SEAMAP Reef Fish Survey of Offshore Banks:
Yearly Indices of Abundance for red grouper (*Epinephelus morio*)

Christopher T. Gledhill[1], G. Walter Ingram, Jr. [1], Kevin R. Rademacher[1],
Paul Felts[1], Brandi Trigg[1], and Linda Lombardi-Carlson[2]
NOAA Fisheries, Southeast Fisheries Science Center
[1]Mississippi Laboratories, Pascagoula, MS
[2]Panama City Laboratory, Panama City, FL

INTRODUCTION

The objective of the annual Southeast Area Monitoring and Assessment Program (SEAMAP) offshore reef fish survey is to provide an index of the relative abundances of fish species associated with topographic features (banks, ledges) located on the continental shelf of the Gulf of Mexico (Gulf) in the area from Brownsville, TX to the Dry Tortugas, FL (Figure 1). The total reef area surveyed is approximately 1771 km²; 1244 km² in the eastern and 527 km² in the western Gulf. The offshore reef fish survey was initiated in 1992, with sampling conducted during the months of May to August from 1992-1997, and in 2001-2005. No surveys were conduced from 1998 to 2000 and in 2003. The 2001 survey was abbreviated due to ship scheduling.

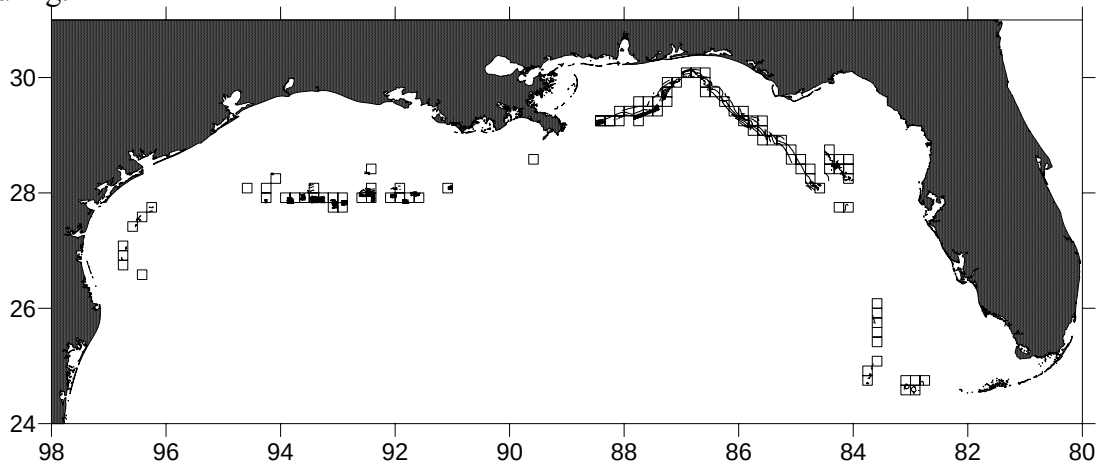

Figure 1. Gulf of Mexico shelf-edge banks sampled during SEAMAP offshore reef fish survey with sample blocks.

SAMPLE DESIGN

The survey area is large. Therefore, a two-stage sampling design is used to minimize travel times between sample stations. The first-stage or primary sampling units (PSUs) are blocks 10 minutes of latitude by 10 minutes of longitude (Figures 2 and 3). The first-stage units are selected by stratified random sampling. The blocks were stratified, with strata defined by geographic region (4 regions: South Florida, Northeast Gulf, Louisiana-Texas Shelf, and SouthTexas), and by reef habitat area (Blocks ≤ 20 km² reef, Block > 20 km² reef). There are a total of 7 strata. The ultimate sample sites (second stage units) within a block are selected randomly. However, stratum 1 (South Florida, small blocks) and stratum 7 (S. Texas, small blocks) were not consistently sampled. So, these were dropped from annual indices.

