Standardized catch rates for gag grouper from the United States Gulf of Mexico handline fishery during 1993-2004

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Introduction

Handline catch and fishing effort of commercial vessels operating in the Gulf of Mexico 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 data by fishing trip on catch and effort for vessels with permits to fish in a number of fisheries managed by the Gulf of Mexico Fishery Management Council. The Gulf of Mexico coastal logbook program began in 1990 with the objective of a complete census of reef fish fishery 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 the reef fish fishery.

The available catch per unit effort (CPUE) series, from 1993 - 2004, was used to develop three abundance indices for gag grouper. Several regulatory controls on fishing effort and landings were considered in those analyses. The minimum allowable size for gag grouper commercial landings had changed from 20 to 24 inches TL on June 19, 2000. No size data is available in the logbook database, therefore, effects of the change in minimum size are difficult to examine directly. Separate indices were developed for the period 1993 – June 18, 2000; from June 19, 2000 – 2004, and for the complete time series, 1993 – 2004. Commercial harvest and sale of gag, black, and red grouper is prohibited each year from February 15 to March 15. This prohibition began in 2001. Additionally, in 2004 commercial harvest of shallow water grouper species, including gag grouper, was closed on November 15th because the shallow water grouper quota was met. Those periods of harvest moratorium were excluded from the analyses.

Methods

For each fishing trip, the logbook database includes a unique trip identifier, the landing date, fishing gear deployed, areas fished (equivalent to NMFS shrimp statistical grids, Figure 1), number of days at sea, number of crew, gear specific fishing effort (for handline: 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 may be recorded for a single fishing trip. In such cases, assigning catch and effort to specific locations was not possible; therefore, only trips in which one area fished was reported were included in these analyses. Prior to 2001, handline and electric reel (bandit rigs) gears were reported as a single gear type. Data from trips using those gear types were combined in these analyses.

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

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

This differs from a previous catch series analysis by Heinemann (2001) where trip length in days was used as the measure of effort. Heinemann noted concerns about some elements in the coastal logbook database

and chose to use trip length (days at sea) as a measure of effort. To the extent possible, those data issues have since been addressed.

Data were restricted geographically to Areas 1 – 11 (Figure 1). These areas accounted for approximately 97.6% of the gag grouper handline landings during the years 1993 – 2004. Landings from Area 3 – 9 accounted for 95% of total gag grouper handline landings. Such geographic variation in the proportion of handline trips landing gag grouper support restricting the analyses to data reported from these areas.

Proper species identification in the coastal logbook landings data was of concern during the development of the gag grouper indices of abundance. Specifically, the proportion of gag grouper to black grouper reported to the coastal logbook program differed considerably from that reported in the Trip Interview Program (TIP). Area specific percentages of gag to black grouper, determined from the TIP, were used to estimate the total gag grouper landings by summing gag and black grouper landings reported from an area and multiplying those totals by the appropriate gag to black grouper percentage.

Gag grouper handline trips could be readily characterized by the number of hooks fished per line (10 or fewer), the number of lines fished (six or fewer), the number of days at sea (15 or fewer), and the number of crew (four or fewer). Trips that met those criteria accounted for 92-96% of all gag grouper handline landings reported each year to the coastal logbook program. All handline trips in areas 1 – 11 during 1993 – 2004 that met the criteria listed above were considered potential gag grouper handline trips and were included in the data set to develop indices of abundance.

Index Development

Six factors were considered as possible influences on the proportion of trips that landed gag grouper and are summarized below:

Factor	Levels	Value
YEAR	8, 5, or 12*	1993-2000, 2000-2004, or 1993 – 2004*
AREA	11	Gulf of Mexico shrimp grids 1-11
DAYS	3	1 = <6 days at sea, 2 = 6-10 days at sea, 3=11-15 days at sea
MONTH	12	Month of the year
CREW	4	1-4 crew members

* Three indices were developed, one for each range of years presented under Value, the first two covered periods with different gag grouper size limits and the third covered the full time series. Levels and values of YEAR varied among the three indices

The delta lognormal model approach (Lo et al. 1992) was used to develop standardized indices of abundance. This method combines separate generalized linear model (GLM) analyses of the proportion of successful trips (trips that landed gag grouper) 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 procedure 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 ln(CPUE). The response variable was calculated as: ln(CPUE) = ln(pounds of gag grouper/hook hours). All 2-way interactions among significant main effects were examined.

A stepwise approach was used to quantify the relative importance of the factors. First a GLM model was fit on year. These results reflect the distribution of the nominal data. Next, 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.

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:

Gag grouper 1993-2000 (Period 1):

PPT = YEAR + AREA + DAYS + YEAR*AREA

LN(CPUE) = YEAR + AREA + DAYS + MONTH + CREW + AREA*CREW + YEAR*AREA

The linear regression statistics of the final models are summarized in Table 1.

Gag grouper 2000-2004 (Period 2):

PPT = YEAR + AREA + DAYS + MONTH + AREA*MONTH

LN(CPUE) = YEAR + AREA + MONTH + DAYS + YEAR*MONTH + AREA*DAYS + AREA*MONTH

Final model linear regression statistics are provided in Table 2.

Gag grouper 1993-2004 (full time series):

PPT = YEAR + AREA + DAYS + MONTH + YEAR*AREA

LN(CPUE) = YEAR + AREA + MONTH + DAYS + YEAR*AREA + YEAR*MONTH + AREA*DAYS

The linear regression statistics of the final GLM models are summarized in Table 3.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Tables 4-6 for gag grouper in period 1 (1993-2000), period 2 (2000-2004), and the full time series (1993-2000). The delta-lognormal abundance indices developed for each time period, with 95% confidence intervals, are shown in Figures 1- 3. In a number of cases, GLMMIX failed to converge when all the significant interaction terms identified in the GLM analyses were included in the GLMMIX model. Small sample size and inclusion of many factors likely caused the lack of convergence in the GLMMIX models.

In developing the gag grouper 2000-2004 index, the GLMMIX model failed to converge when the interaction term AREA*MONTH from the binomial model and the lognormal interaction terms AREA*MONTH and AREA*DAYS were included. Those terms were excluded from the analysis.

Similarly, for the full time series index, GLMMIX failed to converge with the lognormal model interaction AREA*DAYS included. That interaction term was excluded during development of the full time series index.

Frequency distributions of ln(CPUE) for positive catches and plots of residuals for lognormal models on successful catch rates by each main effect are shown in Figures 5-10 (gag grouper 1993-2000), Figures 15-19 (gag grouper 2000-2004), and Figures 25-29 (gag grouper 1993-2004). In addition, plots of chi-square residuals for delta lognormal models on proportion successful trips by each main effect and QQ plots of residuals for successful catch rates are provided in Figures 11-14, 20-24, and 30-34 for each gag grouper index. Those diagnostic plots indicate that the fit of these data to the lognormal and binomial models was acceptable, although there were some outliers.

Standardized catch rates for gag grouper increased during all three of the time series examined, although substantially less that those reported by Heinemann (2001). The index developed for the period 1993-2000 had only a slight increase in CPUE over time. Standardized CPUE remained constant from 2001 to 2003 in the 2000-2004 index, however CPUE overall increased markedly from 2000 to 2004. The index developed for the full time series 1993-2004 indicates an increase in CPUE over time. During several periods during the time series, CPUE was nearly constant for two or three year intervals. Those intervals of near constant CPUE were generally followed by increases in CPUE resulting in higher CPUE by 2004. Increase in gag grouper minimum legal size did not result in diminished CPUE, rather the period following the size limit increase had the highest increase in CPUE. That period also coincides with the implementation of a closed season for gag, black, and red grouper.

Literature Cited

Heinemann, D. 2001. Catch Rates for Gag Caught in the Handline Fishery in the eastern Gulf of Mexico during 1991 to 2000 (Preliminary Results). Sustainable Fisheries Division Contribution SFD-99/00-130

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 gag grouper in the Gulf of Mexico for vessels reporting handline landings 1993-2000.

a.

source	df	% reduction dev/df	chi square	p>chi square
year	7		397.14	<0.0001
area	10	25.42	19641.00	<0.0001
days	2	3.00	1843.97	<0.0001
year*area	70	1.82	1157.17	<0.0001

b.

source	df	% reduction dev/df	chi square	p>chi square
year	7		171.51	<0.0001
area	10	28.78	5202.29	<0.0001
days	2	4.43	1382.12	<0.0001
month	11	3.88	1303.49	<0.0001
crew	3	1.29	87.85	<0.0001
area*crew	30	1.41	488.63	<0.0001
year*area	70	1.21	471.86	<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 gag grouper in the Gulf of Mexico for vessels reporting handline landings 2000-2004.

a.

source	df	% reduction dev/df	chi square	p>chi square
year	4		58.00	<0.0001
area	10	30.26	12921.60	<0.0001
days	2	3.23	1144.12	<0.0001
month	11	1.31	344.45	<0.0001
area*month	110	1.25	518.68	<0.0001

b.

source	df	% reduction dev/df	chi square	p>chi square
year	4		218.01	<0.0001
area	10	23.87	1861.94	<0.0001
month	11	5.38	253.72	<0.0001
days	2	2.50	46.39	<0.0001
year*month	38	1.48	378.73	<0.0001
area*days	17	1.49	366.94	<0.0001
area*month	109	1.17	379.78	<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 gag grouper in the Gulf of Mexico for vessels reporting handline landings 1993-2004.

a.

source	df	% reduction dev/df	chi square	p>chi square
year	11		386.33	<0.0001
area	10	27.05	33378.30	<0.0001
days	2	3.10	3138.39	<0.0001
month	11	1.02	959.40	<0.0001
year*area	110	1.37	1377.89	<0.0001

b.

source	df	% reduction dev/df	chi square	p>chi square
year	11		925.21	<0.0001
area	10	26.67	4369.57	<0.0001
month	11	4.77	2428.02	<0.0001
days	2	3.33	250.21	<0.0001
year*area	110	1.44	880.85	<0.0001
year*month	120	1.15	767.59	<0.0001
area*days	19	1.08	623.81	<0.0001

