Standardized catch rates of king mackerel from the United States Gulf of Mexico, South Atlantic, and Mixing Zone commercial hook and line fisheries, 1993-2006

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Introduction

Handline, electric reel (bandit rig), and trolling (defined here as "hook and line fisheries") landings and fishing effort of commercial vessels operating in the Gulf of Mexico and U.S. south Atlantic have been monitored by the National Marine Fisheries Service (NMFS) through the coastal logbook program (conducted by the NMFS Southeast Fisheries Science Center). The program collects landings and effort data by fishing trip from vessels with permits to fish in a number of fisheries managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. The coastal logbook program began in 1990 with the objective of a complete census of coastal fisheries permitted vessel activity, with the exception of Florida, where a 20% sample of vessels was targeted. Beginning in 1993, the sampling in Florida was increased to require reports from all vessels permitted in coastal fisheries.

The available catch per unit effort (CPUE) series, from 1993 - 2006, was used to develop three abundance indices for king mackerel. Separate indices were developed for the Gulf of Mexico, south Atlantic, and the king mackerel "Mixing Zone". Catch and effort data reporting to the coastal logbook program were not required for vessels landing king mackerel prior to 1998. Although some vessels did report catch and effort data from king mackerel trips, the level or reporting is unknown and was likely not random among vessels. The degree of data bias during the years prior to 1998 is unknown. Given the underreporting of king mackerel data, additional indices were constructed for each region for the period 1998-2006.

Methods

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. Data for the three hook and line fisheries were combined in these analyses.

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

CPUE = total kilograms 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 and 2. The south Atlantic was defined as the area north of 30^{o} N to 37^{o} 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 and 2.

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 80% of the reported hook and line gear landings of king mackerel over the period 1993-2006 or 1998-2006, as appropriate for the index. 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. Vessel selection for the 1998-2006 indices was dependent upon king mackerel landings for those years, therefore, a different suite of vessels may have been selected for the 1998-2006 indices than were selected in the construction of the 1993-2006 indices. 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, more than 10 days at sea, or more than 1,415 kilograms (3,120 pounds) of king mackerel landed.

Index Development

Eight 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 eight factors were defined as:

Gulf of Mexico

Factor	Levels	Value
Year*	14/9	Two indices:1993-2006, 1998-2006
Area	9	Gulf of Mexico shrimp grids 3-5, 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
Season	2	1=November-March, 2=April-October
Crew	4	1, 2, 3, or 4+ crew members
Vessel length (VES_LEN)	4	35 feet or less, >35 to 45, >45, unknown
Number of lines fished (NUMGEAR1)	4	1-2, 3, 4, 5-7
Number of hooks/line*** (EFFORT1)	5/4	1, 2, 3-10, 11-15, 16-20 for 1993-2006 index 1, 2, 3-10, 11-20 for 1998-2006 index
Gear	2	Handline (includes electric reels), trolling

* Two indices were developed, one for each range of years presented under Value.
**Names in parentheses appear in some figures and tables.
***Number of lines fished values differed between the 1993-2006 and 1998-2006 indices.

Mixing Zone

Factor	Levels	Value
Year*	14/9	Two indices:1993-2006, 1998-2006
Area**	9	Areas1-2 and 2482; 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
Season	2	1=November-March, 2=April-October
Crew	2	1, 2+ crew members
Vessel length (VES_LEN)	5	25 feet or less, >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

* Two indices were developed, one for each range of years presented under Value.
**Areas 1-2 and 2482 were combined.
***Names in parentheses appear in some figures and tables.

South Atlantic

Factor	Levels	Value
Year*	14/9	Two indices:1993-2006, 1998-2006
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
Season	2	1=November-March, 2=April-October
Crew	3	1, 2, 3+ crew members
Vessel length (VES_LEN)	4	30 feet or less, >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

* Two indices were developed, one for each range of years presented under Value.
**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(kilograms of king mackerel/hook hours). All 2-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 ≥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. 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 + HOOKS/LINE + AREA + SEASON + LINES FISHED + YEAR + YEAR*AREA + AREA*SEASON + AREA* LINES FISHED

LOG(CPUE) = HOOKS/LINE + AREA + DAYS at SEA + GEAR + LINES FISHED + YEAR + VESSEL LENGTH + AREA* DAYS at SEA + AREA*LINES FISHED + AREA*GEAR + AREA*YEAR + AREA*VESSEL LENGTH + HOOKS/LINE*YEAR + AREA*GEAR + YEAR*VESSEL LENGTH + HOOKS/LINE*LINES FISHED

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

Gulf of Mexico 1998-2006:

PPT = GEAR + HOOKS/LINE + SEASON + LINES FISHED + CREW + YEAR + HOOKS/LINE* LINES FISHED

LOG(CPUE) = HOOKS/LINE + AREA + DAYS at SEA + GEAR + LINES FISHED + VESSEL LENGTH + SEASON + YEAR + AREA* DAYS at SEA + HOOKS/LINE*AREA + AREA*LINES FISHED + DAYS at SEA*GEAR + AREA*YEAR + AREA*GEAR + VESSEL LENGTH*YEAR + HOOKS/LINE*YEAR

Final model linear regression statistics and analysis of the mixed model formulations are provided in Table 2.

Mixing Zone 1993-2006:

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

LOG(CPUE) = LINES FISHED + HOOKS/LINE + AREA + YEAR + SEASON +GEAR + DAYS at SEA + AREA*SEASON + AREA*YEAR + LINES FISHED*AREA + AREA*DAYS at SEA

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

Mixing Zone 1998-2006:

PPT = GEAR + AREA + LINES FISHED + VESSEL LENGTH + YEAR + AREA*VESSEL LENGTH + AREA*LINES FISHED + GEAR*LINES FISHED

LOG(CPUE) = LINES FISHED + HOOKS/LINE + AREA + SEASON + YEAR +AREA*SEASON + LINES FISHED*AREA + AREA*YEAR

The linear regression statistics and analysis of the mixed model formulations of the final GLM models are summarized in Table 4.

South Atlantic 1993-2006:

PPT = GEAR + LINES FISHED + AREA + YEAR + HOOKS/LINE + AREA * HOOKS/LINE + AREA*YEAR
LOG(CPUE) = GEAR + HOOKS/LINE + DAYS at SEA + SEASON + AREA + CREW + YEAR + GEAR*DAYS at SEA + DAYS at SEA*SEASON + HOOKS/LINE*AREA + AREA*YEAR

The linear regression statistics and analysis of the mixed model formulations of the final GLM models are summarized in Table 5.

South Atlantic 1998-2006:

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

LOG(CPUE) = DAYS at SEA + HOOKS/LINE + GEAR + SEASON + AREA + CREW + YEAR + DAYS at SEA*GEAR + DAYS at SEA*SEASON + HOOKS/LINE*AREA + GEAR*AREA

The linear regression statistics of the final GLM models are summarized in Table 6.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Tables 7 and 8 for Gulf of Mexico king mackerel, Tables 9 and 10 for the Mixing Zone, and Tables 11 and 12 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- 7.

In developing the Gulf of Mexico1993-2006 index, the GLMMIX model failed to converge when the interaction term HOOKS/LINE*AREA from the binomial and lognormal models were included. Those terms were excluded from the analysis. Similarly, for the Gulf of Mexico 1998-2006 index, GLMMIX failed to converge with the lognormal model interaction AREA*VESSEL LENGTH included. That interaction term was excluded during development of the index. Small sample size and inclusion of many factors likely caused the lack of convergence in the GLMMIX 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 8-11 (Gulf of Mexico 1993-2006), Figures 12-15 (Gulf of Mexico 1998-2006), Figures 16-19 (Mixing Zone 1993-2006), Figures 20-23 (Mixing Zone 1998-2006), Figures 24-27 (south Atlantic 1993-2006), Figures 28-31 (south Atlantic 1998-2006). 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 were somewhat skewed from the expected normal distribution. Those variations from the expected fit of the data were not sufficient to violate assumptions of the analyses.

Standardized catch rates for king mackerel were higher over the second half of the Gulf of Mexico 1993-2006 cpue series (Figure 2). Over the period 1993-1997 the index had no clear trend. Yearly mean standardized cpues during the period 1999-2006 also had no obvious trend, but were higher than those of earlier years in the time series. The standardized mean cpue for 1998 was intermediate between initial and later yearly mean cpues. The proportion of positive trips was increased after 1998 and may have partially driven the concomitant increase in nominal cpue. Coefficients of variation were highest during the initial years of the series (Table 7). The Gulf of Mexico 1998-2006 index was similar to the corresponding years in the 1993-2006 index with no apparent trend in yearly mean cpue (Figure 3). Coefficients of variation were roughly equal over the 1998-2006 time series (Table 8).

An overall increase in yearly mean standardized cpue was found for both Mixing Zone indices (Figures 4 and 5). 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 earlier years of the series. In the 1993-2006 index, the number of reported trips doubled (in some years had almost tripled) beginning in 1998, although the number of trips decreased in 2006. Coincidentally, the proportion of positive trips also doubled beginning in 1998. More positive trips may have contributed to the observed doubling of the yearly mean nominal cpue that also began in 1998. Coefficients of variation were highest during the first three years of the 1993-2006 index (Table 9), but varied little over the 1998-2006 index (Table 10).

Both indices constructed for the south Atlantic indicated no particular trend in yearly mean cpue (Figures 6 and 7). Differing from the pattern observed in the other regions, the proportion of positive king mackerel trips was relatively stable throughout the time series. The proportion of positive trips, therefore, was likely not a factor in increasing yearly mean nominal cpue. Coefficients of variation were slightly larger over the second half of the 1993-2006 index (Table 11). The 1998-2006 index also had slightly larger coefficients of variation in the second half of the time series (Table 12), but all were much lower than the coefficients of variation of the south Atlantic 1993-2006 index or any of the indices developed for the other two regions.

Acknowledgments

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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 final GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the Gulf of Mexico for vessels reporting hook and line gear catch 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	104	35.70	2.75	0.0007	0.0022
gear	1	3595	1460.17	1460.17	<.0001	<.0001
effort1	4	3595	231.56	57.89	<.0001	<.0001
area	8	104	44.83	5.60	<.0001	<.0001
season	1	3595	109.57	109.57	<.0001	<.0001
numgear1	3	3595	39.09	13.03	<.0001	<.0001
*area*season*	8	3595	309.13	38.64	<.0001	<.0001
*area*numgear1*	24	3595	186.52	7.77	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	13	38	15.61	1.20	0.2709	0.3161
effort1	4	52	264.54	66.14	<.0001	<.0001
area	8	104	249.70	31.21	<.0001	<.0001
days at sea	3	9458	266.83	88.94	<.0001	<.0001
gear	1	9458	468.22	468.22	<.0001	<.0001
numgear1	3	9458	15.70	5.23	0.0013	0.0013
ves_len	3	38	16.17	5.39	0.0010	0.0034
*area*days at sea*	24	9458	316.92	13.21	<.0001	<.0001
*area*numgear1*	24	9458	349.51	14.56	<.0001	<.0001
*days at sea*gear*	3	9458	331.81	110.60	<.0001	<.0001
*area*ves_len*	24	9458	235.31	9.80	<.0001	<.0001
*area*gear*	8	9458	201.62	25.20	<.0001	<.0001
*numgear1*effort1*	5	9458	70.80	14.16	<.0001	<.0001

Table 1 (continued). Analysis of the mixed model formulations of the Gulf of Mexico1993-2006 models (**C**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final models are indicated with gray shading. See text for factor (effect) definitions.

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+Effort1+Area+Season+Numgear1 +Area*Season+Area*Numgear1	18581.1	18583.1	18589.1	-	-
Year+Gear+Effort1+Area+Season+Numgear1 +Area*Season+Area*Numgear1+year*area	18261.5	18265.5	18271.2	319.6	<0.0001
Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
YEAR+Effort1+Area+Days at sea+Gear+Numgear1 +Ves_len+Area*Days at sea+Area*Numgear1 +Days at sea*Gear+Area*Ves_len+Area*Gear +Effort1*Numgear1	31113.0	31115.0	31122.2	-	-
YEAR+Effort1+Area+Days at sea+Gear+Numgear1 +Ves_len+Area*Days at sea+Area*Numgear1+Days at sea*Gear+Area*Ves_len+Area*Gear +Effort1*Numgear1+Year*Area	31037.1	31041.1	31046.7	75.9	<0.0001
YEAR+Effort1+Area+Days at sea+Gear+Numgear1 +Ves_len+Area*Days at sea+Area*Numgear1+Days at sea*Gear+Area*Ves_len+Area*Gear +Effort1*Numgear1+Year*Area+Year*Effort1	30951.4	30957.4	30965.9	85.7	<0.0001
YEAR+Effort1+Area+Days at sea+Gear+Numgear1 +Ves_len+Area*Days at Sea+Area*Numgear1+Days at sea*Gear+Area*Ves_len+Area*Gear+Effort1*Numgear1 +Year*Area+Year*Effort1+year*Ves_len	30907.2	30915.2	30926.5	44.2	<0.0001

Table 2. Linear regression statistics for the final GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the Gulf of Mexico for vessels reporting hook and line gear catch 1998-2006. 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	8	1308	52.58	6.57	<.0001	<.0001
gear	1	1308	1021.04	1021.04	<.0001	<.0001
effort1	3	1308	108.03	36.01	<.0001	<.0001
season	1	1308	213.62	213.62	<.0001	<.0001
numgear1	3	1308	93.57	31.19	<.0001	<.0001
crew	3	1308	96.27	32.09	<.0001	<.0001
*effort1*numgear1*	9	1308	88.90	9.88	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	8	23	2.43	0.30	0.9650	0.9570
effort1	3	24	766.61	255.54	<.0001	<.0001
area	8	64	297.15	37.14	<.0001	<.0001
days at sea	3	7522	272.66	90.89	<.0001	<.0001
gear	1	7522	232.16	232.16	<.0001	<.0001
numgear1	3	7522	110.12	36.71	<.0001	<.0001
ves_len	3	23	14.76	4.92	0.0020	0.0087
season	1	7522	47.51	47.51	<.0001	<.0001
*area*days at sea*	24	7522	327.72	13.65	<.0001	<.0001
*effort1*area*	24	7522	324.72	13.53	<.0001	<.0001
*area*numgear1*	24	7522	227.03	9.46	<.0001	<.0001
*days at sea*gear*	3	7522	253.52	84.51	<.0001	<.0001
*area*gear*	8	7522	118.92	14.86	<.0001	<.0001

Table 2 (continued). Analysis of the mixed model formulations of the Gulf of Mexico1998-2006 models (**C**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final models are indicated with gray shading. See text for factor (effect) definitions.

C.

