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Introduction

Landings and fishing effort of commercial handline, trolling, 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 Council. The coastal logbook program began in 1992 in the US South Atlantic with the objective of a complete census of coastal fisheries permitted vessel activity. During the initial year, however, a 20% sample of vessels in Florida was selected to report with all vessels in other states required 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 standardized abundance indices for cobia. Indices were constructed using data reported from commercial handline and trolling and gillnet trips in the US South Atlantic. Cobia data were sufficient to construct indices of abundance including the years 1993-2010. Two indices were constructed using handline (including electric reels) combined with trolling data (hook and line): a delta-lognormal index including all South Atlantic hook and line data and a lognormal model including only data from positive cobia hook and line trips.

Methods

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 handline and trolling trips included number of lines fished, number of hooks per line, and time fished.

Several filters were applied to the data set. Trips missing the number of lines, number of hooks per line, hours fished, days at sea, schedule (trip identifier), or species landed were excluded. All trips with non-integer values of number of lines or number of hooks per line were removed from the data set. 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. Data from only those trips which reported one subregion (defined below) and one gear fished were included in the analyses. Handline and electric reel (bandit rig) data were combined and data from trips with both those gears reported were included in the analyses. Clear outliers in the data; i.e., values falling outside the 99.5 percentile of the data; were also excluded. In some cases (approximately 25 percent of all trips), lengthy delays (more than 45 days) in logbook reporting has been observed. Such data was presumed to be less reliable than the data contained in timelier logbook reporting. Data reported more than 45 days after the end of a fishing trip were excluded
.

A final data filtering step in the delta-lognormal analysis involved excluding trips that reported landings of tunas, sharks, or deep water grouper and tilefish. Very few trips that reported landings of those species also reported cobia landings. Exclusion of those trips increased the proportion of positive trips and more effectively subset the data set to trips that could have landed cobia.

Index Development

Lognormal index

CPUE was calculated as the weight of Cobia per hook hour fished. Only data from trips reporting cobia landings were included in the analysis. The data were limited spatially from the region north of 28°N to 37°N. Logbook reporting from fishing effort north of North Carolina was limited because fishing in that region was not reported to the CFLP.

Five factors were considered as possible influences on the catch rate of Cobia for the new index. In order to develop a well balanced sample design it was necessary to define categories within the factors examined:

Factor	Levels	Value
Year	18	1993-2010
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Subregion	2	Stat areas: 2800-<2900, 2900-,3700 see Figure 1
Gear (gear1)*	2	Handline (including electric reels), trolling
Crew (crew1)*	2	1, 2+ crew members

*Names in parentheses appear in some figures and tables.

Delta-lognormal index

CPUE was calculated as the weight of cobia per hook hour fished. All handline and trolling data, after filtering, were included in the delta-lognormal analysis. The data were limited spatially from the region north of 28°N to 37°N.

Five factors were considered as possible influences on the catch rate of cobia. 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	18	1993-2010
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Subregion	2	Stat areas: 2800-<2900, 2900-,3700 see Figure 1
Gear (gear1)*	2	Handline (including electric reels), trolling
Crew (crew1)*	2	1, 2+ crew members
Trip effort**	4	hook hours: <18.1; 18.1-31.5; 31.6-48; >48

*Names in parentheses appear in some figures and tables.
**Trip effort was included in the proportion positive analysis only

Statistical analyses

Lognormal index

Data from hook and line commercial fishing trips were used in lognormal models on catch rates of trips reporting cobia landings to construct standardized indices of abundance. Parameterization of the 2012 model was accomplished using a GLM procedure (GENMOD; Version 9.1 of the SAS System for Windows © 2002-03. SAS Institute Inc., Cary, NC, USA). The continuity index used the model developed for SEDAR 17.

For the analysis of catch rates, 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 the hook and line data was calculated as: log(CPUE)=ln(pounds of cobia/hook hour fished). All two-way interactions of significant main effects were examined for inclusion in the final 2012 model. Higher order interaction terms were not examined.

A forward stepwise regression procedure was used to determine the set of main effects 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 lognormal model was fit using a mixed model (PROC MIXED; Version 9.1 of the SAS System for Windows © 2002-03. SAS Institute Inc., Cary, NC, USA). To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean cpue of the series.

