United States Commercial Vertical Line and Longline Vessel Standardized Catch Rates of Black Grouper the Gulf of Mexico and South Atlantic, 1993-2008

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Introduction

Handline, electric reel (bandit rig), and longline landings and fishing effort of commercial vessels operating in the Gulf of Mexico and 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 two abundance indices for black grouper. Separate indices were developed for vertical line gear (handline and electric reels) and for longline gear. Catch and effort data reported to the coastal logbook program were not required for vessels landing black grouper prior to 1992 in the South Atlantic. Given that only a 20% subsample of Florida vessels were reporting from 1990-1992, the time series used for construction of the commercial indices included the years 1993-2008.

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 vertical line gear included number of lines fished, hours fished, and number of hooks per line. Longline effort information included number of sets and number of hooks fished per 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; 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 77 percent of vertical line trips and 66 percent of longline 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.

Analyses were spatially limited by excluding all trips with landings reported from North Carolina. This was necessary due to species misreporting of gag grouper as black grouper (Muller, pers. comm.). Trip Interview Program (TIP) data included no black grouper in observed North Carolina landings, however gag grouper were observed. The longline analysis was limited to the Gulf of Mexico because over the 16 year time series fewer than 200 South Atlantic longline trips reported landings of black grouper.

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 25 lines fished, 50 hooks per line fished, or more than 24 hours fishing per day at sea. Longline data with more than 200 sets per trip, more than 4,500 hooks per set, fewer than 50 hooks per set, or longline lengths more than 10 miles were also excluded from the analyses.

Management measures, specifically closed seasons, required that additional data be excluded from the analyses. Construction of the vertical line index included trips regulated by both the Gulf of Mexico and South Atlantic Fishery Management Councils. Closed seasons did not coincide in the two regions. Shallow water grouper were closed to fishing in the Gulf of Mexico from February 15th and March 15th, but black grouper was closed to fishing during March and April in the South Atlantic. Reported trips made in both the Gulf of Mexico and South Atlantic during the period February 15th through April 30th were excluded from the analysis. In addition, the shallow water grouper fishery was closed in the Gulf of Mexico beginning November 15, 2004 through December 31, 2004 and again beginning October 10, 2005 through December 31, 2005 due to quota restrictions. All trips reporting landings, in either the Gulf of Mexico or South Atlantic, during those periods were excluded from the analysis. The longline analysis was limited to trips reported from the Gulf of Mexico, therefore data reported from February 15th and March 15th or during the 2004 and 2005 closures due to quota restrictions were excluded from the analysis.

A final data issue involved the misreporting of gag grouper as black grouper. This was particularly problematic in the Gulf of Mexico, as was noted in the SEDAR 10 gag grouper data workshop. Area specific corrections for misreporting in the Gulf of Mexico were made using the TIP gag:black grouper ratios reported by Chih and Turner (2006). Total pounds of reported black and gag grouper were summed for individual trips and the appropriate area specific gag:black ratio applied to calculate corrected landings for both species. If the calculated landings for either species was less than one pound, landings for that species for the trip were assumed to be zero. In cases where both species were reported for a trip, no misreporting was assumed and the reported landings were used in all analyses. Proper reporting was assumed in the South Atlantic, except when a trip reported landings in North Carolina, as noted above.

Black 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 black 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 black 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 black 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 black grouper occurring when the species was actually absent (false positives) while also minimizing incorrect predictions of black 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 black grouper/(number of lines fished*number of hooks per line*total hours fished)

Longline catch rate was calculated as weight of black grouper per hook fished (hours fished were not consistently reported for longline gear to the CFLP and could not be reliably included in the analysis):

CPUE = pounds of black grouper/(number of sets*number of hooks per set)

Five factors were considered as possible influences on vertical line proportion of trips that landed black grouper and on the catch rate of black grouper. Six factors were examined for their possible affect on longline

proportion positive trips and catch rate. In order to develop a well balanced sample design it was necessary to define categories within some of the factors examined:

Vertical Line

Factor	Levels	Value
Year	16	1993-2008
Month	10	Jan, Feb, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
Subregion	11	Statistical areas 1, 2, 3-4, 5, 6, 7, 8-21, 2479-2480, 2481-2482, 2500-3000, 3000-3700 see Figure 1.
Days at sea (DAYS)*	4	1, 2-3, 4-5, 6-7, 8+
Crew (CREW1)*	3	1, 2, 3+ crew members

Longline

Factor	Levels	Value
Year	16	1993-2008
Month	12	All months included except for closures
Subregion	10	Statistical areas 1-3, 4, 5, 6 see Figure 1.
Longline length (LENGTH1)*	6	le 3, >3-4, >4-5, >5-6, >6-7, >7-10
Days at sea (DAYS)*	2	1-7, 8-14, 15+
Crew (CREW1)*	2	1-2, 3, 4+ 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 black 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 black grouper/hook hour). Longline data response variable was calculated as: log(CPUE)=ln(pounds of black grouper/hooks fished). 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. Individual vessels were included as repeated measures terms. 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:

Vertical line 1993-2008:

PPT = Subregion + Days at Sea + Year

LOG(CPUE) = Subregion + Days at Sea + Crew Number + Year + Month + Subregion*Year + Subregion*Days at Sea + Subregion*Month

In the proportion positive analysis, year did not meet the criteria for inclusion in the final model, but was included in the final binomial portion of the model. No two-way interactions involving Year were tested for inclusion in the final binomial portion of the model. The linear regression statistics and analysis of the mixed model formulations of the final models are summarized in Table 1.

