Addendum to SEDAR16-DW-22

Introduction

Six king mackerel indices of abundance, two for each region – Gulf of Mexico, South Atlantic, and Mixing Zone, were constructed for the SEDAR16 data workshop using coastal logbook commercial fishery data. The regulatory history of the king mackerel commercial fishery was not available until the data workshop began, therefore, possible effects of regulatory measures were not considered in the construction of those initial indices. In addition, reporting king mackerel landings to the coastal logbook program was not required prior to 1998. The effect of that underreporting on the initial indices was unknown.

The indices working group recommended several revisions to the commercial logbook indices. These included:

Account for regulatory measures in the construction of commercial indices:

Ignore minimum size regulations – this will be accounted for in the population model
Exclude data from closed seasons
Examine effects of trip limits on fishing effort and determine the feasibility of index construction

Treat individual vessels as repeated measures in the analyses to address possible differences in catch per unit effort (CPUE) among vessels that had reported landings and effort throughout the time series and vessels that provided landings and effort only after reporting became mandatory in 1998.

Revised indices, incorporating the SEDAR 16 data workshop recommendations were constructed using the available coastal logbook CPUE series, from 1993 - 2006. Separate indices were developed for the Gulf of Mexico, South Atlantic, and the king mackerel "Mixing Zone".

Methods

Effects of regulations

Examination of the effects of regulatory trip limits on index construction is described in SEDAR16-AW-02. As part of that analysis, trips were categorized by the percentage of king mackerel (by weight) in the trip landings. That categorization was used as a proxy for targeting and was used as a factor in the revised indices. Based upon examination of the regulatory effects, only the 25 fish per trip limit in the Mixing Zone was assumed to effect index construction. Landings and effort data reported from the Mixing Zone during periods with a 25 fish per trip limit were, therefore, excluded from the analysis. In addition, data from periods when the king mackerel fishery was closed were also excluded. No other data restrictions were made due to regulatory measures.

Available data

For each fishing trip, the coastal logbook database includes 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 (for hook and line fisheries: number of lines fished, number of hooks per line and estimated total fishing time), species caught and whole weight of the landings. 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. Only data from hook and line fisheries were used in these analyses.

Hook and line catch rate was calculated in weight of fish per hook-hour. For each trip, CPUE was calculated as:

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

Three regions were defined (Figure 1) in the analyses. The Gulf of Mexico included all areas from southwest Florida to Mexico other than areas 1-3. The south Atlantic was defined as the area north of 30° N to 37° N. The "Mixing Zone" was defined as the area south of 30° N to 24° N in the south Atlantic and including Gulf of Mexico fishing areas 1-3.

Data used in constructing the commercial hook and line fishery indices of abundance were limited to catch and effort reported from vessels that together accounted for the highest 80% of the reported hook and line gear landings of king mackerel over the period 1993-2006. The selection of vessels was made for each region by ordering all vessels firstly by the number of years each reported king mackerel landings in the region and secondly by the vessel's total king mackerel landings from the region. For example, vessels that reported king mackerel landings in 14 years during 1993-2006 in the Mixing Zone were ordered by their total reported king mackerel landings in the Mixing Zone followed by vessels that reported king mackerel landings in 13 years. Vessels were added to a region-specific data set until 80% of the total king mackerel landings from a region were accounted for by the landings reported by those included vessels. Once the vessel list for each region was defined, all hook and line gear trips within each region reported by the selected vessels were considered potential king mackerel trips and were included in the analyses.

Clear outliers in the data, i.e. values falling outside the 99.5 percentile of the data, were excluded from the analyses. These included data from trips reporting more than seven lines fished, 20 hooks per line fished, or more than 10 days at sea.

Index Development

Ten factors were considered as possible influences on both the proportion of trips that landed king mackerel and the catch rate of king mackerel. In order to develop a well -balanced sample design, the ten factors were defined as:

Gulf of Mexico

Factor	Levels	Values
Year	14	1993-2006
Area	9	Gulf of Mexico shrimp grids 4-5, 6-7, 8, 9, 10-12, 13, 14-15, 16-17, 18-21 see Figure 1.
Days at sea (AWAY1)*	4	1, 2, 3, 4-10
Target	4	<25% of catch was king mackerel, 25-50%, 50-75%, >75%
Crew (CREW1)	4	1, 2, 3, or 4+ crew members
Vessel length (VES_LEN)	4	≤35 feet, >35 to 45, >45, unknown
Number of lines fished (NUMGEAR1)	4	1-2, 3, 4, 5-7
Number of hooks/line (EFFORT1)	5	1, 2, 3-10, 11-15, 16-20
Gear	2	Handline (includes electric reels), trolling
Hours fished (Hrs_fished)	6	≤6, >6-8, >8-12, >12-24, >24-48, >48

*Names in parentheses appear in some figures and tables.

Mixing Zone

Factor	Levels	Value
Year	14	1993-2006
Area*	10	Areas1-2 and 2482; 3; 2479-2480; 2481; 2575-2580; 2674-2679; 2680; 2777-2779; 2780-2781; 2842-2981 see Figure 1.
Days at sea (AWAY1)**	2	1, 2-10
Target	4	<25% of catch was king mackerel, 25-50%, 50-75%, >75%
Crew (CREW1)	2	1, 2+ crew members
Vessel length (VES_LEN)	5	≤25 feet, >25-30, >30 to 35, >35, unknown
Number of lines fished (NUMGEAR1)	4	1, 2, 3, 4-7
Number of hooks/line (EFFORT1)	2	1, 2-20
Gear	2	Handline (includes electric reels), trolling
Hours fished (Hrs_fished)	5	≤5, >5-7, >7-8, >8-10, >10

*Areas 1-2 and 2482 were combined.
**Names in parentheses appear in some figures and tables.

South Atlantic

Factor	Levels	Value
Year	14	1993-2006
Area	5	Areas 3075-3280; 3370-3379; 3470-3476; 3477-3478; 3570-3677 see Figure 1.
Days at sea (AWAY1)*	3	1, 2-3, 4-10
Target	4	<25% of catch was king mackerel, 25-50%, 50-75%, >75%
Crew (CREW1)	3	1, 2, 3+ crew members
Vessel length (VES_LEN)	4	≤30 feet, >30-35, >35, unknown
Number of lines fished (NUMGEAR1)	3	1-2, 3, 4-7
Number of hooks/line (EFFORT1)	3	1, 2, 3-20
Gear	2	Handline (includes electric reels), trolling
Hours fished (Hrs_fished)	6	≤6, >6-8, >8-12, >12-24, >24-48, >48

*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 generalized linear model (GLM) analyses of the proportion of successful trips (trips that landed king mackerel) 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 was calculated as: log(CPUE) = ln(pounds of king mackerel/hook-hours). All two-way interactions among significant main effects were 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. Higher order interaction terms were not examined.

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:

Gulf of Mexico 1993-2006:

PPT = GEAR + AREA + HOOKS/LINE + YEAR + LINES FISHED + VESSEL LENGTH + AREA*LINES FISHED + AREA*HOOKS/LINE + AREA*VESSEL LENGTH

LOG(CPUE) = TARGET + HOOKS/LINE + AREA + HOURS FISHED + LINES FISHED + VESSEL LENGTH + NUMBER OF CREW + YEAR + TARGET*HOURS FISHED + AREA*VESSEL LENGTH + AREA*YEAR + AREA*HOURS FISHED + AREA*LINES FISHED + HOOKS/LINE*AREA

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

Mixing Zone 1993-2006:

PPT = GEAR + AREA + LINES FISHED + GEAR*AREA + AREA*LINES FISHED

LOG(CPUE) = TARGET + LINES FISHED + HOOKS/LINE + AREA + YEAR + HOURS FISHED + VESSEL LENGTH + AREA*YEAR + AREA*HOURS FISHED

Year was included in the final binomial portion of the model. The linear regression statistics and analysis of the mixed model formulations of the final GLM models are summarized in Table 2.

South Atlantic 1993-2006:

PPT = GEAR + LINES FISHED + AREA + YEAR + HOOKS/LINE + AREA*HOOKS/LINE + AREA*YEAR

LOG(CPUE) = TARGET + HOOKS/LINE + HOURS FISHED + LINES FISHED + AREA + TARGET*HOURS FISHED + HOOKS/LINE*AREA + LINES FISHED*AREA

Year was included in the final lognormal portion of the model. The linear regression statistics and analysis of the mixed model formulations of the final GLM models are summarized in Table 3.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 4 for Gulf of Mexico king mackerel, Table 5 for the Mixing Zone, and Table 6 for the south Atlantic. The delta-lognormal abundance indices developed for each region and time series, with 95% confidence intervals, are shown in Figures 2-4.

