Standardized catch rate indices for gag grouper (*Mycteroperca microlepis*) landed by the commercial longline fishery in the U.S. Gulf of Mexico during 1990-2012

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SEDAR33-AW07

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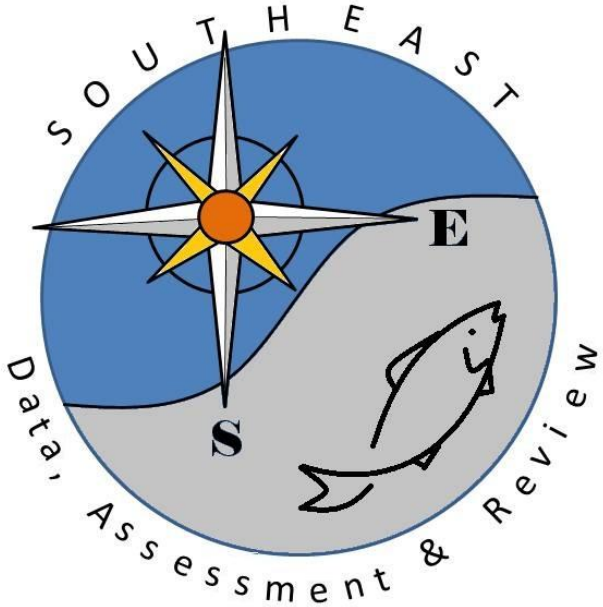

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STANDARDIZED CATCH RATE INDICES FOR GAG GROUPER (*MYCTEROPERCA MICROLEPIS*) LANDED BY THE COMMERCIAL LONGLINE FISHERY IN THE U.S. GULF OF MEXICO DURING 1990-2012

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ABSTRACT

Standardized catch rate indices (delta-lognormal) were constructed for the SEDAR33 data workshop (Tampa, FL. May 2013). The indices were constructed using NMFS Gulf of Mexico Reef Fish Logbook data. An index was constructed for the entire time period (1990-2012), and a second was constructed for the period before IFQs (1990-2009). The SEDAR 33 data workshop discussed the use of the CPUE indices developed for the commercial longline fishery in the U.S. Gulf of Mexico. Since the imposition of the IFQ fishery in 2010, the nominal catch rates have decreased substantially. It was not clear whether changes in fishing behavior and reduced quotas reduced catch rates after the imposition of the IFQ program, or whether the lower catch rates indicate decreased abundance of gag grouper. Therefore, the Data Workshop panel rejected the use of Index 1 (1990-2012) and recommended Index 2 (1990-2009; Pre-IFQ). The AW panel discussed this decision further, and upheld the recommendation during the AW Webinar on Aug. 21, 2013.

1. INTRODUCTION

Commercial vessels operating in the U. S. Gulf of Mexico have been monitored by the NMFS Gulf of Mexico Reef Fish Logbook Program since 1990. Catch and effort data from commercial longline trips occurring within the Gulf of Mexico were used to develop standardized catch rate indices for gag grouper. This document describes the development of the indices which are presented for the consideration of the SEDAR33-DW panel (Tampa, FL. May 2013).

2. METHODS

Data Sources

The NMFS Gulf of Mexico Reef Fish Logbook Program collects catch and effort data by trip for permitted vessels that participate in fisheries managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. The program began in 1990 with a complete census of commercial reef fish trips by vessels permitted in TX, LA, MS and AL. A 20% sample of vessels permitted in FL was required until 1993, when all permitted reef fish vessels were required to submit logs. We constructed catch rate indices for the period 1990-2012, and a second for the period prior to IFQs (1990-2009).

Data Eliminations

The logbook data base includes unique trip and vessel identifiers and information regarding trip date, gear class, fishing area (identical to shrimp statistical grid; Fig. 1), days at sea, fishing effort, species caught and landed weight. A vessel may fish in multiple areas using multiple gears on a single trip. However, while catch is reported by gear and area, effort is not. Instead total effort by gear is reported for each trip. Therefore it is not possible to calculate the catch per unit effort by area on trips that fished in more than one area. For this reason, trips that fished in multiple areas were excluded from the analysis. For similar reasons, trips that fished with multiple gears were also excluded from the analysis.

Closures occurred as described below:

1990: Closed 11/7 – 12/31
1999 - 2003: Closed 2/15 – 3/15
2004: Closed 2/15 – 3/15, Closed 11/15 – 12/31
2005: Closed 2/15 – 3/15. Closed 10/10 – 12/31
2006-2009: Closed 2/15 – 3/15

The dataset was restricted to those time periods for which fishing on gag grouper was allowed in every year (i.e. Jan – Feb 14 and March 16 – October 10). In addition, data were restricted to those longline trips occurring within the U.S Gulf of Mexico areas 1 to 10. On average, >95% of the total annual landings of gag grouper occur in these areas.

Trips that contained obviously erroneous logbook data were also excluded. These exclusions are summarized below.

1) NUMGEAR (sets) missing or equal to 0
2) EFFORT (hooks per set) missing or equal to 0
3) EFFORT < 50 or >4000
4) LENGTH (of longline) < 1 mile or > 20 miles
5) AREA missing or equal to 0

6) Sets/Day > 24
7) Trips with long delays in reporting (i.e. >45 days)
8) Trips that reported before the date of fishing

Species Misidentification

There is concern that gag grouper is often misidentified as black grouper, particularly in South Florida and the Keys. To examine this problem, NOAA Trip Interview Program (TIP) observations of commercial longline landings were examined. TIP species identifications are made by trained scientific observers. Therefore, the species identifications may be more reliable than those reported in the Reef Fish Logbook dataset. The proportion of gag and black groupers landed by commercial longliners that were identified as gag grouper by TIP scientific samplers is summarized by area in **Table 1**. These proportions were used to adjust the landings of gag grouper per trip in an attempt to account for gag grouper misidentified as "black grouper" in the logbook dataset using Equation 1:

$$Gag'\ (lbs) = [Gag(lbs) + Black(lbs)] * propGag \qquad \text{(Eq. 1)}$$

where *Gag'* is the adjusted weight of gag landed on a trip, *Gag* and *Black* are the weight of gag and black groupers landed on a trip, and *propGag* is the proportion of gag + black groupers that were identified as gag grouper by the TIP observers, by area *a*.

Index Development

Two indices were constructed. The first considered the entire time series (1990-2012) and the second was constructed for the pre-IFQ period (1990-2009). The various size limits were not considered since Stock Synthesis (the model that will be used to assess gag grouper) can account for changes in size limits directly (i.e. by re-estimating the retention functions).

For each index, the following factors were considered as possible influences on the proportion of trips that observed gag grouper, and the catch rates on positive trips.

Entire Time Series: 1990-2012

FACTOR	LEVELS	VALUES
YEAR	23	1990-2012
SEASON	4	WINTER (JAN-FEB)
		SPRING (MAR-MAY)
		SUMMER (JUNE-AUG)
		AUTUMN (SEPT-OCT)
AREA	8	1&2, 3,4,5,6,7,8,9&10

Pre-IFQ: 1990-2009

FACTOR	LEVELS	VALUES
YEAR	20	1990-2009
SEASON	4	WINTER (JAN-FEB)
		SPRING (MAR-MAY)
		SUMMER (JUNE-AUG)
		AUTUMN (SEPT-OCT)
AREA	8	1&2, 3,4,5,6,7,8,9&10

A delta-lognormal approach (Lo et al. 1992) was used to develop the standardized catch rate indices. This method combines separate generalized linear modeling (GLM) analyses of the proportion positive trips (trips that caught gag grouper) and the catch rates of successful trips to construct a single standardized index of abundance. 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 the lognormal models, the responsevariable, ln(CPUE), was calculated:

$$\ln(CPUE) = \ln\left[\frac{Gag'(lbs)}{(sets * hooks/set)}\right] \qquad \text{(Eq. 2)}$$

where Gag′ is the adjusted weight of gag grouper landed per trip (see Eq. 1). Note that the effort variable is "hooks" rather than "hooks/angler hour". This is due to a change in the logbook form that caused confusion in this variable for longline trips. Many anglers record "total hours fished per trip", but a significant portion report "average hours fished per set". Although some errors can be corrected using deductive reasoning, many cannot. Therefore, rather than deleting these trips, the response variable "hooks" was adopted.