Delta-lognormal index

The delta lognormal model approach (Lo et al. 1992) was used to construct standardized indices of abundance from handline and trolling data. This method combines separate general linear model (GLM) analyses of the proportion of successful trips (trips that landed cobia) and the catch rates on successful trips to construct a single standardized CPUE index. Parameterization of the 2012 models was accomplished using a GLM analysis (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 longline data was calculated as: log(CPUE)=ln(pounds of cobia/hook hour fished). All two-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). To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean cpue of the series.

Results and Discussion

Lognormal index

The final model for the lognormal on CPUE of successful trips:

LOG(CPUE) = Year + Gear Fished + Quarter + Year*Quarter + Gear Fished*Year

The linear regression statistics for fixed effects and the analyses of the mixed model formulations of the final model are summarized in Table 1.

Relative nominal CPUE, number of trips, and the standardized abundance index are provided in Table 2. Yearly mean cpue ranged from 0.72 to 1.3. Coefficients of variation (CV) were low, ranging from 0.24-0.28 over the time series. Confidence intervals around the mean cpue were similarly narrow. The abundance index, along with 95% confidence intervals, is shown in Figure 2.

Plots of the nominal cpue, frequency distribution of log(CPUE), cumulative normalized residuals (Q-Q plot), and plots of Chi-square residuals by each main effect for lognormal models are shown in Figures 3-5. A few outliers among the data were identified in the Chi-square residual plots, however there were no clear patterns in the distribution of Chi-square residuals. In addition, the distribution of log(cpue) of positive catches approximated a normal distribution, therefore, the data appear appropriate for the analysis.

Delta-lognormal index

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

PPT = Year + Subregion + Gear Fished

LOG(CPUE) = Year + Gear Fished + Quarter + Year*Quarter + Gear Fished*Year

The linear regression statistics for fixed effects of the final models are summarized in Table 3. Year did not meet the inclusion criteria for the binomial model, however it was included in the final model.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 4. Yearly mean standardized cpue ranged from 0.62 to 2.2. The proportion of positive trips was very low (0.027-0.098). Coefficients of variation (CV) were highest during 1993-1997 and those higher CVs were likely due to smaller sample size (number of trips). The abundance index, along with 95% confidence intervals, is shown in Figure 6. Yearly mean cpue was variable, but without trend during much of the time series. During the final two years of the series, however, cpue was higher than during the earlier years.

Plots of the proportion positive, nominal cpue, frequency distribution of log(CPUE), cumulative normalized residuals (Q-Q plot), and plots of Chi-square residuals by each main effect for the binomial and lognormal models are shown in Figures 7-10. Although a few outliers among the data were identified in the Chi-square residual plots, there were no clear patterns in the distribution of Chi-square residuals. The distribution of log(cpue) of positive catches approximated a normal distribution, therefore, the data appear appropriate for the analysis.

Higher yearly mean cpues during 2009-2010 were calculated using the delta-lognormal method than were calculated in the lognormal only index. Those results may have been due to higher proportion positive trips during the final two years of the delta-lognormal time series. During the initial 16 years of both time series, cpue was variable but showed no trend. Results of these analyses should be used cautiously because of the very restrictive trip limits of the fishery (two cobia per person per day) and the often opportunistic fishing in the fishery. Those characteristics of the commercial cobia fishery made construction of an index of abundance from coastal logbook data problematic. The effort data in the coastal logbook data set was trip based and could not be accurately subdivided within an individual trip. If a trip limit was reached and targeting then changed to other species on the same trip, cobia-specific effort could not be properly apportioned making cobia cpue calculations less reliable.

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.

Table 1. Linear regression statistics for the catch rates on positive trips for cobia in the South Atlantic from vessels reporting handline and trolling landings. See text for factor (effect) definitions.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	17	17	0.56	0.8762
GEAR1	1	17	32.35	<.0001
quarter	3	51	11.33	<.0001

Table 2. Commercial cobia handline and trolling relative nominal CPUE, number of trips, and standardized abundance index in the South Atlantic lognormal index.

