsample of Florida vessels were selected for reporting landings and effort data, the time series used for construction of the commercial indices included the years 1993-2008.

Methods

Available Data

For each fishing trip, the CFLP 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 vertical line gear included number of lines fished, hours fished, and number of hooks per line. 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 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. Approximately 81 percent of vertical line trips were retained for analyses. 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, e.g. values falling outside the 99.5 percentile of the data, were also excluded from the analyses. These included vertical line data from trips reporting more than 14 lines fished, 17 hooks per line fished, or more than 24 hours fishing per day at sea. Trips with 13 or more crew were also omitted.

Red grouper 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 red grouper 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 method was an objective approach in which a logistic regression was applied to estimate the probability that red grouper 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 red grouper. 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 red grouper occurring when the species was actually absent (false positives) while also minimizing incorrect predictions of red grouper absence when the species was actually present (false negatives).

Index Development

Vertical line catch rate was calculated in weight of fish per hook-hour. For each trip, catch per unit effort was calculated as:

CPUE = pounds of red grouper/(number of lines fished*number of hooks per line*total hours fished)

Four factors were considered as possible influences on both the proportion of trips that landed red grouper and the catch rate of red grouper. In order to develop a well balanced sample design it was necessary to define categories within three of the four factors examined:

Factor	**Levels**	**Value**
Year	16	1993-2008
Area(*area_cat*)*	3	Latitude degrees: 24 – 31 (‘FL-GA’), 32 – 33 (‘SC’), 34 – 36 (‘NC’) see Figure 1.
Days at sea (*days_cat*)*	3	1, 2-4, 5+
Crew (*crew_cat*)*	3	1, 2, 3+ crew members

*Names in parentheses appear in some figures and tables.

The delta lognormal model approach (Lo et al. 1992) was used to construct standardized indices of abundance. This method combines separate general linear model (GLM) analyses of the proportion of successful trips (trips that landed red grouper) 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 of vertical line data was calculated as: log(CPUE) = ln(pounds of red grouper/hook hour). 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.

Once a set of fixed factors was identified, the influence of the YEAR*FACTOR interactions were examined. YEAR*FACTOR interaction terms were 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). 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 (PPT) and the lognormal on CPUE of successful trips were:

PPT = Year + Area + Days at Sea

LOG(CPUE) = Days at Sea + Area + Crew Number + Year

The linear regression statistics of the final models are summarized in Table 1.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 2. The delta-lognormal abundance indices developed, with 95% confidence intervals, is shown in Figure 2.

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 3-6. The yearly proportion of positive red grouper trips varied from approximately 40 to 80% and were within the acceptable limits required for the analysis. Nominal CPUE increased over the initial seven years of the time series, remained relatively constant from 1999 through 2005, then increased approximately three-fold by 2007 with a decrease in 2008. There were a few outliers among these data apparent in the plots of residuals, however, overall the diagnostic plots indicate that the fit of the data to the lognormal and binomial models was acceptable.

Red grouper standardized catch rates for vertical line vessels increased by almost eightfold over the time series through 2008. Coefficients of variation were low and decreased by almost 70% between 1993 and 1999, but remained relatively constant over the remainder of the time series.

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 red grouper in the South Atlantic for vessels reporting vertical line gear landings 1993-2008. 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	15	124	289.14	19.28	<.0001	<.0001
days_cat	2	124	271.34	135.67	<.0001	<.0001
area_cat	2	124	233.37	116.69	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	15	19E3	1193.46	79.56	<.0001	<.0001
days_cat	2	19E3	2292.91	1146.46	<.0001	<.0001
area_cat	2	19E3	1494.56	747.28	<.0001	<.0001
crew_cat	2	19E3	1364.20	682.10	<.0001	<.0001

Table 2. Vertical line relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for red grouper (1993-2008) in the South Atlantic.

YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.249802	988	0.408907	0.313331	0.220243	0.445762	0.177641
1994	0.29867	1,820	0.408242	0.296877	0.227863	0.386794	0.132867
1995	0.476702	2,024	0.479249	0.488562	0.399869	0.596928	0.100417
1996	0.362009	1,877	0.548748	0.486361	0.403475	0.586276	0.093624
1997	0.633103	2,439	0.603936	0.626811	0.543432	0.722983	0.071461
1998	0.867402	2,423	0.685927	0.950609	0.843615	1.071173	0.059757
1999	1.165701	1,944	0.803498	1.399444	1.257253	1.557716	0.053611
2000	1.117681	1,848	0.723485	1.069951	0.942042	1.215229	0.063724
2001	0.930686	2,236	0.637746	0.836165	0.728358	0.959929	0.069099
2002	1.006297	2,210	0.597285	0.849904	0.735875	0.981601	0.072125
2003	1.081551	1,784	0.640135	1.039766	0.898614	1.20309	0.073046
2004	0.974075	1,664	0.671274	0.986405	0.855541	1.137285	0.071256
2005	0.86667	1,559	0.694676	0.895343	0.772231	1.038081	0.074063
2006	1.581477	1,550	0.791613	1.399341	1.237043	1.582932	0.061697
2007	2.346077	1,841	0.785986	2.02523	1.817331	2.256912	0.054197
2008	2.042096	1,700	0.808235	2.3359	2.095787	2.603523	0.054274

Figure 1. Coastal Logbook defined fishing areas.

