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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 in the northeast Gulf of Mexico, off Panama City, FL. The primary objective of the PC survey was 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. Initially, the PC survey used the same chevron trap configuration and soak time that has been used by the South Atlantic MARMAP program for over 30 years (McGovern et. al. 1998), as traps are efficient at capturing a broad size range of several species of reef fish (Nelson et. al.1982, Collins 1990). However, 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 tend 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 (Fig. 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 in 2005, 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 directly followed by a single trap. Beginning in 2009, trap effort was reduced ~50%, with one deployed at every other video site. This was done to increase the number of video samples, and thereby the accuracy and precision of the video abundance estimates. 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.

Through 2009, sampling was systematic because of a very limited sampling universe. In 2010, the design was changed to 2-stage unequal probability sampling design after side scan sonar surveys that year yielded an order of magnitude increase in that universe (Fig. 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 selected first. Then, two known reef sites, a minimum of 250 m apart within each selected block are randomly selected (Fig. 2). Alternates are also selected for use and are utilized when another boat is found to be fishing the site or no hard bottom can be found with sonar at the designated location.

Depth coverage was ~8-30 m during 2004-07 and steadily expanded to ~8 – 52 m in 2008 (Fig. 3). Sampling effort has also increased since 2004 with a minimum of 59 and maximum of 184 video samples per year. Sample sizes per year are displayed in Table 1.

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 (Fig. 4) Sampling east of Cape San Blas in 2013 was greatly reduced (down ~66%) and done later than normal (Oct. and Nov.) because of late receipt of funding, ship mechanical issues, and weather delays.

Methods

Sampling was conducted during daytime from one hr after sunrise until one hr before sunset. Chevron traps were baited each new drop, with 3 previously frozen Atlantic mackerel *Scomber scombrus,* and soaked for 1.5 hr. Traps were dropped 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 a max of 5 randomly subsampled specimens of 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 (2009-2014) and SeaGIS software (2015). 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 in 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, predetermined, equal portions of each edge of the video monitor were digitally cropped so that only the central 65° of the field of view was visible due to the GoPro's much larger field of view (122 vs 65º). Twenty min of the tape were viewed, beginning when the cloud of sediment disturbed by the landing of the array had 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, fish identifications were confirmed on the 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). Stereo 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 stereo files were examined to obtain fish measurements using VMS or SeaGIS, 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 data. All video samples were screened, and those with no visible hard or live bottom and no visible species of fish strongly associated with hard bottom habitat, as well as samples where the view was obscured because of poor visibility, video out of focus, etc., were excluded from calculations of relative abundance. In 2014, ten video samples from an area with an ongoing red tide bloom which showed no or virtually no evidence of living fish, were also censored. Results of video censoring are displayed in Table 2.

The CPUE and proportion positive findings for the trap survey were based on all samples except those from sites which had already been sampled in a given year and 8 sites in 2014 located in an ongoing red tide bloom.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for gray snapper (Pennington, 1983; Bradu and Mundlak, 1970). 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 (*cf.* Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) was estimated as:

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

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:

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

and

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

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 using the delta method approximation

(4) $$V(I_y) \approx V(c_y) p_y^2 + c_y^2 V(p_y).$$

A covariance term is not included in the variance estimator since there is no correlation between the estimator of the proportion positive and the mean CPUE given presence. The two estimators are derived independently and have been shown to not covary for a given year (Christman, unpublished).

The submodels of the delta-lognormal model were built using a backward selection procedure based on type III analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC. Variables that could be included in the submodels were:

Year: 2006 – 2015
Depth: 6.2 – 57.2 m (continuous variable)
Month: May – November
Region: East of Cape San Blas, FL, West of Cape San Blas, FL

Results

Since the Panama City lab reef fish survey began in 2004/5, gray snapper have consistently and commonly been observed with stationary video gear, but seldom captured in chevron traps across the inner and mid-West Florida shelf, both east and west of Cape San Blas (Tables 1 and 3, Fig. 5 A and B) (DeVries et al. 2008, 2009, 2012). Out of 970 traps, only 3 captured gray snapper, so there are no trap results herein. The overall frequency distribution of min counts suggests that the species often forms small schools, with approximately 90% of positive observations being 10 fish or less (Fig. 6). Gray snapper were encountered throughout the full depth range on both sides of the Cape and did not show any correlation between depth and length (Fig. 15).