YEAR	Normalized Nominal CPUE	Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.925	49	0.906	0.518	1.583	0.285
1994	1.067	103	1.090	0.656	1.809	0.258
1995	0.991	59	0.812	0.471	1.399	0.278
1996	1.279	55	1.219	0.714	2.081	0.272
1997	1.100	73	0.962	0.578	1.602	0.259
1998	0.740	136	0.951	0.588	1.537	0.244
1999	0.888	130	0.907	0.561	1.468	0.244
2000	0.679	127	0.801	0.495	1.297	0.244
2001	0.628	155	0.716	0.445	1.154	0.242
2002	0.659	168	0.799	0.497	1.284	0.241
2003	0.863	146	0.951	0.590	1.533	0.242
2004	1.162	134	1.291	0.796	2.095	0.246
2005	1.245	138	1.167	0.722	1.886	0.244
2006	1.024	165	1.063	0.661	1.708	0.241
2007	1.278	166	1.111	0.690	1.788	0.241
2008	0.985	190	0.926	0.576	1.488	0.241
2009	1.060	300	1.083	0.678	1.730	0.237
2010	1.428	266	1.247	0.779	1.997	0.239

Table 3. Linear regression statistics for the GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) of cobia in the South Atlantic for vessels reporting handline and trolling landings during 1993-2010. 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	17	52	50.12	2.95	<.0001	0.0014
subregion	1	52	115.36	115.36	<.0001	<.0001
GEAR1	1	52	84.76	84.76	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	17	17	9.58	0.56	0.9202	0.8764
GEAR1	1	17	32.33	32.33	<.0001	<.0001
quarter	3	51	33.99	11.33	<.0001	<.0001

Table 4. Commercial cobia handline relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index in the South Atlantic lognormal index.

YEAR	Normalized Nominal CPUE	Trips	Proportion Positive	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.925	939	0.052	0.945	0.369	2.424	0.498
1994	1.067	1,823	0.057	1.302	0.603	2.815	0.400
1995	0.991	1,637	0.036	0.654	0.267	1.602	0.471
1996	1.279	1,220	0.045	1.208	0.491	2.971	0.474
1997	1.100	1,795	0.041	0.895	0.391	2.048	0.432
1998	0.740	4,512	0.030	0.624	0.307	1.269	0.366
1999	0.888	4,252	0.031	0.638	0.312	1.307	0.370
2000	0.679	4,647	0.027	0.487	0.237	1.001	0.372
2001	0.628	4,196	0.037	0.594	0.298	1.183	0.355
2002	0.659	3,889	0.043	0.731	0.371	1.441	0.349
2003	0.863	3,327	0.044	0.897	0.447	1.800	0.359
2004	1.162	3,048	0.044	1.268	0.622	2.584	0.368
2005	1.245	3,059	0.045	1.129	0.558	2.287	0.364
2006	1.024	3,285	0.050	1.110	0.562	2.189	0.350
2007	1.278	3,798	0.044	1.039	0.526	2.051	0.350
2008	0.985	4,003	0.047	0.874	0.449	1.700	0.342
2009	1.060	4,345	0.069	1.402	0.756	2.601	0.317
2010	1.428	2,728	0.098	2.201	1.173	4.131	0.323

Figure 1. Coastal Logbook defined fishing areas.

