Standardized catch rates of Spanish mackerel from commercial handline, trolling, and gillnet fishing vessels in the US South Atlantic, 1998-2010

K. McCarthy

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Standardized Catch Rates of Spanish Mackerel from Commercial Handline, Trolling and Gillnet Fishing Vessels in the US South Atlantic, 1998-2010

Kevin McCarthy

National Marine Fisheries Service, Southeast Fisheries Science Center
Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, FL, 33149-1099
Kevin.J.McCarthy@noaa.gov
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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 Spanish mackerel. Indices were constructed using data reported from commercial handline and trolling and gillnet trips in the US South Atlantic. Spanish mackerel data were sufficient to construct indices of abundance including the years 1998-2010 (1998 was the initial year of required Spanish mackerel landings reporting to the CFLP and the initial year used in SEDAR 17). Indices were constructed using handline (including electric reels) combined with trolling data (hook and line); with separate indices constructed using gillnet data. Two indices were constructed following the methods used in SEDAR 17 (continuity indices). The available data were further examined for the construction of new indices (2012 indices).

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. Effort data available for gillnets included net length, net depth, and total soak time. Reports of landings of Spanish mackerel to the CFLP were not required prior to 1998, therefore data prior to 1998 were excluded from the analysis.

Several additional filters were applied to the data set. For the continuity indices, data exclusions included deleting records with fishing reported as more than 24 hours per day. Trips missing the number of lines, number of hooks per line, net length (for gillnets), depth of net, hours fished, days at sea, schedule (trip identifier), or species landed were also excluded. All trips with non-integer values of number of lines or number of hooks per line were removed from the data set. The continuity indices included only those data reported from fishing trips between 31^{o}N and 40^{o}N latitude. To remove outliers (possible data entry errors) those records with the highest one percent of CPUE values from each gear type were also removed.

Data filtering for the 2012 indices was more extensive than that used in SEDAR 17. 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.

Index Development

Continuity hook and line index

Handline and trolling catch rate was calculated as weight of Spanish mackerel per hook hour fished. Following the methods of SEDAR 17, only data from trips that had Spanish mackerel landings were included in the analysis. The main effects of year, subregion (triparea defined as 31^{o}N to 33^{o}N latitude and 34^{o}N to 40^{o}N latitude) and gear (handline and trolling) were included in then analysis. No interaction terms were examined.

2012 hook and line index

CPUE was calculated as the weight of Spanish mackerel per hook hour fished. As with the continuity hook and line index, only data from trips reporting Spanish mackerel landings were included in the analysis. The data were limited spatially from the region south of the Florida Keys and east of the Dry Tortugas to 37^{o}N latitude. Logbook reporting from fishing effort north of North Carolina was limited because fishing in that region is not required to report to the CFLP. Data reported from north of 37^{o}N latitude were excluded from this analysis.

Five factors were considered as possible influences on the catch rate of Spanish mackerel 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	13	1998-2010
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Subregion	4	Stat areas: 2380-2482, 2579-2680, 2778-2780, 2879-3675 see Figure 1
Gear fished (gear1)*	2	Handline (included electric reels), trolling
Crew (crew1)*	2	1, 2+ crew members

*Names in parentheses appear in some figures and tables.

Continuity gillnet index

Gillnet vessel catch rate was calculated as weight of Spanish mackerel per square yard (of net) hour fished. Following the methods of SEDAR 17, data from all gillnet trips in the region were included in the analysis. Only the main effects of year and subregion (triparea defined as 31^{o}N to 33^{o}N latitude and 34^{o}N to 40^{o}N latitude) were included in the analysis. The interaction year*subregion was not examined.

2012 gillnet index

CPUE was calculated as the weight of Spanish mackerel per hook hour fished. As with the continuity gillnet index all gillnet trips in the South Atlantic were included in the analysis. Unlike the SEDAR 17 and continuity indices, data used to construct the 2012 index were limited spatially from the region south and east of the Florida Keys to 37^{o}N latitude.

Five factors were considered as possible influences on the catch rate of Spanish mackerel. 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	13	1998-2010
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Subregion	4	Stat areas: 2379-2480, 2860-2880, 2978-3477, 3525-3675 see Figure 1
Crew (crew1)*	3	1, 2, 3+ crew members
Trip effort**	4	Square yard hours: <4,801; 4,801-10,800; 10,801-25,600; >25,600

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

Statistical analyses

Hook and line indices

Data from hook and line commercial fishing trips were used in lognormal models on catch rates of trips reporting Spanish mackerel 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 Spanish mackerel/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 models (continuity and 2012 models) were 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.

Gillnet indices

The delta lognormal model approach (Lo et al. 1992) was used to construct standardized indices of abundance from the gillnet data. This method combines separate general linear model (GLM) analyses of the proportion of successful trips (trips that landed Spanish mackerel) 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). The continuity index used the models reported from SEDAR 17.

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 Spanish mackerel/square yard hour fished). All two-way interactions among significant main effects were examined for the 2012 index. 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 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

Continuity handline/trolling index

The final model reported in SEDAR 17 and used in the continuity analysis for the lognormal on CPUE of successful trips:

LOG(CPUE) = Year + Triparea + Gear Fished

The linear regression statistics for fixed effects are summarized in Table 1.

Relative nominal CPUE, number of trips, and relative abundance indices are provided in Table 2. Yearly mean cpue ranged from 0.81 to 1.2 (in 2010). Coefficients of variation (CV) were low, ranging from 0.13-0.20. Similarly, confidence intervals around the mean cpue were narrow. The abundance index, along with 95% confidence intervals, is shown in Figure 2A. No clear trend in yearly cpue was apparent.

A comparison of the SEDAR 17 hook and line index with the continuity index is shown in Figure 2B. 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 in the lognormal model are shown in Figures 3-5. There were a few outliers among the data, particularly in the Chi-square residual by year (Figure 5A). No obvious patterns in the distribution of Chi-square residuals were apparent and the data appear appropriate for the analysis.

2012 hook and line index

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

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

The linear regression statistics for fixed effects and the analyses of the mixed model formulations of the final model are summarized in Table 3.

Relative nominal CPUE, number of trips, and the standardized abundance index are provided in Table 4. Yearly mean cpue ranged from 0.75 to 1.5. Coefficients of variation (CV) were higher than in the continuity index and were approximately 0.34 throughout the time series. Similarly, confidence intervals around the mean cpue were broader than the continuity index. Yearly mean cpue was highest in the final two years of the time series, however the confidence intervals were sufficiently broad that no strong conclusions regarding any trend in cpue should be made. The abundance index, along with 95% confidence intervals, is shown in Figure 6.

Plots of the nominal cpue, frequency distribution of log(CPUE), cumulative normalized residuals (Q-Q plot), and plots of Chi-squareresiduals by each main effect for lognormal models are shown in Figures 7-9. The frequency distribution of log(cpue) was bimodal. Further distributions of log(cpue) by gear (handline and trolling) are shown in Figures 10A-B. The two gears clearly have different distributions of log(cpue) and some, but not all, of the bimodality of the data may be explained by gear differences. The other diagnostic plots do not indicate that the data were inappropriate for the analysis. The deviation from normality of the log(cpues) may indicate that alternative analyses should be considered.

Continuity gillnet index

The final models as defined in SEDAR 17for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips were:

PPT = Year + Triparea

LOG(CPUE) = Year + Triparea

The linear regression statistics for fixed effects are summarized in Table 5.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 6. Yearly mean cpue ranged from 0.69 to 1.4. Coefficients of variation (CV) were low: 0.2 to 0.23. Similar to the hook and line continuity index, confidence intervals around the mean cpue were narrow. The abundance index, along with 95% confidence intervals, is shown in Figure 11A. No trend in yearly mean cpue was apparent. The SEDAR 17 gillnet and continuity gillnet indices are plotted in Figure 11B. The two indices differ in the range of mean cpue among years with the SEDAR 17 index having much greater variability among years in cpue. An index using only positive Spanish mackerel gillnet data was constructed, however that index did not have any better agreement with the SEDAR 17 index. Determining reasons for the observed differences in the SEDAR 17 and continuity indices will require further investigation.

Plots of the observed proportion positives, 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 12-15. There were outliers among the data, particularly in the binomial Chi-square residuals by year and subregion (triparea [Figure 13A-B]). The distribution of log(cpue) on positive catches approximated a normal distribution, indicating the data were appropriate for the analysis.

2012 gillnet index

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

PPT = Year* + Crew + Subregion + Quarter + Trip effort + Subregion*Quarter + Subregion*Trip effort + Crew*Subregion + Crew*Quarter

LOG(CPUE) = Year + Subregion + Quarter + Subregion*Quarter + Subregion*Year + Quarter*Year

The linear regression statistics for fixed effects and the analyses of the mixed model formulations of the final model are summarized in Table 7. 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 8. Yearly mean cpue ranged from 0.62 to 1.5. Coefficients of variation (CV) were higher than the continuity index, approximately 0.45 during each year in the series. Similarly, confidence intervals around the mean cpue were larger than those of the continuity index. The abundance index, along with 95% confidence intervals, is shown in Figure 16. Although yearly mean nominal cpue was much higher during the final four years of the series, the standardized index showed no obvious trend in cpue across 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 17-20. 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.

No clear long term change in yearly mean cpue was found in any of the Spanish mackerel indices. A small increase in cpue was found in the hook and line 2012 index, however confidence intervals around the mean were large. The 2012 gillnet index had an increasing trend in cpue during the period 2002-2008 followed by a decrease in cpue during 2009-2010, but with high variability in those data.

As with any index of abundance constructed using fisheries dependent data, the yearly mean cpues reported here may not reflect Spanish mackerel abundance; but rather the ability of fishers to successfully target the species.

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 Spanish mackerel in the South Atlantic for vessels reporting handline and trolling landings; continuity index. See text for factor (effect) definitions.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	12	1317	0.83	0.6153
triparea	1	1317	7.96	0.0048
gear1	1	1317	2.04	0.1533

Table 2. Commercial Spanish mackerel handline and trolling relative nominal CPUE, number of trips, and standardized abundance index in the South Atlantic; continuity index.

YEAR	Normalized Nominal CPUE	Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.781017	124	0.897685	0.68577	1.175086658	0.135251
1999	1.097137	145	1.120625	0.869977	1.443485889	0.127096
2000	0.908808	125	0.908444	0.693896	1.189328431	0.135319
2001	0.993453	99	1.004748	0.745889	1.35344482	0.149788
2002	1.322812	88	1.240505	0.905697	1.699081789	0.158262
2003	1.112789	75	0.962054	0.686199	1.348803369	0.170164
2004	1.349282	74	1.035624	0.737113	1.455025223	0.171245
2005	0.933657	136	0.926864	0.712937	1.204982649	0.131774
2006	1.269081	80	1.203024	0.865028	1.673087393	0.166044
2007	0.721231	113	0.811365	0.610916	1.077582375	0.142596
2008	0.97385	53	1.112263	0.748108	1.65367604	0.200268
2009	0.874882	139	0.859442	0.663962	1.112475796	0.129569
2010	0.662001	81	0.917356	0.660993	1.273149868	0.164983

Table 3.