Encounter rates

From 2006-2015, overall gray snapper annual proportion of positive video samples ranged from 0.27 to 0.51 ($\bar{x}$ =0.41). During those years annual proportion of positive video samples ranged from 0.28 to 0.49 ($\bar{x}$ = 0.42) east of Cape San Blas and 0.22 to 0.65 ($\bar{x}$ = 0.41) west of the Cape (Table 1, Fig. 9). From 2006-2009 the annual proportion positive was consistently higher in the west ($\bar{x}$ =.40 vs .58). In 2013-2015 the annual proportion positive was consistently higher in the east (.45 vs .27) with 2010-2012 showing relatively similar encounter rates across both regions (Fig. 9). Gray snapper were frequently observed across all but the shallowest depth ranges east of Cape San Blas, but were common by a depth of 10m. The region west of Cape San Blas did not have any samples shallower than 16m and gray snapper were observed throughout the entire depth range. This difference in sampling between regions is attributed to a much shallower slope of the West Florida Shelf in the east, which hosts a large amount of hard bottom habitat. In the east, the encounter rates increased with depth, moving from a mean of 0.11 in the 5-15m depth range, to 0.38 in the 17-25m range, and then 0.65 in the 25-51m range. In the western region, the annual proportion positive of video samples showed a decreasing trend with increasing depth. In the depth range of 15-35m, the mean encounter rate was 0.54 decreasing to 0.18 in the 35-45m range (Table 3, Fig. 8 A and B).

Abundance trends

Not surprisingly, patterns in relative abundance of gray snapper were very similar to those seen in proportion positives. A significant decline in mean nominal video min counts was observed on both sides of Cape San Blas in 2007 ($\bar{x}$ =2.35 to 0.45, p=.01 East; $\bar{x}$ =3.13 to 0.72, p=.006 West), followed by a sharp increase in 2008 ($\bar{x}$ =0.45 to 0.5.41, p=.003 East; $\bar{x}$ =0.72 to 2.76, p=.007 West) (Tables 1 and 3 Figures 11 and 12). Along with similarities in the proportion positive occurrences, abundance trends provide evidence of the entrance of a strong year classes, and likely a single stock inhabiting both sides of Cape San Blas.

Gray snapper relative abundance appeared to be relatively stable in 2009 and 2010 with a drop in relative abundance and frequency of occurrence in the eastern region in 2011 ($\bar{x}$ =2.67 to 0.76, p<.0001) then increasing again in 2012 ($\bar{x}$ = 0.76 to 1.36, p=.02). The western region showed a modest decline from 2010 to 2013, showing a mean of 2.43 in 2010 to 0.88 in 2013 (p=.02). 2014 and 2015 showed increasing frequency of occurrence in the western region as well as non-significant increases in relative abundance.

Annual GIS plots of video min counts of gray snapper showed similar geographic patterns in relative abundance trends between 2005 and 2015 (Fig. 12).

Gray snapper lengths calculated from stereo cameras during 2009-2015 displayed normal distributions both east and west of Cape San Blas (Figs.13, 14). However, mean lengths of gray snapper were significantly larger ($p<.00001$) west of Cape San Blas than the east - $\bar{x}$ ± 95% CL: 409 ± 14 vs 373 ±10 mm FL)(Table 4). The minimum length was slightly smaller in the east and the proportion of small fish was higher in the east than the west – 170 vs 199 mm and 18% vs 9% <300 mm FL in the east vs the west (Fig. 14).

Annual size distributions in the east from the stereo camera survey shifted to greater lengths (although sample sizes were small) each year from 2009 to 2011, and then dropped noticeably in 2012 to a median size of ~371 mm, suggesting recruitment into the region of a new year class noticeably larger than those in the previous two years (Fig. 16). The size structure continued to decline in 2013, suggesting a larger proportion of smaller fish being recorded by the stereo cameras. Small sample sizes in the video survey obscured modal progressions of annual length frequencies, making it difficult to interpret the observed patterns. These results add credence to the previous assertion that there appeared to be a new strong year class that first became vulnerable to survey gear in 2012, and probably a similar event in 2009. While the western region displayed a similar size range to the eastern region, it did not display large influxes of small fish (Fig. 16).