Longline 1993-2008:

PPT = Subregion + Year + Days at Sea

LOG(CPUE) = Subregion + Year + Length of Longline + Days at Sea

The linear regression statistics of the final GLM models are summarized in Table 2.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 3 for the vertical line model and in Table 4 for the longline model. The delta-lognormal abundance indices developed for each data set, with 95% confidence intervals, are shown in Figures 2 and 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 (vertical line) and Figures 8-11 (longline). 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, however, and the frequency distribution of log(CPUE) from the vertical line and longline data were somewhat skewed from the expected normal distribution. Those variations from the expected fit of the data were not sufficient to violate assumptions of the analyses. The observed proportion positive vertical line trips ranged from approximately 64 to 79% and were within the acceptable range required for the analysis. Longline proportion positive trips, though higher (73-92%) were also within the range appropriate for the analysis.

Black grouper standardized catch rates for vertical line vessels increased over the time series through 2006. Mean yearly CPUE almost doubled from 1993 to 2006, but decreased in 2007 and 2008. Coefficients of variation were generally consistent over the entire time series and were relatively low, particularly when compared to the CVs of the longline index. The black grouper longline index increased six-fold during the ten year from 1994 through 2004 then decreased over the final three years of the time series. Coefficients of variation of the longline index were high, however, ranging from two to ten times greater than the CVs of the

vertical line index. The 95% confidence intervals of the longline index were large and suggest that there may be no trend in mean yearly CPUE over the longline time series.

Literature Cited

Chih, CP. And S. Turner. 2006. Estimation of species misidentification in the commercial landing data of gag groupers and black groupers in the Gulf of Mexico. SEDAR10-DW-24. Pp. 16.

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 black grouper in the Gulf of Mexico and South Atlantic for vessels reporting vertical line gear landings 1993-2008. Analysis of the mixed model formulations of the positive trip model (**C**). 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	15	797	69.50	4.63	<.0001	<.0001
subregion	10	797	2063.21	206.32	<.0001	<.0001
days	4	797	204.88	51.22	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	15	150	138.25	9.22	<.0001	<.0001
subregion	10	150	3341.76	334.18	<.0001	<.0001
days	4	23E3	414.73	103.68	<.0001	<.0001
crew1	2	23E3	615.78	307.89	<.0001	<.0001
month	9	23E3	25.16	2.80	0.0028	0.0028
*subregion*days*	40	23E3	445.80	11.15	<.0001	<.0001
*subregion*month*	90	23E3	351.23	3.90	<.0001	<.0001

C.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Subregion + Days + Crew1 + Year + Month	78407.0	78409.0	78417.0	-	-
*Subregion + Days + Crew1 + Year + Month + Subregion*Year*	78075.9	78079.9	78086.2	331.1	<0.0001

Table 2. Linear regression statistics for the GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for black grouper in the Gulf of Mexico for vessels reporting longline 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	171	237.80	15.85	<.0001	<.0001
subregion	3	171	377.16	125.72	<.0001	<.0001
days	2	171	227.16	113.58	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	15	7119	810.39	54.03	<.0001	<.0001
subregion	3	7119	3200.52	1066.84	<.0001	<.0001
length1	5	7119	203.38	40.68	<.0001	<.0001
days	2	7119	114.58	57.29	<.0001	<.0001

Table 3. Vertical line relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for black grouper (1993-2008) in the Gulf of Mexico and South Atlantic.

YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	1.005205	1,549	0.706262	0.760265	0.584593	0.988727	0.131945
1994	0.937506	2,175	0.647816	0.753406	0.588052	0.965257	0.124372
1995	1.03721	1,881	0.681021	0.807998	0.631444	1.033918	0.123745
1996	1.163521	1,923	0.74207	0.830801	0.652144	1.058402	0.121507
1997	0.70797	2,647	0.697015	0.749053	0.586204	0.957143	0.123033
1998	0.779819	2,693	0.752692	0.970882	0.7647	1.232655	0.119787
1999	0.766768	2,375	0.784421	0.75778	0.589364	0.974323	0.126173
2000	0.858588	2,337	0.792897	0.821114	0.639876	1.053686	0.12518
2001	1.002164	2,571	0.793855	1.24974	0.984355	1.586674	0.119779
2002	0.966789	2,317	0.764782	1.150358	0.905669	1.461156	0.120006
2003	1.292723	2,224	0.727518	1.279496	1.003433	1.631509	0.12197
2004	1.304033	2,017	0.76946	1.348231	1.062721	1.710446	0.119403
2005	1.076439	1,819	0.778999	1.317928	1.037823	1.673633	0.119895
2006	1.152239	1,393	0.737976	1.381648	1.076979	1.772506	0.125043
2007	1.239348	1,136	0.682218	1.017537	0.787554	1.314682	0.128632
2008	0.709679	1,101	0.642144	0.803761	0.604597	1.068533	0.143094

Table 4. Longline relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for black grouper (1993-2008) in the Gulf of Mexico.

