SEAMAP Reef Fish Video Survey: Relative Indices of Abundance of Red Grouper

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SEAMAP Reef Fish Video Survey:
Relative Indices of Abundance of Red Grouper
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Matthew D. Campbell, Kevin R. Rademacher, Michael Hendon, Paul Felts,
Brandi Noble, Michael Felts, Joseph Salisbury, and John Moser
Southeast Fisheries Science Center
Mississippi Laboratories, Pascagoula, MS

Introduction

The primary objective of the annual Southeast Area Monitoring and Assessment Program (SEAMAP) reef fish video survey is to provide an index of the relative abundances of fish species associated with topographic features (e.g reefs, banks, and ledges) located on the continental shelf of the Gulf of Mexico (GOM) from Brownsville, TX to the Dry Tortugas, FL (Figures 1, and 8-23). Secondary objectives include quantification of habitat types sampled (video and side-scan), and collection of environmental data throughout the survey. Because the survey is conducted on topographic features the species assemblages targeted are typically classified as reef fish (e.g. red snapper, *Lutjanus campechanus*), but occasionally fish more commonly associated with pelagic environments are observed (e.g. Amberjack, *Seriola dumerili*). The survey has been executed from 1992-1997, 2001-2002, and 2004-present and historically takes place from May – April, however in limited years the survey was conducted through the end of July. The 2001 survey was abbreviated due to ship scheduling, during which, the only sites that were completed were located in the western Gulf of Mexico. Types of data collected on the survey include diversity, abundance (minimum count), fish length, habitat type, habitat coverage, bottom topography and water quality. The size of fish sampled with the video gear is species specific however red grouper sampled over the history of the survey had fork lengths ranging from 190 – 971 mm, and mean annual fork lengths ranging from 471 – 516 mm. Age and reproductive data cannot be collected with the camera gear but beginning with the 2012 survey, a vertical line component will be coupled with the video drops to collect hard parts, fin clips, and gonads and will be included in the life history information provided by the NMFS Panama City Laboratory.

Methods

Sampling design

Total reef area available to select survey sites from is approximately 1771 km^2, of which 1244 km^2 is located in the eastern GOM and 527 km^2 in the western GOM. The large size of the survey area necessitates a two-stage sampling design to minimize travel times between stations. The first-stage uses stratified random sampling to select blocks that are 10 minutes of latitude by 10 minutes of longitude in dimension (Figure 1). The block strata were defined by geographic region (4 regions: South Florida, Northeast Gulf, Louisiana-Texas Shelf, and South Texas), and by total reef habitat area contained in the block (blocks ≤ 20 km^2 reef, block > 20 km^2 reef). There are a total of 7 strata. A 0.1 by 0.1 mile grid is then overlaid onto the reef area contained within a given block and the ultimate sampling sites (second stage units) are randomly selected from that grid.

Gear and deployment

The SEAMAP reef fish survey has employed several camcorders in underwater housings since 1992. Sony VX2000 DCR digital camcorders mounted in Gates PD150M underwater housings were used from 2002 to 2005 and Sony PD170 camcorders during the years 2006 and 2007. In 2008 a stereo video camera system was developed and assembled at the NMFS Mississippi Laboratories Stennis Space Center Facility and has been used in all subsequent surveys. The stereo video unit consists of a digital stereo still camera head, digital video camera, CPU, and hard drive mounted housed in an aluminum casing. All of the camcorder housings are rated to a maximum depth of 150 meters while the stereo camera housings are rated to 600 meters. Stereo cameras are mounted orthogonally at a height of 50 cm above the bottom of the pod and the array is baited with squid during deployment.

At each sampling site the stereo video unit is deployed for 40 minutes total, however the cameras and CPU delay filming for 5 minutes to allow for descent to the bottom, and settling of suspended sediment following impact. Once turned on, the cameras film for approximately 30 minutes before shutting off and retrieval of the array. During camera deployment the vessel drifts away from the site and a CTD cast is executed, collecting water depth, temperature, conductivity, and transmissivity from the surface to the maximum depth. Seabird units are the standard onboard NOAA vessels however the model employed was vessel/cruise dependent.

Video tape viewing

One video tape from each station is randomly selected for viewing out of all viewable videos. Videos that have issues with visibility, obstructions or camera malfunction cannot be randomly selected and are not viewed. Selected videos are viewed for twenty minutes starting from the time when the view clears from suspended sediment. Viewers identify, and enumerate all species to the lowest taxonomic level during the 20 minute viewable segment. From 1993-2007 the time when each fish entered and left the field of view was recorded a procedure referred to as time in - time out (TITO) and from these data a minimum count was calculated. The minimum count is the maximum number of individuals of a selected taxon in the field of view at one instance. Each 20 minute video is evaluated to determine the highest minimum count observed during a 20 minute recording. From 2008-present the digital video allows the viewer to record a frame number or time stamp of the image when the maximum number of individuals of a species occurred, along with the number of taxon identified in the image, but does not use the TITO method. Both the TITO and current viewing procedure result in the minimum count estimation of abundance (i.e. - mincount). Minimum count methodology is preferred because it prevents counting the same fish multiple times (e.g. if a fish were swimming in circles around the camera).

Fish length measurement

Beginning in 1995 fish lengths were measured from video using lasers attached on the camera system with known geometry. However, the frequency of hitting targets with the laser is low and precluded estimating size frequency distributions. Additionally, the same fish can be measured more than once at a given station. So, the lengths measured provide the range of sizes observed. The stereo cameras used in 2008-present allow size estimation from fish images. The Vision Measurement System (Geometrics Inc.) was used to estimate size of fish. Fish measurement is only performed at the point in the video corresponding to the mincount.

Data reduction

Various limitations either in design, implementation, or performance of gear causes limitations in calculating mincount and are therefore dropped from the design-based indices development and analysis as follows. In 1992, each fish was counted every time it came into view over the entire record time and the total of all these counts was the maximum count. Maximum count methodologies are not preferred and the 1992 video tapes were destroyed during Hurricane Katrina and cannot be re-viewed, so 1992 data is excluded from analyses (unknown number of stations). From 1998 – 2000 and in 2003 the survey was not conducted. The 2001 survey was abbreviated due to ship scheduling, during which, the only sites that were completed were located in the western GOM. Because of the spatial imbalance associated with data gathered in 2001, that entire year has been dropped (80 total sites). Occasionally tapes are unable to be read (i.e. organisms cannot be identified to species) for the following reasons including: 1) camera views are more than 50% obstructed, 2) sub-optimal lighting conditions, 3) increased backlighting, 4) increased turbidity, 5) cameras out of focus, 6) cameras failed to film. In all of these cases the station is flagged as 'XX' in the data set and dropped (190 total sites). Sites that did not receive a stratum assignment are also dropped (62) and all of those occurred early in the survey (1994-1995).

Delta lognormal indices

Delta-lognormal modeling methods were used to estimate relative abundance indices for red grouper (Lo *et al*. 1992). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data (Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) as described by Lo *et al*. (1992) was estimated as:

(2) $$I_y = c_y p_y,$$

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(3) $$\ln(c) = X\beta + \varepsilon$$

and

(4) $$p = \frac{e^{\mathbf{X\beta+\varepsilon}}}{1+e^{\mathbf{X\beta+\varepsilon}}},$$

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE(c_y) and SE(p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated as:

(5) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(6) $$\mathrm{Cov}(c, p) \approx \rho_{\mathrm{c,p}} [\mathrm{SE}(c_y)\mathrm{SE}(p_y)],$$

and $\rho_{c,p}$ denotes correlation of c and p among years.

A delta-lognormal modeling approach (Lo et al., 1992) was used to develop abundance indices. Independent variables tested in the model were year, region, stratum, block, depth, reef, silt/sand/clay, shell/gravel, sponge, algae, hard corals, soft corals, sea whips, average relief and maximum relief. Region is divided into east and west at 89.15 west longitude. Stratum is assigned based on region (east and west) and reef area contained in each 10 min lat/lon block. Depth is the maximum depth at the site in meters. Reef is a boolean variable denoting the presence or absence of rock or hard coral. Average relief is the average vertical elevation observed in a video, while the maximum relief is the maximum observed. All other habitat variables are approximate estimates of the percent cover in a video (silt/sand/clay, shell/gravel, sponge, algae, hard corals, soft corals, and sea whips) and conform to the coastal and marine ecological classification standard (CMECS). The GLIMMIX and MIXED procedures in SAS (v. 9.2) were used to develop the binomial and lognormal sub-models, respectively. A backward selection procedure was used to determine which variables retained from the GENMOD procedure were to be included into each final sub-model based on a type 3 analyses with a level of significance for inclusion of $\alpha = 0.01$. Year was including in all terminal models regardless of significance, while stratum and reef were retained in the binomial model while algae was retained in the lognormal sub-models. The estimates from each model were weighted using the stratum area, and separate covariance structures were developed for each survey year. For the binomial models, a logistic-type mixed model was employed.

Results

Red grouper were primarily observed in the eastern Gulf of Mexico and years prior to 2004 most of the distribution was located east of Cape San Blas, Florida (Figures 8-23). After 2004 the population appears to expand eastward to the Mobile Pinnacles region and in 2007, 2011, and 2012 red grouper were observed on various banks offshore of Louisiana. While the geographic range appears to have expanded through time the species was observed at very few reefs and at low abundances west of the Mississippi Delta in any given year. Because of the low frequency of occurrence west of the Mississippi Delta the index was limited spatially to the region east of 89.15 west Longitude. The spatial distributions observed are highly reflective of the reef sampling universe used to select sampling sites (Figure 1). Gaps in habitat level information exist on the central portion of the west Florida shelf, Mississippi river delta region, and portions of the Texas coast. In most years the survey shows good coverage in the defined sampling universe, and coverage improved through time as the sampling universe expanded and more sites were added to the survey. The most recent mapping and sampling efforts in south Texas and in the central portion of the west Florida shelf were accomplished in 2012-13 but were not available for incorporation into this index.