In constructing the Gulf of Mexico and Mixing Zone indices, the GLMMIX models failed to converge under the full models described above. With the Gulf of Mexico index, the GLMMIX model failed to converge when the interaction terms were included in either the binomial or lognormal models. Only main effects were included in developing the Gulf of Mexico index. Small sample size, resulting in the inclusion of many factors, likely caused the lack of convergence in the GLMMIX models. Similarly, construction of the Mixing Zone could be completed only when interaction terms were excluded from the final binomial and lognormal models.

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 5-8 (Gulf of Mexico), Figures 9-12 (Mixing Zone), and Figures 13-16 (South Atlantic). 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 Gulf of Mexico and South Atlantic data differed somewhat from the expected normal distribution. Those variations from the expected fit of the data were not sufficient to violate assumptions of the analyses.

Standardized catch rates for king mackerel in the Gulf of Mexico had no clear trend over the complete time series (Figure 2). During the period 1993-1996 the mean annual cpue increased slightly. The trend in yearly mean cpue during the period 1998-2006 had decreasing cpues over time. Coefficients of variation were highest during the initial years of the series (Table 4).

An overall increase in yearly mean standardized cpue was found for the Mixing Zone (Figure 3). Although there was some variation among years, the highest cpues were found in the last few years of the time series and the lowest cpues occurred during the earliest years of the series. Coefficients of variation were highest during the first three years of the index (Table 5).

The index constructed for the south Atlantic indicated no strong trend in yearly mean cpue (Figure 4). Additionally, the nominal cpue series differed from the standardized cpue series. Nominal cpue was lower in the initial years of the series and higher in the final years of the series compared to the standardized cpues. The mean annual nominal cpue showed a clear increase over the 14 year series. The highest annual standardized cpues, however, were found during the first two years of the series. The marked differences in the nominal and standardized series require additional investigation. Coefficients of variation were consistently largest during the final five years of the time series (Table 6).

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 revised GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the Gulf of Mexico data from commercial vessels reporting hook and line gear landings and effort 1993-2006. 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	13	2045	99.03	7.62	<.0001	<.0001
gear	1	324	604.75	604.75	<.0001	<.0001
area1	8	652	257.02	32.13	<.0001	<.0001
effort1	3	936	186.21	62.07	<.0001	<.0001
numgear1	3	1068	85.37	28.46	<.0001	<.0001
ves_len	3	2045	75.76	25.25	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
year	13	1596	3.02	0.0002
target	3	710	2485.97	<.0001
effort1	3	433	1048.50	<.0001
area1	8	338	72.57	<.0001
hrs_fished	5	1670	110.19	<.0001
numgear1	3	540	182.47	<.0001
ves_len	3	1596	12.88	<.0001
crew1	3	680	18.80	<.0001

Table 2. Linear regression statistics for the revised GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the Mixing Zone data from commercial vessels reporting hook and line gear landings and effort 1993-2006. 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	13	5266	229.39	17.65	<.0001	<.0001
gear	1	1176	2594.16	2594.16	<.0001	<.0001
area1	9	1989	2479.00	275.44	<.0001	<.0001
numgear1	3	4186	533.74	177.91	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
year	13	4445	10.33	<.0001
target	3	5048	13949.1	<.0001
numgear1	3	2054	1234.02	<.0001
effort1	1	946	5173.23	<.0001
area1	9	1164	39.06	<.0001
hrs_fished	4	5894	102.19	<.0001
ves_len	4	4445	31.72	<.0001

Table 3. Linear regression statistics for the revised GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the south Atlantic data from commercial vessels reporting hook and line gear landings and effort 1993-2006. (**C**) The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final binomial 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	13	52	34.99	2.69	0.0008	0.0057
gear	1	7080	1329.43	1329.43	<.0001	<.0001
numgear1	2	7080	471.17	235.58	<.0001	<.0001
area1	4	52	31.72	7.93	<.0001	<.0001
effort1	2	7080	183.98	91.99	<.0001	<.0001
area1*effort1	8	7080	375.94	46.99	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
year	13	2393	2.90	0.0003
target	3	1448	2790.30	<.0001
effort1	2	838	981.49	<.0001
hrs_fished	5	2902	11.56	<.0001
numgear1	2	1294	338.93	<.0001
area1	4	451	14.43	<.0001
target*hrs_fished	15	78	51.55	<.0001
effort1*area1	8	2	11.11	0.0852
numgear1*area1	8	12	2.88	0.0485

C.

ANALYSIS OF MIXED MODEL FORMULATIONS					
Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Year+Gear+Numgear1+Area1+Effort1+Area1*Effort1	32029.2	32033.2	32045.0	-	-
Year+Gear+Numgear1+Area1+Effort1+Area1*Effort1+Area1*Year	31717.2	31723.2	31729.9	312.0	<0.0001

Table 4. Revised relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel 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	0.17059	672	0.178571	0.719864	0.553338	0.936506	0.132118
1994	0.36103	552	0.338768	0.881232	0.720546	1.077753	0.100911
1995	0.64503	643	0.399689	0.989605	0.821223	1.192511	0.093458
1996	0.762972	1,131	0.47038	0.973609	0.832576	1.138532	0.078363
1997	1.164979	993	0.594159	1.30679	1.139315	1.498882	0.068654
1998	1.300654	1,464	0.468579	1.288452	1.124224	1.476671	0.068254
1999	1.179421	1,625	0.557538	1.117879	0.98158	1.273105	0.065081
2000	1.577386	1,650	0.638182	1.068021	0.943548	1.208915	0.062017
2001	1.079694	1,713	0.563923	1.055385	0.928151	1.20006	0.064299
2002	1.331662	1,568	0.625638	0.994054	0.879432	1.123617	0.061315
2003	1.364618	1,285	0.654475	0.984621	0.857448	1.130655	0.069231
2004	1.250621	1,260	0.539683	0.923012	0.79699	1.068961	0.073499
2005	0.851199	1,544	0.321244	0.731576	0.607567	0.880896	0.09307
2006	0.960144	1,447	0.418106	0.965899	0.817894	1.140686	0.083307

Table 5. Revised relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel in the Mixing Zone.

Year	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.403139	4,309	0.247157	0.650916	0.545575	0.776596	0.088442
1994	0.436905	5,162	0.276443	0.658274	0.566274	0.765219	0.075378
1995	0.474768	5,586	0.276942	0.679931	0.586303	0.788512	0.074179
1996	0.623902	6,915	0.345336	0.947111	0.846368	1.059846	0.056276
1997	0.542535	7,350	0.328844	0.805788	0.716925	0.905666	0.058475
1998	1.041776	13,972	0.628614	1.038867	0.952335	1.133263	0.043506
1999	0.998888	15,484	0.570137	1.002828	0.921878	1.090886	0.042102
2000	0.878666	15,145	0.605282	0.930869	0.856611	1.011565	0.041586
2001	0.972751	15,520	0.610438	0.973615	0.897284	1.056438	0.040838
2002	1.050351	14,922	0.603806	1.053141	0.97041	1.142925	0.040924
2003	1.576674	15,224	0.645231	1.277778	1.180265	1.383347	0.039707
2004	1.68558	11,773	0.601376	1.278257	1.171333	1.394941	0.043698
2005	1.450711	10,115	0.573109	1.269829	1.155745	1.395174	0.047095
2006	1.863354	9,934	0.636602	1.432796	1.30433	1.573915	0.046995

Table 6. Revised relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel in the south Atlantic.

Year	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.501149	1,806	0.594684	1.37864	1.183834	1.605503	0.07628
1994	0.444777	2,235	0.501566	1.213336	1.03489	1.422551	0.079665
1995	0.641366	2,815	0.479929	1.122426	0.942012	1.337393	0.087783
1996	0.477344	2,998	0.386258	0.814378	0.651294	1.018299	0.112082
1997	0.858752	3,382	0.466884	1.114656	0.939493	1.322476	0.085637
1998	1.099067	3,998	0.524262	1.022549	0.87639	1.193083	0.077236
1999	1.105474	4,155	0.540554	1.026217	0.876941	1.200903	0.078719
2000	1.074708	4,125	0.578667	1.052164	0.904698	1.223667	0.075609
2001	0.98175	4,256	0.546053	0.909673	0.772893	1.070658	0.081607
2002	0.88771	3,803	0.440968	0.780102	0.637082	0.955229	0.101523
2003	1.093054	3,153	0.453853	0.739851	0.599173	0.913558	0.105743
2004	1.53297	3,104	0.465206	0.893362	0.726105	1.099147	0.103928
2005	1.59833	2,870	0.521603	0.995332	0.830641	1.192677	0.090625
2006	1.703548	2,720	0.531618	0.937315	0.779609	1.126921	0.092309

Figure 1. Coastal Logbook defined fishing areas with king mackerel regions indicated.