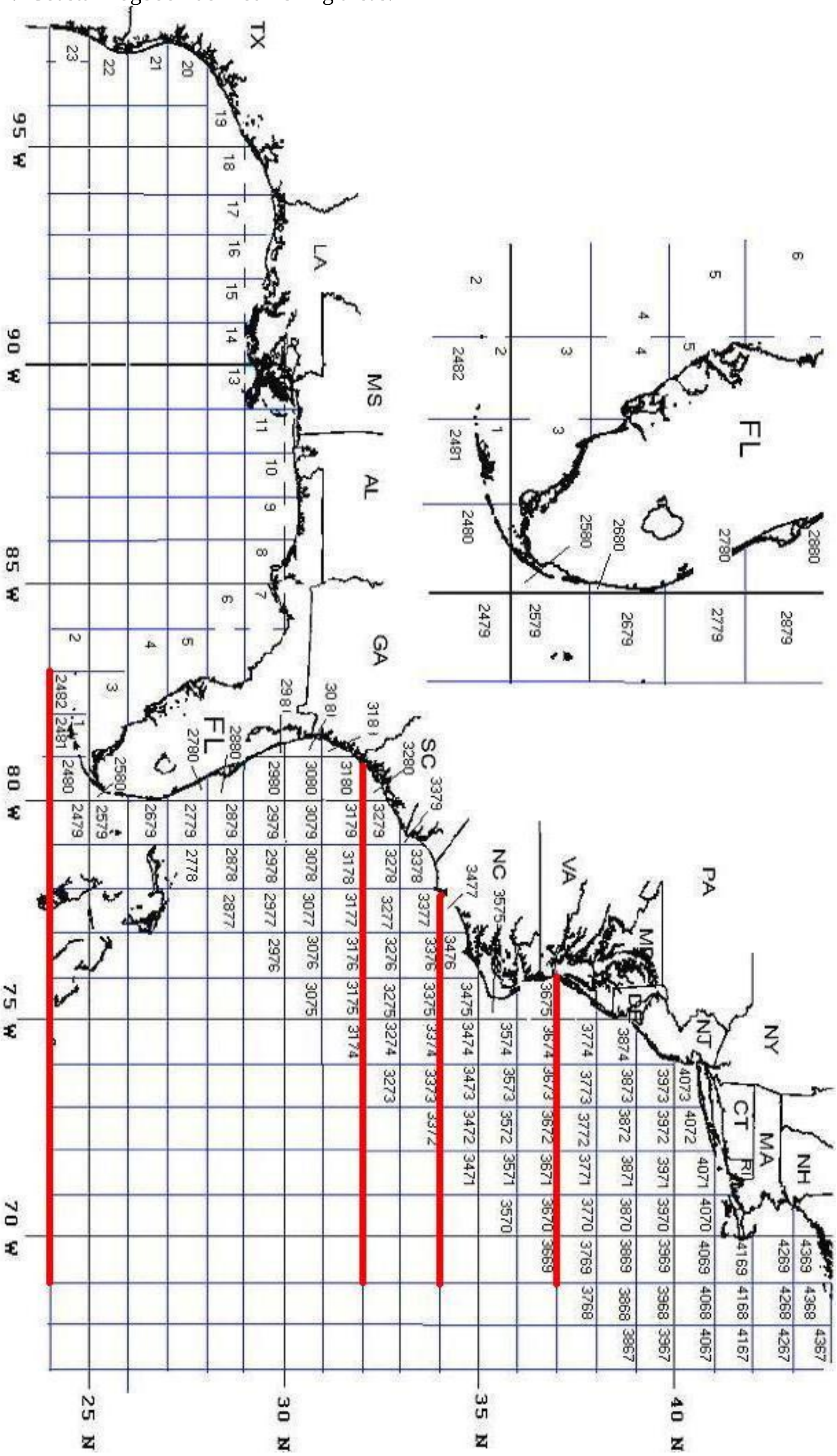


Figure 2. Red grouper nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing vertical line gear in the South Atlantic.

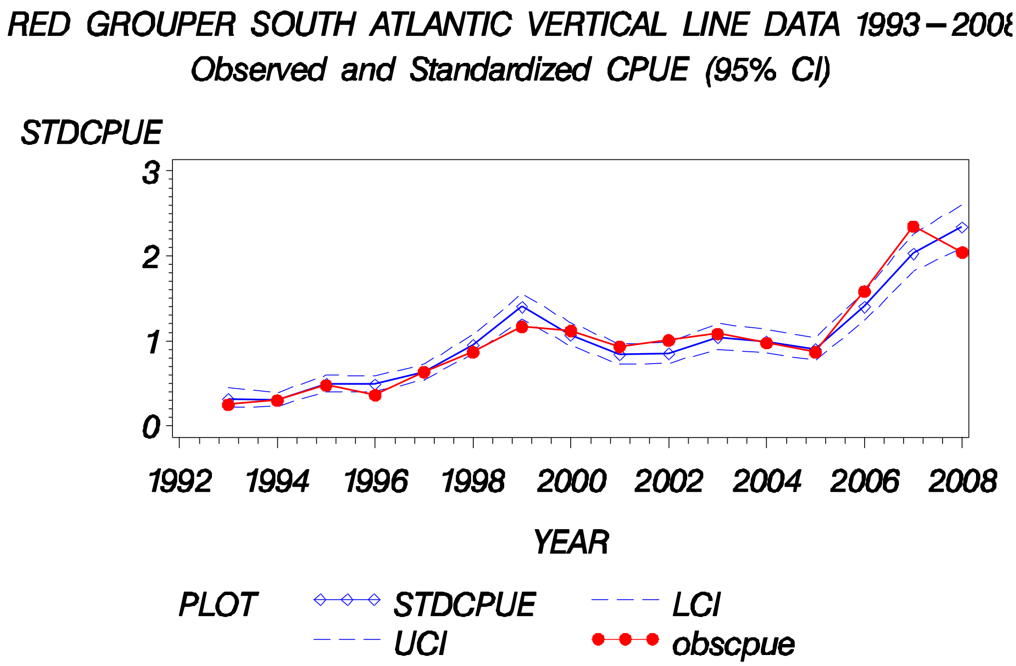
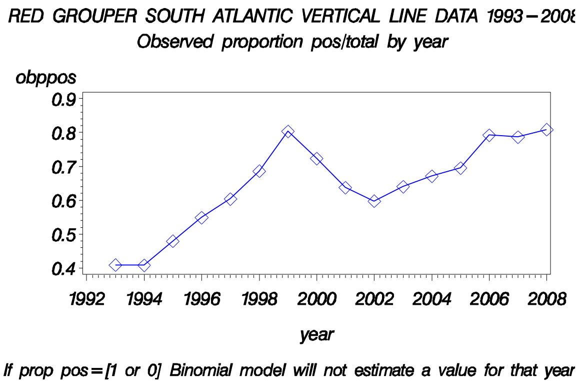


Figure 3. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE for the South Atlantic1993-2008 red grouper commercial vertical line gear model.