Table 4. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for gag grouper (1993-2000) 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	0.656	6,965	0.457	0.827	0.553	1.239	0.204
1994	0.717	8,063	0.455	0.684	0.447	1.046	0.215
1995	0.703	7,994	0.467	0.910	0.613	1.352	0.200
1996	0.747	7,702	0.535	0.922	0.630	1.350	0.192
1997	0.854	8,145	0.560	0.924	0.630	1.356	0.193
1998	1.577	8,310	0.630	1.486	1.033	2.139	0.184
1999	1.278	8,914	0.613	1.094	0.751	1.594	0.190
2000	1.468	4,844	0.604	1.152	0.790	1.680	0.190

Table 5. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for gag grouper (2000-2004) 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)
2000	0.739	4,417	0.583	0.691	0.454	1.052	0.212
2001	1.030	8,792	0.608	1.042	0.703	1.546	0.199
2002	1.047	8,713	0.597	1.012	0.682	1.502	0.199
2003	0.927	8,414	0.599	0.967	0.651	1.435	0.199
2004	1.256	7,422	0.643	1.287	0.869	1.906	0.198

Table 6. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for gag grouper (1993-2004) 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	0.542	6,965	0.457	0.672	0.482	0.936	0.167
1994	0.592	8,063	0.455	0.523	0.371	0.736	0.173
1995	0.580	7,994	0.467	0.709	0.510	0.986	0.166
1996	0.617	7,702	0.535	0.725	0.526	0.999	0.162
1997	0.705	8,145	0.560	0.727	0.526	1.004	0.163
1998	1.303	8,310	0.630	1.201	0.875	1.648	0.159
1999	1.056	8,914	0.613	0.880	0.638	1.212	0.161
2000	1.091	9,261	0.594	0.868	0.630	1.197	0.162
2001	1.334	8,792	0.608	1.319	0.958	1.817	0.161
2002	1.355	8,713	0.597	1.295	0.940	1.785	0.161
2003	1.200	8,414	0.599	1.338	0.971	1.845	0.161
2004	1.625	7,422	0.643	1.743	1.267	2.397	0.160

Figure 1. Gulf of Mexico Commercial Logbook defined fishing areas.

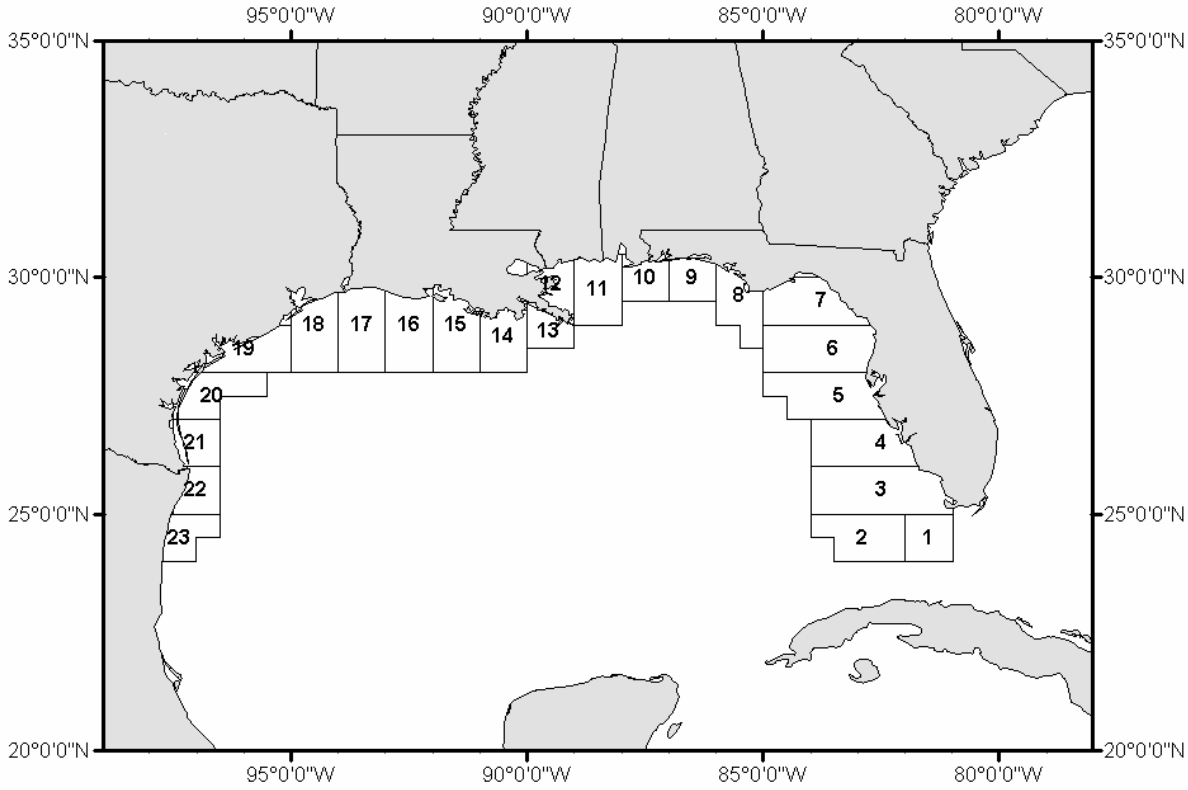
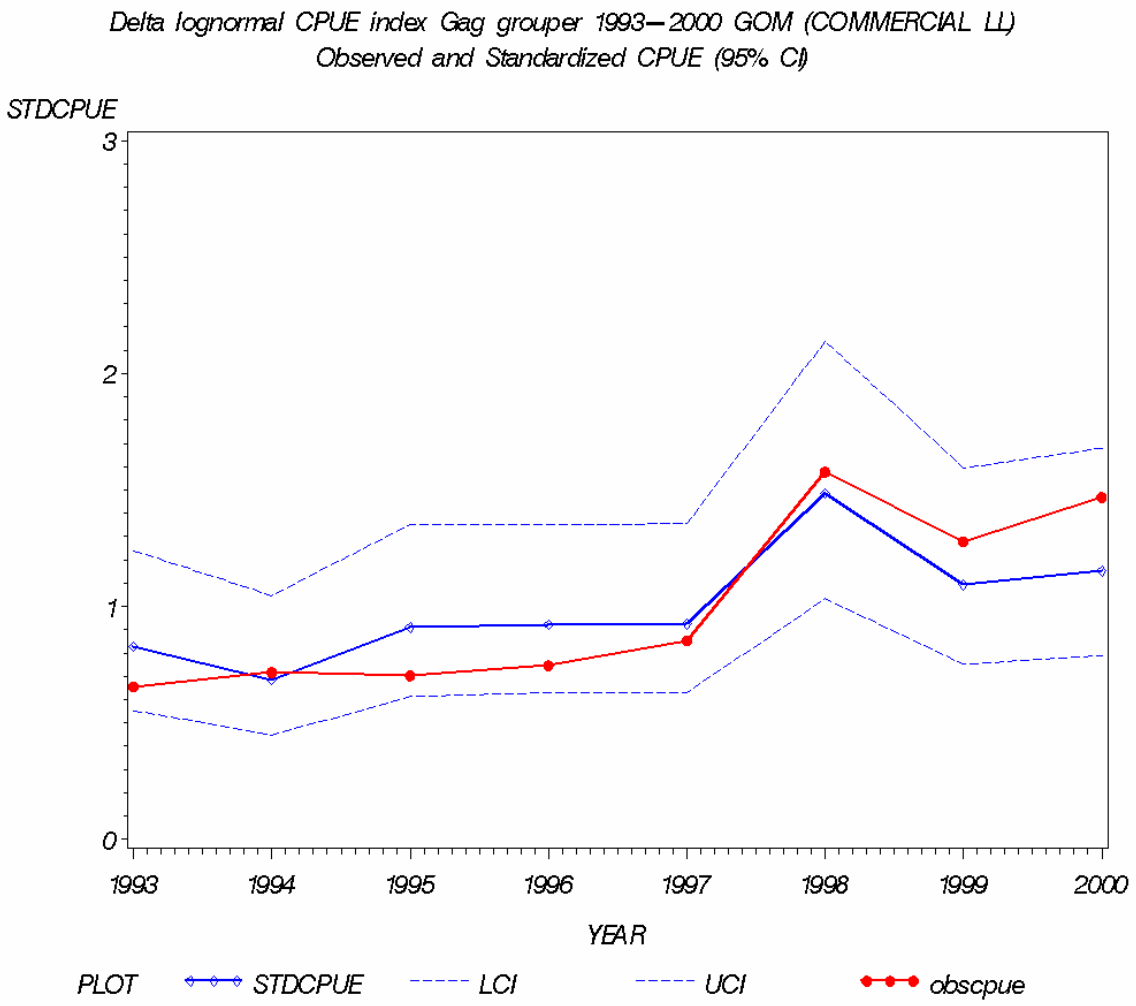


Figure 2. Gag grouper (1993-2000) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted) for vessels fishing handlines in the Gulf of Mexico.