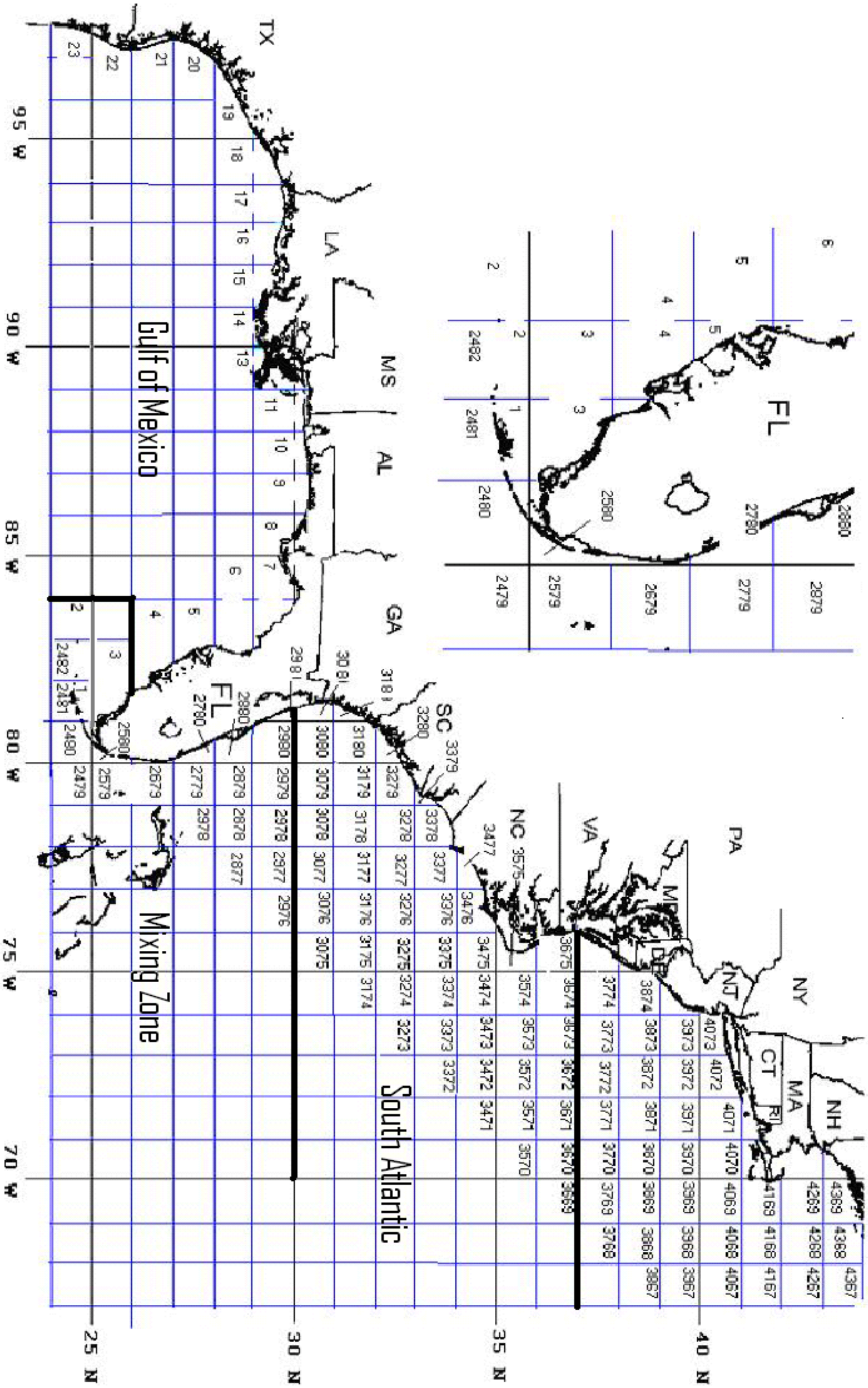


Figure 2. Revised king mackerel (1993-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) of the standardized CPUE estimates for commercial vessels fishing hook and line gear (handline, electric reel, and trolling) in the Gulf of Mexico.

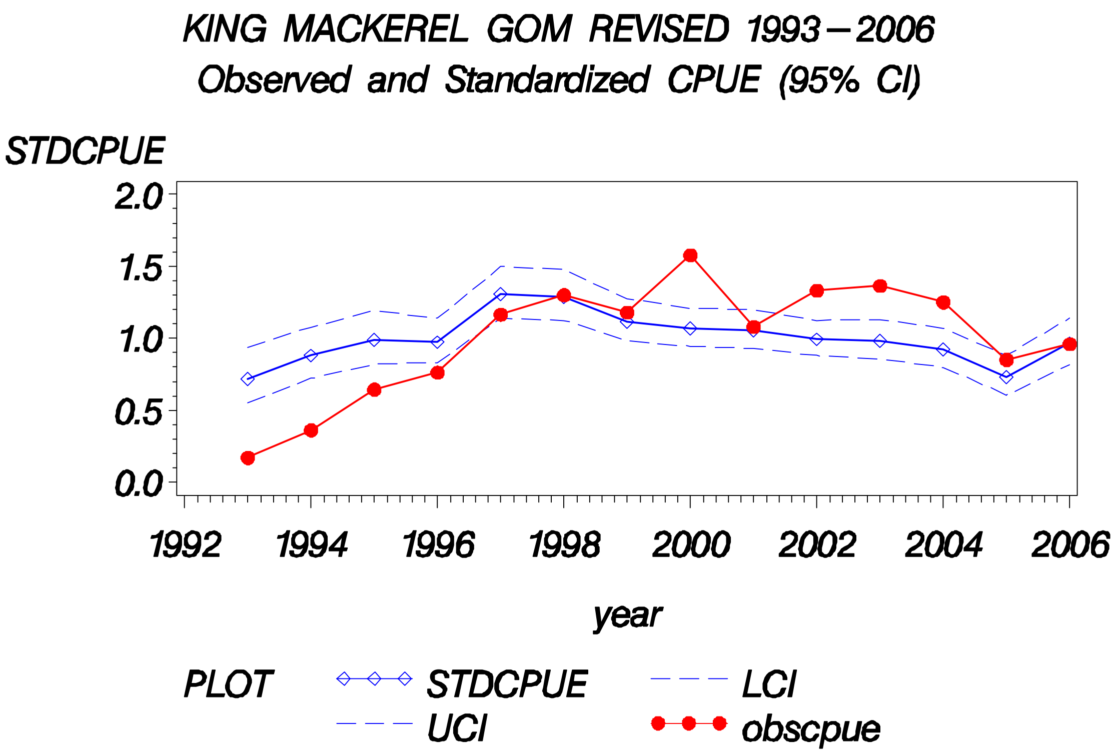


Figure 3. Revised king mackerel (1993-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) of the standardized CPUE estimates for commercial vessels fishing hook and line gear in the Mixing Zone.

