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Red Grouper *Epinephelus morio* Findings from the NMFS Panama City Laboratory Trap & Camera Fishery-Independent Survey – 2004-2014

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Survey history and overview

In 2002 the Panama City NMFS lab began development of a fishery-independent trap survey (PC survey) of natural reefs on the inner shelf of the eastern Gulf of Mexico off Panama City, FL, with the primary objective of establishing an age-based annual index of abundance for young (age 0-3), pre-recruit gag, scamp, and red grouper. Secondary objectives included examining regional catch, recruitment, demographic, and distribution patterns of other exploited reef fish species. The chevron trap is efficient at capturing a broad size range of several species of reef fish (Nelson et. al.1982, Collins 1990), and has been used by the South Atlantic MARMAP program for over 20 yr (McGovern et. al. 1998). Initially the PC survey used the same trap configuration and soak time used by MARMAP (McGovern et. al. 1998), but an in-house study in 2003 indicated that traps with a throat entrance area 50% smaller than that in the MARMAP traps were much more effective at meeting our objective of capturing sufficient numbers of all three species of grouper. Video data from our study and consultations with fishermen suggested that the presence of larger red grouper in a trap tended to deter other species from entering. Beginning in 2004, the 50% trap throat size became the standard. That same year the survey was expanded east of Panama City to Apalachee Bay off the Big Bend region of Florida (Figure 1), an area separated from the shelf off Panama City by Cape San Blas - an established hydrographic and likely zoogeographic boundary (Zieman and Zieman 1989).

Beginning in 2005, the collection of visual (stationary video) data was added to the survey to provide insight on trap selectivity, more complete information on community structure, relative abundance estimates on species rarely or never caught in the trap, and additional, independent estimates of abundance on species typically caught in the traps. Video sampling was only done in Apalachee Bay that first year, but was expanded to the entire survey in 2006. Also in 2005 the target species list was expanded to include the other exploited reef fishes common in the survey area , i.e., red, vermilion, gray, and lane snapper; gray triggerfish, red porgy, white grunt, black seabass, and hogfish. From 2005 through 2008 each site was sampled with the camera array followed immediately by a single trap. Beginning in 2009 trap effort was reduced ~50%, with one deployed at about every other video site, starting with the first site of the day. This was done so the number of video samples, and thereby the accuracy and precision of the video abundance estimates, could be increased. Camera arrays are much less selective and provide abundance estimates for many more species than traps, and those estimates are usually much less biased (DeVries et al. 2009). At each site, a CTD cast was made to collect temperature, salinity, oxygen, and turbidity profiles.

The survey sampling design was systematic through 2009 because of a very limited sampling universe. In 2010 the design was changed to 2 stage random after side scan sonar surveys that year yielded an order of magnitude increase in that universe (Figure 1). Five by five minute blocks known to contain reef sites, and proportionally allocated by region, sub-region, and depth (10-20, 20-30, 30+ m) to ensure uniform geographic and bathymetric coverage, are randomly chosen first. Then 2 known reef sites a minimum of 300 m apart within each selected block are randomly selected (Figure 2). Alternates are also selected for use when another boat is found to be fishing the site or no hard bottom can be found with sonar at that site.

Depth coverage was ~8-30 m during 2004-07, and then subsequently steadily expanded to ~8 – 52 m (Figure 3). Sampling effort has also increased since 2004. Sample sizes were 59 in 2004 (33 West: 26 East), 101 in '05 (24 W: 77 E), 114 in '06 (25 W: 89 E), 86 in '07 (29 W: 57 E), 97 in '08 (31 W: 66 E), 143 in '09 (47 W: 96 E), 162 in '10 (53 W: 109 E), 180 in '11 (65 W: 115 E), 178 in '12 (61 W: 117 E), 112 in 2013 (71 W: 41 E), and 184 in 2014 (113E: 71 W). Nine sites in 2004 and 23 in 2005 were sampled twice; thereafter each site was only sampled once in a given year. All sampling has occurred between May and October (with the exception of four sites in November, 2013), but primarily during June through August (Figure 4) Sampling east of Cape San Blas in 2013 was limited (down ~66%) and done later than normal (Oct. and Nov.) because of late receipt of funding, ship mechanical issues, and weather problems.

Methods

Sampling was conducted during daytime from 1 hr after sunrise until 1 hr before sunset. Chevron traps were baited each set with 3 previously frozen Atlantic mackerel *Scomber scombrus*, and soaked for 1.5 hr. Traps were fished as close as possible to the exact location sampled by the camera array. All trap-caught fish were identified, counted and measured to maximum total and fork length (FL only for gray triggerfish and TL only for black seabass). Both sagittal otoliths were collected from 4-5 randomly subsampled specimens of all snappers (gray, lane, red, and vermilion), groupers (gag, red, and scamp), black seabass, red porgy, hogfish, white grunt, and gray triggerfish (first dorsal spine for the latter).

Visual data were collected using a stationary camera array composed of 4 Hi 8 video cameras (2005 only) or 4 high definition (HDEF), digital video cameras (2006-08) mounted orthogonally 30 cm above the bottom of an aluminum frame. From 2007 to 2009, parallel lasers (100 mm spacing) mounted above and below each camera were used to estimate the sizes of fish which crossed the field of view perpendicular to the camera. In 2009 and 2010, one of the HDEF cameras was replaced with a stereo imaging system (SIS) consisting of two high resolution black and white still cameras mounted 8 cm apart, one digital video (mpeg) color camera, and a computer to automatically control these cameras as well as store the data. The SIS provides images from which fish measurements can be obtained with the Vision Measurement System (VMS) software. Beginning in 2011, a second SIS facing 180º from the other was added, reducing the number of HDEFs to two; and both SIS's were also upgraded with HDEF, color mpeg cameras. In 2012 the two HDEFs were replaced with hi-def GoPro cameras. The camera array was unbaited 2005-2008, but since 2009 has been freshly baited each drop with one previously frozen Atlantic mackerel placed in a mesh bag near the center.

Before stereo camera systems were used (prior to 2009), soak time for the array was 30 min to allow sediment stirred up during camera deployment to dissipate and ensure tapes with an unoccluded view of at least 20 min duration (Gledhill and David 2003). With the addition of stereo cameras in 2009, soak time was increased to 45 min to allow sufficient time for the SIS to be settled on the bottom before starting its hard drive, and to insure the hard drive had time to shut down before retrieval. In mid-2013, stereo cameras were upgraded with solid state hard drives, enabling soak time to be reduced back to 30 min. Prior to 2009, tapes of the 4 HDEF cameras were scanned, and the one with the best view of the habitat was analyzed in detail. If none was obviously better, one was randomly chosen. In 2009 only the 3 HDEF video cameras were scanned and the one with the best view of the reef was analyzed. Starting in 2010, all 4 cameras – the HDEFs and the SIS MPEGs, which have virtually the same fields of view (64 vs 65º) – were scanned, and again, the one with the best view of the habitat was analyzed. Beginning in 2012, when a video from a GoPro camera was selected to be read, because they have a much larger field of view than the SIS MPEGs (122 vs 65º), predetermined, equal portions of each edge of the video monitor were covered so that only the central 65° of the field of view was visible. Twenty min of the tape were viewed, beginning when the cloud of sediment disturbed by the landing of the array has dissipated. All fish captured on videotape and identifiable to at least genus were counted. Data on habitat type and reef morphometrics were also recorded. If the quality of the MPEG video derived from the SIS was less than desirable (a common problem), fish identifications were confirmed on the much higher quality and concurrent stereo still frames. The estimator of abundance was the maximum number of a given species in the field of view at any time during the 20 min analyzed (= min count; Gledhill and Ingram 2004, or MaxN; Ellis and DeMartini 1995), and VMS measurements were taken from a still frame showing the min count of a given species (but not necessarily the same frame the actual min count came from) to eliminate the possibility of measuring the same fish more than once. Even for deployments where the SIS did not provide a good view of the reef habitat, the files were examined to obtain fish measurements using VMS, and again, those measurements were only taken from a still frame showing the min count of a given species. In contrast, when scaling lasers were used to obtain length data, there was no way to eliminate the possibility of double measuring a given fish, although this was probably not a serious problem, as usable laser hits were typically rare for any one sample.

Because of the significant differences we observed in both species composition and abundance of many reef fishes east and west of Cape San Blas, and because of the Cape's known status as a hydrographic and likely zoogeographic boundary (Zieman and Zieman 1989), many of the results presented herein are shown separately for the two areas.

Censored data sets were used in deriving the indices of relative abundance from video and trap data. Prior to 2010, the year we began using side scan sonar to locate reefs, lack of knowledge of reef habitat locations east of Cape San Blas necessitated making a much higher proportion of "exploratory" camera and trap drops there versus west of the Cape. To compensate, more overall effort was expended in the east. Some of these "exploratory" sample sites turned out to be sand, mostly sand, or very marginal reef habitat at best, yielding little or no reef fish data. In addition, the gear occasionally missed the intended, often small, very low relief reef site. Inclusion of data from those sites would have reduced the precision of the abundance estimates and confounded any analyses. For that reason, video data – both habitat classification and fish counts – from all sites were screened, and those with no evidence that hard or live bottom was in close proximity, as well as sites where the view was obscured for some reason (poor visibility, bad camera angle), were censored (excluded) from calculations of relative abundance. In addition, 10 video samples from 2014 from within an area with an ongoing serious red tide bloom, and which showed no or virtually no evidence of living fish, were also censored. As a result of this screening, of video samples east of the Cape, only 31 of 41 in 2005, 47 of 89 in 2006, 23 of 57 in 2007, 56 of 66 in 2008, 62 of 97 in 2009, 95 of 109 in 2010, 99 of 115, in 2011, and 100 of 115 in 2012, 38 of 39 in 2013, and 103 of 113 in 2014 met the reef and visibility criteria and were retained. In contrast, west of the Cape, 24 of 25 sites in 2006, 29 of 29 in 2007, 29 of 31 in 2008, 42 of 47 in 2009, 52 of 53 in 2010, 57 of 64 in 2011, 49 of 59 in 2012, 66 of 72 in 2013, and 71 of 71 in 2014 were retained for analyses.

For trap samples, only sites which had already sampled in a given year and 8 sites in 2014 located in an ongoing red tide bloom were excluded from index calculations. As a result of this screening, of trap samples east of the Cape, 16 of 17 in 2004, 44 of 68 in 2005, 68 of 68 in 2006, 44 of 44 in 2007, 50 of 50 in 2008, 53 of 53 in 2009, 52 of 52 in 2010, 50 of 50 in 2011, and 59 of 59 in 2012, and 14 of 14 in 2013, and 47 of 56 in 2014 were retained. West of the Cape, 18 of 24 in 2004, 18 of 18 in 2005, 23 of 23 sites in 2006, 20 of 20 in 2007, 31 of 31 in 2008, 29 of 30 in 2009, 17 of 17 in 2010, 30 of 30 in 2011, 30 of 30 in 2012, and 37 of 37 in 2013, and 33 of 33 in 2014 were retained for analyses.

Indices of relative abundance from video and trap data

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

(1) $I_y = c_y p_y$,

where c_y is the estimate of mean CPUE for positive observations only for year y; 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:

(2) $\ln(\mathbf{c}) = \mathbf{X\beta} + \boldsymbol{\varepsilon}$

and

(3) $\mathbf{p} = \dfrac{e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}}{1+e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}}$, 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, $\boldsymbol{\beta}$ is the parameter vector for main effects, and $\boldsymbol{\varepsilon}$ is a vector of independent normally distributed errors with expectation zero and variance σ^2.