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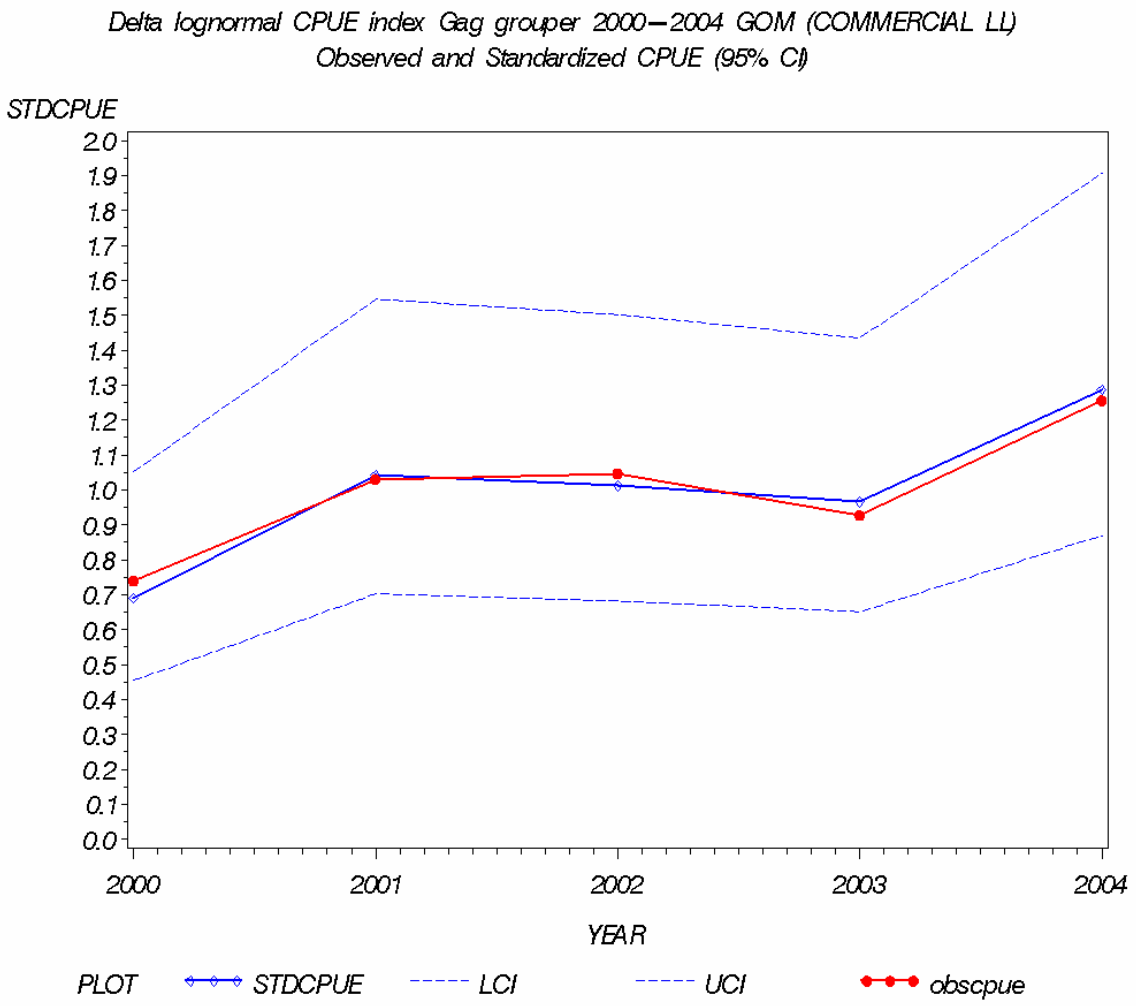

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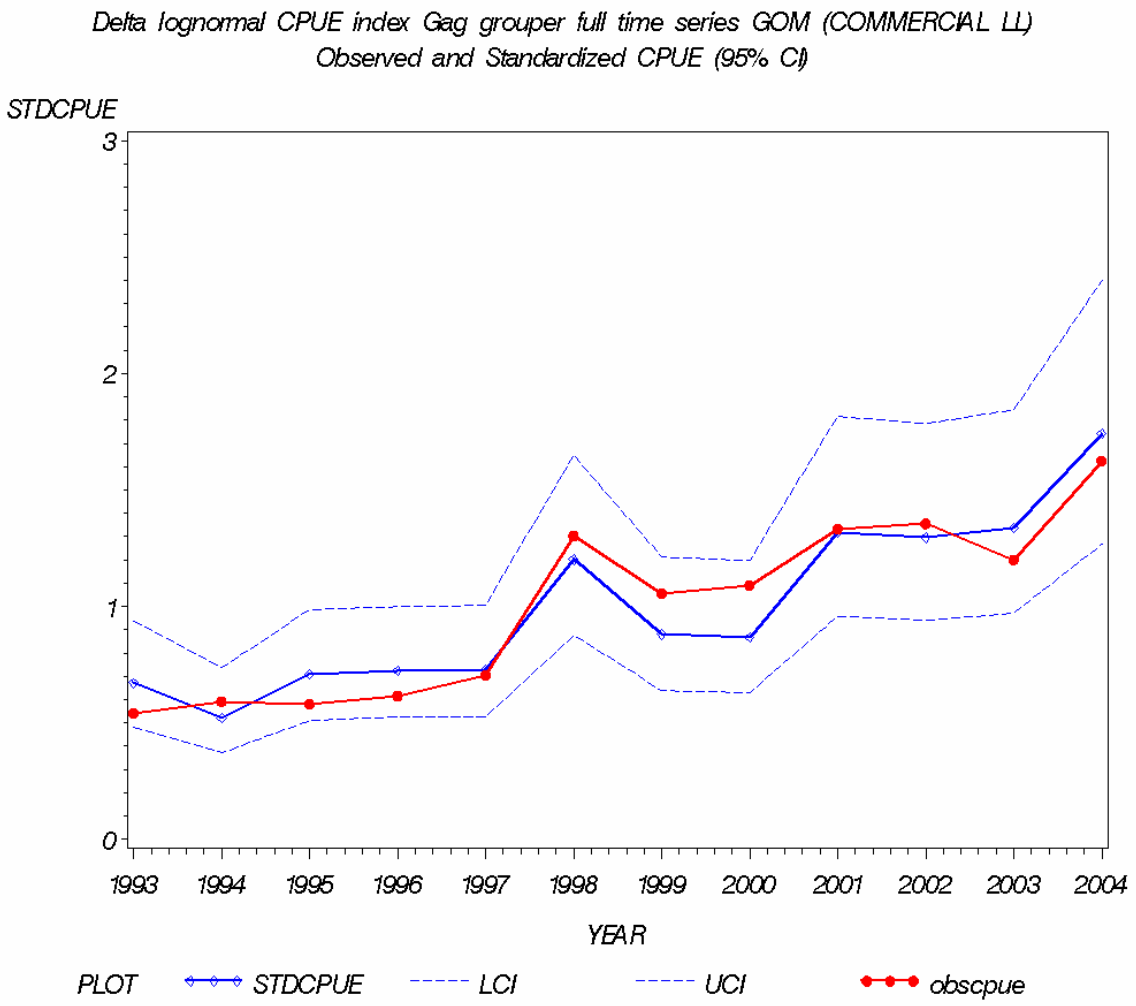

Figure 5. Frequency distribution of ln(CPUE) for positive catches of gag grouper (1993-2000) reported from vessels fishing handlines in the Gulf of Mexico. The solid line is the expected normal distribution.

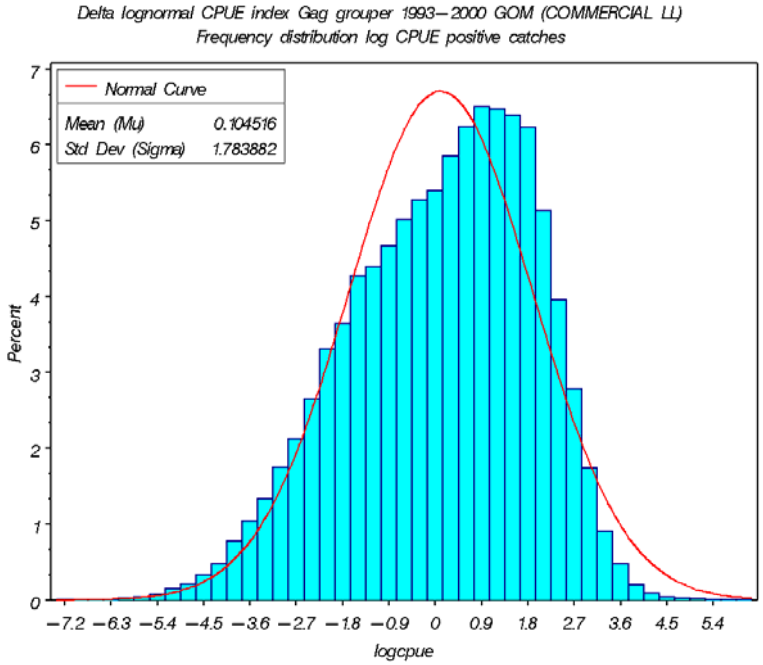

Figure 6. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2000) from vessels fishing handlines by year in the Gulf of Mexico.

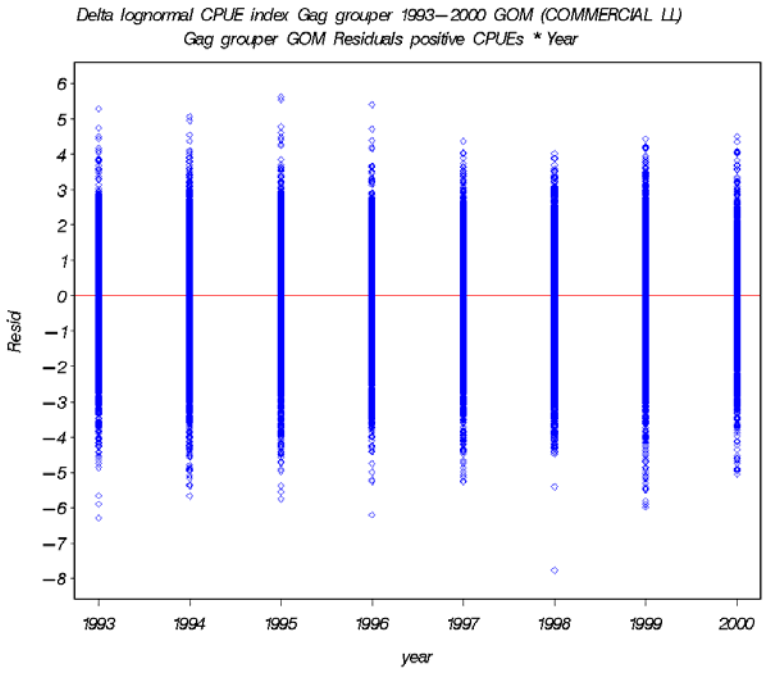

Figure 7. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2000) from vessels fishing handlines by area in the Gulf of Mexico.