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. For both the binomial and lognormal portions of the delta-lognormal model, deviance tables were constructed to determine the proportion of total variance explained by the addition of each factor or interaction term. In addition, a χ^2 analysis was performed to test the significance of the reduction in deviance between each consecutive set of nested models (McCullagh and Nelder 1989). Factors and interaction terms were selected for final analysis if: 1) the relative percent of deviance explained by adding the factor exceeded 1% , 2) the χ^2 test was significant and 3) the Type-III test was significant for the specified model.

Once a set of fixed factors was identified, the influence of the YEAR*FACTOR interactions were examined. As per the recommendation of the statistics and methods working group of the

SCRS (1999), 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 the SAS macro GLIMMIX and the SAS procedure PROC MIXED (SAS Institute Inc. 1997) following the procedures described by Lo et al. (1992).

3. RESULTS

Index 1 (Entire time series):

A total of 15,102 longline trips were included in this analysis. Of these, 9,694 landed gag grouper (after adjustment for misidentification; Eq. 1). The final models for the binomial on proportion positive trips and the lognormal on CPUE were:

PPT = Area + Year + Season + Area*Season + Year*Season + Year*Area
LN(CPUE) = Year + Area + Season + Year*Season + Year*Area

The construction of the delta-lognormal model is described in **Tables 2-4**. The Nominal CPUE, number of trips, number of positive trip, proportion positive trips (PPT), standardized index of abundance and index statistics are summarized in **Table 5**.

The annual proportion of positive trips (PPT) ranged from 51% to 76% (**Figure 2; Table 5**) and generally varied without notable trend. Nominal CPUE generally increased between 1990-2001, then decreased substantially through 2012 (**Figure 3; Table 5**).

Diagnostic plots were constructed to examine the fit of the components of the delta-lognormal model. The frequency distribution of proportion positive catches by the factors YEAR, AREA and SEASON are shown in **Figure 4**. Chi-square residuals for the binomial model on proportion positive trips by factor and the lognormal model on positive catch rates are illustrated in **Figures 5 and 6,** respectively. . In general, the residuals were distributed equally above and below zero, indicating no significant departure from expectation. The frequency distribution of nominal catch rates is shown in **Figure 7** and the corresponding QQ-Plot in **Figure 8.** According to these diagnostic plots, there is no evidence that the assumption of a normal fit to the distribution of log(CPUE) is violated to any significant degree.

The delta-lognormal catch rate index, with 95% confidence intervals, is shown in **Figure 9** and summarized in **Table 5**. To facilitate comparison, the nominal CPUE and the standardized index were relativized by dividing each annual estimate by the series mean. The standardized abundance index is similar to the nominal CPUE series.

Index 2 (1990-2009; Pre-IFQ period):

A total of 14,260 longline trips were included in this analysis. Of these, 9,222 landed gag grouper (after adjustment for misidentification; Eq. 1). The final models for the binomial on proportion positive trips and the lognormal on CPUE were:

PPT = Area + Year + Season + Area*Season + Year*Season
LN(CPUE) = Year + Area + Season + Year*Season + Year*Area

The construction of the delta-lognormal model is described in **Tables 6-8**. The Nominal CPUE, number of trips, number of positive trip, proportion positive trips (PPT), standardized index of abundance and index statistics are summarized in **Table 9**.

The annual proportion of positive trips (PPT) ranged from 52% to 76% (**Figure 10; Table 9**) and generally varied without notable trend. Nominal CPUE generally increased between 1992-2001, then decreased substantially through 2009 (**Figure 11; Table 9**).

Diagnostic plots were constructed to examine the fit of the components of the delta-lognormal model. The frequency distribution of proportion positive catches by the factors YEAR, AREA and SEASON are shown in **Figure 12**. Chi-square residuals for the binomial model on proportion positive trips by factor and the lognormal model on positive catch rates are illustrated in **Figures 13 and 14,** respectively. . In general, the residuals were distributed equally above and below zero, indicating no significant departure from expectation. The frequency distribution of nominal catch rates is shown in **Figure 15** and the corresponding QQ-Plot in **Figure 16.** According to these diagnostic plots, there is no evidence that the assumption of a normal fit to the distribution of log(CPUE) is violated to any significant degree.

The delta-lognormal catch rate index, with 95% confidence intervals, is shown in **Figure 17** and summarized in **Table 9**. To facilitate comparison, the nominal CPUE and the standardized index were relativized by dividing each annual estimate by the series mean. The standardized abundance index is similar to the nominal CPUE series.

4. DISCUSSION

The SEDAR 33 data workshop discussed the use of the CPUE indices developed for the commercial longline fishery in the U.S. Gulf of Mexico. Since the imposition of the IFQ fishery in 2010, the nominal catch rates have decreased substantially. It was not clear whether changes in fishing behavior and reduced quotas reduced catch rates after the imposition of the IFQ program, or whether the lower catch rates indicate decreased abundance of gag grouper. Therefore, the Data Workshop panel rejected the use of Index 1 (1990-2012) and recommended Index 2 (1990-2009; Pre-IFQ). The AW panel discussed this decision further, and upheld the recommendation (AW Webinar Aug. 21, 2013).

Table 1. Proportion of the total (gag+black) that were identified as gag grouper, by area.

Area	Proportion GAG
YEAR = 1990 to 2009	
area=1	0.093
area=2	0.420
area=3	0.786
area=4	0.905
area=5	0.957
area=6	0.983
area 7 to 10	0.999
YEAR = 2010 to 2012	
area=1	0.087
area=2	0.299
area=3	0.547
area=4	0.791
area=5	0.942
area=6	0.993
area 7 to 10	0.998

Table 2. The deviance table for the binomial model on proportion positive trips for Index 1 (1990-2012). Factors were assumed to be significant if they explained >1% of the total deviance (shaded cells), and were significant according to a Chi-Square test.

Binomial Model Factors - Proportion Positive	DF	DF	Residual Deviance	Reduction in Deviance	% of Total Deviance	Log Like	Chi Square	P
Null	1	15101	19702.6	0.0	0.0	-9851.3		
Area	7	15094	18046.3	1656.3	77.3	-9023.2	1656.3	<0.001
Area + ***Year***	22	15072	17753.7	292.6	13.7	-8876.8	292.6	<0.001
Area + Year + ***Season***	3	15069	17708.0	45.7	2.1	-8854.0	45.7	<0.001
Area + Year + Season + ***Area*Season***	21	15048	17559.1	148.9	6.9	-8779.5	149.0	<0.001

Table 3. The deviance table for the lognormal model on catch rates of positive trips for Index 1 (1990-2012). Factors were assumed to be significant if they explained >1% of the total deviance (shaded cells), and were significant according to a Chi-Square test.