GEAR

The SEAMAP reef fish survey currently employs four Sony VX2000 DCR digital camcorders mounted in Gates PD150M underwater housings. The housings are rated to a maximum depth of 150 meters. The four Sony VX2000 camcorders are mounted orthogonally and a height of 30 cm above the bottom of the pod. A chevron (or arrow) fish trap with 1.5-inch vinyl-clad mesh is used to capture fish for biological samples. In its greatest dimensions, the trap is 1.76 m in length, 1.52 m in width and 0.61 m in depth. A 0.4 m by 0.29 m blow out panel is placed on one side and kept closed using 7-day magnesium releases. The magnesium releases are examined after each soak and replaced as needed. The trap is deployed at a randomly selected subset of video stations. Both the camera pod and fish trap are baited with squid.

VIDEO TAPE VIEWING PROCEDURES

One video tape from each station is selected out of the four for viewing. If all four video cameras face reef fish habitat and are in focus, the viewed tape is selected randomly. Tape viewers examine 20 minutes of the selected video tape, identify, and enumerate all species for the duration of the tape. Identifications are made to the lowest taxonomic level and the time when each fish enters and leaves the field of view is recorded. This is referred as a time in - time out procedure (TITO).

Tapes are viewed from the time when the view clears from any silt plume raised by the gear when it landed. Less than 20 minutes may be viewed if the duration when water is not clear enough to count fish is less than 20 minutes, or if the camera array is dragged. If a tape contains a large amount of fish, it is sub-sampled. There are four cases for sub-sampling: 1) when there is generally a large number of fish of a given species present throughout the tape so that following individual fish is difficult; 2) large number of fish occur in pulses periodically during the tape; 3) a single school of fish; and, 4) multiple schools of fish. Three estimators of relative abundance are available from the video data: 1) presence and absence; 2) maximum count (each fish of each taxon is counted each time it appears on the screen); and, 3) a minimum count (i.e., mincount: the greatest number of a taxon that appears on screen at one time). Presence and absence (frequency of occurrence) and mincount estimators are advantageous because they avoid the potential of multiple counting of fish, and are reported here.