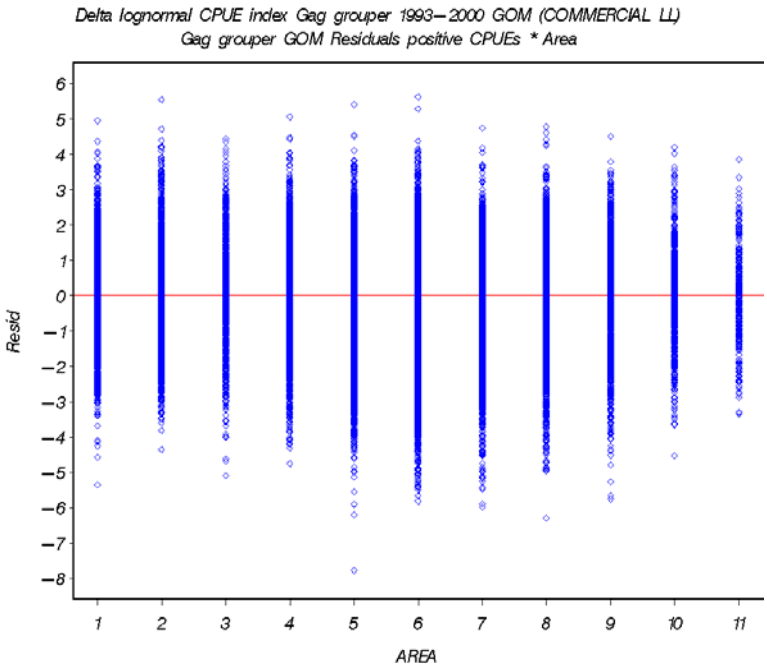

Figure 8. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2000) from vessels fishing handlines by days at sea class in the Gulf of Mexico.

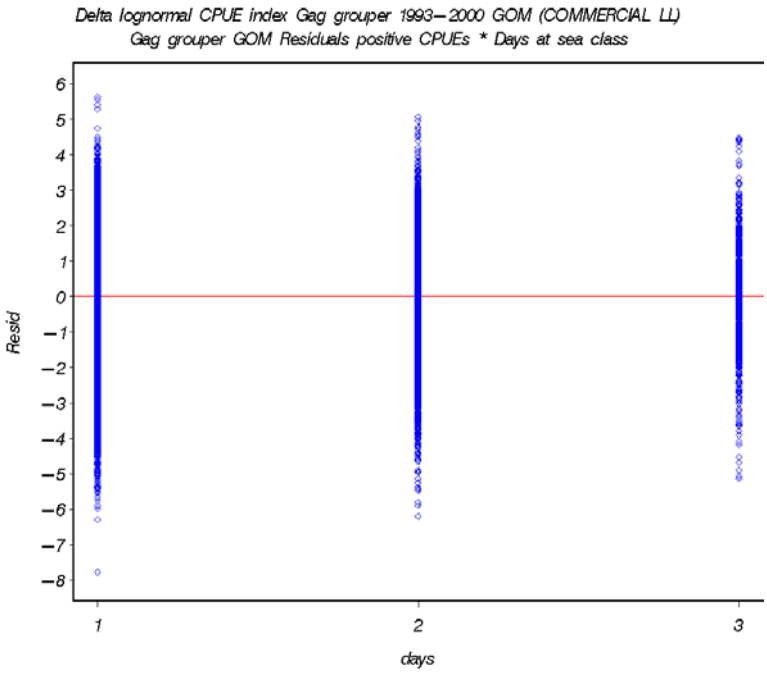

Figure 9. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2000) from vessels fishing handlines by month in the Gulf of Mexico.

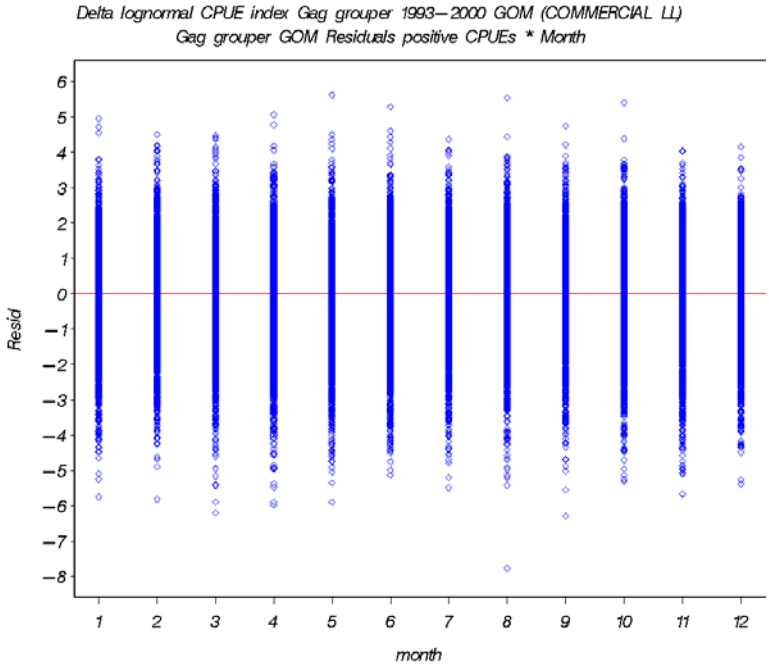

Figure 10. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2000) from vessels fishing handlines by number of crew in the Gulf of Mexico.

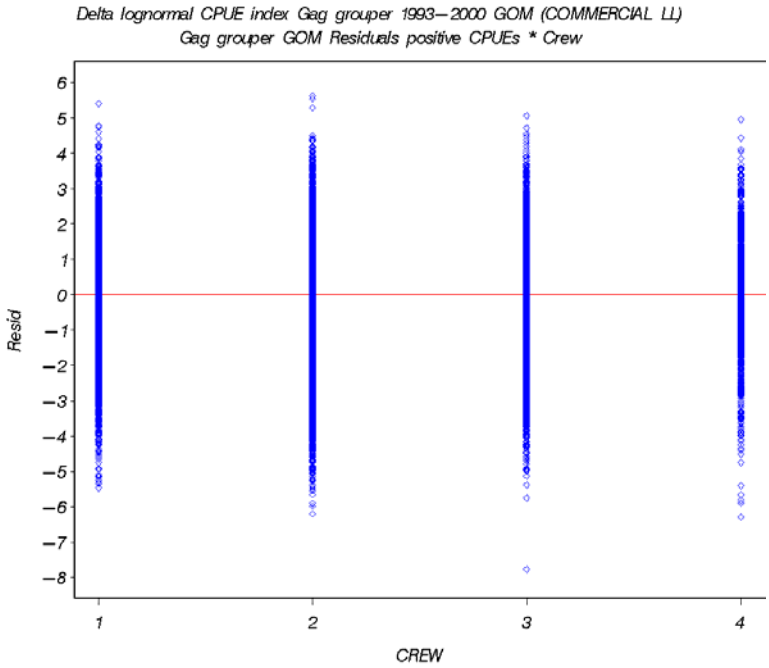

Figure 11. Chi-square residuals for delta lognormal model on proportion successful gag grouper (1993-2000) trips, by year, for vessels fishing handlines in the Gulf of Mexico.

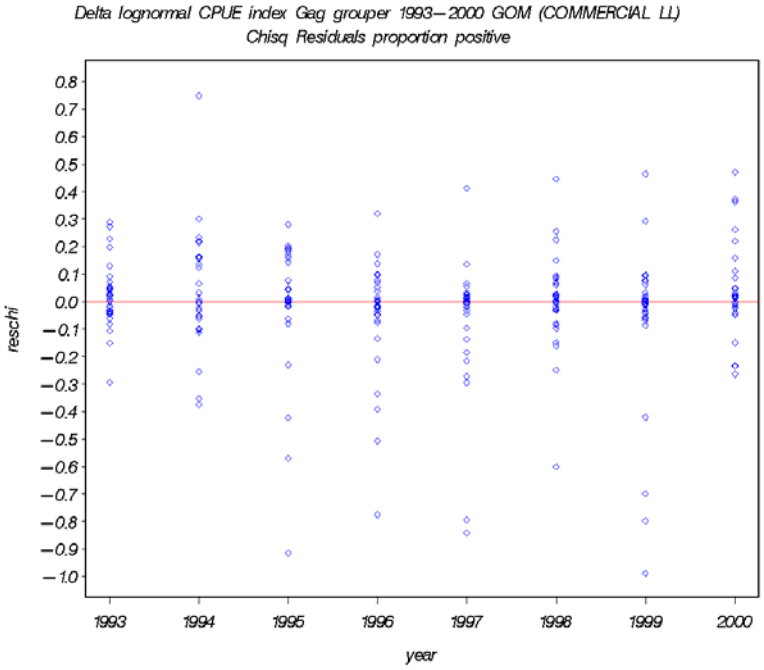

Figure 12. Chi-square residuals for delta lognormal model on proportion successful gag grouper (1993-2000) trips, by area, for vessels fishing handlines in the Gulf of Mexico.