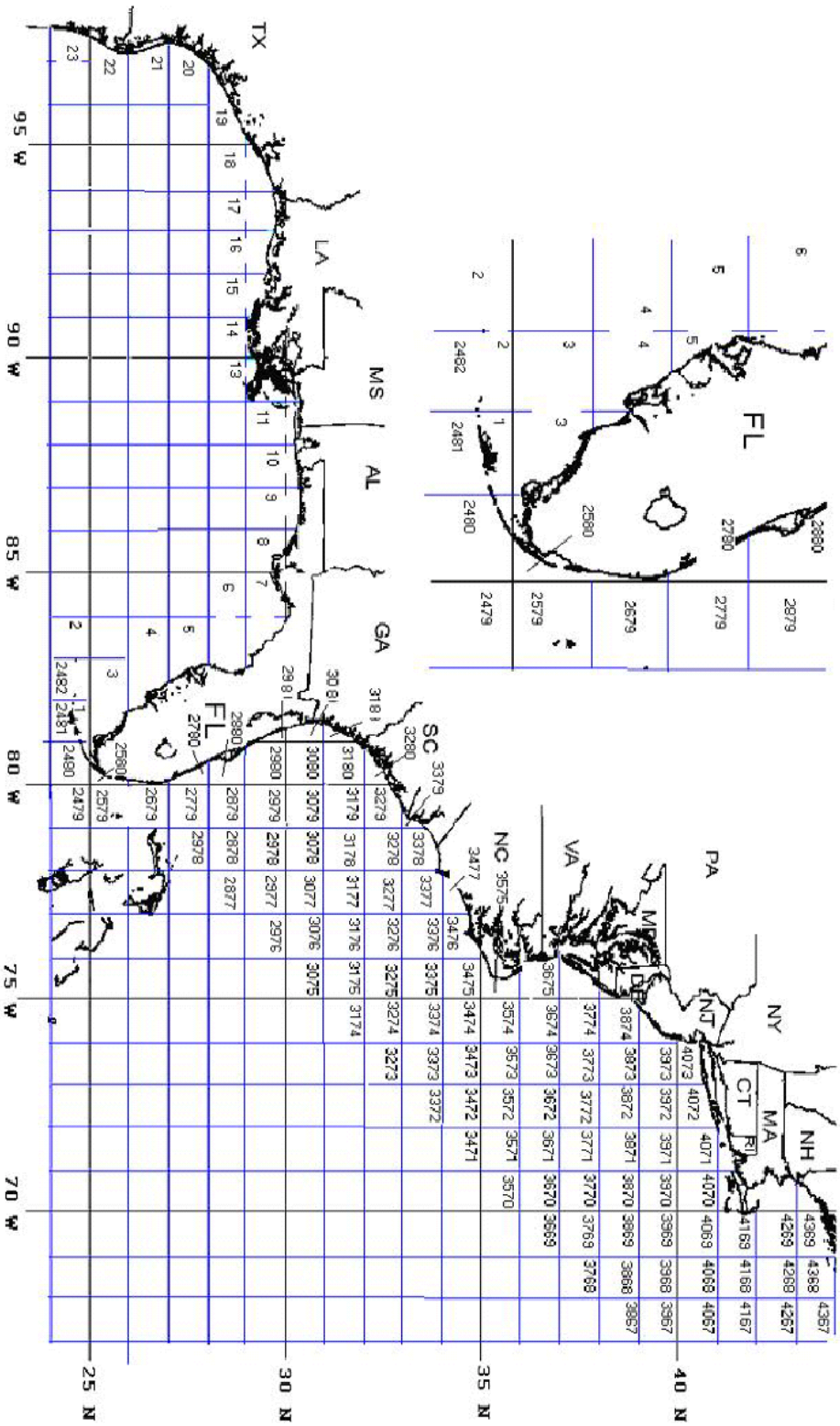


Figure 2. A. Cobia nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial handline and trolling fishing vessels in the South Atlantic lognormal index. CPUE = pounds cobia/hook hour fished.

A.

