Commercial Vertical Line Vessel Standardized Catch Rates of Black Sea Bass in the US South Atlantic, 1993-2010

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Introduction

Handline, electric and hydraulic 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 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 Gulf of Mexico and South Atlantic Fishery Management Councils. 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, however in Florida a 20% sample of vessels was selected to report. Beginning in 1993, reporting in Florida was increased to include all vessels permitted for federally managed coastal fisheries.

The CFLP available catch per unit effort (CPUE) data were used to construct a standardized abundance index for black sea bass. The index was constructed using data reported from commercial vertical line (handline and bandit rig) trips in the US South Atlantic. Black sea bass data were sufficient to construct an index of abundance including the years 1993-2010.

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, number of hooks fished per line, and hours fished. Multiple areas fished and multiple gears fished may be recorded for a single fishing trip. In such cases, assigning catch and effort to specific locations or gears was not possible; therefore, only trips which reported one area (i.e., subregion, as defined below) and one gear fished (vertical line) were included in these analyses.

Data were further restricted to include only those trips with landings and effort data reported within 45 days of the completion of the trip. Reporting delays beyond 45 days (some reporting delays were longer than one year) likely resulted in less reliable effort data. Landings data, however, may have been 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 excluded from the analyses. These included vertical line data from trips reporting fishing more than 24 hours per day, more than eight hooks per line, or more than six lines fished. Data from trips with reported crews of more than five or trips of more than 10 days at sea were also excluded from the analyses. Approximately 70 percent of vertical line trips were retained for analyses following all data filtering.

Management measures, specifically closed seasons, required that additional data be excluded from the analyses. Closed seasons occurred during 2009 and 2010 due to quota restrictions and data reported during closed seasons were excluded from the analyses. Closures were particularly lengthy during 2010 when the commercial fishery was open during June-October 7th and again from December 1-15.

The minimum size of black sea bass for commercial harvest was eight inches total length from 1982-1998. Beginning in 1999 the minimum size was increased to 10 inches total length. Three indices of abundance were constructed to examine any effect the minimum size change may have had on cpue calculated using commercial landings data. The three indices included data from 1) only those years of available data prior to the size change (1993-1998), 2) those years following the size change (1999-2010), and 3) spanning the size change by including all years of available data (1993-2010).

Black sea bass 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 presumptive black sea bass 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 sea bass 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 sea bass. 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 sea bass occurring when the species was actually absent (false positives) while also minimizing incorrect predictions of black sea bass absence when the species was actually present (false negatives). Separate Stephens and MacCall analyses were used to identify trips targeting black sea bass for each of the constructed indices. Figures 2-4 provide species-specific regression coefficients from each analysis. The magnitude of the coefficients indicates the predictive impact of each species. Patterns were similar among all three analyses.

Index Development

Vertical line catch rate was calculated as weight of black sea bass per hook hour fished:

CPUE = pounds of black sea bass/(number of lines fished*number of hooks/line*hours fished)

Five factors were considered as possible influences on the proportion of trips that landed black sea bass and on the catch rate of black sea bass. An additional factor, number of hooks fished, was examined for its affect on the proportion of positive trips. Spatially, the analyses were limited to the area between 26^{o}N and 36^{o}N due to very low sample size farther south and regulatory boundary at Cape Hatteras. 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 (6 and12)	1993-2010 or split 1993-98 and 1999-2010
Season	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Subregion	4	Stat areas 2679-3181, 3275-3280, 3374-3379, 3470-3576 see Figure 1
Days at sea (seadays)*	3	1, 2- 3, 4-9 days
Crew (crew1)*	2	1-2, 3-5 crew members
Hooks hours fished (hkhours)*[1]	N/A	Continuous

* Names in parentheses appear in some figures and tables.
[1] Hooks fished was examined only for the proportion positive analyses.

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 sea bass) and the catch rates on successful trips to construct a single standardized CPUE index. Parameterization of each model 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 vertical line data was calculated as: log(CPUE)=ln(pounds of black sea bass/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 ≥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 models were 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

Models for each of the three indices differed slightly. The final model of the 1993-2010 time series for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips for each species were:

PPT = Subregion + Year + Days at Sea

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

Final models for the 1993-1998 time series were:

PPT = Subregion + Days at Sea + Year

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

*Year was not a significant effect, but was included in the final model; no two-way interactions including year were tested.

Final models for the 1999-2010 time series were:

PPT = Subregion + Year

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

The linear regression statistics for fixed effects and the analyses of the mixed model formulations of the final models are summarized in Tables 1-3 for the three indices.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Tables 4-6 for each of the black sea bass analyses. Differences in yearly sample sizes between the 1993-2010 index and the shorter indices were due to slightly different targeting identified during the separate Stephens and MacCall analyses. Yearly mean cpue in the 1993-2010 index ranged from 0.55 to 2.52 (in 2010). Coefficients of variation (CV) for the 1993-2010 index ranged from 0.206-0.238 and were typically larger during the final years of the time series. Similarly, confidence intervals around the mean cpue were highest for 2010. The 1993-1998 index had very low CVs (<0.1) and narrow confidence intervals. The 1999-2010 index had CVs ranging from 0.09-0.13 with the highest CV in 2010. The smallest sample sizes were from the years 2009-10 due to fishery closures and may have contributed to the greater variability in cpue during those years.

The delta-lognormal abundance indices constructed for each time series, along with 95% confidence intervals, are shown in Figures 5-7. Plots of all three indices are provided in Figure 8. Plotted confidence intervals were calculated for the 1993-2010 index. The three indices could not be normalized to a common scale because the two shorter time series had no years in common. The shorter time series, nevertheless, clearly had cpue trends similar to those of the full time series.

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 9-20. Those diagnostic plots indicate that the fit of the data to the lognormal and binomial models was acceptable. There were, however, a few outliers among the data, particularly in the binomial data sets (Figures 10 A-C, 14 A-C, 18 A-B). No clear patterns in the distribution of Chi-square residuals were apparent. The data appear appropriate for analyses.

Black sea bass standardized catch rates for vertical line vessels appear to have periodic increases in cpue for one to two years on an approximately five year cycle. During the final two years of the time series (2009-10), cpue was particularly high. Given the variability around those mean cpues, however, it is unclear if that pattern is statistically significant. CPUE may have been constant during the period 1993-2009 with a higher cpue in 2010 only. Caution should be used when making conclusions, based upon a single data source, about black sea bass abundance or possible trends in recruitment.

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 1993-2010 series GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for black sea bass in the South Atlantic for vessels reporting vertical line gear landings. 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	17	193	92.89	5.46	<.0001	<.0001
subregion	3	193	186.08	62.03	<.0001	<.0001
seadays	2	193	84.53	42.26	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	17	51	93.37	5.49	<.0001	<.0001
subregion	3	51	159.25	53.08	<.0001	<.0001
seadays	2	14E3	3250.09	1625.04	<.0001	<.0001
season	3	14E3	367.59	122.53	<.0001	<.0001
crew1	1	14E3	207.80	207.80	<.0001	<.0001
*seadays*season*	6	14E3	267.99	44.67	<.0001	<.0001

C.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
YEAR + subregion + seadays + season + crew1 + seadays*season	47686.0	47688.0	47695.5	-	-
YEAR + subregion + seadays + season + crew1 + seadays*season + subregion*year	47577.2	47581.2	47585.8	108.8	<0.0001

Table 2. Linear regression statistics for the 1993-1998 (8 inch minimum size) GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for black sea bass in the South Atlantic for vessels reporting vertical line gear landings. 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	5	61	36.24	7.25	<.0001	<.0001
subregion	3	61	132.48	44.16	<.0001	<.0001
seadays	2	61	45.77	22.88	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	5	6187	24.48	4.90	0.0002	0.0002
seadays	2	6187	1351.54	675.77	<.0001	<.0001
season	3	6187	173.14	57.71	<.0001	<.0001
crew1	1	6187	160.84	160.84	<.0001	<.0001
subregion	3	6187	146.12	48.71	<.0001	<.0001
*seadays*season*	6	6187	104.56	17.43	<.0001	<.0001

Table 3. Linear regression statistics for the 1999-2010 (10 inch minimum size) GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for black sea bass in the South Atlantic for vessels reporting vertical line gear landings. See text for factor (effect) definitions.