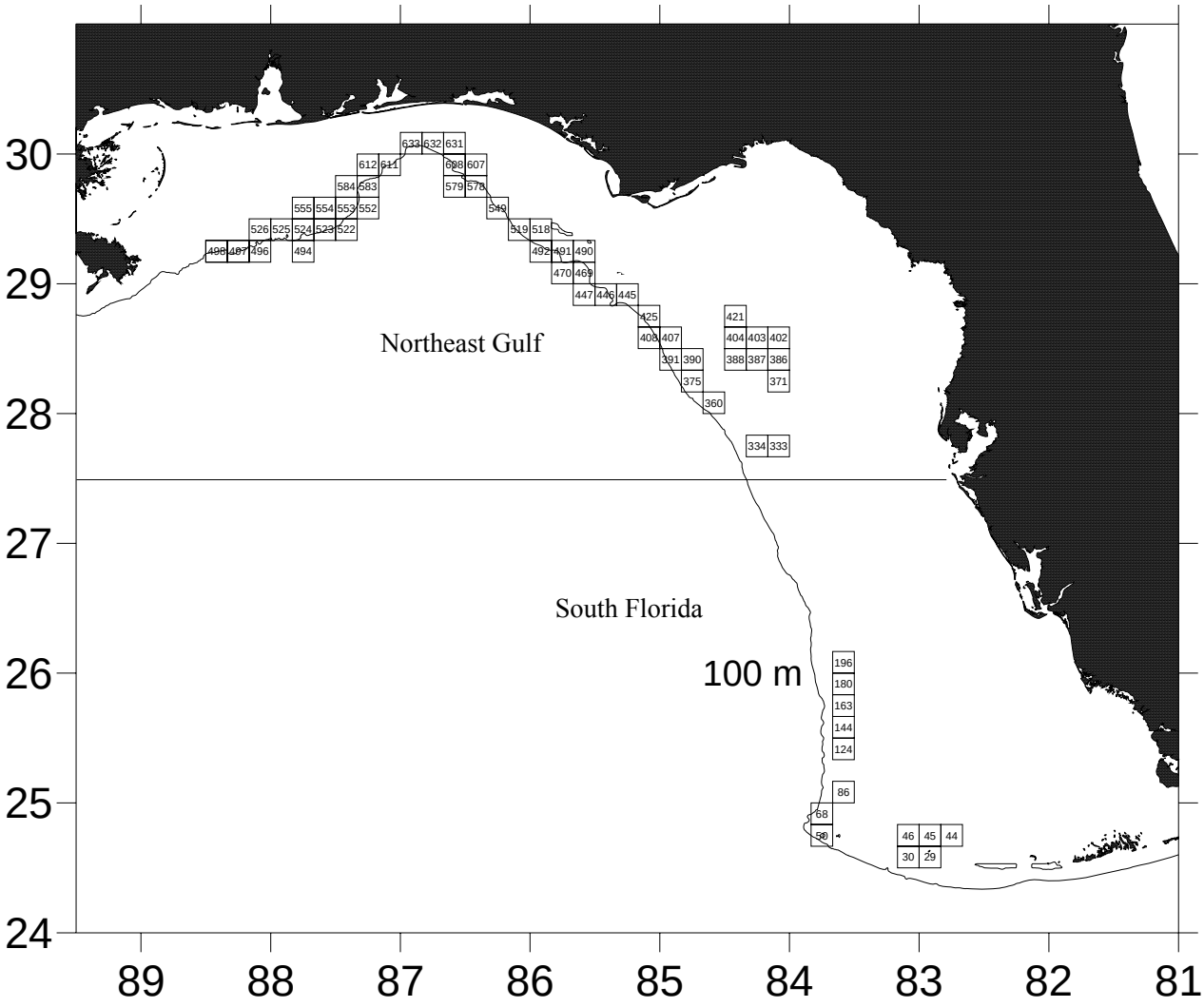

Figure 2. SEAMAP offshore reef fish survey sample blocks in the eastern Gulf of Mexico.

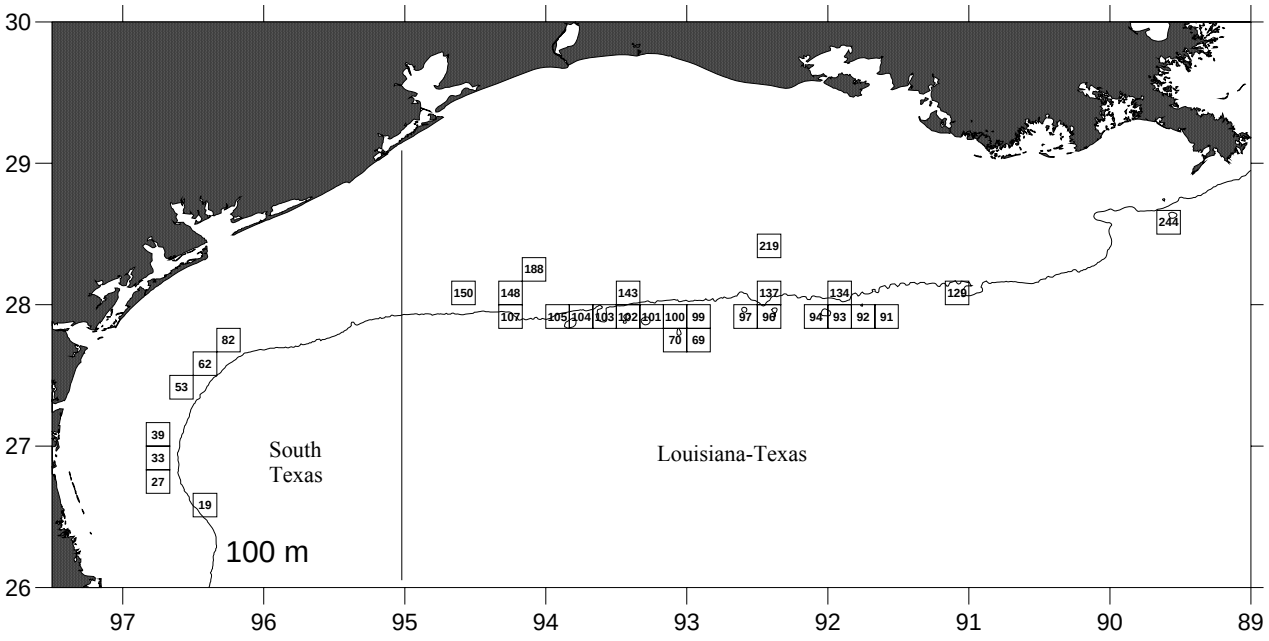

Figure 3. SEAMAP offshore reef fish survey sample blocks in western Gulf of Mexico.