A. Linear regression statistics for the catch rates on positive trips for Spanish mackerel in the South Atlantic for 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	12	36	1.08	0.4032
subregion	3	36	99.16	<.0001
quarter	3	36	73.76	<.0001
gear1	1	2E4	66.80	<.0001
*subregion*quarter*	9	2E4	37.19	<.0001
*quarter*gear1*	3	2E4	71.46	<.0001
*subregion*gear1*	3	2E4	71.26	<.0001

B. Analysis of the mixed model formulations of the positive trip model 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.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
YEAR + subregion + quarter + gear1 + subregion*quarter	80772.6	80774.6	80782.5	-	-
YEAR + subregion + quarter + gear1 + subregion*quarter + quarter*year	80576.5	80580.5	80584.4	196.1	<0.0001
YEAR + subregion + quarter + gear1 + subregion*quarter + quarter*year + subregion*year	80392.1	80398.1	80404.0	184.4	<0.0001
YEAR + subregion + quarter + gear1 + subregion*quarter + quarter*year + subregion*year + quarter*gear1	80181.7	80187.7	80193.5	210.4	<0.0001
YEAR + subregion + quarter + gear1 + subregion*quarter + quarter*year + subregion*year + quarter*gear1 + subregion*gear1	79977.5	79983.5	79989.3	204.2	<0.0001

Table 4. Commercial Spanish mackerel handline and trolling relative nominal CPUE, number of trips, and standardized abundance index in the South Atlantic.

YEAR	Normalized Nominal CPUE	Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.381386	1,159	0.755857	0.387092	1.475927	0.344182
1999	0.439209	1,303	0.932353	0.478606	1.816281	0.342902
2000	0.654737	1,493	0.902788	0.463066	1.760063	0.343327
2001	0.637523	1,547	0.869272	0.44655	1.692159	0.342505
2002	0.611767	1,622	0.759367	0.390078	1.478267	0.342525
2003	0.868865	1,315	0.846332	0.433929	1.650682	0.343552
2004	1.215625	1,277	1.090223	0.559023	2.126183	0.343506
2005	1.512291	1,401	0.96869	0.497243	1.887126	0.342919
2006	1.584756	1,529	1.114079	0.571727	2.170917	0.343058
2007	1.290086	1,941	0.962192	0.49417	1.873471	0.34263
2008	1.205476	1,717	0.986909	0.505941	1.925105	0.343621
2009	1.085695	1,925	1.301718	0.66866	2.534126	0.342537
2010	1.512584	1,915	1.510221	0.774637	2.944305	0.343327

Table 5. Linear regression statistics for the continuity gillnet GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) of Spanish mackerel in the South Atlantic for vessels reporting handline and trolling gear landings 1998-2010. 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	12	10	12.12	1.01	0.4361	0.5010
triparea	1	10	24.69	24.69	<.0001	0.0006

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	12	7737	159.11	13.26	<.0001	<.0001
triparea	1	7737	0.42	0.42	0.5156	0.5156

Table 6. Commercial Spanish mackerel continuity gillnet relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index in the South Atlantic.

YEAR	Normalized Nominal CPUE	Trips	Proportion Positive	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.933	610	0.68	0.824	0.528	1.285	0.225
1999	0.921	729	0.70	0.702	0.455	1.084	0.219
2000	0.982	935	0.64	0.801	0.518	1.238	0.220
2001	1.465	851	0.65	1.179	0.755	1.841	0.226
2002	1.252	968	0.74	1.297	0.871	1.931	0.201
2003	0.819	895	0.76	1.060	0.716	1.568	0.198
2004	1.112	941	0.68	1.156	0.763	1.751	0.210
2005	0.635	892	0.64	0.690	0.453	1.053	0.214
2006	0.753	958	0.70	0.831	0.559	1.234	0.200
2007	0.905	935	0.72	1.124	0.751	1.682	0.204
2008	1.057	812	0.67	0.881	0.575	1.349	0.216
2009	1.186	933	0.64	1.402	0.906	2.170	0.221
2010	0.979	942	0.61	1.053	0.669	1.657	0.230

Table 7. Linear regression statistics for the gillnet GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) of Spanish mackerel in the South Atlantic for vessels reporting gillnet landings during 1998-2010. 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	12	1518	23.03	1.92	0.0275	0.0283
crew1	2	1518	143.83	71.91	<.0001	<.0001
subregion	3	1518	123.92	41.31	<.0001	<.0001
quarter	3	1518	76.14	25.38	<.0001	<.0001
tripeffort1	3	1518	119.64	39.88	<.0001	<.0001
*subregion*quarter*	9	1518	307.65	34.18	<.0001	<.0001
*subregion*tripeffort*	9	1518	154.38	17.15	<.0001	<.0001
*crew1*subregion*	6	1518	109.97	18.33	<.0001	<.0001
*crew1*quarter*	6	1518	53.71	8.95	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	12	36	7.43	0.62	0.8279	0.8117
subregion	3	36	22.26	7.42	<.0001	0.0005
quarter	3	36	57.28	19.09	<.0001	<.0001
*subregion*quarter*	9	13E3	1035.71	115.08	<.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 + quarter + subregion*quarter	55972.0	55974.0	55981.5	-	-
YEAR + subregion + quarter + subregion*quarter + subregion*year	55476.5	55480.5	55484.4	495.5	<0.0001
YEAR + subregion + quarter + subregion*quarter + subregion*year + quarter*year	55292.8	55298.8	55304.7	183.7	<0.0001

Table 8. Commercial Spanish mackerel gillnet relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index in the South Atlantic.

YEAR	Normalized Nominal CPUE	Trips	Proportion Positive	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.420	1,761	0.758	0.618	0.262	1.458	0.450
1999	0.307	1,296	0.759	0.710	0.300	1.679	0.451
2000	0.272	1,469	0.741	0.696	0.295	1.640	0.449
2001	0.250	1,376	0.719	1.015	0.430	2.394	0.450
2002	0.262	1,394	0.755	0.860	0.365	2.026	0.449
2003	0.688	1,098	0.759	0.996	0.422	2.350	0.450
2004	0.312	1,139	0.705	0.923	0.391	2.180	0.450
2005	0.656	1,270	0.721	1.063	0.451	2.505	0.449
2006	0.977	1,545	0.766	1.281	0.545	3.012	0.448
2007	2.510	1,623	0.784	1.317	0.557	3.111	0.450
2008	2.567	1,338	0.708	1.494	0.636	3.511	0.448
2009	1.961	1,469	0.743	1.176	0.497	2.780	0.451
2010	1.819	1,142	0.690	0.852	0.357	2.030	0.455

Figure 1. Coastal Logbook defined fishing areas.

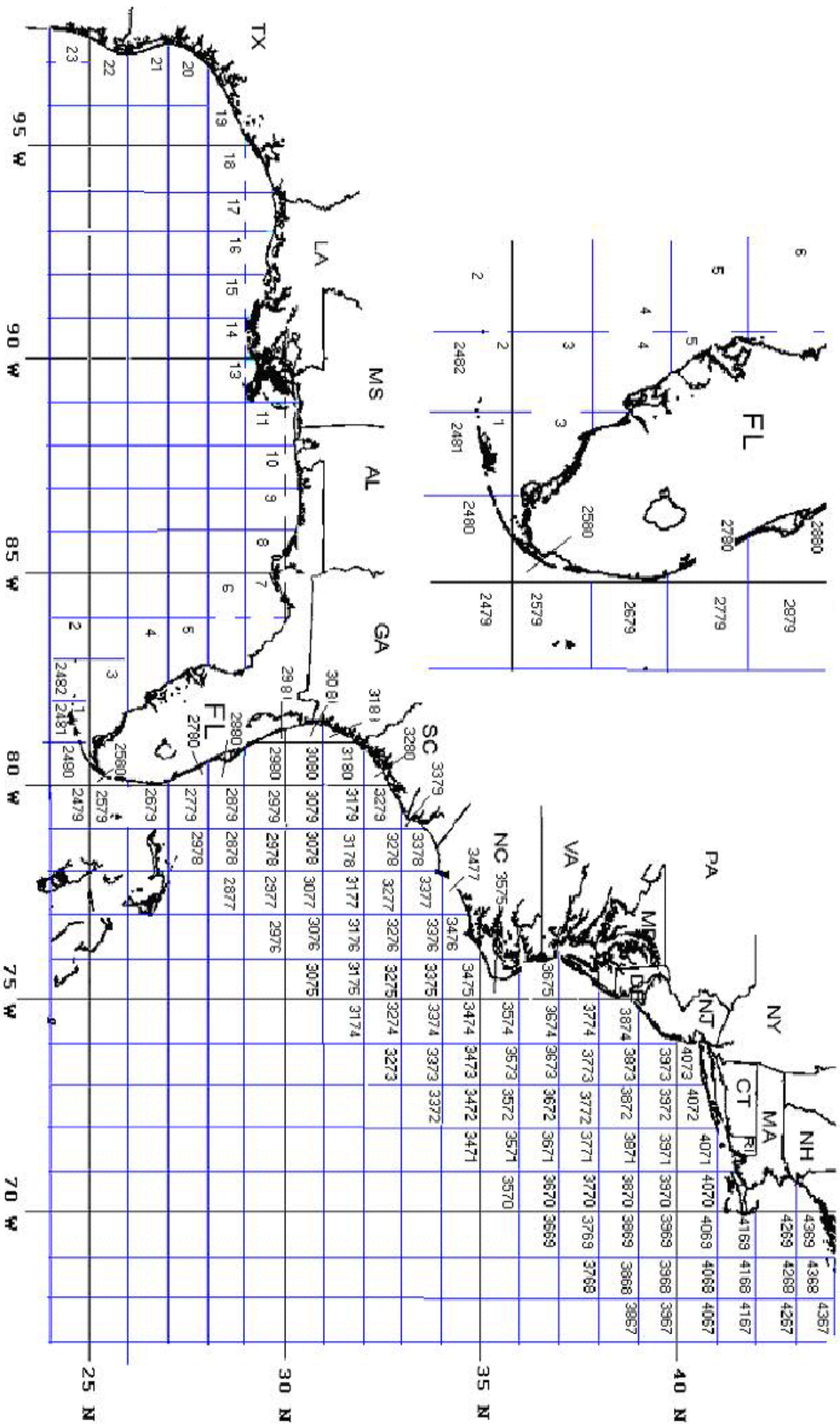
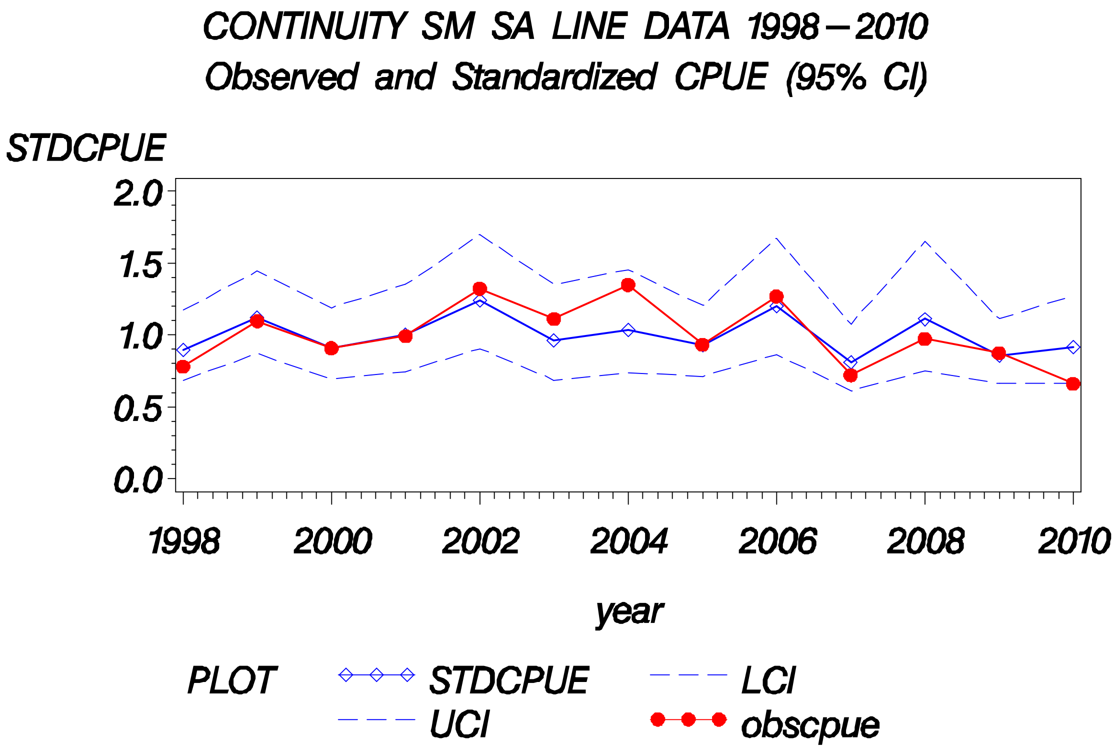