A.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	11	33	48.10	4.37	<.0001	0.0005
subregion	3	33	66.06	22.02	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	11	7679	213.03	19.37	<.0001	<.0001
seadays	2	7679	1793.39	896.70	<.0001	<.0001
subregion	3	7679	236.79	78.93	<.0001	<.0001
season	3	7679	168.63	56.21	<.0001	<.0001
crew1	1	7679	76.64	76.64	<.0001	<.0001
*seadays*season*	6	7679	172.01	28.67	<.0001	<.0001

Table 4. Full time series (1993-2010) vertical line relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index for black sea bass in the South Atlantic.

YEAR	Normalized Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.720563	1,071	0.68	1.04566	0.682611	1.601799	0.215687
1994	0.95139	1,967	0.69	0.971267	0.645773	1.460822	0.20622
1995	0.939677	1,950	0.53	0.613684	0.400022	0.941467	0.216453
1996	0.820392	1,477	0.54	0.630099	0.408621	0.971622	0.219108
1997	0.748086	1,776	0.62	0.797507	0.52474	1.212061	0.211606
1998	0.964602	1,801	0.68	1.098211	0.725438	1.662539	0.20958
1999	1.405986	1,238	0.64	1.149422	0.745998	1.771009	0.218695
2000	1.119476	1,007	0.57	0.788	0.498677	1.245181	0.231795
2001	0.729371	1,478	0.60	0.842406	0.548661	1.293418	0.216878
2002	0.845932	1,524	0.56	0.784195	0.507315	1.212189	0.22037
2003	1.389748	1,176	0.57	0.998496	0.63979	1.558317	0.22534
2004	1.326806	1,110	0.59	1.412633	0.905688	2.203331	0.225031
2005	1.01238	1,044	0.58	1.010472	0.644155	1.585106	0.227999
2006	1.144549	1,014	0.59	0.899179	0.569793	1.418976	0.231104
2007	0.704136	1,167	0.45	0.550369	0.344111	0.880258	0.238087
2008	0.633502	1,147	0.50	0.726998	0.459564	1.15006	0.232371
2009	0.997483	875	0.60	1.157559	0.734961	1.82315	0.230087
2010	1.545919	480	0.73	2.523842	1.585367	4.017858	0.23566

Table 5. The 1993-1998 (8 inch minimum size) series vertical line relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index for black sea bass in the South Atlantic.

YEAR	Normalized Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.809855	1,050	0.70	1.123760	0.944643	1.336840	0.086978
1994	1.101898	1,865	0.72	1.134838	0.993594	1.296162	0.066532
1995	1.127417	1,792	0.56	0.784639	0.661587	0.930578	0.085446
1996	1.019019	1,393	0.57	0.836254	0.697161	1.003097	0.091146
1997	0.8634	1,709	0.64	0.911352	0.781742	1.062451	0.076815
1998	1.078411	1,740	0.70	1.209157	1.043892	1.400586	0.073583

Table 6. The 1999-2010 (10 inch minimum size) series vertical line relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index for black sea bass in the South Atlantic.

YEAR	Normalized Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1999	1.324897	1,240	0.63	1.058996	0.876078	1.280104	0.512835
2000	0.984528	1,064	0.55	0.757392	0.604526	0.948912	0.381087
2001	0.699951	1,519	0.60	0.820021	0.685394	0.981092	0.270934
2002	0.817559	1,589	0.55	0.721388	0.598287	0.869819	0.316457
2003	1.275184	1,186	0.56	0.970097	0.785921	1.197433	0.493593
2004	1.301483	1,152	0.59	1.363917	1.109416	1.676802	0.503772
2005	0.916099	1,088	0.58	0.973739	0.785042	1.207792	0.3546
2006	1.014016	1,039	0.57	0.784301	0.626139	0.982413	0.392501
2007	0.669036	1,189	0.44	0.504814	0.392013	0.650072	0.258967
2008	0.614621	1,178	0.48	0.649809	0.513088	0.82296	0.237905
2009	0.903952	909	0.60	1.060857	0.845848	1.330519	0.349898
2010	1.478674	478	0.73	2.33467	1.790356	3.04447	0.572359

Figure 1. Coastal Logbook defined fishing areas.

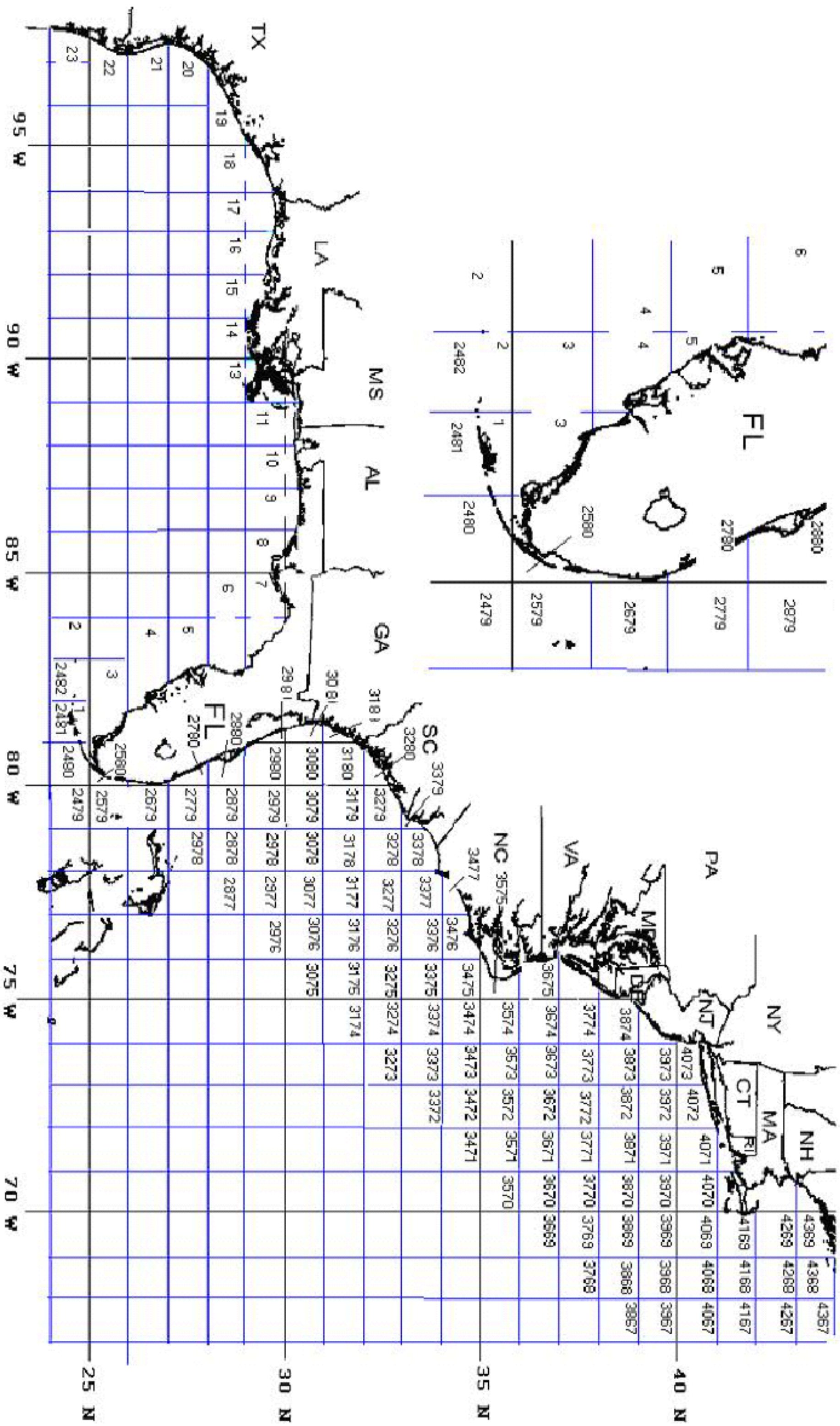


Figure 2. Regression coefficients from the 1993-2010 series Stephens & MacCall analyses. Positive coefficients signify species that had positive associations with the target species. The magnitude of the coefficients indicates the predictive impact of each species. The value for "non co-occurring" is the regression intercept and denotes the probability a trip was fishing in the target species' habitat, but did not report any of the listed species. Species included were reported on at least one percent of vertical line trips in the South Atlantic.