Design based analysis retained year in the binomial and lognormal models. Strata and reef were retained in the binomial model, and algae in the lognormal model. Stratum are defined first by region and then by the amount of reef contained in an area and are set a priori. Reef was a boolean value that was is determined by the presence of 5% coverage of either rock or hard coral coverage at a station. The variable algae represents the percent cover of algae observed on the video. Therefore the probability of observing red grouper is a function of the presence and coverage of reef in an area and the abundance appears to be positively associated with increased algae. Design based east-GOM red grouper proportion positives ranged from 0.17 (2007) to 0.41 (2004) (Table 1, Figure 5), and the standardized index of abundance ranged from 0.72 (2008) to 1.36 (2004) (Table 1, Figure 2). General trends show that since the last benchmark assessment conducted in 2005 the relative index would suggest that red grouper population size decreased from 2005-2008, followed by an increase through 2011, and small decreases in both 2012 and 2013. Since the survey has been conducted the relative index has been fluctuating within the same range of standardized mincount, showing no consistent trend in positive or negative directions. Residuals for the binomial submodel show no trend through time (Figure 4) and observed versus expected values are similar (Figure 5). Positive catch residuals appear to not fit a normal model well showing an 'S' type pattern in the QQ plot (Figure 7), suggesting that the lognormal model may not be optimal and perhaps other distributions should be considered for this type of count data. Annual mean fork lengths for east GOM red grouper have ranged from 191 to 971 mm (Figure 24). Mean length measured with lasers mounted on cameras was 471.82 (sd=88.28) and with stereo cameras was 516.99 (sd=119.52).

Literature cited

Cochran, W.G. 1977. Sampling Techniques. John Wiley & Sons. New York, NY. 428 p.

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.

M. Ortiz, C.M. Legault, N.M. Ehrhardt. 2000. An alternative method for estimating bycatch from the U.S. shrimp trawl fishery in the Gulf of Mexico, 1972–1995. Fish. Bull. 98:583–599.

Figure 1. Spatial distribution of known reef from which stations are randomly selected for sampling for the reef fish video survey. Over the history of the survey (1992-2013) new reef tract has been discovered and mapped and therefore this map represents what was available in 2013, and not necessarily what has been available over the entire time series.

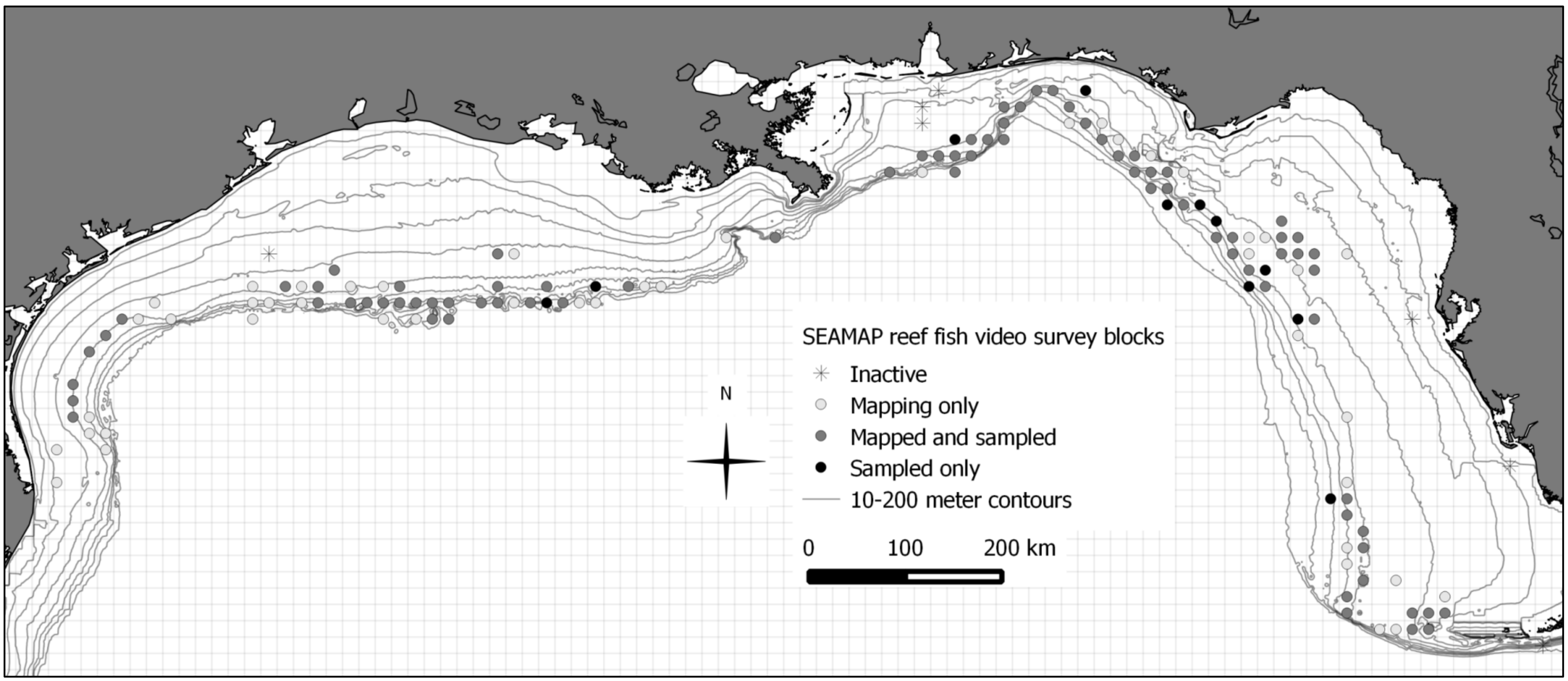

Table 1. Delta lognormal mincount for red grouper index output.

Year	Frequency	N	LoIndex	StdIndex	SE	CV	LCL	UCL
1993	0.25439	114	0.34315	0.77419	0.052935	0.15426	0.56970	1.05209
1994	0.33333	75	0.41528	0.93692	0.063590	0.15313	0.69099	1.27040
1995	0.35185	54	0.47355	1.06839	0.076546	0.16164	0.77488	1.47309
1996	0.30400	125	0.39021	0.88038	0.049376	0.12654	0.68422	1.13276
1997	0.38562	153	0.50333	1.13558	0.045883	0.09116	0.94668	1.36218
2002	0.36424	151	0.44964	1.01446	0.050798	0.11297	0.80988	1.27073
2004	0.41216	148	0.60281	1.36003	0.051940	0.08616	1.14510	1.61528
2005	0.36015	261	0.57048	1.28710	0.039899	0.06994	1.11927	1.48008
2006	0.30403	273	0.38456	0.86762	0.030508	0.07933	0.74051	1.01655
2007	0.17450	298	0.33405	0.75366	0.039534	0.11835	0.59530	0.95414
2008	0.23158	190	0.31967	0.72123	0.036439	0.11399	0.57463	0.90524
2009	0.27711	249	0.38500	0.86862	0.033850	0.08792	0.72880	1.03526
2010	0.31863	204	0.40480	0.91328	0.040261	0.09946	0.74890	1.11373
2011	0.33230	322	0.50365	1.13631	0.035875	0.07123	0.98561	1.31005
2012	0.30268	261	0.51283	1.15702	0.040640	0.07925	0.98768	1.35539
2013	0.28571	147	0.49873	1.12521	0.054828	0.10994	0.90371	1.40099

Figure 2. Observed and standardized mincount with 95% confidence intervals of the delta lognormal mincount.

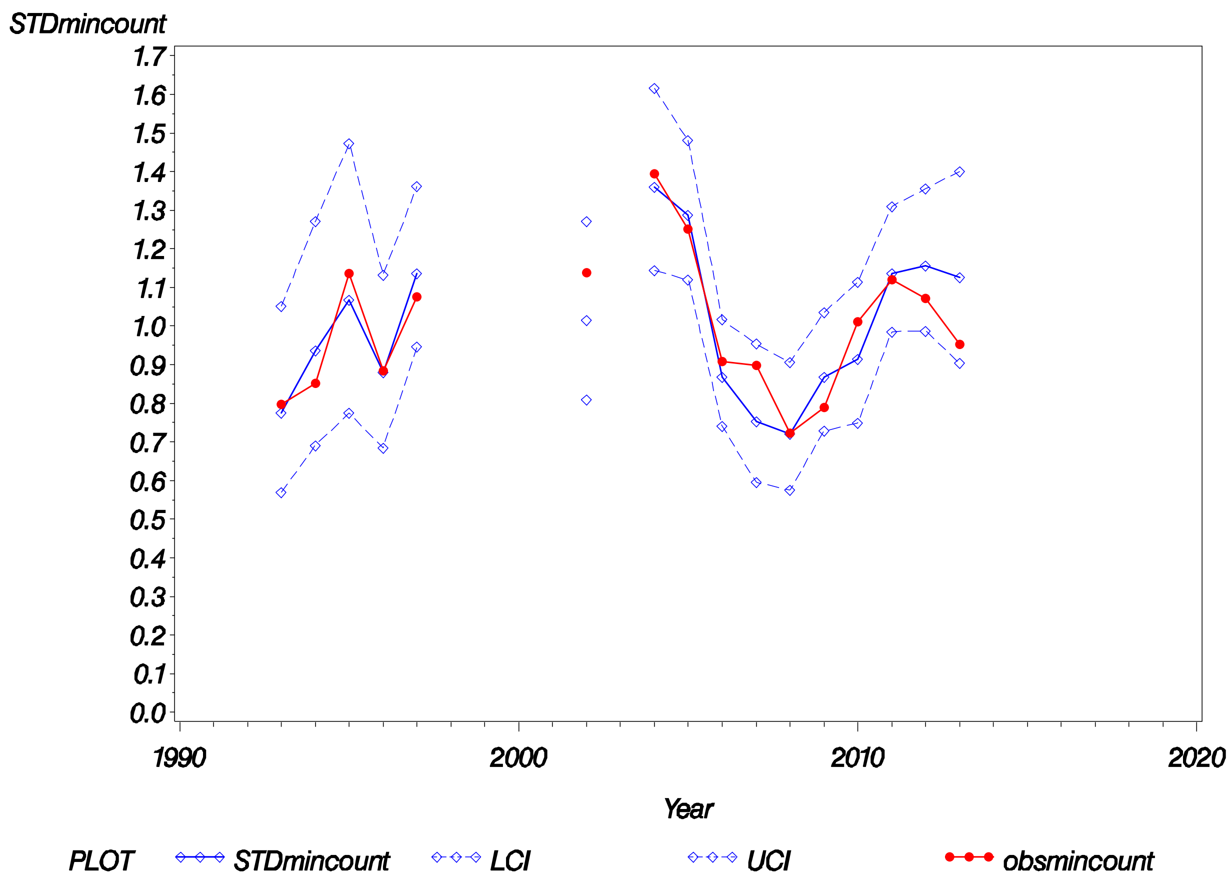

Table 2. Delta lognormal GLIMMIX output from the binomial sub-model information criteria.