We used the GLIMMIX and MIXED procedures in SAS (v. 9.1, 2004) to develop the binomial and lognormal submodels, respectively. Similar covariates were tested for inclusion for both submodels: water depth, survey region [two regions in the northeastern GOM: East (east of Cape san Blas) and West (west of east of Cape san Blas)], month and year. A backward selection procedure was used to determine which variables were to be included into each submodel based on type 3 analyses with a level of significance for inclusion of $\alpha = 0.05$. If year was not significant then it was forced into each submodel in order to estimate least-squares means for each year, which are predicted annual population margins (i.e., they estimate the marginal annual means as if over a balanced population).

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 (5), and its variance calculated as

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

where

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

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

Results

Since the Panama City lab reef fish survey began in 2004/5, red grouper have consistently and commonly been observed with stationary video gear and captured in chevron traps across the inner and mid-West Florida shelf both east and west of Cape San Blas (Tables 1 and 2, Fig. 5) (DeVries et al. 2008, 2009, 2012). The annual percent of positive video samples ranged from 16.7 to 66.2 % east of Cape San Blas during 2005-2014, and 20 to 69.8 % west of the Cape during 2006-2014 (Table 1). The annual percent of positive red grouper trap catches during 2004-2014 ranged from 13.2 to 62.0 % east of Cape San Blas and 5.0 to 51.6 % west of the Cape (Table 1). Red grouper were encountered by both gears across virtually the entire depth range sampled, although encounter rates did increase noticeably with depth from 6 to 16 m, then only slightly up to ~40 m (Fig. 6 and 7). The sharp drop in occurrence of red grouper beyond 46 m is likely related to very low sample sizes at those depths.

Red grouper taken in chevron traps during 2004-2014 ranged from 211 to 798 mm FL, with a modal size of ~375-400 mm FL and a mean of 448 mm; while those observed with stereo cameras, 2009-2014, ranged from 274 to 885 mm FL with a modal size of roughly 400-450 mm FL and a mean of 503 mm (Fig. 8). Not surprisingly, a comparison of size data from trap catches with that from stereo images from the same years (2009-13) indicated that the traps do select against most red grouper >750 mm FL, although fish that large are much less common in the survey area based on the few stereo measurements obtained (Fig. 8). The stereo camera gear is also selective, but it tends to select against small (<325 mm FL) red grouper, which tend to be much more cryptic than larger individuals and less likely to be visible to camera gear.

The survey strongly targeted pre-recruit red grouper, especially east of Cape San Blas, where 81% of trap-caught fish were below the minimum legal size limit of 487 mm FL, compared to 44% west of the Cape. Red grouper east of Cape San Blas averaged much smaller than those on the west - 416 vs. 509 mm FL (Fig. 9). East of the Cape, 20% of the fish were <350 mm and only 4% were >600 mm, while in the west only 6% were <350 mm but 21% were >600 mm. This pattern can also be clearly seen in the annual length composition data from 2005-2009 (Fig. 10), the years when the distribution of depths sampled was quite different east and west of Cape San Blas (Fig. 3). We found a significant positive relationship between size and depth in red grouper, probably reflecting ontogenetic movements and decreasing fishing mortality rates with distance from shore (Fig. 11).

Despite small sample sizes in some years, annual size structure data revealed at least two obvious modes and one probable one which tracked for a few to several years, during which they steadily shifted to increasingly larger sizes (Fig. 10). One of the modes (325-350 mm FL) was present in 2004 when the trap survey began, and was clearly visible through 2006 when it was ~400-450 mm. The most persistent modal group appeared in 2007 at about 250 mm FL and was readily identifiable every year thereafter through 2014. These patterns suggest different, strong cohorts were moving through the population during those periods. Size data from the video survey stereo images showed the same shift in size structure from 2009 through 2014.

As expected, given the regional differences observed in size structure, red grouper were also younger east of the Cape than west, with individuals caught in the trap survey ranging from ages 1 to 8 yr with a mode of 3-4 yr (Fig. 12). West of the Cape, red grouper ranged from ages 1 to 19 yr, although most were 1-10 yr, and modal age was 5. Annual age structure data from the trap catches clearly showed that the red grouper population on the northern West Florida Shelf was characterized by periodic (3 to at least 7 yr) strong year classes (Fig. 13). From 2004 through

2006, trap catches were dominated by the 1999 and 2002 cohorts. The 2002 group was last evident in 2007, but the 1999 year class has continued to be an identifiable mode through 2014. The early disappearance of the dominant 2002 cohort after 2007 may have been related to the very strong red tide event in the survey area in 2005. In 2007 the 2006 cohort first appeared and it has dominated survey catches through 2014, although in 2011 it became apparent the 2007 year class was also quite strong. This 2007 cohort was the last obvious strong year class, with no evidence of any subsequent good recruitment years through 2014.

Video and trap indices of abundance

Both video gear and chevron traps showed similar trends in overall frequency of occurrence and nominal CPUE data, with peak values during 2008-2010 or 2011 and then fairly steep declines through 2013 (Fig.14). Regionally, video frequency of occurrence and min count data showed very similar patterns east and west of Cape San Blas, strongly suggesting that only one stock of red grouper dominated the Panama City survey area (Fig. 15 and 16). The noisier trap data from the two sides of the Cape did not track each other as closely, especially prior to 2011 (Fig. 15 and 16).

The backward selection procedure used to develop the delta-lognormal model for red grouper collected by video is summarized in Table 3. The month effect was dropped from the binomial submodel based on type 3 analyses, and there was a corresponding decrease in AIC. Next, the region effect was dropped from the binomial submodel based on type 3 analyses. However, with the variable removal there was a corresponding increase in AIC (Table 3), but due to the high insignificance of the region variable, it was left out of the model. For the lognormal submodel for nonzero observations of red grouper, the region and water depth variables were dropped from the model, and there were corresponding decreases in the AIC values (Table 3). Figure 17 and its adjoining table summarize indices of red grouper developed from the Panama City video data, 2005-2014, using a delta-lognormal model. The index, scaled to a mean of one over the time series, peaked in 2009; and based on the age frequency data from trap catches (Fig. 13), the fish were primarily from the 2006 and 2007 year classes. The index declined in 2010 to 2013, perhaps as the influence of the apparently strong 06 and 07 cohorts waned with no new strong cohorts replacing them. Figures 18 and 19 provide diagnostics for each of the submodels in the index development; and the QQ plots in each indicate a divergence from a normal distribution of the residuals of corresponding submodels.

The backward selection procedure used to develop the delta-lognormal model for red grouper collected by trap is summarized in Table 4. The month effect was dropped from the binomial submodel based on type 3 analyses, and there was a corresponding increase in AIC, but due to the high insignificance of the month variable, it was left out of the model. For the lognormal submodel for nonzero observations of red grouper, the region and water depth variables were dropped from the model, and there were corresponding decreases in the AIC values (Table 4). Figure 20 and its adjoining table summarize indices of red grouper developed from the Panama City trap data, 2005-2014, using a delta-lognormal model. The index, scaled to a mean of one over the time series, peaked in 2009; and based on the age frequency data from trap catches (Fig. 13), the fish were primarily from the 2006 and 2007 year classes. The index declined in 2010 to 2013, perhaps as the influence of the apparently strong 06 and 07 cohorts waned with no new strong cohorts replacing them. Figures 21 and 22 provide diagnostics for each of the submodels in the index development; and the QQ plots in each indicate a divergence from a normal distribution of the residuals of corresponding submodels.

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Tables

Table 1. Annual video survey sample sizes, % positive occurrences, mean nominal video min counts, and standard errors of red grouper east and west of Cape San Blas, 2005-2014. Estimates calculated using censored data sets (see Methods).

	Total sites sampled			% Positive occurrences			Mean nominal min count			Standard error		
Year	East	West	Total	East	West	Total	East	West	Total	East	West	Total
2005	41		41	24.4		24.4	0.268		0.268	0.078		0.078
2006	84	25	109	28.6	28.0	28.4	0.381	0.280	0.358	0.072	0.092	0.059
2007	48	25	73	16.7	20.0	17.8	0.167	0.240	0.192	0.054	0.105	0.050
2008	60	29	89	38.3	69.0	48.3	0.450	0.828	0.573	0.080	0.132	0.071
2009	68	43	111	66.2	69.8	67.6	1.044	0.930	1.000	0.136	0.122	0.096
2010	97	51	148	59.8	58.8	59.5	0.835	0.765	0.811	0.090	0.124	0.073
2011	100	59	159	43.0	61.0	49.7	0.570	0.729	0.629	0.076	0.093	0.059
2012	105	54	159	33.3	35.2	34.0	0.400	0.389	0.396	0.060	0.077	0.047
2013	38	66	104	21.1	24.2	23.1	0.289	0.273	0.279	0.106	0.063	0.055
2014	93	71	164	22.6	28.2	25.0	0.226	0.296	0.256	0.044	0.058	0.035

Table 2. Annual trap survey sample sizes, % positive catches, mean catch per trap hour, and standard errors of red grouper east and west of Cape San Blas, 2004-2014. Estimates calculated using censored data sets (see Methods).

	Total sites sampled			% Positive catches			Mean nominal catch/trap hr			Standard error		
Year	East	West	Total	East	West	Total	East	West	Total	East	West	Total
2004	16	18	34	50.0	33.3	41.2	0.415	0.313	0.361	0.135	0.134	0.094
2005	44	18	62	36.4	50.0	40.3	0.371	0.600	0.437	0.086	0.171	0.079
2006	68	23	91	13.2	30.4	17.6	0.175	0.433	0.240	0.057	0.146	0.057
2007	44	20	64	13.6	5.0	10.9	0.214	0.016	0.152	0.082	0.016	0.058
2008	50	31	81	40.0	51.6	44.4	0.433	0.502	0.459	0.088	0.114	0.069
2009	53	29	82	54.7	31.0	46.3	0.470	0.248	0.391	0.080	0.090	0.062
2010	52	17	69	57.7	23.5	49.3	0.428	0.265	0.388	0.072	0.145	0.065
2011	50	30	80	62.0	50.0	57.5	0.458	0.411	0.441	0.079	0.101	0.062
2012	59	30	89	28.8	23.3	27.0	0.339	0.198	0.292	0.081	0.078	0.060
2013	14	37	51	14.3	8.1	9.8	0.214	0.077	0.115	0.146	0.047	0.052
2014	47	33	80	23.4	21.2	22.5	0.315	0.273	0.298	0.089	0.097	0.066

Table 3. Backward selection procedure for building delta-lognormal submodels for red grouper observed during PC Video Surveys in the northeastern Gulf of Mexico. ** indicates the model chosen for the index.

Model Run #1	Binomial Submodel Type 3 Tests (AIC = 5236.8)						Lognormal Submodel Type 3 Tests (AIC = 340.2)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	1148	116.06	12.90	<.0001	<.0001	9	438	2.76	0.0038
Month	6	1148	5.12	0.85	0.5291	0.5294	6	438	2.01	0.0628
Region	1	1148	1.12	1.12	0.2902	0.2904	2	438	1.93	0.1467
Depth	1	1148	43.84	43.84	<.0001	<.0001	1	438	4.42	0.0360
Model Run #2	Binomial Submodel Type 3 Tests (AIC = 5222.43)						Lognormal Submodel Type 3 Tests (AIC = 339.1)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	1155	125.37	13.93	<.0001	<.0001	9	440	2.65	0.0054
Month			dropped				6	440	3.04	0.0063
Region	1	1155	0.63	0.63	0.4262	0.4264		dropped		
Depth	1	1155	47.68	47.68	<.0001	<.0001	1	440	3.18	0.0754
Model Run #3*	Binomial Submodel Type 3 Tests (AIC = 5224.3)						Lognormal Submodel Type 3 Tests (AIC = 331.8)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	1157	126.33	14.04	<.0001	<.0001	9	441	2.34	0.0139
Month			dropped				6	441	2.80	0.0110
Region			dropped					dropped		
Depth	1	1157	52.22	52.22	<.0001	<.0001		dropped		

Table 4. Backward selection procedure for building delta-lognormal submodels for red grouper observed during PC Trap Surveys in the northeastern Gulf of Mexico. ** indicates the model chosen for the index.

