Standardized catch rates of red snapper (*Lutjanus campechanus*) from the United States commercial handline fishery in the Gulf of Mexico during 1996-2003: additional indices

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INTRODUCTION

Two indices of red snapper abundance were previously developed for the Gulf of Mexico (SEDAR7-DW-47). Those indices included landings data from red snapper class one licensed vessels fishing during the open red snapper season. Commercial vessels are required to have permits to possess or land red snapper. A class one permit allows possession or landing of up to 2,000 pounds of red snapper. A class two permit allows possession or landing of up to 200 pounds of red snapper. A second index was developed that used a species association statistic to identify fishing trips taken by commercial vessels that had a high probability of catching red snapper based upon the species assemblage landed from that particular fishing trip (SEDAR7-DW-47). Upon review of those indices, the Commercial Fisheries Working Group suggested that separate indices be developed for the eastern and western Gulf of Mexico. Use of a lognormal analysis, rather than a delta-lognormal analysis, was recommended for those data sets with high proportion of positive fishing trips. Also, modification of the species assemblage method (SEDAR7-DW-47) of identifying potential red snapper fishing trips was recommended. All of these recommendations were considered in our analyses.

The available catch per unit effort (CPUE) series, from 1996 - 2003, was used to develop three additional abundance indices for red snapper. Data were limited to this period because the minimum limit of 15 inches has been in effect for red snapper since 1996. The minimum allowable size for landings had changed several times since the inception of the logbook program and prior to 1996. No size data is available in the logbook data base, therefore, data from only those years of consistent minimum allowable size were included in the analyses. In addition to the Working Group recommendations, several regional subdivisions of the fishery, based upon differences in landings or CPUE trends, were considered in the analyses presented here.

Data included in the analyses were handline catch and fishing effort of commercial vessels operating in the Gulf of Mexico. This fishing effort has been monitored by the National Marine Fisheries Service (NMFS) through the reef fish 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 and South Atlantic Fishery Management Councils. The Gulf of Mexico reef fish logbook program began in 1990 with the objective of a 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.

MATERIAL AND METHODS

For each fishing trip, the logbook data base 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, 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, we calculated catch per unit effort as:

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

The species assemblage method (SEDAR7-DW-47) of identifying potential red snapper fishing trips was reconsidered. The suggestion that species that have low (less that one) association statistics could be used to eliminate trips in which those species were caught was rejected as arbitrary. For example, a trip that landed 2,000 pounds of red snapper and five pounds of a "non-associated" species would potentially be eliminated from the analysis. Attempts to set limits based upon percentage of total catch of associated and non-associated species were also judged arbitrary. A similar argument concerning the arbitrary nature of the association statistic can, also, be made. The association statistic, as now calculated, is also of limited utility in cases where a species is efficiently targeted, such as in the western Gulf of Mexico. The determination of potential red snapper trips based upon the species association statistic was not included in further analyses of commercial handline data.

Three indices of abundance for red snapper in the Gulf of Mexico were developed. The first index, developed for the eastern Gulf of Mexico (Fig. 1. areas 1-12), used configuration of the fishing gear (number of hooks per line fished) to identify trips with a higher probability of catching red snapper. A second index of abundance was developed for the western Gulf of Mexico and included landings data from fishing trips made by class one permitted vessels fishing during open red snapper season. A final index of abundance was developed for the entire Gulf of Mexico using landings data from class one permitted vessels fishing during open red snapper season. Several other indices were developed, but were rejected because the approach was determined to be inappropriate or the data failed to meet assumptions of the analyses. These indices are summarized in Table 1.

Defining Red Snapper Trips Based Upon Gear Configuration

In order to more accurately estimate fishing effort, the gear configuration of vessels (number of hooks per line fished) was examined. The reef fish logbook dataset includes number of handlines fished, number of hooks per handline, and number of hours fished in addition to landings. Examination of landings by the number of hooks per handline fished for class one vessels during red snapper open season revealed that 86.8% of the eastern Gulf of Mexico red snapper landings by those vessels were made on fishing trips when 10 or more hooks per line were fished. Similarly, a high percentage of the total trips in the eastern Gulf of Mexico (77.2%) made by class one vessels fishing during open red snapper season had gear configured with 10 or more hooks per handline. This suggests that the red snapper directed fishing effort is primarily conducted by vessels using gear configured with 10 or more hooks per handline. Development of the eastern Gulf of Mexico index of abundance, therefore, included all trips where the gear was configured with 10 or more hooks per line.

Index Development

In order to develop a well balanced sample designs, it was necessary to construct the following categorical variables. For eastern Gulf and the entire Gulf indices, the factor SUBREGION reflected geographic differences in number of red snapper fishing trips and CPUE in the eastern Gulf. Two levels were considered in the eastern Gulf.

"north" = Eastern Gulf of Mexico, including fishing areas 7-11.
"south" = Eastern Gulf of Mexico, including fishing areas 5-6.

For the entire Gulf of Mexico, an additional level was included.

"west" = Western Gulf of Mexico, including fishing areas 13-21.

Areas 1-4 and 12 were excluded from the analysis because the landings from those areas was very small, often less than 1% of the total landings. Also, CPUE trends over time in those areas were contradictory to the trends found in other areas where most of the fishing occurred.

The factor SEASON1 was constructed for all indices to create three periods generally reflective of differential CPUE and possible weather associated impacts on the fishery. Those periods were:

January – April,	SEASON1 = 1
May – August,	SEASON1 = 2
September – December,	SEASON1 = 3

We also examined an alternative SEASON1 definition by constructing two periods.

January – April, September – December,	SEASON1 = 1
May – August,	SEASON1 = 2

We constructed additional categorical variables for the eastern Gulf index we developed. Red snapper permit type and fishing season were defined as variables in that analysis. Two levels of SEASON were defined:

"open" = open red snapper fishing season
"closed" = closed red snapper fishing season

Two levels of PERMIT were also constructed:

"class1" = class 1 red snapper permitted vessel
"other" = class 2 or nonpermitted vessel

We used the delta lognormal model approach (Lo et al. 1992) to develop the standardized index of abundance for the eastern Gulf. This method combines separate generalized linear model (GLM) analyses of the proportion of successful trips (trips that landed red snapper) and the catch rates on successful trips to construct a single standardized CPUE index. In the western Gulf and for the entire Gulf of Mexico a lognormal model approach was used to develop the standardized indices of abundance. The proportion of positive fishing trips was very high in both those analyses and violated assumptions of the delta lognormal approach. The lognormal approach uses the catch rates on successful trips to construct a 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).

Factors considered as possible influences on the proportion of successful trips in the eastern Gulf included YEAR, SEASON1 (considered separately for each definition of this variable), SEASON, PERMIT, and SUBREGION. For the GLM procedure, we fit a type-3 model, assumed a binomial error distribution, and selected the logit link. The response variable was proportion successful trips. We examined the same factors during the analysis of catch rates on successful trips. In this case, a type3 model assuming lognormal error distribution was employed. The linking function selected was "normal", and the response variable was ln(CPUE). We examined all 2-way interactions among significant main effects.

For the western Gulf and entire Gulf indices, the factors SEASON and PERMIT were not considered (only data from class one vessels fishing during the open red snapper season were included in those analyses). The GLM procedure in these analyses was limited to analysis of catch rates on successful trips. As in the first analysis, a type3 model assuming lognormal error distribution was employed. The linking function selected was "normal", and the response variable was ln(CPUE) and all 2-way interactions among significant main effects were examined.

For each GLM, we used a stepwise approach to quantify the relative importance of the factors. First the null model was run. These results reflect the distribution of the nominal data. Next we added each potential factor to the null model one at a time, and examined the resulting reduction in deviance per degree of freedom. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$), and the reduction in deviance per degree of freedom was $\geq 1\%$. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model.