Information Criteria						
Neg2LogLike	*Parms*	*AIC*	*AICC*	*HQIC*	*BIC*	*CAIC*
13948.9	16	13980.9	13981.1	14015.5	14077.1	14093.1

Table 3. Delta lognormal GLIMMIX output from the binomial sub-model, test of fixed effects.

Type 3 Tests of Fixed Effects						
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	15	858	56.49	3.73	<.0001	<.0001
stratum	2	2876	35.16	17.58	<.0001	<.0001
REEF	1	2912	242.83	242.83	<.0001	<.0001

Table 4. Delta lognormal GLIMMIX output from the binomial sub-model for deviance and dispersion statistics.

Description	*Value*
Deviance	1207.1445
Scaled Deviance	2984.9133
Pearson Chi-Square	1097.9589
Scaled Pearson Chi-Square	2714.9294
Extra-Dispersion Scale	0.4044

Figure 3. Distribution of percent positives from the binomial submodel.

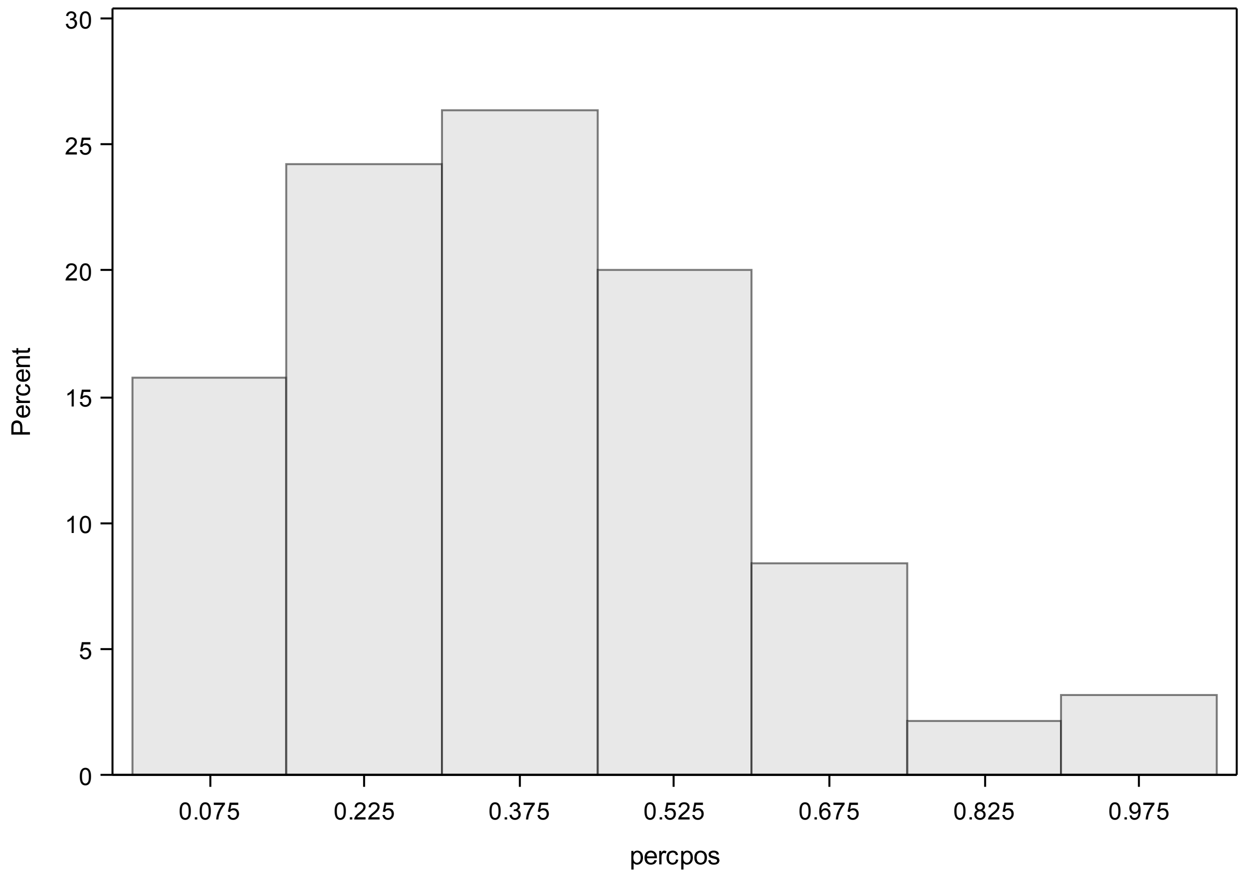

Figure 4. Distribution of chi-square residuals from the binomial submodel.

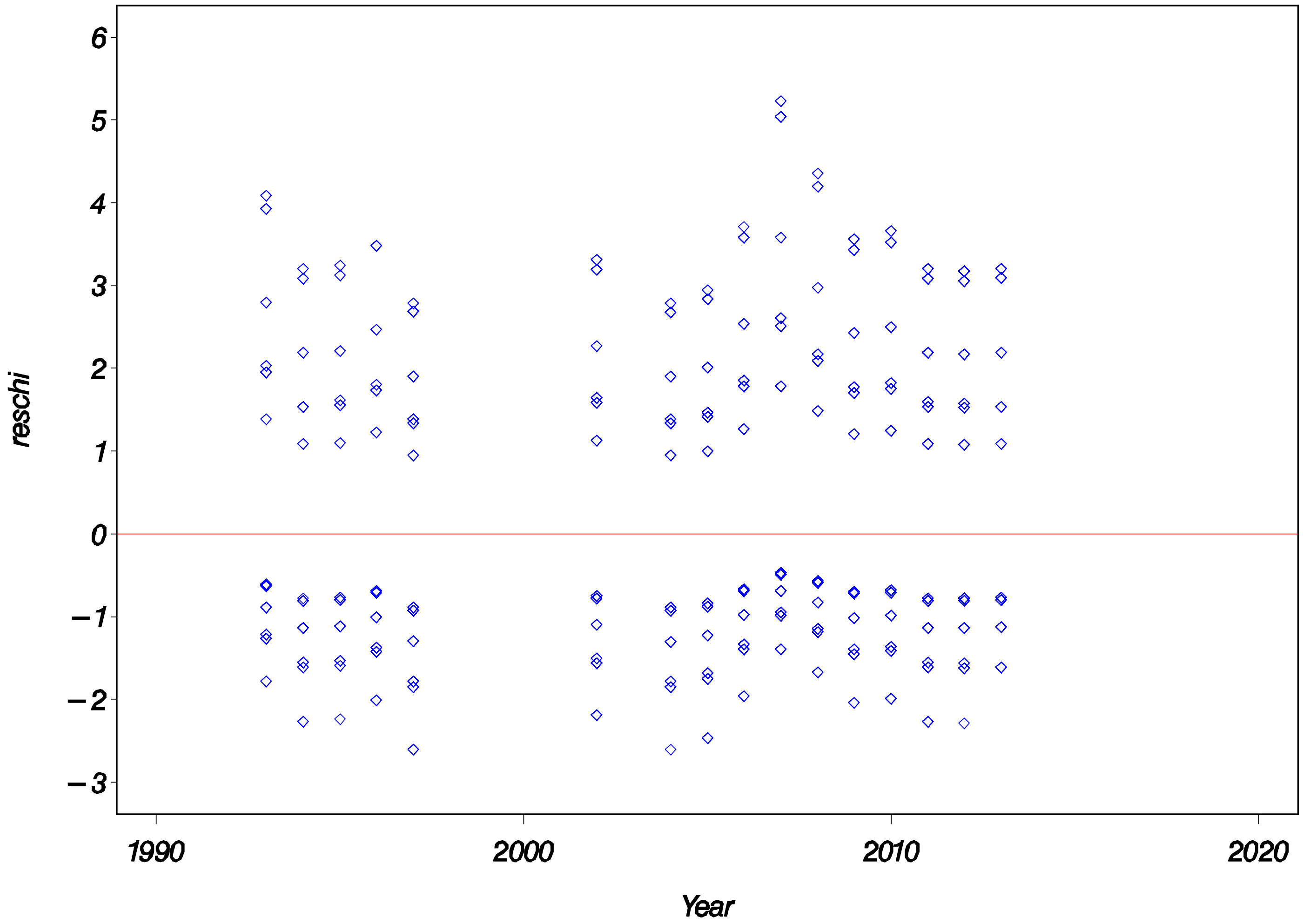

Figure 5. Predicted versus observed proportion positive values from the binomial submodel.