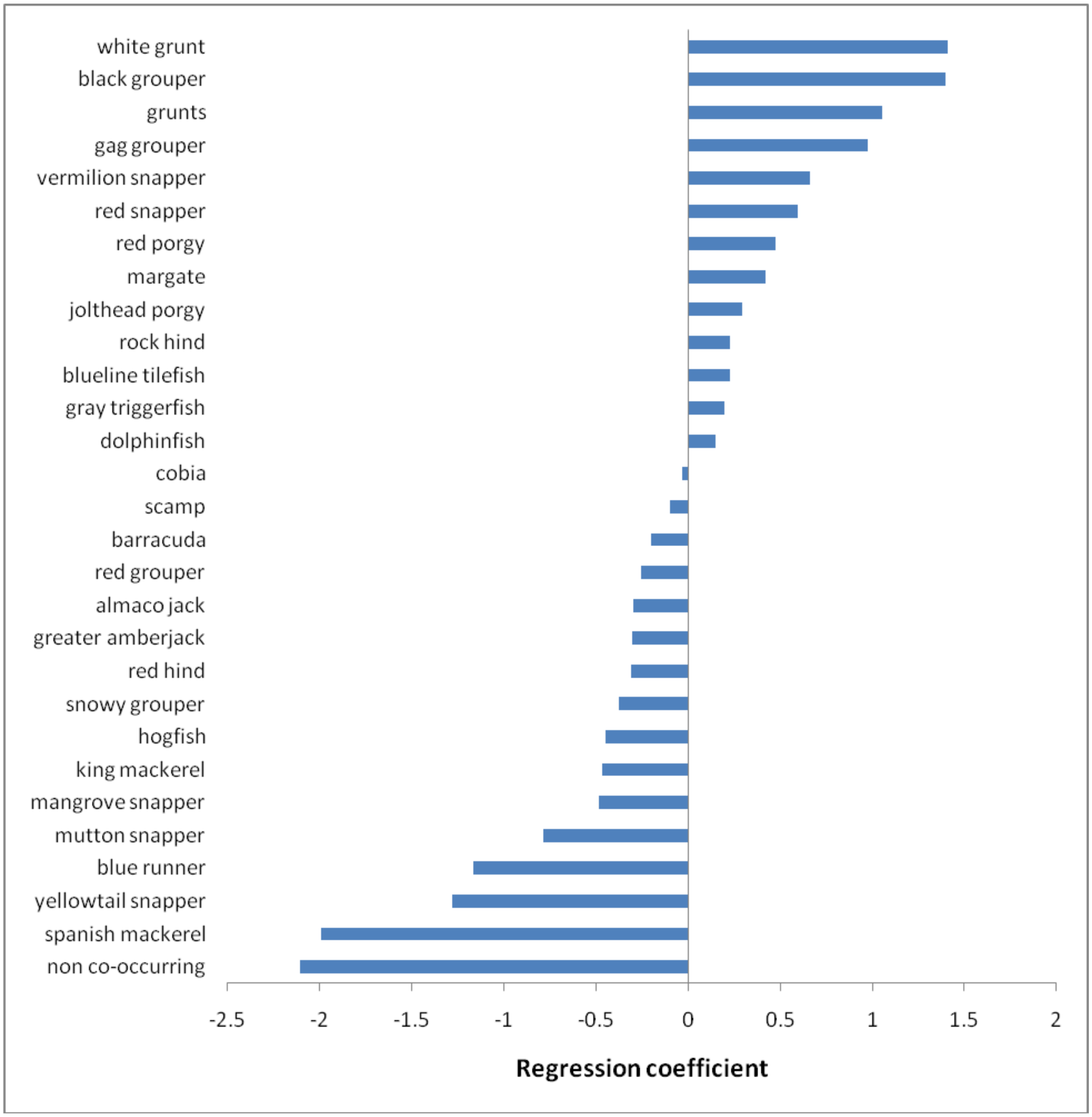


Figure 3. Regression coefficients from the 1993-1998 series Stephens & MacCall analyses. Positive coefficients signify species that had positive associations with the target species. The magnitude of the coefficients indicates the predictive impact of each species. The value for "non co-occurring" is the regression intercept and denotes the probability a trip was fishing in the target species' habitat, but did not report any of the listed species. Species included were reported on at least one percent of vertical line trips in the South Atlantic.

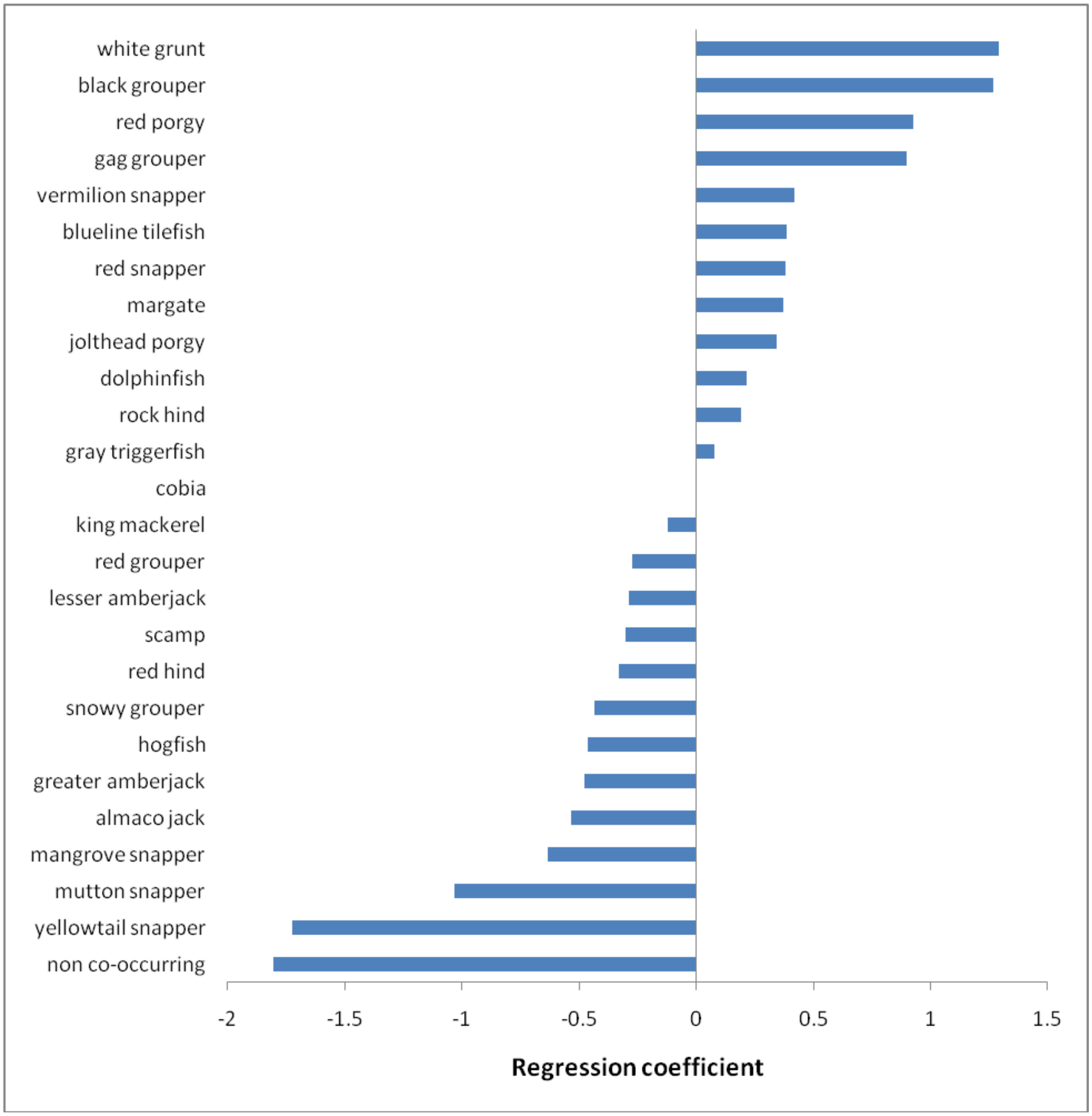


Figure 4. Regression coefficients from the 1999-2010 series Stephens & MacCall analyses. Positive coefficients signify species that had positive associations with the target species. The magnitude of the coefficients indicates the predictive impact of each species. The value for "non co-occurring" is the regression intercept and denotes the probability a trip was fishing in the target species' habitat, but did not report any of the listed species. Species included were reported on at least one percent of vertical line trips in the South Atlantic.