The final delta-lognormal model or lognormal model, as appropriate, was fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute). All factors were modeled as fixed effects. Interaction terms included in the models for the eastern Gulf index were permit*year and year*season1 (3 seasons). No interaction terms were included in the western Gulf or the entire Gulf models because none met the criteria for inclusion in those final models. 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

For the eastern Gulf of Mexico analysis using data from trips with gear configurations of 10 hooks or more per line fished, the stepwise construction of the binomial model of the probability of catching red snapper is summarized in Table 2. (A binomial model was also constructed where SEASON1 included only two seasons, however SEASON1 was not a significant factor in that analysis, therefore we used the model developed as shown in Table 1.) The final model was ***PROPORTION SUCCESSFUL TRIPS =SEASON+PERMIT+SEASON1+ YEAR.*** None of the possible two-way interactions met our criteria for inclusion of the final model. Annual variations in the proportion of successful trips are shown in Figure 2. The proportion successful increased consistently during the first half of the time series, but remained constant from 2000 through 2003. Diagnostic plots were examined to evaluate the fit of the binomial model. The distribution of the chi-square residuals (Fig. 3) indicates an acceptable fit, although some outliers were noted. The frequency distribution of the proportion of successful catches, by year and region was also acceptable (Fig. 4).

The construction of the lognormal model of catch rates on successful trips in the eastern Gulf of Mexico including data from fishing trips with 10 or more hooks per handline is summarized in Table 3 (again, SEASON1 including only two seasons did not meet the criteria for inclusion in the model). The final model was ***ln(CPUE) =PERMIT+ YEAR + SEASON1*** with significant interaction terms ***PERMIT*YEAR*** and ***YEAR*SEASON1***. Annual values of nominal CPUE are shown in Figure 5. CPUE more than tripled over the time series. Diagnostic plots created to assess the fit of the lognormal model were acceptable. The residuals were distributed evenly around zero (Fig. 6). The frequency distribution of ln(CPUE), by year and region, approximated a normal distribution; although the distribution was slightly skewed from normal (Fig. 7). In summary, all diagnostic plots met our expectations, and supported an acceptable fit to the selected models.

The delta-lognormal abundance index developed for the eastern Gulf of Mexico, with 95% confidence intervals, is shown in Figure 8. To allow quick visual comparison with the nominal values, both series were scaled to their respective means. The index statistics can be found in Table 4. The standardized abundance index is quite similar to the nominal CPUE series. CPUE has increased through the time series such that CPUE estimates for 2003 are approximately five times greater than the estimated CPUE for 1996.

The stepwise construction of the lognormal model of catch rates on successful trips for class one permitted vessels during open red snapper seasons in the western Gulf is summarized in Table 5. The final model was ***ln(CPUE) = YEAR.*** SEASON1 (including either two or three levels, only the model construction with three SEASON1 levels is shown) failed to meet our criteria for inclusion in the final model. In order to include all trips reported by class one permitted vessels fishing during red snapper open season (approximately 350 trips of this kind reported no red snapper catch) and because the lognormal analysis employed uses only data from successful trips (some red snapper catch), we added a constant equal to 10% of the mean CPUE to the CPUE of each trip. This allowed the inclusion of zero catch trips in the analysis and is the reason for the higher than expected value in the lower tail of the log(CPUE) frequency distribution (Fig. 11). Annual values of nominal CPUE are shown in Figure 9. CPUE decreased over the time series from approximately 4.9 in 1996 to 2.8 in 2003. Diagnostic plots created to assess the fit of the lognormal model were acceptable. The residuals were distributed evenly around zero (Fig. 10). The frequency distribution of ln(CPUE), by year and region, approximated a normal distribution (Fig. 11) as in the previous analysis. All diagnostic plots again met our expectations and supported an acceptable fit to the selected models.

The lognormal abundance index developed using data from trips with class one permitted vessels fishing during the open red snapper season in the western Gulf, with 95% confidence intervals, is shown in Figure 12. As with the first index, visual comparison with the nominal values is facilitated by scaling both series to their respective

means. The index statistics can be found in Table 6. The standardized abundance index is, again, similar to the nominal CPUE series. CPUE declined over the years examined such that the CPUE in 2003 was approximately 60% of the 1996 value.

Construction of the lognormal model of catch rates on successful trips for class one permitted vessels during open red snapper seasons for the entire Gulf is summarized in Table 7. The final model was ***ln(CPUE) = YEAR+SUBREGION.*** Again, SEASON1 failed to meet our criteria for inclusion in the final model. The YEAR*SUBREGION interaction also failed to meet the criteria for model inclusion. As with the western Gulf analysis, we added a constant equal to 10% of the mean CPUE to the CPUE of each trip so the zero catch trips were included in the analysis. Annual values of nominal CPUE are shown in Figure 13. CPUE, as in the western Gulf, decreased overall for the years examined. Diagnostic plots created to assess the fit of the lognormal model were acceptable. The residuals were distributed approximately evenly around zero (Fig. 14). The frequency distribution of ln(CPUE), by year and region, again approximated a normal distribution (Fig. 15) with a greater than expected frequency of occurrence in the lower tail of the distribution as in the western Gulf analysis. The diagnostic plots supported an acceptable fit to the selected models.

The lognormal abundance index developed for the entire Gulf of Mexico using data from trips of class one permitted vessels fishing during open red snapper season, with 95% confidence intervals, is shown in Figure 16. As with the other two indices, visual comparison with the nominal values is facilitated by scaling both series to their respective means. The index statistics can be found in Table 8. The standardized abundance index is, again, similar to the nominal CPUE series. CPUE declined over the years examined similarly to the CPUE decline found in the western Gulf index.

DISCUSSION

Two of the three indices calculated here show nearly identical trends. The index for the entire Gulf may be driven by trends in the western Gulf red snapper fishery. The majority of both the red snapper catch and the number of red snapper trips for class one vessels occur in the western Gulf. The CPUE trend in the eastern Gulf is entirely different from that indicated from the other two indices. CPUE in the eastern Gulf has increased dramatically, although this area accounts for a much lower percentage of red snapper landings than are reported for the western Gulf of Mexico

LITERATURE CITED

Lo, N.C., L.D. Jackson, J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models.

Table 1. Summary of red snapper indices of abundance developed for the Gulf of Mexico from commercial logbook handline data. See index development section for description of factors.

Index	Factors	Decision
Delta lognormal, eastern Gulf, Class 1 Vessels	Year, season of the year	Improve analysis with inclusion of zero catch trips
Delta lognormal, eastern Gulf, trips determined by species association statistic	Year, season of the year, permit type, subregion, red snapper open or closed season	Association statistic inappropriate
Delta lognormal, western Gulf, trips determined by species association statistic	Year, season of the year, permit type, red snapper open or closed season	Association statistic inappropriate
Delta lognormal, western Gulf, trips determined by gear configuration	Year, season of the year, permit type, red snapper open or closed season	Does not meet analysis assumptions
Lognormal, western Gulf, trips determined by gear configuration, add 10% of mean CPUE*	Year, season of the year, permit type, red snapper open or closed season	Does not meet analysis assumptions
Delta lognormal, Gulf of Mexico, trips determined by species association statistic	Year, season of the year, permit type, subregion, red snapper open or closed season	Association statistic inappropriate
Delta lognormal, Gulf of Mexico, trips determined by gear configuration	Year, season of the year, permit type, subregion, red snapper open or closed season	Does not meet analysis assumptions
Gulf of Mexico, trips determined by gear configuration, add 10% of mean CPUE*	Year, season of the year, permit type, subregion, red snapper open or closed season	Does not meet analysis assumptions

***** A constant, equal to 10% of the mean CPUE was added to the CPUE of each trip so the zero catch trips were included in the analysis. See Results for additional description.