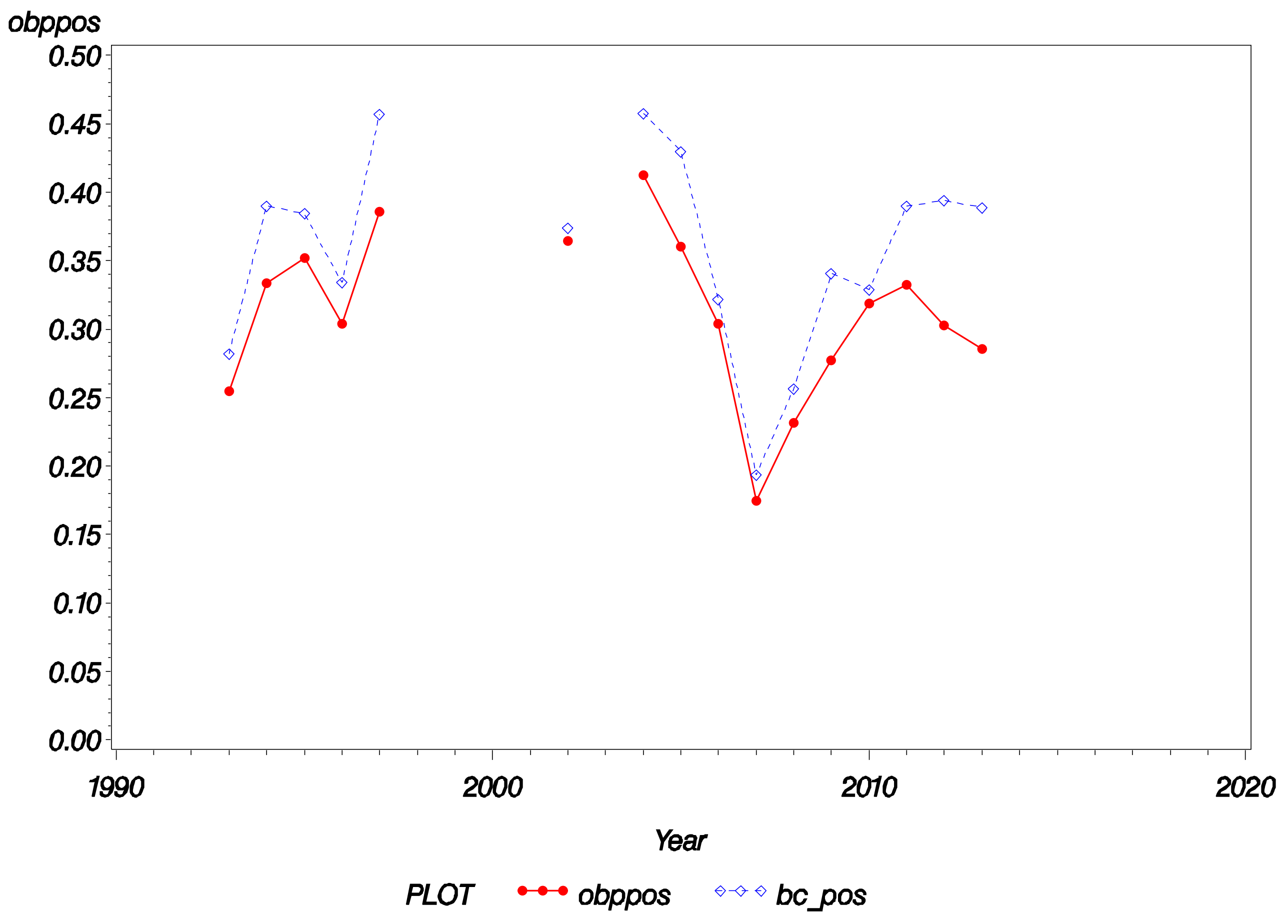

Table 5. Delta lognormal GLM output from the lognormal sub-model information criteria.

Information Criteria						
Neg2LogLike	*Parms*	*AIC*	*AICC*	*HQIC*	*BIC*	*CAIC*
836.9	1	838.9	838.9	840.8	843.7	844.7

Table 6. Delta lognormal GLM output from the lognormal sub-model, test of fixed effects.

Type 3 Tests of Fixed Effects				
Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	15	904	4.45	<.0001
ALG	1	904	2.79	0.0954

Table 7. Delta lognormal goodness of fit tests of the normal distribution.

Goodness-of-Fit Tests for Normal Distribution				
Test		*Statistic*	*p Value*	
Kolmogorov-Smirnov	*D*	0.2936159	*Pr > D*	<0.010
Cramer-von Mises	*W-Sq*	19.4707600	*Pr > W-Sq*	<0.005
Anderson-Darling	*A-Sq*	95.8096433	*Pr > A-Sq*	<0.005

Table 8. Delta lognormal QQ plot residuals, tests of location.

Tests for Location: Mu=0				
Test		*Statistic*	*p Value*	
Student's t	*t*	-0.07596	*Pr > |t|*	0.9395
Sign	*M*	-230.5	*Pr >= |M|*	<.0001
Signed Rank	*S*	-34608.5	*Pr >= |S|*	<.0001

Figure 6. Distribution of the residuals of positive mincounts from the lognormal submodel.

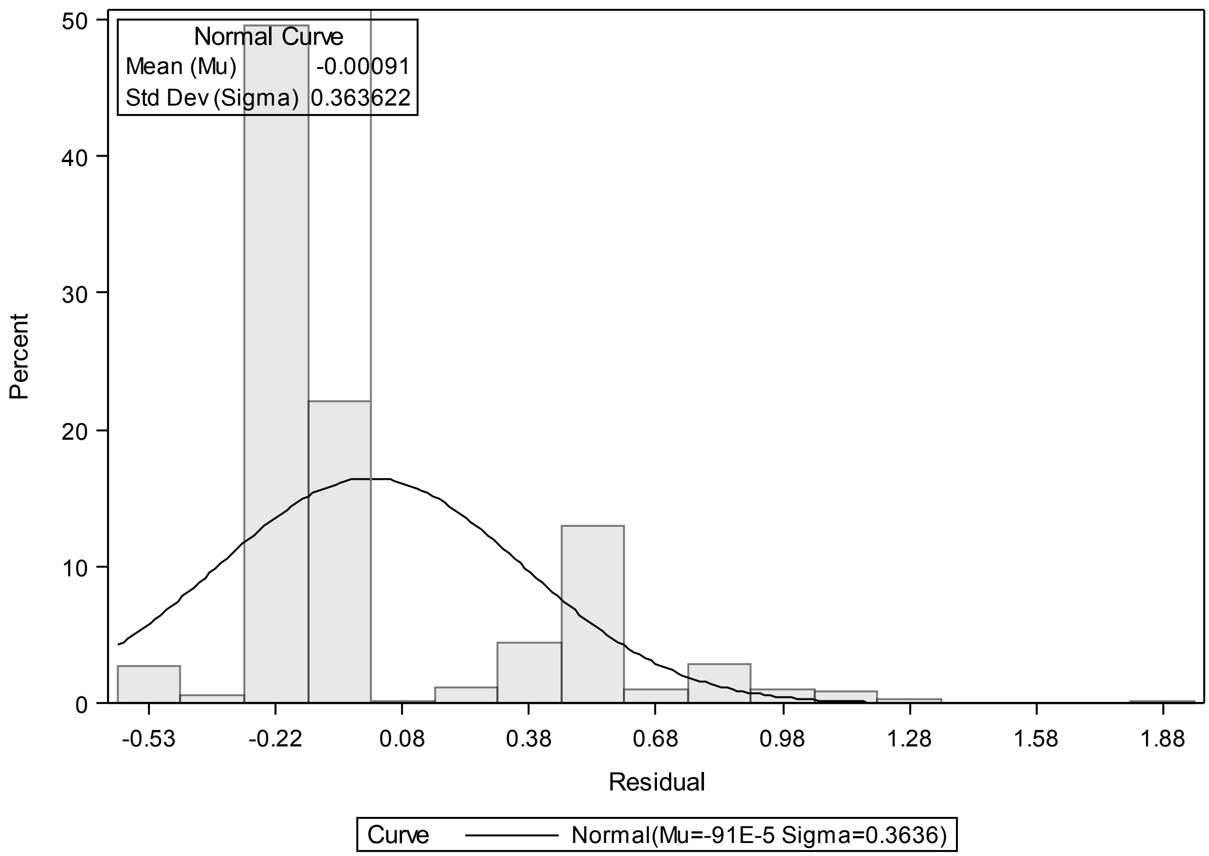

Figure 7. QQ plot of the residuals of positive mincounts from the lognormal submodel.