Lognormal Model Factors - CPUE

Lognormal Model Factors - CPUE	DF	DF	Residual Deviance	Reduction in Deviance	% of Total Deviance	Log Like	Chi Square	P
Null	1	9693	24517.2	0.0	0.0	-18252.6		
Year	22	9671	22003.0	2514.2	71.0	-17728.1	1048.82	<0.001
Year + ***Area***	7	9664	21267.9	735.1	20.8	-17563.4	329.41	<0.001
Year + Area + ***Season***	3	9661	21029.8	238.1	6.7	-17508.9	109.15	<0.001
Year + Area + Season + Area*Season	21	9640	20978.4	51.4	1.5	-17497.0	23.72	0.307

Table 4. Analysis of the mixed model formulations for the components of the delta-model (Index 1 1990-2012). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final model is indicated with gray shading.

ANALYSIS OF MIXED MODEL FORMULATIONS

Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P	Scaled Deviance	Dispersion
Area + Year + Season + Area*Season	1799.9	1801.9	1806.4	-	-	678.08	2.18
Area + Year + Season + Area*Season + Year*Season	1765.6	1769.6	1774.6	34.3	<0.0001	649.75	1.84
Area + Year + Season + Area*Season + Year*Season + Year*Area	***1760.8***	***1766.8***	***1774.3***	***4.8***	***0.0285***	***625.61***	***1.72***

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Year + Area + Season	35132.1	35134.1	35141.3	-	-
Year + Area + Season + Year*Season	35063.9	35067.9	35072.9	68.2	<0.0001
Year + Area + Season + Year*Season + Year*Area	***35025.9***	***35031.9***	***35039.4***	***106.2***	***<0.0001***

Table 5. Nominal CPUE, number of trips, number of positive trip, proportion positive trips (PPT), standardized index of abundance and index statistics.

YEAR	Nom CPUE	Trips	Pos Trips	PPT	Relative Index	CV	LCI	UCI
1990	31.037	65	47	0.723	0.852	0.442	0.366	1.981
1991	25.427	241	139	0.577	0.690	0.359	0.344	1.384
1992	13.632	229	120	0.524	0.541	0.364	0.267	1.096
1993	15.798	428	320	0.748	0.708	0.292	0.400	1.254
1994	14.192	654	395	0.604	0.412	0.306	0.226	0.748
1995	12.148	804	453	0.563	0.526	0.299	0.293	0.944
1996	23.502	626	340	0.543	0.541	0.309	0.296	0.990
1997	12.790	989	597	0.604	0.687	0.283	0.394	1.197
1998	22.125	850	545	0.641	1.002	0.282	0.576	1.742
1999	26.221	877	583	0.665	0.886	0.287	0.504	1.555
2000	27.067	877	507	0.578	0.926	0.288	0.526	1.630
2001	36.318	1025	670	0.654	1.736	0.274	1.013	2.973
2002	47.825	961	591	0.615	1.524	0.289	0.865	2.686
2003	41.563	1005	655	0.652	1.800	0.279	1.041	3.111
2004	45.045	1046	742	0.709	2.191	0.271	1.287	3.731
2005	48.041	1053	772	0.733	2.387	0.265	1.417	4.019
2006	27.486	965	683	0.708	1.269	0.273	0.743	2.170
2007	22.999	666	432	0.649	0.980	0.290	0.555	1.728
2008	21.788	575	442	0.769	1.047	0.271	0.614	1.784
2009	10.181	324	189	0.583	0.474	0.355	0.238	0.943
2010	15.433	179	122	0.682	0.918	0.333	0.480	1.755
2011	6.277	316	170	0.538	0.346	0.345	0.177	0.678
2012	10.200	347	180	0.519	0.558	0.345	0.285	1.093

Table 6. The deviance table for the binomial model on proportion positive trips for Index 2 (1990-2009). Factors were assumed to be significant if they explained >1% of the total deviance (shaded cells), and were significant according to a Chi-Square test.

Binomial Model Factors - Proportion Positive	DF	DF	Residual Deviance	Reduction in Deviance	% of Total Deviance	Log Like	Chi Square	P
Null	1	14259	18522.7	0.0	0.0	-9261.34		
Area	7	14252	16846.8	1675.9	80.3	-8423.4	1675.9	<0.001
Area + ***Year***	19	14233	16628.9	217.9	10.4	-8314.5	217.9	<0.001
Area + Year + ***Season***	3	14230	16566.4	62.5	3.0	-8283.2	62.5	<0.001
Area + Year + Season + ***Area*Season***	21	14209	16435.8	130.6	6.3	-8217.9	130.6	<0.001

Table 7. The deviance table for the lognormal model on catch rates of positive trips for Index 2 (1990-2009). Factors were assumed to be significant if they explained >1% of the total deviance (shaded cells), and were significant according to a Chi-Square test.

Lognormal Model Factors - CPUE

Lognormal Model Factors - CPUE	DF	DF	Residual Deviance	Reduction in Deviance	% of Total Deviance	Log Like	Chi Square	P
Null	1	9221	23556.0	0.0	0.0	-17409.6		
Year	19	9202	21206.2	2349.8	70.6	-16925.0	969.11	<0.001
Year + ***Area***	7	9195	20498.2	708.0	21.3	-16768.5	313.14	<0.001
Year + Area + ***Season***	3	9192	20276.5	221.7	6.7	-16718.3	100.28	<0.001
Year + Area + Season + Area*Season	21	9171	20225.8	50.7	1.5	-16706.8	23.1	0.3384

Table 8. Analysis of the mixed model formulations for the components of the delta-model (Index 2 1990-2009). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final model is indicated with gray shading.

ANALYSIS OF MIXED MODEL FORMULATIONS

Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P	Scaled Deviance	Dispersion
Area + Year + Season + Area*Season	1482.5	1484.5	1488.8	-	-	589.36	2.11
Area + Year + Season + Area*Season + Year*Season	***1460.1***	***1464.1***	***1468.8***	***22.4***	***<0.0001***	***565.85***	***1.84***
Area + Year + Season + Area*Season + Year*Season + Year*Area	1457.6	1463.6	1470.6	2.5	0.1138	546.80	1.74

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Year + Area + Season	33542.9	33544.9	33552.0	-	-
Year + Area + Season + Year*Season	33478.6	33482.6	33487.3	64.3	<0.0001
Year + Area + Season + Year*Season + Year*Area	***33440.6***	***33446.6***	***33453.7***	***102.3***	***<0.0001***

Table 9. Index 2 (Pre-IFQ 1990-2009) Nominal CPUE, number of trips, number of positive trip, proportion positive trips (PPT), standardized index of abundance and index statistics.

YEAR	Nom CPUE	Trips	Pos Trips	PPT	Relative Index	CV	LCI	UCI
1990	31.037	65	47	0.723	0.824	0.438	0.357	1.902
1991	25.427	241	139	0.577	0.642	0.354	0.323	1.275
1992	13.632	229	120	0.524	0.511	0.358	0.255	1.023
1993	15.798	428	320	0.748	0.670	0.293	0.377	1.190
1994	14.192	654	395	0.604	0.378	0.302	0.209	0.683
1995	12.148	804	453	0.563	0.480	0.295	0.269	0.857
1996	23.502	626	340	0.543	0.504	0.304	0.278	0.914
1997	12.790	989	597	0.604	0.642	0.281	0.369	1.115
1998	22.125	850	545	0.641	0.952	0.280	0.549	1.649
1999	26.221	877	583	0.665	0.854	0.283	0.490	1.489
2000	27.067	877	507	0.578	0.877	0.285	0.501	1.534
2001	36.318	1025	670	0.654	1.637	0.274	0.956	2.804
2002	47.825	961	591	0.615	1.438	0.285	0.821	2.516
2003	41.563	1005	655	0.652	1.706	0.277	0.991	2.939
2004	45.045	1046	742	0.709	2.063	0.272	1.209	3.519
2005	48.041	1053	772	0.733	2.260	0.266	1.339	3.816
2006	27.486	965	683	0.708	1.199	0.273	0.701	2.050
2007	22.999	666	432	0.649	0.922	0.288	0.525	1.620
2008	21.788	575	442	0.769	0.994	0.274	0.580	1.702
2009	10.181	324	189	0.583	0.448	0.346	0.229	0.878