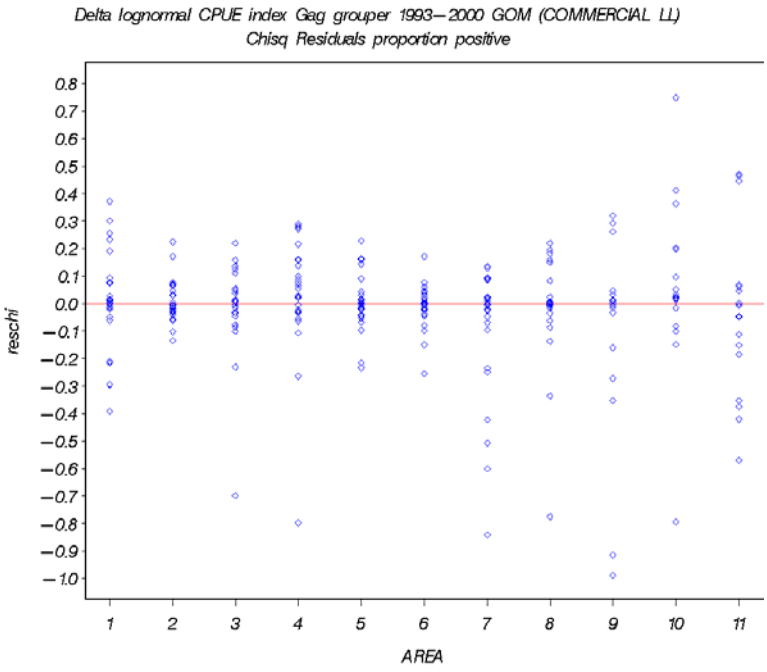

Figure 13. Chi-square residuals for delta lognormal model on proportion successful gag grouper (1993-2000) trips, by days at sea class, for vessels fishing handlines in the Gulf of Mexico.

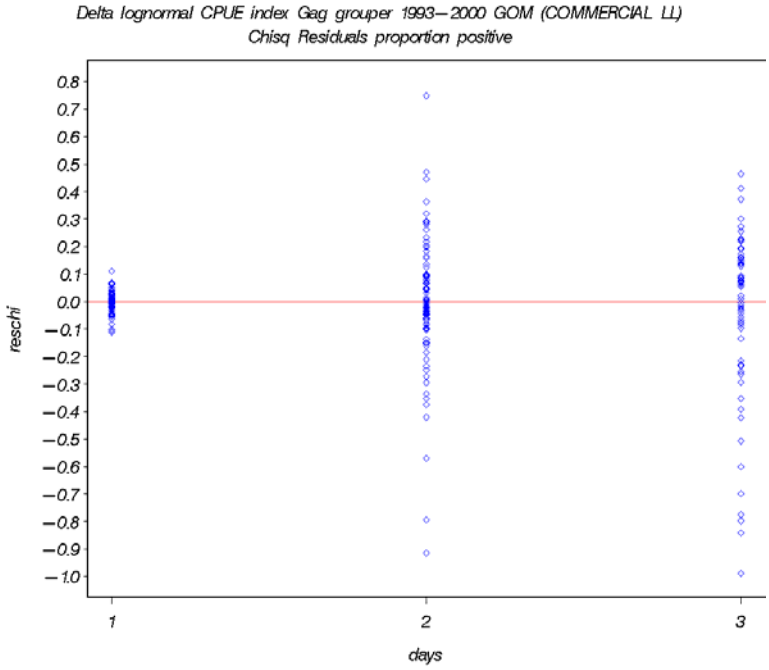

Figure 14. QQ plots of residuals for successful catch rates for gag grouper (1993-2000) from vessels fishing handlines by hook hours in the Gulf of Mexico.

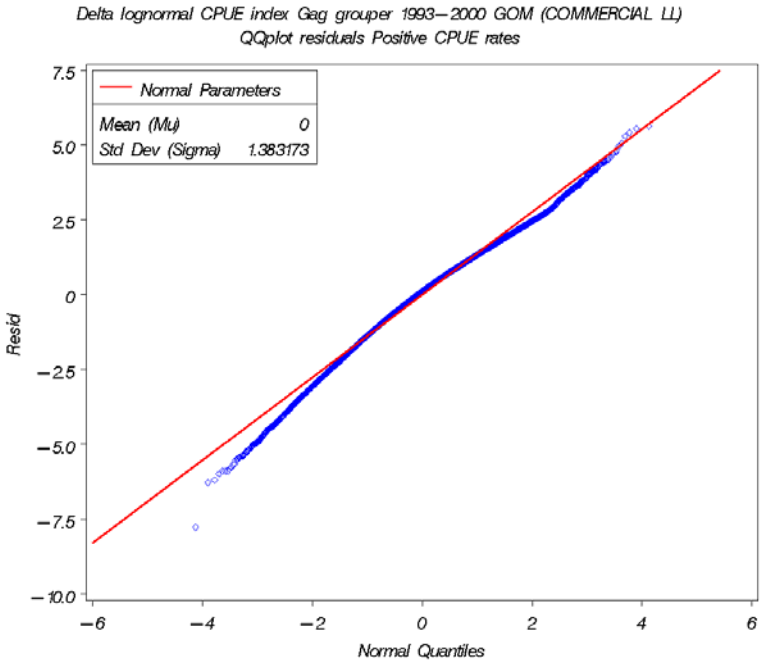

Figure 15. Frequency distribution of ln(CPUE) for positive catches of gag grouper (2000-2004) reported from vessels fishing handlines in the Gulf of Mexico. The solid line is the expected normal distribution.

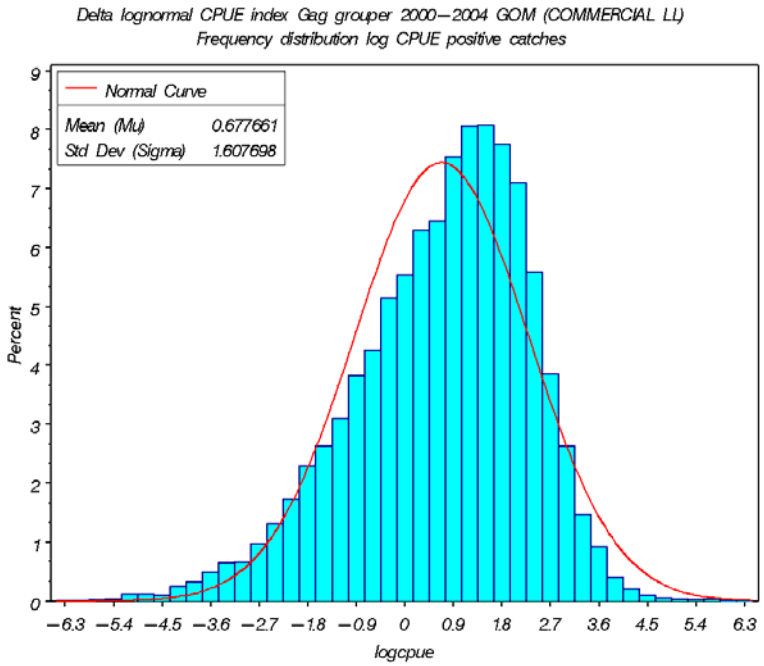

Figure 16. Residuals for the lognormal model on successful catch rates for gag grouper (2000-2004) by year from vessels fishing handlines in the Gulf of Mexico.

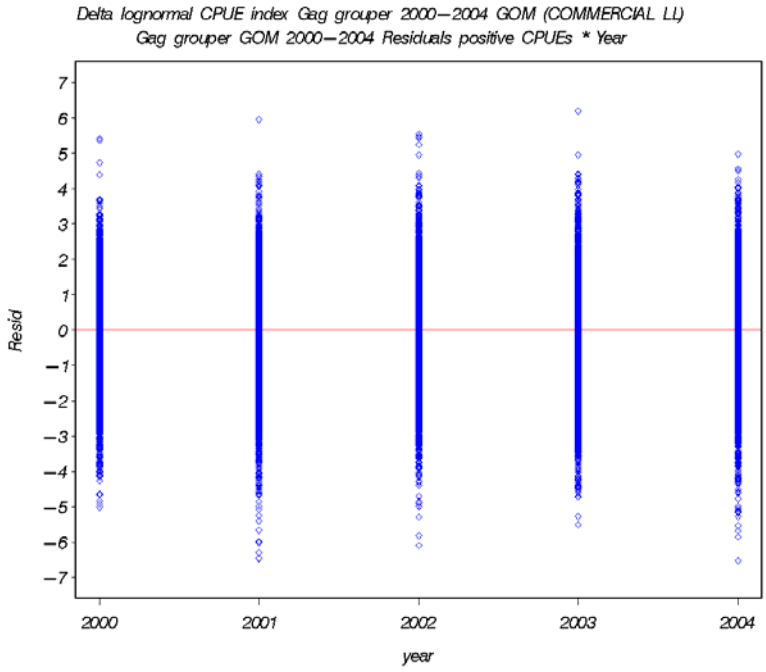

Figure 17. Residuals for the lognormal model on successful catch rates for gag grouper (2000-2004) by area from vessels fishing handlines in the Gulf of Mexico.

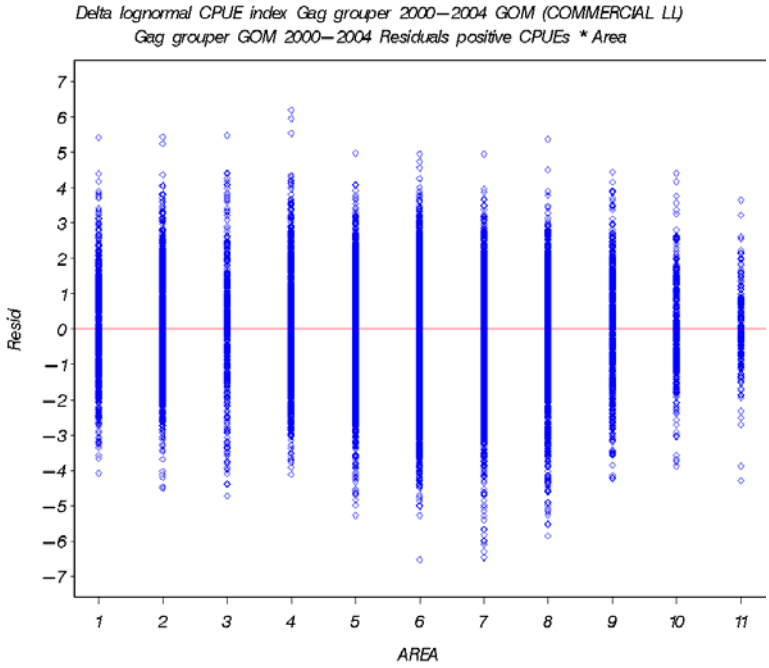

Figure 18. Residuals for the lognormal model on successful catch rates for gag grouper (2000-2004) by month from vessels fishing handlines in the Gulf of Mexico.