STATISTICS

Design-based Estimator

The design-based estimators of abundance are those for stratified, two-stage sampling (Cochran, 1977). The number of strata and number of blocks sampled in the eastern and western Gulf of Mexico during SEAMAP reef fish survey are shown in Table 1.

1. Block means

$\bar{x}_{hi} = \frac{\sum_{j=1}^{m_{hi}} x_{hij}}{m_{hi}}$, where x_{hij} is the number of fish observed at the j-th site in the i-th block within the h-th stratum, and m_{hi} in the number of sites sampled in the i-th block and h-th stratum.

2. Stratum means

$\bar{x}_h = \frac{\sum_{j=1}^{n_h} \bar{x}_{hi}}{n_h}$, where $\bar{x}_{hi}$ is the i-th block mean in the h-th stratum and n_h is the number of blocks sampled in the h-th stratum.

3. Stratified mean

$\bar{x}_{st} = \sum_h w_h \bar{x}_h$, where w_h is the stratum weight estimated as the area of the stratum divided by the total survey area (A_h/A).

4. Variance of the stratified mean ($V(\bar{x}_{st})$), ignoring finite population correction

$V_{\bar{x}_{st}} = \sum_h w_h^2 \left[\frac{s_{1h}^2}{n_h} + \frac{s_{2h}^2}{n_h m_h} \right]$, where w_h is the stratum weight, s^2_{1h} and s^2_{2h} are the variances among the first-stage and second-stage units, n_h and m_h are the number of first stage and second-stage units sampled.

5. Variance among first-stage units, s^2_{1h}

$$s_{1h}^2 = \frac{\sum_h \left(\bar{x}_{hi} - \bar{x}_h\right)^2}{n_h - 1}.$$

6. Variance among second-stage units, s^2_{2h}

$$s_{2h}^2 = \frac{\sum_i \sum_j \left(x_{hij} - \bar{x}_{hi}\right)^2}{n_h\left(m_{hi} - 1\right)}.$$

The estimates for the frequency of occurrence of each species were calculated using the same equations where x_{hij} was either 0 or 1. The final estimate is a stratified mean proportion.

Model-based Index

In addition to the calculations of stratified means, a delta-lognormal modeling approach (Lo *et al*., 1992) was employed in order to develop standardized indices of annual average mincount for red grouper in the U.S. Gulf of Mexico. This index is a mathematical combination of yearly mincount estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive mincounts (i.e., presence/absence) and lognormal model which describes variability in only the nonzero mincount data. The GLMMIX and MIXED procedures in SAS were employed to provide yearly index values for both the binomial and lognormal sub-models, respectively. A backward stepwise selection procedure was employed to develop both sub-models. Type 3 analyses were used to test each parameter for inclusion or exclusion into the sub-model. Both variable inclusion and exclusion significance level was set at an $\alpha = 0.05$. The parameters tested for inclusion in each sub-model were region, year, stratum, and block nested within stratum, station depth (scaled to a mean of one). All variables were considered fixed except for block nested within station, which was considered random. Also, the estimates from each model were weighted using the stratum area, and separate covariance structures were developed for each survey year. For the binomial sub-models, a logistic-type mixed model was employed. The fit of each model was evaluated using the fit statistics provided by the GLMMIX macro. Initially, several sub-model types were used to describe the nonzero mincount data. These included lognormal, Poisson and negative binomial. Based on analyses of residual scatter and QQ plots, the lognormal sub-model was more fitting than the others in describing the variability in the nonzero data.

Fish Sizes

The size of red grouper observed during the SEAMAP survey comes from fish measured on video tape using laser reference points and from fish captured in the trap. Lasers were first introduced in 1995. We developed length frequency histograms for red grouper measured by laser on video and captured in the trap. Also, all trap captured fish were aged by examining

sectioned otoliths, and an age frequency histograms was developed. These length and age data were used to identify the size and age ranges of red grouper that this survey has sampled.