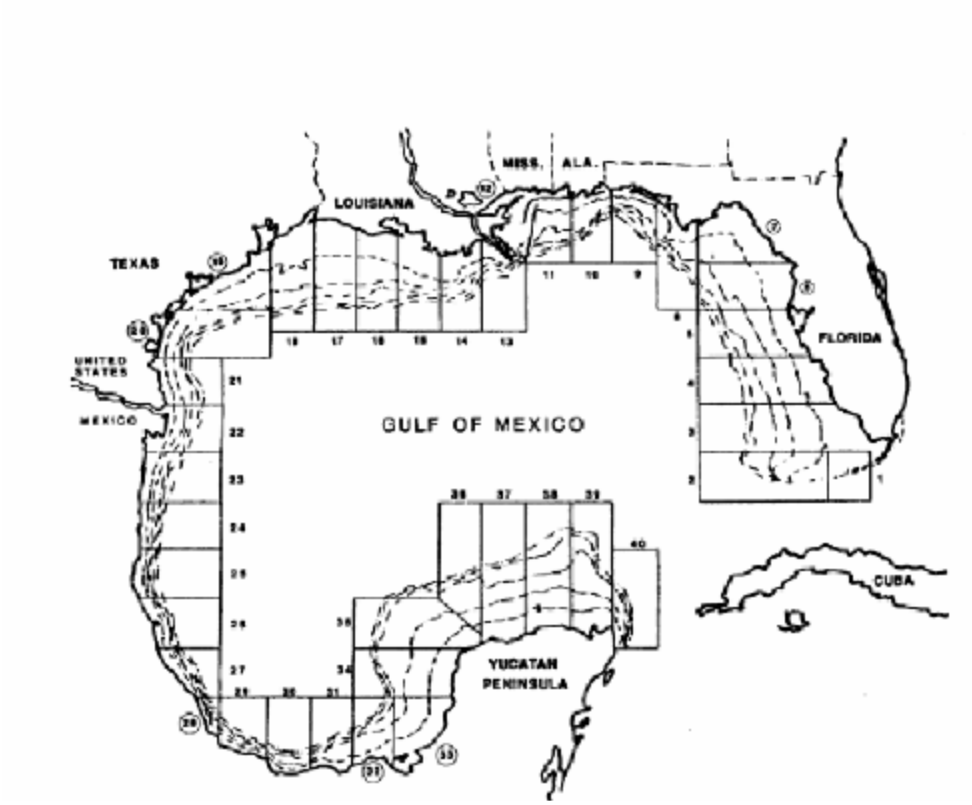

Figure 1. Gulf of Mexico with NMFS statistical grids. Areas 1-10 were included in this analysis.

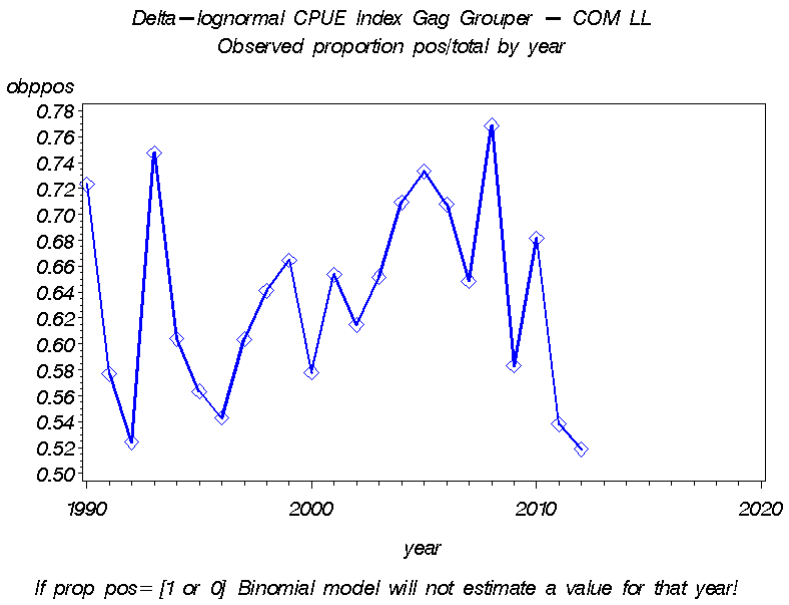

Figure 2. Proportion positive trips 1990-2012.

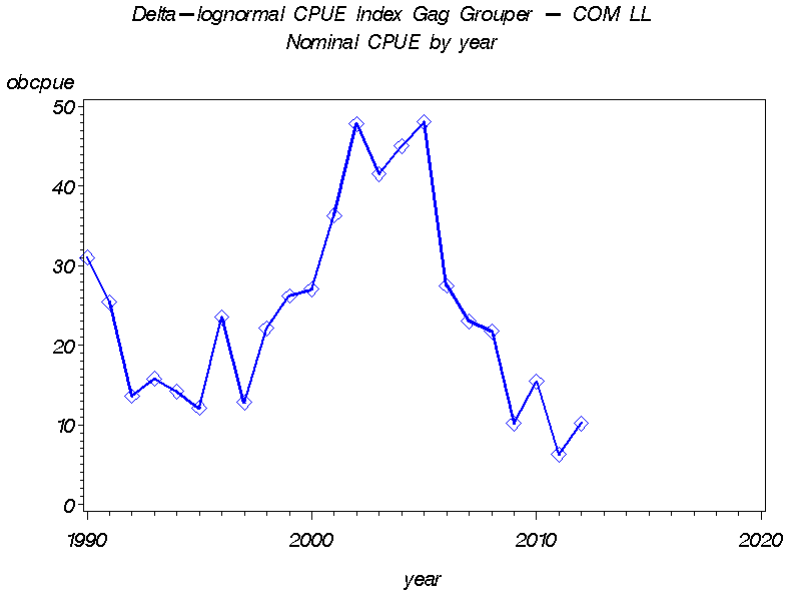

Figure 3. Nominal CPUE 1990-2012.

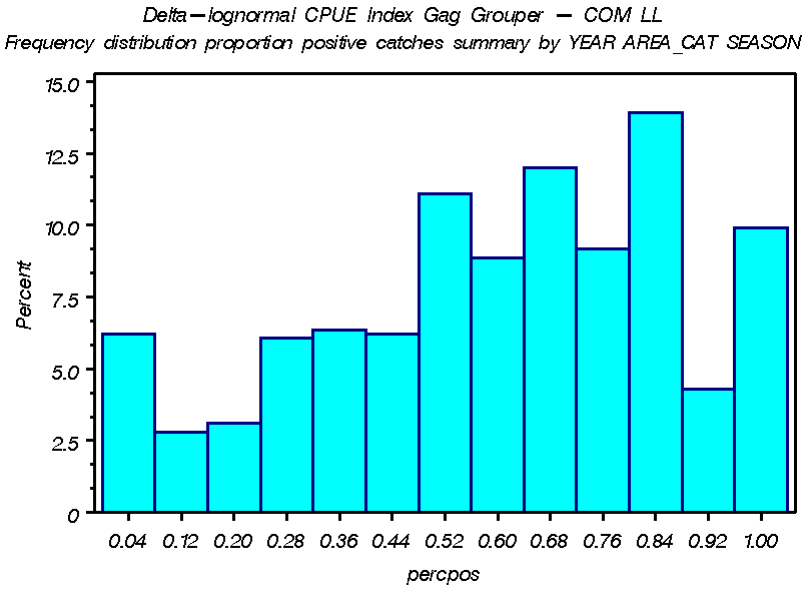

Figure 4. Frequency distribution of proportion positive catches by the factors YEAR, AREA and SEASON (***Index 1***; Entire Time Series).