Figure 2. A. Spanish mackerel nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial handline and trolling fishing vessels in the South Atlantic; continuity index. CPUE = pounds Spanish mackerel/hook hour fished.

A.



B. Comparison of Spanish mackerel handline and trolling indices constructed for SEDAR 17 and SEDAR 28.

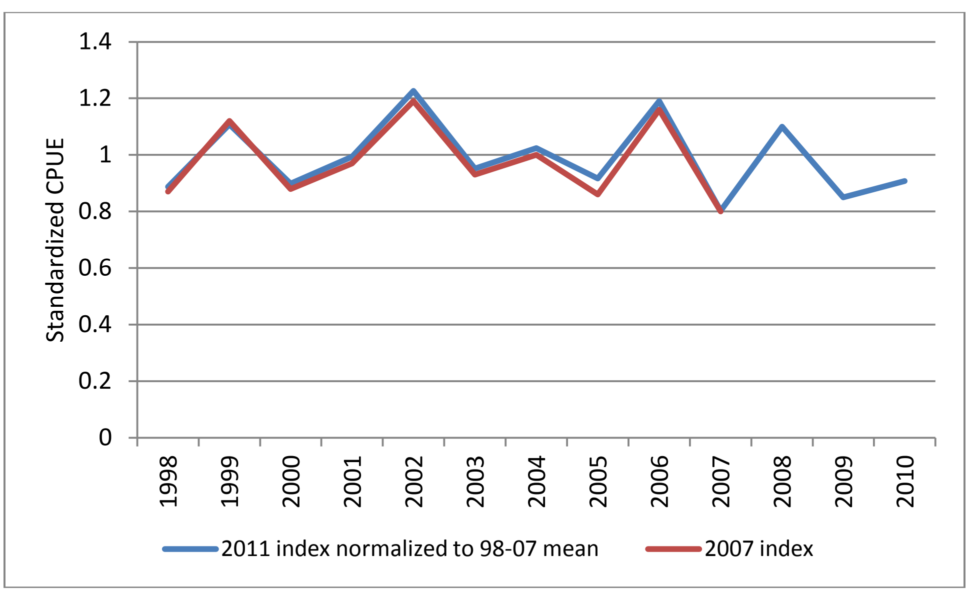


Figure 3. 1998-2010 time series annual trends in nominal CPUE (pounds/hook hour fished) of the South Atlantic Spanish mackerel commercial handline and trolling data; continuity index.

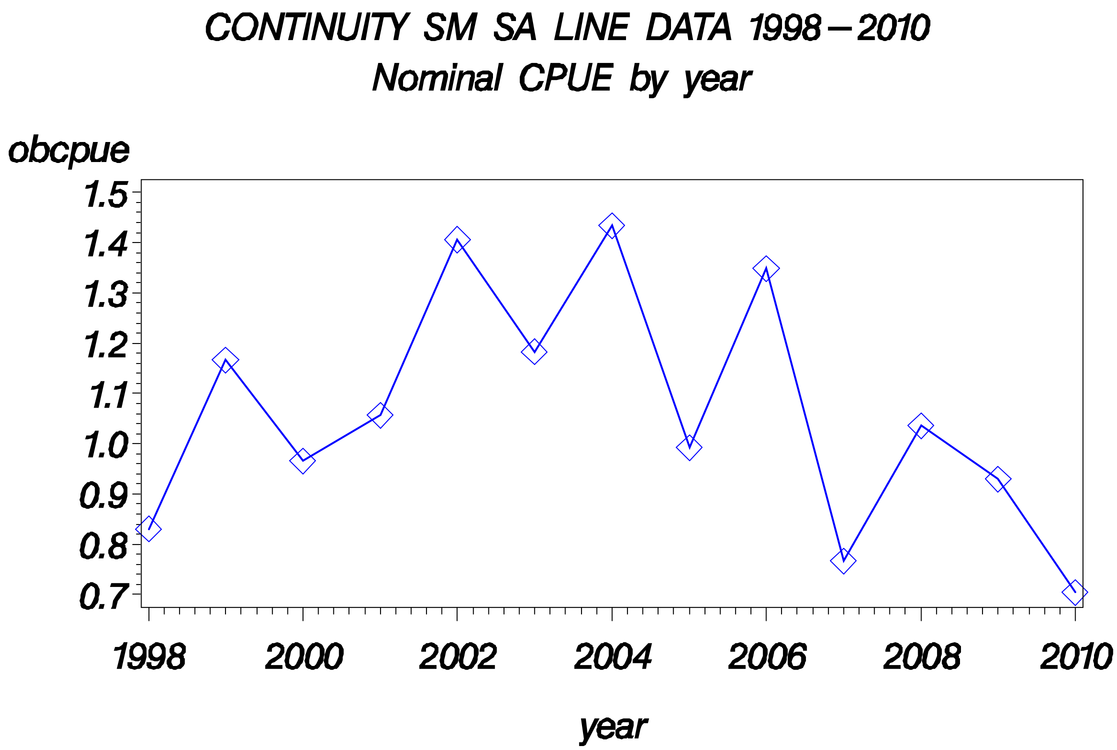
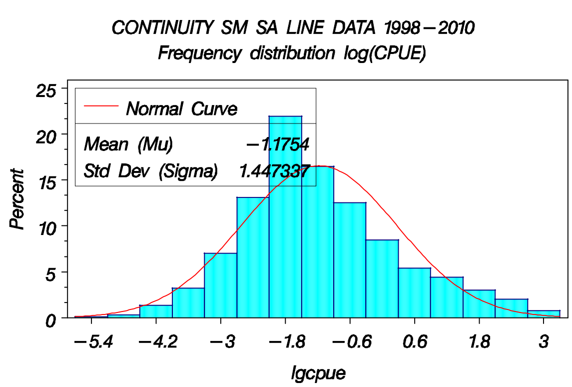


Figure 4. Diagnostic plots for the lognormal component of the South Atlantic 1998-2010 Spanish mackerel commercial handline and trolling gear model (continuity index): **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

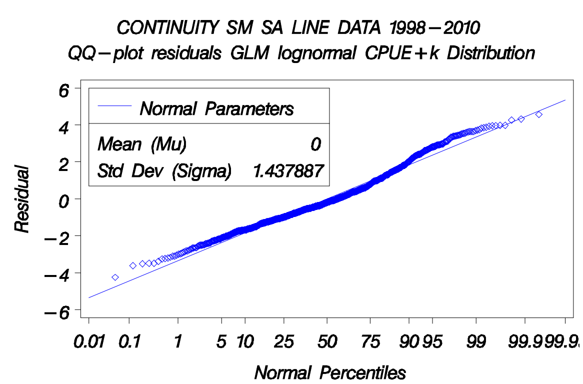
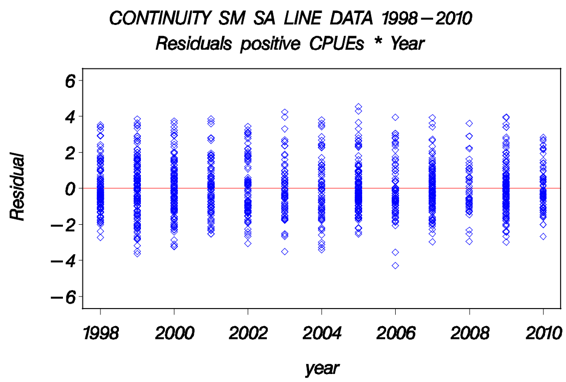
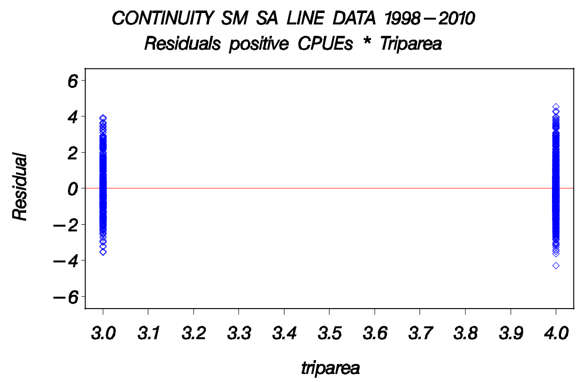


Figure 5. Diagnostic plots of the South Atlantic 1998-2010 Spanish mackerel commercial handline and trolling lognormal model (continuity index): **A**. the Chi-square residuals by year; **B**. the Chi-square residuals by triparea (subregion); and **C**. the Chi-square residuals by gear fished.

A.



B.



C.