Year	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.263172	382	0.837696	0.389993	0.06256	2.43118	1.144533
1994	0.293037	462	0.727273	0.304463	0.037176	2.493504	1.42157
1995	0.460769	295	0.738983	0.402581	0.046863	3.458447	1.475914
1996	0.455659	403	0.801489	0.454841	0.0834	2.480589	1.026217
1997	0.884469	619	0.739903	0.459357	0.091212	2.313402	0.960229
1998	1.124559	578	0.875433	0.753783	0.259771	2.18727	0.572764
1999	1.221014	596	0.901007	0.832058	0.315092	2.197198	0.515587
2000	1.483386	498	0.901606	1.061633	0.446348	2.525084	0.454379
2001	1.462713	584	0.917808	1.406196	0.720808	2.743294	0.343682
2002	1.408771	517	0.905222	1.580777	0.826448	3.023607	0.332981
2003	1.059397	630	0.907937	1.836644	1.026655	3.285683	0.297076
2004	1.986202	636	0.900943	1.868794	1.08469	3.219713	0.277109
2005	1.491005	591	0.886633	1.802807	1.039227	3.127432	0.280741
2006	1.046025	656	0.829268	1.106723	0.472748	2.590884	0.445274
2007	0.983704	460	0.854348	1.04919	0.353905	3.110436	0.58606
2008	0.376118	498	0.779116	0.69016	0.177923	2.67711	0.763618

Figure 1. Coastal Logbook defined fishing areas.