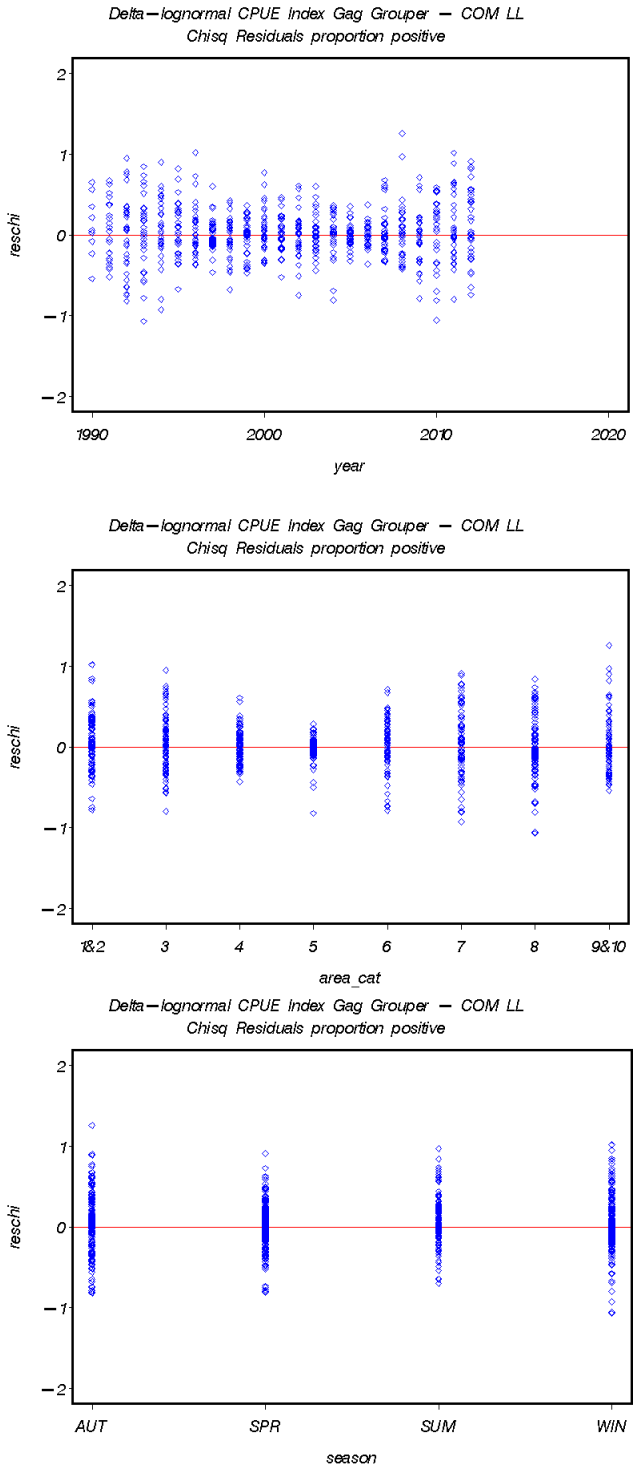

Figure 5. Chi-square residuals for the binomial model on proportion positive trips by YEAR (top), AREA (middle) and SEASON (bottom).

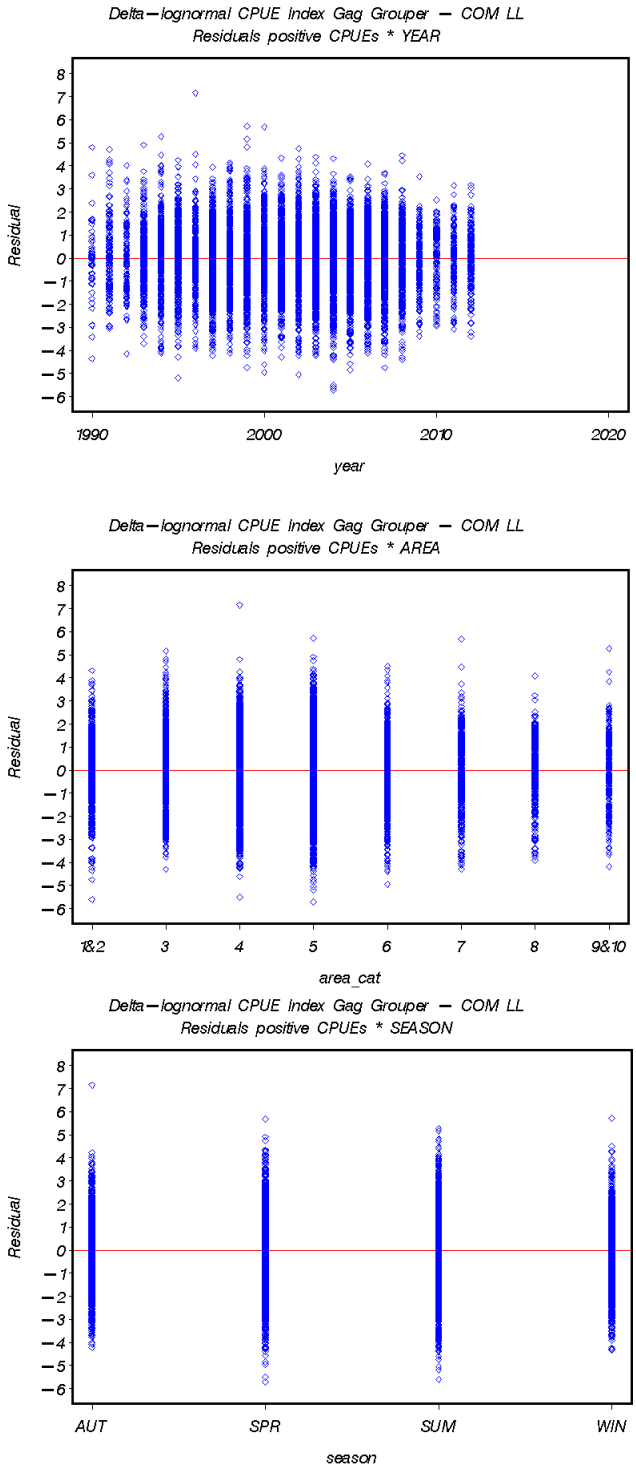

Figure 6. Residuals for the lognormal model on catch rates of positive trips by YEAR (top), AREA (middle) and SEASON (bottom).