ANALYSIS OF MIXED MODEL FORMULATIONS					
Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
YEAR+Effort1+Area+Days at sea+Gear+Numgear1+Ves_len+Season +Area*Days at sea+Effort1*Area+Area*Numgear1 +Days at sea*Gear+Area*Gear	23688.2	23690.2	23697.2	-	-
YEAR+Effort1+Area+Days at sea+Gear+Numgear1+Ves_len+Season +Area*Days at sea+Effort1*Area+Area*Numgear1+Days at sea*Gear+Area*Gear+Year*Area	23635.0	23639.0	23643.7	53.2	<0.0001
YEAR+Effort1+Area+Days at sea+Gear+Numgear1+Ves_len+Season +Area*Days at sea+Effort1*Area+Area*Numgear1+Days at sea*Gear+Area*Gear+Year*Area+Year*Ves_len	23585.1	23591.1	23598.3	49.9	<0.0001
YEAR+Effort1+Area+Days at sea+Gear+Numgear1+Ves_len+Season +Area*Days at sea+Effort1*Area+Area*Numgear1+Days at sea*Gear +Area*Gear+Year*Area+Year*Ves_len+Year*Effort1	23562.4	23570.4	23580.0	22.7	<0.0001

Table 3. Linear regression statistics for the final GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the Mixing Zone for vessels reporting hook and line gear catch 1993-2006. Analysis of the mixed model formulations of the Mixing Zone 1993-2006 models (**C**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final models are 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	104	69.80	5.37	<.0001	<.0001
gear	1	785	1062.28	1062.28	<.0001	<.0001
area	8	104	608.96	76.12	<.0001	<.0001
numgear1	3	785	191.25	63.75	<.0001	<.0001
*area*numgear1*	24	785	192.25	8.01	<.0001	<.0001
*gear*area*	8	785	178.05	22.26	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	13	104	72.81	5.60	<.0001	<.0001
numgear1	3	84E3	7249.70	2416.57	<.0001	<.0001
effort1	1	84E3	6951.46	6951.46	<.0001	<.0001
area	8	104	384.62	48.08	<.0001	<.0001
season	1	84E3	1269.21	1269.21	<.0001	<.0001
gear	1	84E3	955.88	955.88	<.0001	<.0001
days at sea	1	84E3	191.09	191.09	<.0001	<.0001
*area*season*	8	84E3	1693.66	211.71	<.0001	<.0001
*numgear1*area*	24	84E3	1455.98	60.67	<.0001	<.0001
*area*days at sea*	8	84E3	924.57	115.57	<.0001	<.0001

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+Area+Numgear1+Area*Numgear1+Gear*Area	2880.3	2882.3	2887.1	-	-
Year+Gear+Area+Numgear1+Area*Numgear1+Gear*Area+Year*Area	2858.5	2862.5	2868.2	21.8	<0.0001
Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
YEAR+Numgear1+Effort1+Area+Season+Gear+Days at sea+Area*Season+Numgear1*Area+Area*Days at sea	257346.1	257348.1	257357.5	-	-
YEAR+Numgear1+Effort1+Area+Season+Gear+Days at sea+Area*Season+Numgear1*Area+Area*Days at sea+Year*Area	256092.2	256096.2	256101.9	1253.9	<0.0001

Table 4. Linear regression statistics for the final GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the Mixing Zone for vessels reporting hook and line gear catch 1998-2006. Analysis of the mixed model formulations of the Mixing Zone 1998-2006 models (**C**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final models are 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	8	2156	54.10	6.76	<.0001	<.0001
gear	1	2156	699.64	699.64	<.0001	<.0001
area	8	2156	711.42	88.93	<.0001	<.0001
numgear1	3	2156	62.92	20.97	<.0001	<.0001
ves_len	4	2156	115.92	28.98	<.0001	<.0001
*area*ves_len*	32	2156	530.81	16.59	<.0001	<.0001
*area*numgear1*	24	2156	343.01	14.29	<.0001	<.0001
*gear*numgear1*	3	2156	190.12	63.37	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	8	64	31.23	3.90	0.0001	0.0008
numgear1	3	73E3	4135.60	1378.53	<.0001	<.0001
effort1	1	73E3	6536.09	6536.09	<.0001	<.0001
area	8	64	348.84	43.60	<.0001	<.0001
season	1	73E3	986.88	986.88	<.0001	<.0001
*area*season*	8	73E3	1929.55	241.19	<.0001	<.0001
*numgear1*area*	24	73E3	1294.57	53.94	<.0001	<.0001

C.

ANALYSIS OF MIXED MODEL FORMULATIONS

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
YEAR+Numgear1+Effort1+Area+Season +Area*Season+Numgear1*Area	221096.1	221098.1	221107.3	-	-
YEAR+Numgear1+Effort1+Area+Season +Area*Season+Numgear1*Area+Year*Area	220197.3	220201.3	220206.1	898.8	<0.0001

Table 5. Linear regression statistics for the final GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the south Atlantic for vessels reporting hook and line gear catch 1993-2006. Analysis of the mixed model formulations of the south Atlantic 1993-2006 models (**C**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final models are 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	36.86	2.84	0.0004	0.0038
gear	1	990	891.68	891.68	<.0001	<.0001
numgear1	2	990	323.34	161.67	<.0001	<.0001
area	4	52	37.43	9.36	<.0001	<.0001
effort1	2	990	123.39	61.69	<.0001	<.0001
*area*effort1*	8	990	255.45	31.93	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	13	52	8.87	0.68	0.7825	0.7709
gear	1	23E3	1069.82	1069.82	<.0001	<.0001
effort1	2	23E3	4006.63	2003.32	<.0001	<.0001
days at sea	2	23E3	507.21	253.60	<.0001	<.0001
season	1	23E3	558.96	558.96	<.0001	<.0001
area	4	52	128.30	32.07	<.0001	<.0001
crew	2	23E3	353.82	176.91	<.0001	<.0001
*gear*days at sea*	2	23E3	700.65	350.33	<.0001	<.0001
*days at sea*season*	2	23E3	422.94	211.47	<.0001	<.0001
*effort1*area*	8	23E3	346.62	43.33	<.0001	<.0001

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+Area+Effort1+Area*Effort1	3986.2	3988.2	3993.1	-	-
Year+Gear+Numgear1+Area+Effort1+Area*Effort1+Year*Area	3794.8	3798.8	3803.3	191.4	<0.0001
Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
YEAR+Gear+Effort1+Days at sea +Season+Area+Crew+Gear*Days at sea +Days at sea*Season+Effort1*Area	72588.9	72590.9	72598.9	-	-
YEAR+Gear+Effort1+Days at sea +Season+Area+Crew+Gear*Days at sea +Days at sea*Season+Effort1*Area+Year*Area	72414.2	72418.2	72422.7	174.7	<0.0001

Table 6. Linear regression statistics for the final GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for king mackerel in the south Atlantic for vessels reporting hook and line gear catch 1998-2006. 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	8	682	61.66	7.71	<.0001	<.0001
gear	1	682	710.52	710.52	<.0001	<.0001
numgear1	2	682	304.88	152.44	<.0001	<.0001
effort1	2	682	77.96	38.98	<.0001	<.0001
area	4	682	123.77	30.94	<.0001	<.0001
*effort1*area*	8	682	266.22	33.28	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	8	16E3	49.75	6.22	<.0001	<.0001
days at sea	2	16E3	423.56	211.78	<.0001	<.0001
effort1	2	16E3	2331.60	1165.80	<.0001	<.0001
gear	1	16E3	973.64	973.64	<.0001	<.0001
season	1	16E3	358.69	358.69	<.0001	<.0001
area	4	16E3	755.46	188.87	<.0001	<.0001
crew	2	16E3	111.74	55.87	<.0001	<.0001
*days at sea*gear*	2	16E3	566.47	283.24	<.0001	<.0001
*days at sea*season*	2	16E3	324.20	162.10	<.0001	<.0001
*effort1*area*	8	16E3	300.26	37.53	<.0001	<.0001
*gear*area*	4	16E3	190.16	47.54	<.0001	<.0001

Table 7. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel (1993-2006) 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	0.123555	1,340	0.085075	0.454380	0.151004	1.367251	0.595355
1994	0.236274	1,518	0.128458	0.690912	0.281546	1.695495	0.472445
1995	0.401100	1,781	0.152162	0.491794	0.176727	1.368563	0.547131
1996	0.454153	2,822	0.183203	0.568332	0.221974	1.455133	0.497277
1997	0.560204	3,082	0.183971	0.620486	0.247003	1.558693	0.486086
1998	0.858931	3,358	0.195354	0.818353	0.349948	1.913717	0.444653
1999	1.108219	3,635	0.276479	1.075171	0.496729	2.327210	0.400941
2000	1.602305	3,676	0.316376	1.236256	0.610104	2.505031	0.364405
2001	1.301125	3,561	0.308060	1.518382	0.762870	3.022119	0.354603
2002	1.437522	3,448	0.325696	1.338842	0.671849	2.668008	0.355266
2003	1.303909	3,228	0.301115	1.420399	0.695515	2.900775	0.368705
2004	1.353158	2,842	0.279381	1.107671	0.525863	2.333187	0.385789
2005	1.483829	2,373	0.247366	1.164672	0.541792	2.503657	0.397101
2006	1.775717	2,209	0.323676	1.494349	0.735184	3.037445	0.366114

Table 8. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel (1998-2006) 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)
1998	0.650428	2,356	0.224533	0.688704	0.416593	1.138551	0.255373
1999	0.830656	2,748	0.316958	1.000625	0.618454	1.618955	0.244102
2000	1.208361	2,943	0.357119	1.019607	0.635529	1.635800	0.239697
2001	0.943813	3,033	0.350478	1.102069	0.687584	1.766411	0.239200
2002	1.013228	3,073	0.355353	0.979926	0.612152	1.568655	0.238541
2003	0.932864	3,016	0.329244	1.180047	0.732356	1.901412	0.241954
2004	1.017504	2,621	0.310950	0.900936	0.556184	1.459384	0.244717
2005	1.088789	2,140	0.281776	0.846927	0.514198	1.394959	0.253437
2006	1.314357	1,981	0.368501	1.281159	0.783103	2.095982	0.249903

Table 9. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel (1993-2006) 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	0.628571	4,769	0.263577	0.719997	0.526744	0.984152	0.157225
1994	0.379176	6,083	0.249384	0.576532	0.420222	0.790984	0.159117
1995	0.432955	6,674	0.269853	0.624256	0.462573	0.842453	0.150724
1996	0.618813	7,487	0.339789	0.917275	0.699001	1.203708	0.136507
1997	0.496609	8,626	0.301067	0.722752	0.544530	0.959307	0.142285
1998	0.986350	15,189	0.590954	1.068421	0.824782	1.384030	0.129953
1999	0.979227	15,963	0.546514	0.992244	0.762146	1.291810	0.132491
2000	0.857775	15,649	0.580676	0.868512	0.666710	1.131397	0.132793
2001	0.949557	15,994	0.587533	0.973572	0.750065	1.263679	0.130962
2002	1.056768	15,008	0.596415	1.007351	0.778563	1.303370	0.129351
2003	1.614024	15,144	0.644083	1.354996	1.054966	1.740356	0.125637
2006	1.644270	11,685	0.602824	1.322998	1.023296	1.710475	0.128967

Table 10. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel (1998-2006) in the Mixing Zone.

Year	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.799632	11,927	0.667645	0.903502	0.701194	1.164179	0.127258
1999	0.781926	13,160	0.609119	0.890428	0.690103	1.148903	0.127949
2000	0.682293	13,578	0.642215	0.776547	0.601717	1.002175	0.128056
2001	0.760695	14,471	0.643217	0.862622	0.669496	1.111459	0.127237
2002	0.824933	14,195	0.646073	0.856939	0.666003	1.102616	0.126539
2003	1.244859	14,643	0.692208	1.127546	0.879069	1.446258	0.124952
2004	1.285037	11,443	0.644149	1.118056	0.868888	1.438677	0.126569
2005	1.149593	9,866	0.608453	1.091646	0.846759	1.407355	0.127527
2006	1.471033	9,568	0.678094	1.372714	1.067997	1.764372	0.125998

Table 11. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel (1993-2006) 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	0.503334	1,806	0.594131	1.240778	0.895965	1.718292	0.163881
1994	0.447731	2,235	0.501119	1.152735	0.826842	1.607077	0.167293
1995	0.646973	2,811	0.479545	1.045857	0.74292	1.472321	0.172260
1996	0.477602	2,994	0.385438	0.753881	0.517578	1.098069	0.189712
1997	0.859802	3,380	0.465680	1.088512	0.773479	1.531857	0.172089
1998	1.098419	4,033	0.520704	1.066988	0.764277	1.489594	0.168000
1999	1.111831	4,153	0.540092	0.950994	0.678544	1.332839	0.169988
2000	1.064089	4,120	0.577913	1.055069	0.755848	1.472745	0.167927
2001	0.989898	4,256	0.546053	0.916467	0.652101	1.288008	0.171402
2002	0.885326	3,803	0.440442	0.816409	0.568868	1.171668	0.182118
2003	1.094464	3,151	0.452872	0.810965	0.561896	1.170437	0.185008
2004	1.500360	3,100	0.464194	0.912264	0.633481	1.313734	0.183876
2005	1.610483	2,869	0.521087	1.105332	0.783075	1.560206	0.173624
2006	1.709688	2,720	0.531250	1.083749	0.766015	1.533276	0.174804

Table 12. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for king mackerel (1998-2006) in the south Atlantic.

Year	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.936623	3,226	0.524799	1.139407	1.039186	1.249293	0.046059
1999	0.938754	3,622	0.540585	0.993184	0.905547	1.089301	0.046213
2000	0.858712	3,926	0.571829	1.087486	0.997529	1.185555	0.043191
2001	0.800080	4,180	0.543541	0.950849	0.870685	1.038393	0.044059
2002	0.686636	3,791	0.435241	0.827485	0.746957	0.916695	0.051226
2003	0.858979	3,221	0.454828	0.869600	0.779651	0.969926	0.054634
2004	1.212350	3,094	0.467033	0.935772	0.835481	1.048103	0.056728
2005	1.334965	2,915	0.525214	1.128376	1.020942	1.247116	0.050058
2006	1.372902	2,764	0.534370	1.067842	0.963494	1.183491	0.051448

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

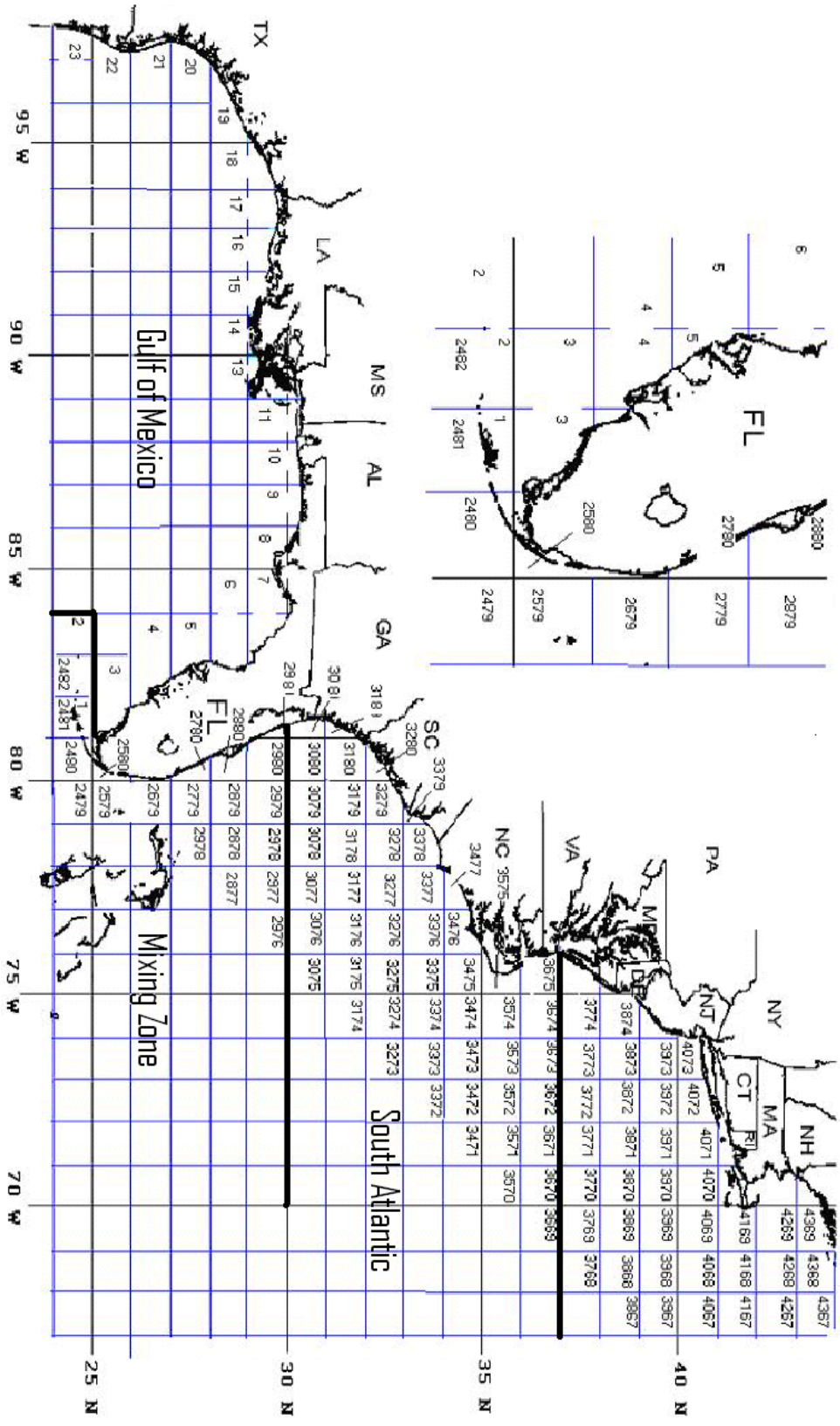


Figure 2. King mackerel (1993-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing hook and line gear (handline, electric reel, and trolling) in the Gulf of Mexico.