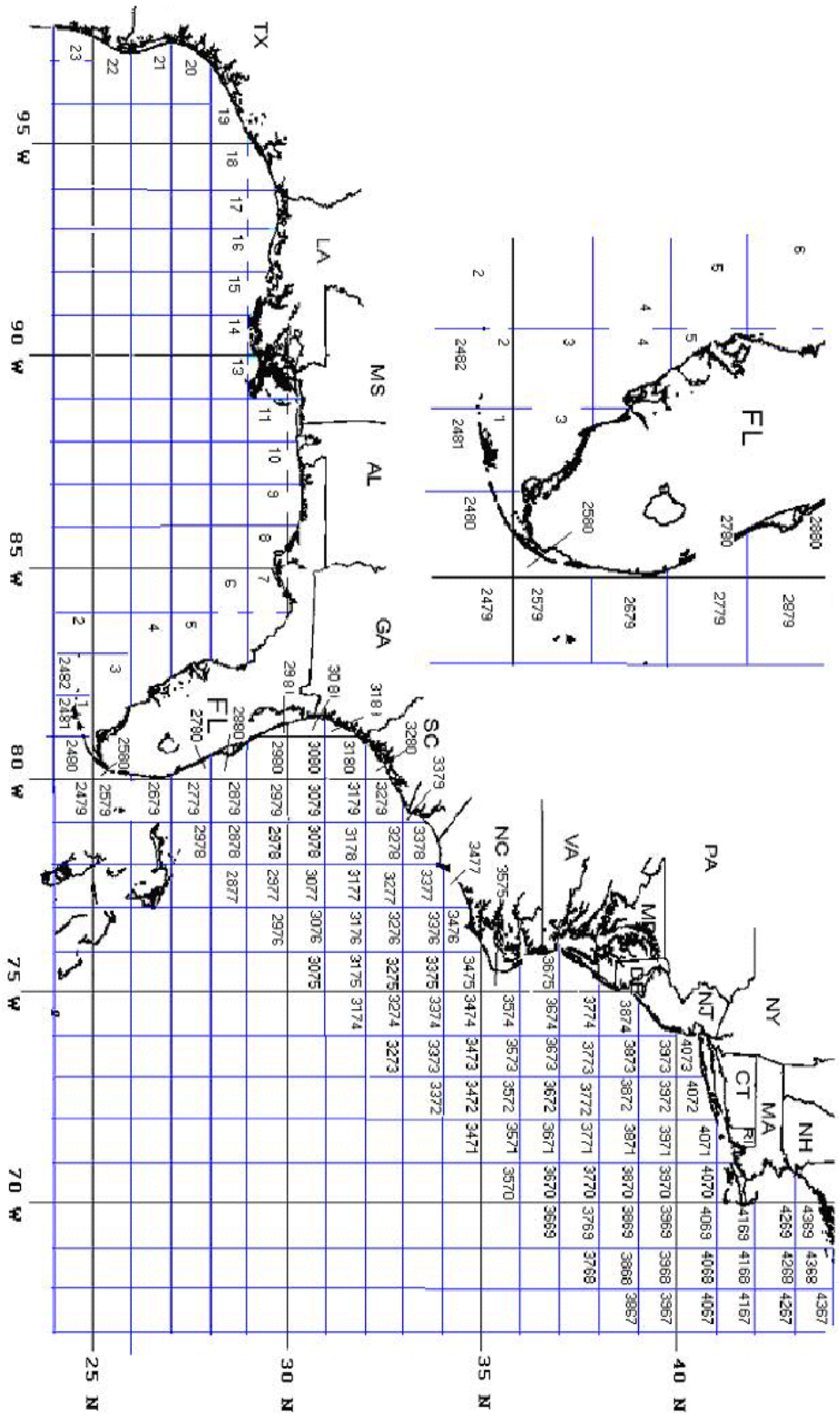


Figure 2. Black grouper nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing vertical line gear in the Gulf of Mexico and South Atlantic.

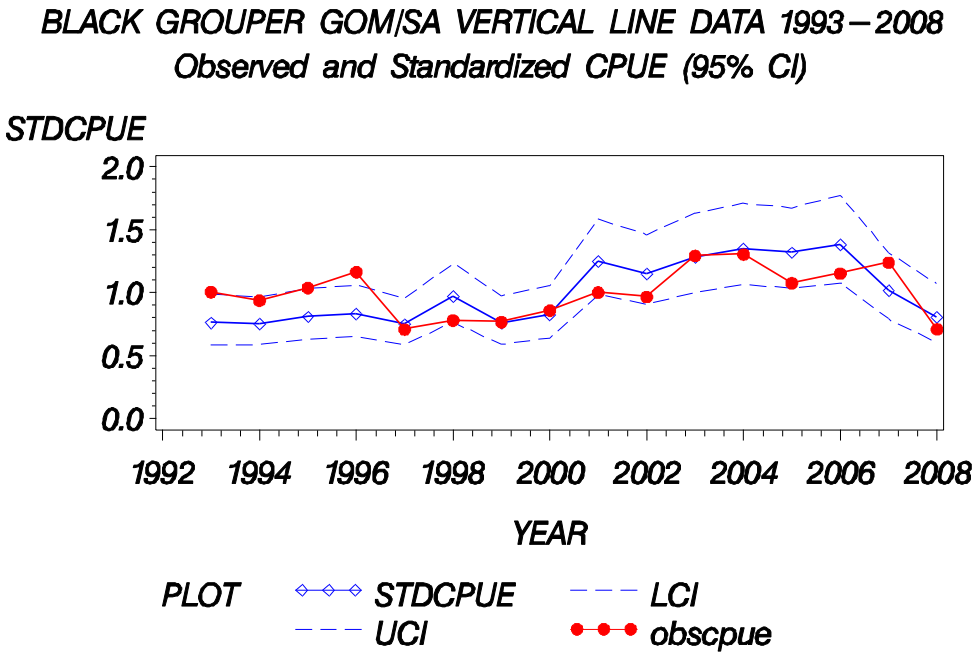


Figure 3. Black grouper nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing longline gear in the Gulf of Mexico.

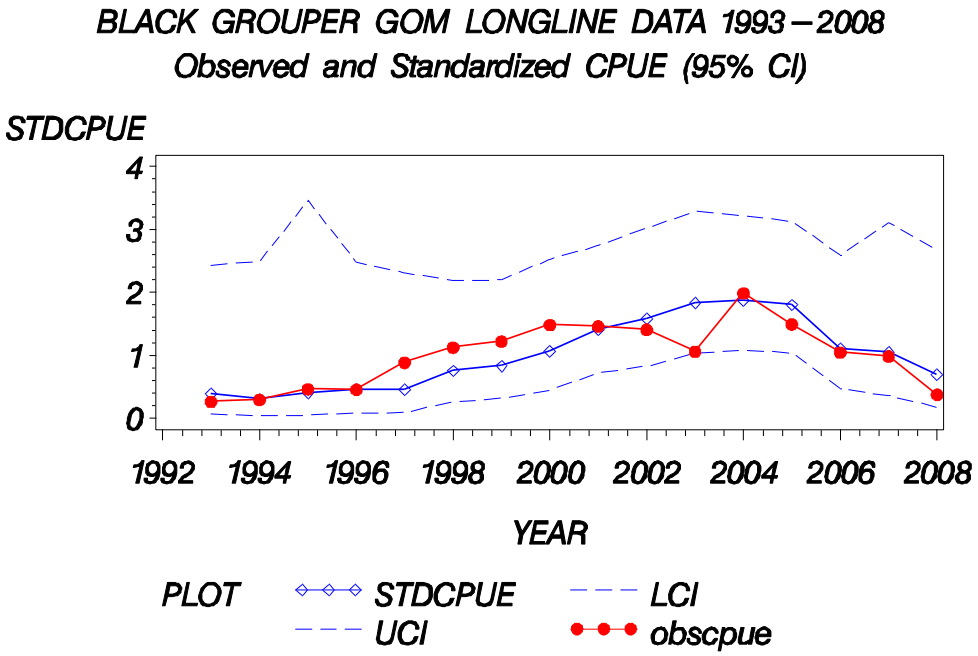
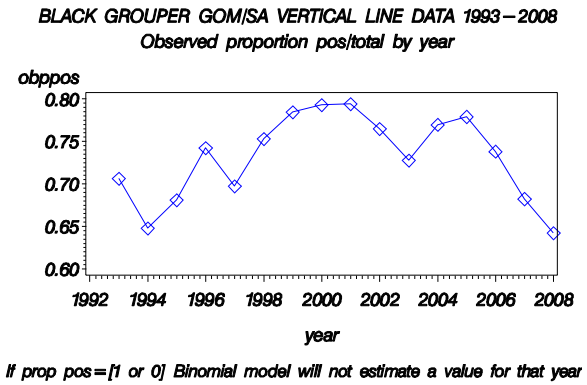