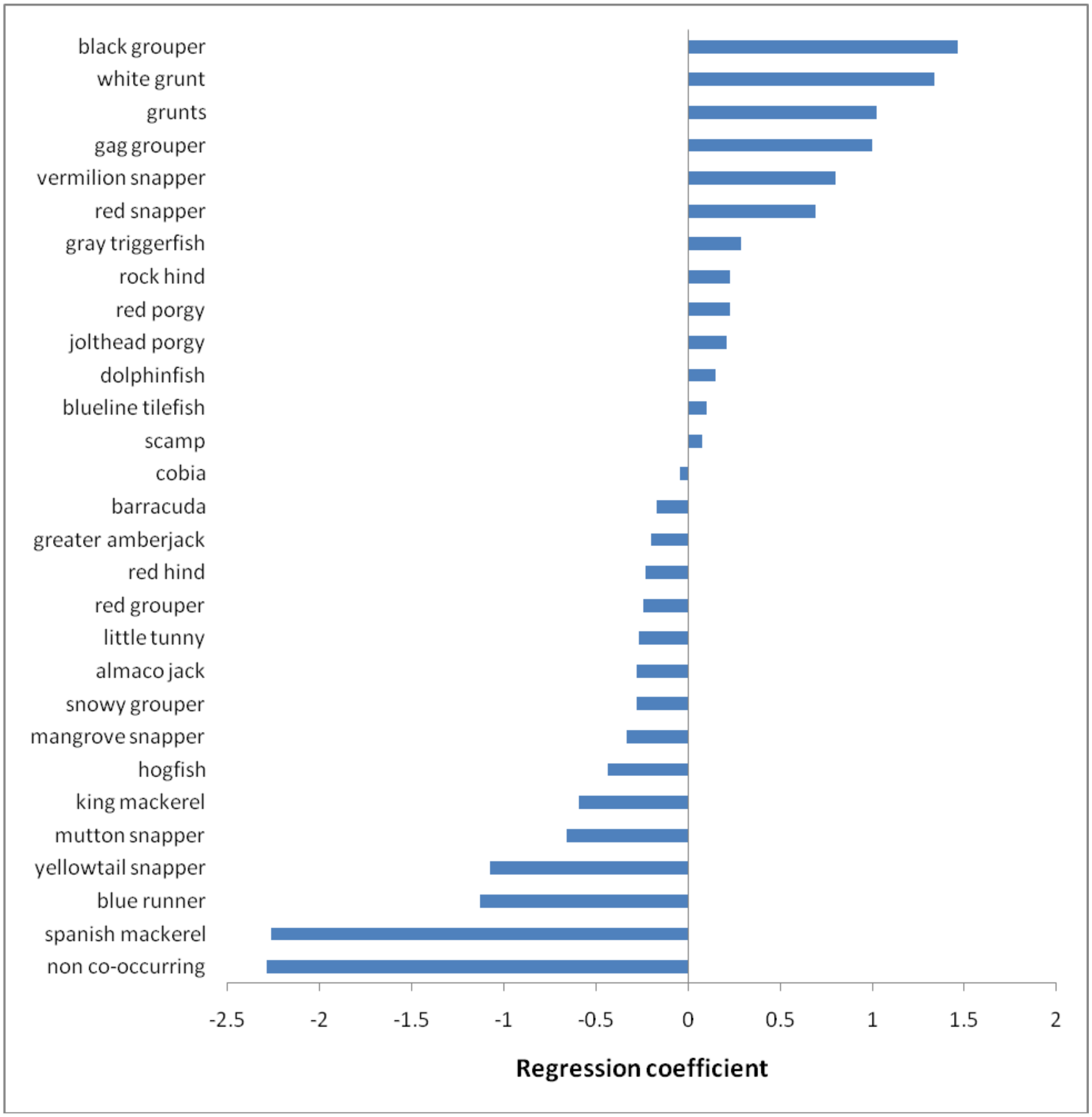


Figure 5. Black sea bass 1993-2010 nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the South Atlantic.

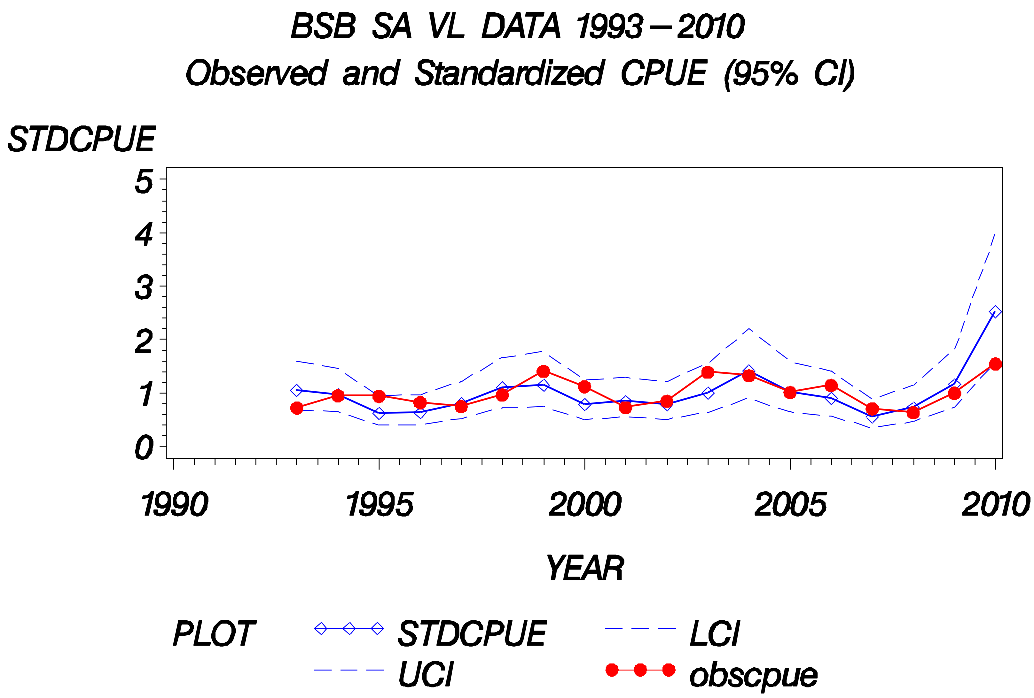


Figure 6. Black sea bass 1993-1998 nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the South Atlantic.

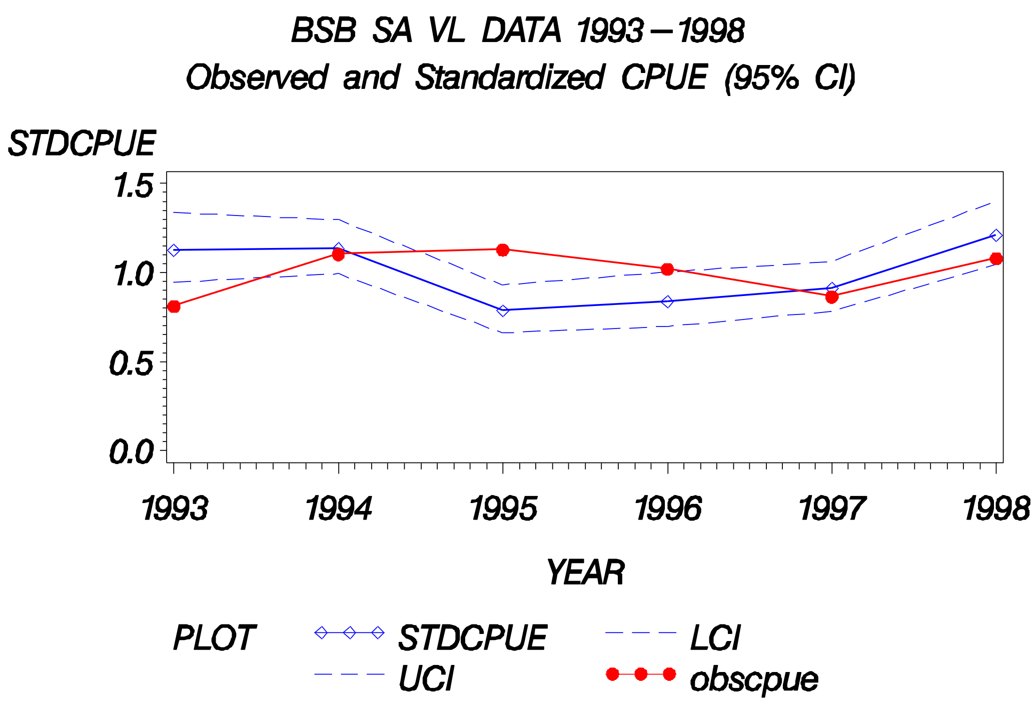


Figure 7. Black sea bass 1999-2010 nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the South Atlantic.