Table 2. A summary of formulation of the binomial model including data limited to vessels fishing with 10 or more hooks/handline, where SUBREGION=north (areas 7-11) and south (areas 5-6) in the eastern Gulf of Mexico. The calendar year was divided into three periods: SEASON1=January-April (1); May-August (2); and September-December (3). PERMIT=class 1 permitted vessels (1) or class 2 or nonpermitted vessels (2). SEASON=red snapper open (1) or closed (2) season. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray shading with bold font). The final model was SUCCESS = SEASON+PERMIT+SEASON1+YEAR.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	7864	10496.4	1.3347		-5248.2		
SEASON	7863	2983.6	0.3794	71.57	-1491.8	7512.78	0.00000
SEASON1	7862	9777.0	1.2436	6.83	-4888.5	719.42	0.00000
YEAR	7857	10079.1	1.2828	3.89	-5039.5	417.30	0.00000
PERMIT	7863	10114.0	1.2863	3.63	-5057.0	382.34	0.00000
SUBREGION	7863	10465.0	1.3309	0.29	-5232.5	31.36	0.00000

The explanatory factors in the base model are: SEASON

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	7863	2983.6	0.3794		-1491.8		
PERMIT	7862	2856.6	0.3633	4.25	-1428.3	127.02	0.00000
SEASON1	7861	2930.5	0.3728	1.76	-1465.2	53.14	0.00000
YEAR	7856	2955.8	0.3762	0.84	-1477.9	27.80	0.00024
SUBREGION	7862	2976.5	0.3786	0.23	-1488.2	7.13	0.00760

The explanatory factors in the base model are: SEASON PERMIT

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	7862	2856.6	0.3633		-1428.3		
SEASON1	7860	2786.8	0.3546	2.42	-1393.4	69.80	0.00000
YEAR	7855	2837.4	0.3612	0.58	-1418.7	19.19	0.00761
SUBREGION	7861	2848.2	0.3623	0.28	-1424.1	8.42	0.00371

The explanatory factors in the base model are: SEASON PERMIT SEASON1

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	7860	2786.8	0.3546		-1393.4		
YEAR	7853	2752.6	0.3505	1.14	-1376.3	34.23	0.00002
SUBREGION	7859	2777.7	0.3534	0.31	-1388.9	9.04	0.00264

The explanatory factors in the base model are: SEASON PERMIT SEASON1 YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	7853	2752.6	0.3505		-1376.3		
SUBREGION	7852	2743.9	0.3495	0.30	-1372.0	8.61	0.00334

The explanatory factors in the base model are: SEASON PERMIT SEASON1 YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	7853	2752.6	0.3505		-1376.3		
SEASON1 * YEAR	7839	2723.7	0.3475	0.87	-1361.9	28.85	0.0109
PERMIT * YEAR	7846	2727.8	0.3477	0.81	-1363.9	24.79	0.0008
SEASON * PERMIT	7852	2734.8	0.3483	0.63	-1367.4	17.75	<0.0001
SEASON * YEAR	7846	2741.5	0.3494	0.31	-1370.7	11.09	0.1345
PERMIT * SEASON1	7851	2749.6	0.3502	0.08	-1374.8	2.93	0.2312
SEASON * SEASON1	7851	2751.6	0.3505	0.01	-1375.8	0.97	0.6169

Table 3. A summary of formulation of the lognormal model including data limited to vessels fishing with 10 or more hooks/handline, where SUBREGION=north (areas 7-11) and south (areas 5-6) in the eastern Gulf of Mexico. The calendar year was divided into three periods: SEASON1=January-April (1); May-August (2); and September-December (3). PERMIT=class 1 permitted vessels (1) or class 2 or nonpermitted vessels (2). SEASON=red snapper open (1) or closed (2) season. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray shading with bold font). The final model was log(CPUE) = PERMIT+YEAR+SEASON1 with interaction terms PERMIT*YEAR and YEAR*SEASON1.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	3041	6168.4	2.0284		-5391.6		
PERMIT	3040	4930.9	1.6220	20.04	-5051.1	681.14	0.00000
YEAR	3034	5819.0	1.9179	5.45	-5303.0	177.36	0.00000
SEASON	3040	6087.9	2.0026	1.27	-5371.7	39.96	0.00000
SEASON1	3039	6152.3	2.0244	0.19	-5387.7	7.94	0.01890
SUBREGION	3040	6165.1	2.0280	0.02	-5390.8	1.59	0.20665

The explanatory factors in the base model are: PERMIT

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	3040	4930.9	1.6220		-5051.1		
YEAR	3033	4678.9	1.5427	4.89	-4971.3	159.61	0.00000
SEASON	3039	4872.2	1.6032	1.16	-5032.9	36.43	0.00000
SEASON1	3038	4875.0	1.6047	1.07	-5033.7	34.71	0.00000
SUBREGION	3039	4924.0	1.6203	0.11	-5048.9	4.24	0.03958

The explanatory factors in the base model are: PERMIT YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	3033	4678.9	1.5427		-4971.3		
SEASON1	3031	4562.2	1.5052	2.43	-4932.8	76.83	0.00000
SEASON	3032	4628.9	1.5267	1.04	-4954.9	32.68	0.00000
SUBREGION	3032	4670.1	1.5403	0.15	-4968.4	5.68	0.01720

The explanatory factors in the base model are: PERMIT YEAR SEASON1

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	3031	4562.2	1.5052		-4932.8		
SEASON	3030	4518.3	1.4912	0.93	-4918.1	29.42	0.00000
SUBREGION	3030	4553.2	1.5027	0.16	-4929.8	6.01	0.01420

The explanatory factors in the base model are: PERMIT YEAR SEASON1

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	3031	4562.2	1.5052		-4932.8		
PERMIT * YEAR	3024	4417.8	1.4609	2.94	-4884.0	97.80	<0.0001
YEAR * SEASON1	3017	4486.9	1.4872	1.19	-4907.5	50.60	<0.0001
PERMIT * SEASON1	3029	4534.7	1.4971	0.54	-4923.7	18.39	0.0001

Table 4. The relative nominal CPUE, proportion successful trips, relative abundance index, and confidence intervals and coefficients of variance associated with the relative abundance index for red snapper caught in the commercial handline fishery by vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico.

YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1996	0.432	930	0.217	0.279	0.065	1.188	0.832
1997	0.408	831	0.226	0.313	0.078	1.245	0.782
1998	0.972	873	0.334	1.002	0.369	2.719	0.532
1999	0.986	1087	0.326	0.620	0.208	1.846	0.589
2000	1.013	888	0.443	1.234	0.496	3.072	0.481
2001	1.305	926	0.487	1.574	0.668	3.708	0.449
2002	1.519	1126	0.496	1.522	0.646	3.586	0.449
2003	1.366	1204	0.502	1.457	0.624	3.401	0.444

Table 5. A summary of formulation of the lognormal model including data limited to vessels with class 1 licenses fishing during the red snapper open season in the western Gulf of Mexico. The calendar year was divided into three periods: SEASON1=January-April (1); May-August (2); and September-December (3). Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray shading with bold font). The final model was log(CPUE) = YEAR.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	15507	12417.7	0.8008		-20281.7		
YEAR	**15500**	**12045.6**	**0.7771**	**2.95**	**-20045.8**	**471.74**	**0.00000**
SEASON1	15505	12217.5	0.7880	1.60	-20155.7	252.08	0.00000

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	15500	12045.6	0.7771		-20045.8		
SEASON1	15498	11954.7	0.7714	0.74	-19987.0	117.59	0.00000

Table 6. The relative nominal CPUE, proportion successful trips, relative abundance index, and confidence intervals and coefficients of variance associated with the relative abundance index for red snapper caught in the commercial handline fishery by vessels with class 1 permits fishing during red snapper open fishing seasons in the western Gulf of Mexico.