Figure 4. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE for the Gulf of Mexico and South Atlantic1993-2008 black grouper commercial vertical line gear model.

A.



B.

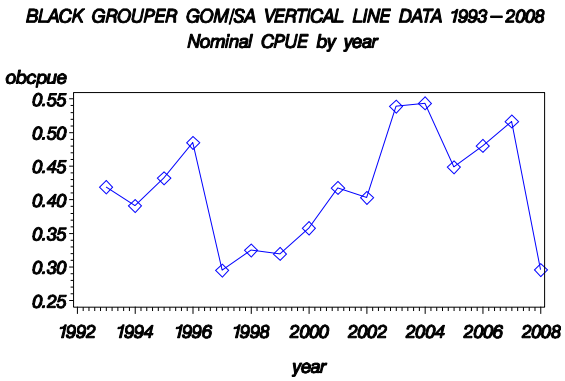
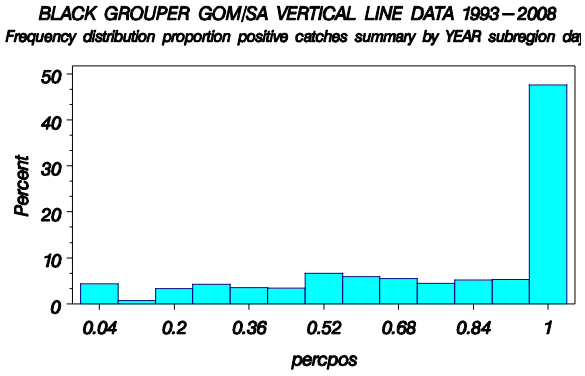
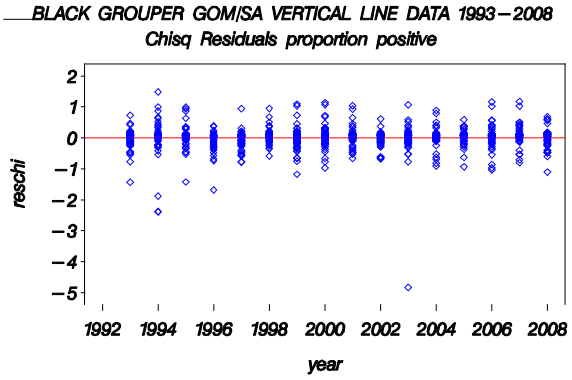


Figure 5. Diagnostic plots for the binomial component of the Gulf of Mexico and South Atlantic 1993-2008 black grouper commercial vertical line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by subregion (subregions 2 and 3 appear on the x-axis but did not exist in the analyses); and **D**. the Chi-Square residuals by days at sea.

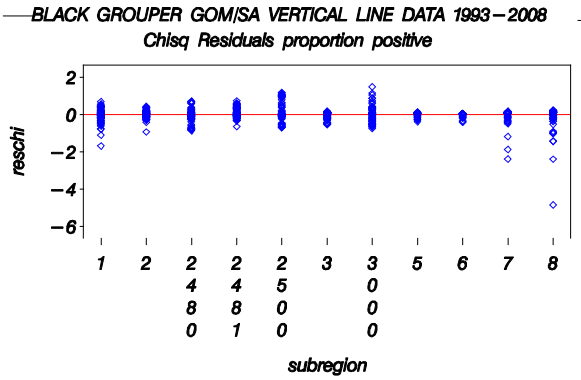
A.



B.



C.



D.