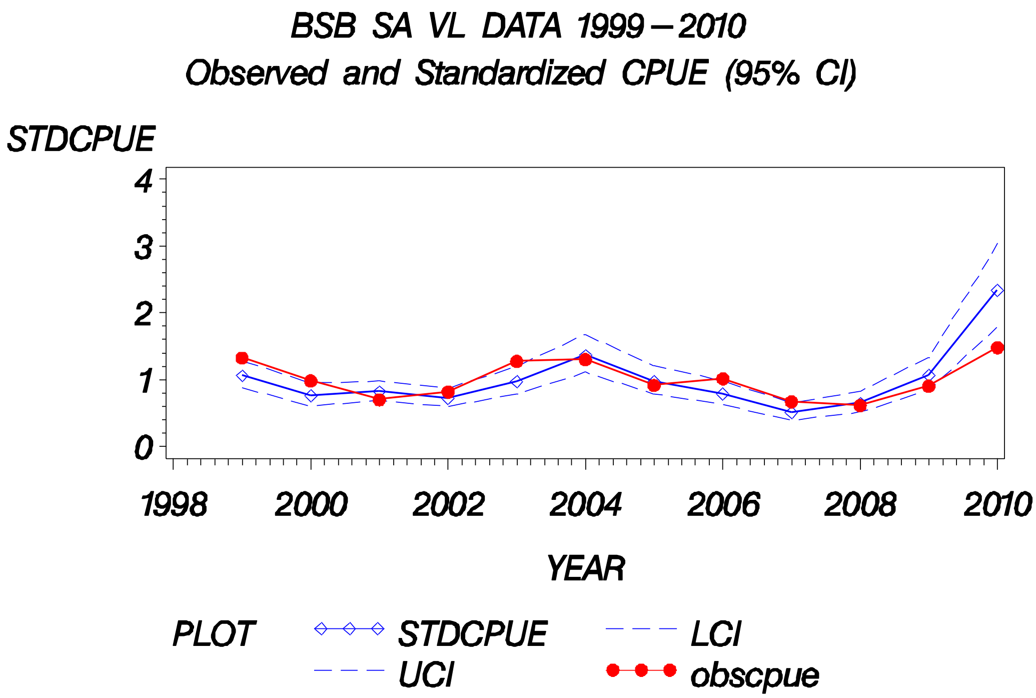


Figure 8. Comparison of the full time series 1993-2010 index with the indices split due to the black sea bass minimum size change (1998/1999). Confidence intervals of the 1993-2010 index are also provided.

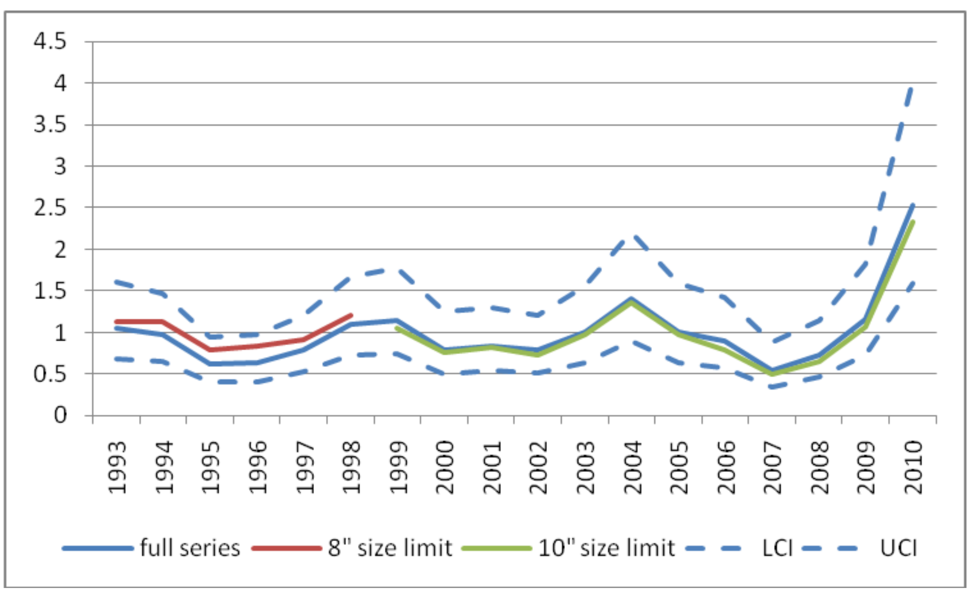


Figure 9. 1993-2010 time series annual trends in **A.** the proportion of positive trips and **B.** nominal CPUE of the South Atlantic black sea bass commercial vertical line gear data.

A. **B.**

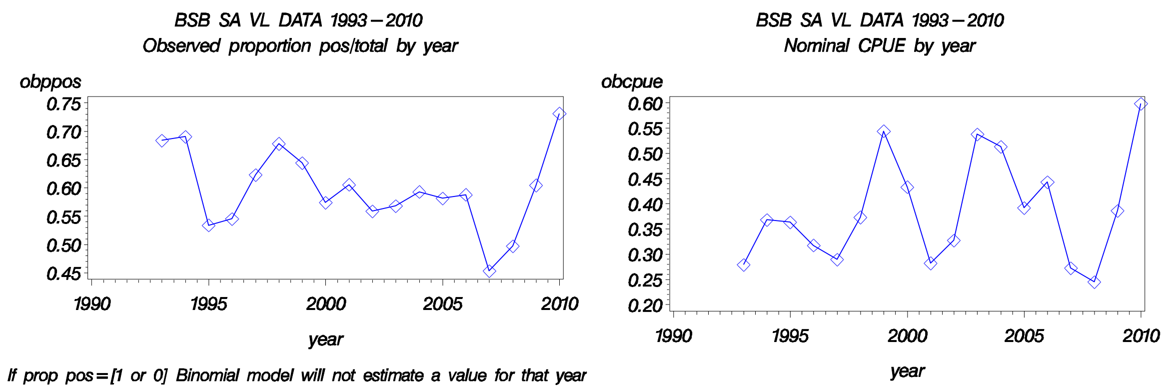
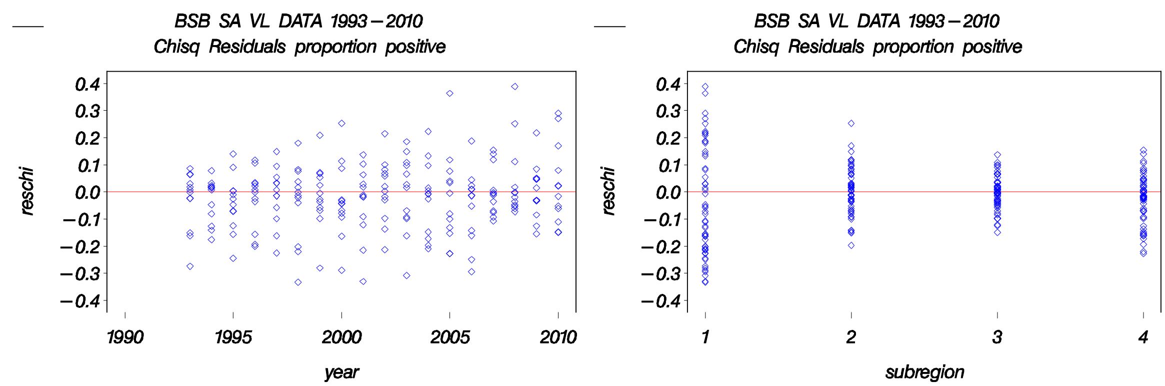


Figure 10. Diagnostic plots for the binomial component of the South Atlantic 1993-2010 black sea bass commercial vertical line gear full time series model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by subregion; and **C**. the Chi-Square residuals by days at sea.