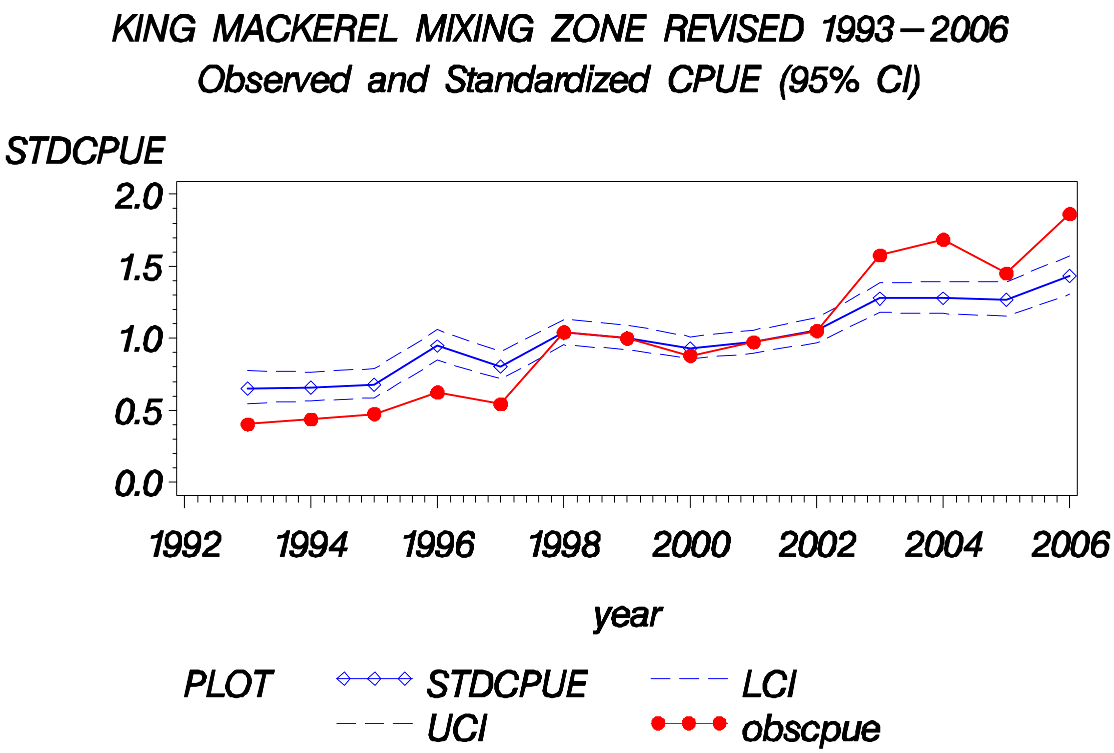


Figure 4. Revised king mackerel (1993-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) of the standardized CPUE estimates for commercial vessels fishing hook and line gear in the south Atlantic.

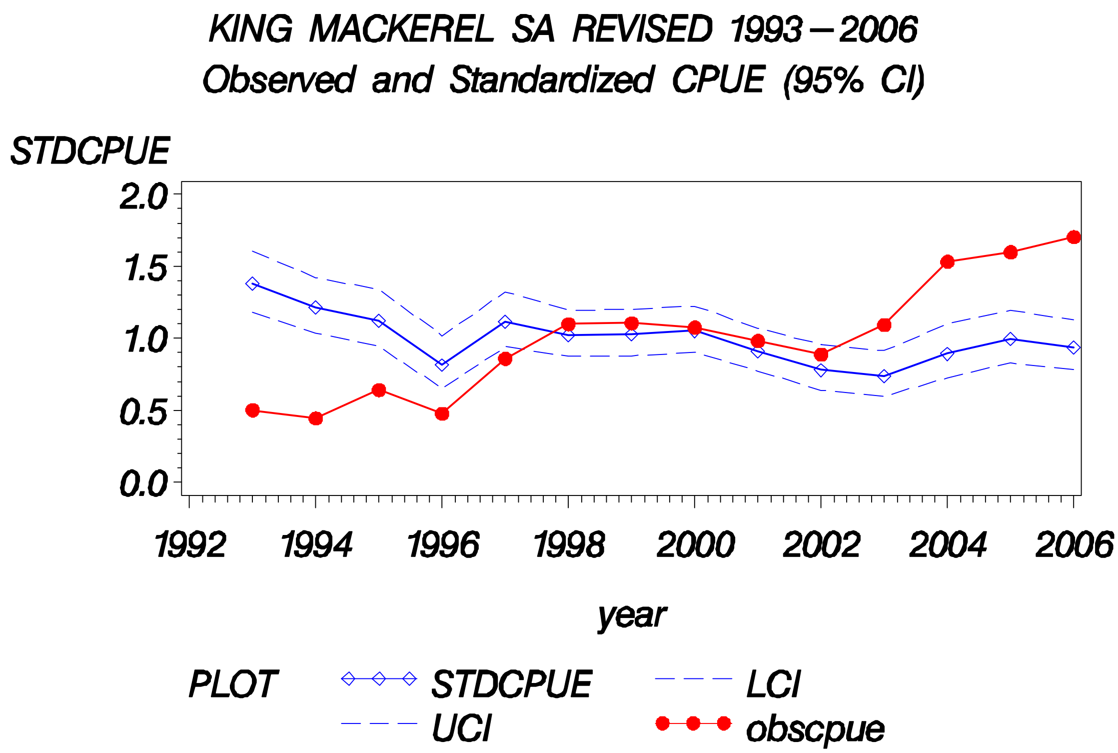
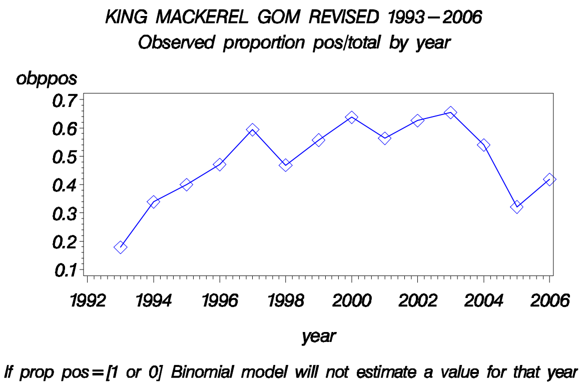


Figure 5. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the revised Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model. Data are plotted by season within years.

A.



B.

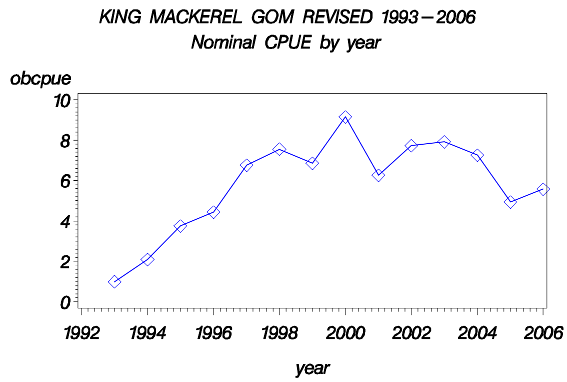
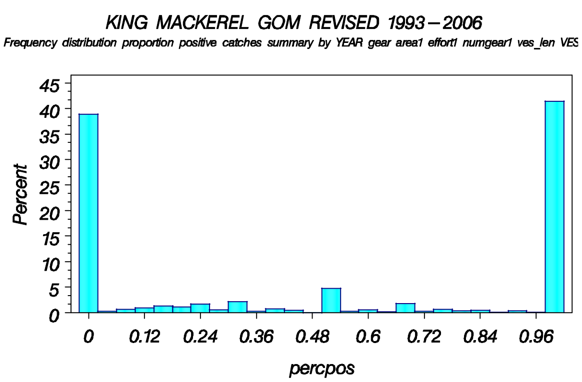
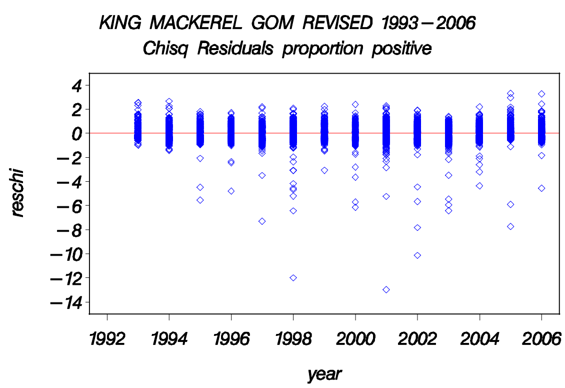


Figure 6. Diagnostic plots for the binomial component of the revised Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by hooks per line (effort1).

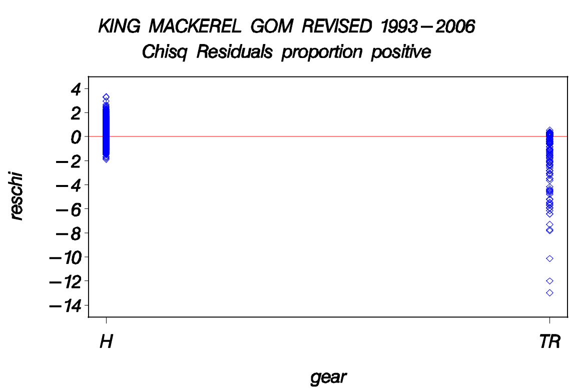
A.



B.



C.



D.