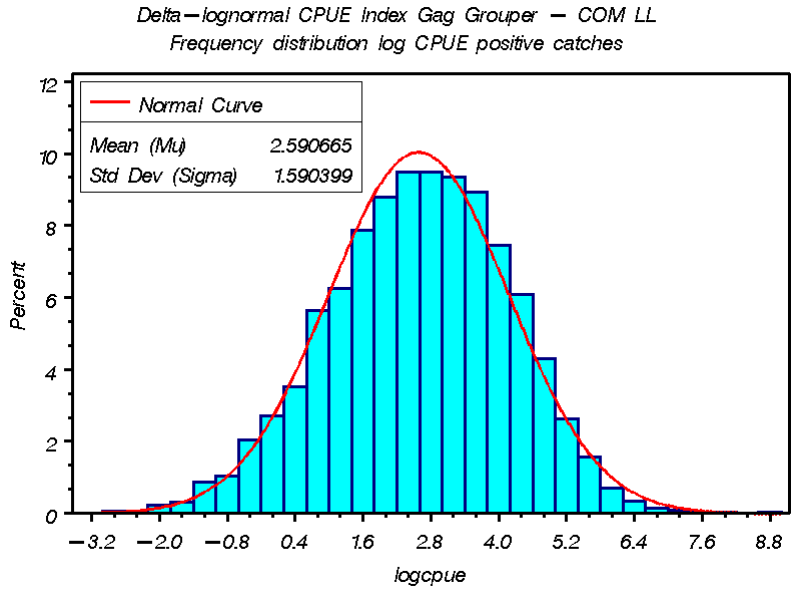

Figure 7. Frequency distribution of log(CPUE) on positive trips (***Index 1***; Entire Time Series).

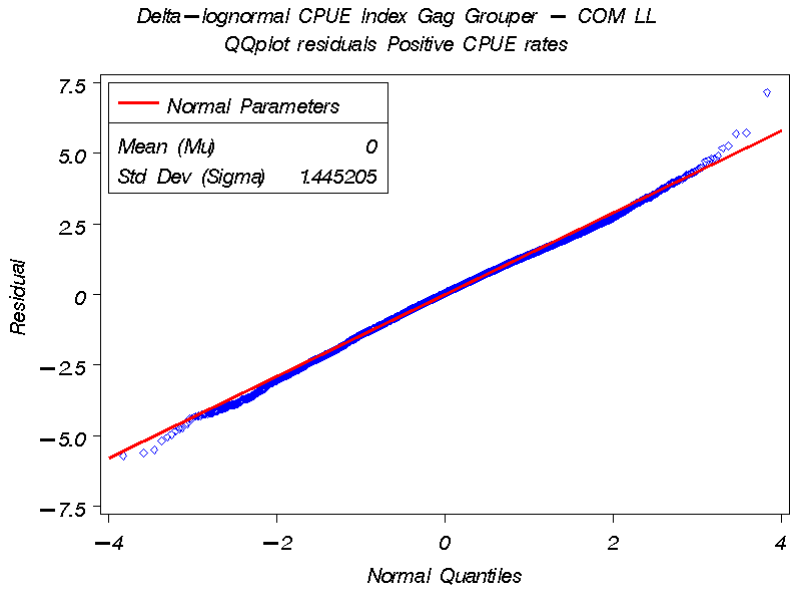

Figure 8. QQ plot of the fit of the lognormal model (***Index 1***; Entire Time Series).

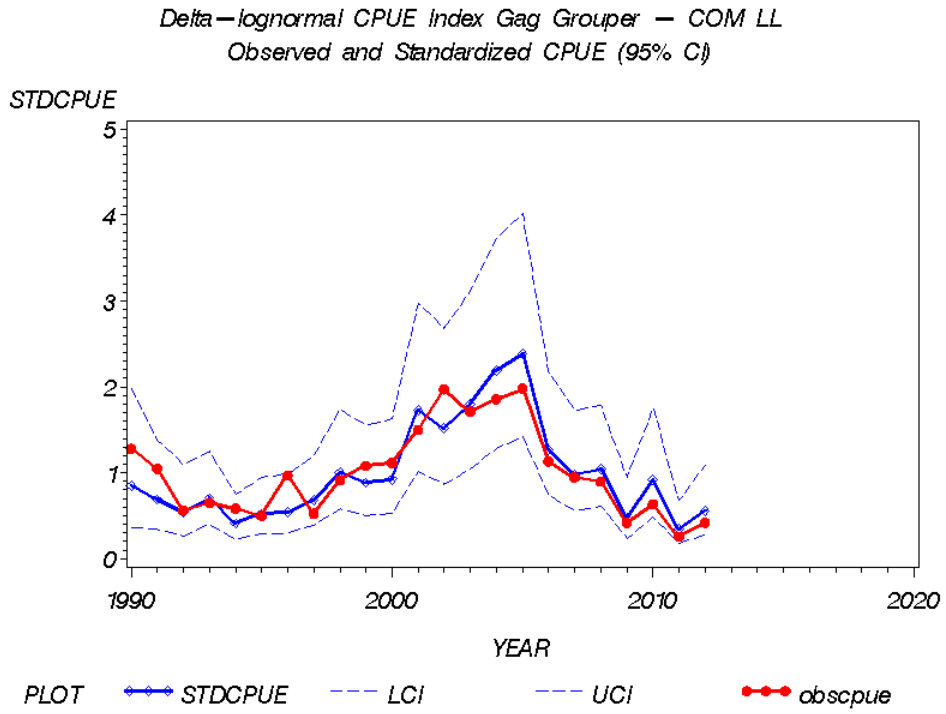

Figure 9. Relative nominal CPUE (red), relative standardized index (blue) and 95% confidence intervals (blue dotted) (***Index 1***; Entire Time Series).

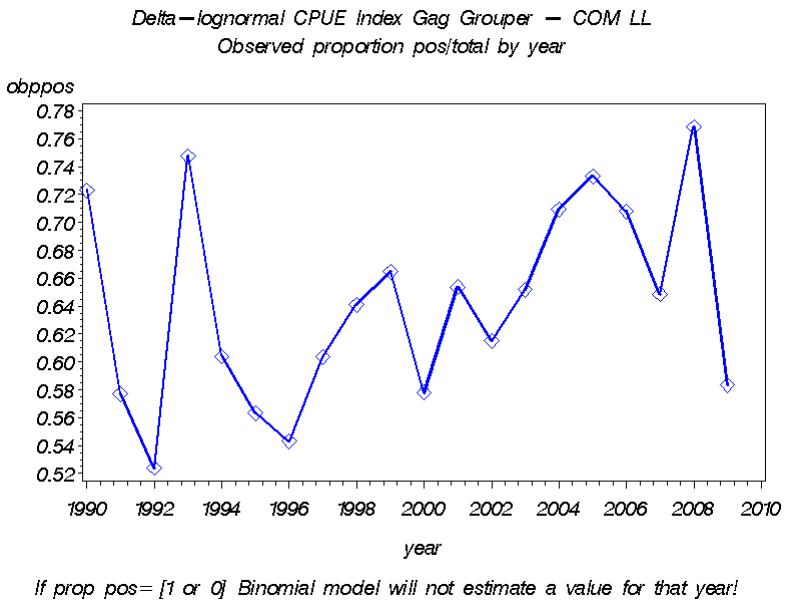

Figure 10. Proportion positive trips in the pre-IFQ period (1990-2009).