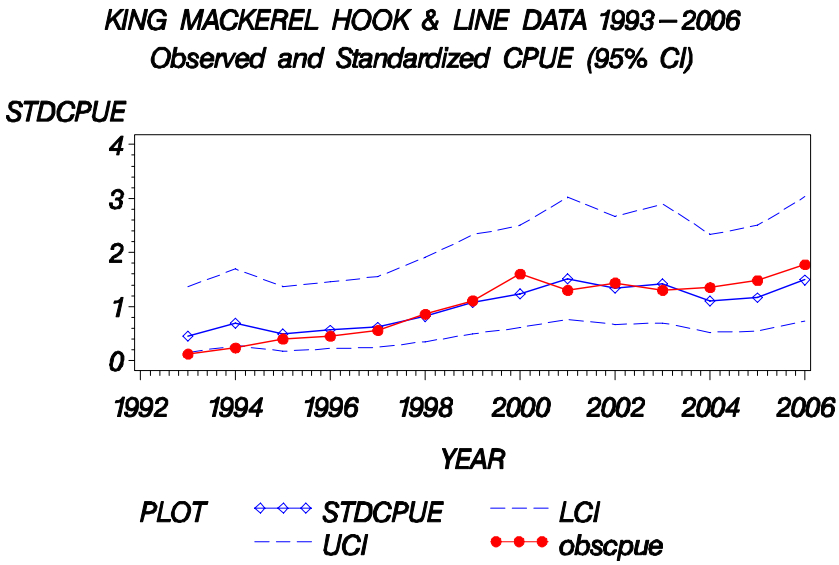


Figure 3. King mackerel (1998-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing hook and line gear in the Gulf of Mexico.

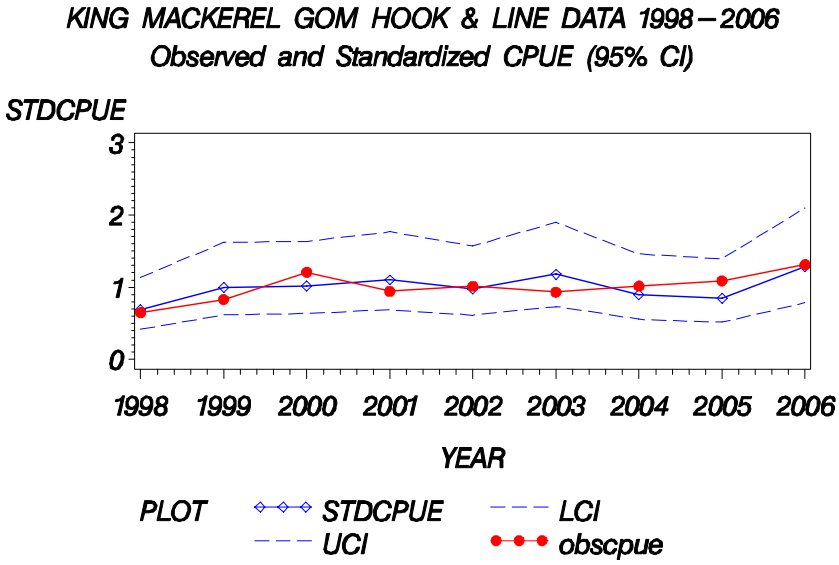


Figure 4. King mackerel (1993-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing hook and line gear in the Mixing Zone.

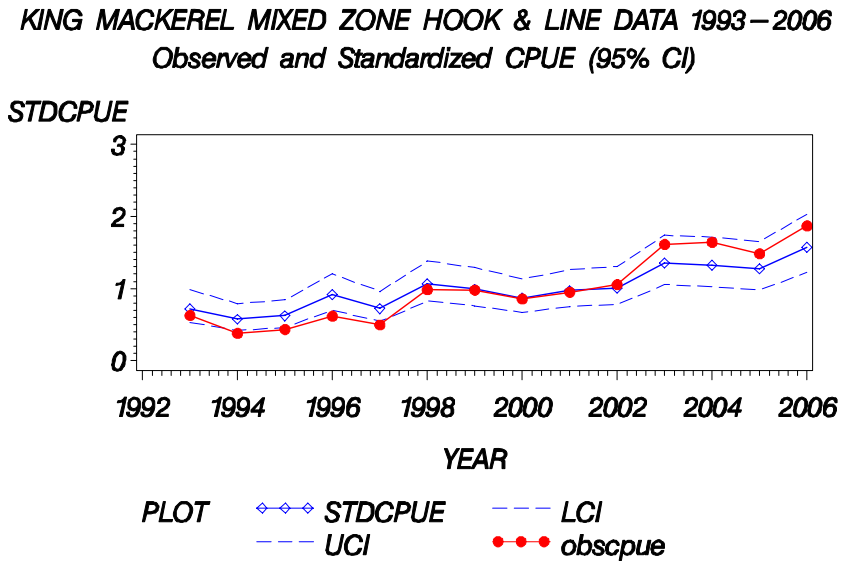


Figure 5. King mackerel (1998-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing hook and line gear in the Mixing Zone.

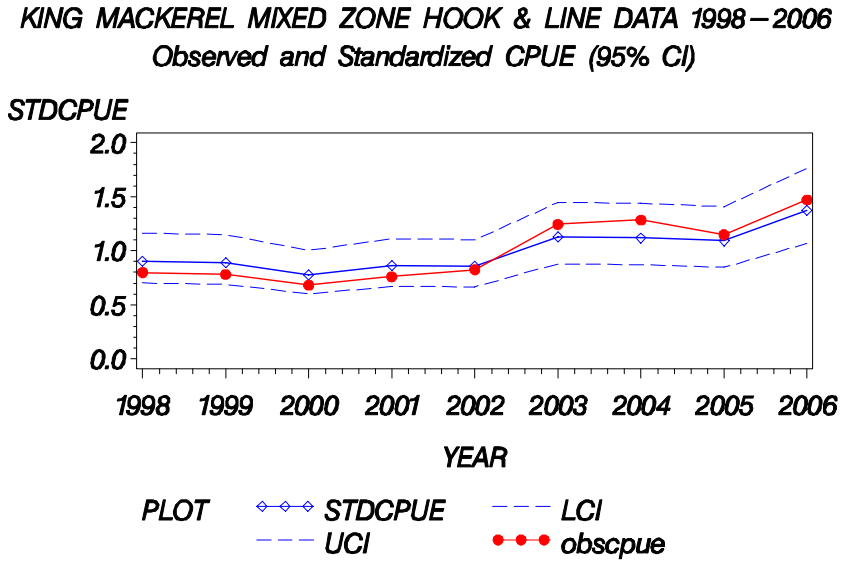


Figure 6. King mackerel (1993-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing hook and line gear in the south Atlantic.

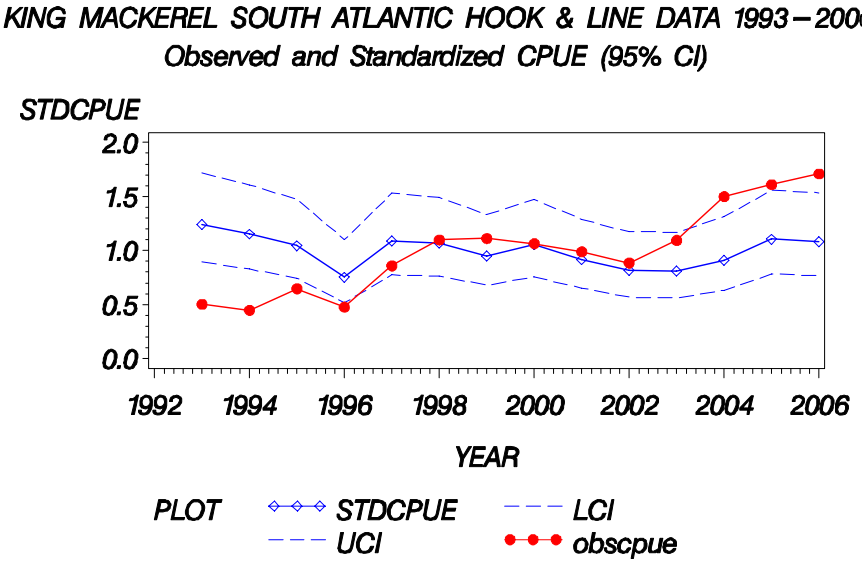


Figure 7. King mackerel (1998-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing hook and line gear in the south Atlantic.

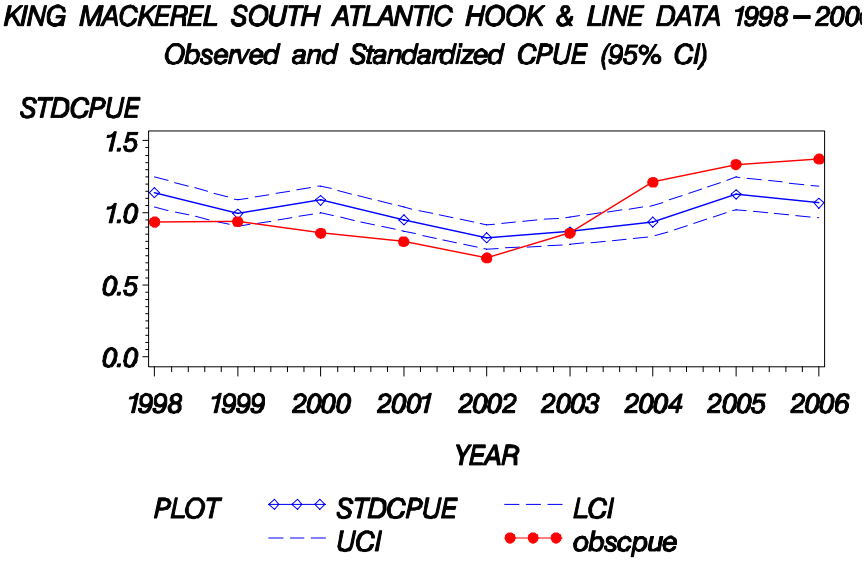
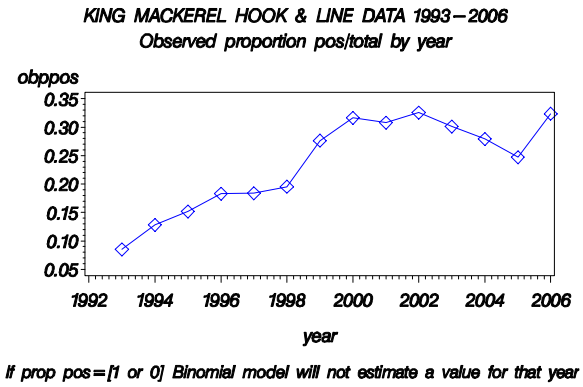


Figure 8. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model.

A.



B.

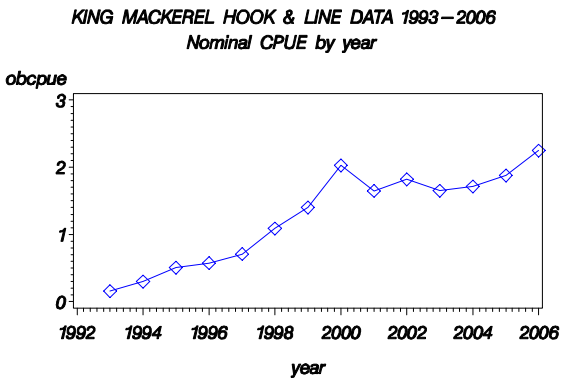
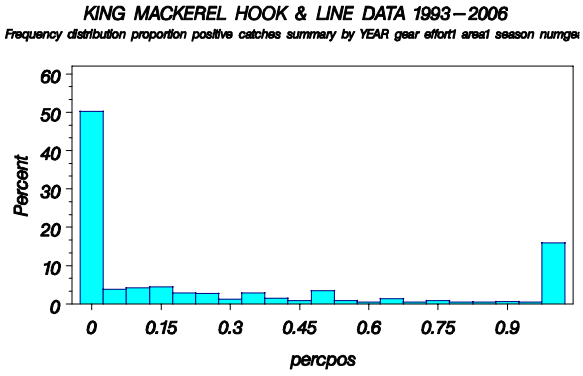
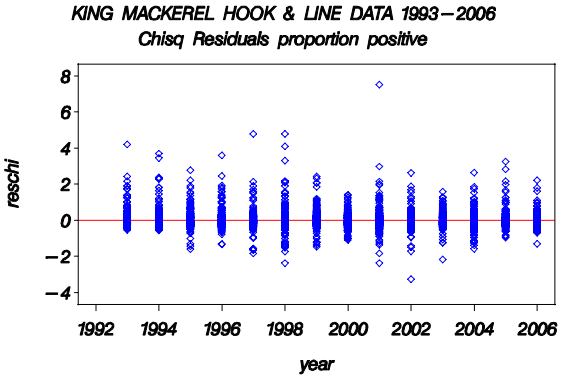


Figure 9. Diagnostic plots for the binomial component of the Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by hooks per line (effort).