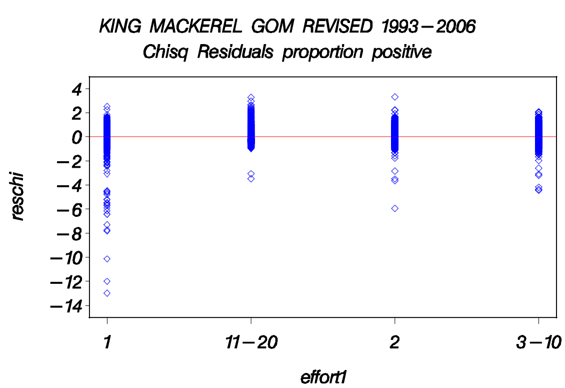
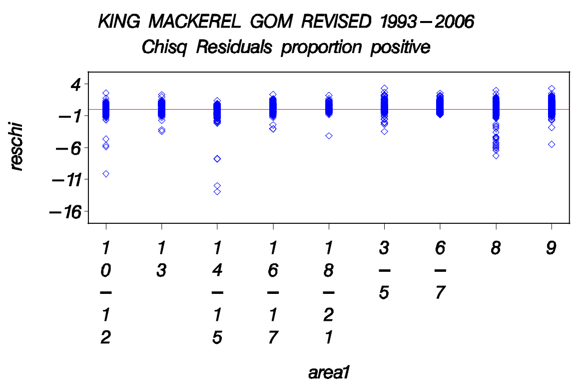
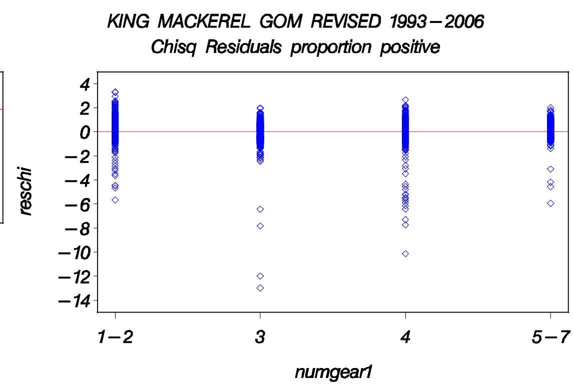


Figure 6 (continued). Diagnostic plots for the binomial component of the revised Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by area; **F**. the Chi-Square residuals by number of lines fished (numgear1); and **G**. the Chi-Square residuals by vessel length (ves_len).

E.



F.



G.

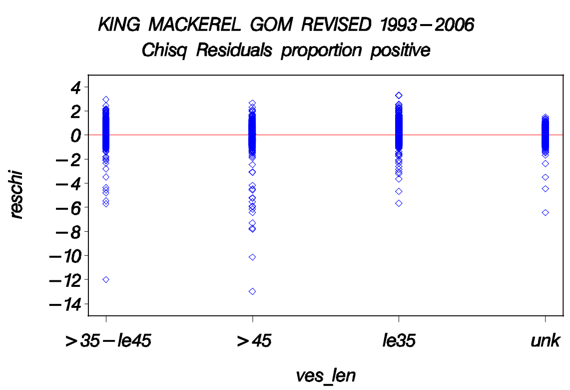
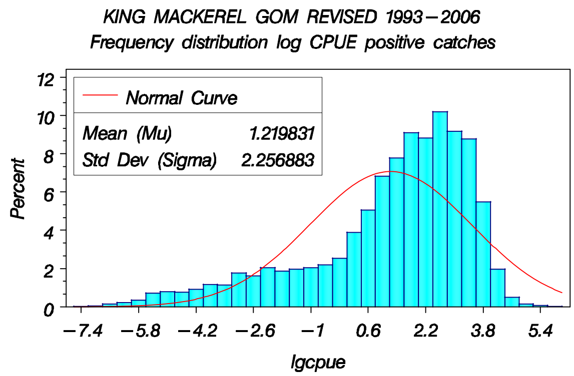


Figure 7. Diagnostic plots for the lognormal component of the revised Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

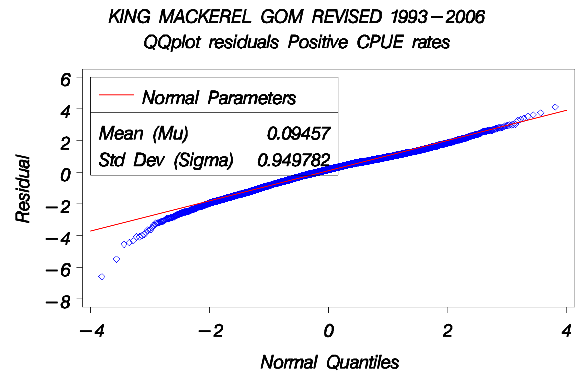
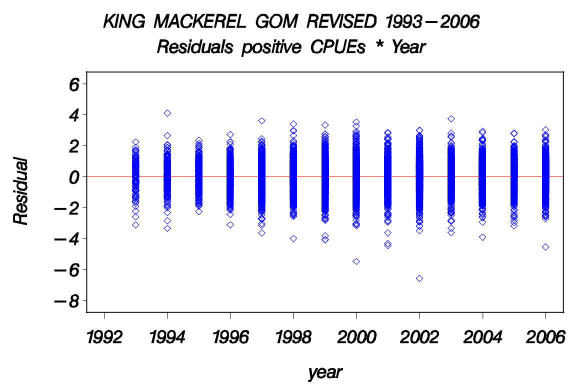
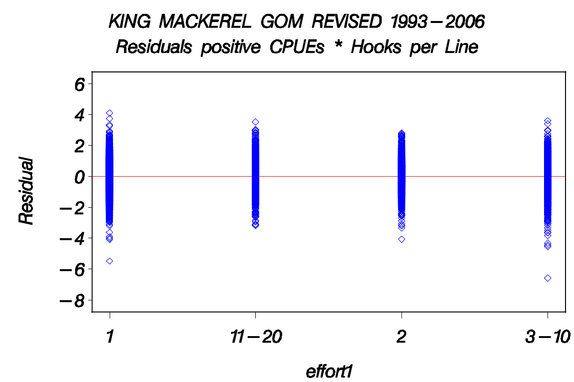


Figure 8. Diagnostic plots for the lognormal component of the revised Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by hooks per line (effort1); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by hours fished (hrs_fished).

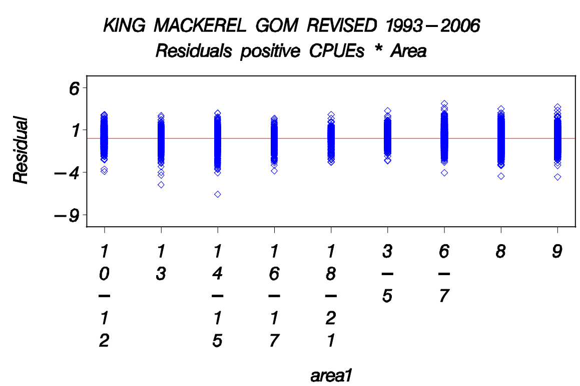
A.



B.



C.



D.

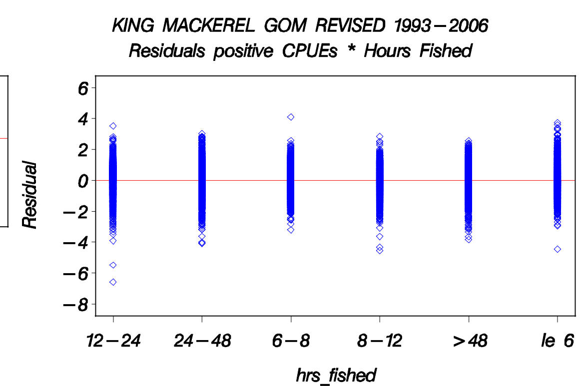
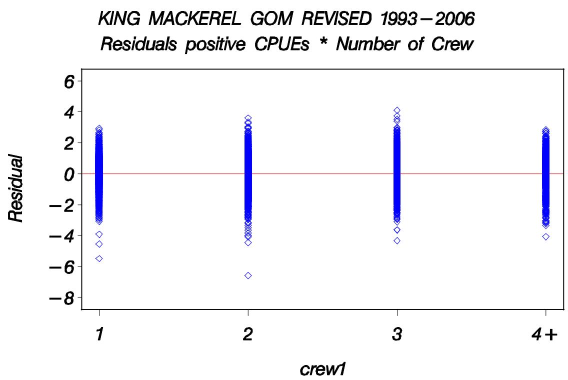
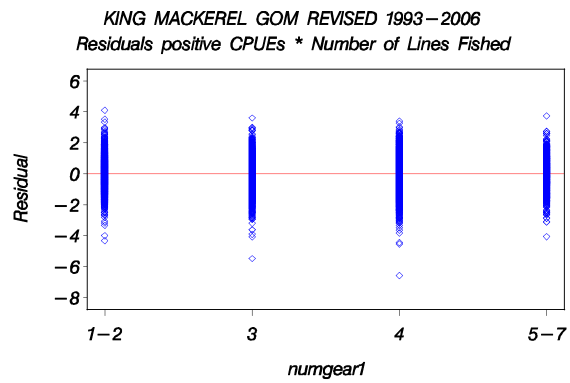