A.



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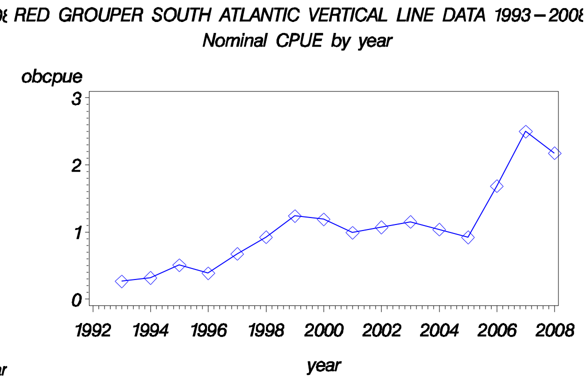
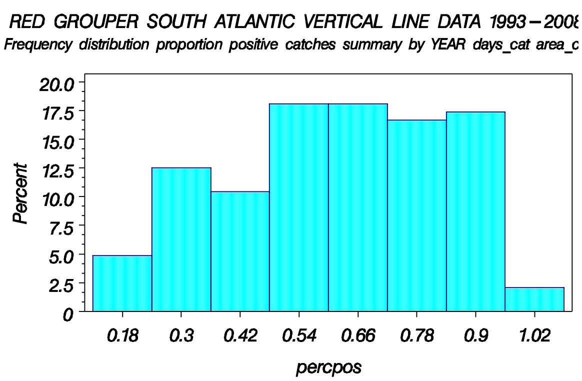


Figure 4. Diagnostic plots for the binomial component of the South Atlantic 1993-2008 red grouper commercial vertical line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by area (area_cat); and **D**. the Chi-Square residuals by days at sea (days_cat).

A.



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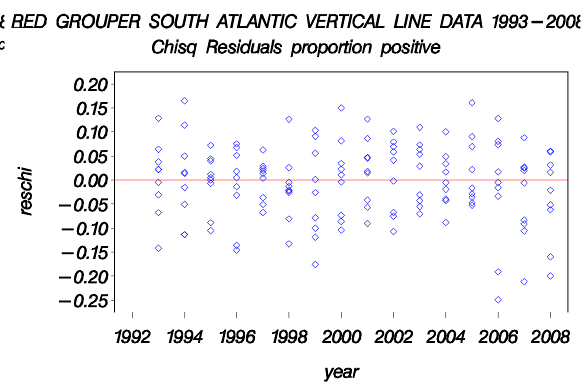
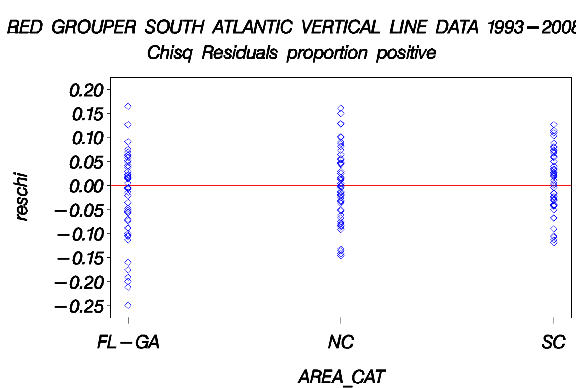


C.



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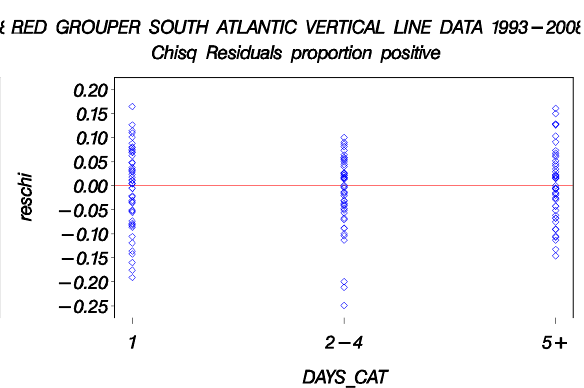
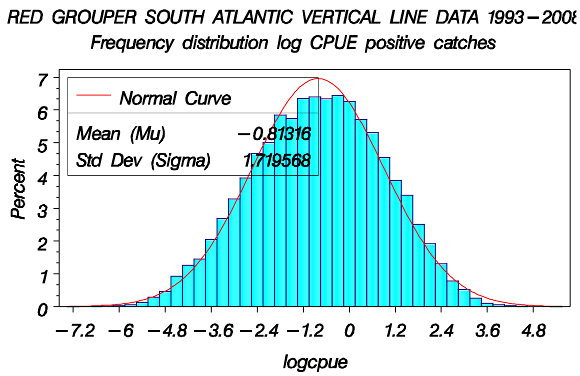