RESULTS

Design-based Results and Conclusions

Abundance data from five strata were included for analysis during all years except 2001. Stratum 1 was sampled only in 1994, 1996, 1997, 2004, and 2005. This stratum was 62.847 km² in area. Stratum 7 was sampled only in 1996, 1997, 2002, 2004, and 2005, and was 13.030 km² in area. Since these strata were not sampled during all years of the survey, they were excluded from design-based and model-based estimates of annual mean mincount. However, when included for those years, the stratified means and variances changed very little since their stratum weights were small. The 2001 survey was abbreviated. Only one stratum was sampled in the eastern Gulf of Mexico. We recommend that the 2001 estimates of abundance for the eastern Gulf of Mexico not be used for estimating trends in fish abundance. However, the two strata in the western Gulf of Mexico were sampled, and provide a real estimate of zero catch. Table 2 summarizes the design-based results.

Model-based Results and Conclusions

Due to the extremely low occurrence of red grouper in the West Gulf (Table 2), only one model was developed: a model for red grouper in the East Gulf. Based on the conclusions in the previous paragraph, we reason that 2001 data should be dropped from analyses due to its low sample size compared to those of all other years. Also, due to issues of model convergence and index calculation, we dropped 1992 data, and began the model-based analyses with 1993 data. Tables 3 – 5 summarize the model-building process by which the index was developed for red grouper from the East Gulf. Table 3 summarizes the results of Type 3 analyses for those variables retained in the binomial sub-model. Table 4 summarizes the results of Type 3 analyses for those variables retained in the lognormal sub-model. Table 5 and Figure 4 summarize the index values for red grouper from the East Gulf. There is an increasing trend over the time series, with the highest index value in the 2005 survey year. Due to the advantages of the model-based approach to standardize annual abundance indices based on the variables described herein, we recommend the use of the model-based indices (Table 5).

Red Grouper Size Results

There were 217 red grouper hit by lasers during SEAMAP surveys (Figure 5). The mean fork length (±SE) of red grouper hit by lasers was 470 (±6) mm. Figure 6 shows the length frequency histogram of red grouper captured by the survey trap (N = 61), and the mean fork length (±SE) was 469 (±9) mm. Figure 7 shows the age frequency histogram of the trap-captured red grouper (N = 59), and the mean age (±SE) was 5.24 (±0.155) years. Only one red grouper less than 300 mm fork length was observed either by lasers or by trap. Therefore, we reason that the indices developed herein should be applied to red grouper that are greater than 300 mm fork length or age 3+.

LITERATURE CITED

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Lo, N. C. H., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-1526.

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Table 1. The number of strata and number of blocks sampled in the eastern and western Gulf of Mexico during SEAMAP reef fish survey.

	Eastern Gulf of Mexico		Western Gulf of Mexico	
Year	Number of Strata	Number of Blocks	Number of Strata	Number of Blocks
1992	3	12	2	11
1993	3	18	2	9
1994	3	14	2	9
1995	3	13	2	10
1996	3	21	2	11
1997	3	20	2	17
2001	1	5	2	9
2002	3	19	2	14
2004	3	18	2	10
2005	3	27	2	16

Table 2. Red grouper stratified mean counts ($\overline{x}_{st}$) by region (2001 not included in east gulf since only a single stratum was sampled; n=number of blocks, CV= $\overline{x}_{st}$ /se_{st}).

	East Gulf				West Gulf			
	n	$\overline{x}_{st}$	se_{st}	CV	n	$\overline{x}_{st}$	se_{st}	CV
1992	12	0.00000	0.00000		11	0.00000	0.00000	
1993	18	0.32266	0.26651	0.82598	9	0.00000	0.00000	
1994	14	0.24113	0.18482	0.76656	9	0.00000	0.00000	
1995	13	0.41958	0.26544	0.63263	10	0.00000	0.00000	
1996	21	0.27735	0.22722	0.81925	11	0.00000	0.00000	
1997	20	0.42355	0.22034	0.52022	17	0.00599	0.01988	3.31637
2001	-	-	-		9	0.00000	0.00000	
2002	19	0.42284	0.26701	0.63147	14	0.00000	0.00000	
2004	18	0.56660	0.31655	0.55868	10	0.00000	0.00000	
2005	27	0.46477	0.29064	0.62534	16	0.00000	0.00000	

Table 3. Solution for random effects and results of Type 3 analyses for those variables retained in the binomial sub-model for occurrence of red grouper in the East Gulf.