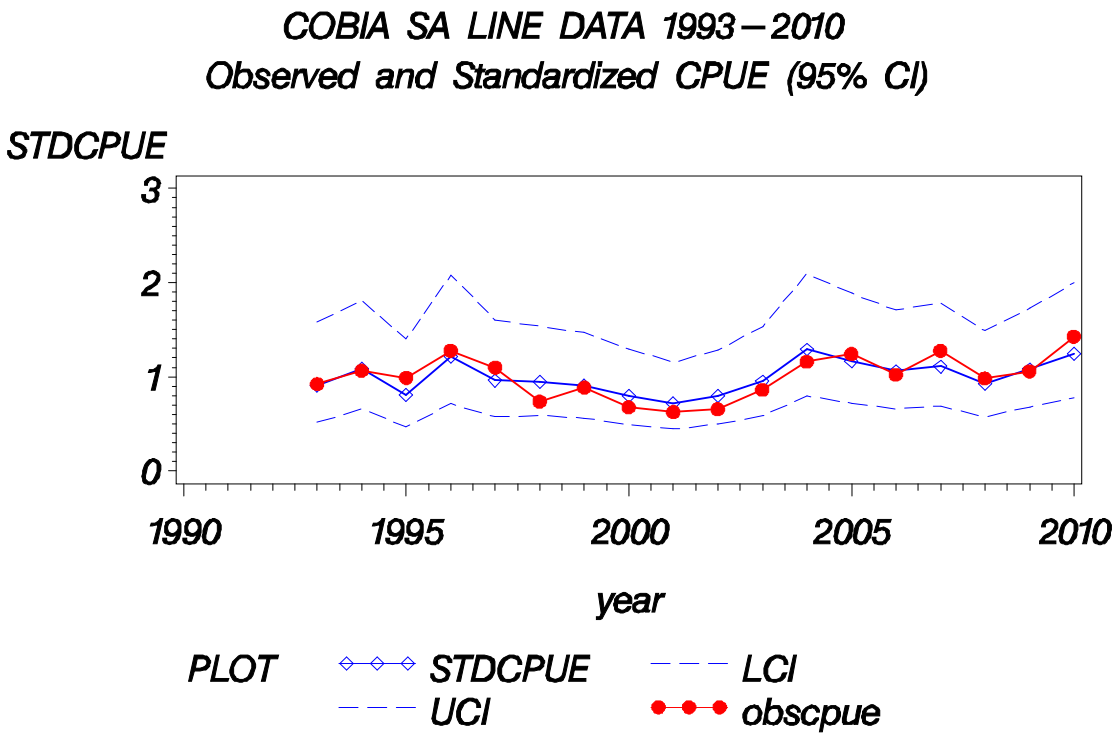


Figure 3. 1993-2010 time series annual trends in nominal CPUE (pounds/hook hour fished) of the South Atlantic cobia commercial handline and trolling data lognormal index.

A.

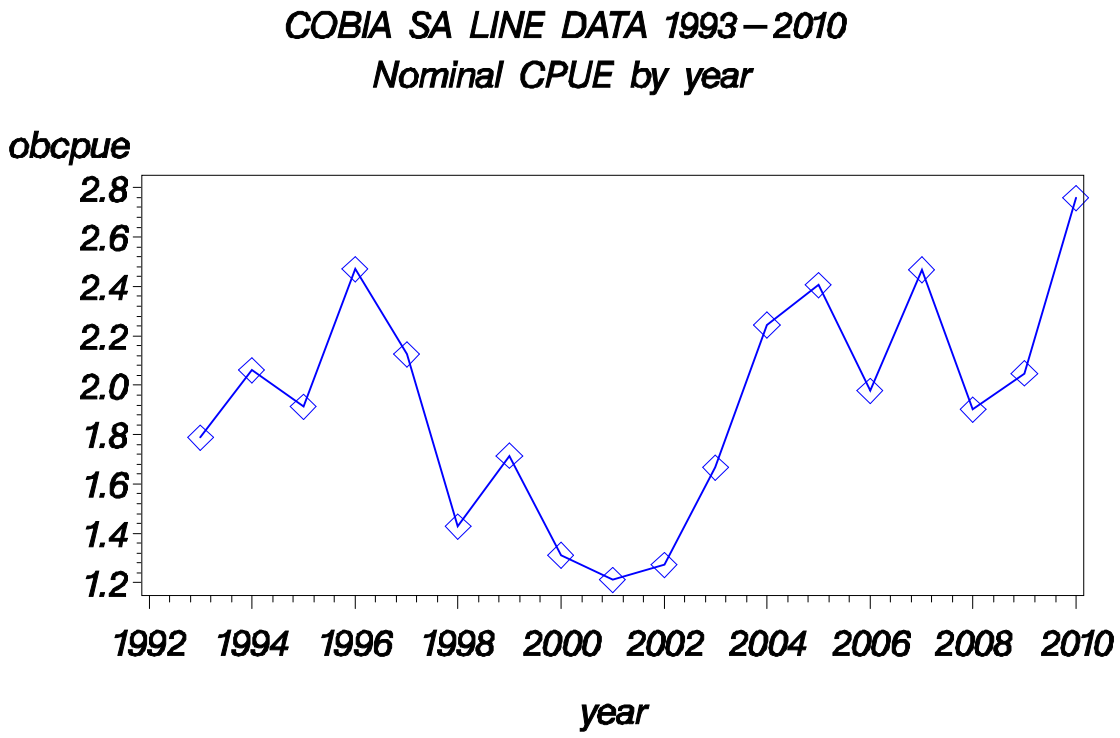


Figure 4. Diagnostic plots for the lognormal component of the South Atlantic 1993-2010 cobia commercial handline and trolling gear model (lognormal index): **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