A. **B.**



C.

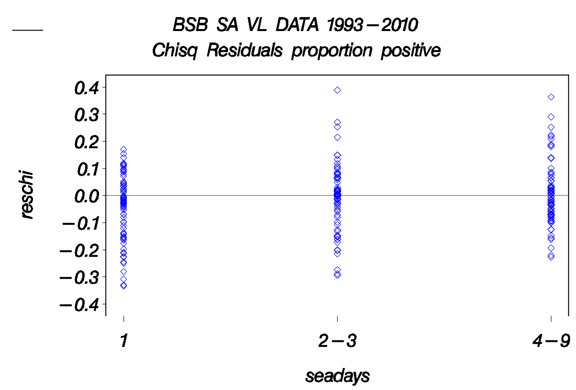


Figure 11. Diagnostic plots for the lognormal component of the South Atlantic 1993-2010 black sea bass commercial vertical line gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

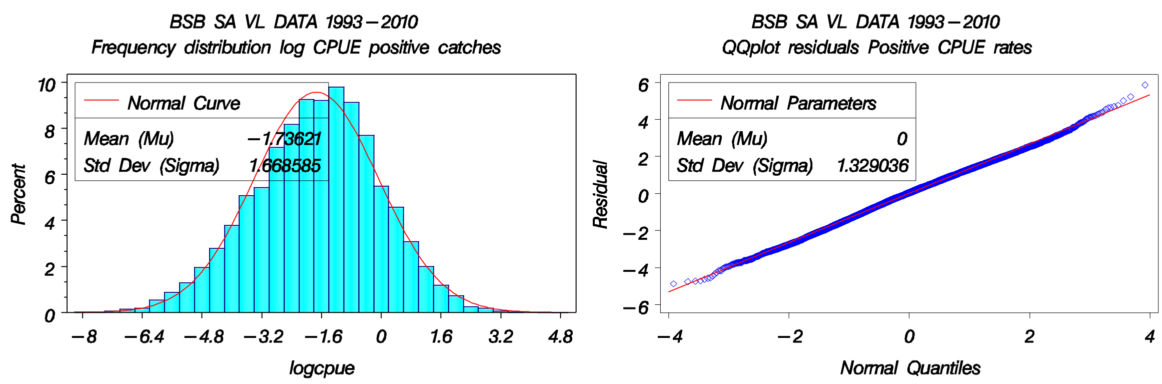
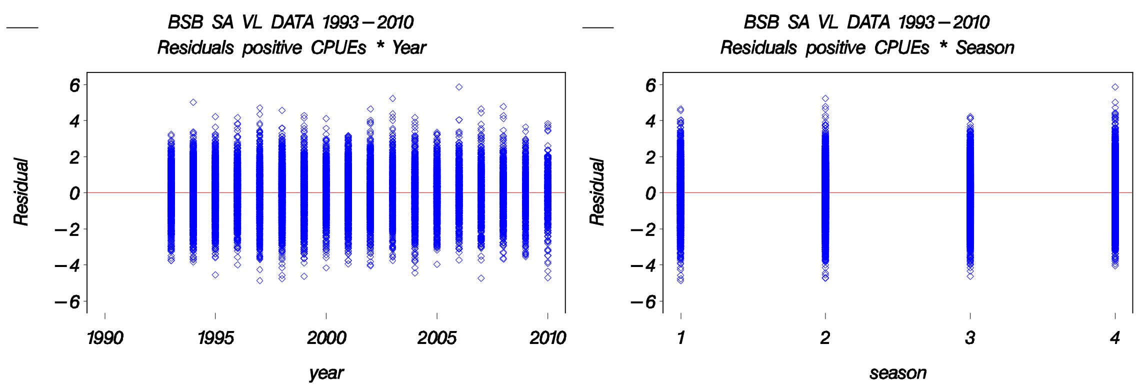


Figure 12. Diagnostic plots for the lognormal component of the South Atlantic 1993-2010 black sea bass commercial vertical line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by season; **C**. the Chi-Square residuals by subregion; **D**. the Chi-Square residuals by number of crew; and **E**. the Chi-Square residuals by days at sea.

A. **B.**



C. **D.**

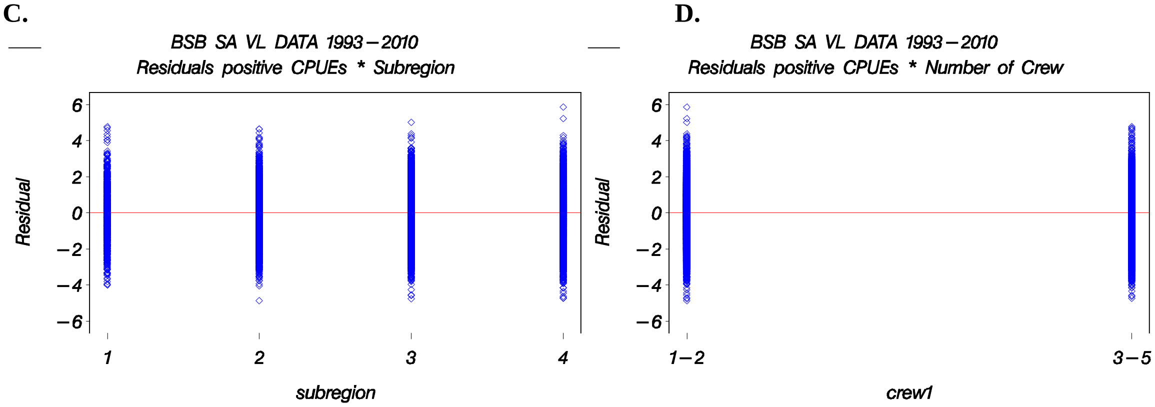


Figure 12. (continued)

E.

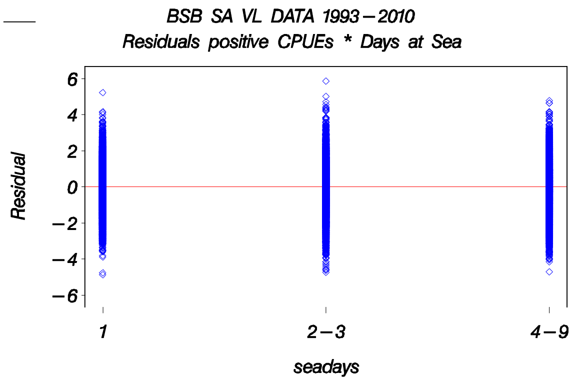
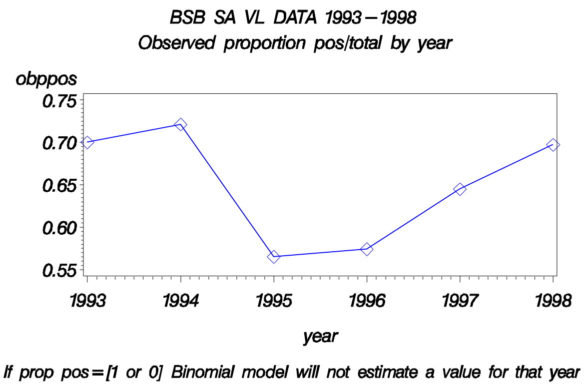


Figure 13. 1993-1998 time series annual trends in **A.** the proportion of positive trips and **B.** nominal CPUE of the South Atlantic black sea bass commercial vertical line gear data.

A.



B.