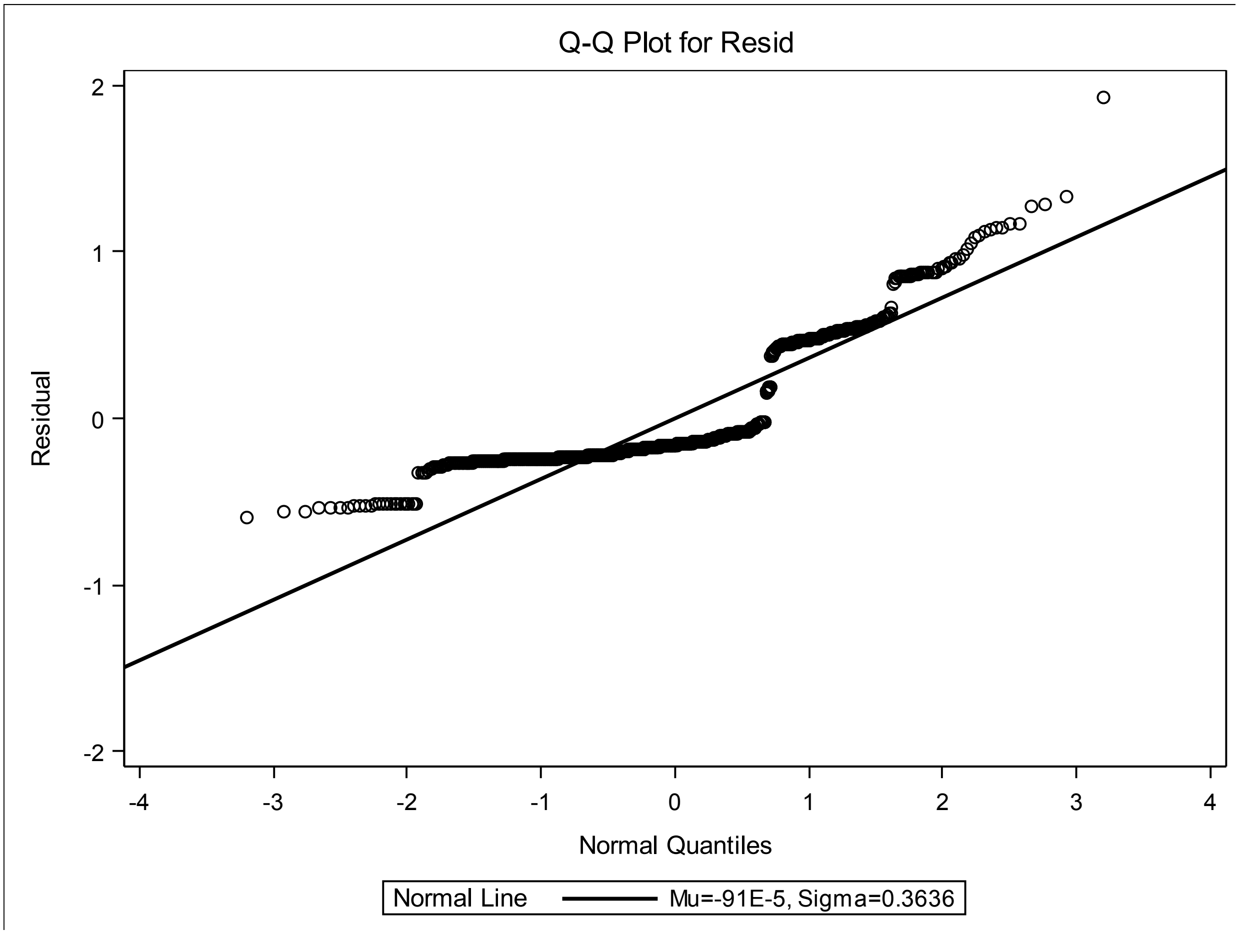

Figure 8. Spatial distribution of red grouper observed and associated min-count values during the 1993 reef fish video survey.

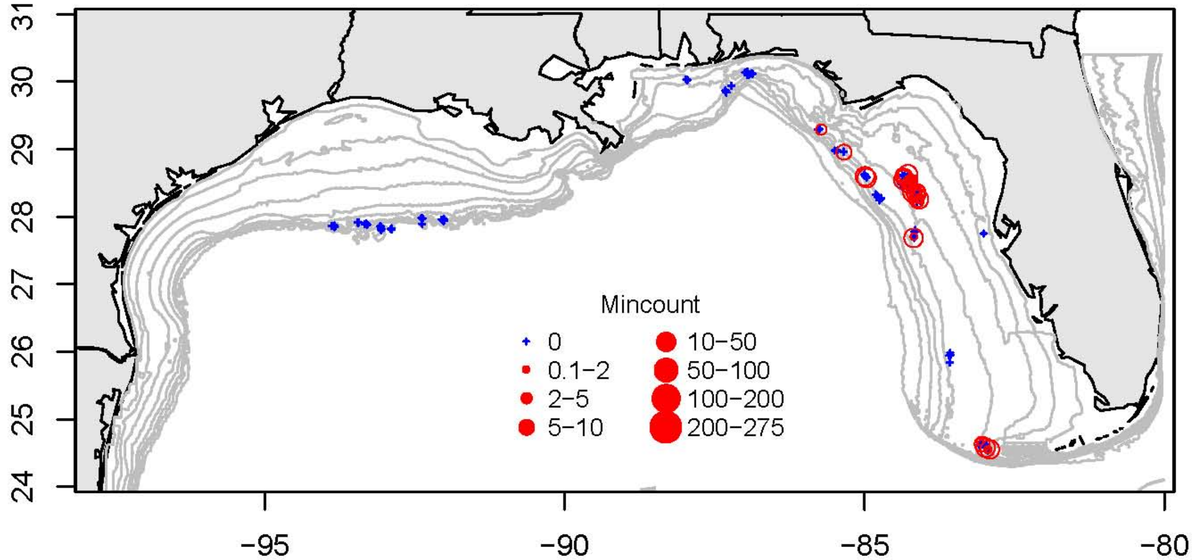

Figure 9. Spatial distribution of red grouper observed and associated min-count values during the 1994 reef fish video survey.

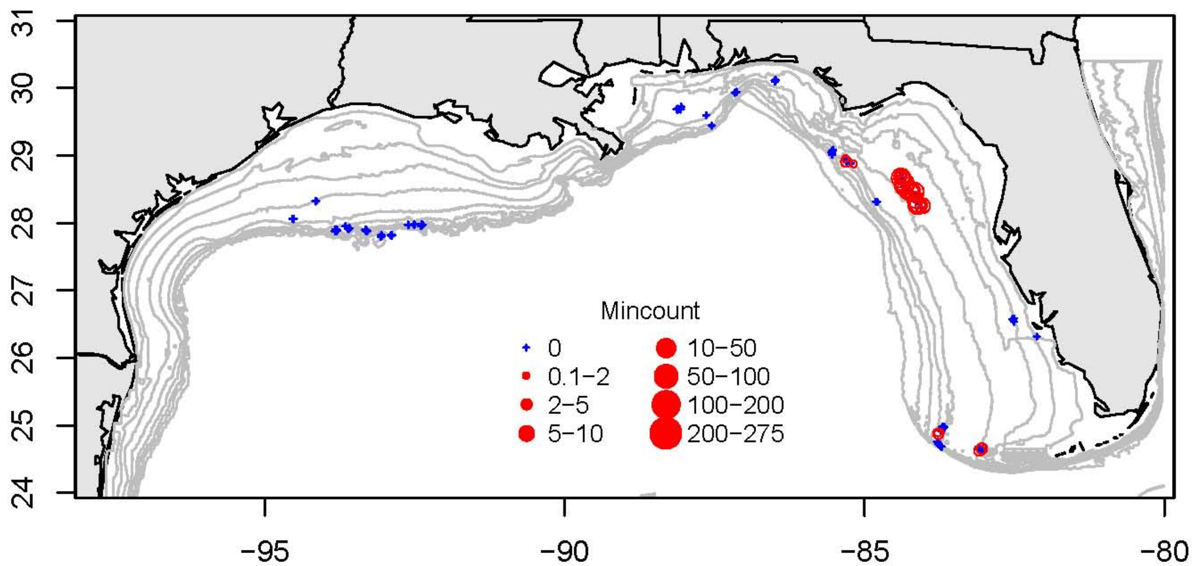

Figure 10. Spatial distribution of red grouper observed and associated min-count values during the 1995 reef fish video survey.

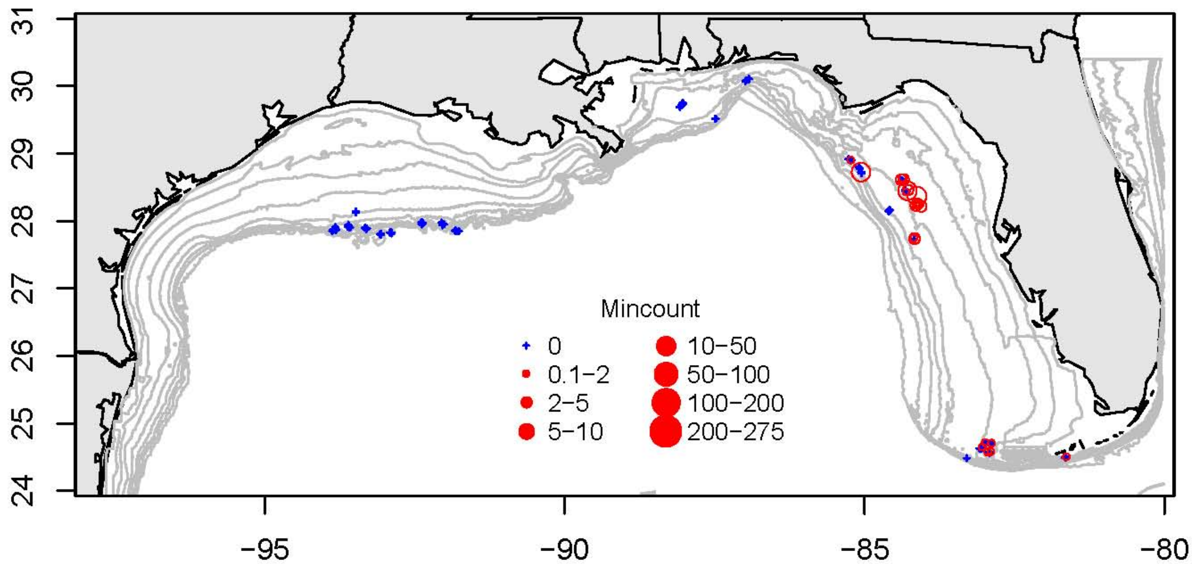

Figure 11. Spatial distribution of red grouper observed and associated min-count values during the 1996 reef fish video survey.