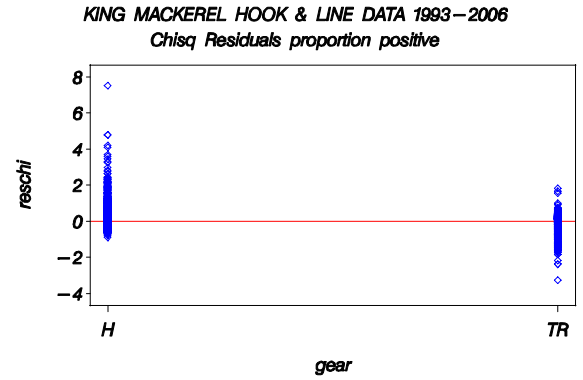
A.



B.



C.



D.

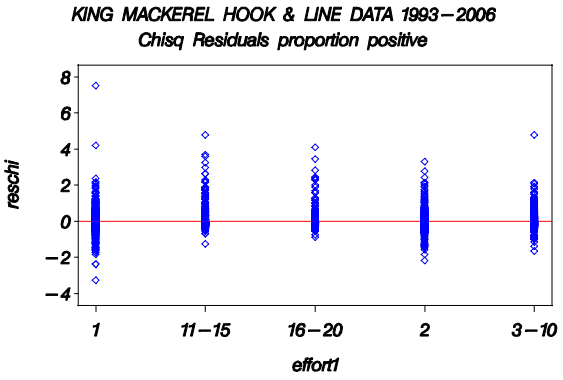
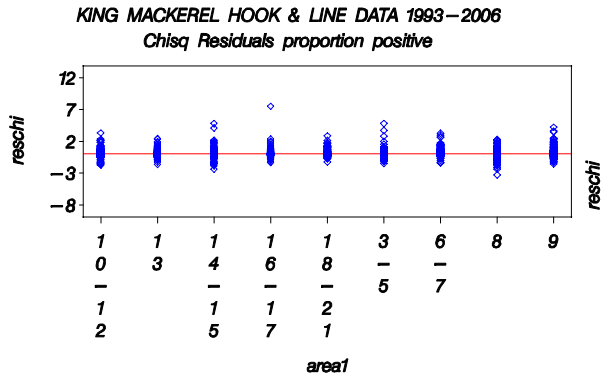
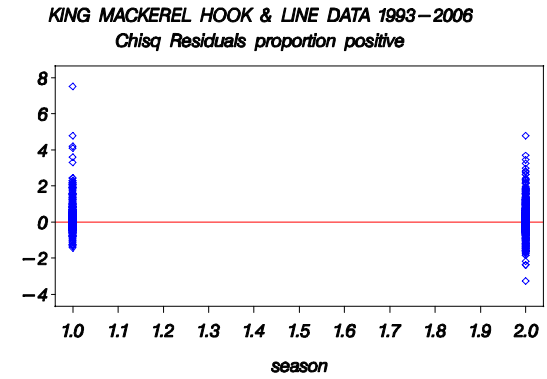


Figure 9 (continued). Diagnostic plots for the binomial component of the Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by area; **F**. the Chi-Square residuals by season; and **G**. the Chi-Square residuals by number of lines fished (Numgear1).

E.



F.



G.

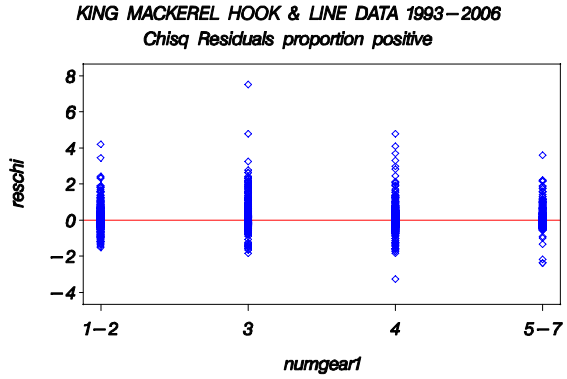
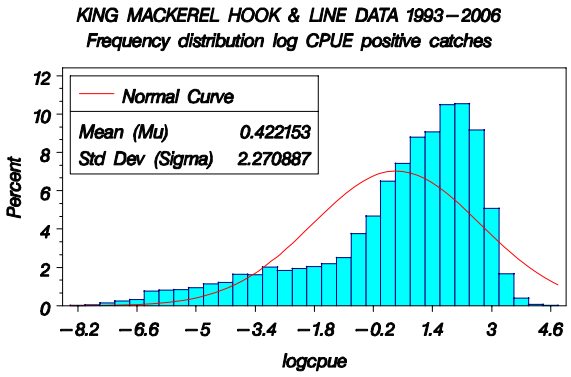


Figure 10. Diagnostic plots for the lognormal component of the Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

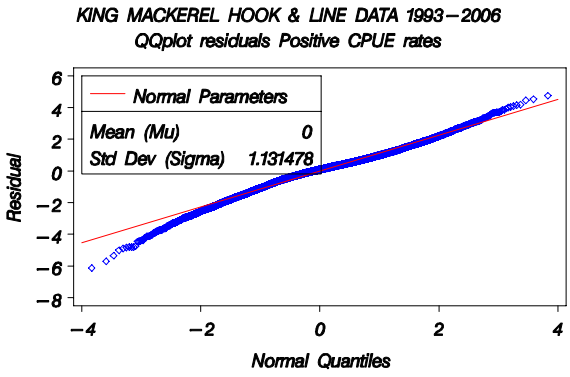
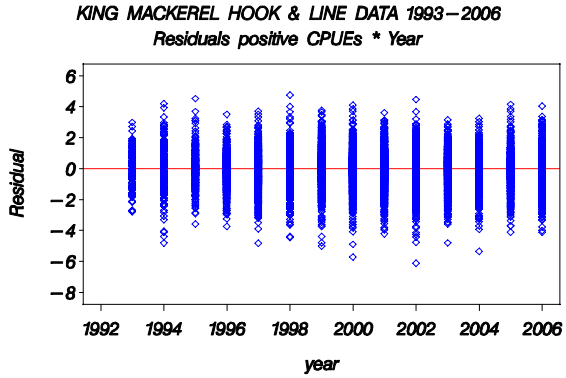
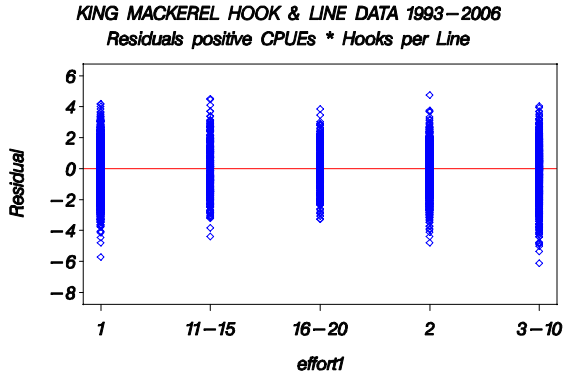


Figure 11. Diagnostic plots for the lognormal component of the Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by hooks per line (effort); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by days at sea (away).

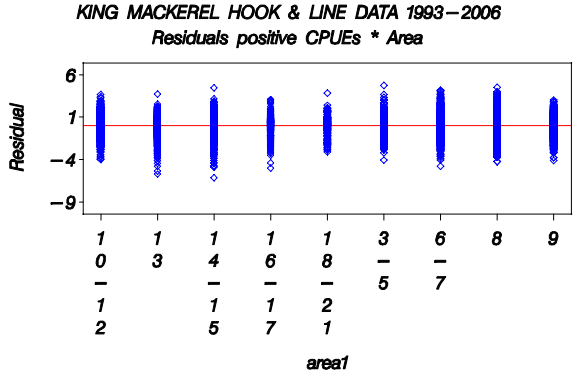
A.



B.



C.



D.

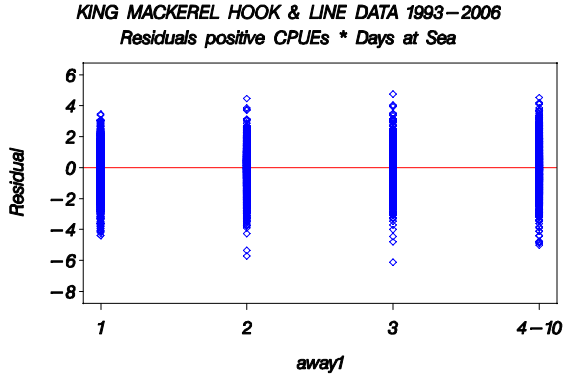
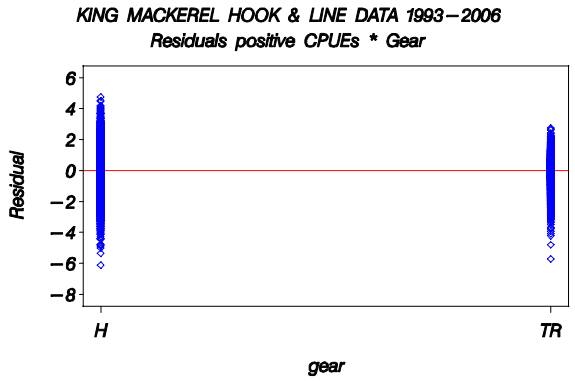
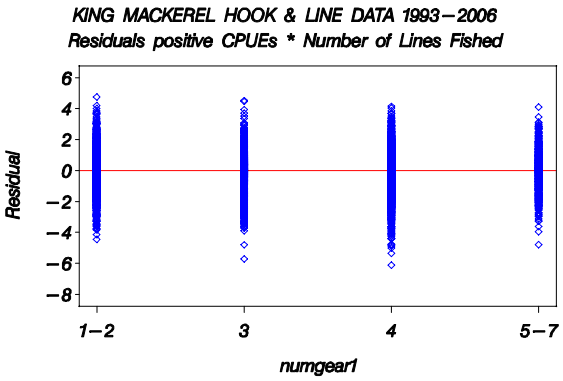


Figure 11 (continued). Diagnostic plots for the lognormal component of the Gulf of Mexico 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by gear; **F**. the Chi-Square residuals by number of lines fished (Numgear1); and **G**. the Chi-Square residuals by vessel length (ves_len).

E.



F.



G.

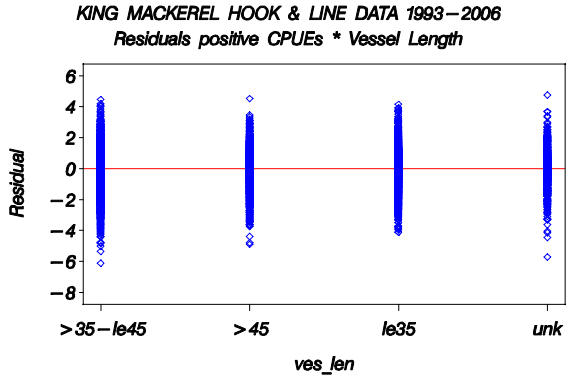
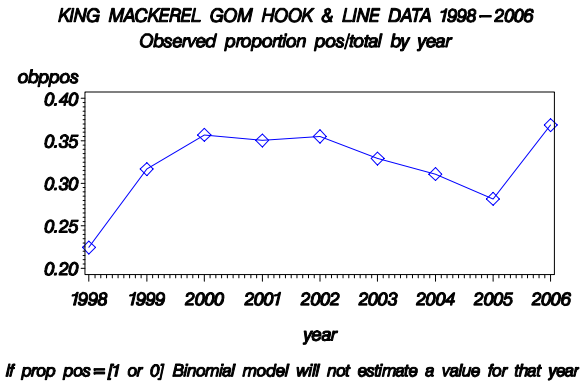


Figure 12. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the Gulf of Mexico 1998-2006 king mackerel commercial hook and line gear model.

A.



B.

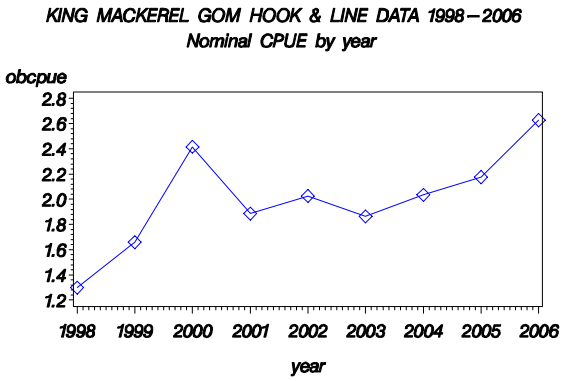
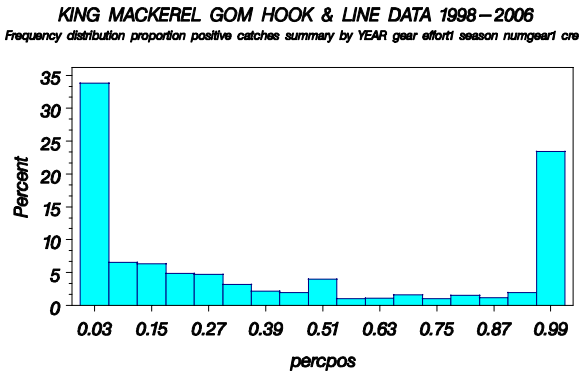
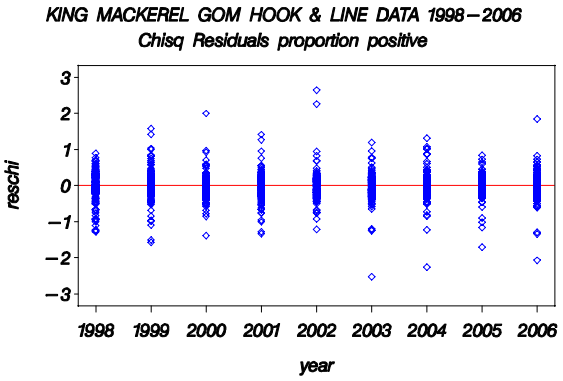


Figure 13. Diagnostic plots for the binomial component of the Gulf of Mexico 1998-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by hooks per line (effort).

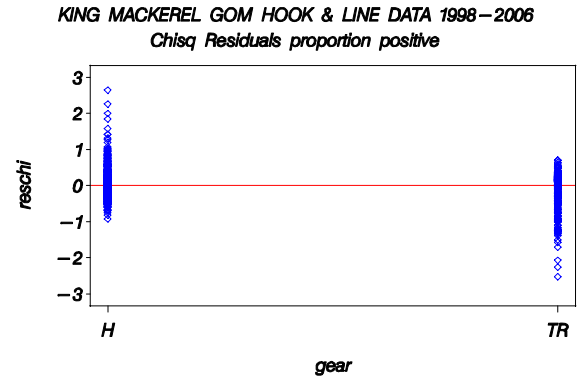
A.



B.



C.



D.