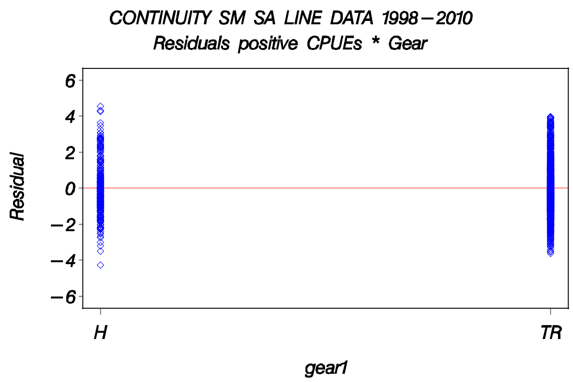


Figure 6. Spanish mackerel nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial handline and trolling fishing vessels in the South Atlantic. CPUE = pounds Spanish mackerel/hook hour fished.

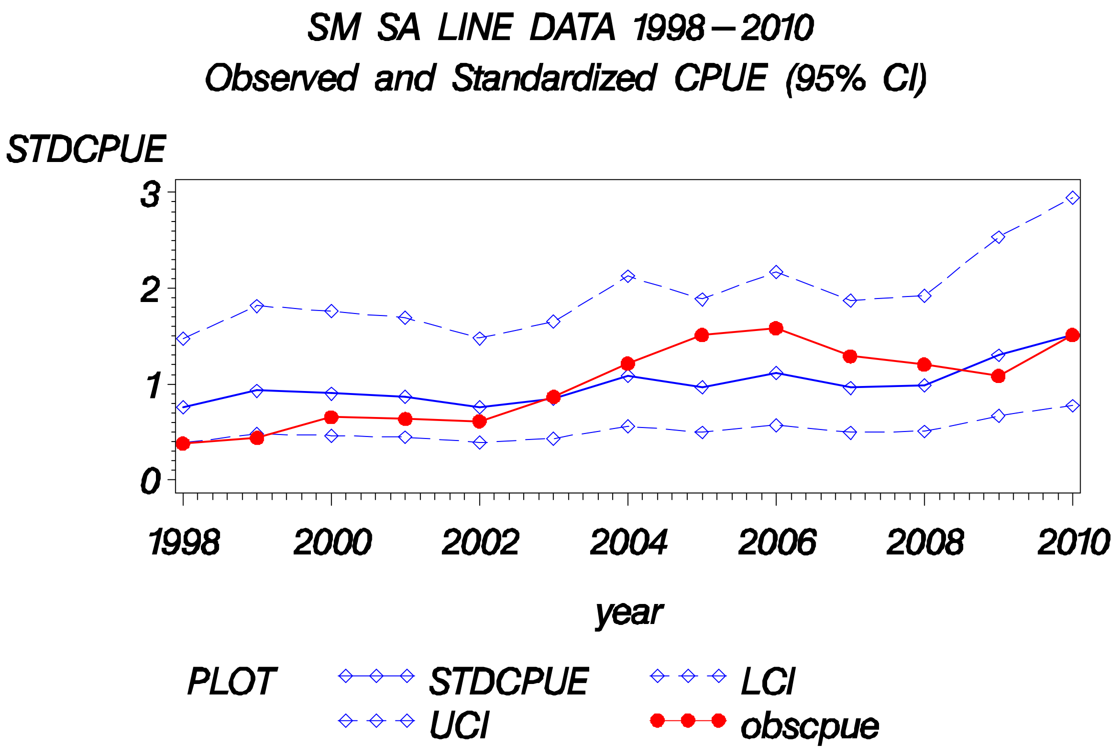


Figure 7. 1998-2010 time series annual trends in nominal CPUE (pounds/hook hour fished) of the South Atlantic Spanish mackerel commercial handline and trolling data.

A.

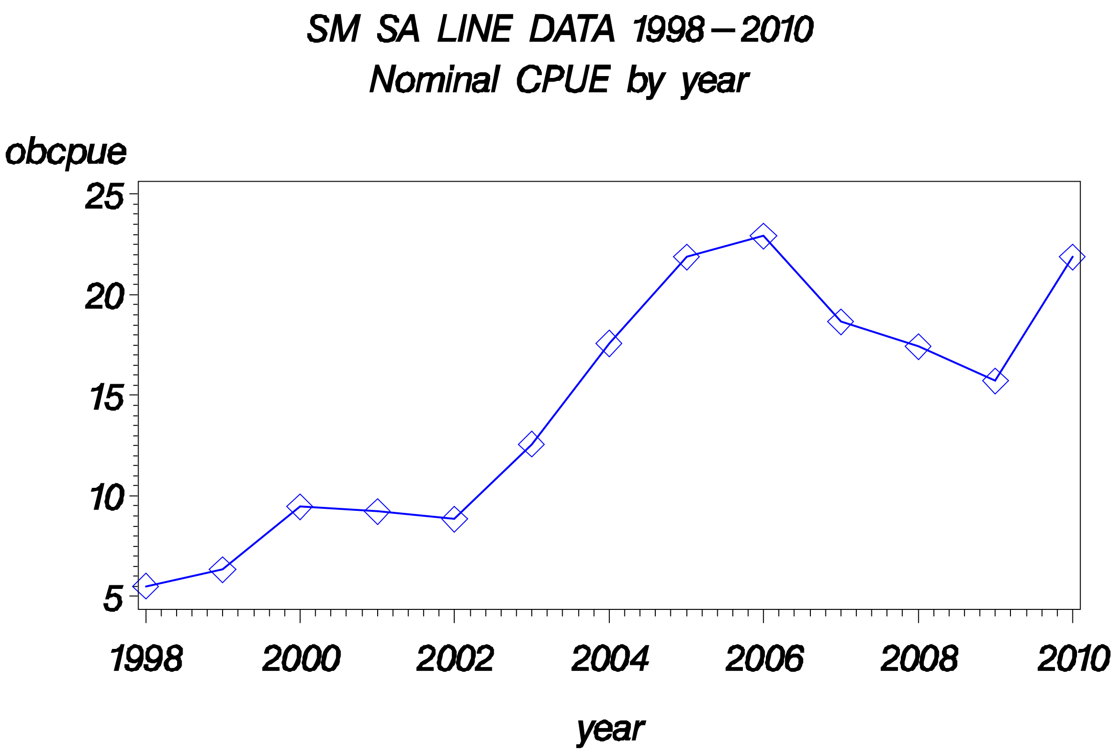
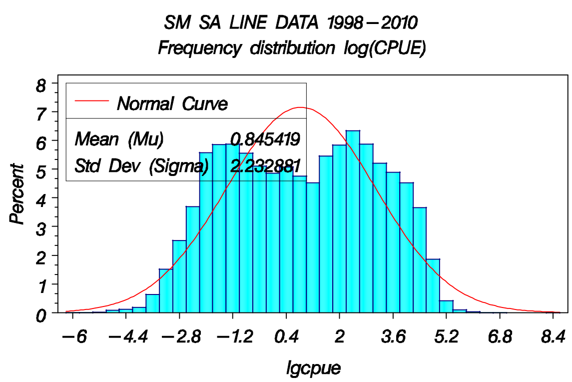


Figure 8. Diagnostic plots for the lognormal component of the South Atlantic 1998-2010 Spanish mackerel commercial handline and trolling gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

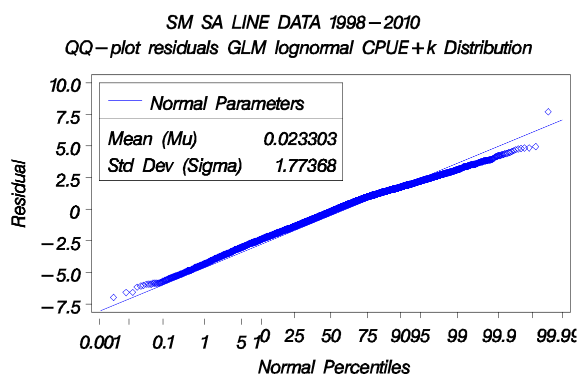
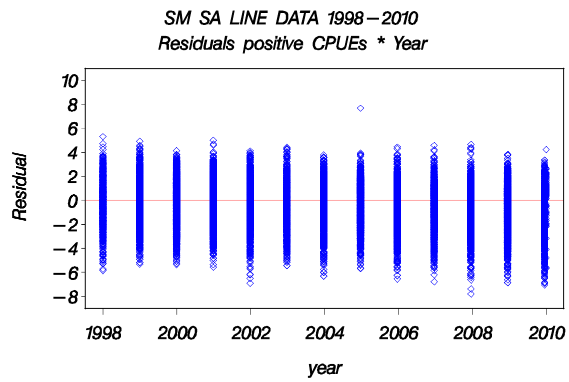
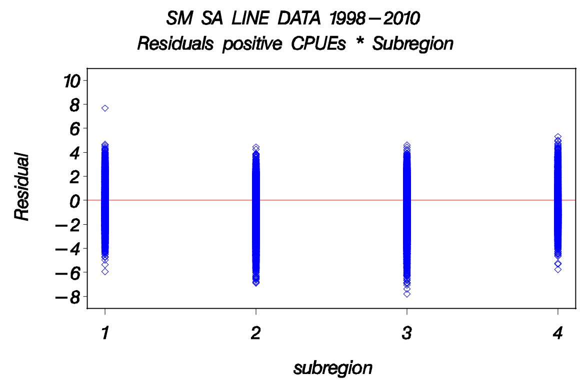


Figure 9. Diagnostic plots of the South Atlantic 1998-2010 Spanish mackerel commercial handline and trolling lognormal modelx: **A**. the Chi-square residuals by year; **B**. the Chi-square residuals by subregion; **C**. the Chi-square residuals by quarter; and **D**. the Chi-square residuals by gear1 (handline or trolling.

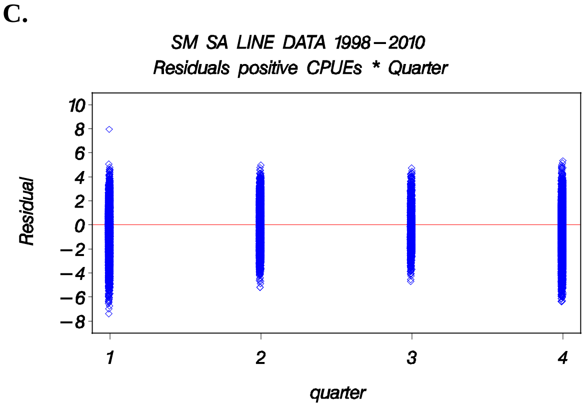
A.



B.



C.



D.