Solution for Random Effects

Effect	*Stratum*	*Estimate*	*Std Err Pred*	*DF*	*t Value*	*Pr > |t|*
Block number nested within stratum	2	0.003024	0.005300	14	0.57	0.5773
Block number nested within stratum	3	-0.00901	0.001807	409	-4.99	<.0001
Block number nested within stratum	4	-0.00544	0.001247	740	-4.36	<.0001

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
Year	7	453	63.21	8.95	<.0001	<.0001
Stratum	2	361	66.09	33.03	<.0001	<.0001
Station Depth	1	1018	97.57	97.57	<.0001	<.0001

Table 4. Results of Type 3 analyses for those variables retained in the lognormal sub-model.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	386	3.87	0.0004

Table 5. Index values for red grouper from the East Gulf. Frequency is the nominal frequency of occurrence, N is the number of video stations, Index is the abundance index in mincount units, Relative Index is that same index scaled to a mean of one, CV is the coefficient of variation on the mean, and LCL and UCL are lower and upper 95% confidence limits for the Relative Index.

Survey Year	*Frequency*	*N*	*Index*	*Relative Index*	*CV*	*LCL*	*UCL*
1993	0.27500	120	0.76058	0.88787	0.18421	0.61614	1.27943
1994	0.35526	76	0.73303	0.85570	0.15312	0.63109	1.16025
1995	0.22078	154	0.55516	0.64807	0.21472	0.42385	0.99089
1996	0.27007	137	0.78798	0.91985	0.16018	0.66907	1.26463
1997	0.39865	148	0.80911	0.94452	0.12614	0.73465	1.21434
2002	0.32353	170	0.95631	1.11635	0.10120	0.91227	1.36607
2004	0.42759	145	1.10605	1.29115	0.08654	1.08631	1.53463
2005	0.35223	247	1.14488	1.33648	0.07097	1.15984	1.54002