YEAR	Relative Nominal CPUE	Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1996	1.390	1906	1.395	1.335	1.458	0.022
1997	1.102	2096	1.179	1.130	1.231	0.021
1998	1.043	2174	1.017	0.974	1.061	0.021
1999	0.887	2022	0.896	0.857	0.937	0.022
2000	0.899	1842	0.951	0.908	0.996	0.023
2001	0.927	1879	0.893	0.853	0.936	0.023
2002	0.956	1847	0.873	0.833	0.914	0.023
2003	0.796	1742	0.796	0.758	0.835	0.024

Table 7. A summary of formulation of the lognormal model including data limited to vessels with class 1 licenses fishing during the red snapper open season in the Gulf of Mexico. The calendar year was divided into three periods: SEASON1=January-April (1); May-August (2); and September-December (3). Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray shading with bold font). The final model was log(CPUE) = YEAR+SUBREGION.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18076	15508.2	0.8579		-24264.8		
YEAR	18069	15106.3	0.8360	2.55	-24027.5	474.71	0.00000
SEASON1	18074	15249.2	0.8437	1.66	-24112.6	304.46	0.00000
SUBREGION	18074	15271.3	0.8449	1.52	-24125.6	278.37	0.00000

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18069	15106.3	0.8360		-24027.5		
SUBREGION	18067	14945.7	0.8272	1.05	-23930.9	193.15	0.00000
SEASON1	18067	14979.9	0.8291	0.83	-23951.5	151.86	0.00000

The explanatory factors in the base model are: YEAR SUBREGION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18067	14945.7	0.8272		-23930.9		
SEASON1	18065	14835.0	0.8212	0.73	-23863.7	134.49	0.00000

The explanatory factors in the base model are: YEAR SUBREGION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18067	14945.7	0.8272		-23930.9		
YEAR * SUBREGION	18056	14843.9	0.8221	0.62	-23869.1	123.55	<0.0001

Table 8. The relative nominal CPUE, proportion successful trips, relative abundance index, and confidence intervals and coefficients of variance associated with the relative abundance index for red snapper caught in the commercial handline fishery by vessels with class 1 permits fishing during red snapper open fishing seasons in the Gulf of Mexico.

YEAR	Relative Nominal CPUE	Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1996	1.359	2076	1.343	1.285	1.403	0.022
1997	1.090	2210	1.148	1.099	1.199	0.022
1998	1.031	2338	1.005	0.963	1.049	0.021
1999	0.875	2329	0.898	0.860	0.938	0.022
2000	0.936	2188	0.977	0.935	1.021	0.022
2001	0.963	2317	0.929	0.889	0.970	0.022
2002	0.974	2387	0.909	0.871	0.949	0.021
2003	0.771	2232	0.792	0.757	0.828	0.022

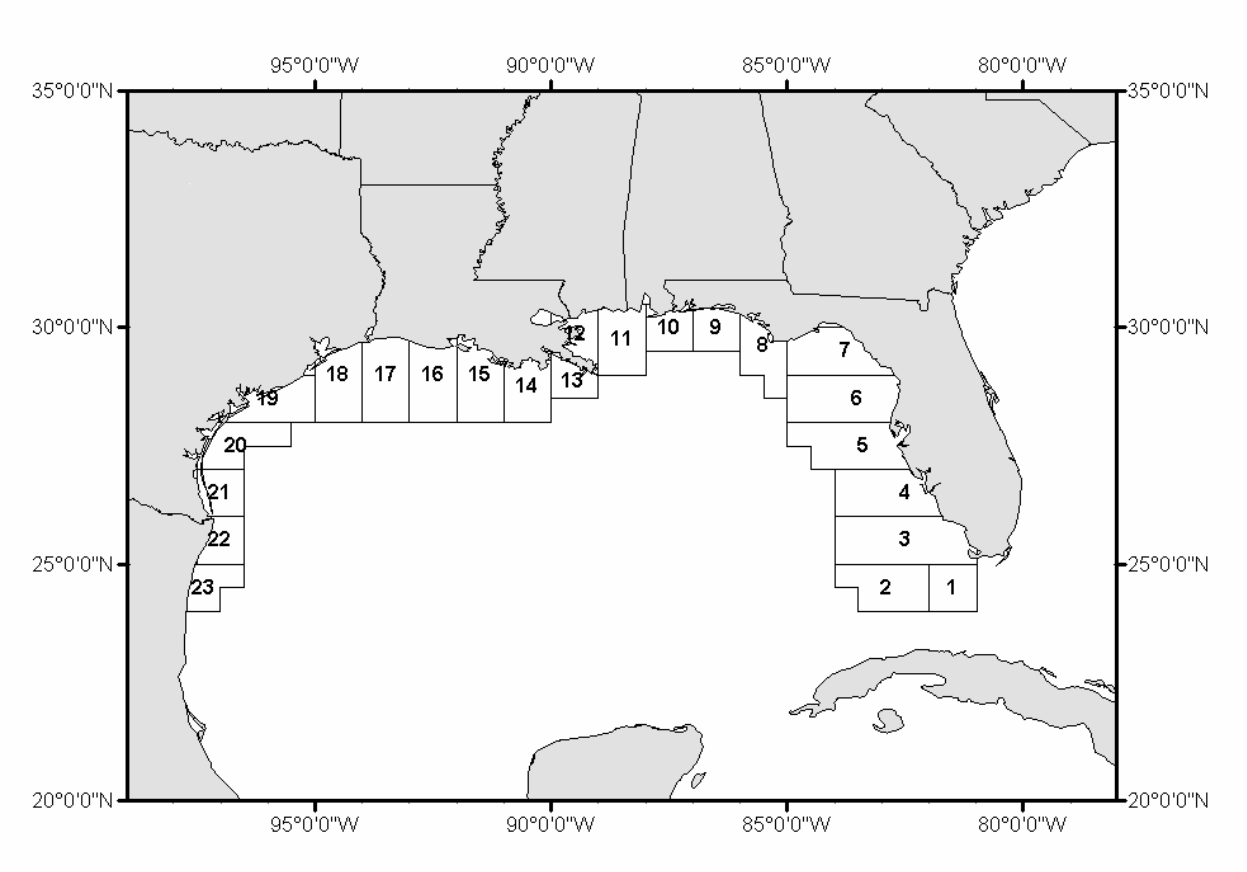

Figure 1. Map of the Gulf of Mexico Commercial Logbook defined fishing areas.

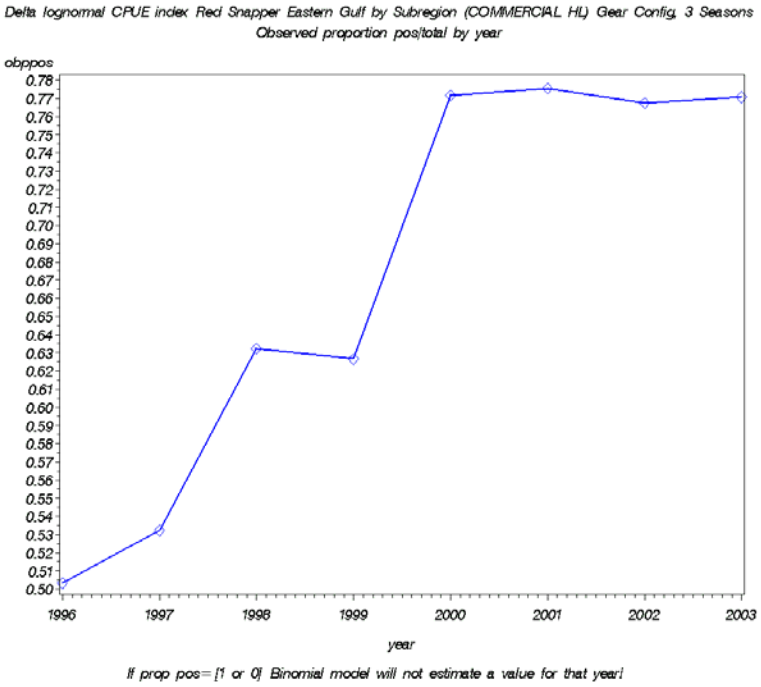

Figure 2. The proportion of successful trips by year for vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico.