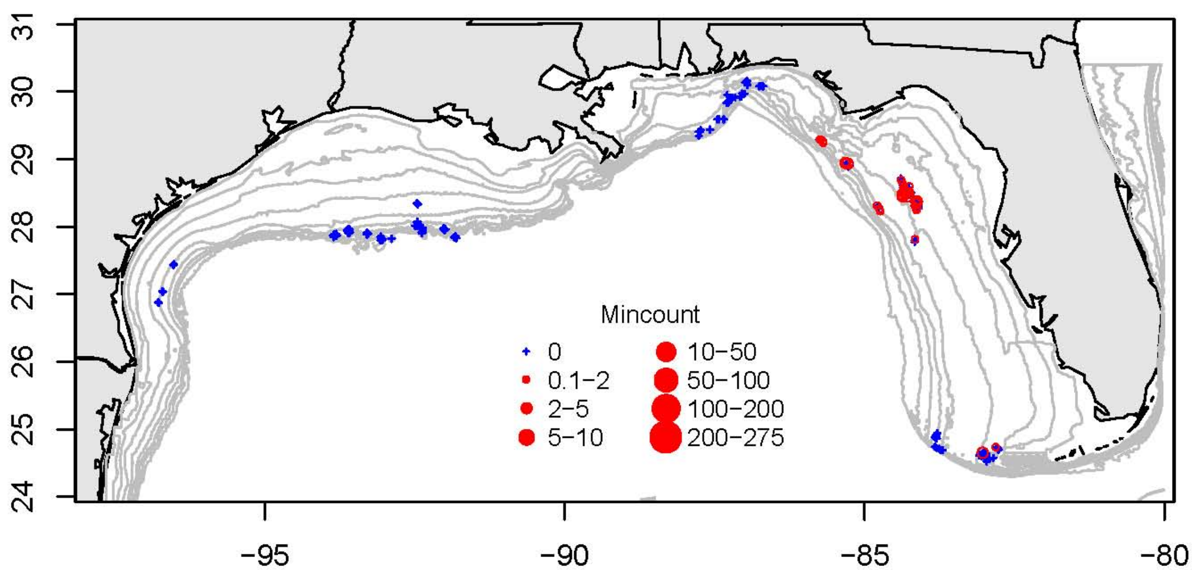

Figure 12. Spatial distribution of red grouper observed and associated min-count values during the 1997 reef fish video survey.

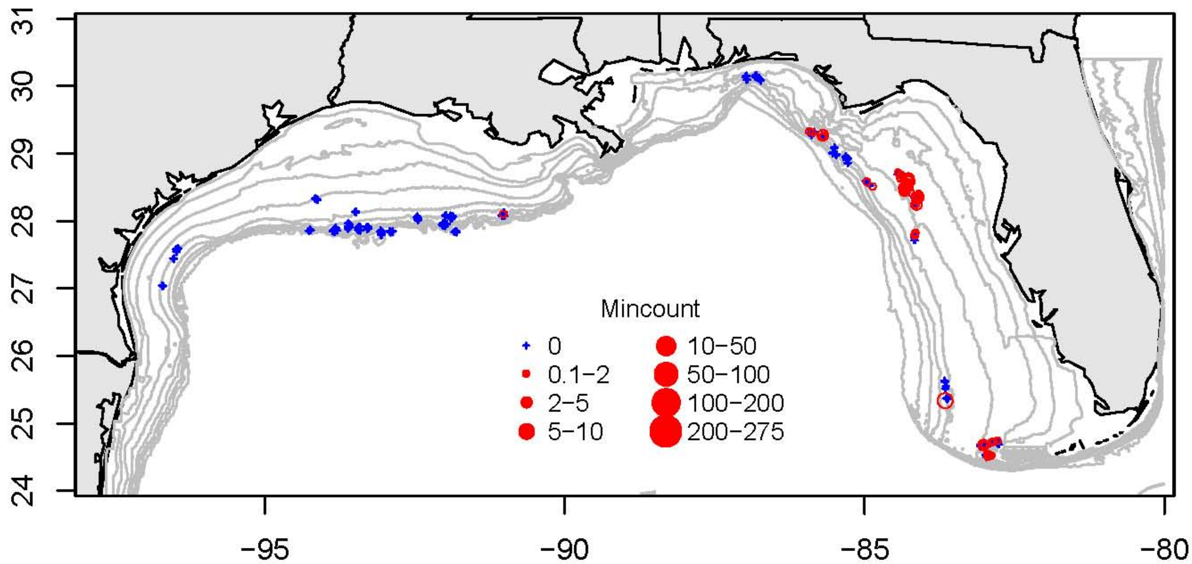

Figure 13. Spatial distribution of red grouper observed and associated min-count values during the 2002 reef fish video survey.

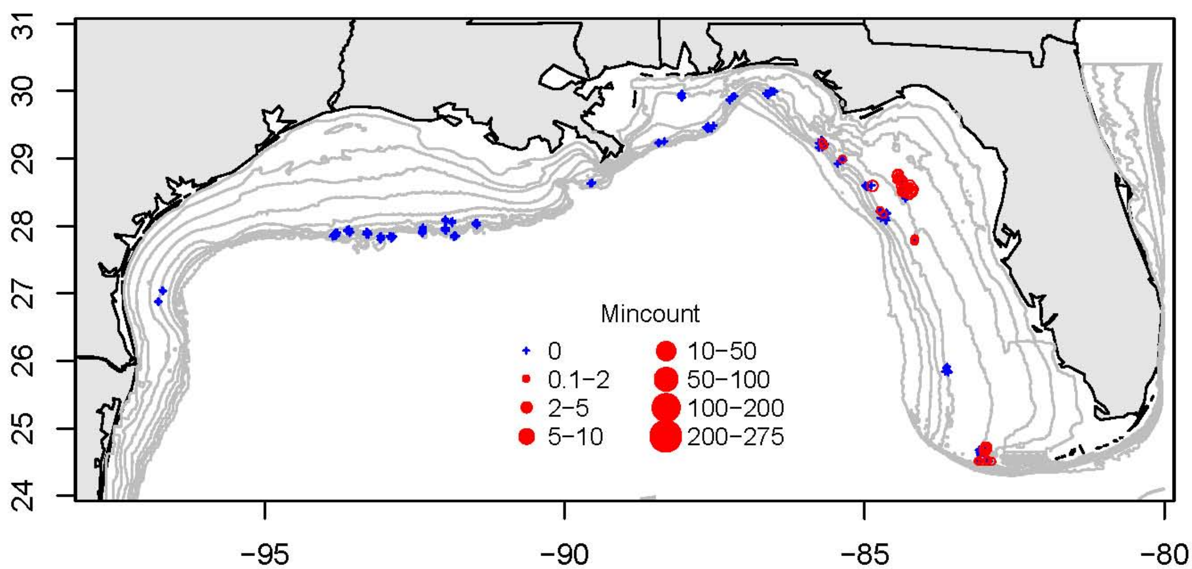

Figure 14. Spatial distribution of red grouper observed and associated min-count values during the 2004 reef fish video survey.

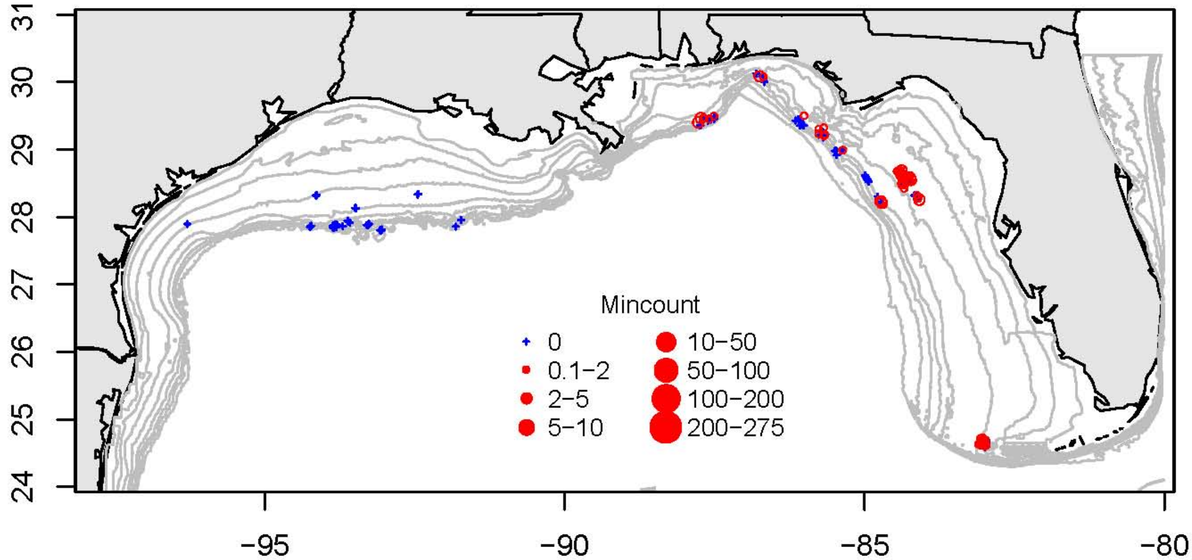

Figure 15. Spatial distribution of red grouper observed and associated min-count values during the 2005 reef fish video survey.

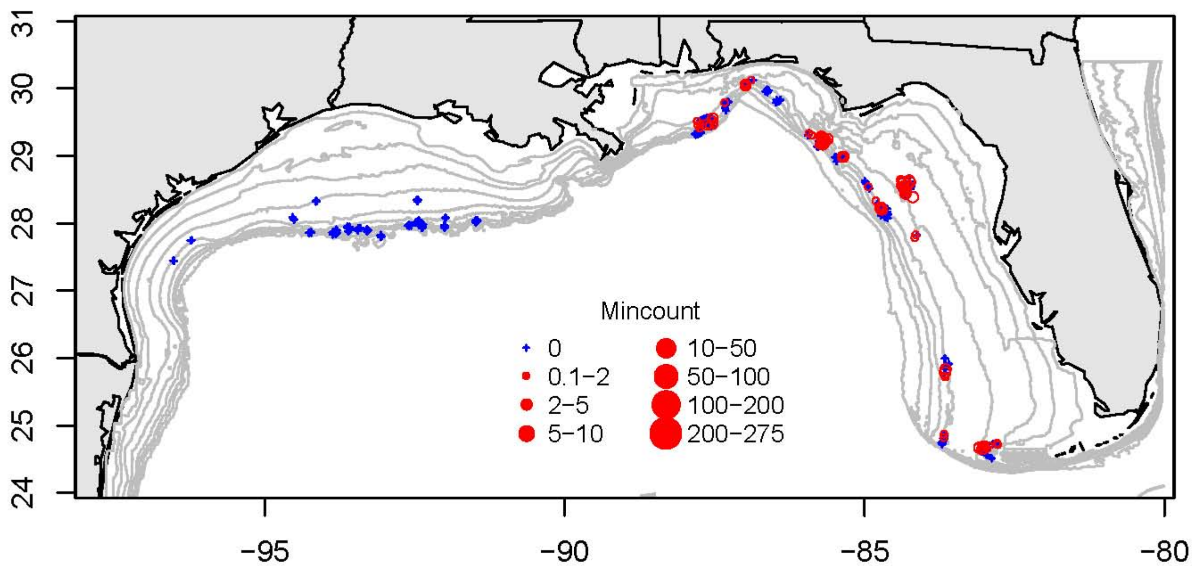

Figure 16. Spatial distribution of red grouper observed and associated min-count values during the 2006 reef fish video survey.