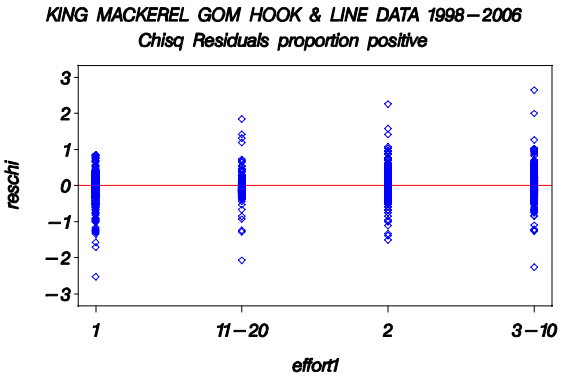
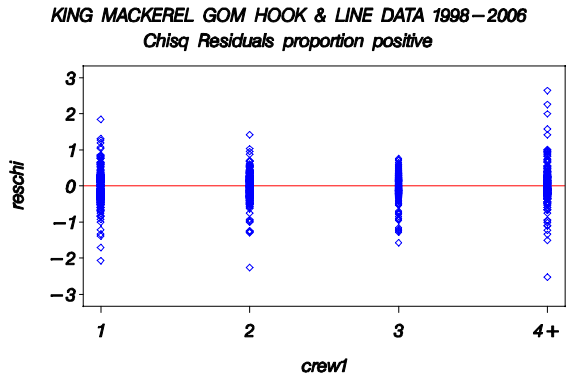
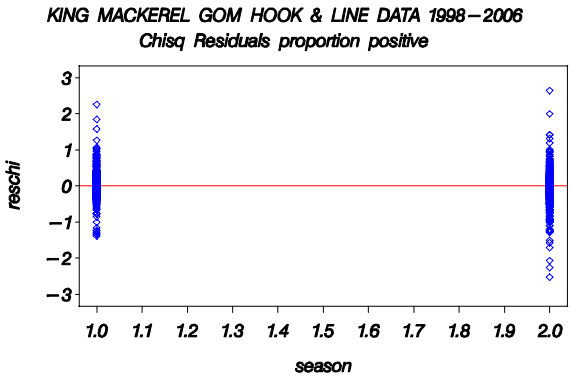


Figure 13(continued). Diagnostic plots for the binomial component of the Gulf of Mexico 1998-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by number of crew; **F**. the Chi-Square residuals by season; and **G**. the Chi-Square residuals by Number of lines fished (numgear1).

E.



F.



G.

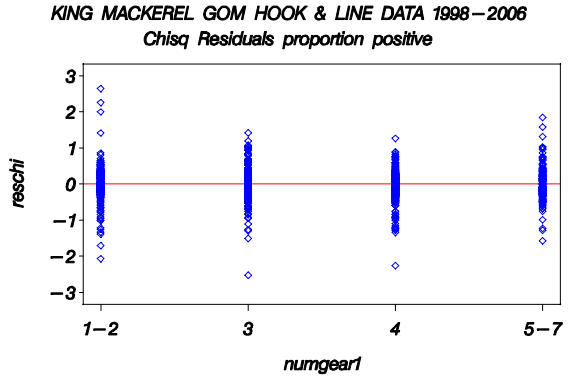
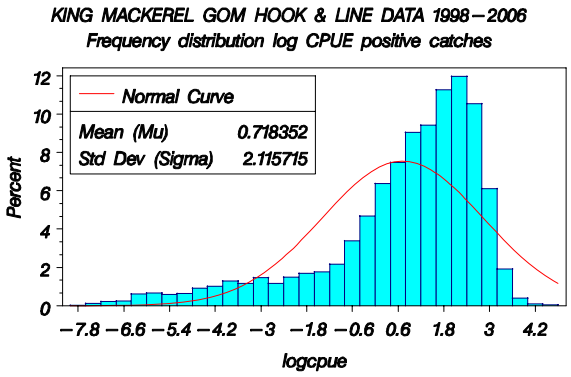


Figure 14. Diagnostic plots for the lognormal component of the Gulf of Mexico 1998-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

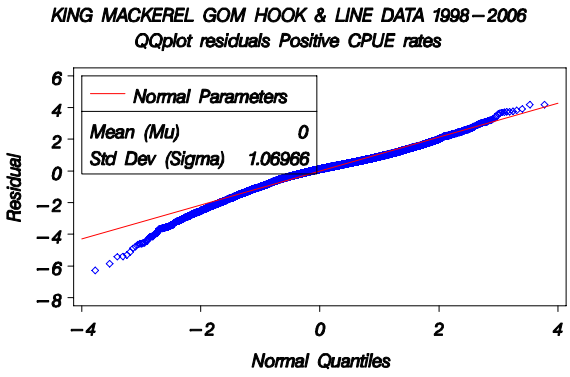
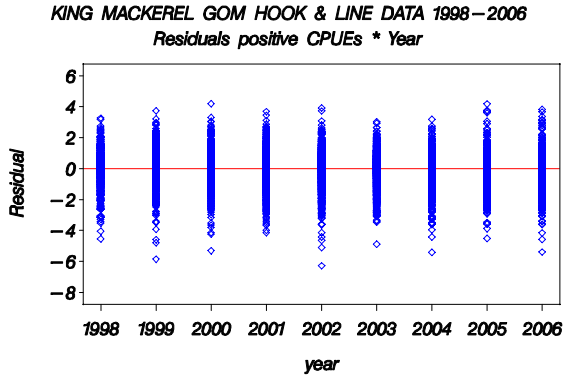
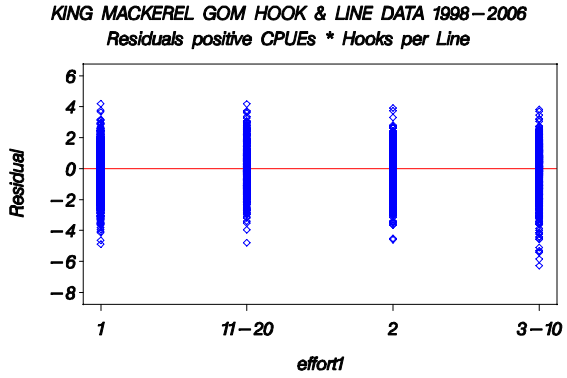


Figure 15. Diagnostic plots for the lognormal component of the Gulf of Mexico 1998-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by hooks per line (effort); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by days at sea (away).

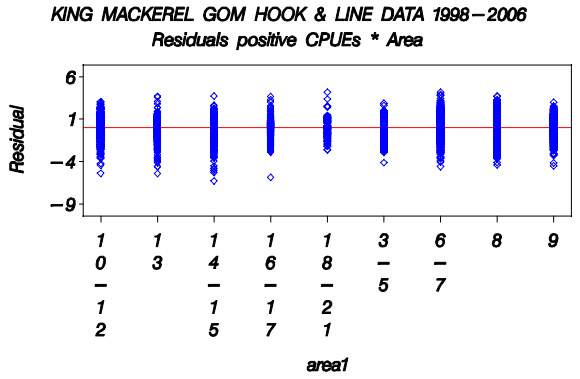
A.



B.



C.



D.

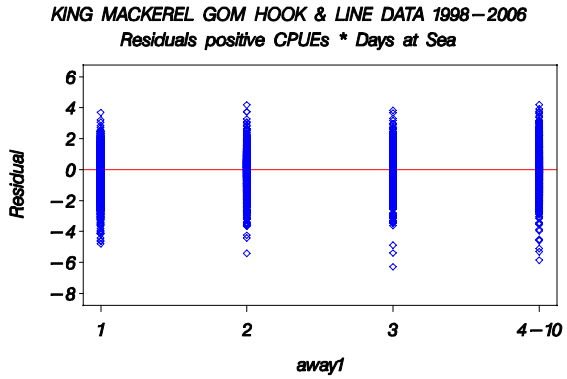
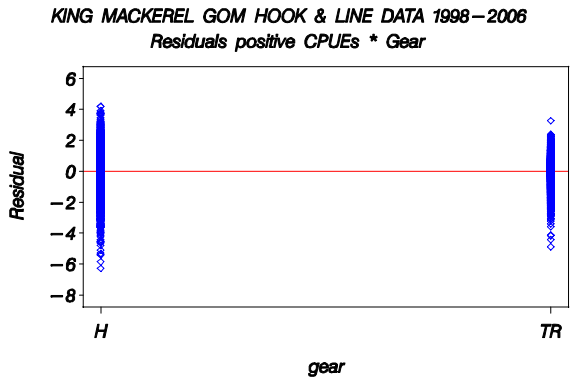
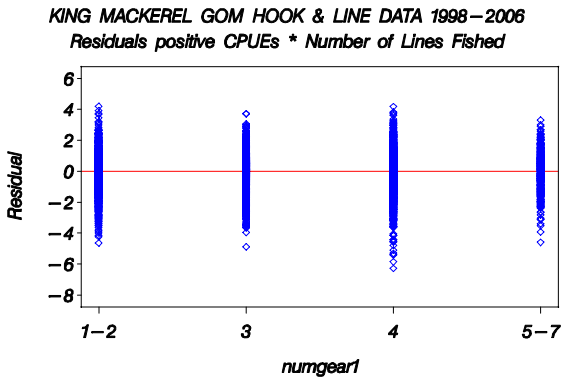


Figure 15 (continued). Diagnostic plots for the lognormal component of the Gulf of Mexico 1998-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by gear; **F**. the Chi-Square residuals by number of lines fished (numgear1); **G**. the Chi-Square residuals by vessel length (ves_len); and **H**. the Chi-Square residuals by season.

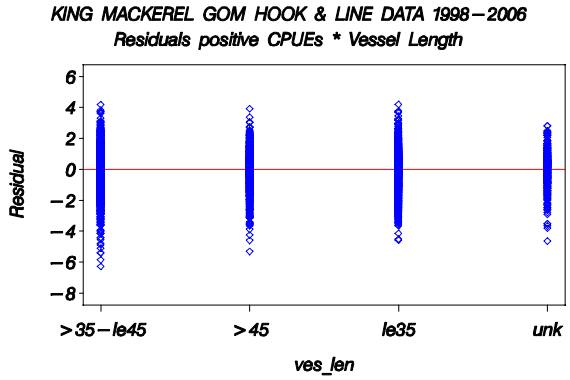
E.



F.



G.



H.

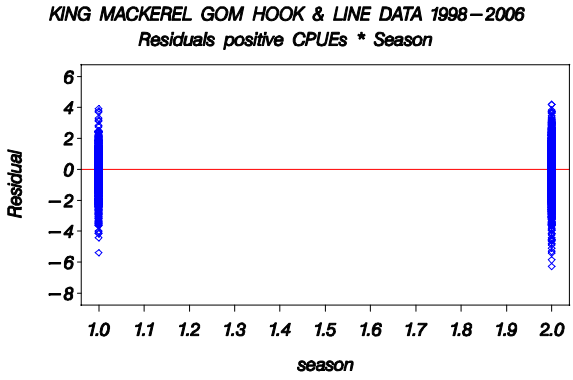
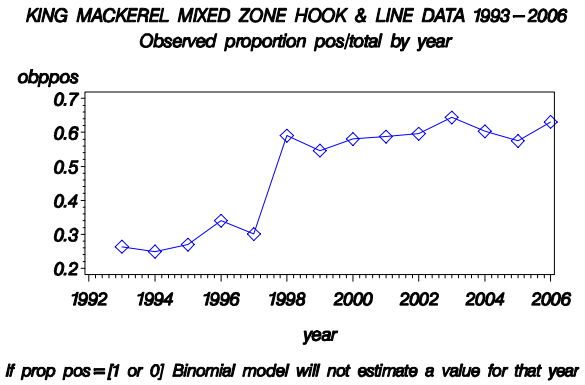


Figure 16. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the Mixing Zone 1993-2006 king mackerel commercial hook and line gear model.

A.



B.

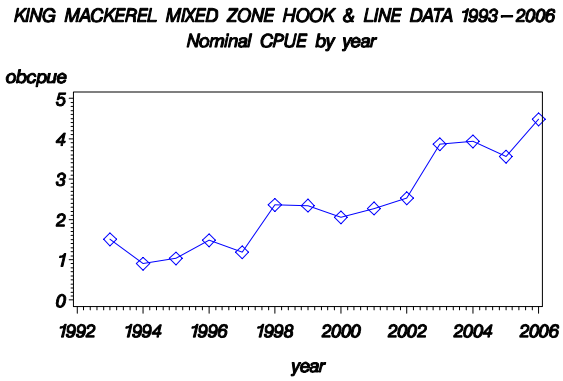
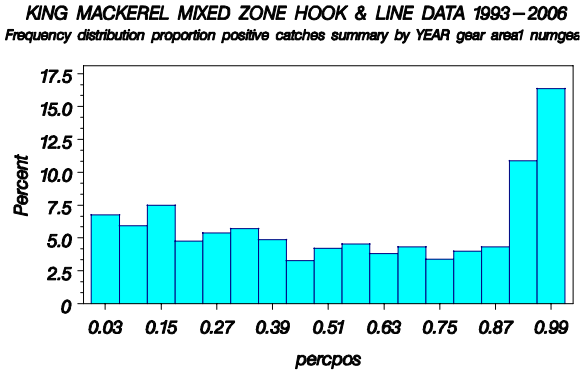
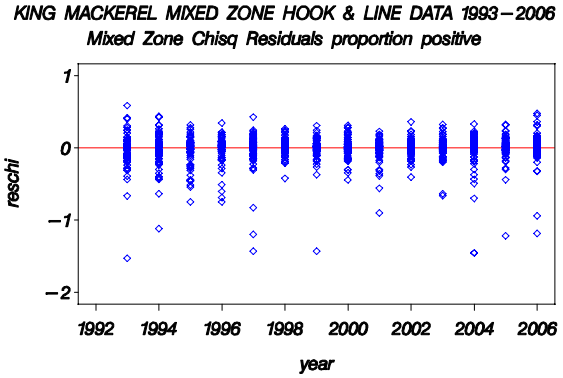


Figure 17. Diagnostic plots for the binomial component of the Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by area.

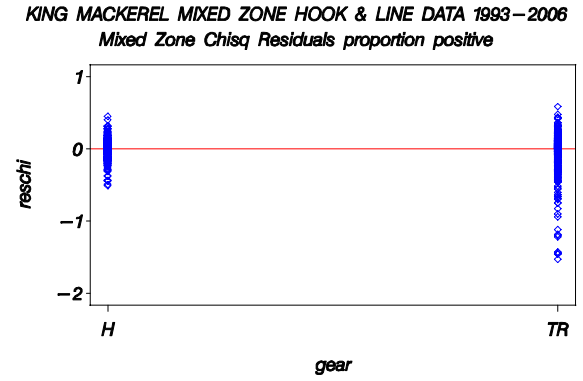
A.



B.



C.



D.

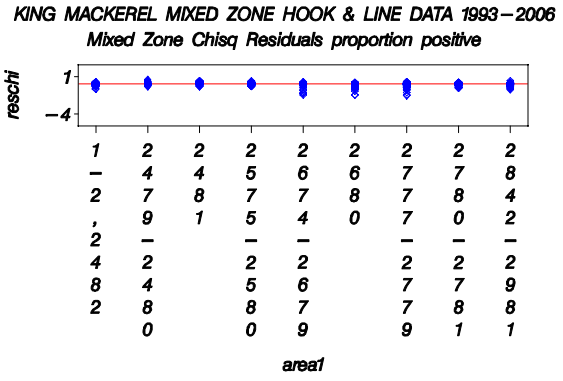


Figure 17(continued). Diagnostic plots for the binomial component of the Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by number of lines fished (numgear1).

E.