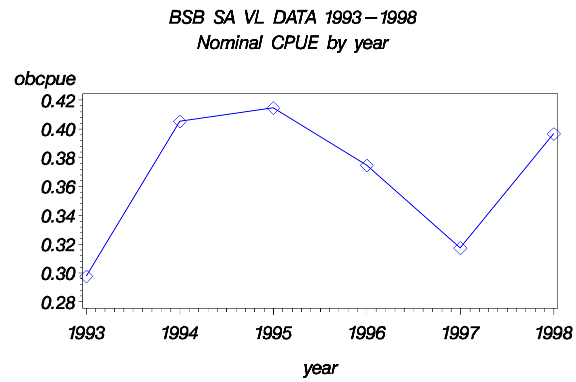
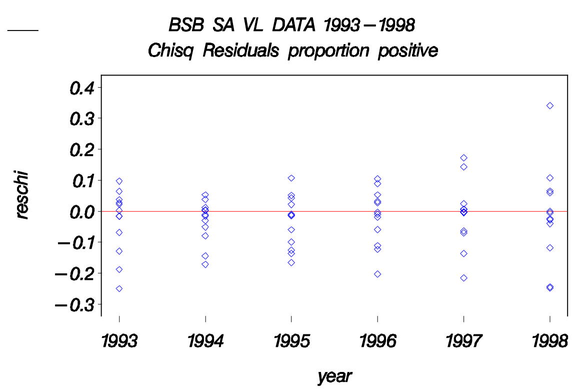
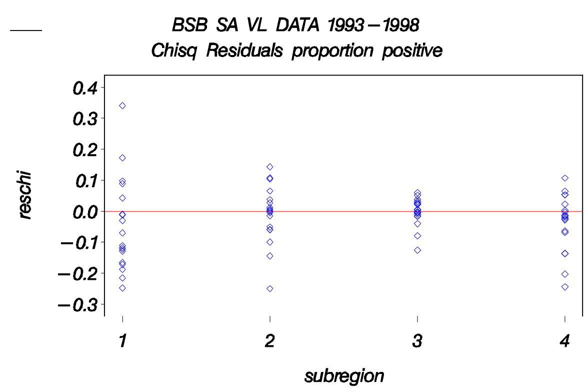


Figure 14. Diagnostic plots for the binomial component of the South Atlantic 1993-1998 black sea bass commercial vertical line gear full time series model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by subregion; and **C**. the Chi-Square residuals by days at sea.

A.



B.



C.

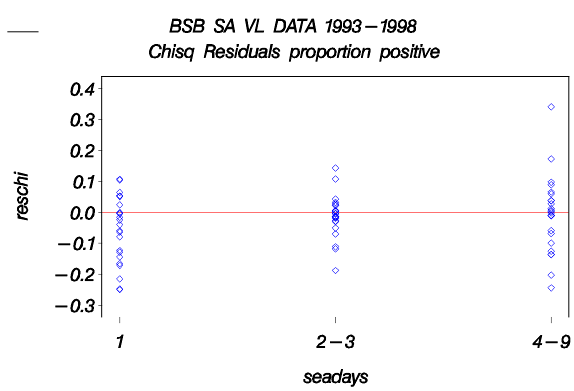
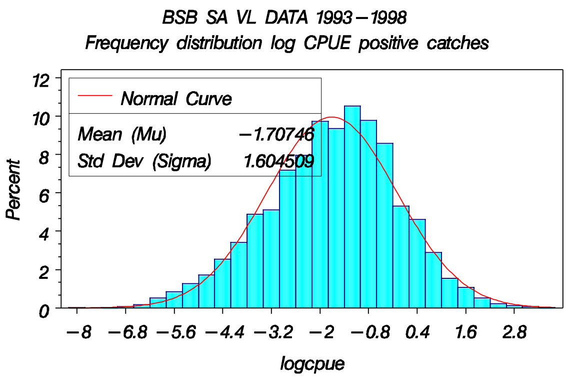


Figure 15. Diagnostic plots for the lognormal component of the South Atlantic 1993-1998 black sea bass commercial vertical line gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

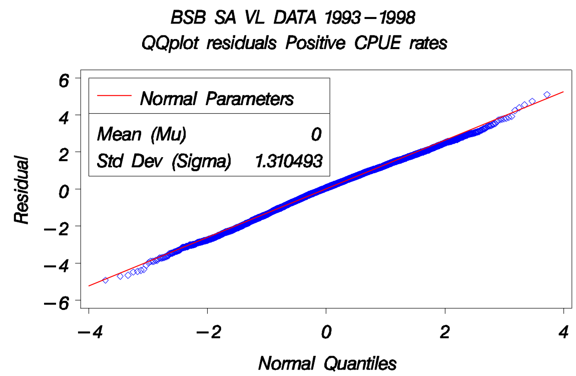
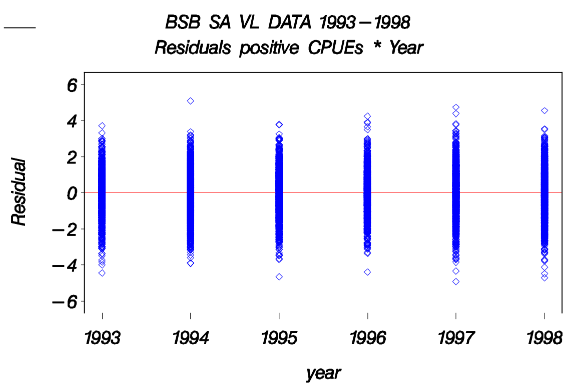
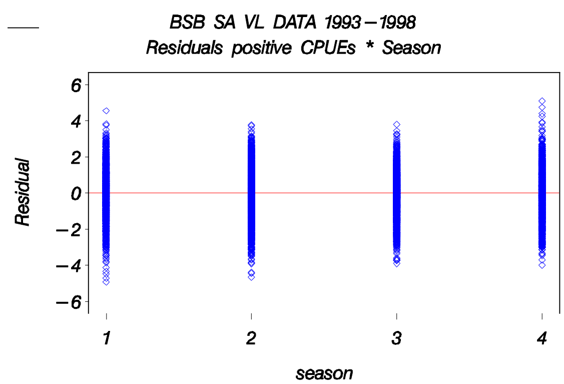


Figure 16. Diagnostic plots for the lognormal component of the South Atlantic 1993-1998 black sea bass commercial vertical line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by season; **C**. the Chi-Square residuals by subregion; **D**. the Chi-Square residuals by number of crew; and **E**. the Chi-Square residuals by days at sea.

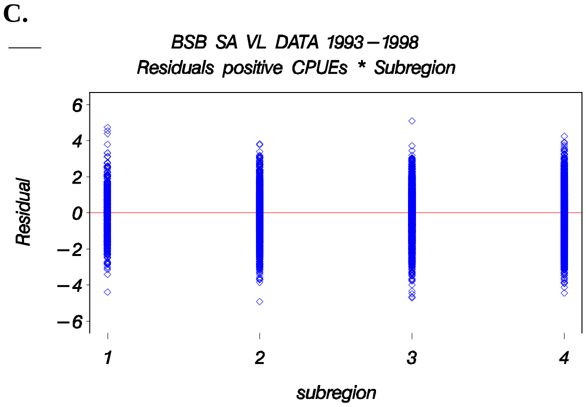
A.



B.



C.



D.

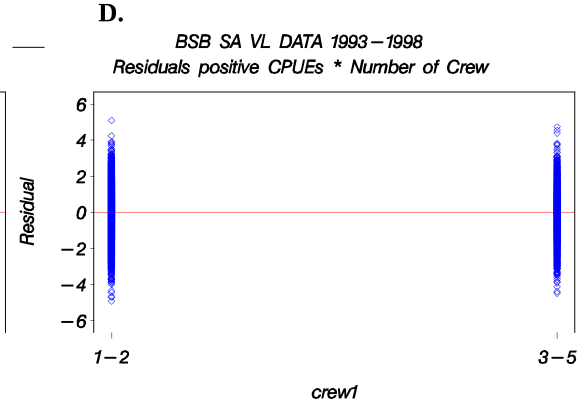


Figure 16. (continued)

E.

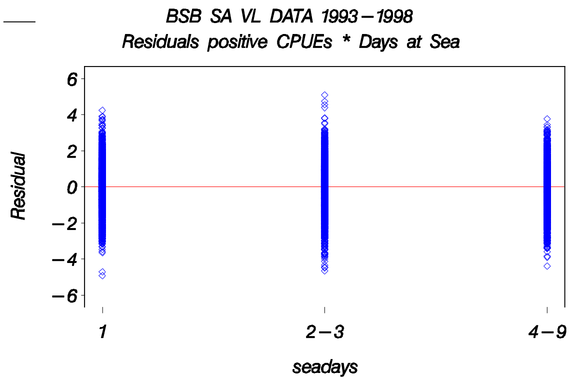


Figure 17. 1999-2010 time series annual trends in **A.** the proportion of positive trips and **B.** nominal CPUE of the South Atlantic black sea bass commercial vertical line gear data.