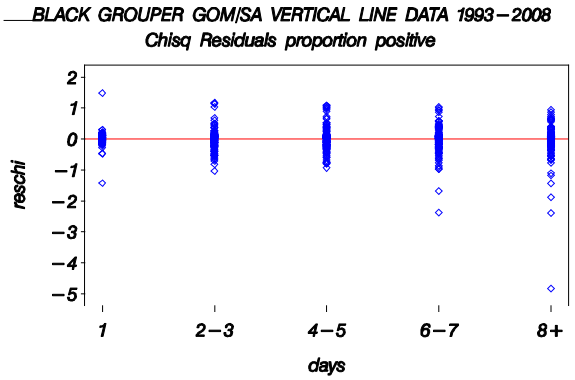


Figure 6. Diagnostic plots for the lognormal component of the Gulf of Mexico and South Atlantic 1993-2008 black grouper commercial vertical line gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

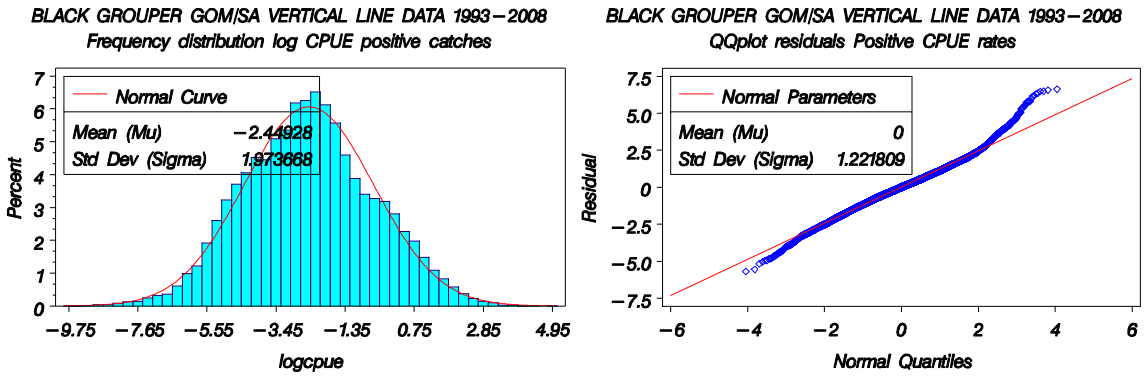
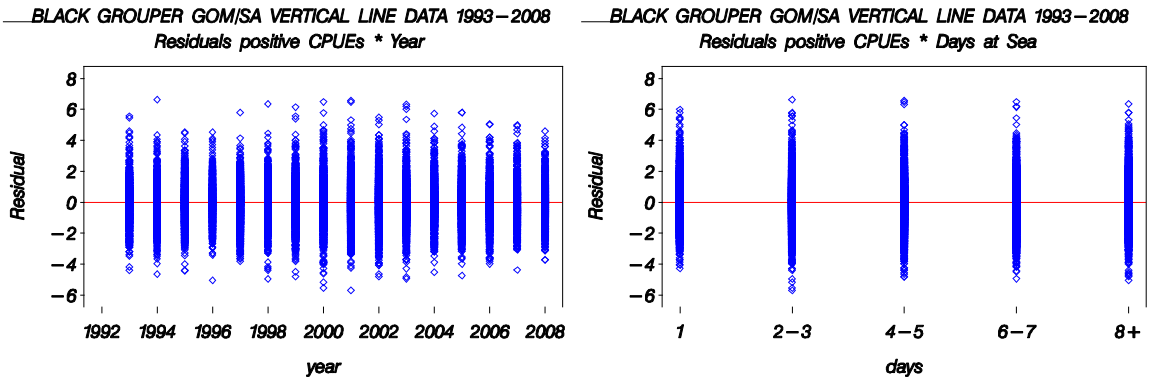


Figure 7. Diagnostic plots for the lognormal component of the Gulf of Mexico and South Atlantic 1993-2008 black grouper commercial vertical line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by days at sea; **C**. the Chi-Square residuals by subregion; and **D**. the Chi-Square residuals by number of crew (crew1).