Model Run #1		*Binomial Submodel Type 3 Tests (AIC = 3398.3)*					*Lognormal Submodel Type 3 Tests (AIC = 525.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	722	66.86	7.43	<.0001	<.0001	9	229	3.54	0.0004
Month	5	722	1.16	0.23	0.9489	0.9488	5	229	2.37	0.0402
Region	1	722	8.74	8.74	0.0031	0.0032	1	229	0.08	0.7725
Depth	1	722	17.83	17.83	<.0001	<.0001	1	229	0.40	0.5298
Model Run #2		*Binomial Submodel Type 3 Tests (AIC = 3414.5)*					*Lognormal Submodel Type 3 Tests (AIC = 523.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	731	72.35	8.04	<.0001	<.0001	9	230	3.56	0.0004
Month		dropped					5	230	2.36	0.0407
Region	1	731	9.80	9.80	0.0017	0.0018		dropped		
Depth	1	731	18.79	18.79	<.0001	<.0001	1	230	0.67	0.4134
Model Run #3*		*Binomial Submodel Type 3 Tests (AIC = 3414.5)*					*Lognormal Submodel Type 3 Tests (AIC = 522.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	731	72.35	8.04	<.0001	<.0001	9	234	3.53	0.0004
Month		dropped					5	234	2.11	0.0653
Region	1	731	9.80	9.80	0.0017	0.0018		dropped		
Depth	1	731	18.79	18.79	<.0001	<.0001		dropped		

Figures

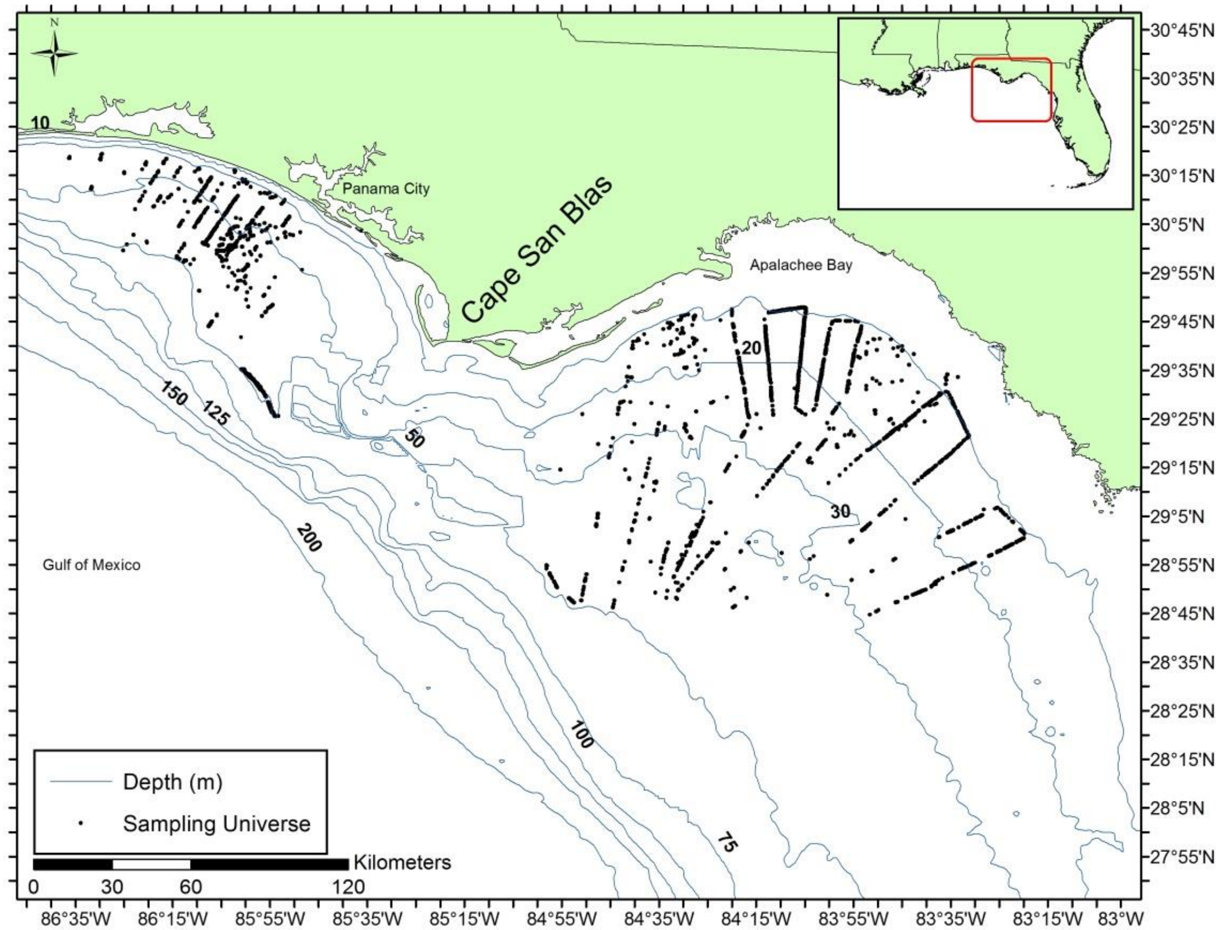


Figure 1. Locations of all natural reefs in the sampling universe of the Panama City NMFS reef fish video survey as of November 2014. Total sites: 2985 -- 1105 west of and 1880 east of Cape San Blas.

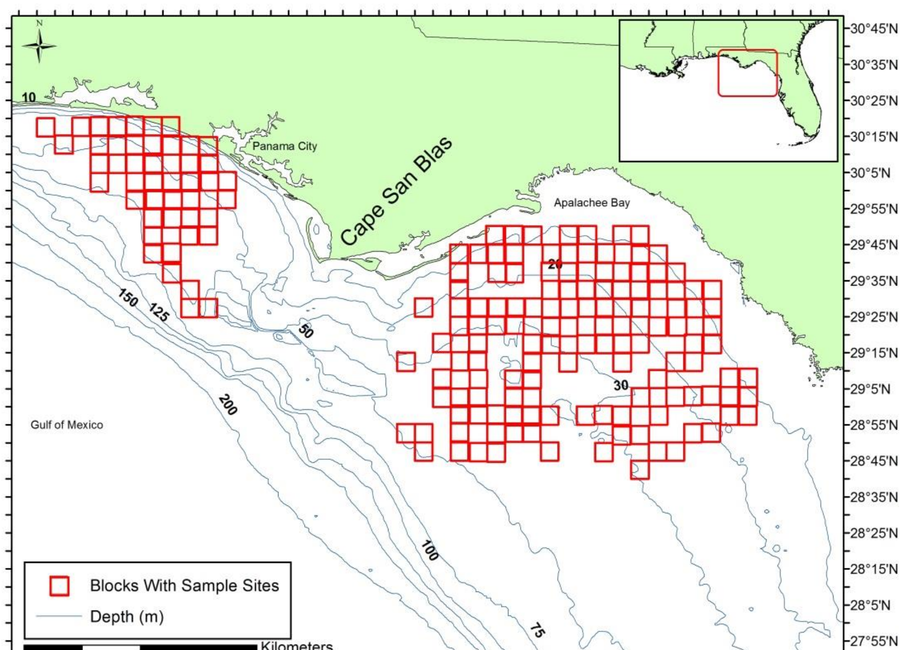


Figure 2. Sampling blocks (5' lat. X 5' long.) of the Panama City reef fish survey as of 2014.

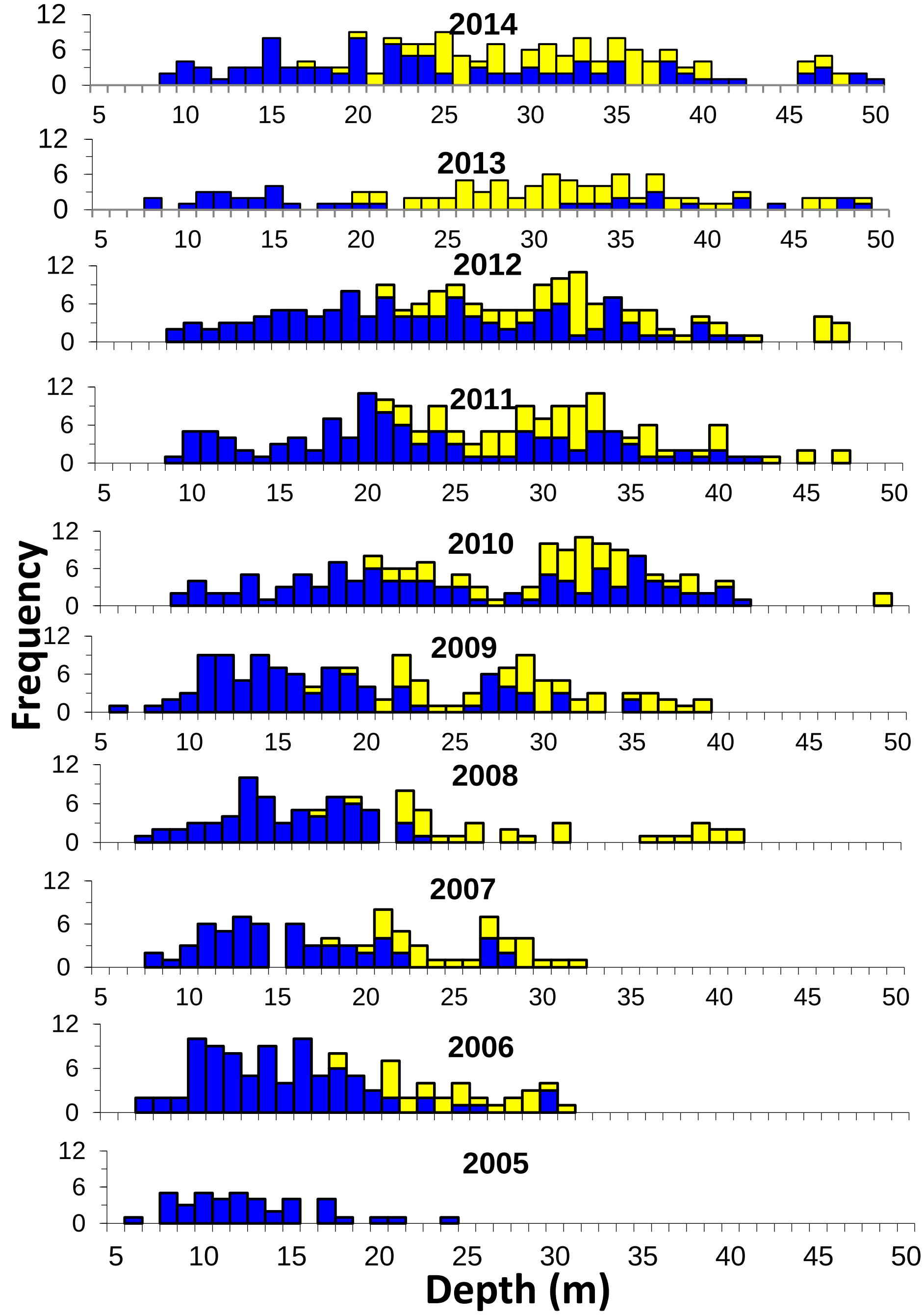


Figure 3. Annual depth distribution of Panama City reef fish survey video sample sites east and west of Cape San Blas, 2005-2014.