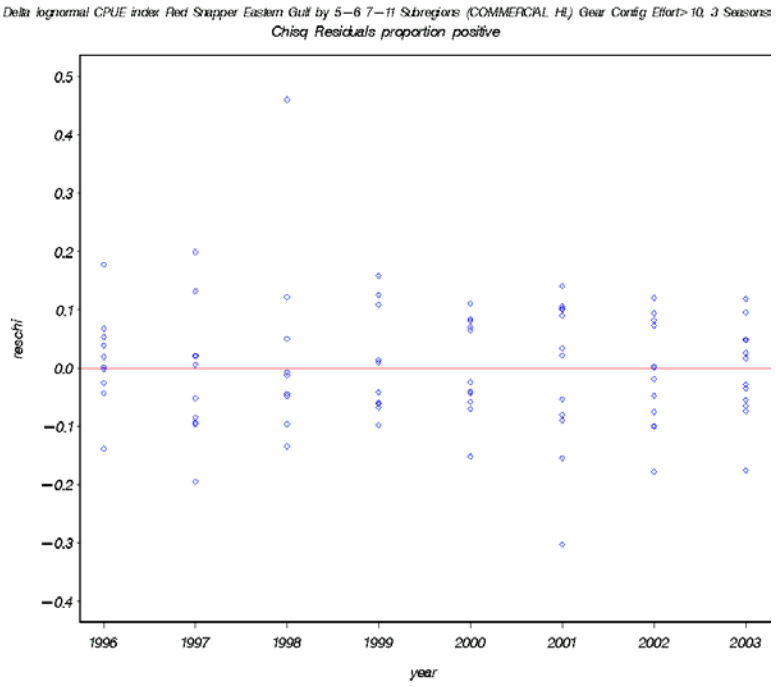

Figure 3. Chi-square residuals for delta lognormal model on proportion successful trips, by year for vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico.

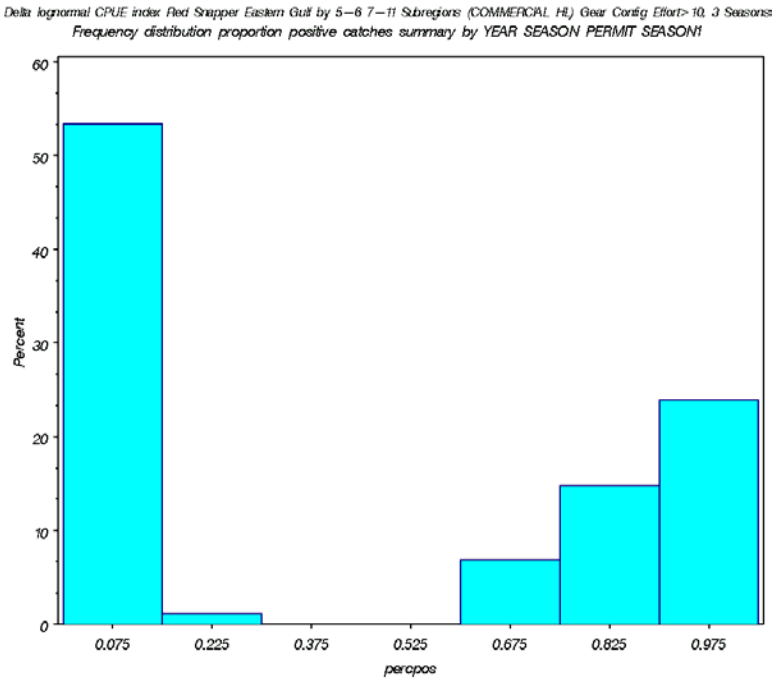

Figure 4. Frequency distribution of proportion successful catches by year for vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico.

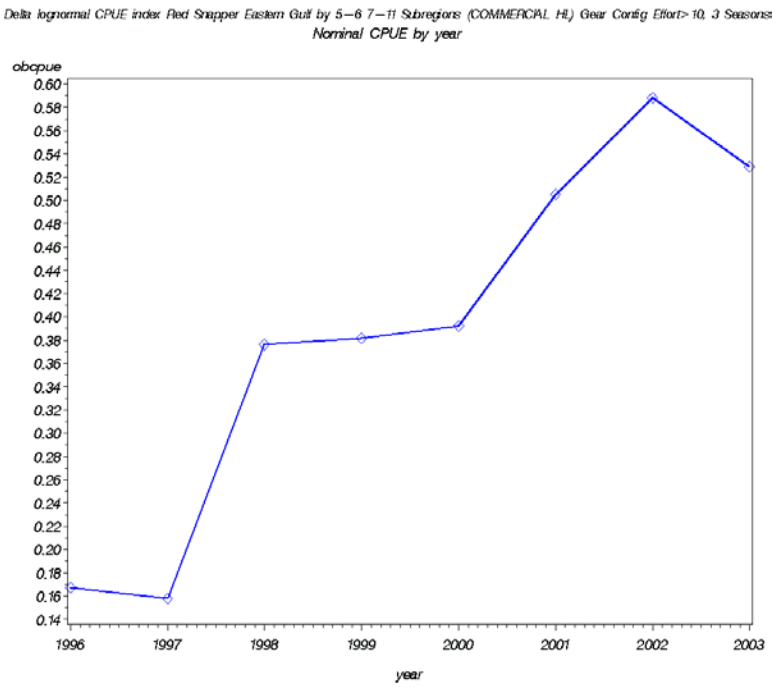

Figure 5. Annual variations in nominal CPUE for trips by vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico.

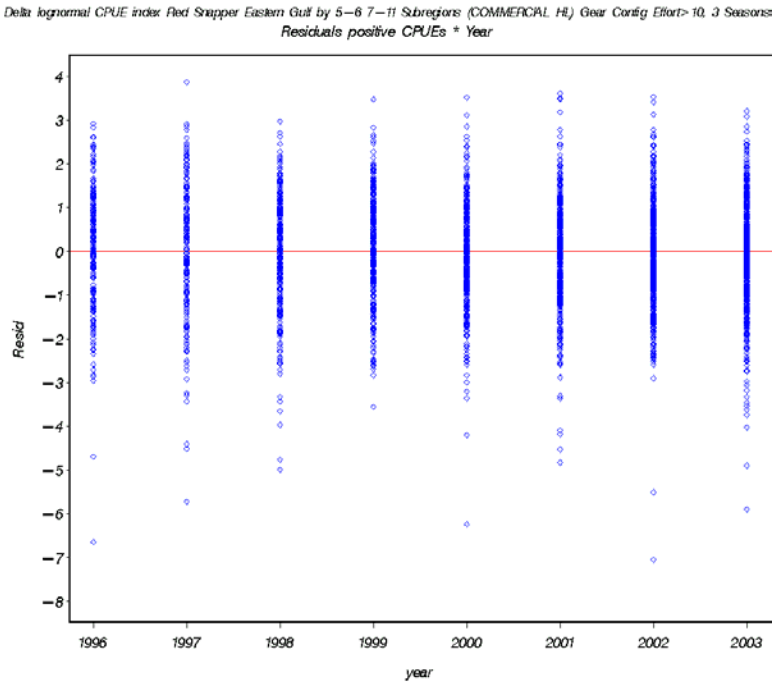

Figure 6. Residuals for the lognormal model on successful catch rates for vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico.

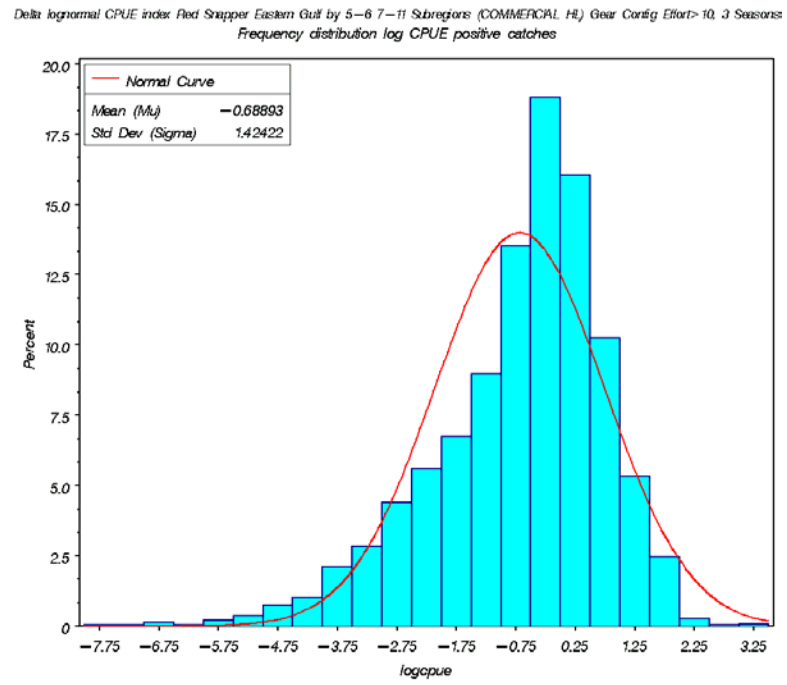

Figure 7. Frequency distribution of ln(CPUE) by year for vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico. The solid line is the expected normal distribution.