Figure 8 (continued). Diagnostic plots for the lognormal component of the revised Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by number of crew (crew1); **F**. the Chi-Square residuals by number of lines fished (Numgear1); **G**. the Chi-Square residuals by vessel length (ves_len); and **H.** the Chi-Square residuals by targeting (percent king mackerel in landings)

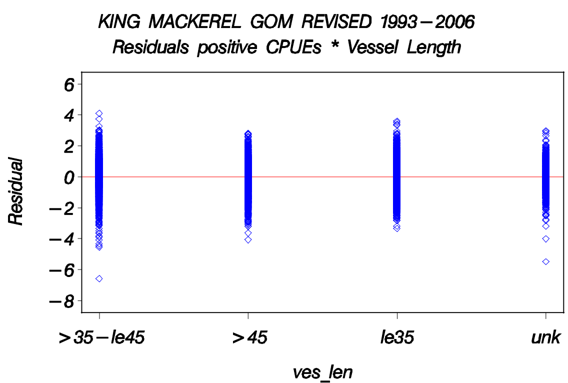
E.



F.



G.



H.

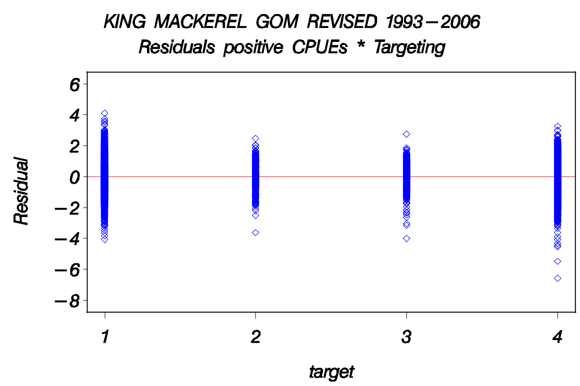
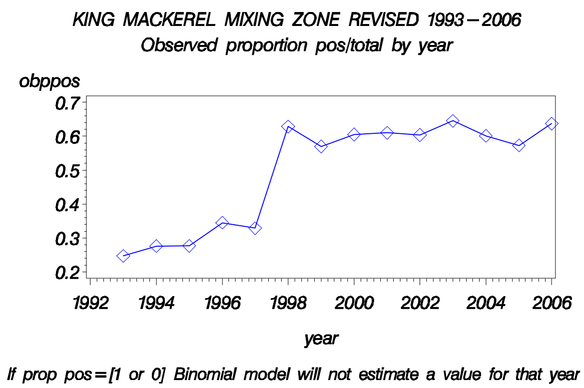


Figure 9. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the revised Mixing Zone 1993-2006 king mackerel commercial hook and line gear model.

A.



B.

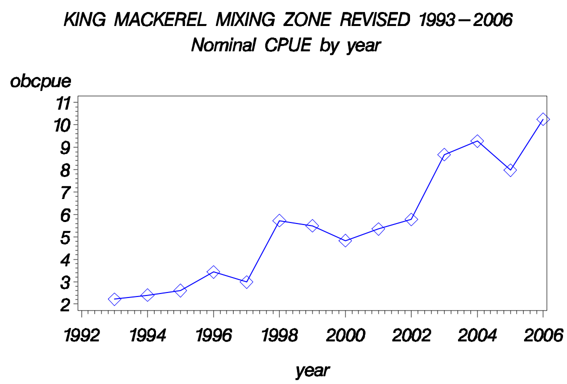
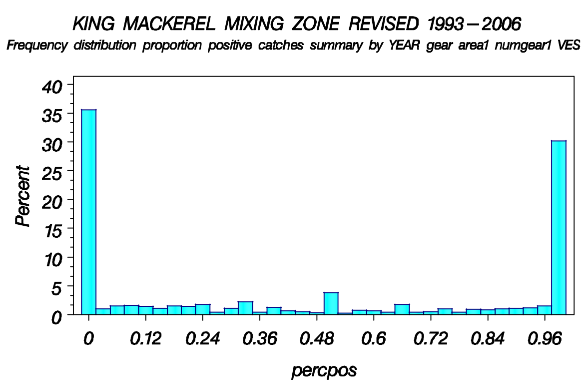
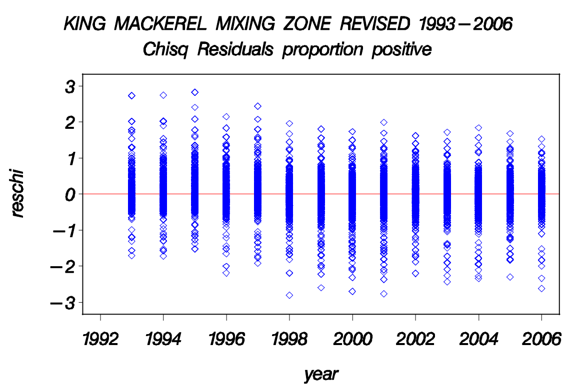


Figure 10. Diagnostic plots for the binomial component of the revised Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by area.

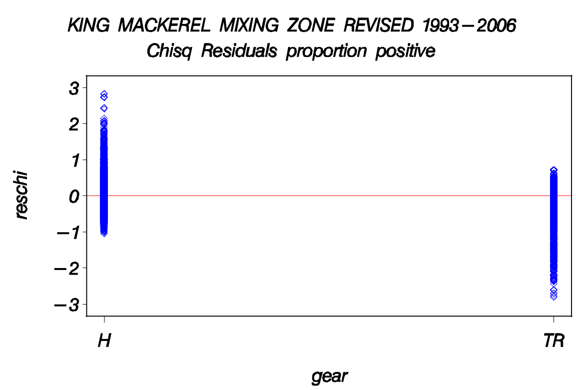
A.



B.



C.



D.

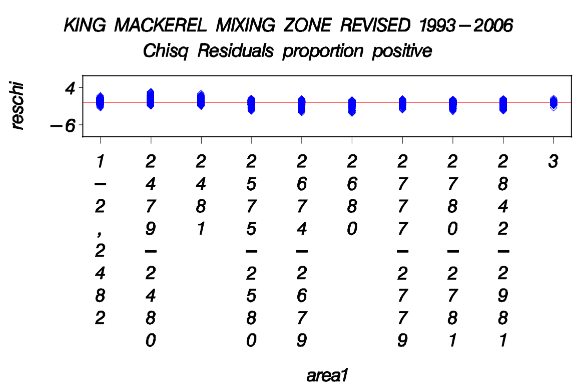
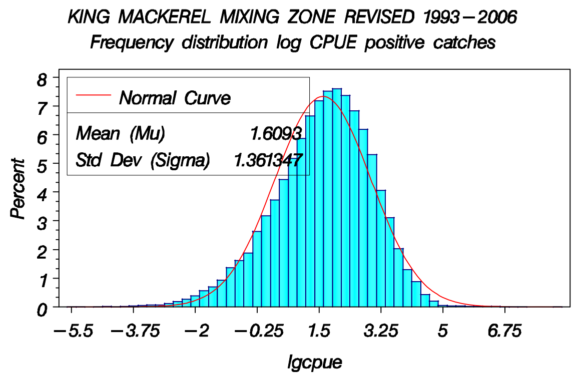


Figure 11. Diagnostic plots for the lognormal component of the revised Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