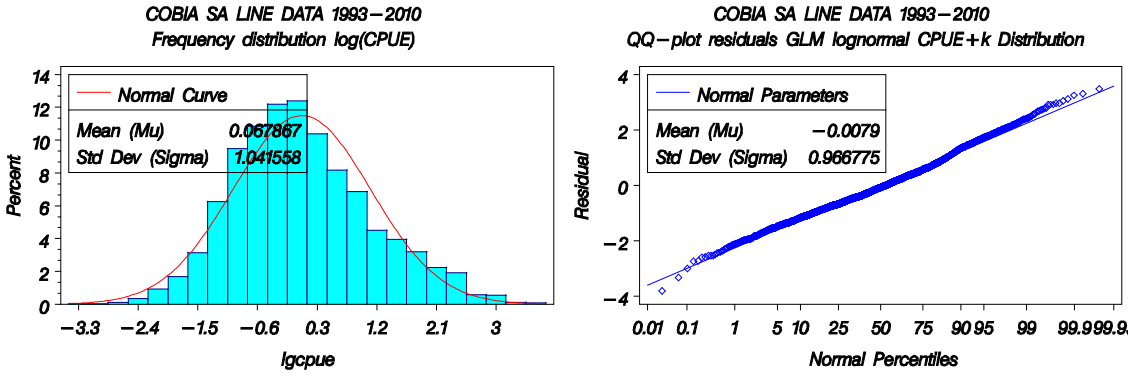
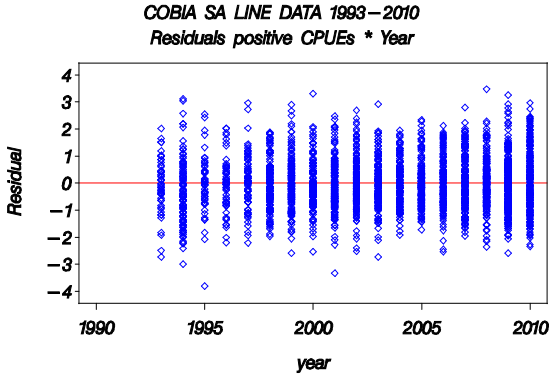
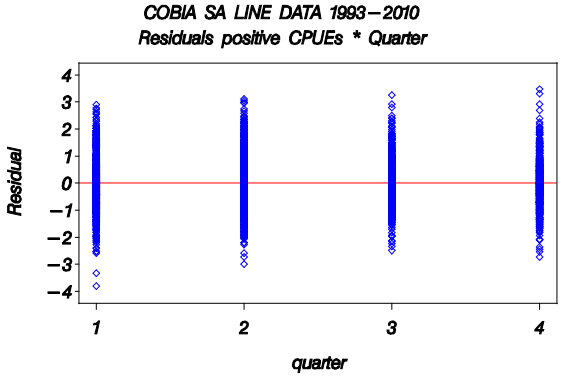


Figure 5. Diagnostic plots of the South Atlantic 1993-2010 cobia commercial handline and trolling lognormal model: **A**. the Chi-square residuals by year; **B**. the Chi-square residuals by quarter; and **C**. the Chi-square residuals by gear fished.

A.



B.



C.

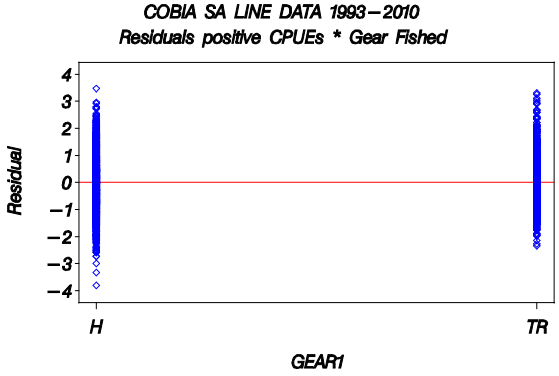


Figure 6. Cobia nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial gillnet fishing vessels in the South Atlantic (delta-lognormal index). CPUE = pounds cobia per hook hour fished.

A.