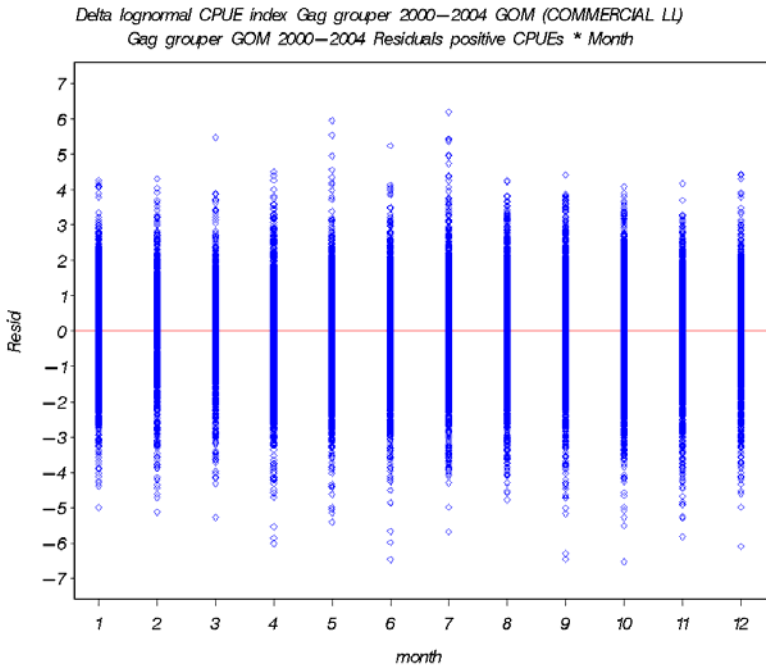

Figure 19. Residuals for the lognormal model on successful catch rates for gag grouper (2000-2004) by days at sea class from vessels fishing handlines in the Gulf of Mexico.

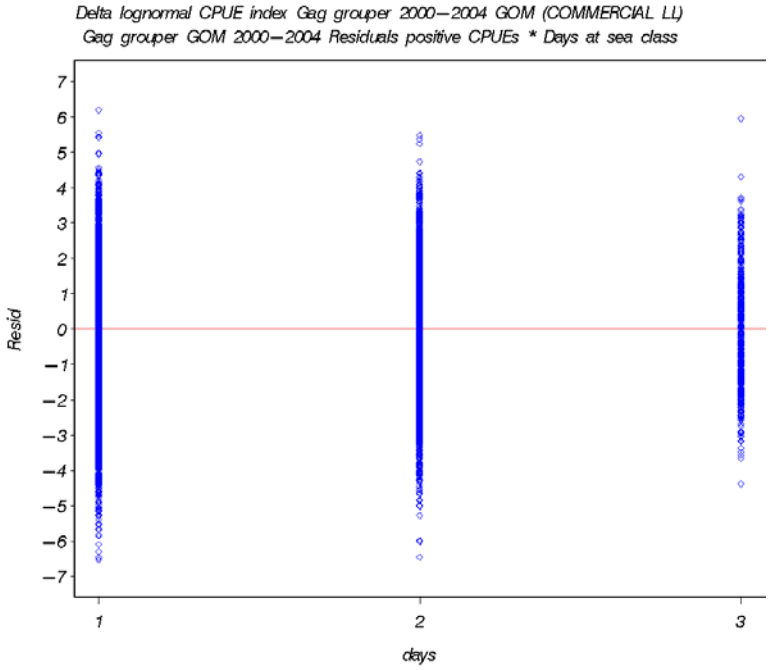

Figure 20. Chi-square residuals for delta lognormal model on proportion successful gag grouper (2000-2004) trips, by year, for vessels fishing handlines in the Gulf of Mexico.

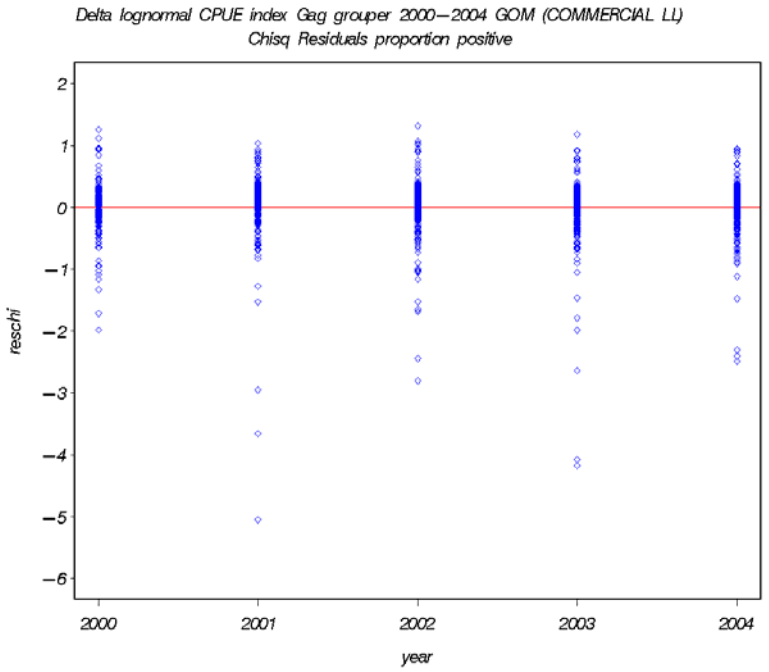

Figure 21. Chi-square residuals for delta lognormal model on proportion successful gag grouper (2000-2004) trips, by area, for vessels fishing handlines in the Gulf of Mexico.

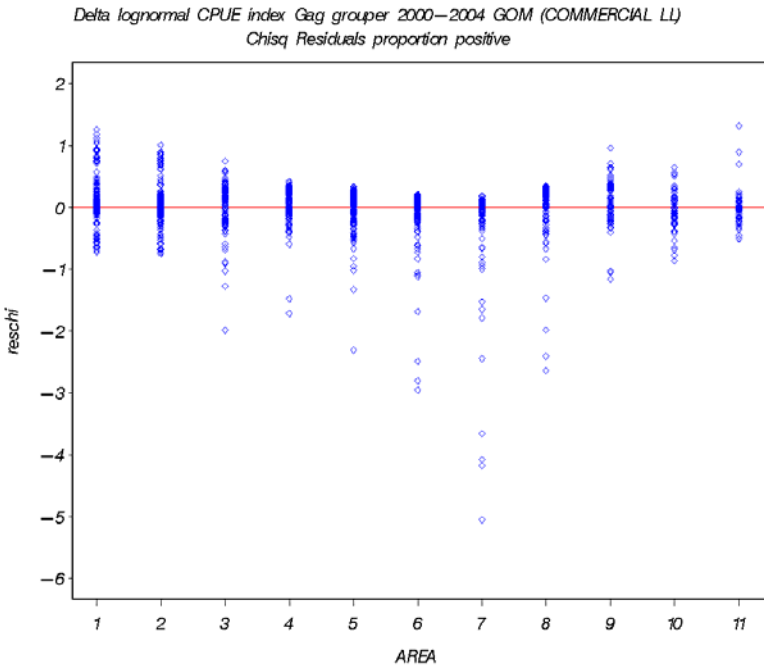

Figure 22. Chi-square residuals for delta lognormal model on proportion successful gag grouper (2000-2004) trips, by days at sea class, for vessels fishing handlines in the Gulf of Mexico.

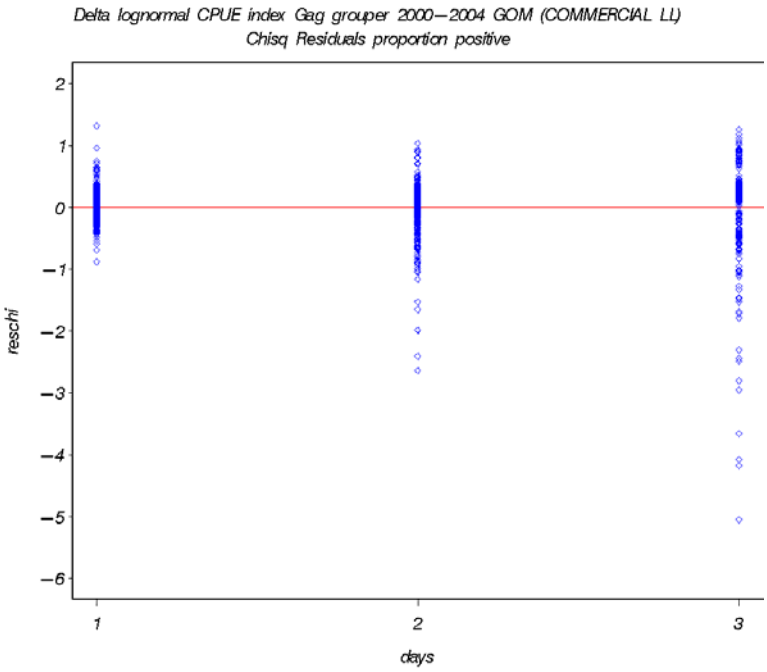

Figure 23. Chi-square residuals for delta lognormal model on proportion successful gag grouper (2000-2004) trips, by month, for vessels fishing handlines in the Gulf of Mexico.