A. **B.**

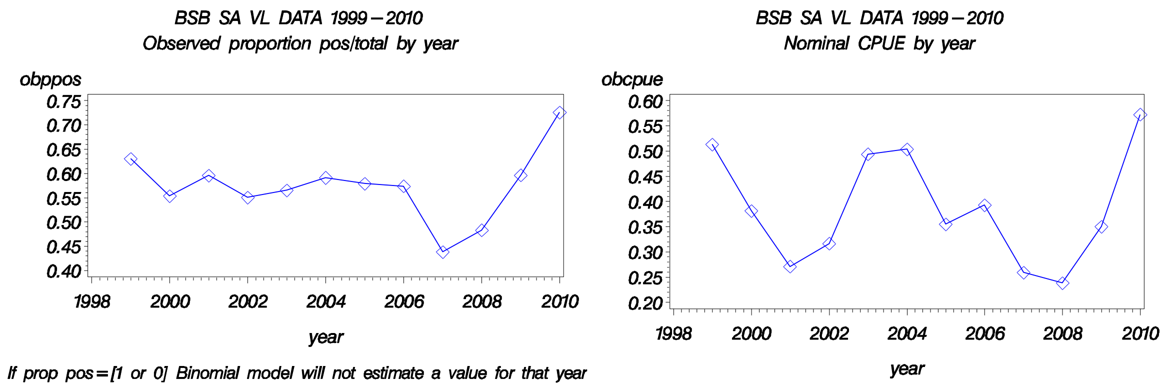


Figure 18. Diagnostic plots for the binomial component of the South Atlantic 1999-2010 black sea bass commercial vertical line gear full time series model: **A**. the Chi-Square residuals by year and **B**. the Chi-Square residuals by subregion.

A. **B.**

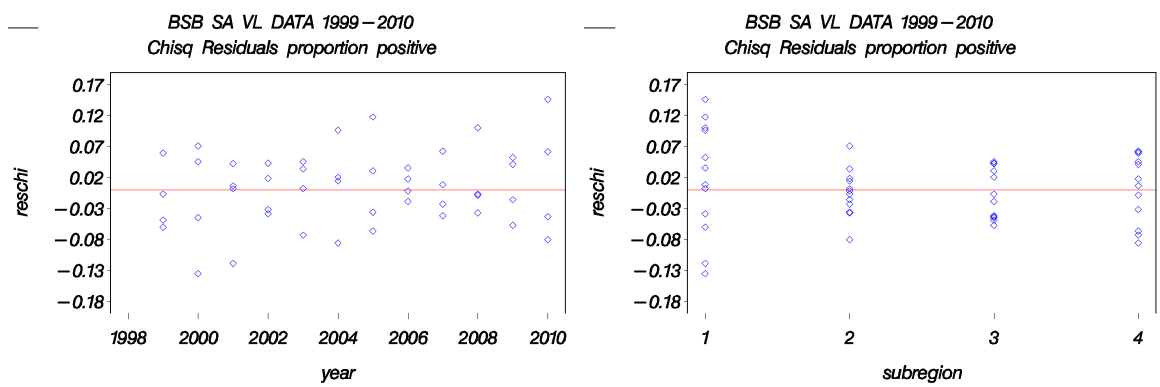


Figure 19. Diagnostic plots for the lognormal component of the South Atlantic 1999-2010 black sea bass commercial vertical line gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

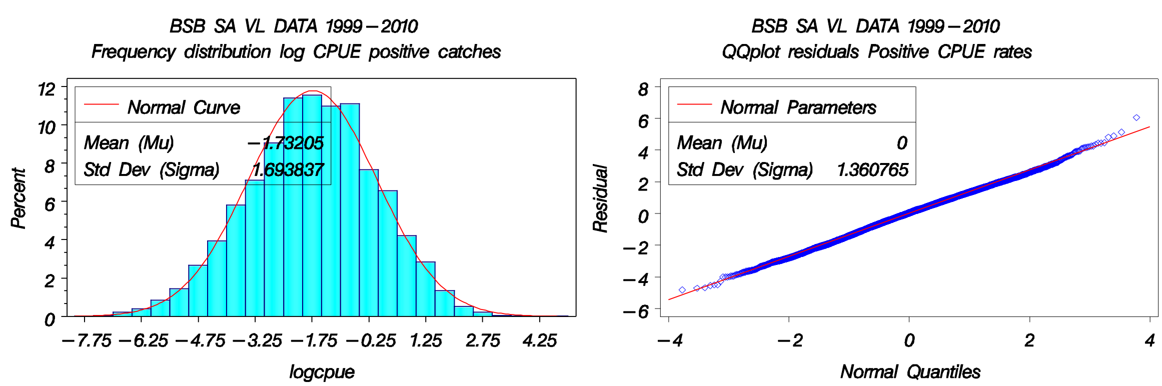
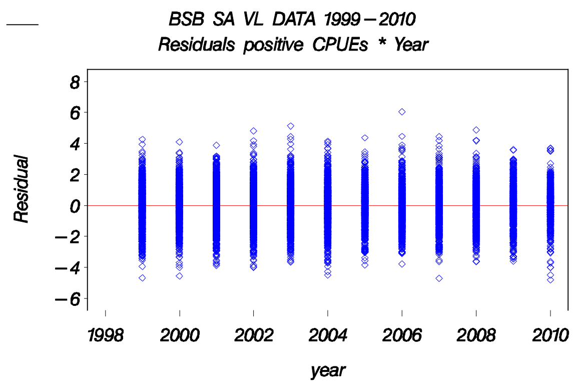
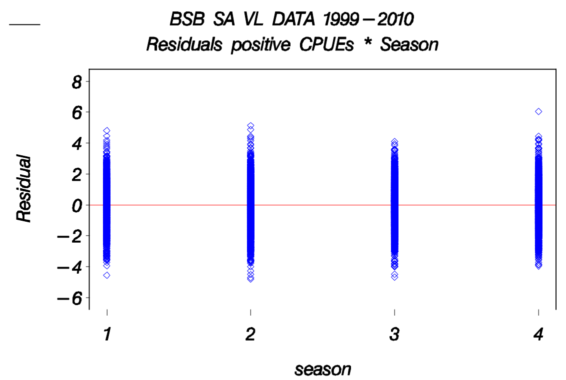


Figure 20. Diagnostic plots for the lognormal component of the South Atlantic 1999-2010 black sea bass commercial vertical line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by season; **C**. the Chi-Square residuals by subregion; **D**. the Chi-Square residuals by number of crew; and **E**. the Chi-Square residuals by days at sea.

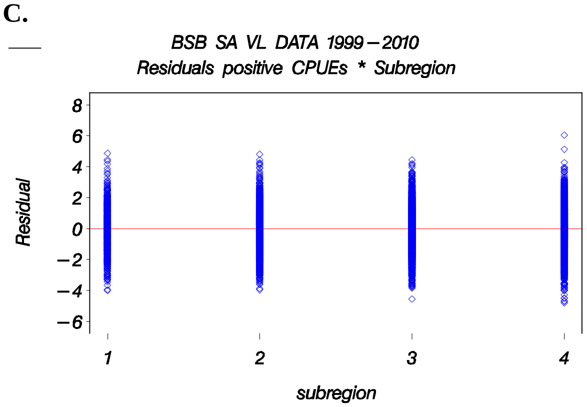
A.



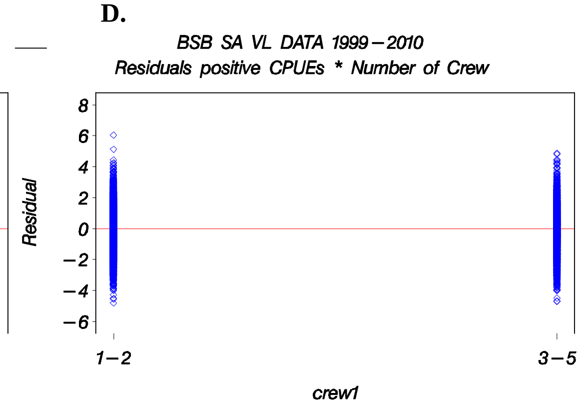
B.



C.



D.



E.