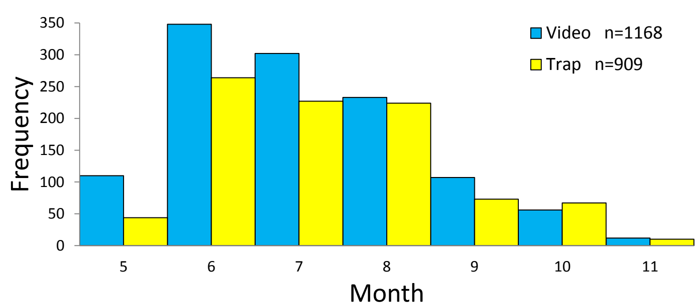


Figure 4. Overall monthly distribution of Panama City reef fish survey video and trap samples (censored data sets only), 2004-2014.

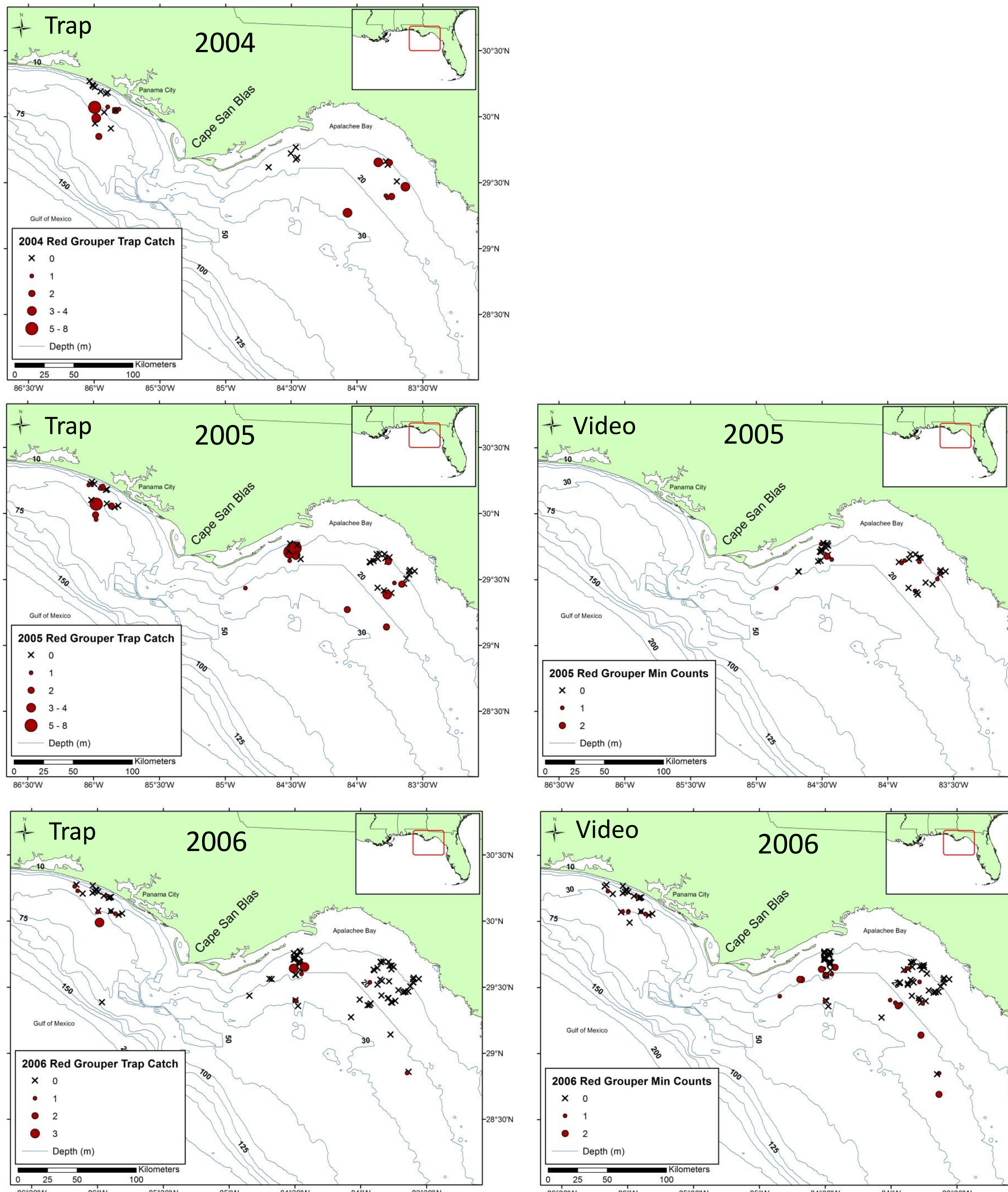


Figure 5. Annual distribution and relative abundance (min counts) of red grouper caught in chevron traps and observed with stationary, high definition video or mpeg cameras in the Panama City NMFS reef fish survey, 2005-2014. Sites sampled with traps or video gear, but where no red grouper were caught or observed, are indicated with an X.

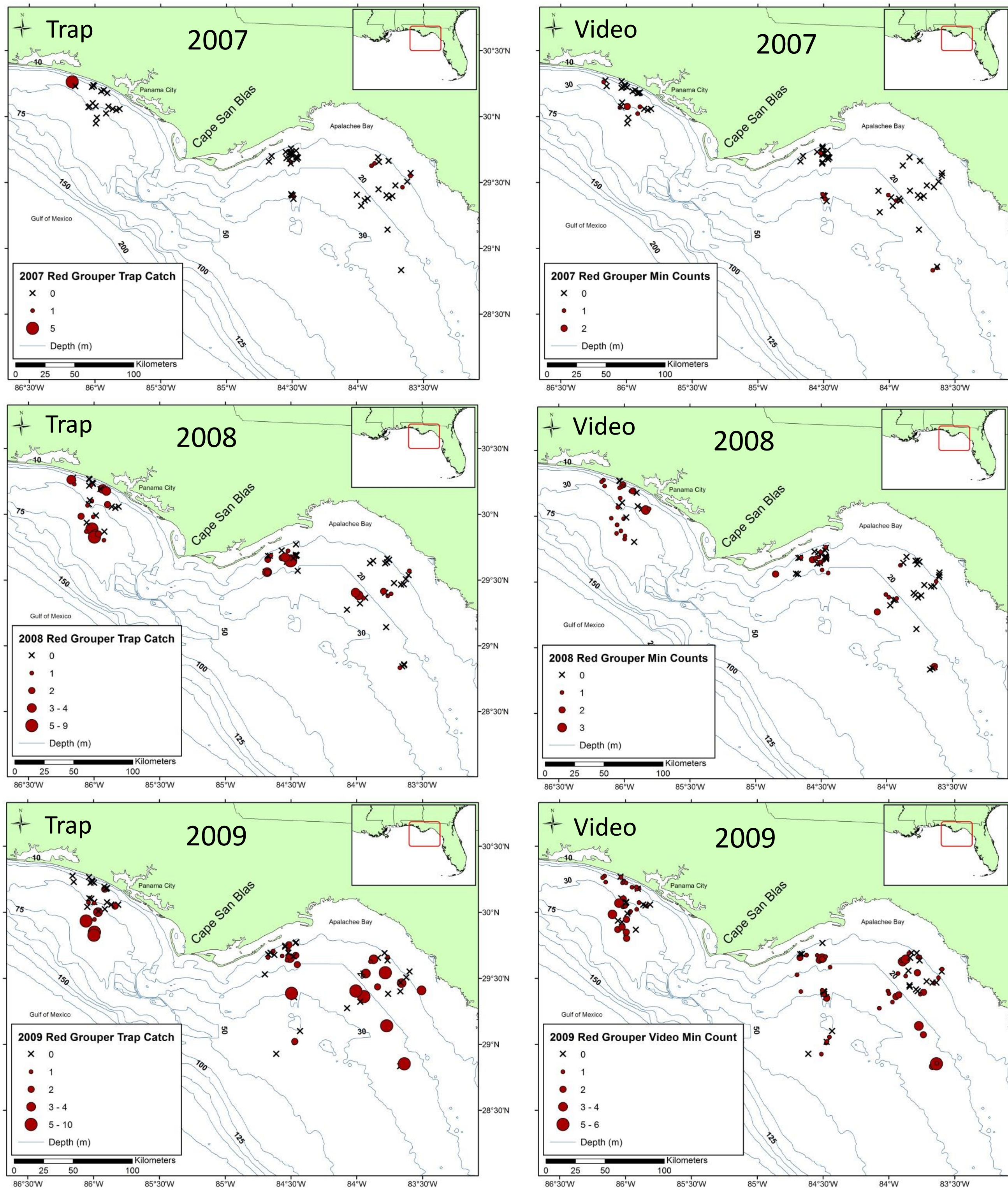


Figure 5 cont. Annual distribution and relative abundance (min counts) of red grouper caught in chevron traps and observed with stationary, high definition video or mpeg cameras in the Panama City NMFS reef fish survey, 2005-2014. Sites sampled with traps or video gear, but where no red grouper were caught or observed, are indicated with an X.

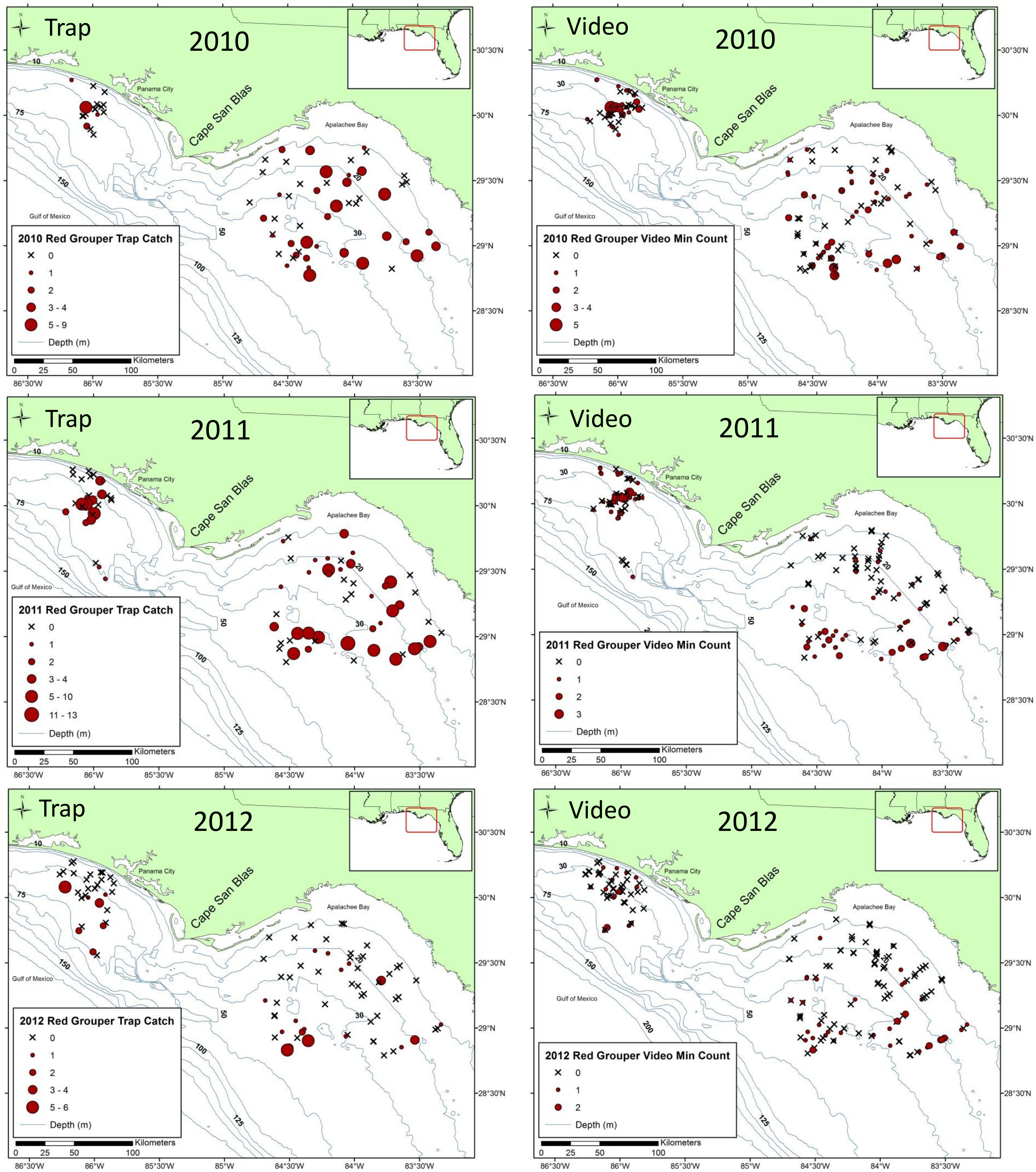


Figure 5 cont. Annual distribution and relative abundance (min counts) of red grouper caught in chevron traps and observed with stationary, high definition video or mpeg cameras in the Panama City NMFS reef fish survey, 2005-2014. Sites sampled with traps or video gear, but where no red grouper were caught or observed, are indicated with an X.