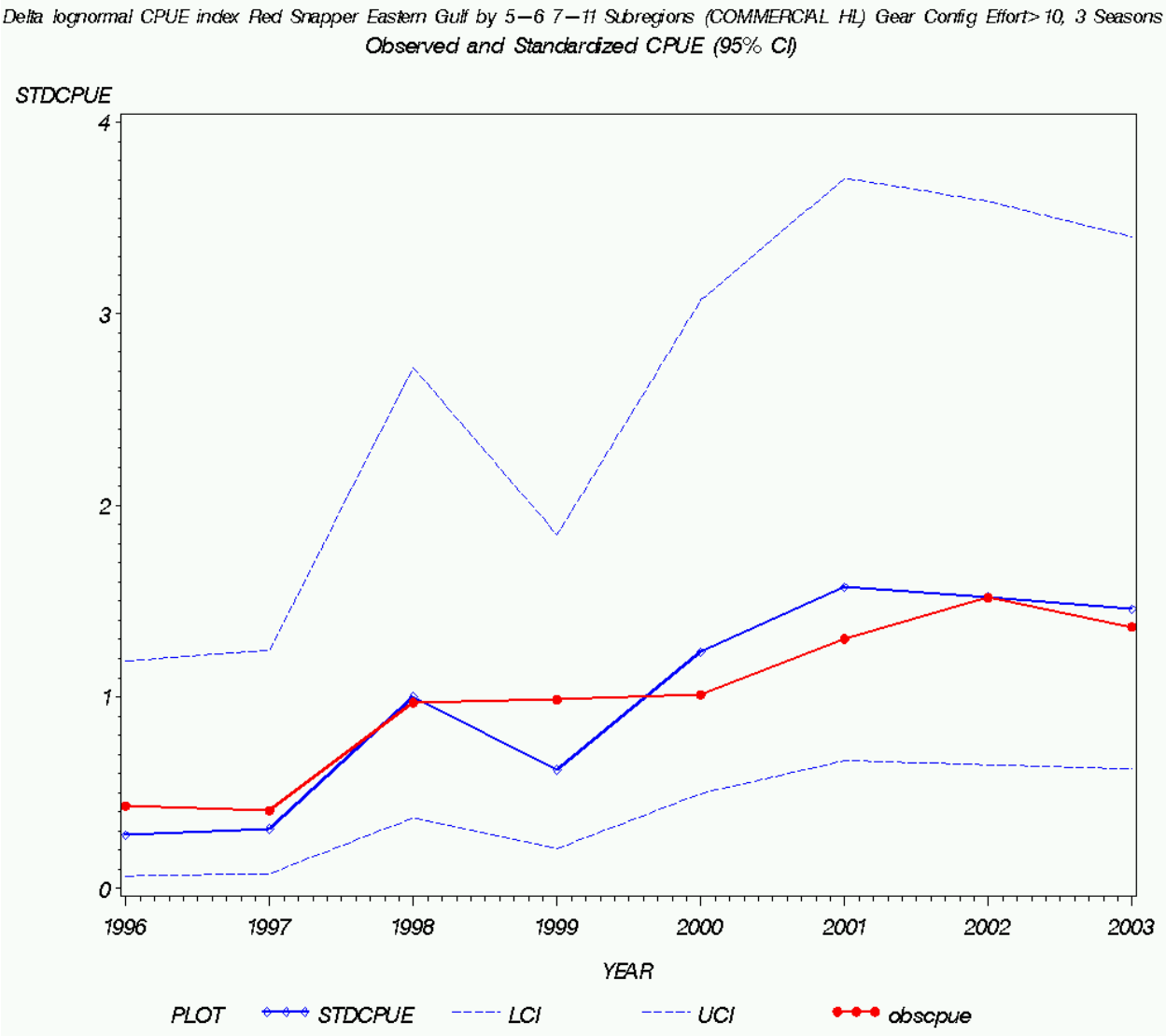

Figure 8. Nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted) for vessels fishing with 10 or more hooks/handline in the eastern Gulf of Mexico.

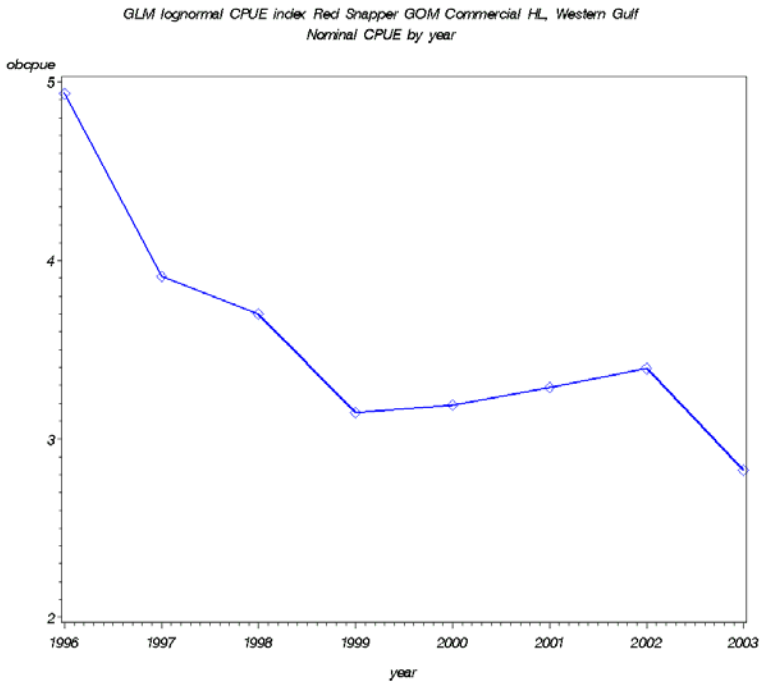

Figure 9. Annual variations in nominal CPUE for trips by class 1 permitted vessels during open red snapper season in the western Gulf of Mexico.

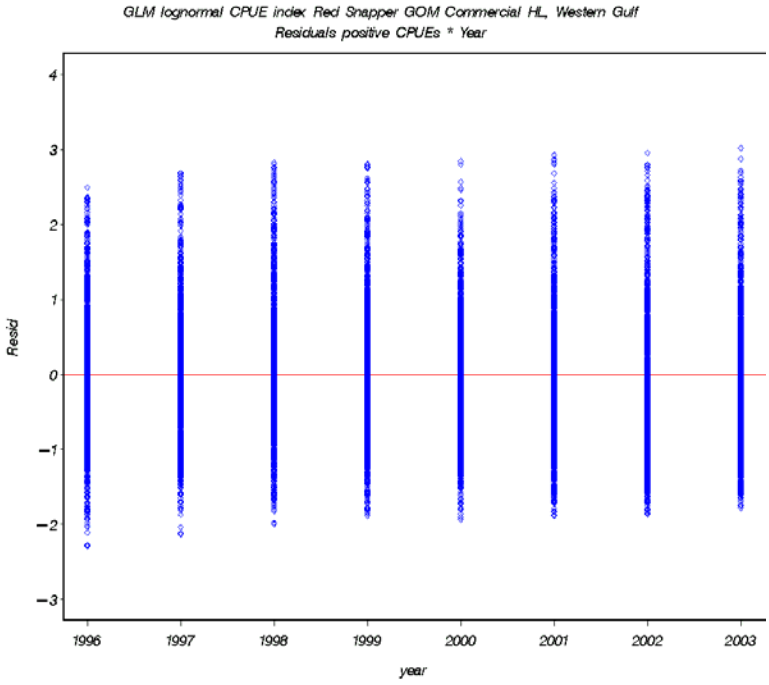

Figure 10. Residuals for the lognormal model on successful catch rates for class 1 permitted vessels during open red snapper season in the western Gulf of Mexico.