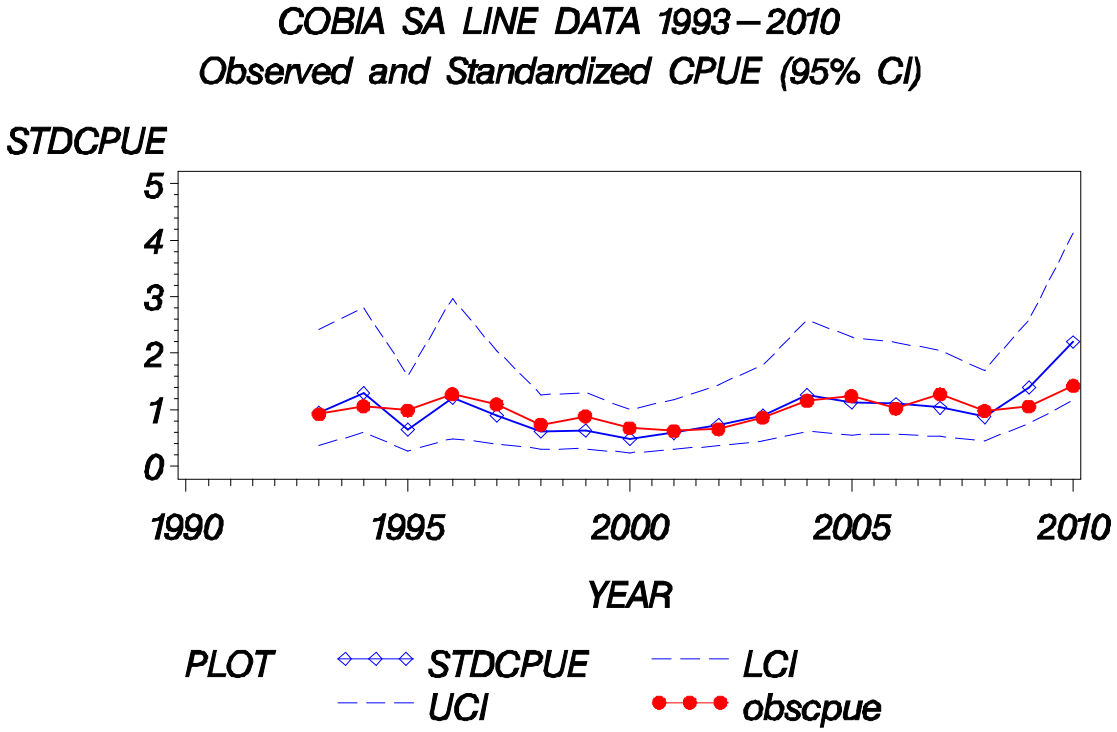
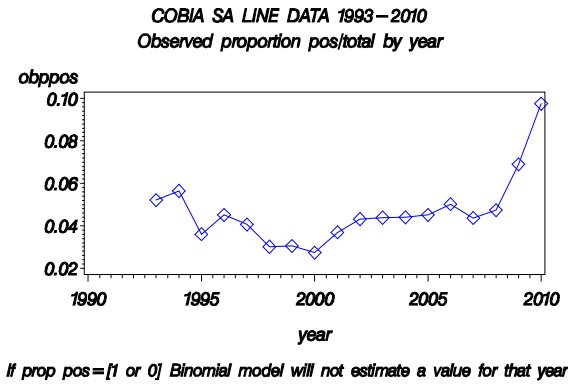


Figure 7. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE of the South Atlantic 1993-2010 commercial handline and trolling fishery (delta-lognormal index).

A.



B.

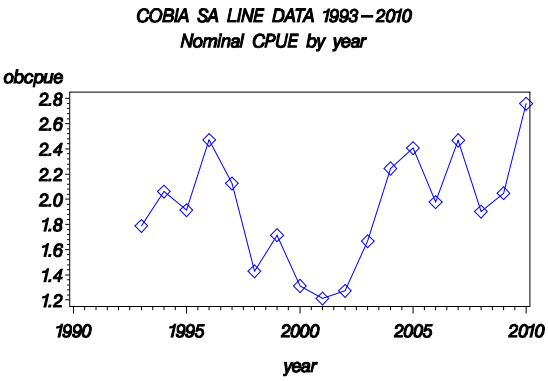
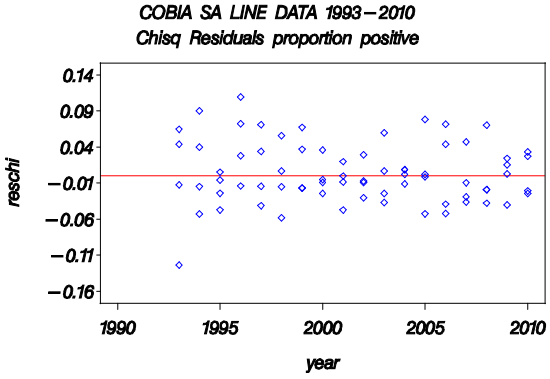
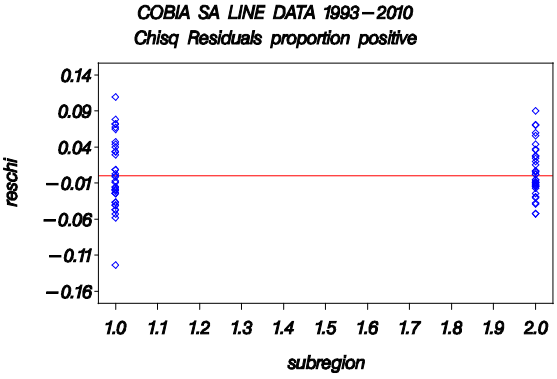


Figure 8. Diagnostic plots for the binomial component of the South Atlantic 1993-2010 commercial handline and trolling model (delta-lognormal index): **A**. the Chi-square residuals by year and **B**. the Chi-square residuals by subregion; and **C.** the Chi-square residuals by gear fished.