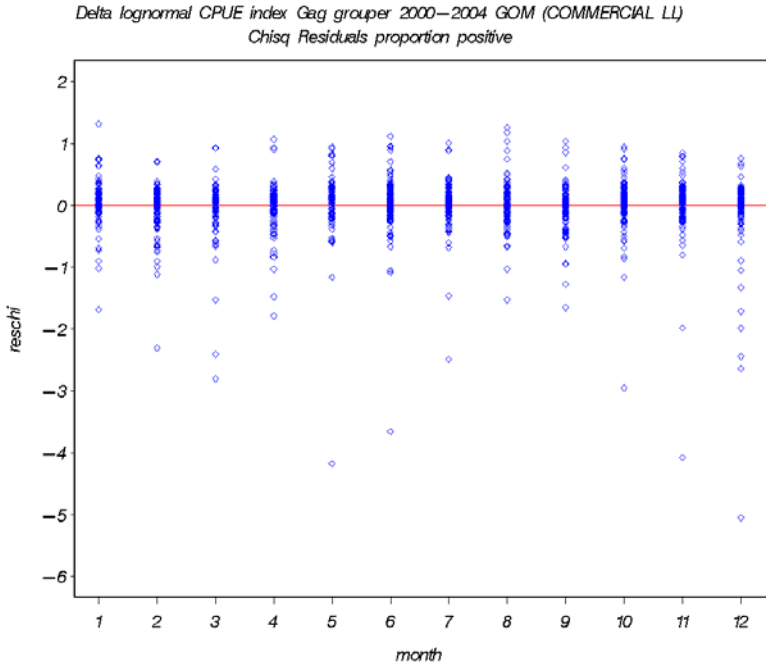

Figure 24. QQ plots of residuals for successful catch rates for gag grouper (2000-2004) from vessels fishing handlines by hook hours in the Gulf of Mexico.

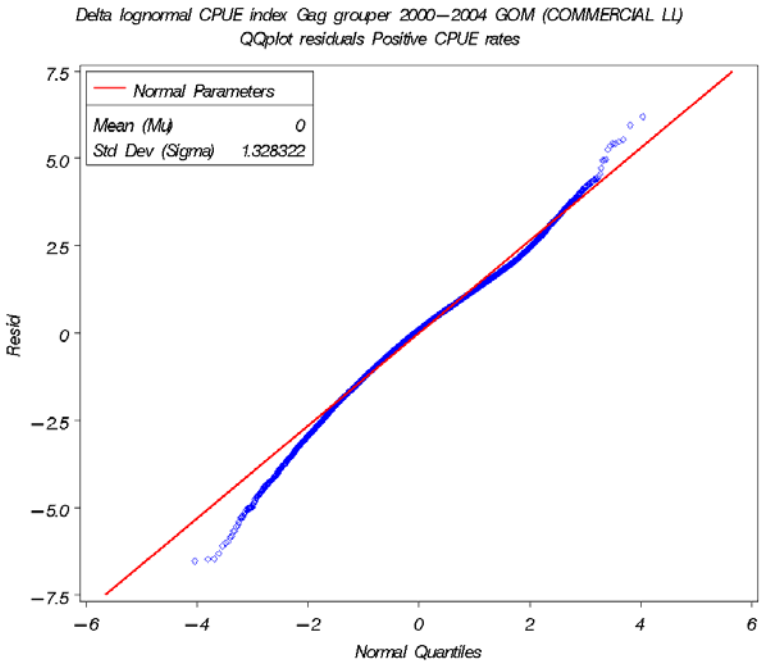

Figure 25. Frequency distribution of ln(CPUE) for positive catches of gag grouper (1993-2004) reported from vessels fishing handlines in the Gulf of Mexico. The solid line is the expected normal distribution.

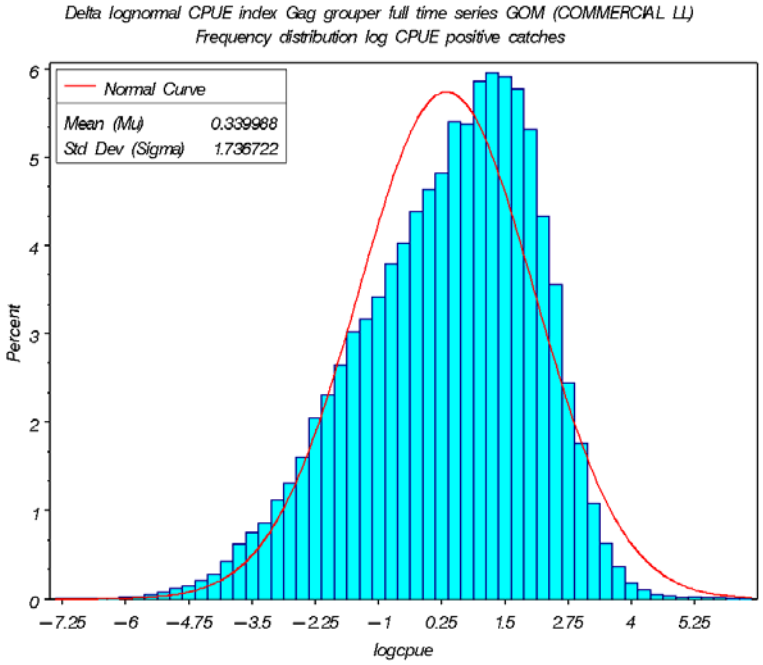

Figure 26. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2004) by year from vessels fishing handlines in the Gulf of Mexico.

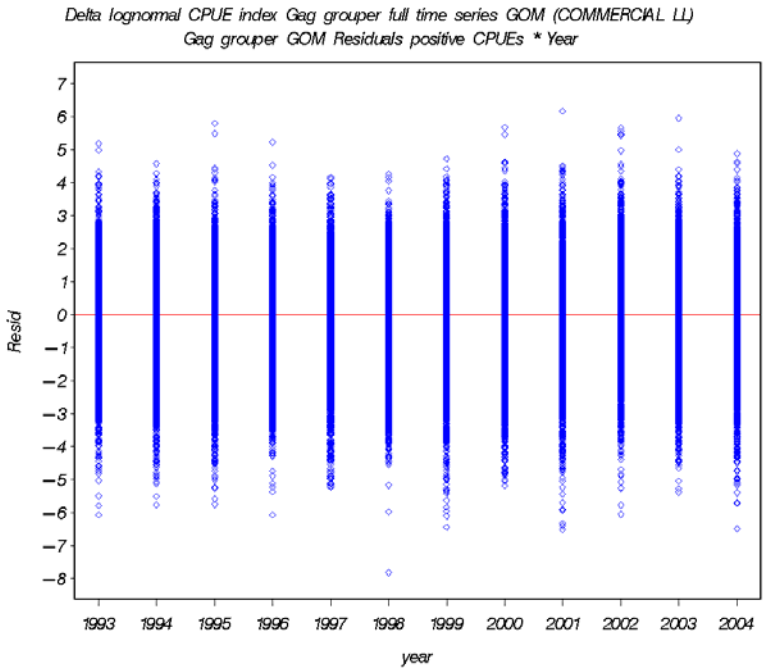

Figure 27. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2004) by area from vessels fishing handlines in the Gulf of Mexico.

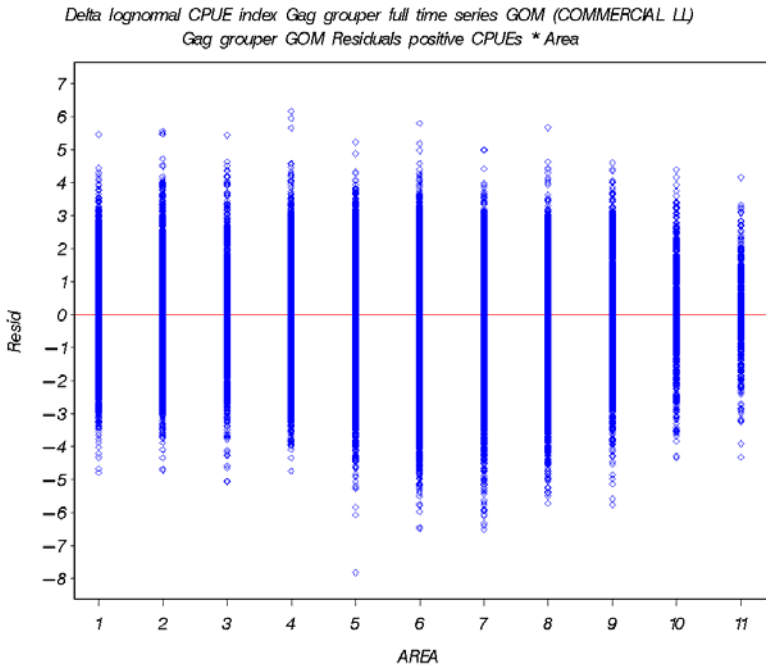

Figure 28. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2004) by month from vessels fishing handlines in the Gulf of Mexico.

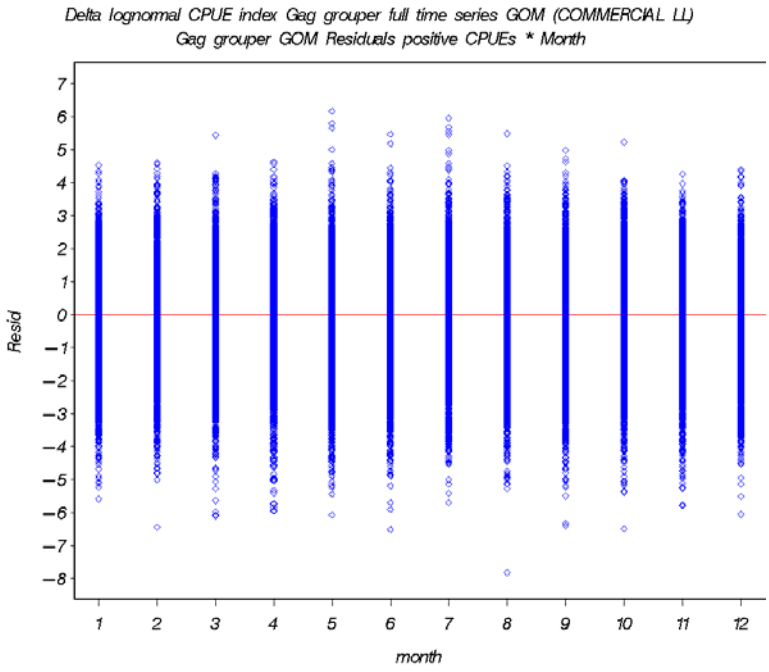

Figure 29. Residuals for the lognormal model on successful catch rates for gag grouper (1993-2004) by days at sea class from vessels fishing handlines in the Gulf of Mexico.