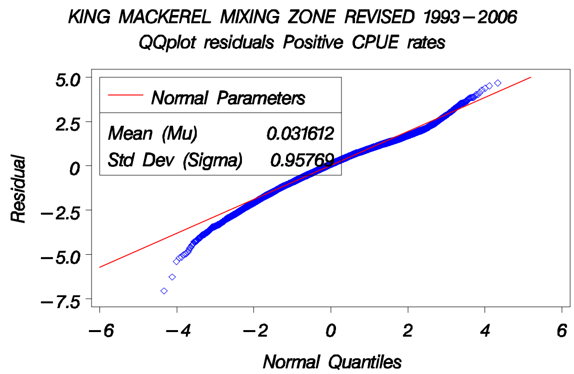
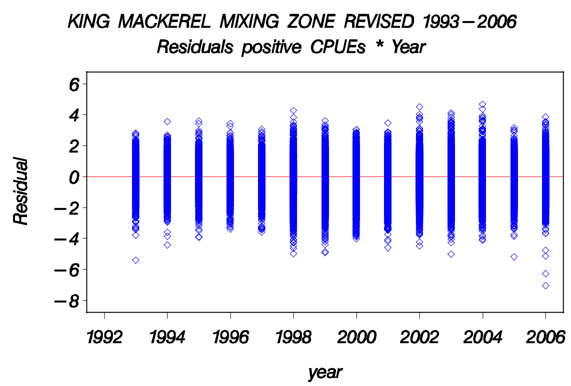
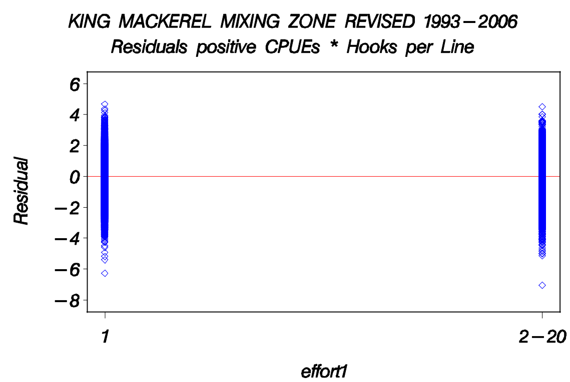


Figure 12. Diagnostic plots for the lognormal component of the revised Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by hooks per line (effort1); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by hours fished (hrs_fished).

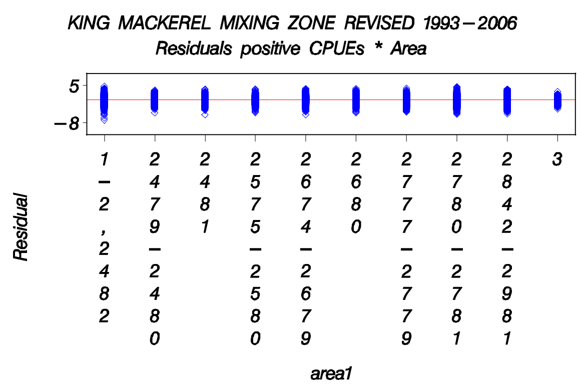
A.



B.



C.



D.

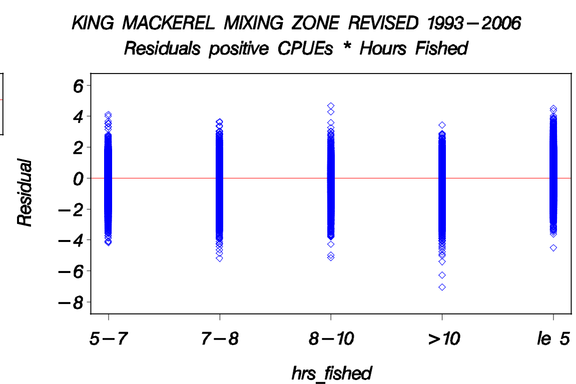
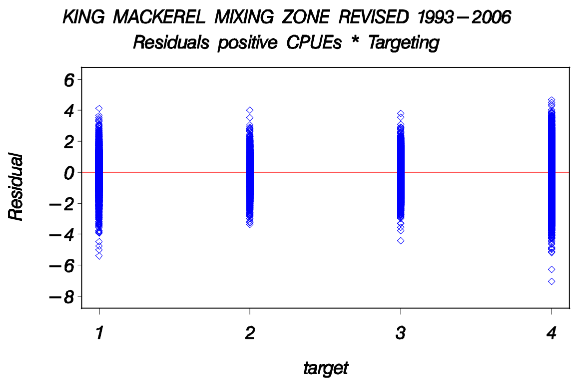
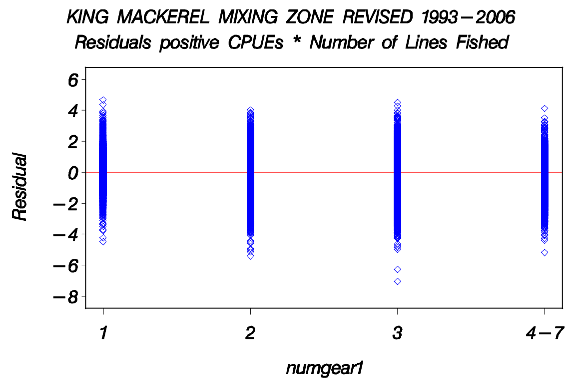


Figure 12 (continued). Diagnostic plots for the lognormal component of the revised Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by targeting; **F**. the Chi-Square residuals by number of lines fished (numgear1); **G**. the Chi-Square residuals by vessel length (ves_len).

E.



F.



G.

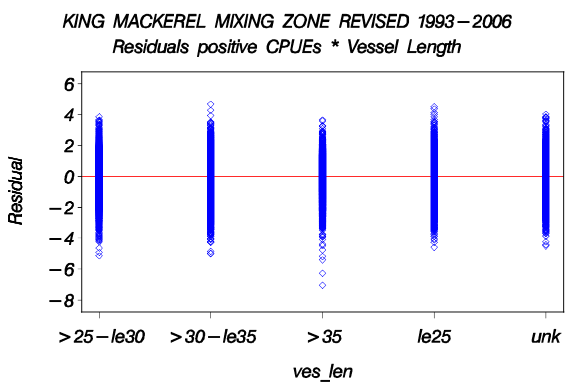
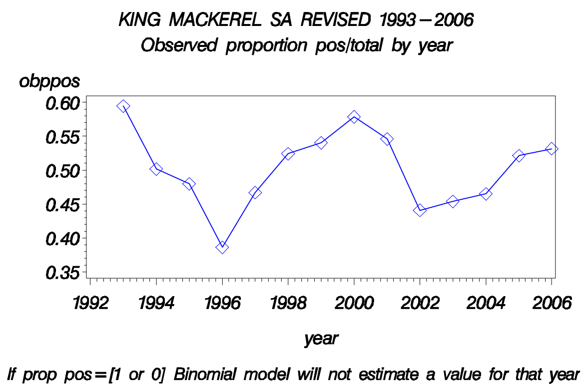


Figure 13. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the revised South Atlantic 1993-2006 king mackerel commercial hook and line gear model.

A.



B.

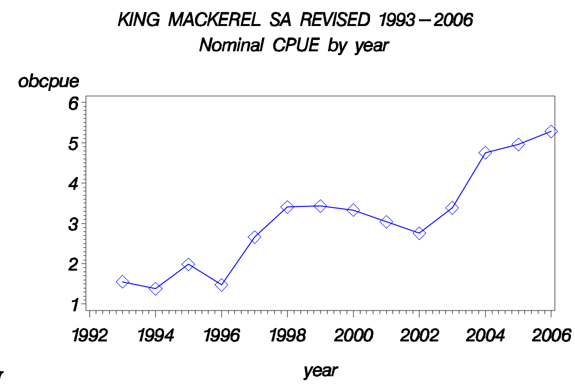
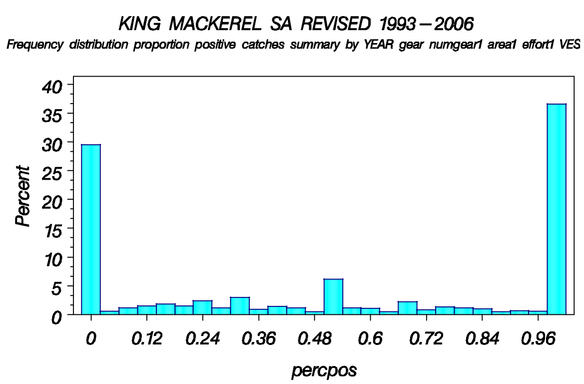
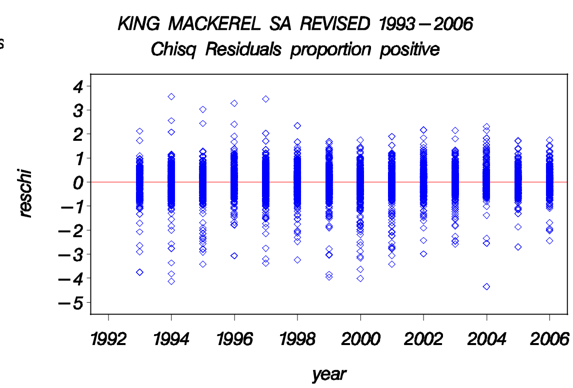


Figure 14. Diagnostic plots for the binomial component of the revised South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by area.