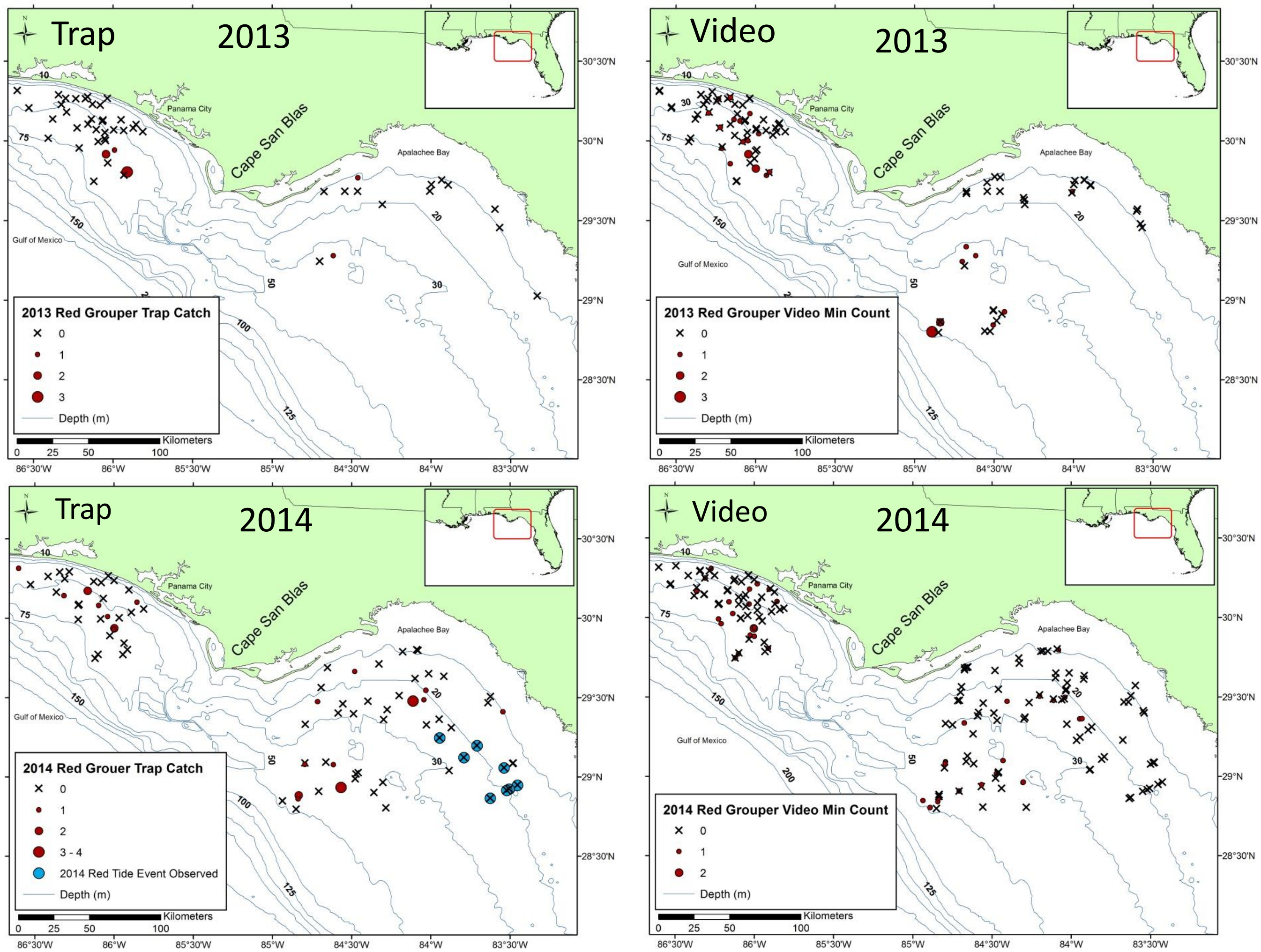


Figure 5 cont. Annual distribution and relative abundance (min counts) of red grouper caught in chevron traps and observed with stationary, high definition video or mpeg cameras in the Panama City NMFS reef fish survey, 2005-2014. Sites sampled with traps or video gear, but where no red grouper were caught or observed, are indicated with an X.

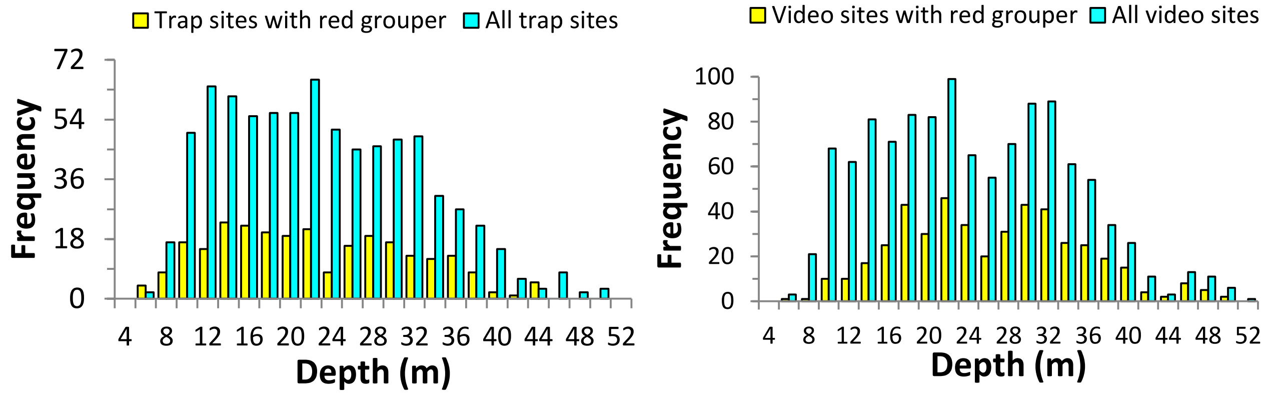


Figure 6. Depth distribution of all trap and video sample sites and all sites with red grouper, 2004-2014.

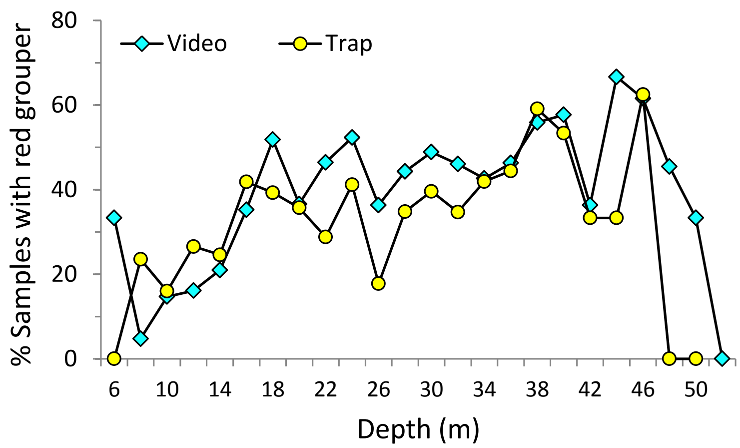


Figure 7. Overall (2004-13) proportions of positive red grouper video and trap samples by depth.

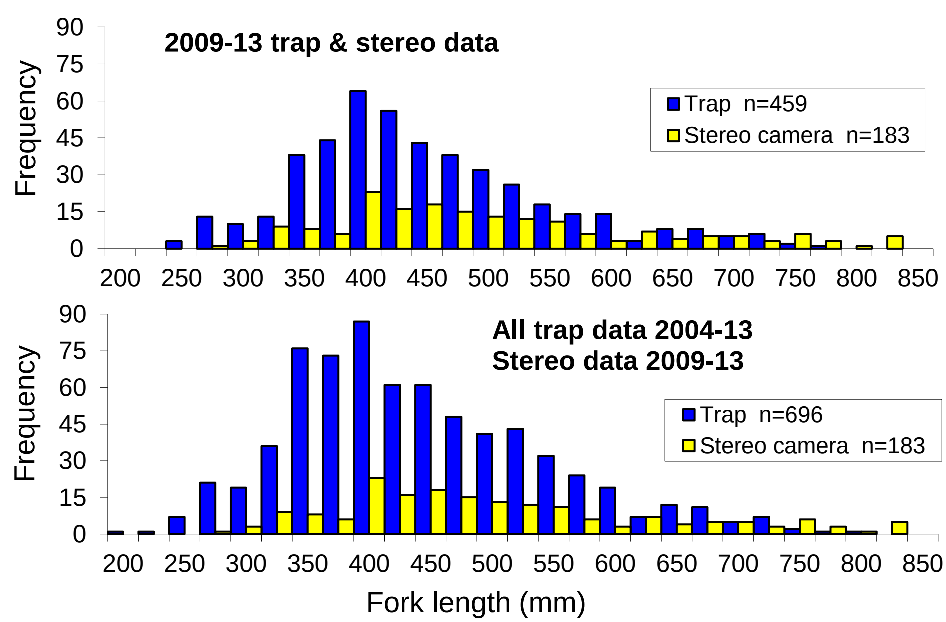


Figure 8. Overall size distributions of (top) all red grouper collected in chevron traps and measured in stereo still images using VMS, 2009-2014, and (bottom) all red grouper collected in chevron traps, 2004-2014, and measured in stereo still images using VMS, 2009-2014.

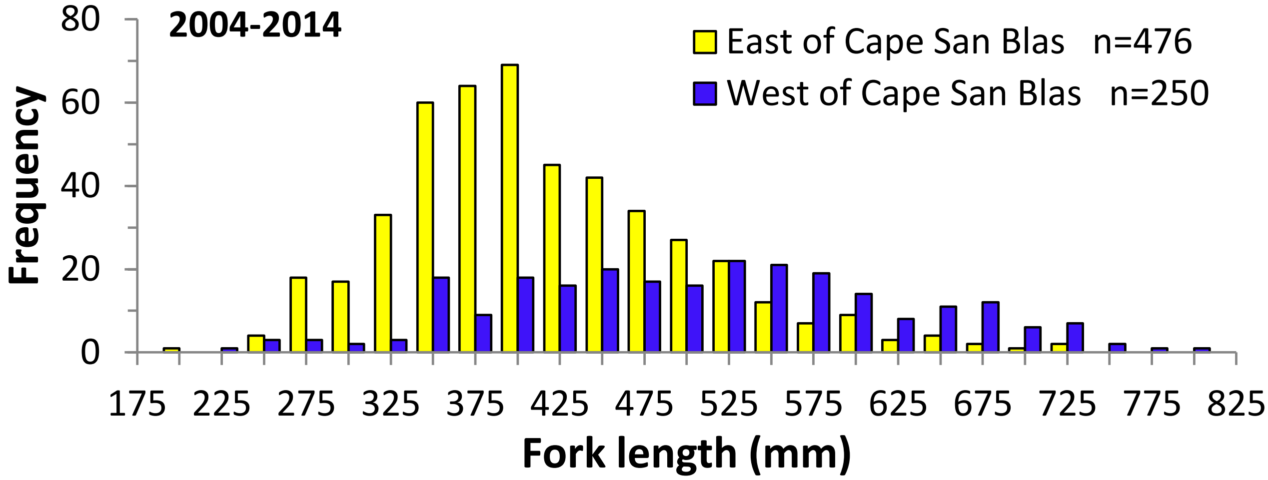


Figure 9. Overall size distributions of trap-caught red grouper by region, 2004-2014.