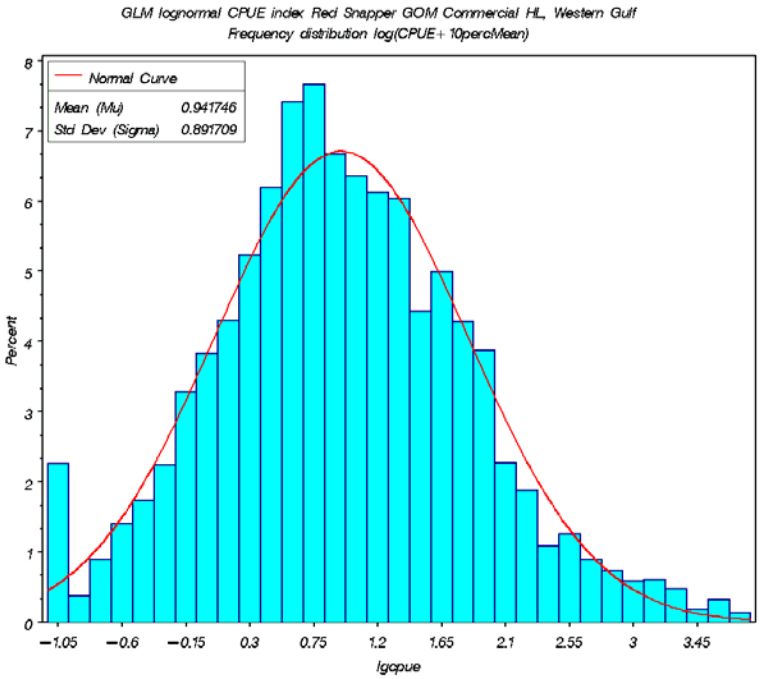

Figure 11. Frequency distribution of ln(CPUE) by year and region for class 1 permitted vessels during open red snapper season in the western Gulf of Mexico. The solid line is the expected normal distribution.

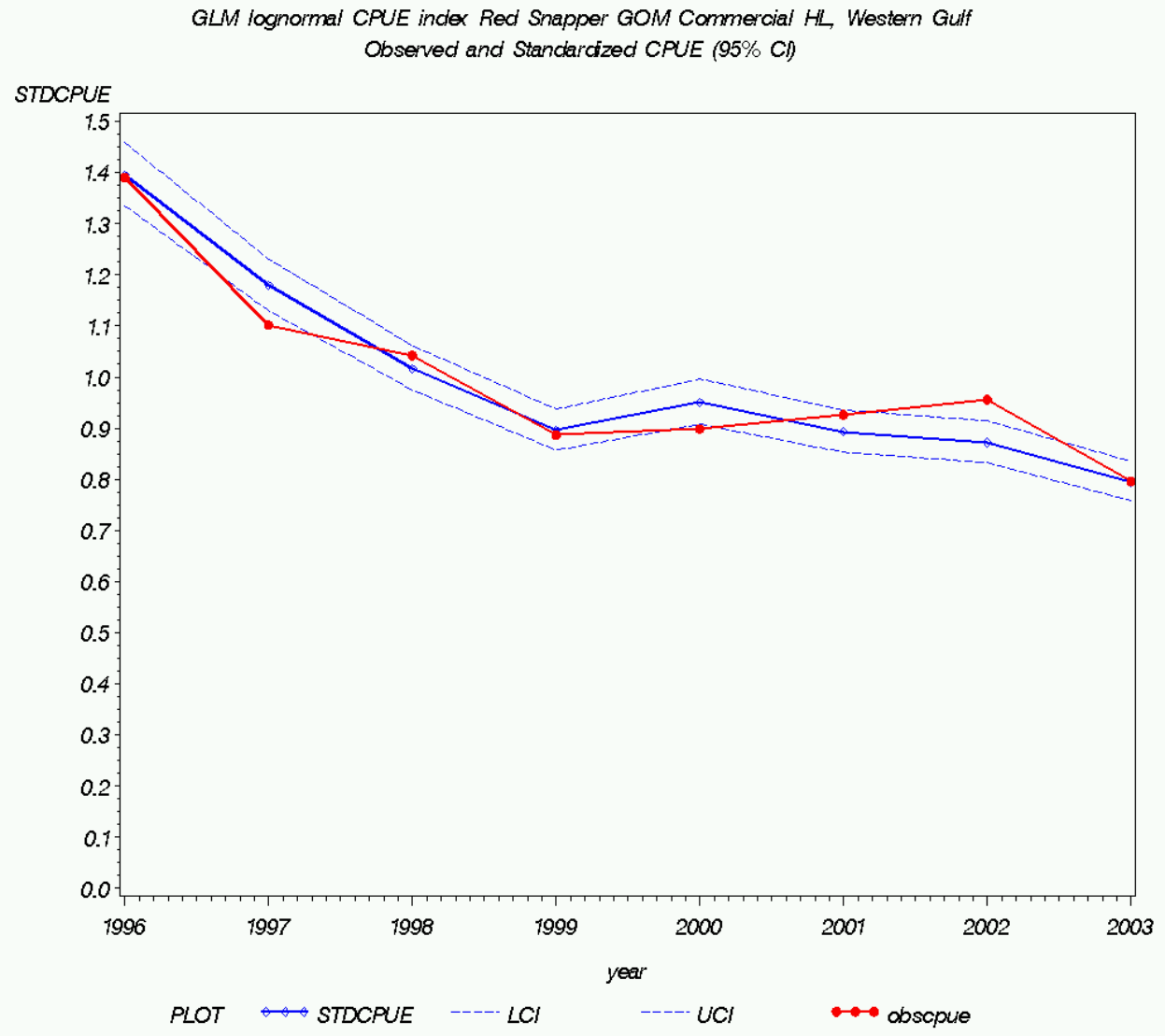

Figure 12. Nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted) for class 1 vessels during open red snapper season in the western Gulf of Mexico.

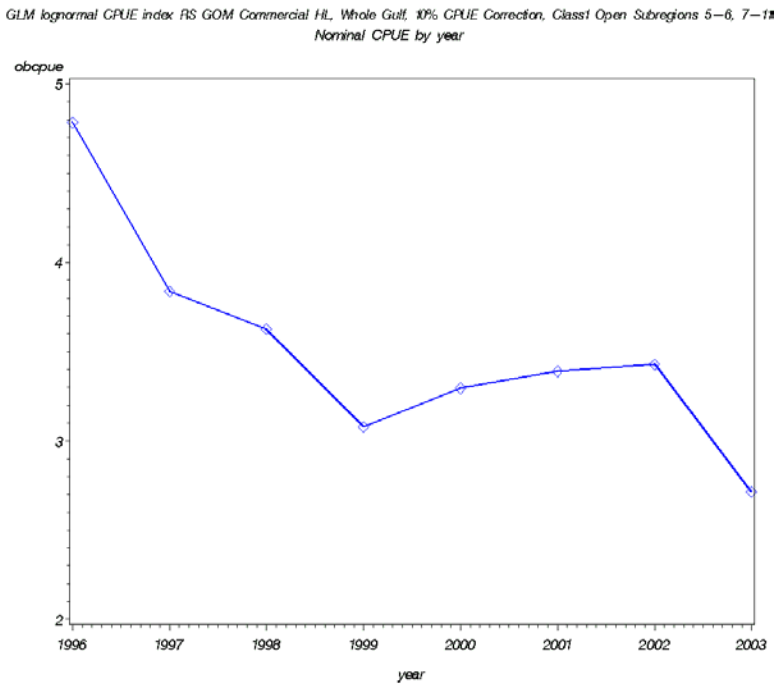

Figure 13. Annual variations in nominal CPUE for trips by class 1 permitted vessels during open red snapper season in the Gulf of Mexico.