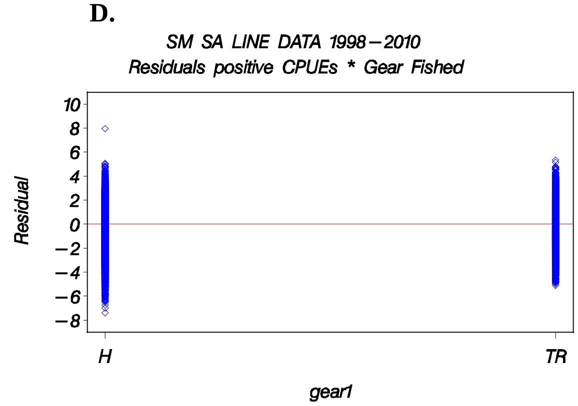
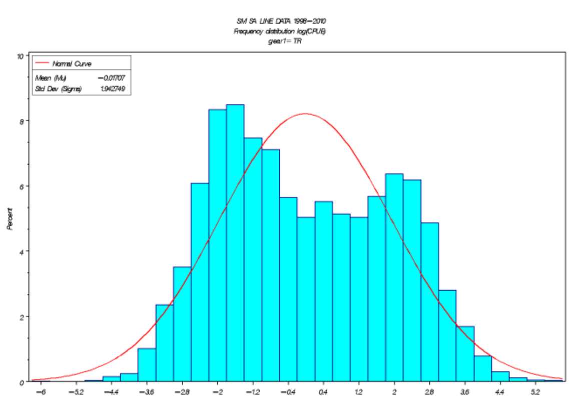


Figure 10. Diagnostic plots for the lognormal component of the South Atlantic 1998-2010 Spanish mackerel commercial handline and trolling gear model: **A.** the frequency distribution of log(CPUE) on positive trolling trips, **B.** the frequency distribution of log(CPUE) on positive trolling trips.

A.



B.

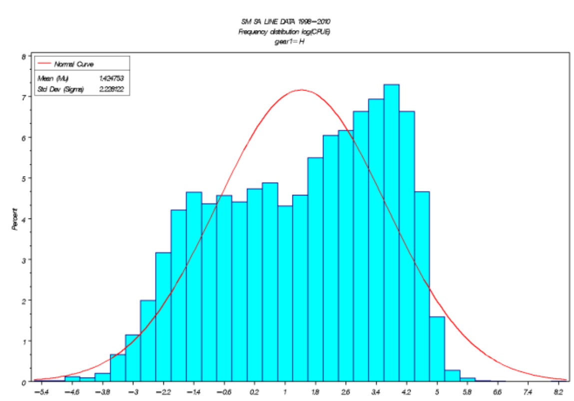
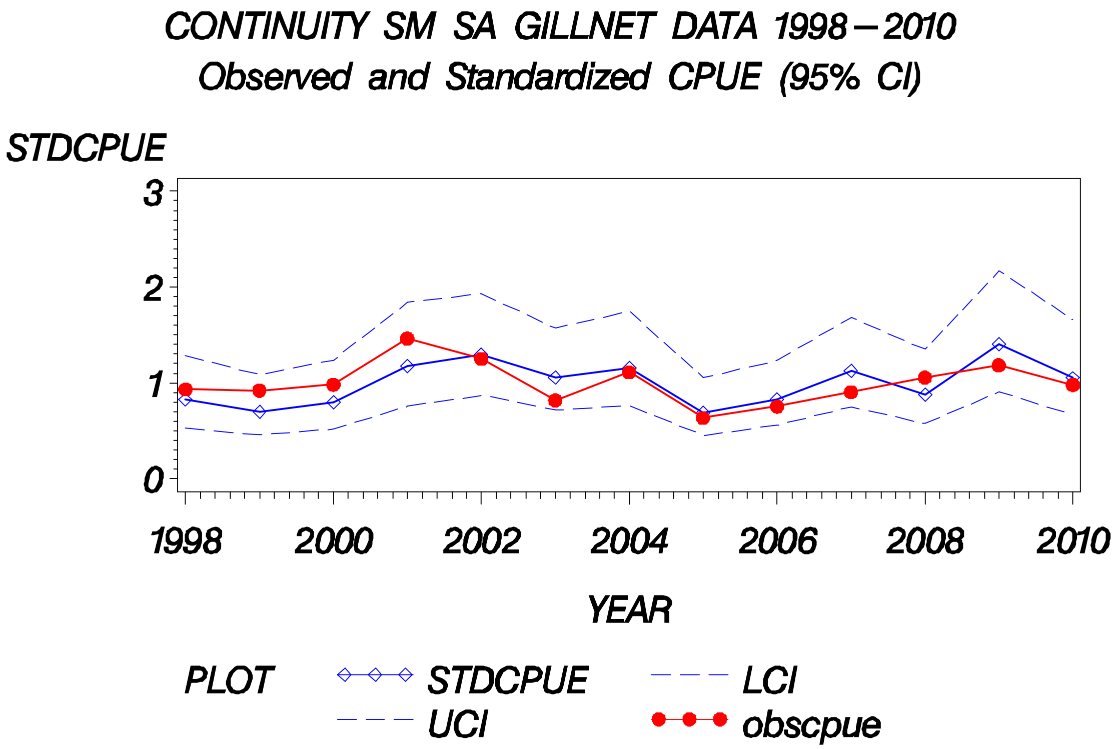


Figure 11. **A.** Spanish mackerel nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial gillnet fishing vessels in the South Atlantic (continuity index). CPUE = pounds Spanish mackerel per square yard hour of gillnet fished. **B.** Comparison of Spanish mackerel gillnet indices constructed for SEDAR 17 and SEDAR 28.

A.



B.

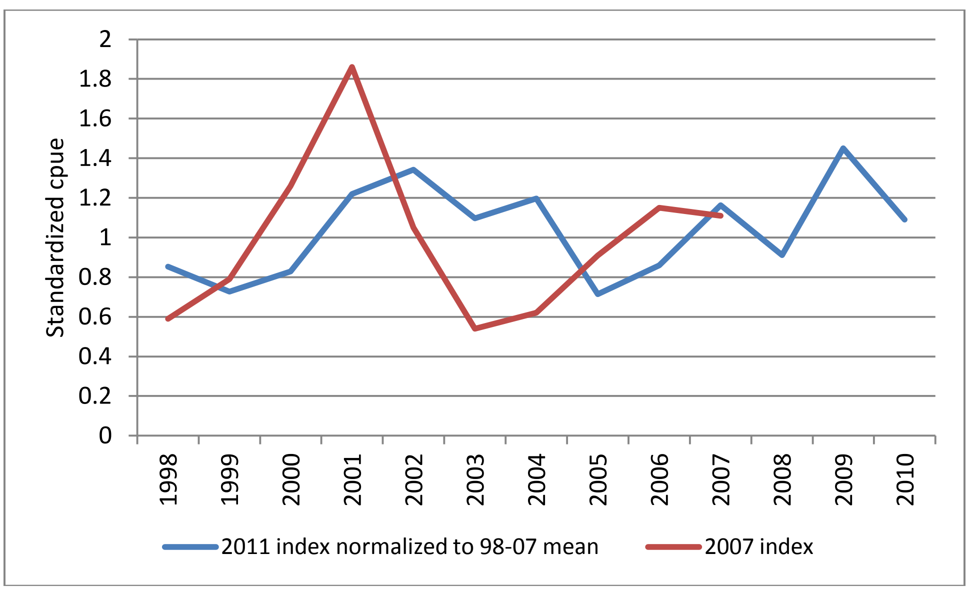


Figure 12. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE of the South Atlantic 1998-2010 commercial gillnet fishery (continuity index).

A. **B.**

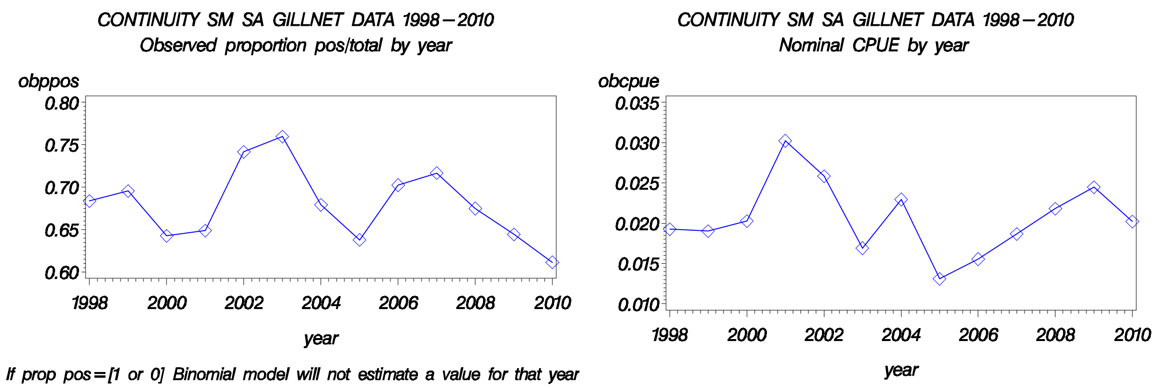


Figure 13. Diagnostic plots for the binomial component of the South Atlantic 1998-2010 commercial gillnet model (continuity index): **A**. the Chi-square residuals by year and **B**. the Chi-square residuals by triparea (subregion).

A. **B.**

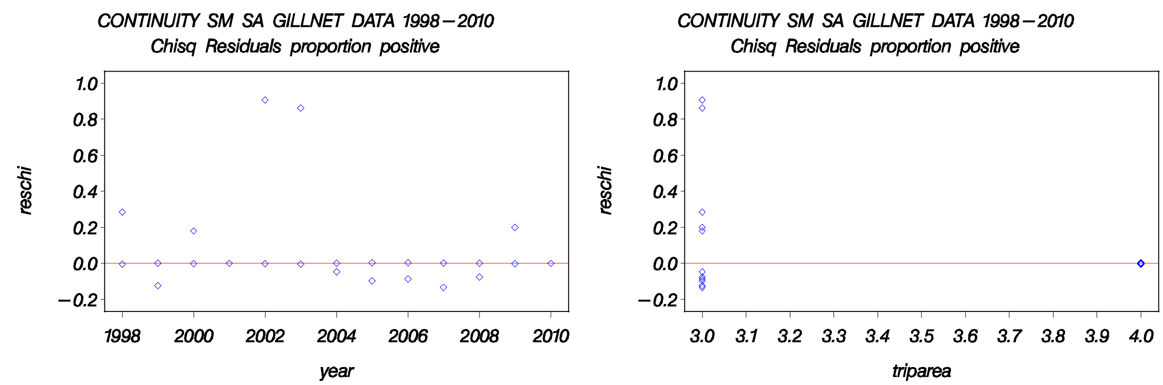
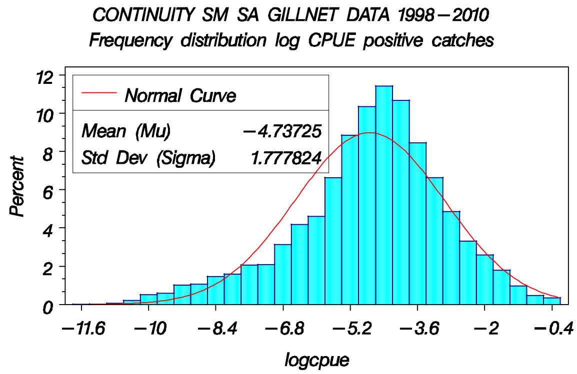