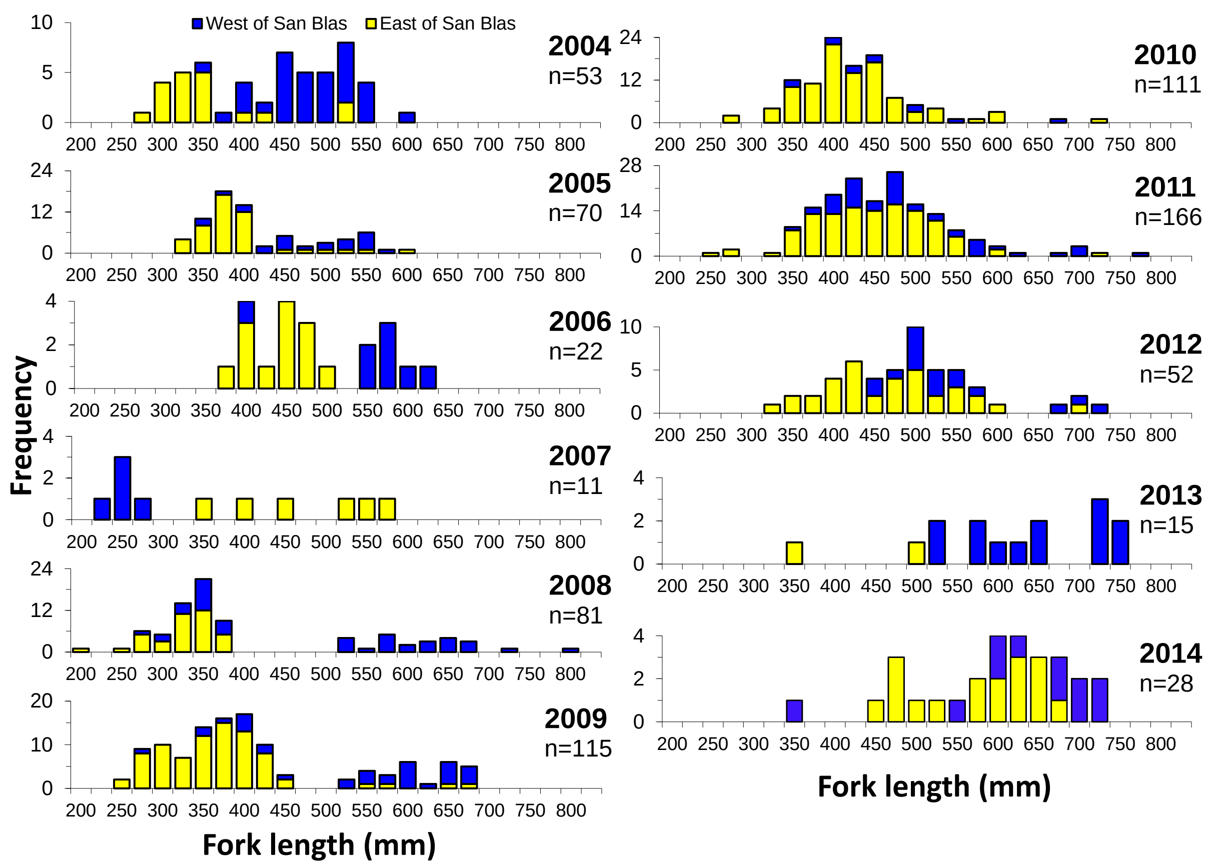


Figure 10. Annual size distributions of red grouper collected in chevron traps, 2004-2014, east and west of Cape San Blas.

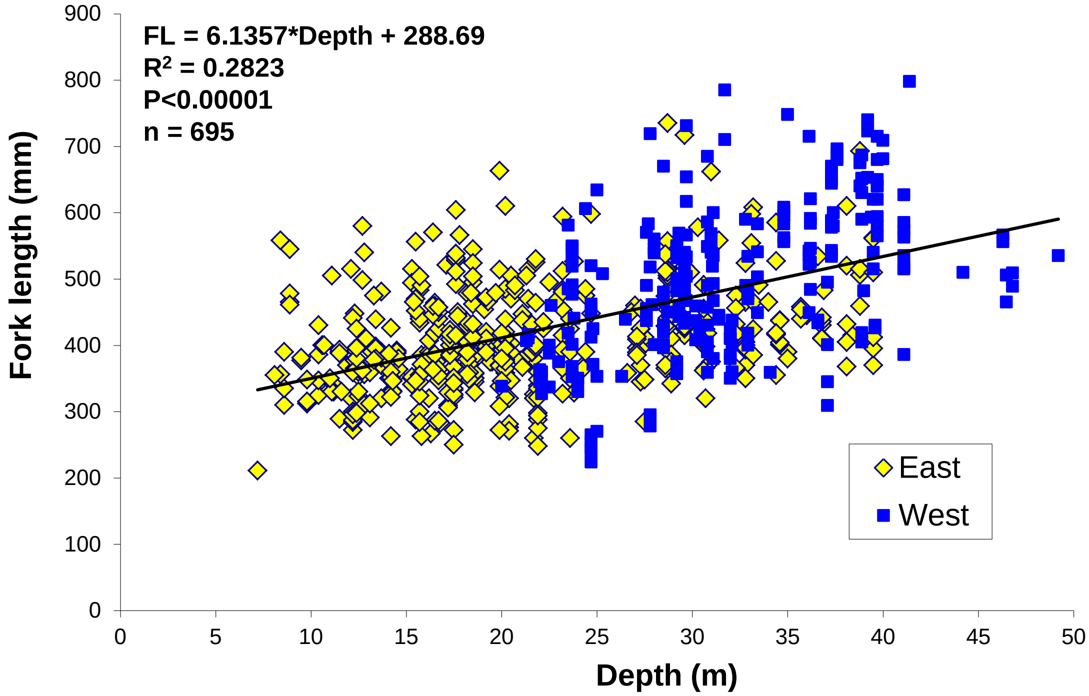


Figure 11. Fork length vs. depth relationship of trap-caught red grouper, 2004-2013.

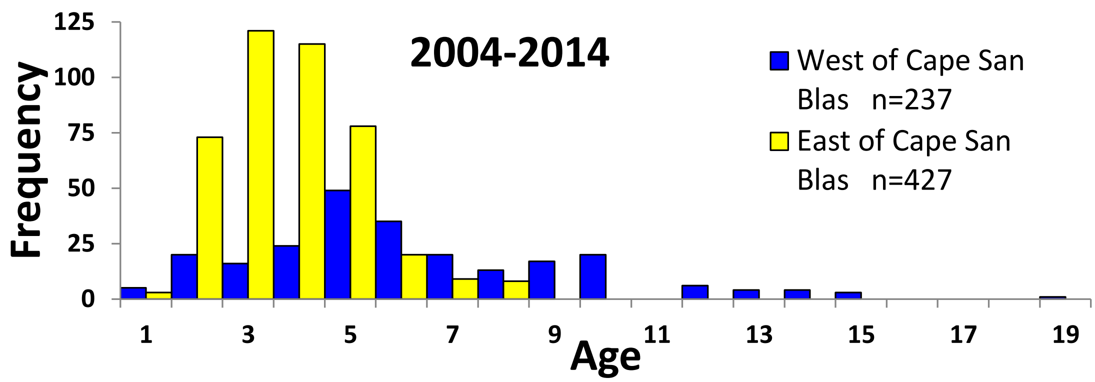


Figure 12. Overall age structure of trap-caught red grouper, 2004-2014, east and west of Cape San Blas.

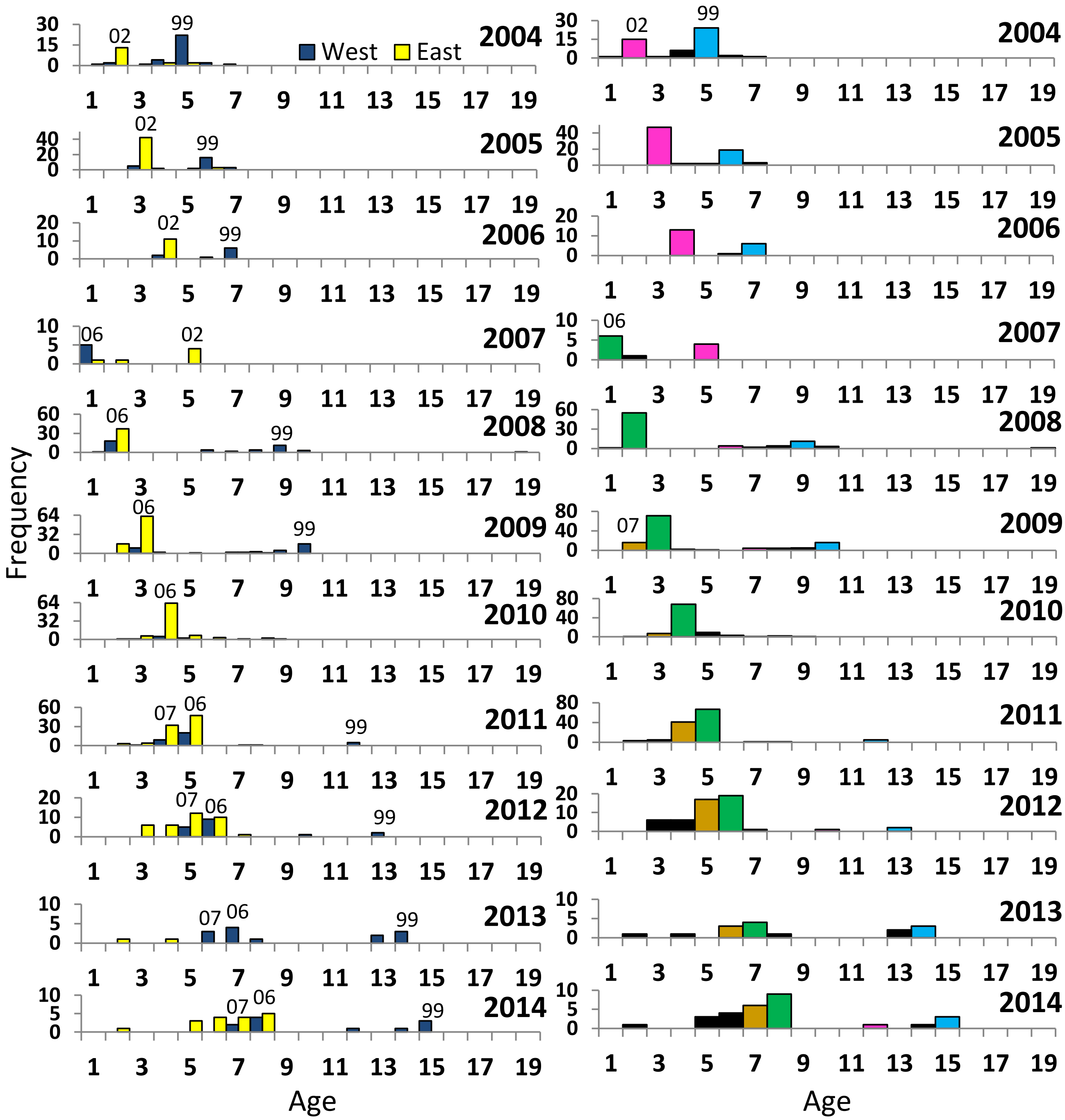


Figure 13. Annual age structure of red grouper caught in chevron traps in the NOAA Panama City lab reef fish survey, 2004-2014, by 1) region, i.e., east (yellow) and west (blue) of Cape San Blas (left panels), and 2) overall (right panels). Strong year classes (1999, 2002, 2006, and 2007) are denoted by year abbreviations in the left panel and by color and year above the first year of appearance in the right panels.