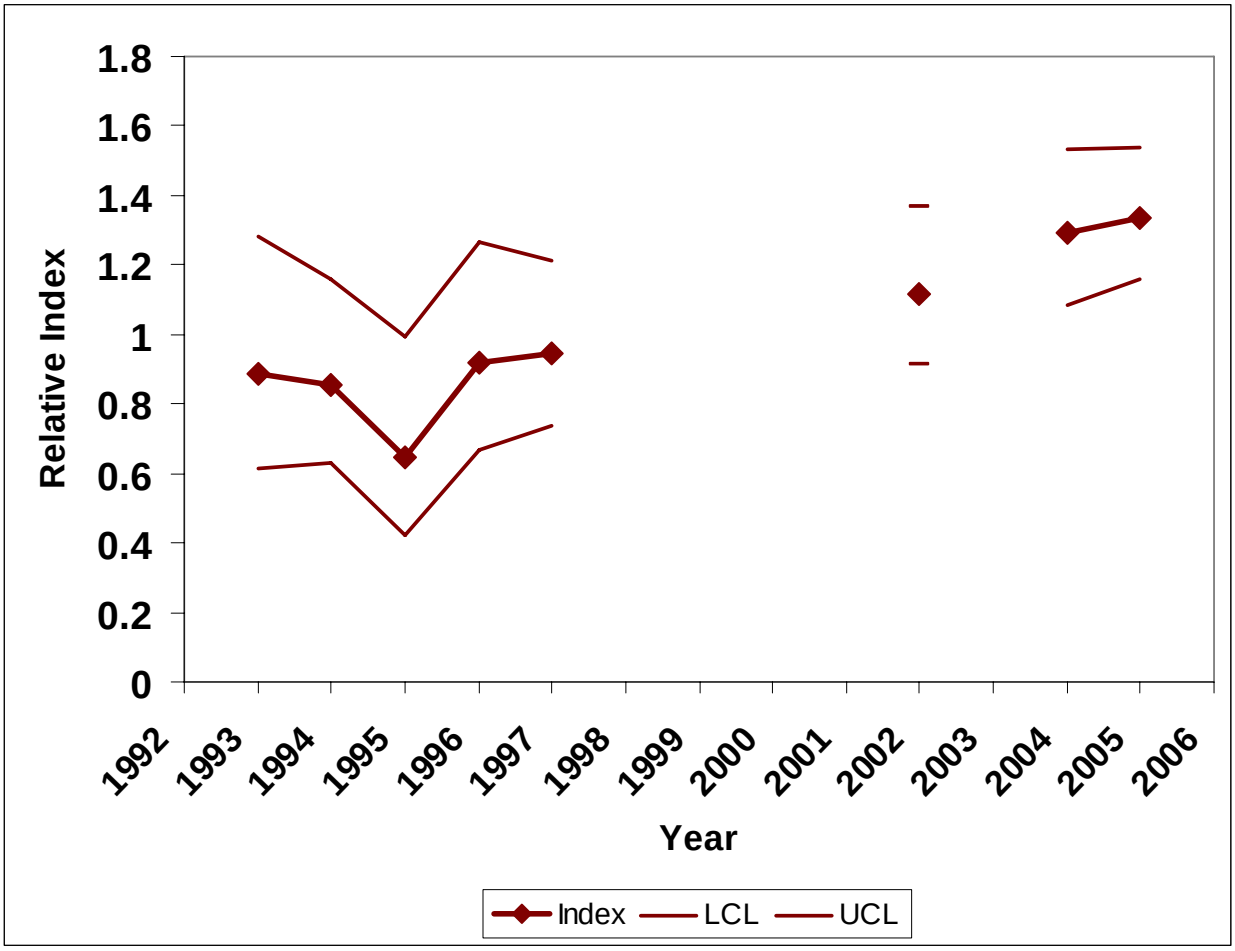
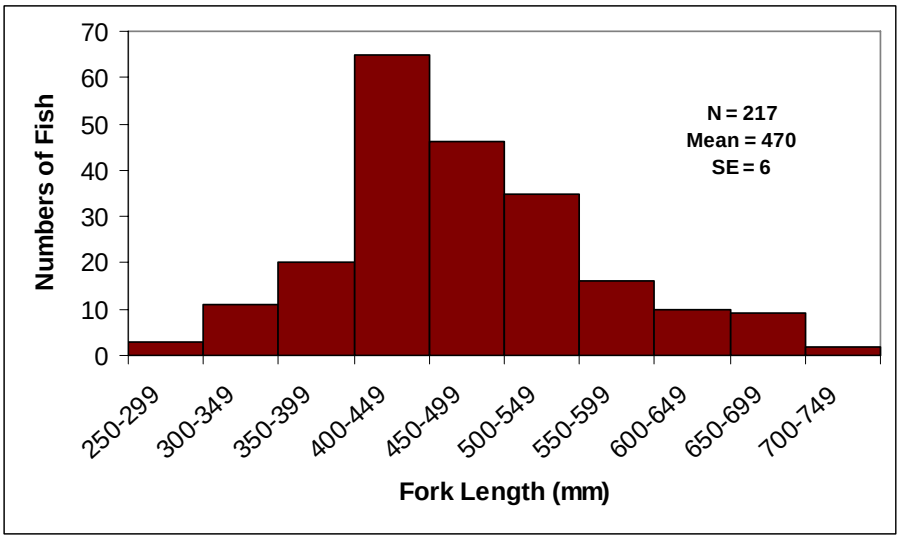
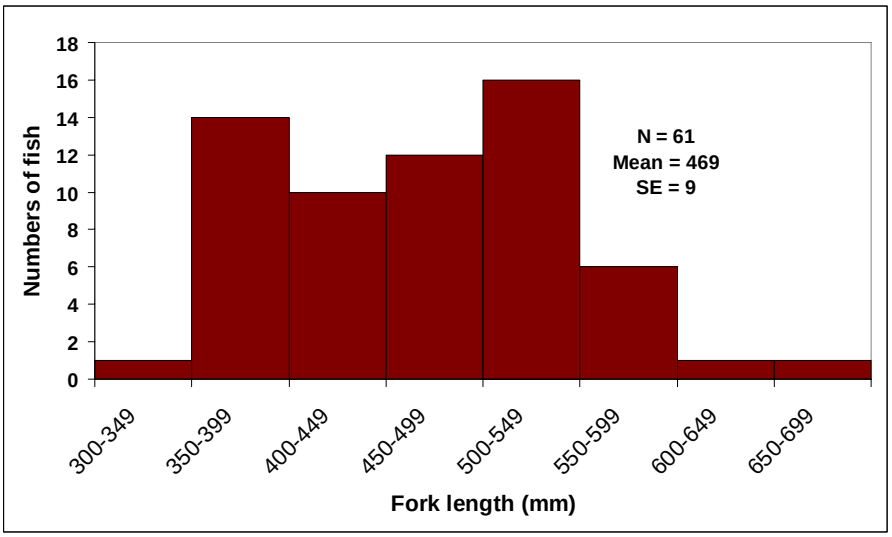