Figure 14. Diagnostic plots for the lognormal component of the South Atlantic 1998-2010 commercial gillnet model (continuity index): **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

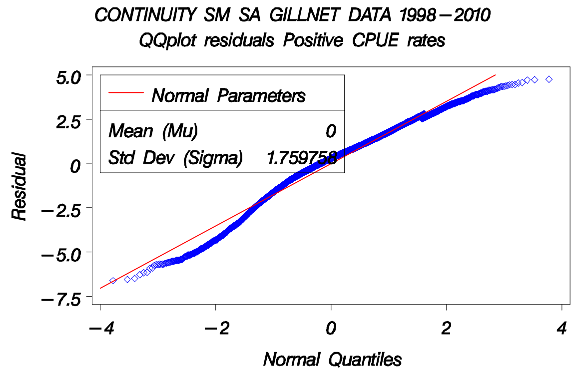
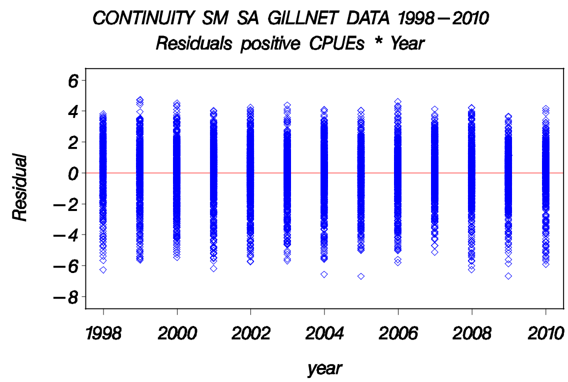


Figure 15. Diagnostic plots for the lognormal component of the South Atlantic 1998-2010 commercial gillnet model: **A**. the Chi-square residuals by year; **B**. the Chi-square residuals by subregion; and **C**. the Chi-square residuals by days at sea.

A.



B.

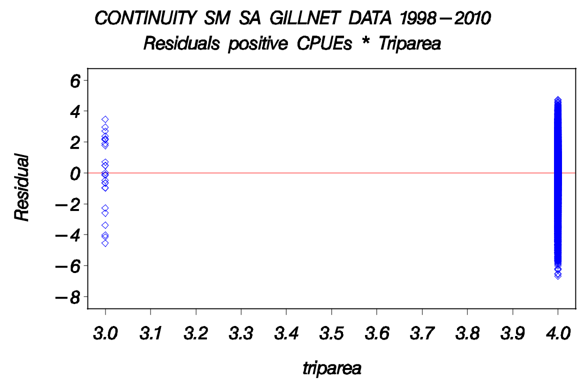


Figure 16. Spanish mackerel nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial gillnet fishing vessels in the South Atlantic. CPUE = pounds Spanish mackerel per square yard hour of gillnet fished.

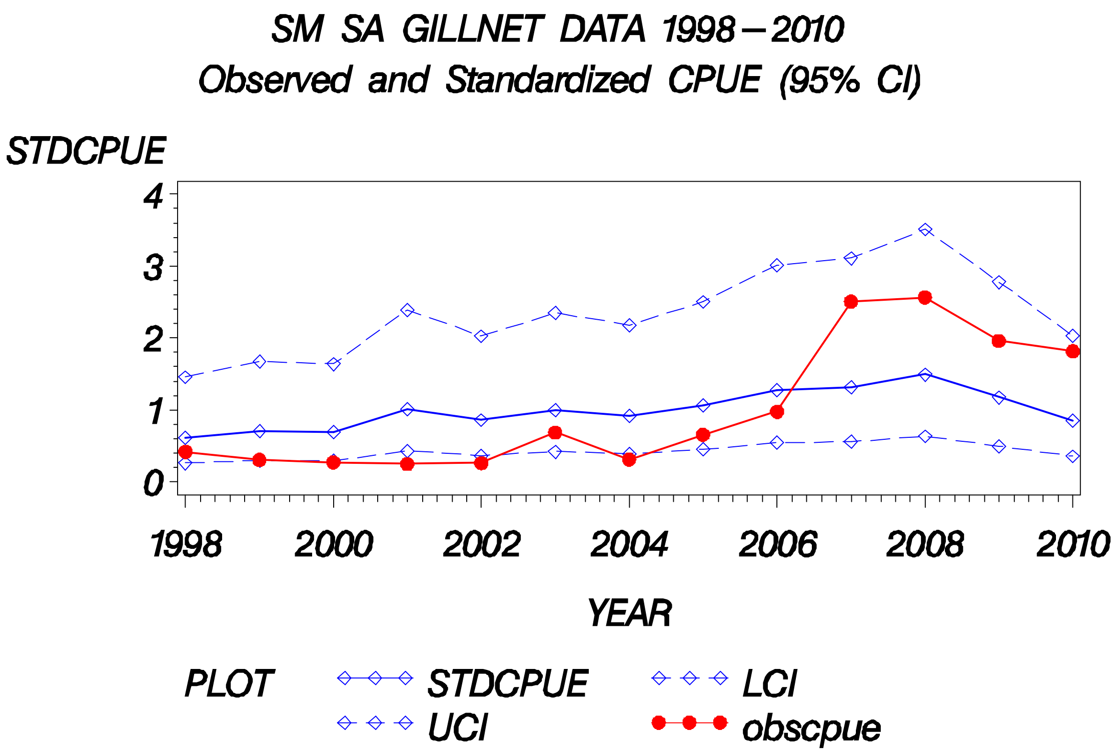
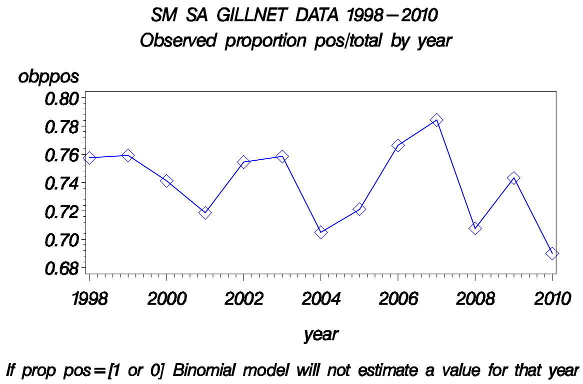


Figure 17. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE of the South Atlantic 1998-2010 commercial gillnet fishery.

A.



B.

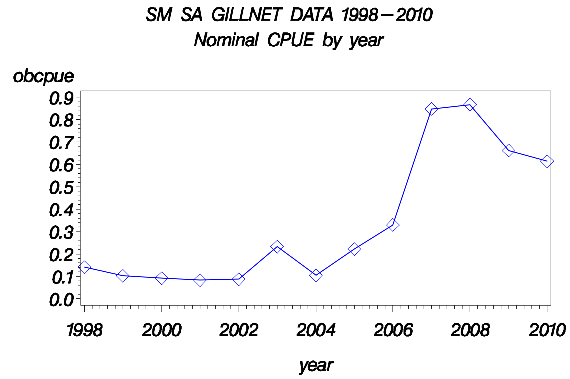
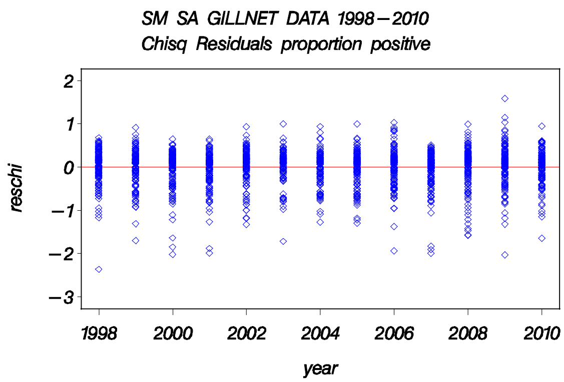
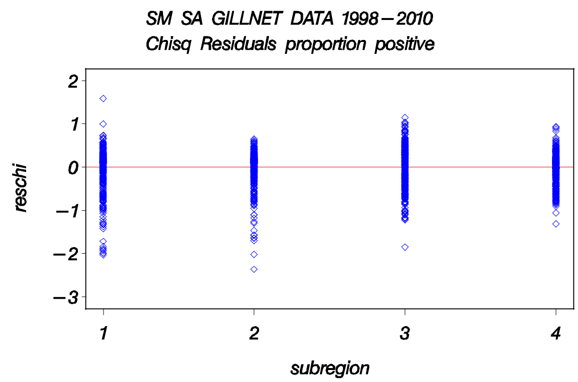


Figure 18. Diagnostic plots for the binomial component of the South Atlantic 1998-2010 commercial gillnet model: **A**. the Chi-square residuals by year and **B**. the Chi-square residuals by triparea (subregion).

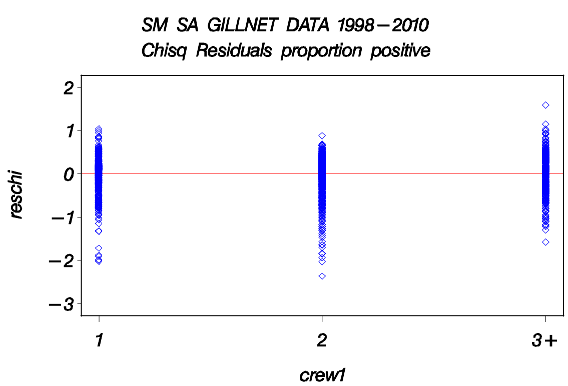
A.



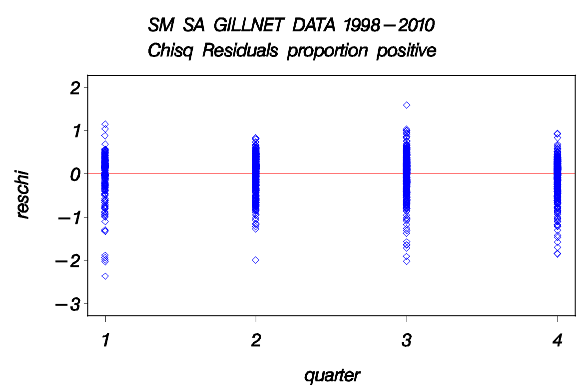
B.



C.



D.



E.