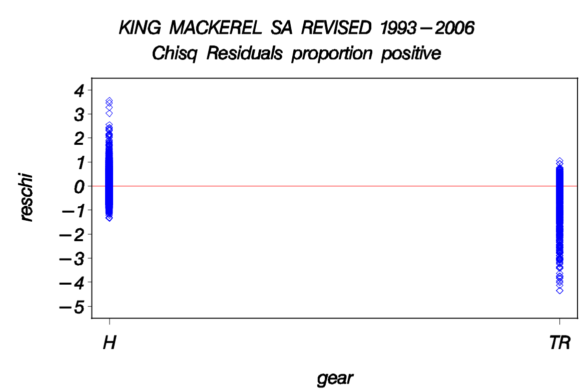
A.



B.



C.



D.

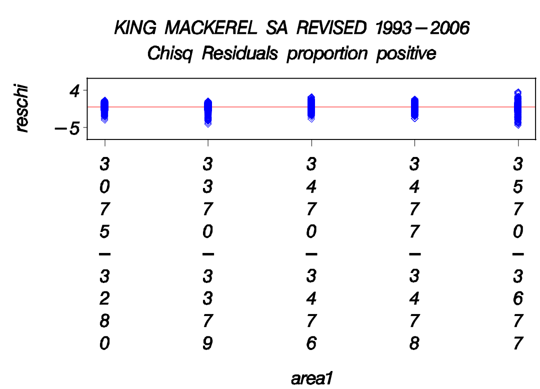
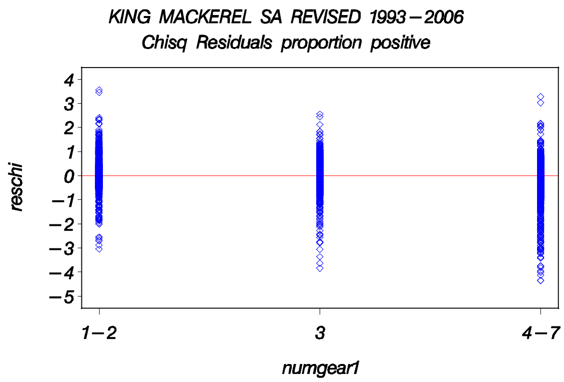


Figure 14 (continued). Diagnostic plots for the binomial component of the revised South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by number of lines fished (numgear1) and **F**. the Chi-Square residuals by hooks per line (effort1).

E.



F.

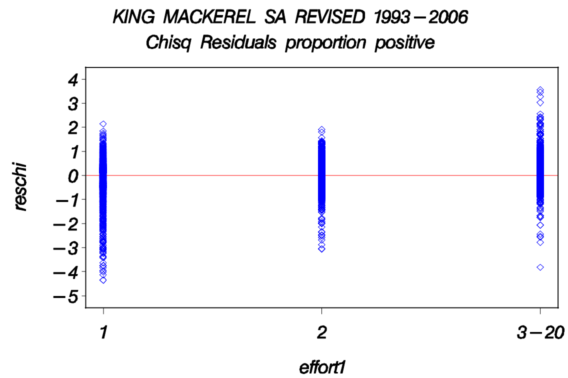
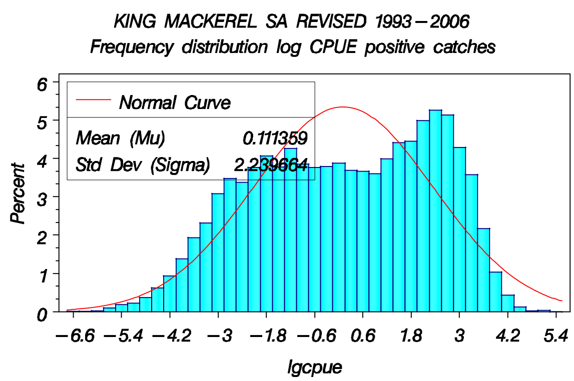


Figure 15. Diagnostic plots for the lognormal component of the revised South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

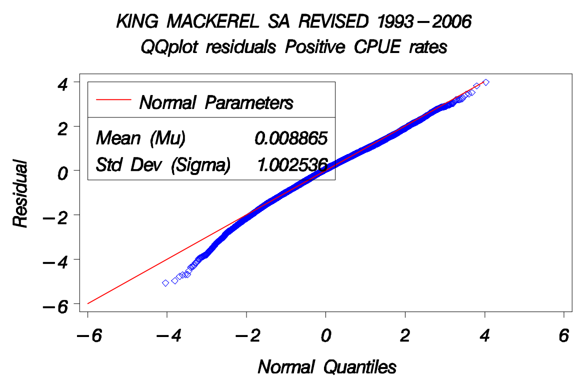
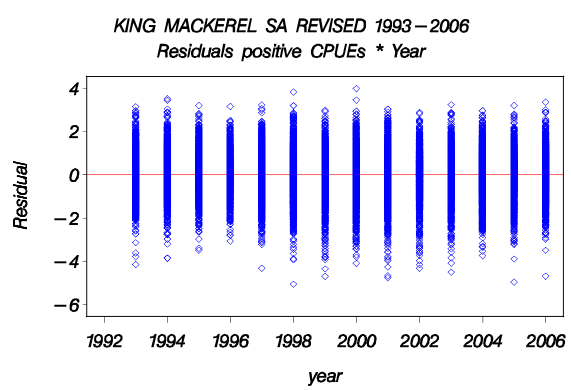
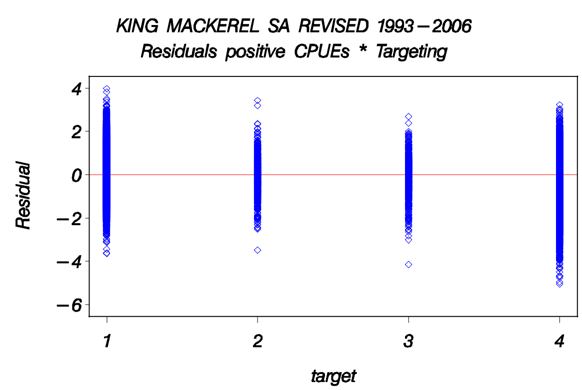


Figure 16. Diagnostic plots for the lognormal component of the revised South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by targeting (percent king mackerel in landings); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by number of lines fished (numgear1).

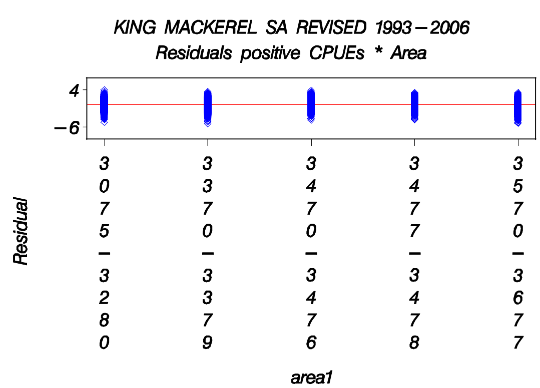
A.



B.



C.



D.

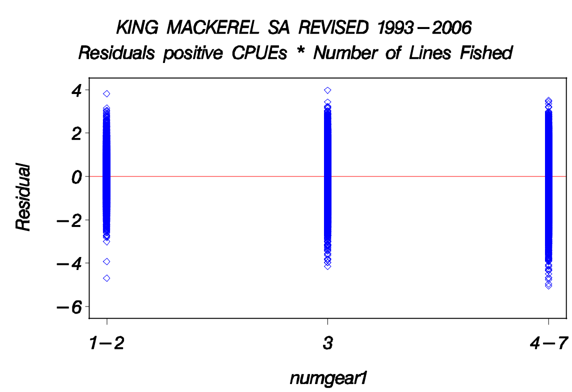
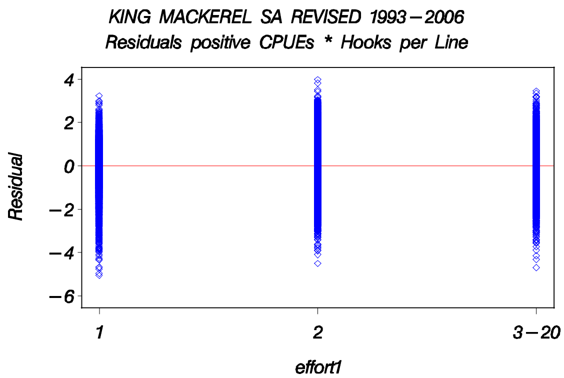


Figure 16 (continued). Diagnostic plots for the lognormal component of the revised South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by hooks per line (effort) and **E**. the Chi-Square residuals by hours fished (hrs_fished).

E.



F.