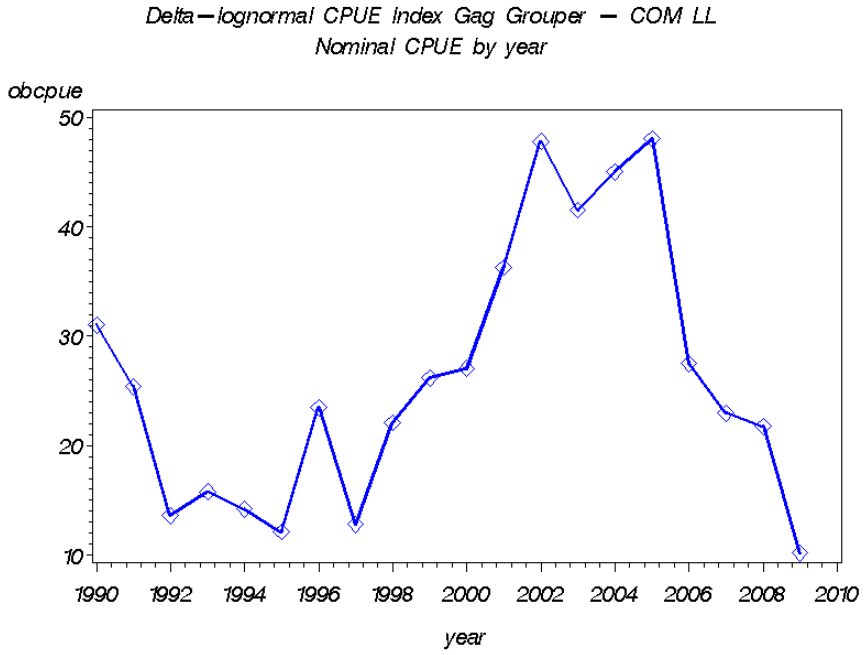

Figure 11. Nominal CPUE in the pre-IFQ period (1990-2009).

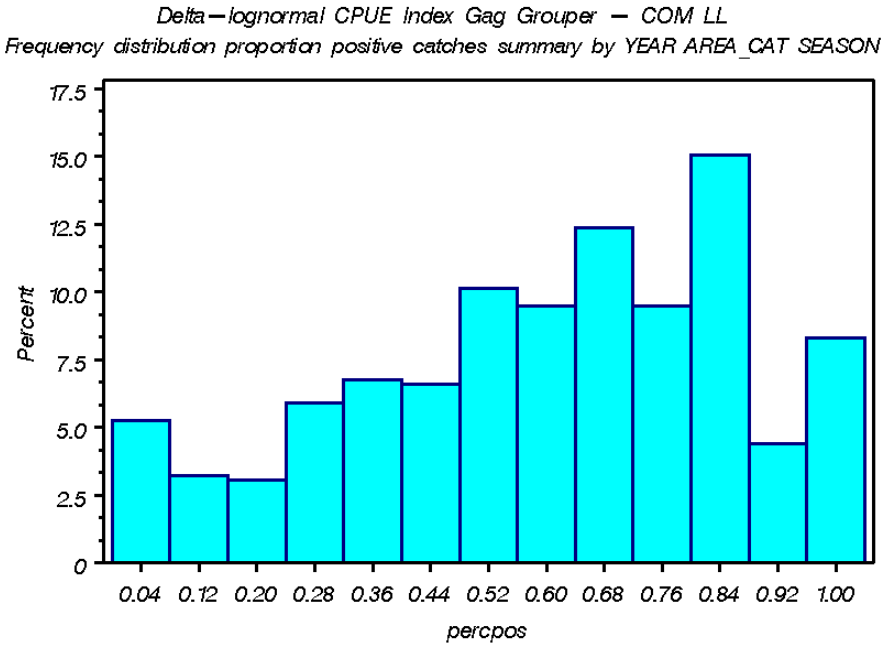

Figure 12. Frequency distribution of proportion positive catches by the factors YEAR, AREA and SEASON (***Index 2***; pre-IFQ 1990-2009).

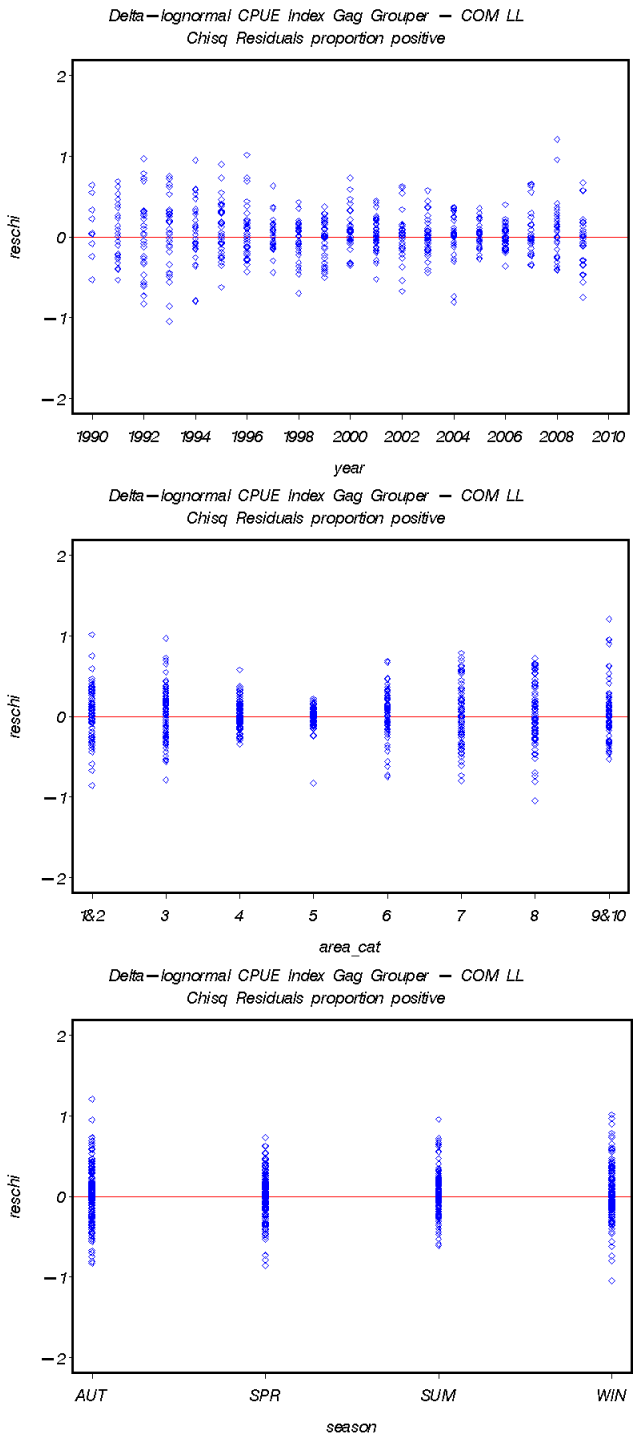

Figure 13. Chi-square residuals for the binomial model on proportion positive trips by YEAR (top), AREA (middle) and SEASON (bottom) for Index 2 (pre-IFQ 1990-2009).