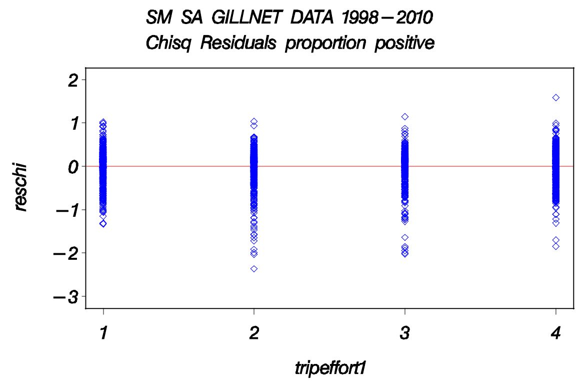
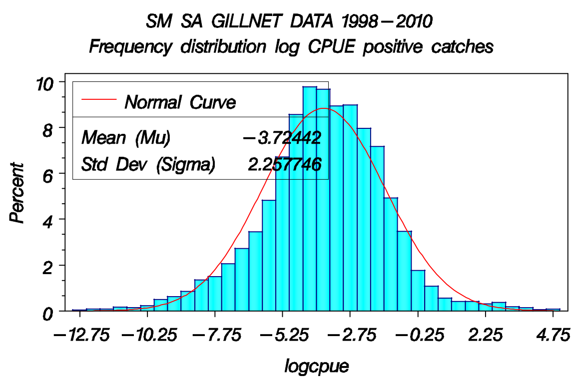


Figure 19. Diagnostic plots for the lognormal component of the South Atlantic 1998-2010 commercial gillnet model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

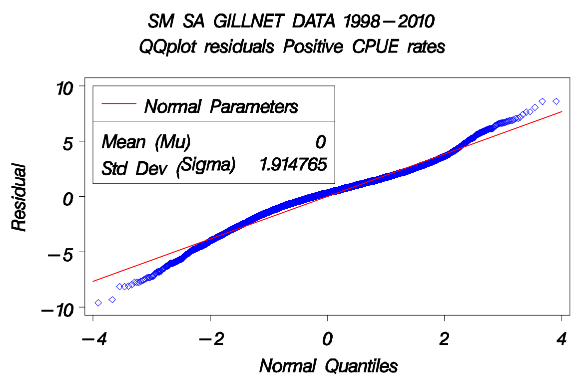
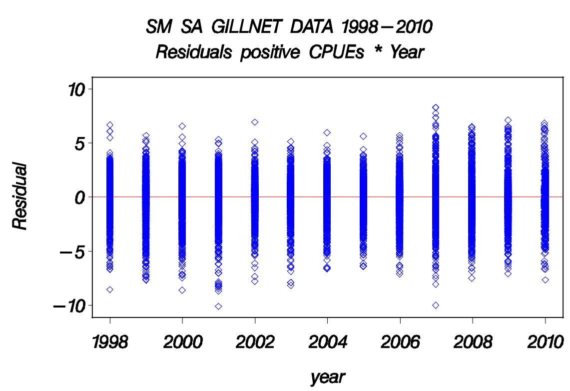
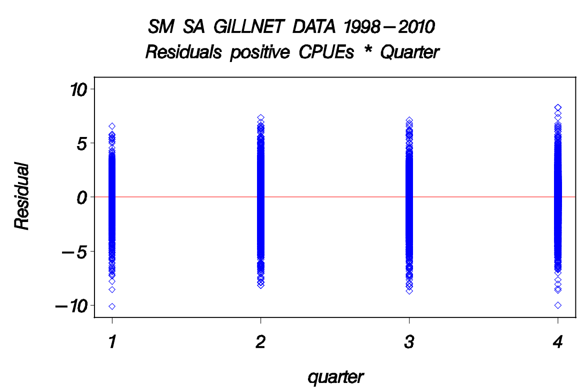


Figure 20. Diagnostic plots for the lognormal component of the South Atlantic 1998-2010 commercial gillnet model: **A**. the Chi-square residuals by year; **B**. the Chi-square residuals by subregion; and **C**. the Chi-square residuals by days at sea.

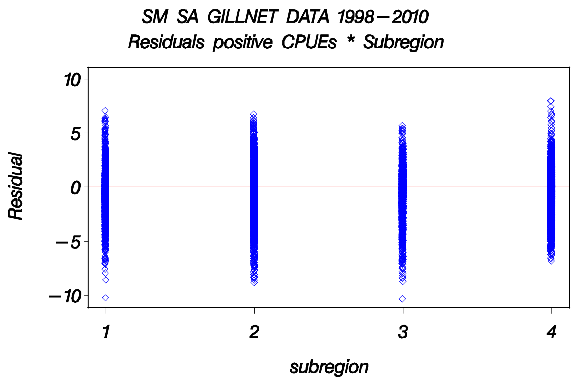
A.



B.



C.


SM SA GILLNET DATA 1998–2010
Residuals positive CPUEs * Subregion
Residual
10
5
0
−5
−10
1
2
3
4
subregion

Standardized Catch Rates of Spanish Mackerel from Commercial Handline, Trolling, and Gillnet Fishing Vessels in the US South Atlantic, 1998-2010 : ADDENDUM

Kevin McCarthy

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

Sustainable Fisheries Division Contribution SFD-2012-007

Introduction

South Atlantic fisheries dependent indices of abundance were constructed using self-reported commercial hook and line (handline, electric/hydraulic reel, and trolling) and gillnet commercial logbook data (SEDAR28-DW-17). The data workshop recommendation, however, was to use the Florida trip ticket hook and line index as an input to the assessment model. In addition, commercial logbook gillnet indices constructed for the data workshop were believed to exhibit hyperstability and, therefore, did not track trends in Spanish mackerel population abundance.

During the SEDAR 28 data workshop it was recommended additional indices be constructed using commercial logbook data from hook and line vessels reporting landings and effort data between 31^{o}N and 37^{o}N latitude in the South Atlantic. The additional index was requested to examine possible differences in cpue trends between a Florida only index and an index constructed using data from Georgia through North Carolina. An additional gillnet index was recommended for construction by the working group following the suggestion that gillnets fished in the region 27^{o}N to 29^{o}N latitude during the months of September-November were passively fished. An index constructed from catch rates of passively fished gear, it was suggested, may provide a good measure of population abundance during the period when much of the South Atlantic population of Spanish mackerel migrates into the region off east central Florida. It was believed that an index constructed using those data may not exhibit the hyperstability suspected of the gillnet index constructed for the entire South Atlantic.

Methods

Data description and filtering methods are described in SEDAR28-DW-17. The gillnet data were additionally limited to those reported from fishing trips that occurred during September to November in the region 27^{o}N to 29^{o}N latitude. Gillnet index construction followed the methods reported in SEDAR28-DW-17 for the 2012 gillnet index. Factors considered as possible influences on gillnet proportion of trips that landed Spanish mackerel and the catch rate of Spanish mackerel were unchanged from that initial index except month replaced quarter, subregion was redefined as 27-28^{o}N and 28-29^{o}N latitudes, and trip effort was categorized as <3,601, 3,601-6,400, 6,401-14,000, and >14,000 net square yard hours fished. Data from one gillnet vessel was excluded from the analysis because the gear used was likely cast net rather than gillnet.

Results and Discussion

The data available for the requested commercial hook and line index differed little from the data included in the hook and line continuity index described in SEDAR28-DW-17. Only 0.8 percent of the trips included in the data set used to construct the continuity index would have been excluded from the new hook and line index requested by the index working group. Such a minor change in the data would likely have resulted in very little change from the continuity index, therefore, a new hook and line index was not constructed. The continuity hook and line index is shown in SEDAR28-DW-17 Figure 2.

The requested gillnet index was constructed. The final models for the binomial on proportion positive gillnet trips (PPT) and the lognormal on CPUE of successful gillnet trips were:

PPT = Trip effort + Year + Month + Crew + Month*Crew

LOG(CPUE) = Month + Year + Month*Year

The linear regression statistics and analysis of the mixed model formulations of the final models are summarized in Table 1A.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index are provided in Table 2A. The delta-lognormal abundance index developed, with 95% confidence intervals, is shown in Figure 1A. Also plotted is the initial 2012 South Atlantic, including Florida, Spanish mackerel gillnet index described in SEDAR28-DW-17.

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 2A-5A. There were outliers among the data. That was particularly evident in the binomial Chi-square residual plots. In addition, the distribution of log(cpue) on positive trips was slightly skewed from a normal distribution. Of more concern was the very high (89 to 98%) observed proportion of positive Spanish mackerel trips. Estimates of the variance around calculated yearly mean cpues may be inaccurate with such high proportion positive trips.

The trend in yearly mean cpue observed in the requested gillnet index differed from that in the original 2010 south Atlantic gillnet index. Nevertheless, the original gillnet index yearly mean cpues fall within the 95 percent confidence intervals of the new index. The new index was more variable among years, but had no long-term increase or decrease in yearly mean cpue. The original south Atlantic gillnet index was much less variable among years and had an apparent increase in yearly mean cpue during the period 1998-2008 with a decline in cpue during the final two years of the time series. The 95 percent confidence intervals around the initial (whole South Atlantic) index were large, however, suggesting limited support for that trend. As with any fishery dependent index of abundance, changes in fisher behavior may have a greater affect on the analysis than does change in fish population abundance. It is unclear if the large fluctuations in the South Atlantic central Florida index represent interannual variation in population abundance or changes in fisher behavior. Change in the behavior of a few fishers in this spatially and temporally limited index may have had a large impact on the observed cpues. Fisher behavior in this fishery has not been fully investigated.

Table 1A. Linear regression statistics for the GLM models on proportion positive trips (**i**) and catch rates on positive trips (**ii**) of Spanish mackerel in the South Atlantic central Florida region for vessels reporting gillnet landings during 1998-2010. Analysis of the mixed model formulations of the positive trip model (**iii**). 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 of SEDAR28-DW-17 for factor (effect) definitions.

i.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
Year	12	329	22.91	1.91	0.0285	0.0324
tripeffort	3	329	19.31	6.44	0.0002	0.0003
Month	2	329	19.23	9.62	<.0001	<.0001
crew	2	329	14.96	7.48	0.0006	0.0007
*month*crew*	4	329	12.85	3.21	0.0120	0.0132

ii.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	12	24	21.47	1.79	0.0439	0.1088
month	2	24	53.61	26.81	<.0001	<.0001

iii.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Year + month	11120.3	11122.3	11128.3	-	-
*Year + month + year*month*	11064.1	11068.1	11071.4	56.2	<0.0001

Table 2A. Gillnet relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for Spanish mackerel (1998-2010) in the South Atlantic central Florida region.

Year	Relative Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	1.494	406	0.923	1.093	0.552	2.162	0.351
1999	0.858	212	0.922	0.646	0.321	1.299	0.360
2000	0.872	215	0.964	1.358	0.680	2.711	0.356
2001	0.619	199	0.917	0.665	0.332	1.331	0.358
2002	0.702	198	0.985	1.225	0.615	2.440	0.355
2003	1.631	154	0.975	1.556	0.772	3.133	0.361
2004	0.717	110	0.982	0.441	0.216	0.899	0.368
2005	0.747	179	0.962	1.163	0.580	2.331	0.358
2006	1.359	244	0.976	1.444	0.727	2.866	0.353
2007	0.831	329	0.976	1.146	0.581	2.260	0.350
2008	1.142	171	0.886	0.694	0.341	1.414	0.367
2009	1.223	180	0.973	0.773	0.389	1.540	0.355

Figure 1A. Spanish mackerel standardized CPUE from the South Atlantic central Florida gillnet fishery (solid blue line) with upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) and the full South Atlantic standardized CPUE series (solid red line) constructed for the data workshop.