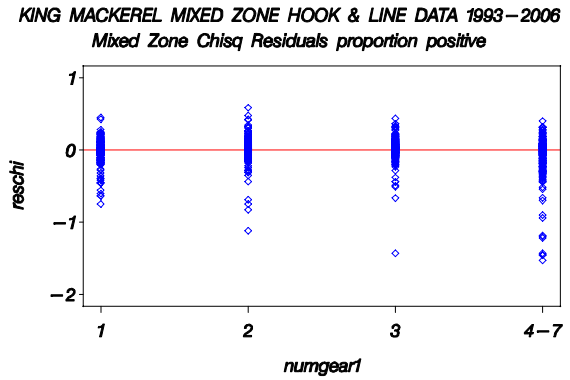


Figure 18. Diagnostic plots for the lognormal component of the Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

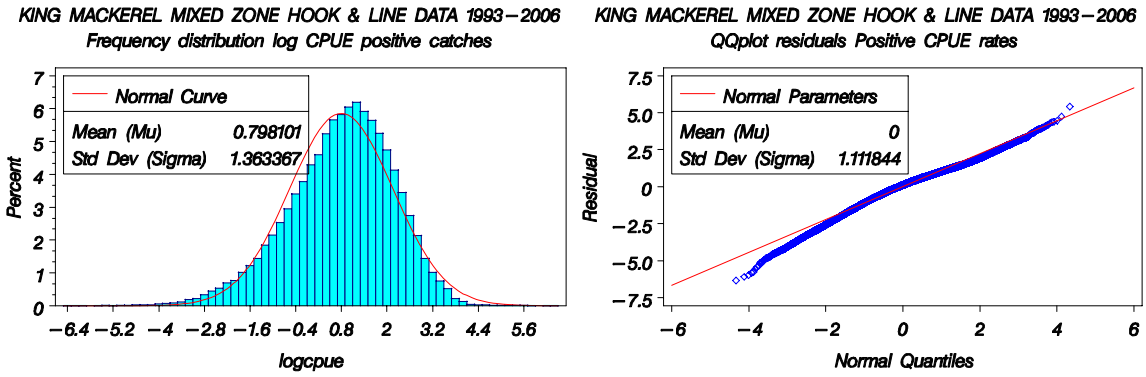
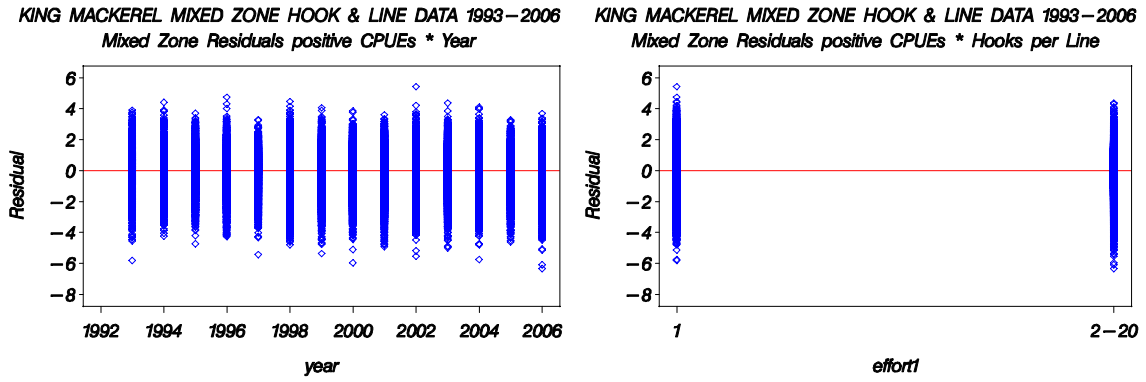


Figure 19. Diagnostic plots for the lognormal component of the Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by hooks per line (effort); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by days at sea (away).

A. **B.**



C. **D.**

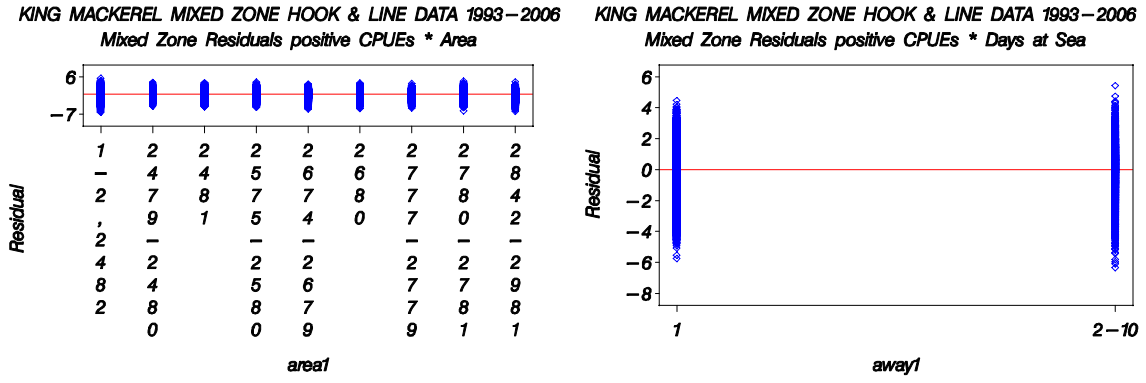
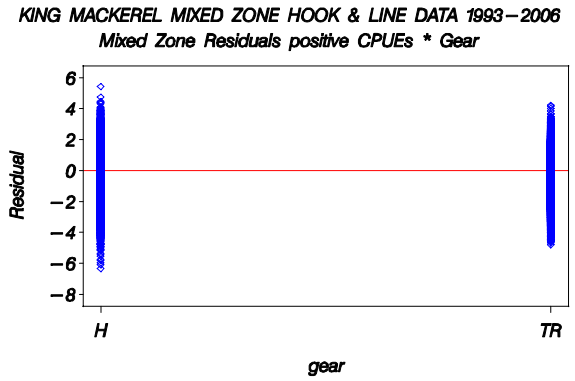
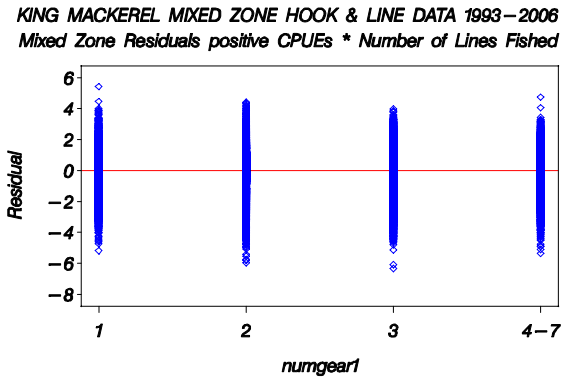


Figure 19 (continued). Diagnostic plots for the lognormal component of the Mixing Zone 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by gear; **F**. the Chi-Square residuals by number of lines fished (numgear1); **G**. the Chi-Square residuals by season.

E.



F.



G.

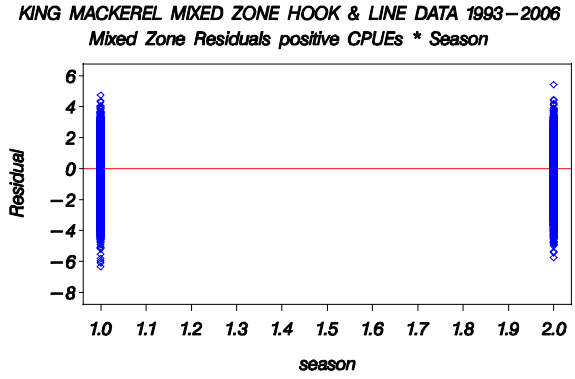
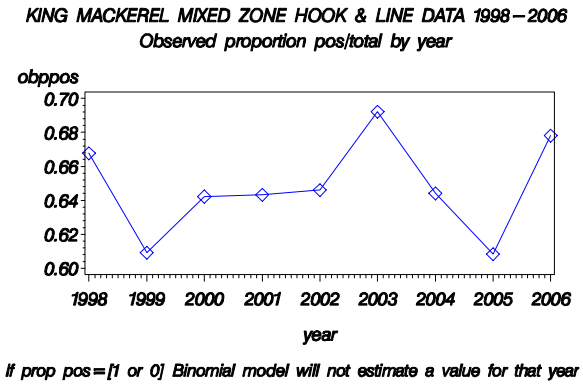


Figure 20. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the Mixing Zone 1998-2006 king mackerel commercial hook and line gear model.

A.



B.

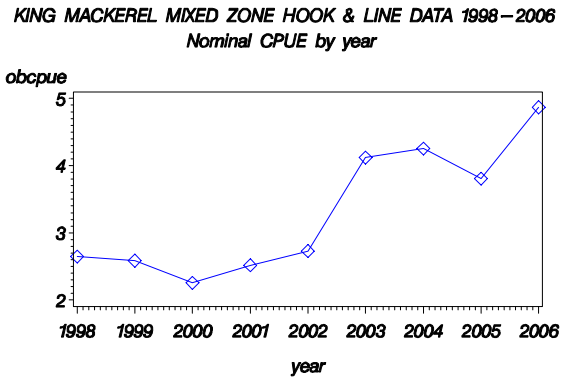
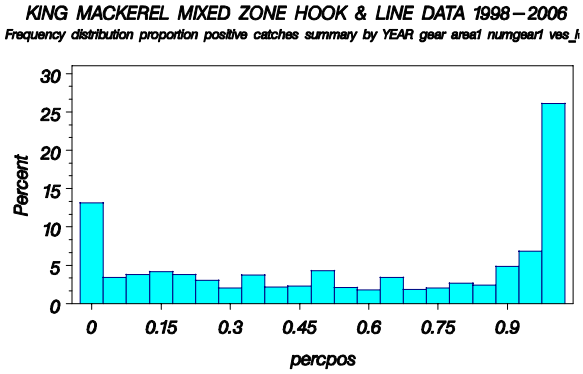
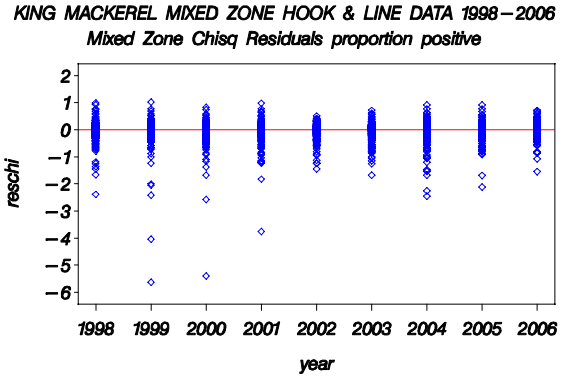


Figure 21. Diagnostic plots for the binomial component of the Mixing Zone 1998-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by area.

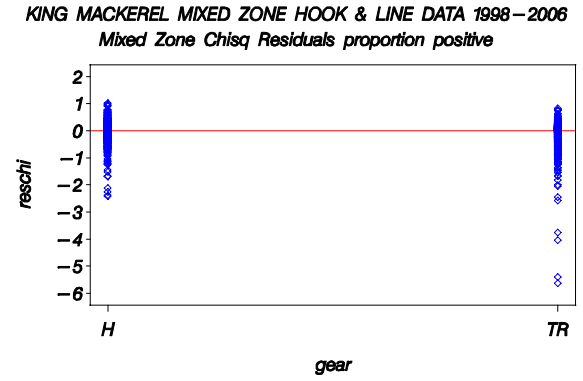
A.



B.



C.



D.

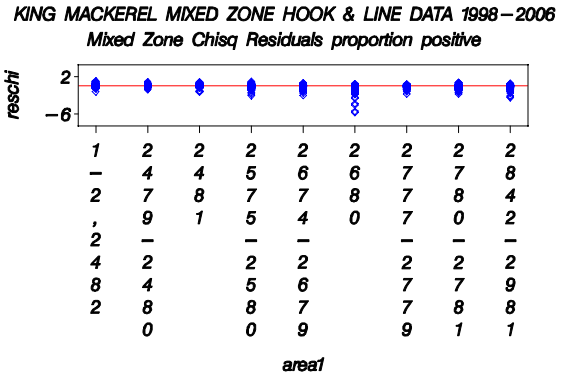
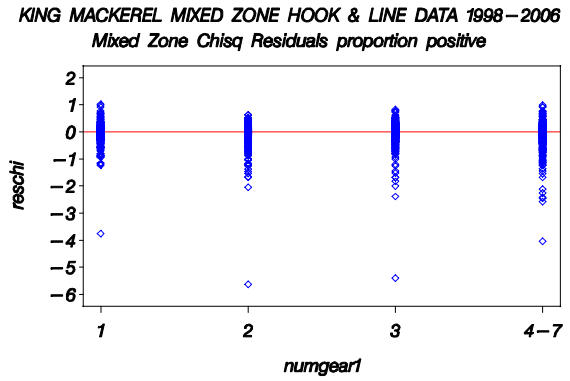


Figure 21 (continued). Diagnostic plots for the binomial component of the Mixing Zone 1998-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by number of lines fished (numgear1); **F**. the Chi-Square residuals by vessel length (ves_len).

E.



F.

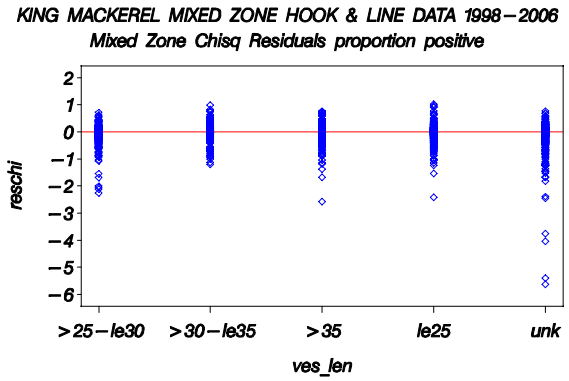
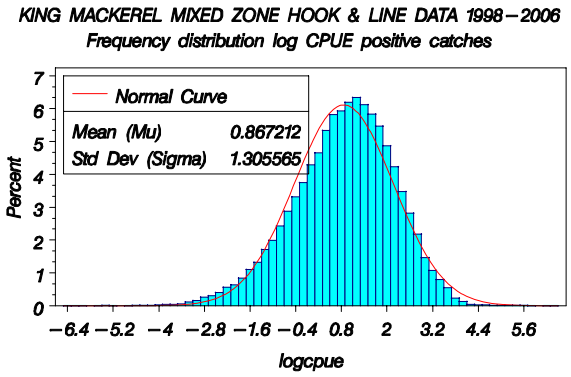


Figure 22. Diagnostic plots for the lognormal component of the Mixing Zone 1998-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

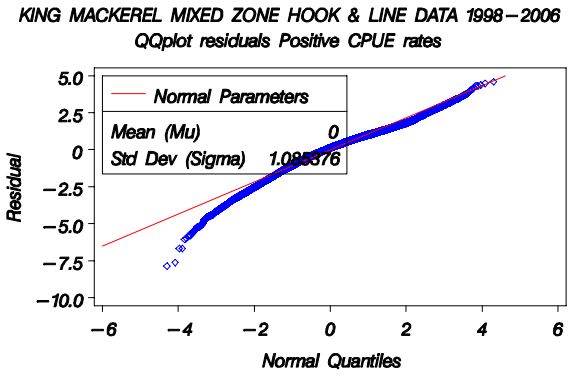
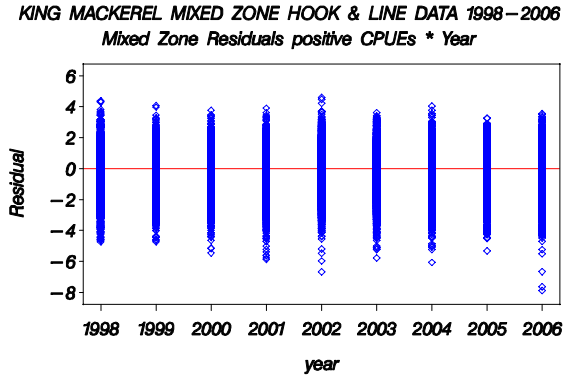
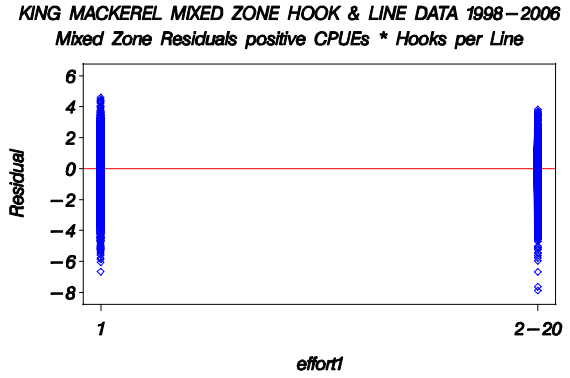


Figure 23. Diagnostic plots for the lognormal component of the Mixing Zone 1998-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by hooks per line (effort); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by number of lines fished (numgear1).