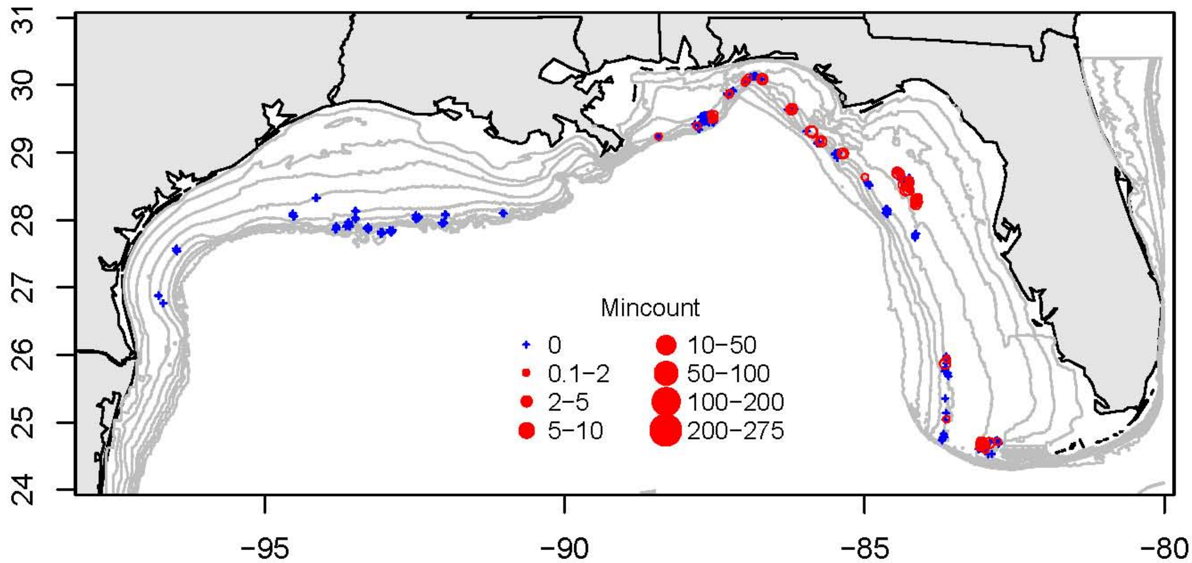

Figure 17. Spatial distribution of red grouper observed and associated min-count values during the 2007 reef fish video survey.

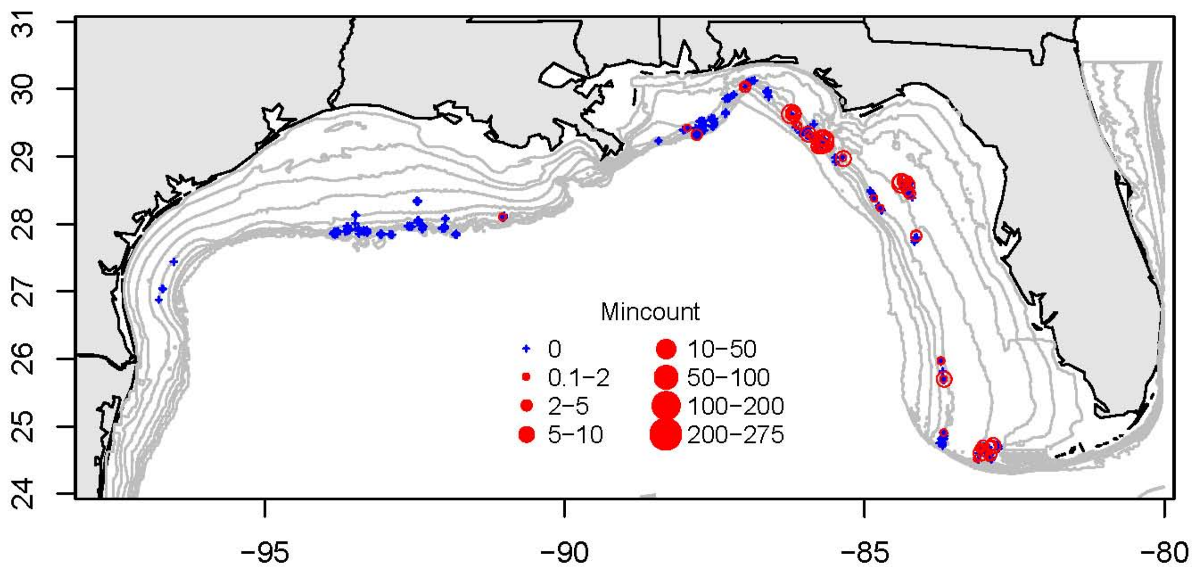

Figure 18. Spatial distribution of red grouper observed and associated min-count values during the 2008 reef fish video survey.

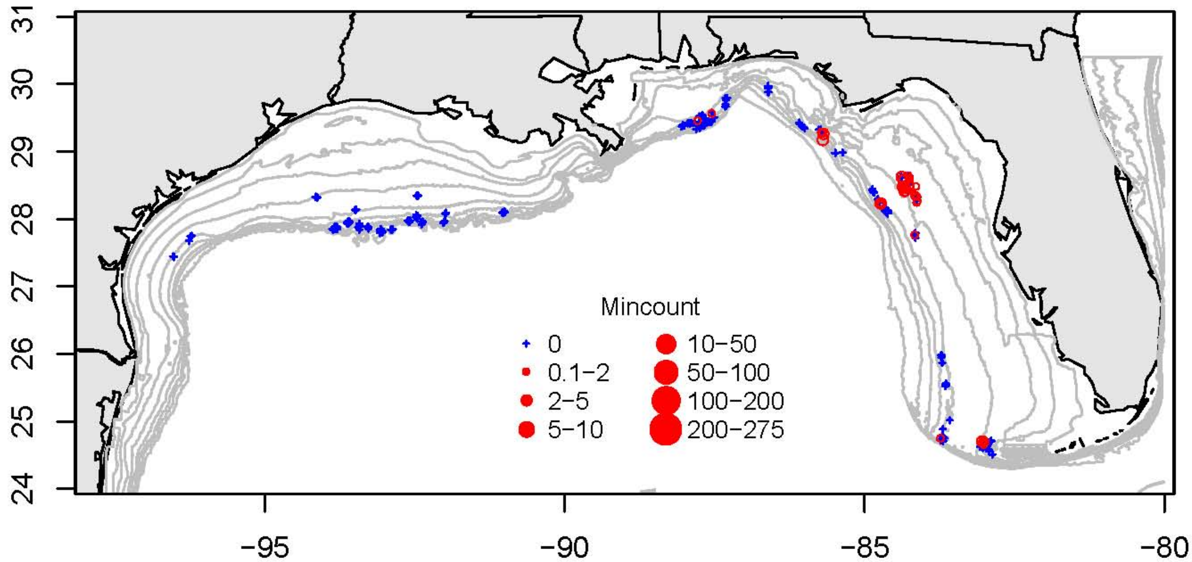

Figure 19. Spatial distribution of red grouper observed and associated min-count values during the 2009 reef fish video survey.

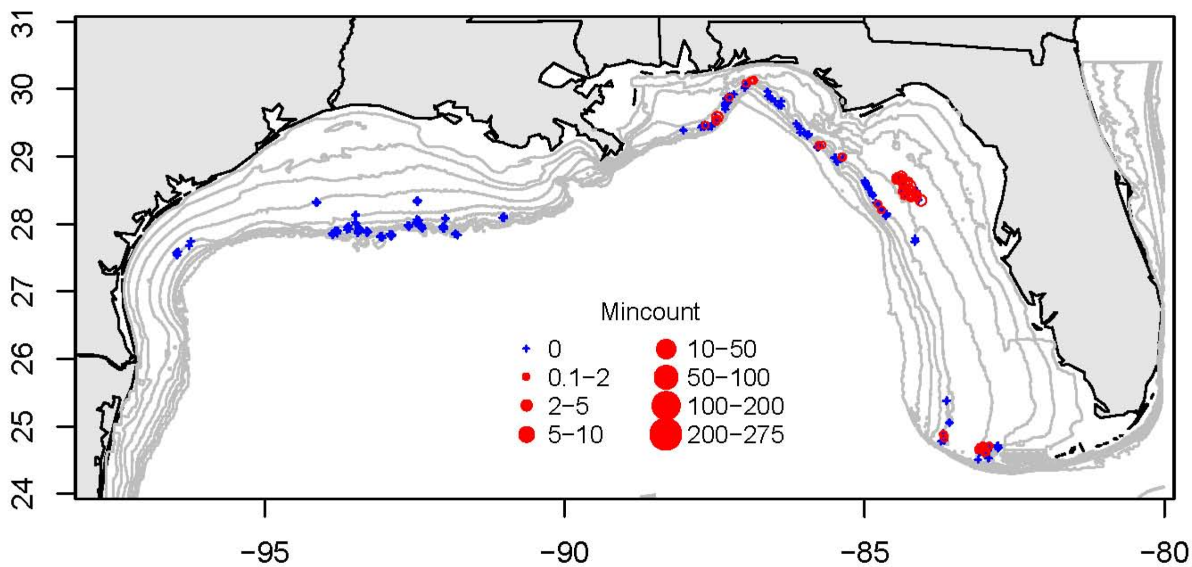

Figure 20. Spatial distribution of red grouper observed and associated min-count values during the 2010 reef fish video survey.