Figure 4. East Gulf red grouper index values with corresponding lower and upper 95% confidence limits.



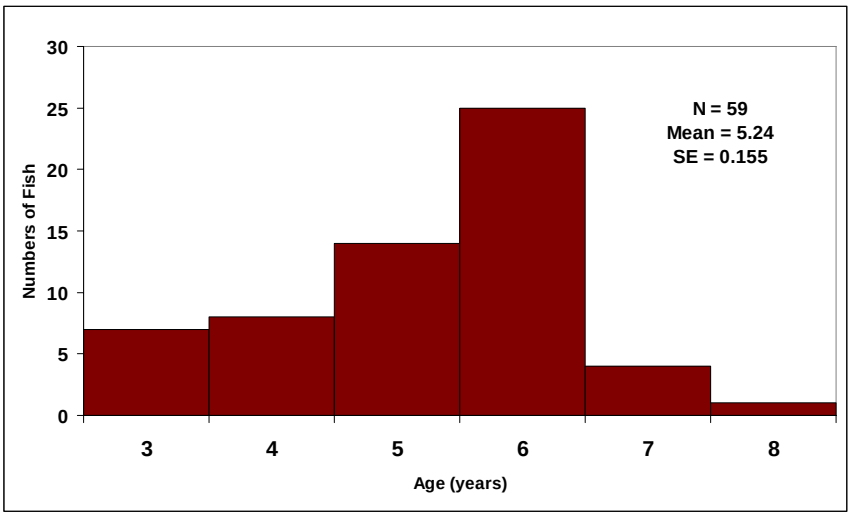
Year	N	Mean	Minimum	Maximum	Standard Error
1996	2	449.50	402	497	47.50
1997	3	477.67	467	489	6.36
2002	16	427.56	344	579	15.58
2004	131	475.44	267	718	8.10
2005	65	468.89	284	654	10.32

Figure 5. Length frequency histogram for red grouper measured from video tapes using laser reference points during SEAMAP surveys from 1996 - 2005 (N = 217). The table contains a summary of mean fork length (mm) statistics by year.



Year	N	Mean	Minimum	Maximum	Standard Error
1994	6	498	392	585	28
1995	19	463	364	610	16
2001	3	425	338	507	49
2002	13	434	369	514	14
2004	2	530	391	669	139
2005	18	493	374	586	14

Figure 6. Length frequency histogram for red grouper collected in traps during SEAMAP surveys (N = 61). The table contains a summary of mean fork length (mm) statistics by year.



Year	N	Mean	Minimum	Maximum	Standard Error
1994	6	4.00	3	5	0.26
1995	17	5.59	4	7	0.17
2001	3	5.00	4	6	0.58
2002	13	4.69	3	7	0.47
2004	2	4.50	4	5	0.50
2005	18	5.83	4	8	0.20

Figure 7. Age frequency histogram for red grouper collected in traps during SEAMAP surveys (N = 59). The table contains a summary of mean age (years) statistics by year.