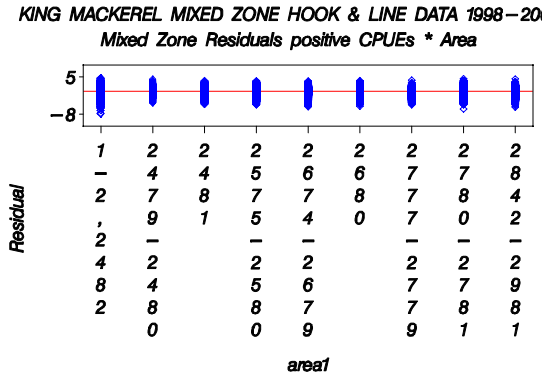
A.



B.



C.



D.

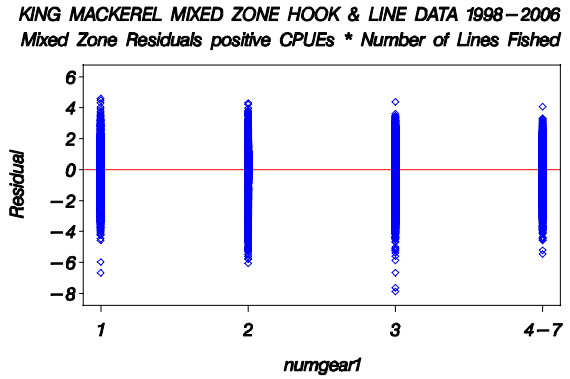


Figure 23 (continued). Diagnostic plots for the lognormal component of the Mixing Zone 1998-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by season.

E.

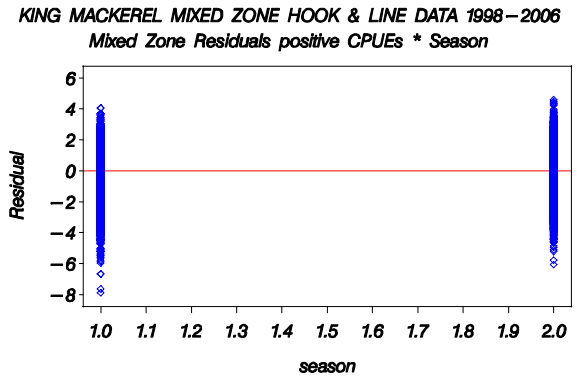


Figure 24. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the South Atlantic 1993-2006 king mackerel commercial hook and line gear model.

A. **B.**

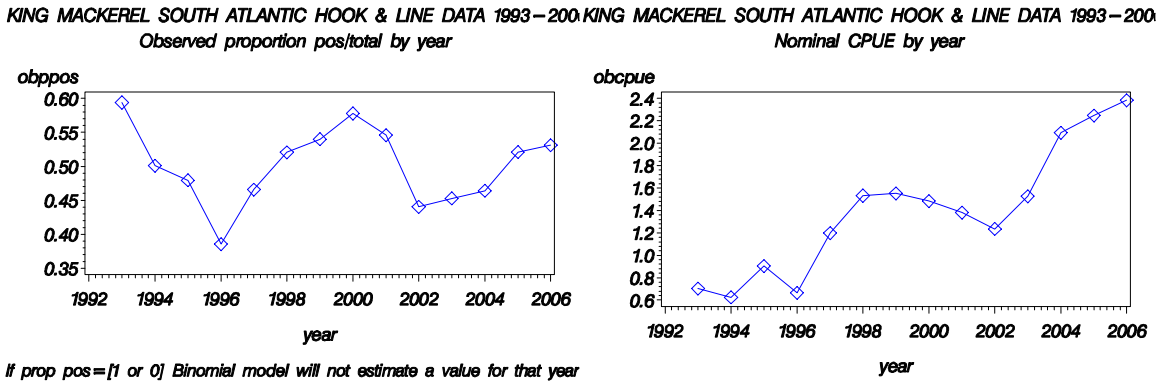
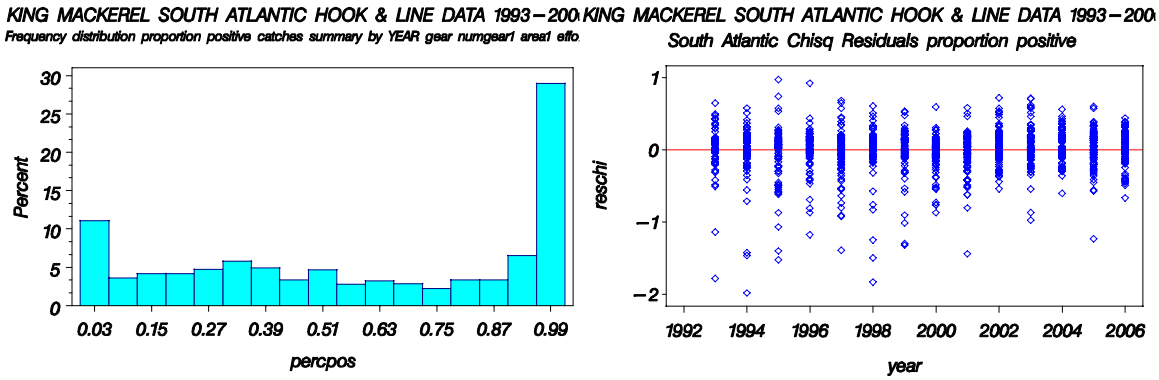


Figure 25. Diagnostic plots for the binomial component of the South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by area.

A. **B.**



C. **D.**

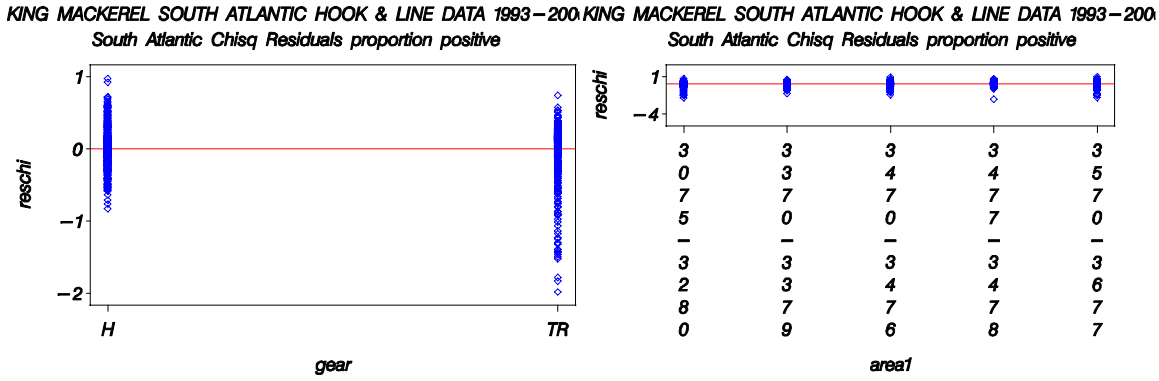
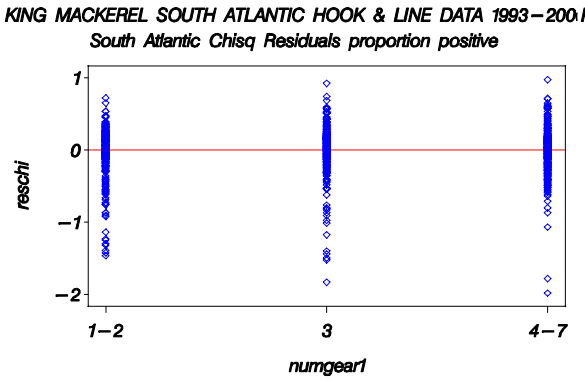


Figure 25 (continued). Diagnostic plots for the binomial component of the South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by number of lines fished (numgear1) and **F**. the Chi-Square residuals by hooks per line (effort).

E.



F.

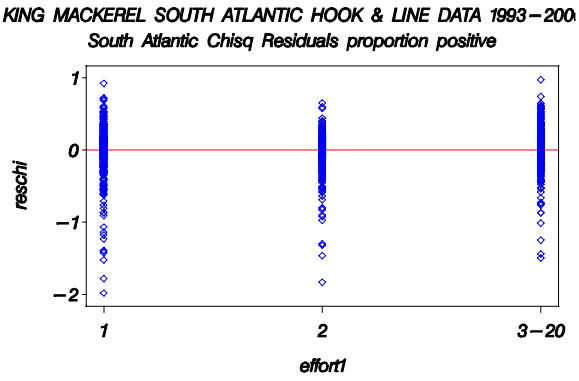


Figure 26. Diagnostic plots for the lognormal component of the South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **A**) the frequency distribution of log(CPUE) on positive trips, **B**) the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

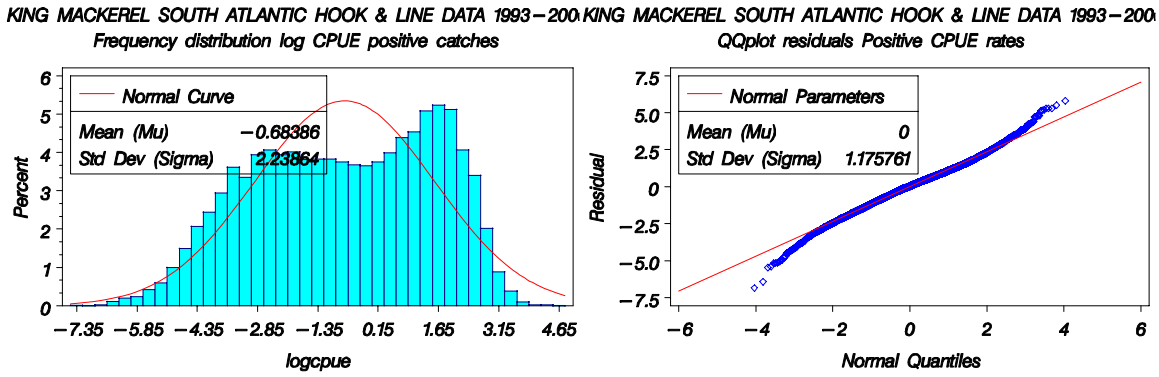
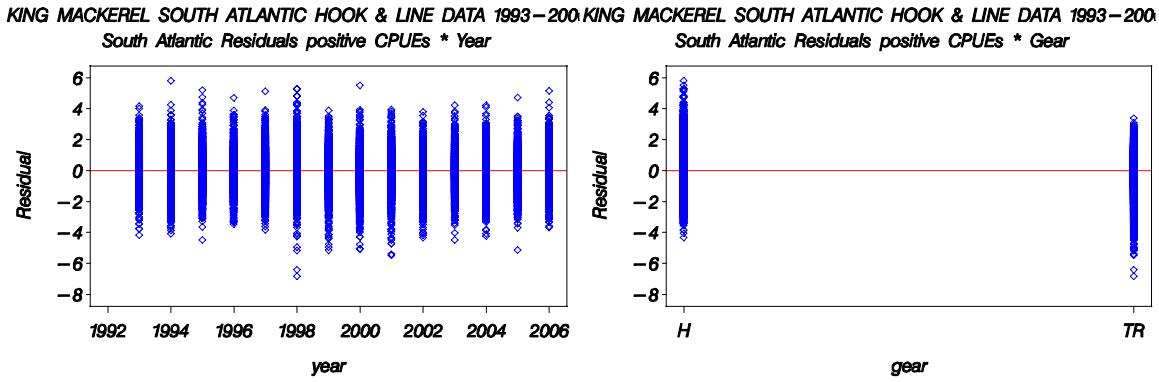


Figure 27. Diagnostic plots for the lognormal component of the South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by gear; **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by number of lines fished (numgear1).

A. **B.**



C. **D.**

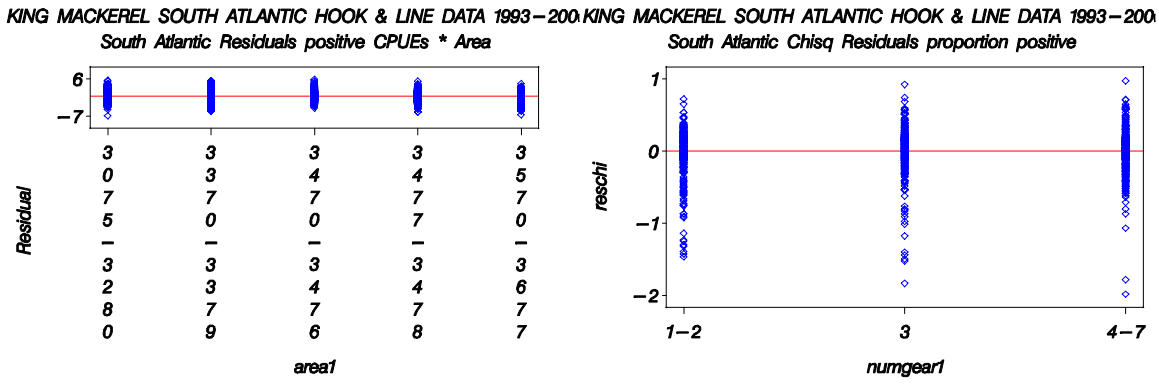
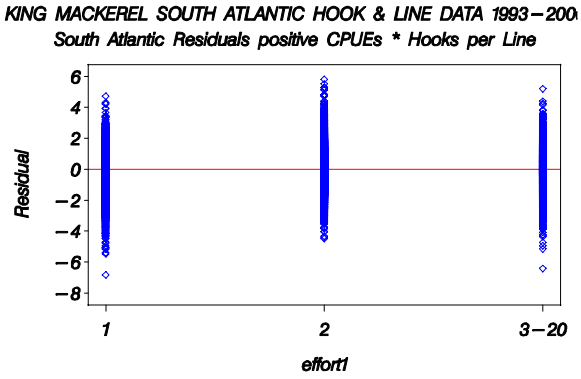
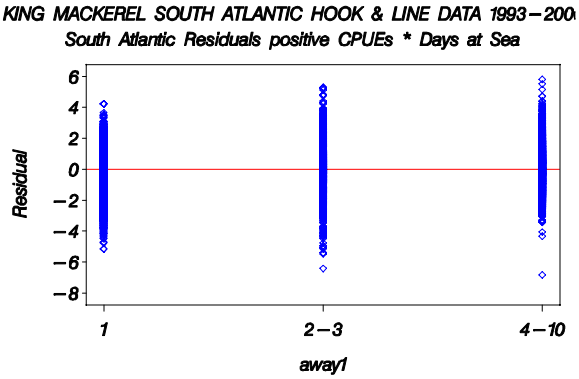


Figure 27 (continued). Diagnostic plots for the lognormal component of the South Atlantic 1993-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by hooks per line (effort); **E**. the Chi-Square residuals by days at sea (away); **E**. the Chi-Square residuals by number of crew; **E**. the Chi-Square residuals by season.