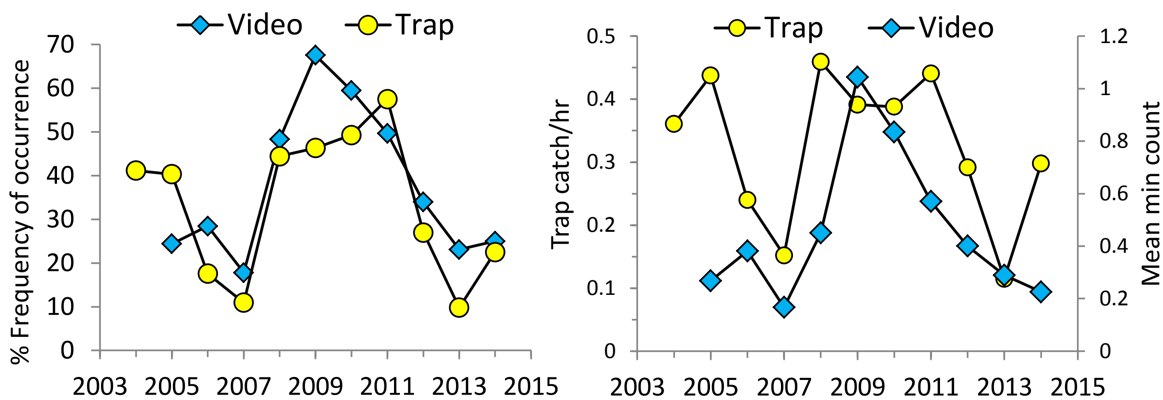


Figure 14. Overall red grouper annual percent frequency of occurrence by gear (left panel) and nominal mean trap catch/hr and video min counts (right panel), 2004-2014.

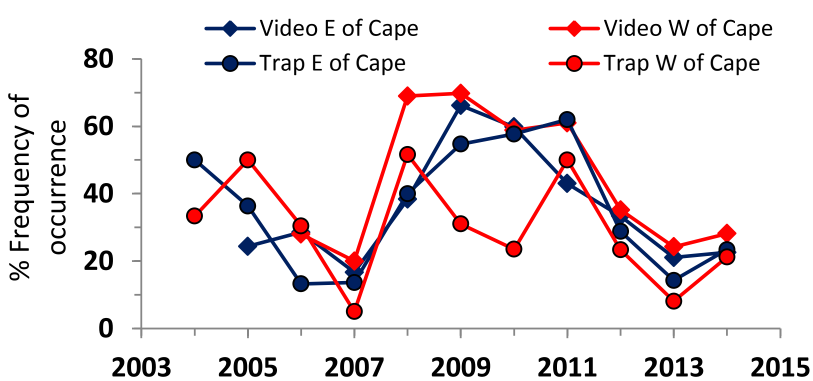


Figure 15. Overall red grouper annual percent frequency of occurrence by gear by area (east and west of Cape San Blas).

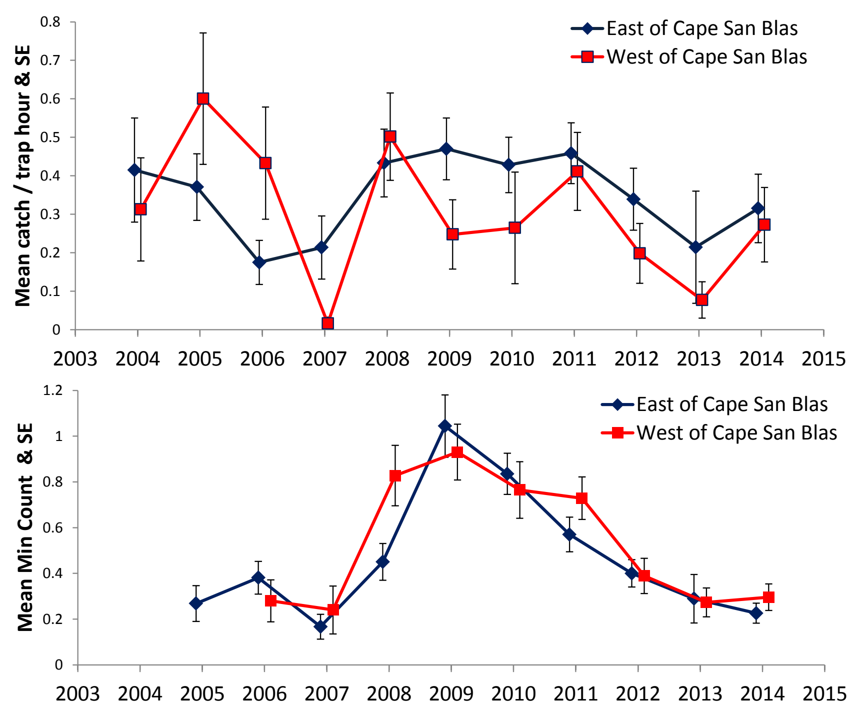
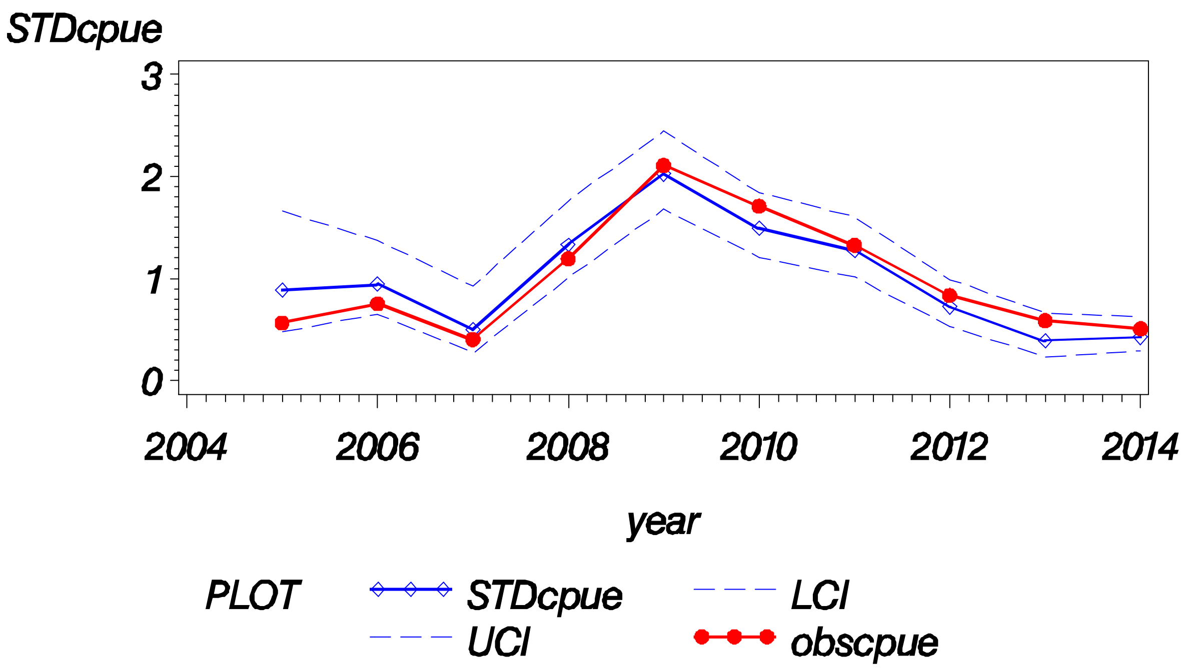


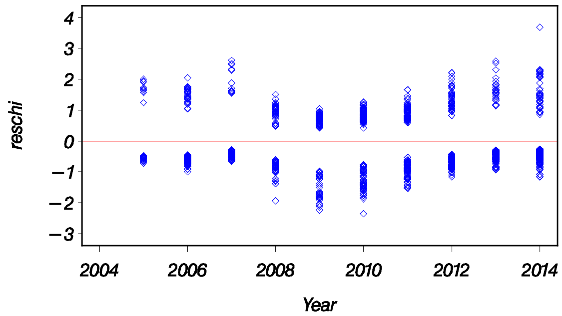
Figure 16. Annual nominal catch/trap hr ± std error (upper panel) and mean video min count ± std error (lower panel) east and west of Cape San Blas.



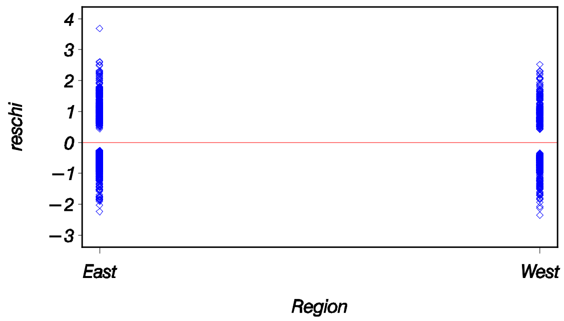
Survey Year	*Frequency*	*N*	*Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
2005	0.24390	41	0.43079	0.88842	0.32002	0.47577	1.65896
2006	0.28440	109	0.45883	0.94625	0.18822	0.65154	1.37428
2007	0.17808	73	0.24214	0.49937	0.31549	0.26969	0.92466
2008	0.47778	90	0.64594	1.33213	0.14026	1.00764	1.76110
2009	0.67568	111	0.98193	2.02505	0.09391	1.67899	2.44243
2010	0.59459	148	0.72365	1.49240	0.10541	1.20942	1.84158
2011	0.49686	159	0.61902	1.27662	0.11443	1.01622	1.60373
2012	0.33962	159	0.35040	0.72264	0.15862	0.52723	0.99047
2013	0.23077	104	0.19017	0.39219	0.26485	0.23299	0.66016
2014	0.23563	174	0.20605	0.42494	0.19604	0.28818	0.62662

Figure 17. PC Video abundance indices for red grouper. STDcpue is the index scaled to a mean of one over the time series. Obscpue is the average nominal CPUE, and LCI and UCI are 95% confidence limits for the scaled index. In the table above, the *frequency* listed is nominal frequency, *N* is the number of video stations, *Index* is the abundance index in CPUE units, *Scaled Index* is the index scaled to a mean of one over the time series, *CV* is the coefficient of variation on the index value, and *LCL* and *UCL* are 95% confidence limits.

a. Chi-square residuals by year.



b. Chi-square residuals by region.



c. QQplot of chi-square residuals.