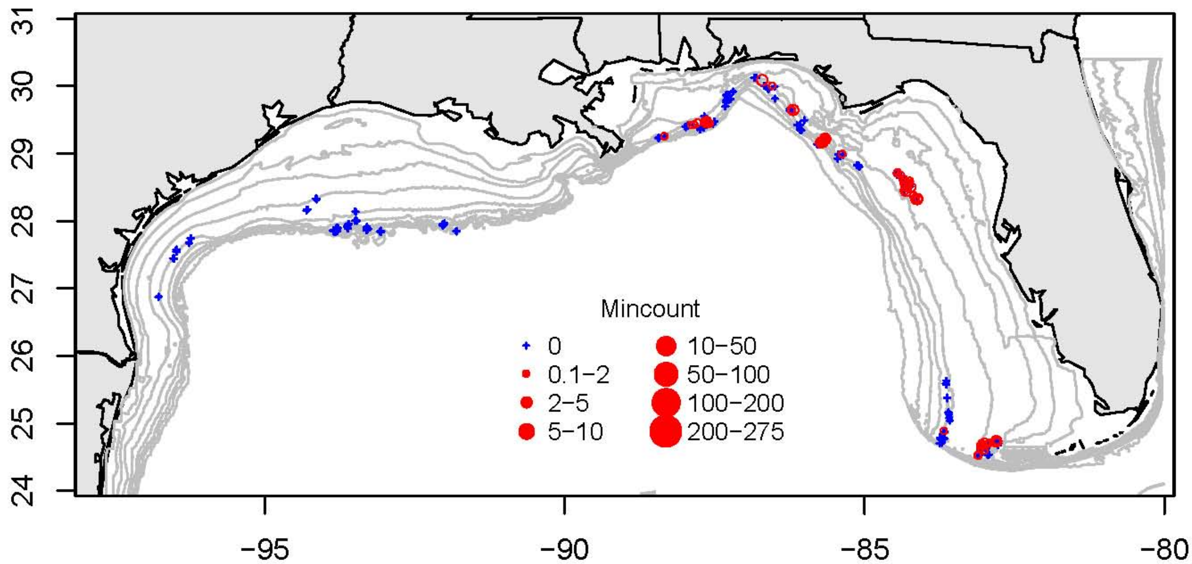

Figure 21. Spatial distribution of red grouper observed and associated min-count values during the 2011 reef fish video survey.

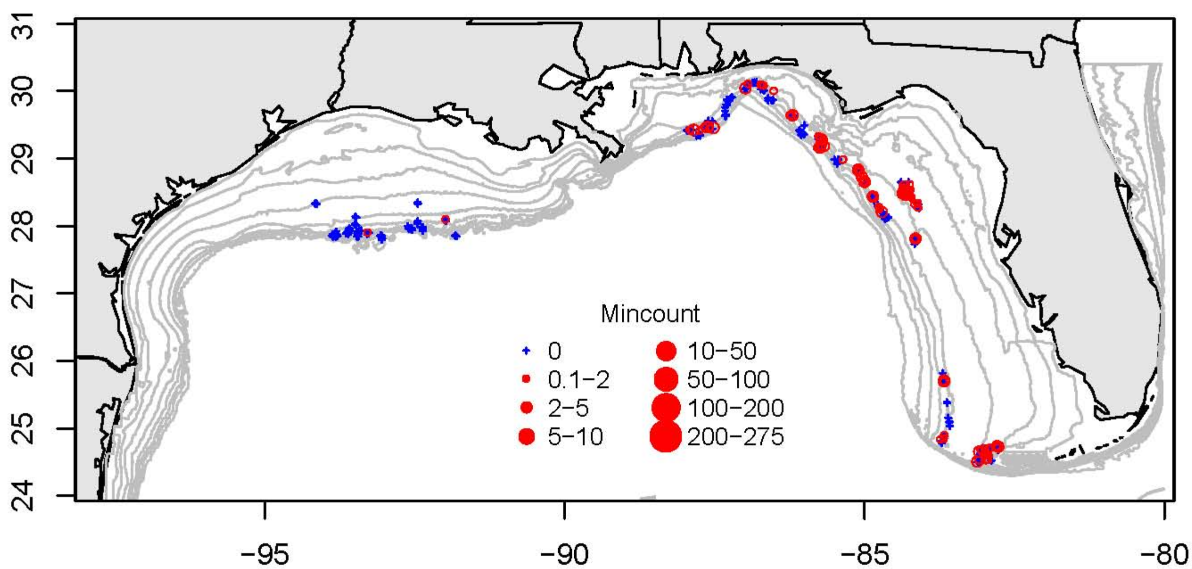

Figure 22. Spatial distribution of red grouper observed and associated min-count values during the 2012 reef fish video survey.

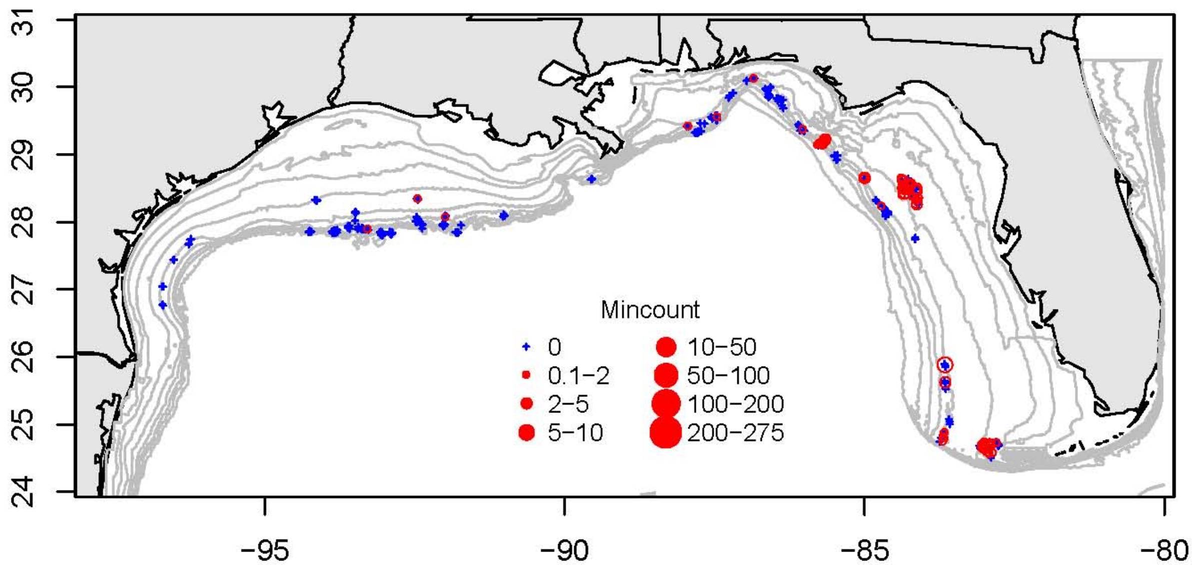

Figure 23. Spatial distribution of red grouper observed and associated min-count values during the 2013 reef fish video survey.

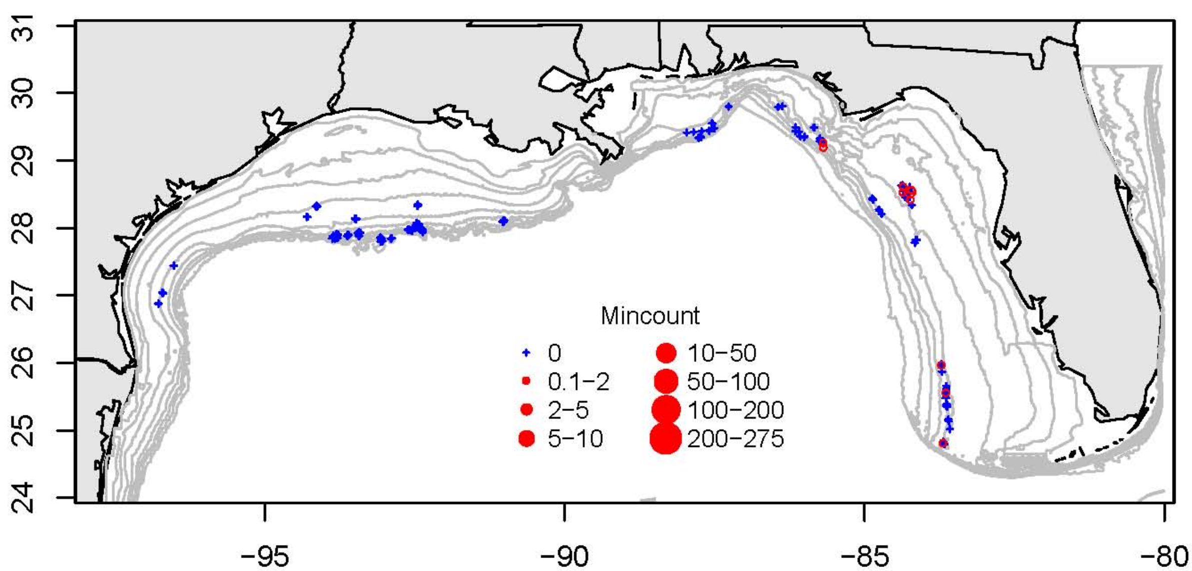

Figure 24. Length frequency distributions for red grouper from laser measurements (mean = 471.8, dotted line) and measured using stereo cameras (mean = 516.99, dotted line).