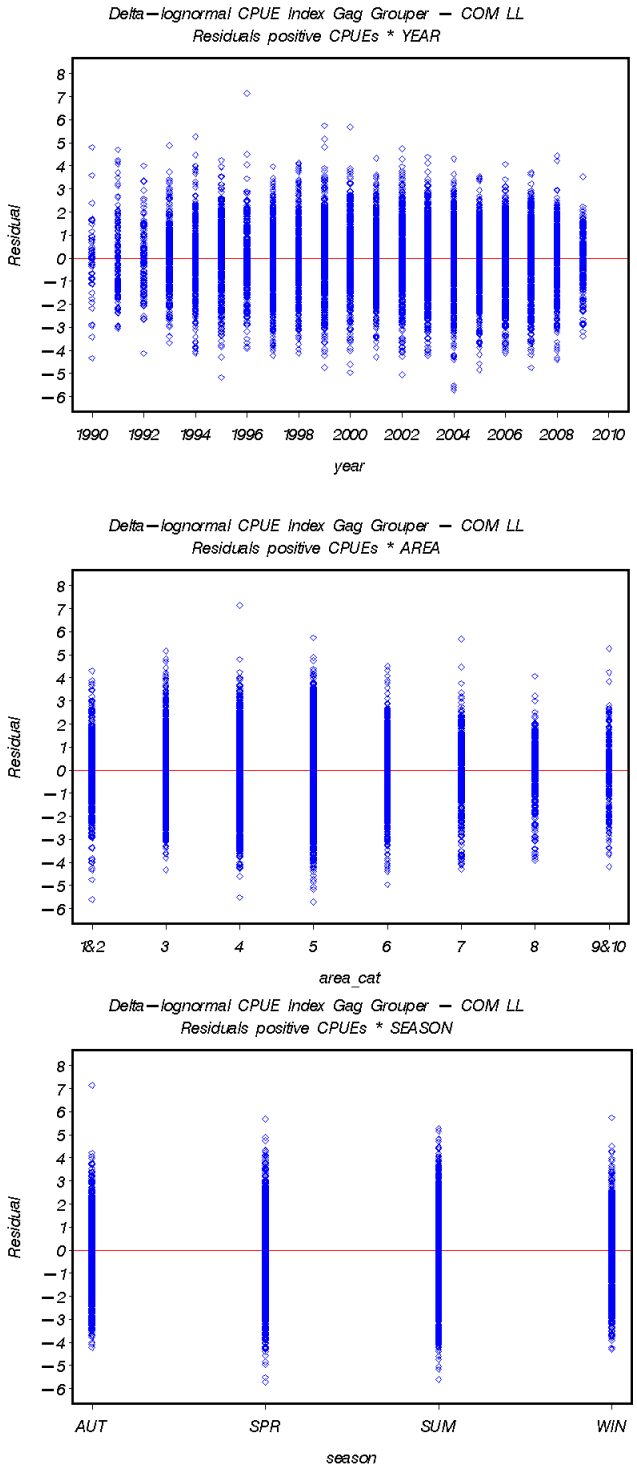

Figure 14. Residuals for the lognormal model on catch rate of positive trips by YEAR (top), AREA (middle) and SEASON (bottom) for Index 2 (pre-IFQ 1990-2009).

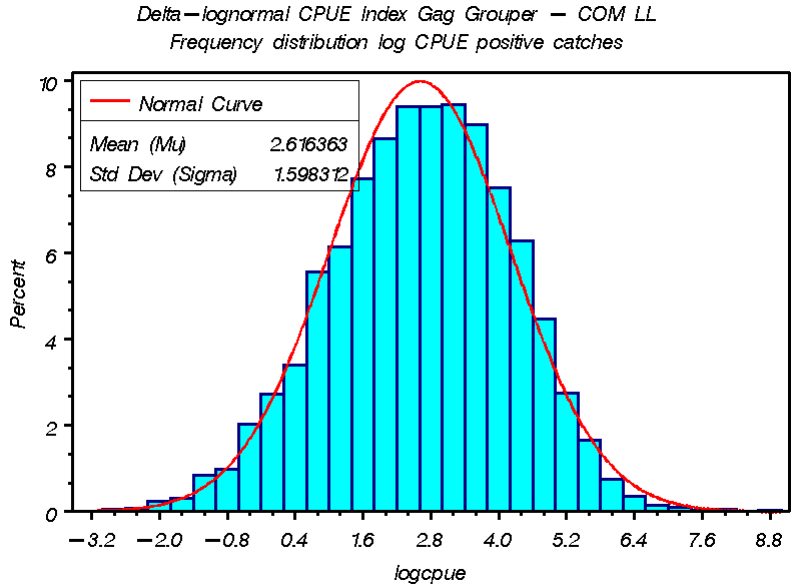

Figure 15. Frequency distribution of log(CPUE) on positive trips (***Index 2***; Pre-IFQ 1990-2009).

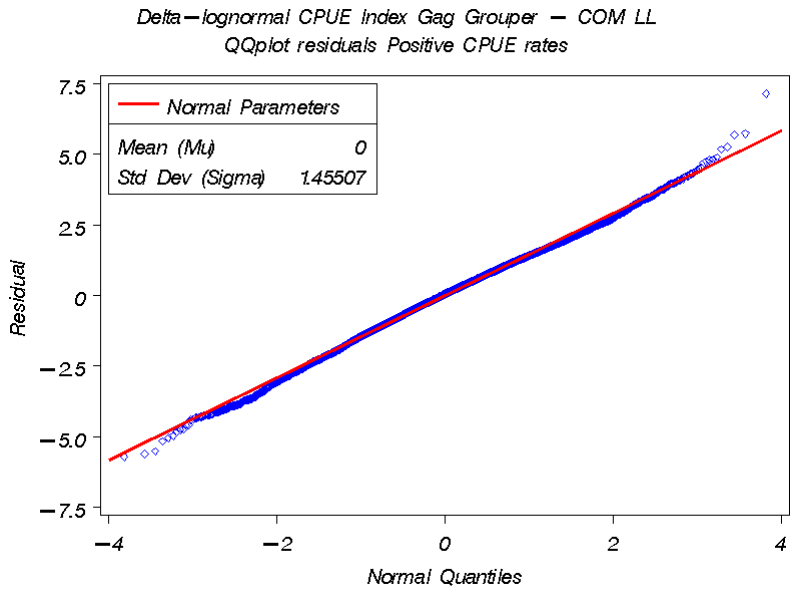

Figure 16. QQ plot of the fit of the lognormal model (***Index 2***; Pre-IFQ 1990-2009).

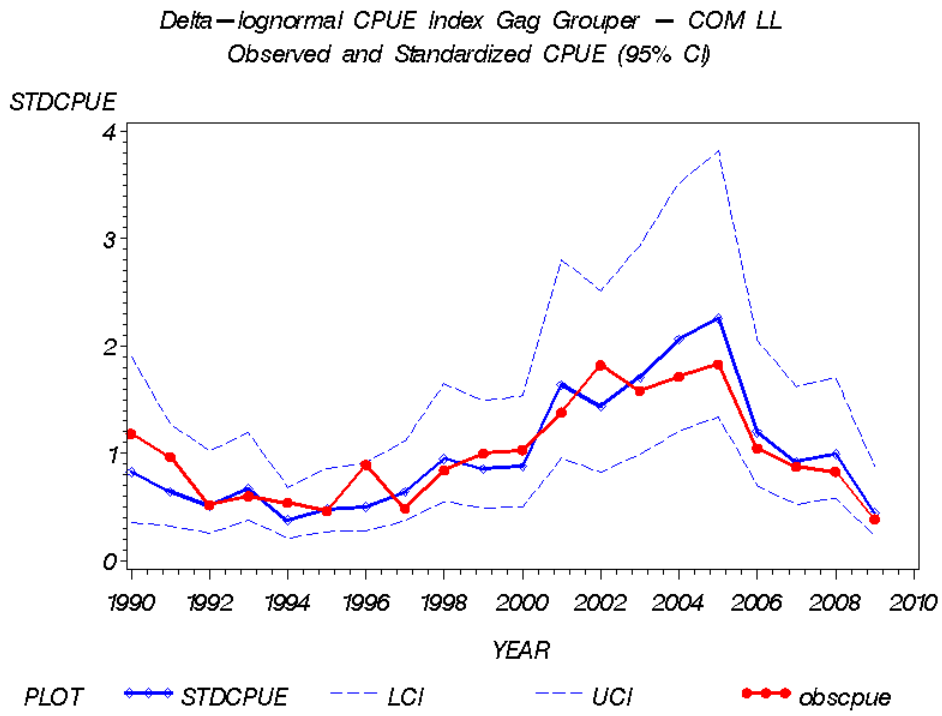

Figure 17. Relative nominal CPUE (red), relative standardized index (blue) and 95% confidence intervals (blue dotted) (***Index 2***; Pre-IFQ 1990-2009).