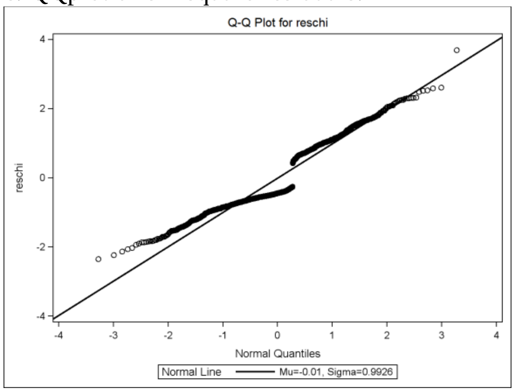
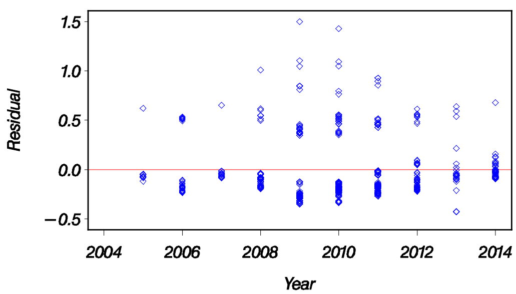
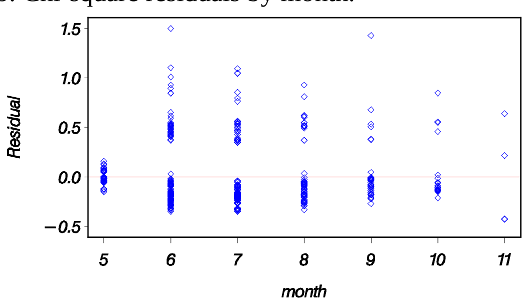


Figure 18. Diagnostic residual plots of the binomial submodel for red grouper observed during PC Video Surveys in the northeastern Gulf of Mexico.

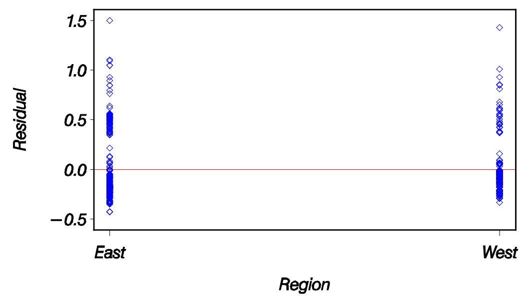
a. Chi-square residuals by year.



b. Chi-square residuals by month.



c. Chi-square residuals by region.



d. QQplot of chi-square residuals.

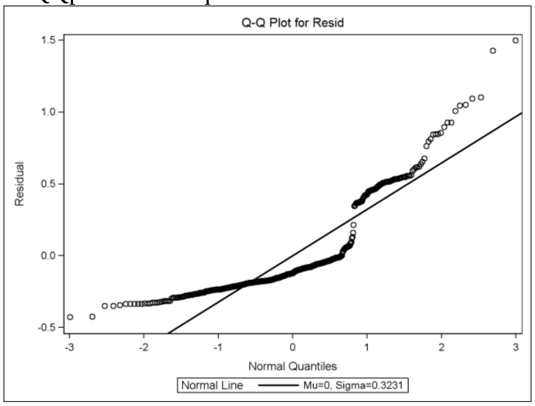
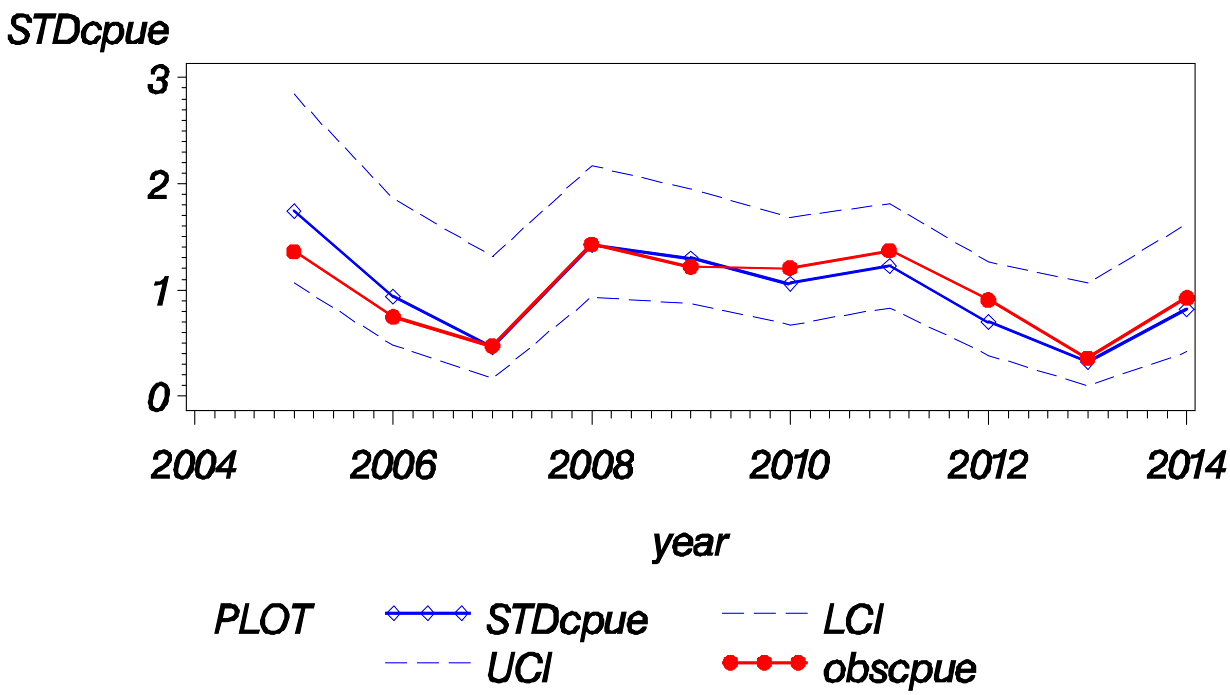


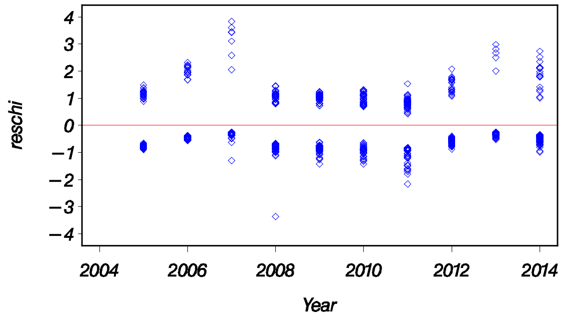
Figure 19. Diagnostic residual plots of the lognormal submodel for red grouper observed during PC Video Surveys in the northeastern Gulf of Mexico.



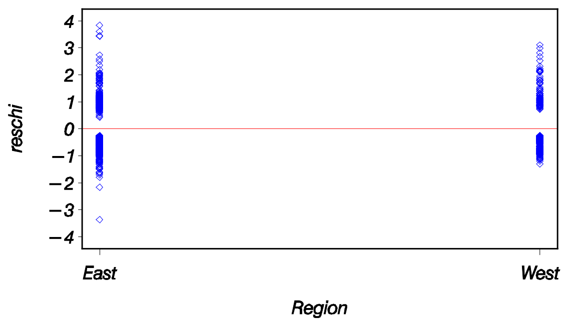
Survey Year	*Frequency*	*N*	*Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
2005	0.40323	62	0.54699	1.74214	0.24819	1.06837	2.84080
2006	0.17582	91	0.29509	0.93985	0.35117	0.47518	1.85890
2007	0.10938	64	0.14559	0.46368	0.55860	0.16352	1.31483
2008	0.44444	81	0.44701	1.42369	0.21248	0.93517	2.16740
2009	0.46341	82	0.40875	1.30183	0.20379	0.86966	1.94878
2010	0.49275	69	0.33341	1.06187	0.23280	0.67070	1.68119
2011	0.57500	80	0.38558	1.22804	0.19659	0.83189	1.81282
2012	0.26966	89	0.21879	0.69684	0.30497	0.38380	1.26522
2013	0.09804	51	0.10093	0.32146	0.65482	0.09734	1.06163
2014	0.22500	80	0.25765	0.82061	0.35132	0.41478	1.62351

Figure 20. PC Trap abundance indices for red grouper. STDcpue is the index scaled to a mean of one over the time series. Obscpue is the average nominal CPUE, and LCI and UCI are 95% confidence limits for the scaled index. In the table above, the *frequency* listed is nominal frequency, *N* is the number of video stations, *Index* is the abundance index in CPUE units, *Scaled Index* is the index scaled to a mean of one over the time series, *CV* is the coefficient of variation on the index value, and *LCL* and *UCL* are 95% confidence limits.

a. Chi-square residuals by year.



b. Chi-square residuals by region.



c. QQplot of chi-square residuals.

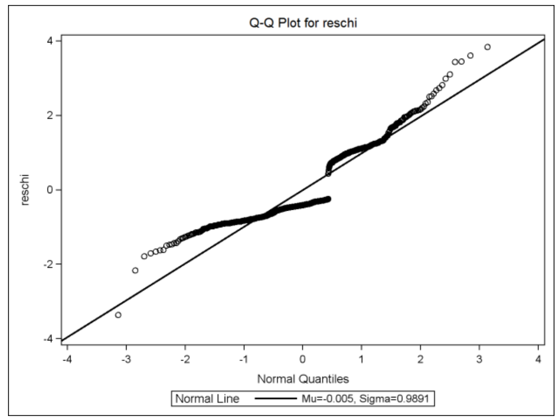
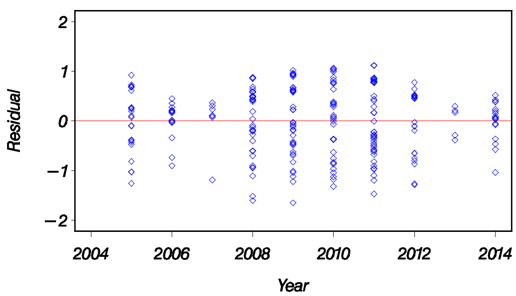
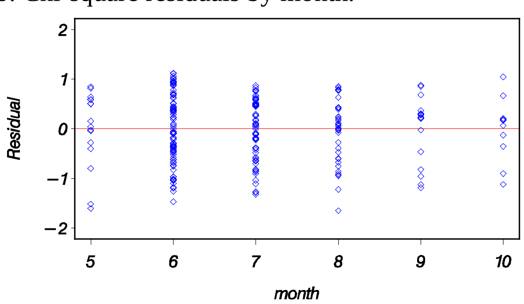


Figure 21. Diagnostic residual plots of the binomial submodel for red grouper observed during PC Trap Surveys in the northeastern Gulf of Mexico.

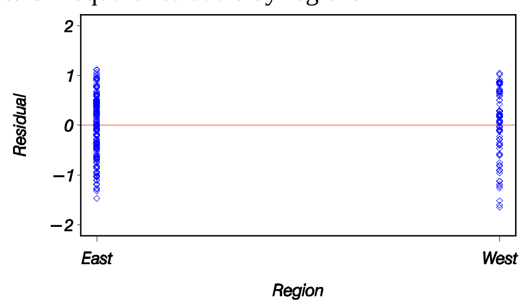
a. Chi-square residuals by year.



b. Chi-square residuals by month.



c. Chi-square residuals by region.



d. QQplot of chi-square residuals.

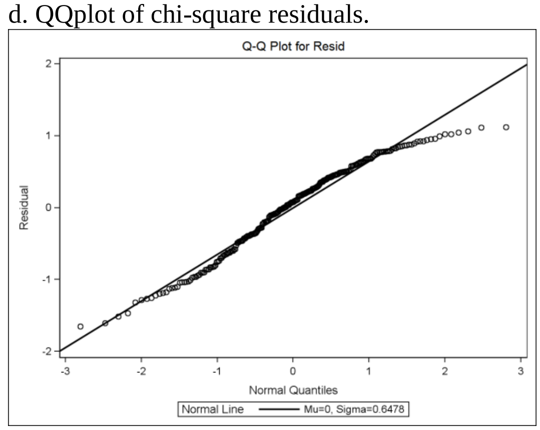


Figure 22. Diagnostic residual plots of the lognormal submodel for red grouper observed during PC Trap Surveys in the northeastern Gulf of Mexico.