A.



B.



C.

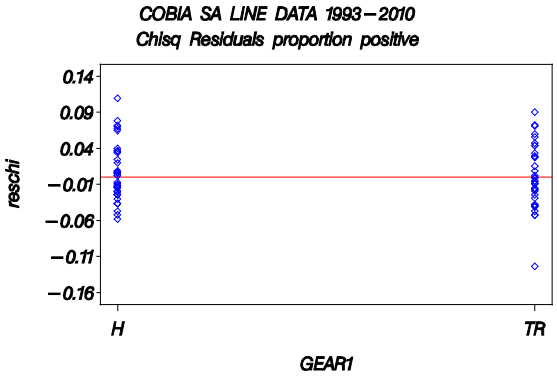
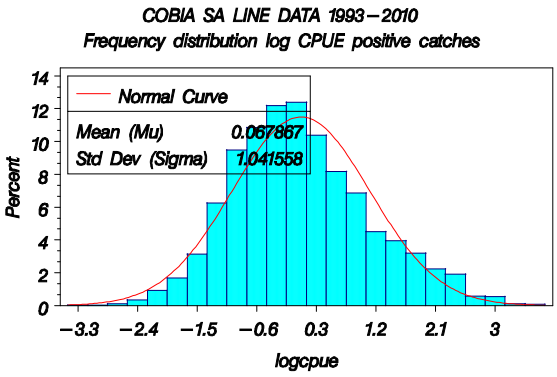


Figure 9. Diagnostic plots for the lognormal component of the South Atlantic 1993-2010 commercial handline and trolling model (delta-lognormal index): **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

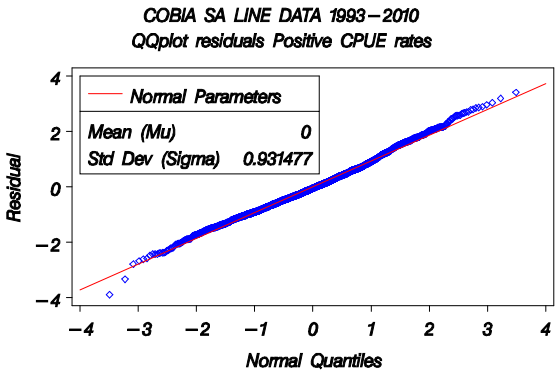
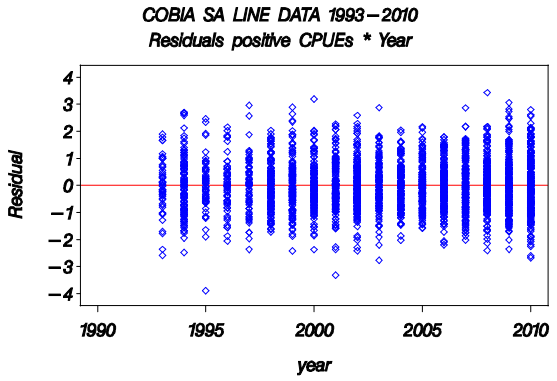
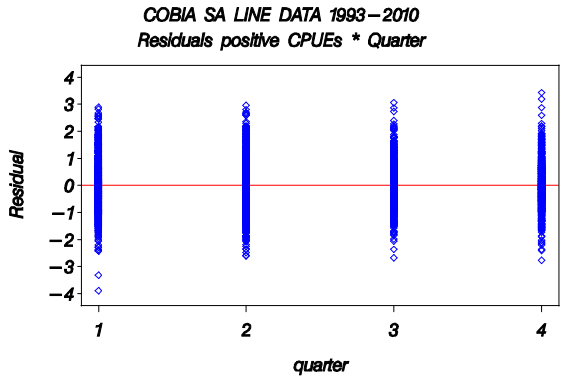


Figure 10. Diagnostic plots for the lognormal component of the South Atlantic 1993-2010 commercial handline and trolling model (delta-lognormal model): **A**. the Chi-square residuals by year; **B**. the Chi-square residuals by quarter; and **C**. the Chi-square residuals by gear fished.

A.



B.



C.