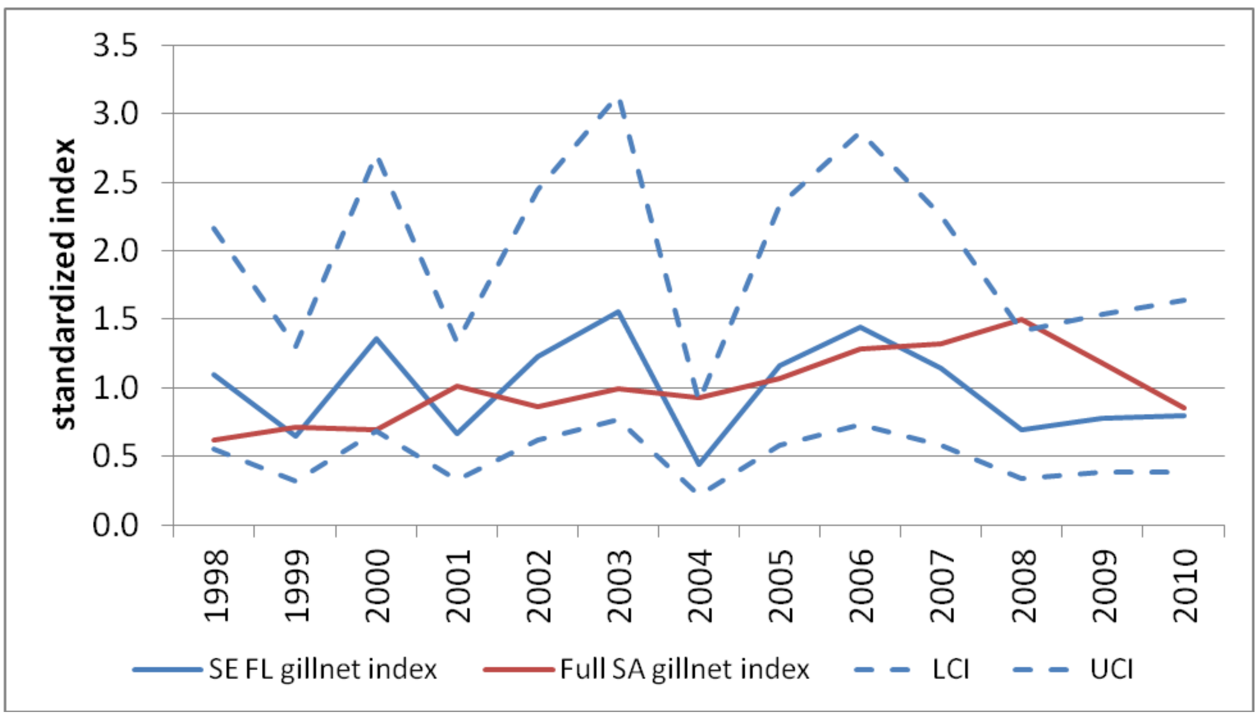
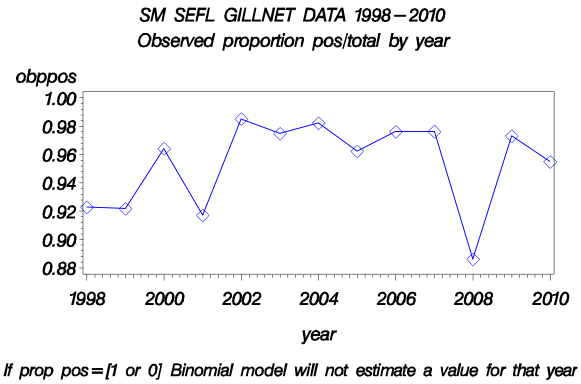


Figure 2A. Annual trend in **i.** the proportion of positive trips and **ii.** nominal CPUE for the South Atlantic central Florida 1998-2010 Spanish mackerel commercial gillnet model.

i.



ii.

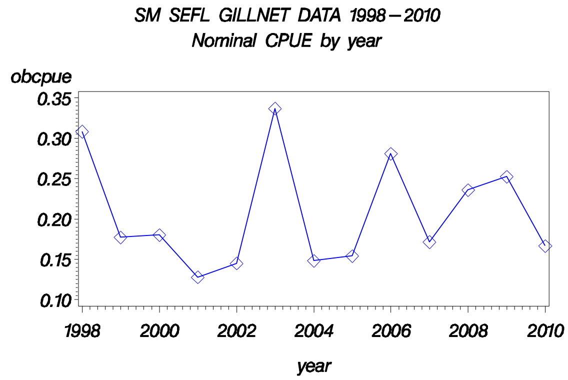
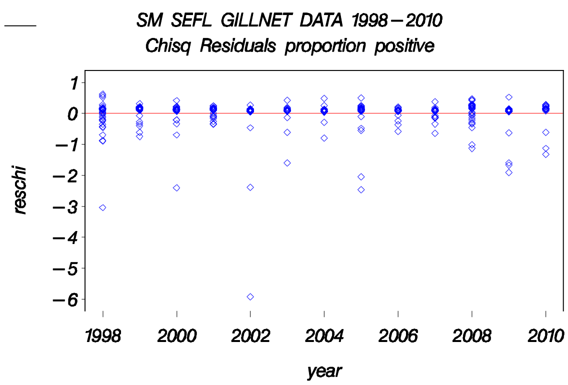
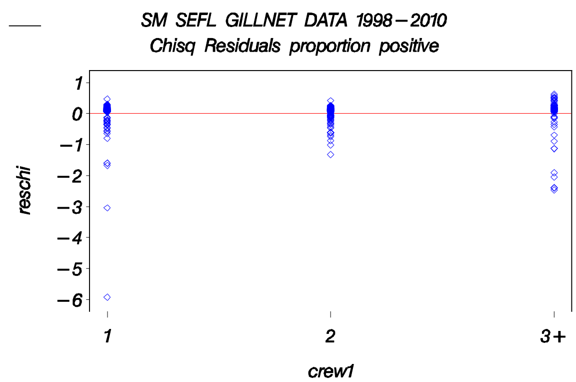


Figure 3A. Diagnostic plots for the binomial component of the South Atlantic central Florida 1998-2010 Spanish mackerel commercial gillnet model: **i**. the Chi-Square residuals by year; **ii**. the Chi-Square residuals by number of crew; **iii**. the Chi-Square residuals by month; and **iv**. the Chi-Square residuals by effort (net square yard hours fished). See SEDAR28-DW-17 for factor descriptions.

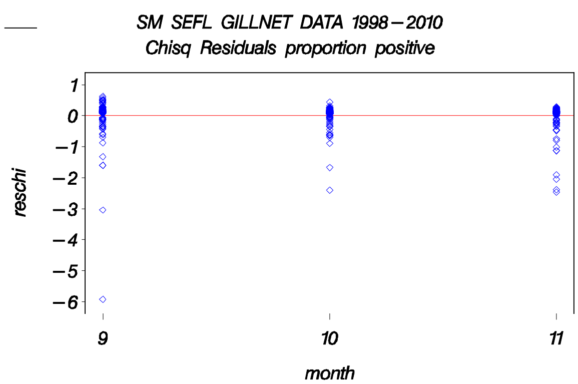
i.



ii.



iii.



iv.

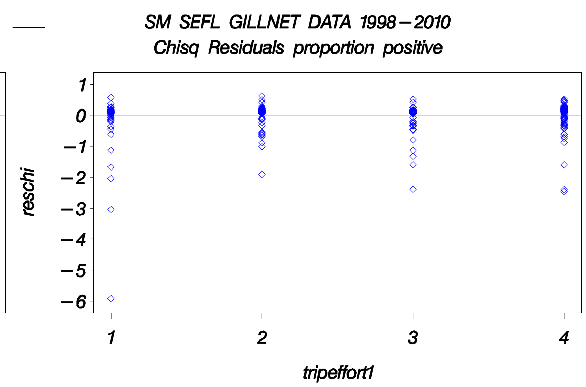
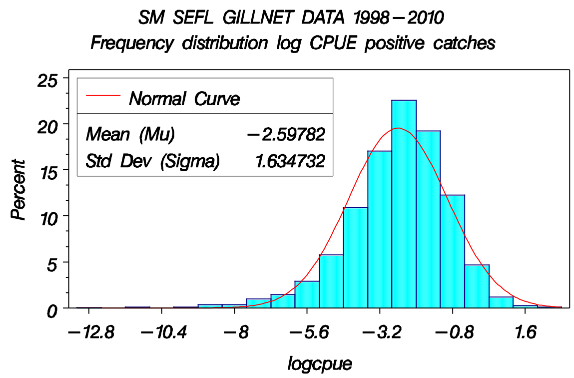


Figure 4A. Diagnostic plots for the lognormal component of the South Atlantic central Florida 1998-2010 Spanish mackerel commercial gillnet model: **i.** the frequency distribution of log(CPUE) on positive trips, **ii.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

i.



ii.

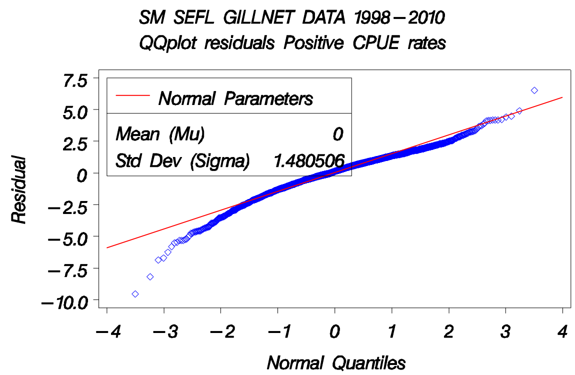
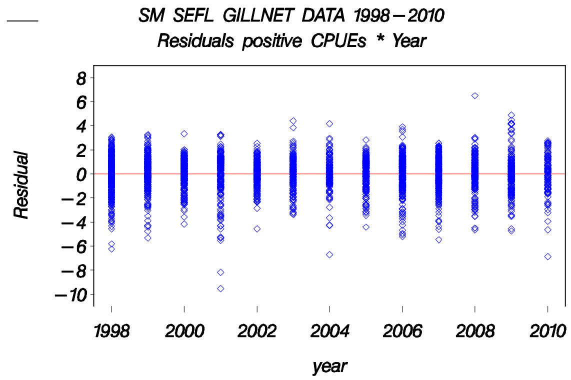


Figure 5A. Diagnostic plots for the lognormal component of the South Atlantic central Florida 1998-2010 Spanish mackerel commercial gillnet model: **i**. the Chi-Square residuals by year and **ii**. the Chi-Square residuals by month. See SEDAR28-DW-17 for factor descriptions.

i.



ii.