A. **B.**



C. **D.**

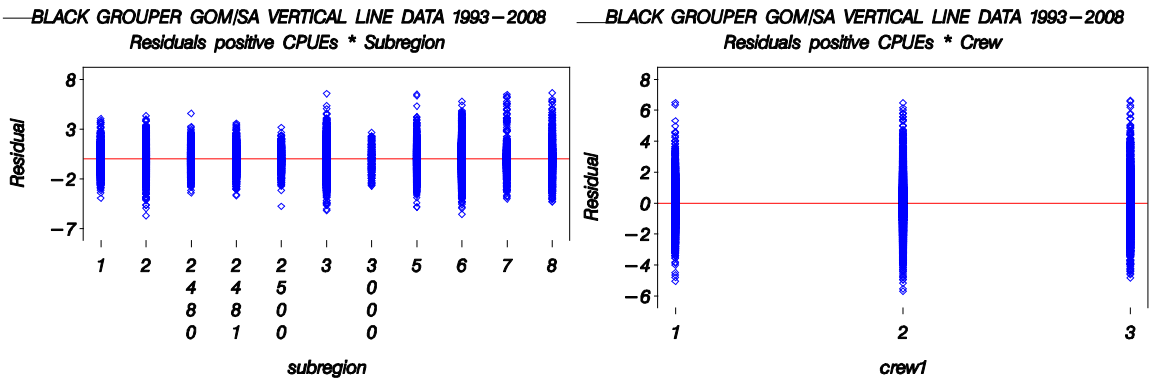


Figure 7 (continued). Diagnostic plots for the lognormal component of the Gulf of Mexico and South Atlantic 1993-2008 black grouper commercial vertical line gear model: **E**. the Chi-Square residuals by month. Periods with closed black grouper season (e.g. March-April) were excluded from the analysis.

E.

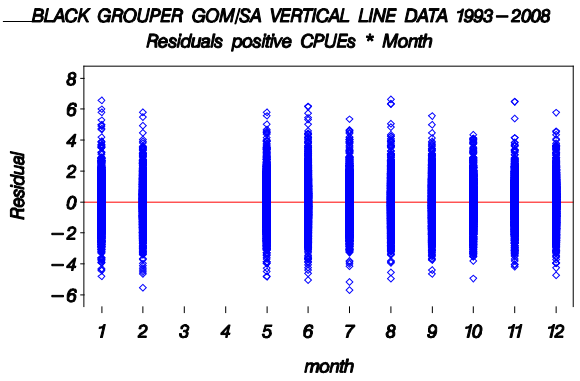
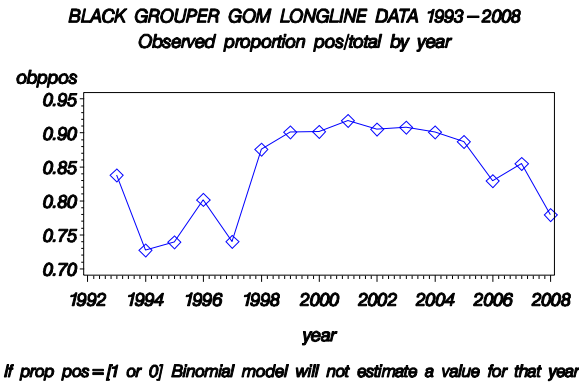


Figure 8. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE for the Gulf of Mexico 1993-2008 black grouper commercial longline gear model.

A.



B.

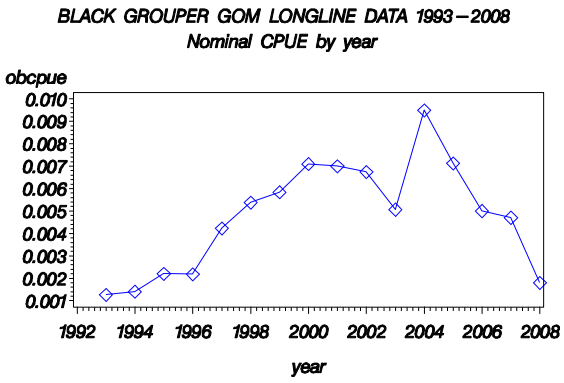
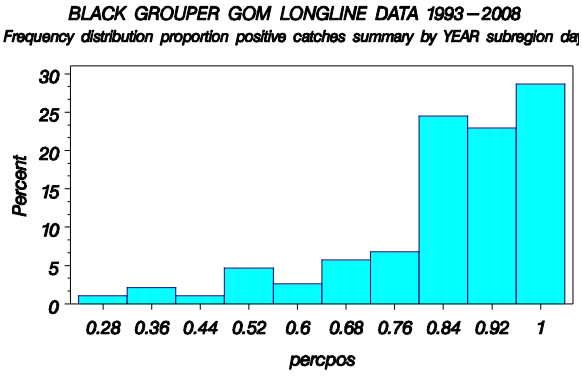
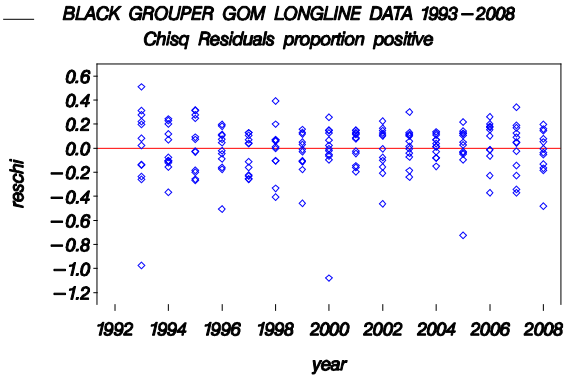


Figure 9. Diagnostic plots for the binomial component of the Gulf of Mexico 1993-2008 black grouper commercial longline gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by subregion (subregions 2 and 3 appear on the x-axis but did not exist in the analyses); and **D**. the Chi-Square residuals by days at sea.