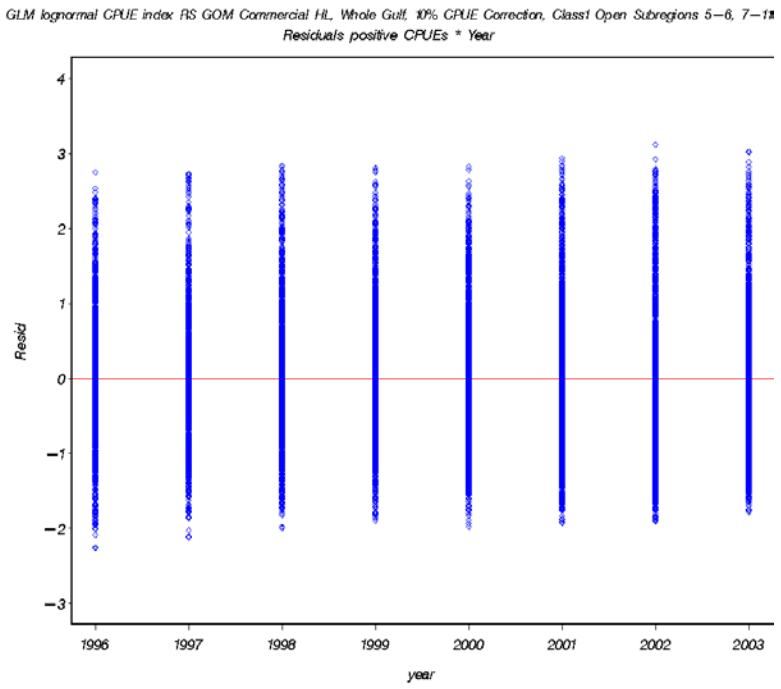

Figure 14. Residuals for the lognormal model on successful catch rates for class 1 permitted vessels during open red snapper season in the Gulf of Mexico.

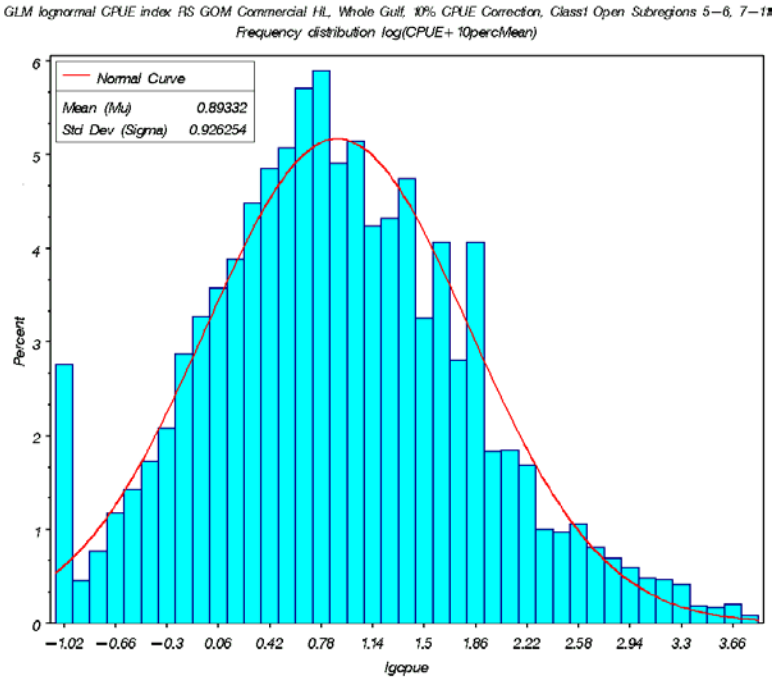

Figure 15. Frequency distribution of ln(CPUE) by year and region for class 1 permitted vessels during open red snapper season in the Gulf of Mexico. The solid line is the expected normal distribution.

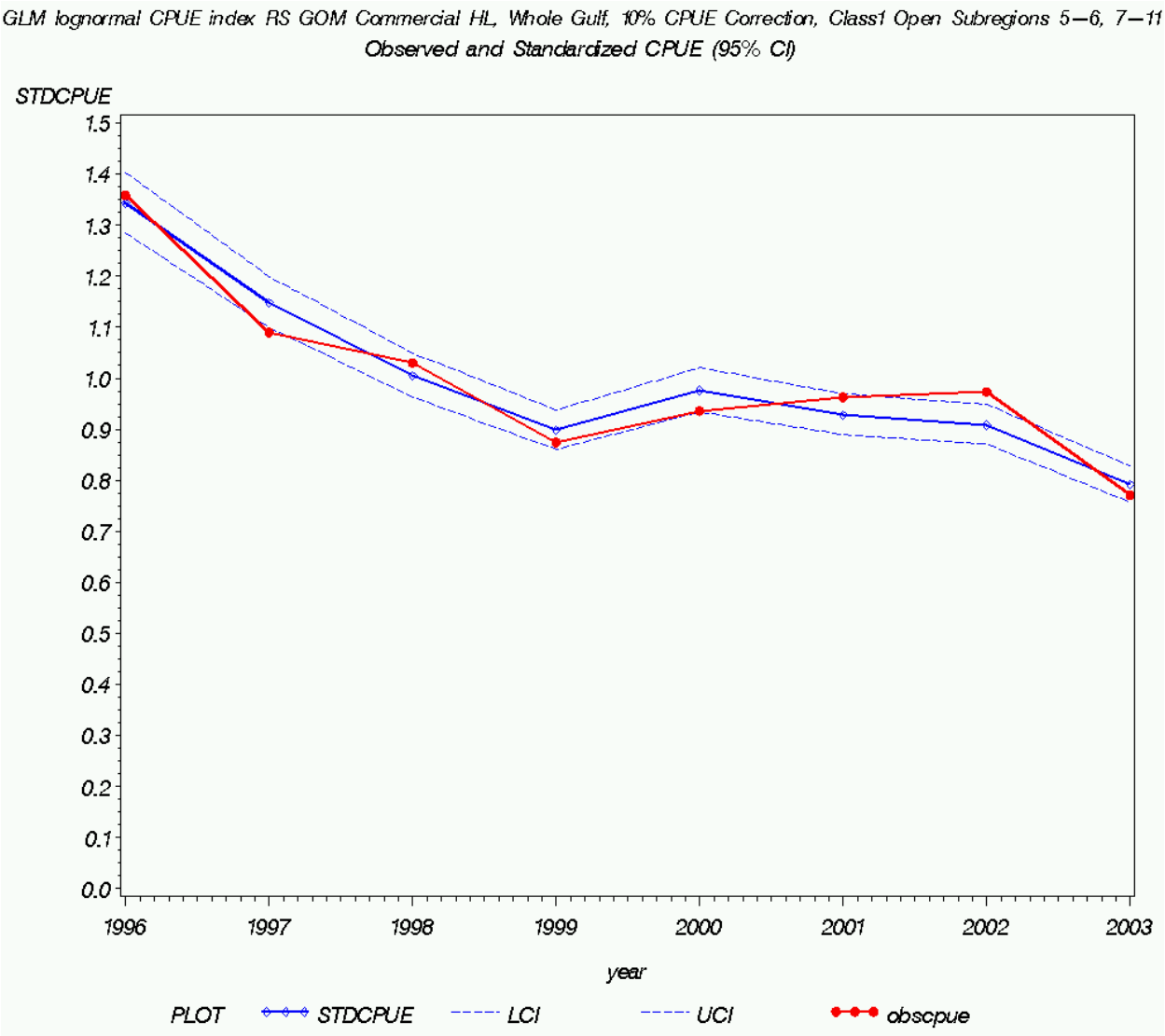

Figure 16. Nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted) for class 1 vessels during open red snapper season in the Gulf of Mexico.