Figure 5. Diagnostic plots for the lognormal component of the South Atlantic 1993-2008 red grouper commercial vertical line gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



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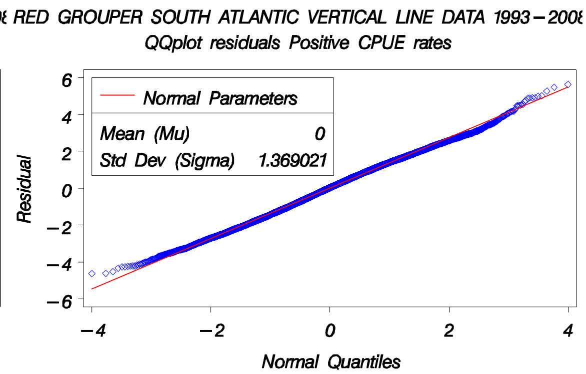
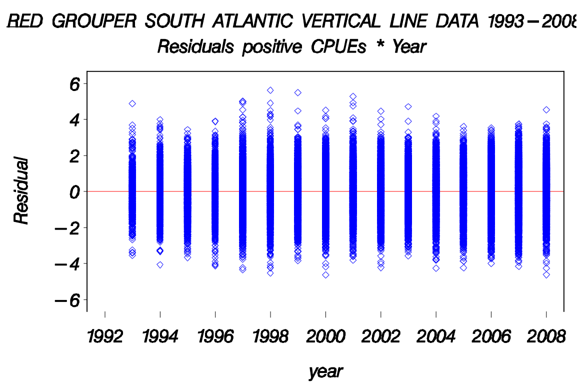


Figure 6. Diagnostic plots for the lognormal component of the South Atlantic 1993-2008 red grouper commercial vertical line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by days at sea (days_cat); **C**. the Chi-Square residuals by area (area_cat); and **D**. the Chi-Square residuals by number of crew (crew_cat).

A.



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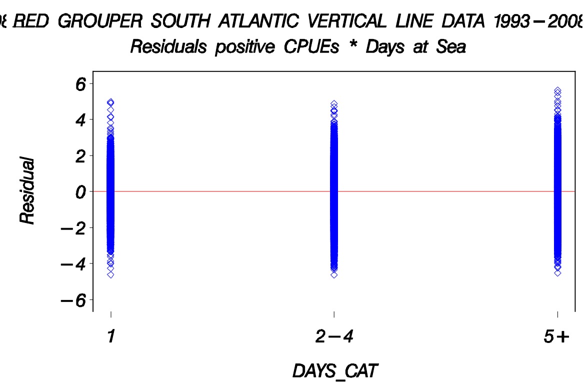

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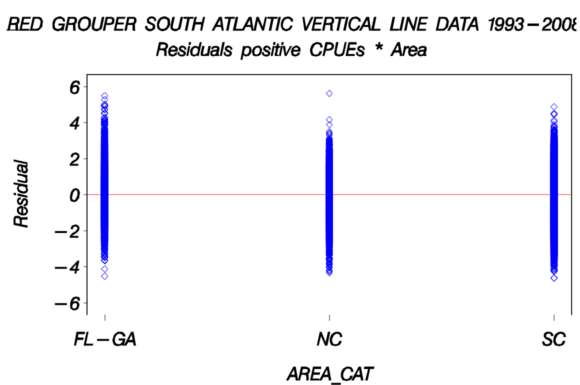

D.