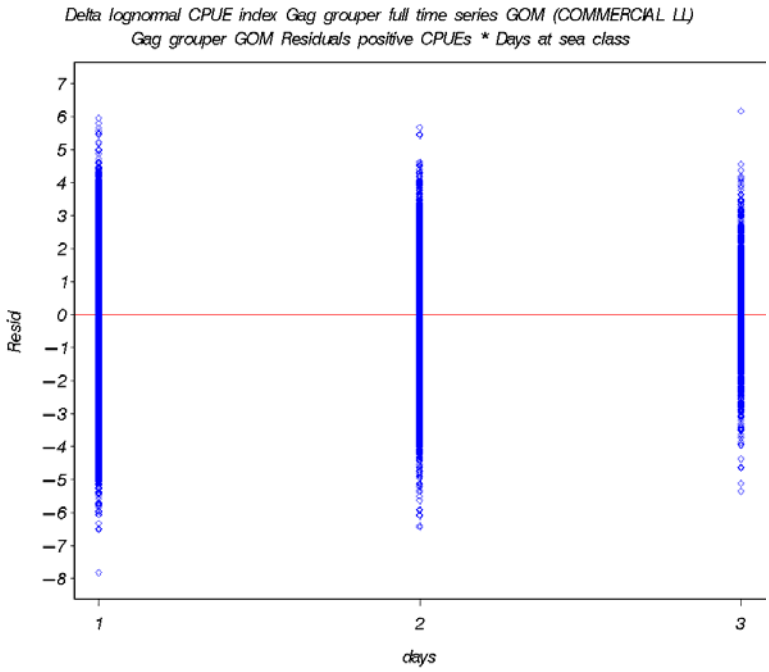

Figure 30. Chi-square residuals for delta lognormal model on proportion successful gag grouper (1993-2004) trips, by year, for vessels fishing handlines in the Gulf of Mexico.

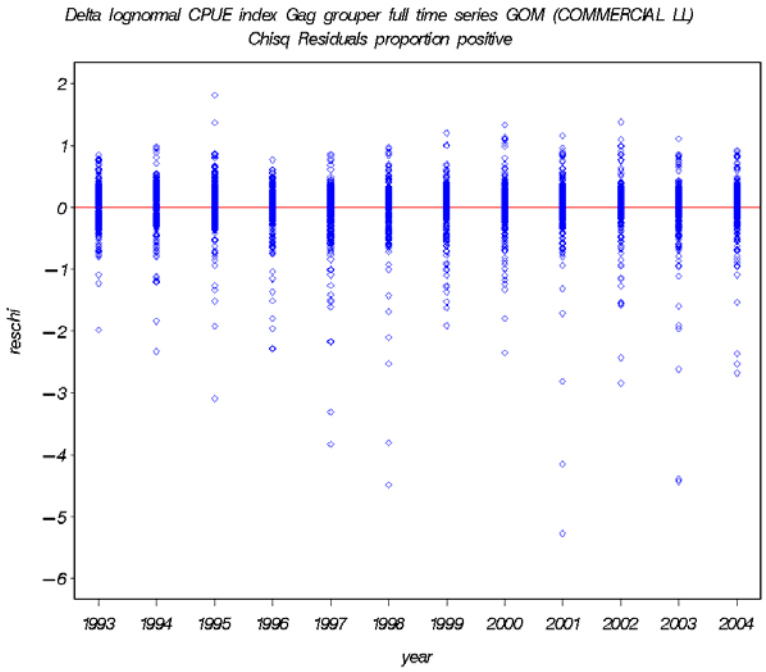

Figure 31. Chi-square residuals for delta lognormal model on proportion successful gag grouper (1993-2004) trips, by area, for vessels fishing handlines in the Gulf of Mexico.

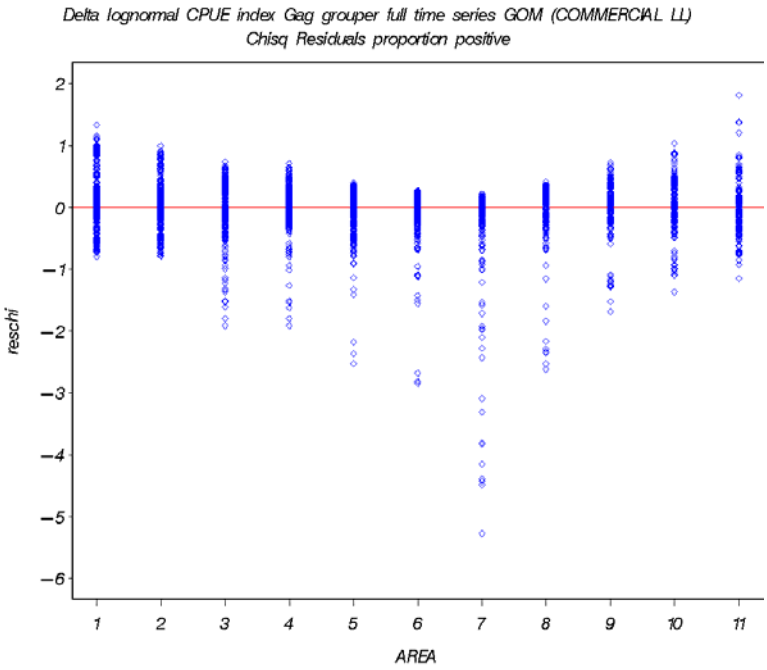

Figure 32. Chi-square residuals for delta lognormal model on proportion successful gag grouper (1993-2004) trips, by days at sea class, for vessels fishing handlines in the Gulf of Mexico.

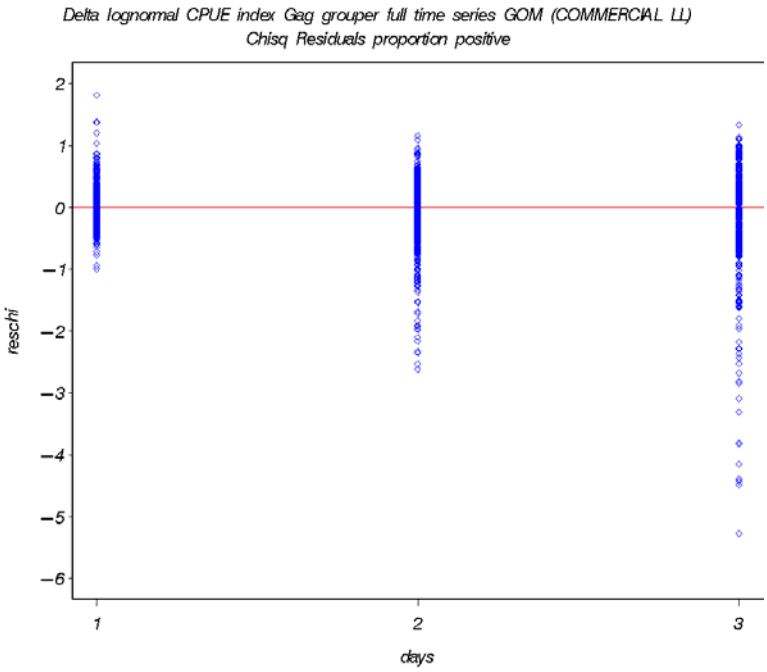

Figure 33. Chi-square residuals for delta lognormal model on proportion successful gag grouper (1993-2004) trips, by month, for vessels fishing handlines in the Gulf of Mexico.

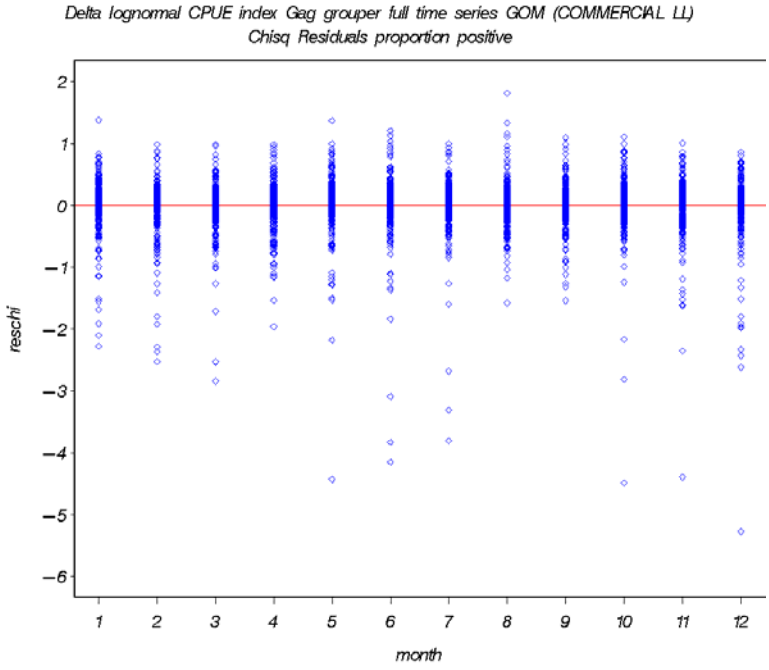

Figure 34. QQ plots of residuals for successful catch rates for gag grouper (1993-2004) from vessels fishing handlines by hooks hours in the Gulf of Mexico.