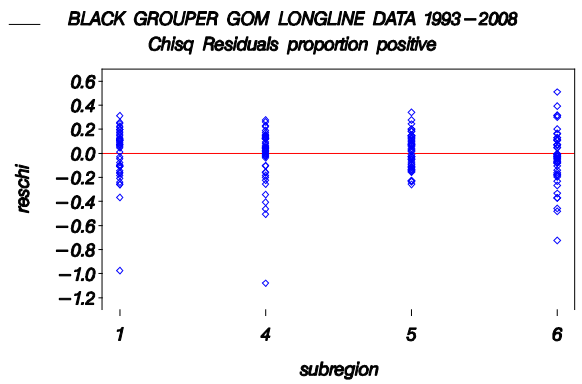
A.



B.



C.



D.

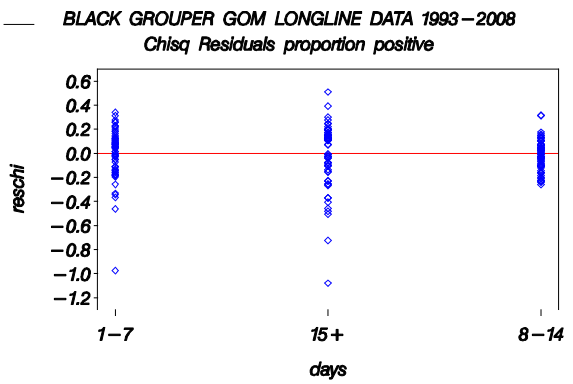


Figure 10. Diagnostic plots for the lognormal component of the Gulf of Mexico 1993-2008 black grouper commercial longline gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

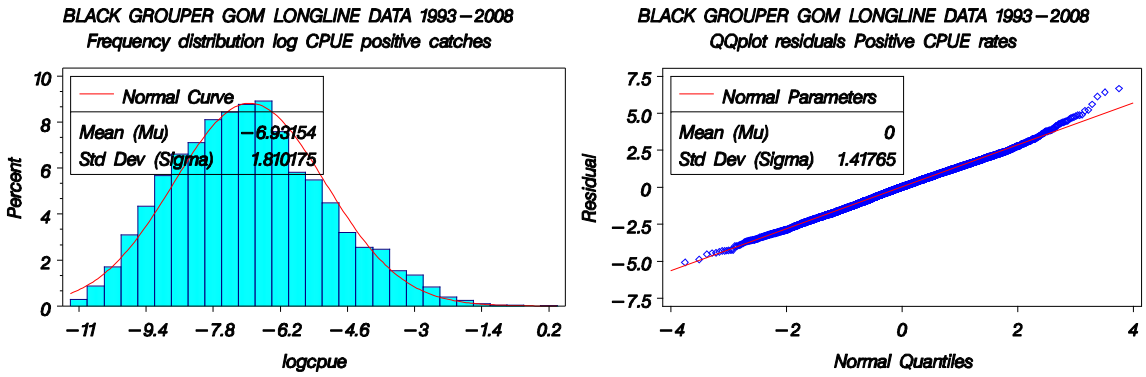
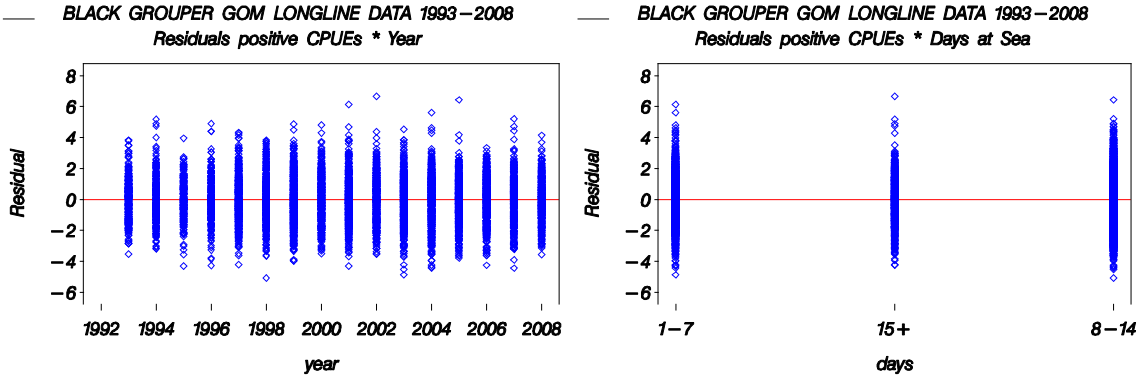


Figure 11. Diagnostic plots for the lognormal component of the Gulf of Mexico 1993-2008 black grouper commercial longline gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by days at sea; **C**. the Chi-Square residuals by subregion; and **D**. the Chi-Square residuals by longline length (length1).

A. **B.**



C. **D.**