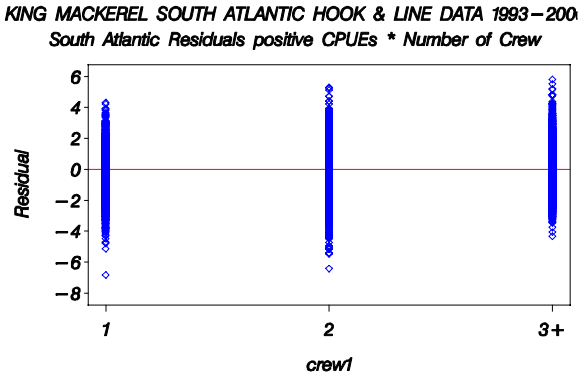
E.



F.



G.



H.

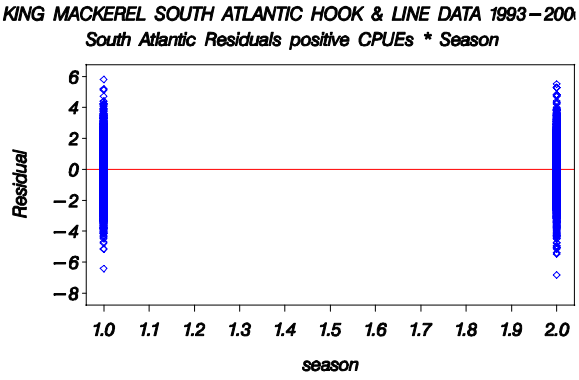
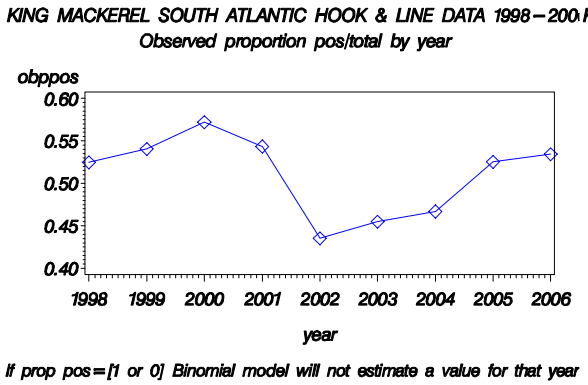


Figure 28. Annual trend in the proportion of positive trips (**A)** and nominal CPUE (**B)** for the South Atlantic 1998-2006 king mackerel commercial hook and line gear model.

A.



B.

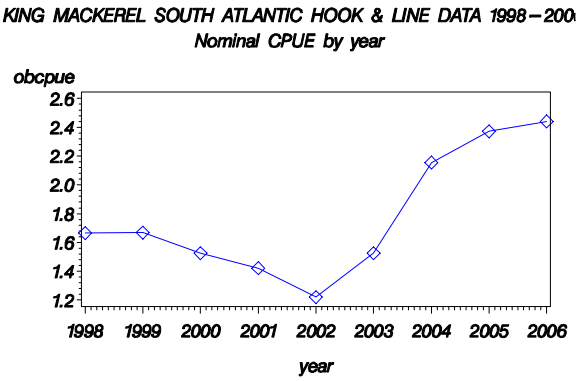
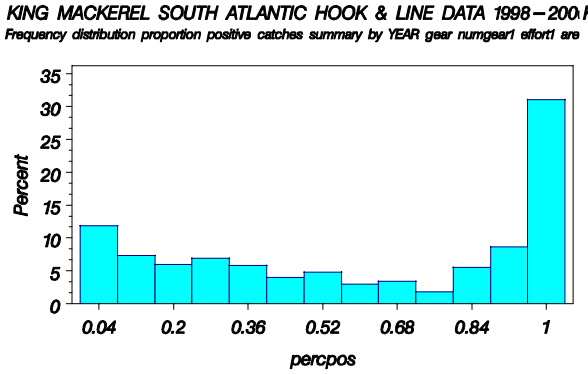
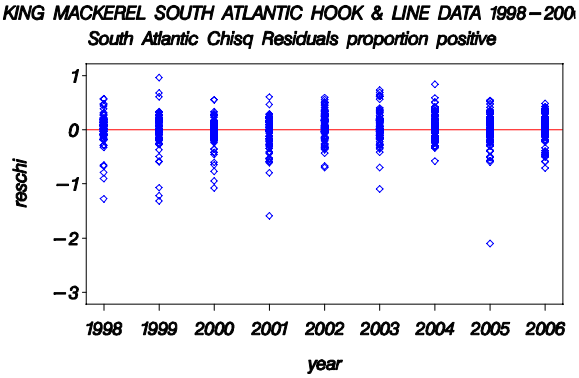


Figure 29. Diagnostic plots for the binomial component of the South Atlantic 1998-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by gear; and **D**. the Chi-Square residuals by area.

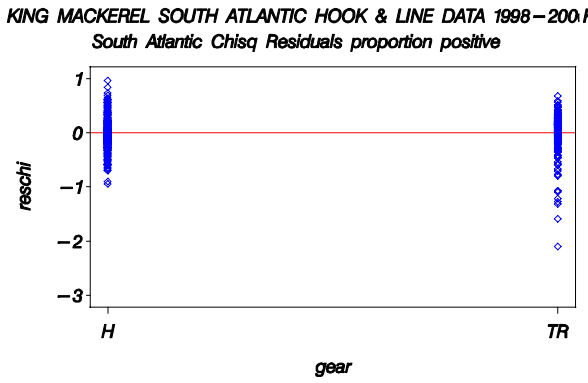
A.



B.



C.



D.

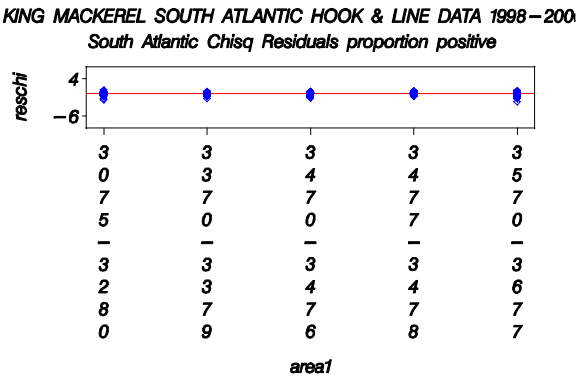
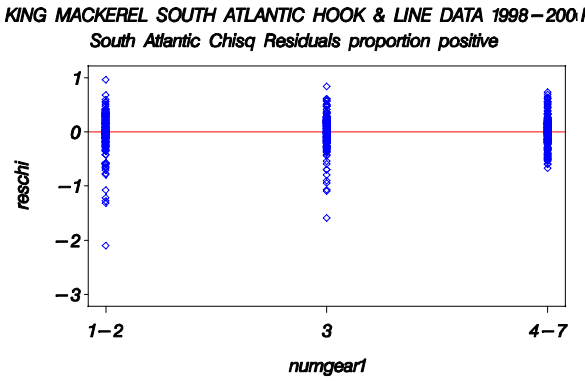


Figure 29 (continued). Diagnostic plots for the binomial component of the South Atlantic 1998-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by number of lines fished (numgear1); **F**. the Chi-Square residuals by hooks per line (effort).

E.



F.

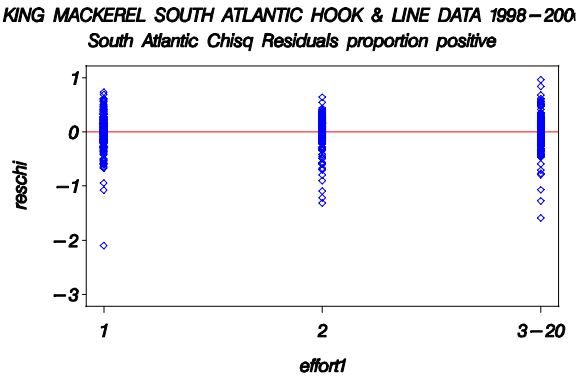


Figure 30. Diagnostic plots for the lognormal component of the South Atlantic 1998-2006 king mackerel commercial hook and line gear model: **A**. the frequency distribution of log(CPUE) on positive trips, **B**. the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. **B.**

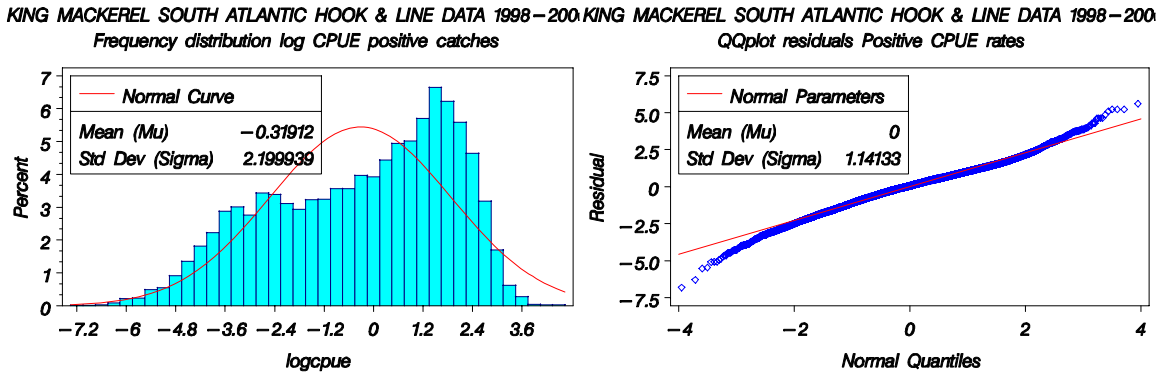
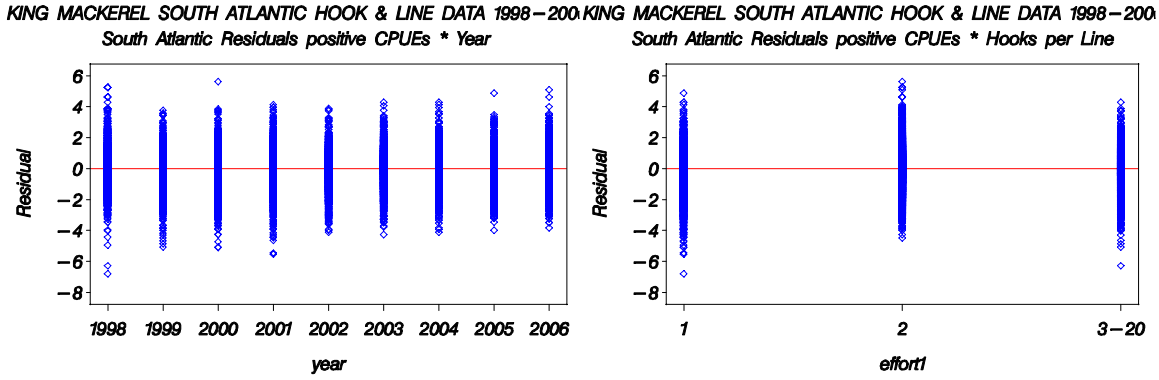


Figure 31. Diagnostic plots for the lognormal component of the South Atlantic 1998-2006 king mackerel commercial hook and line gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by hooks per line (effort); **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by days at sea (away).

A. **B.**



C. **D.**

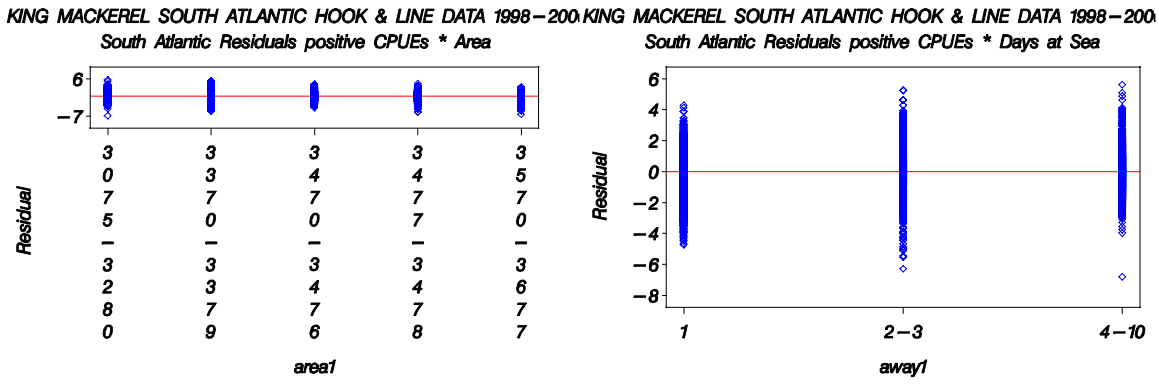
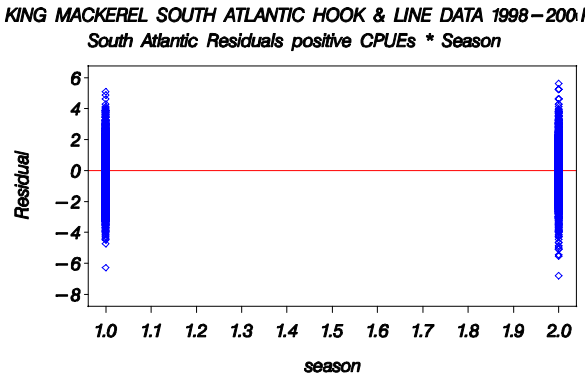
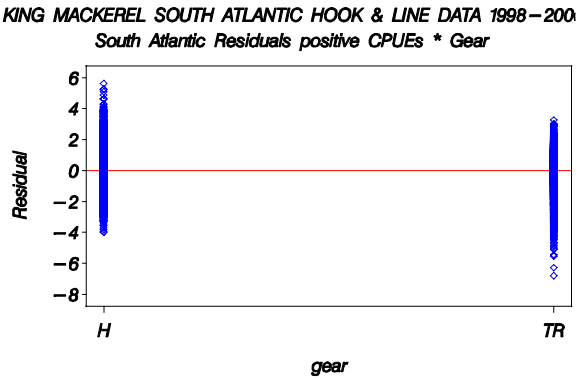


Figure 31 (continued). Diagnostic plots for the lognormal component of the South Atlantic 1998-2006 king mackerel commercial hook and line gear model: **E**. the Chi-Square residuals by season; **F**. the Chi-Square residuals by gear; and **G**. the Chi-Square residuals by number of crew.

E.



F.



G.