The regression of fork length on depth from the video survey was not significant for both regions combined ($p=.92$) as well as the region east of Cape San Blas ($p=.89$) (Fig. 15). The area west of Cape San Blas showed a very moderate correlation of length and depth, however, this only accounted for ~2% of the variation in the regression ($p=.04$) and a wide range of lengths were observed across the entire depth range (Fig 15).

Index of Abundance

For the Panama City Video Survey abundance index of gray snapper, year, depth, month and region were retained in the binomial submodel, while only year was retained in the lognormal submodels. A summary of the factors used in the analysis is presented in Table 7. Table 5 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 5119.7and 1285.3, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 18, and indicate the distribution of the residuals is normal. The index, scaled to a mean of one over the time series, dropped dramatically in 2007 then peaked in 2008. The gray snapper index declined until 2011 where it has been relatively stable since. Annual abundance indices are presented in Table 6 and Figure 17.

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Tables

Table 1: Annual video survey sample sizes, proportion positive occurrences, mean nominal video min counts, and standard errors of gray snapper east and west of Cape San Blas, 2006-2015.

	Total sites sampled			Proportion positive occurrences			Mean min count (MaxN)			Standard error		
Year	East	West	Total	East	West	Total	East	West	Total	East	West	Total
2006	48	23	71	0.35	0.61	0.44	2.35	3.13	2.61	0.81	0.88	0.62
2007	29	22	51	0.45	0.59	0.51	0.45	0.73	0.57	0.09	0.15	0.09
2008	56	29	85	0.38	0.48	0.41	5.41	2.76	4.51	1.74	0.77	1.18
2009	62	37	99	0.42	0.65	0.51	3.53	2.68	3.21	1.03	0.54	0.68
2010	92	51	143	0.49	0.49	0.49	2.67	2.43	2.59	0.45	0.63	0.36
2011	99	57	156	0.28	0.44	0.34	0.76	2.07	1.24	0.19	0.52	0.23
2012	101	49	150	0.42	0.41	0.41	1.36	1.49	1.40	0.21	0.36	0.18
2013	34	60	94	0.38	0.22	0.28	2.38	0.88	1.43	0.73	0.37	0.36
2014	93	71	164	0.49	0.28	0.40	2.15	0.93	1.62	0.38	0.30	0.25
2015	99	58	157	0.47	0.31	0.41	2.21	1.36	1.90	0.59	0.44	0.40
Total	**713**	**457**	**1170**	**0.42**	**0.41**	**0.41**	**2.25**	**1.71**	**2.04**	**0.22**	**0.16**	**0.15**

Table 2: Annual results of video censoring for analysis and index construction.

	East		West		Combined	
Year	Total video sites	Sites retained for analysis	Total video sites	Sites retained for analysis	Total video sites	Sites retained for analysis
2005	41	41			41	41
2006	89	84	25	25	114	109
2007	57	48	29	24	86	72
2008	66	61	31	29	97	90
2009	97	68	47	44	144	112
2010	109	97	53	50	162	147
2011	115	100	64	60	179	160
2012	115	105	59	53	174	158
2013	39	38	72	67	111	105
2014	113	103	71	71	184	174
2015	112	99	65	58	177	157

Table 3: Video survey sample sizes and proportion positive occurrences of gray snapper by depth zone snapper east and west of Cape San Blas, 2006-2015 all years combined.

	Total sites sampled			Proportion positive occurrences		
Depth (m)	East	West	Total	East	West	Total
3-5						
5-7	2		2	0.00		0.00
7-9	12		13	0.00		0.00
9-11	55		55	0.05		0.05
11-13	54		54	0.22		0.22
13-15	75		75	0.27		0.27
15-17	65	1	66	0.18	1.00	0.20
17-19	75	7	82	0.41	0.57	0.43
19-21	76	14	90	0.37	0.43	0.38
21-23	51	49	100	0.35	0.78	0.56
23-25	37	37	74	0.38	0.57	0.47
25-27	20	44	64	0.70	0.39	0.48
27-29	36	43	79	0.56	0.37	0.46
29-31	38	54	92	0.63	0.46	0.53
31-33	26	65	91	0.85	0.34	0.48
33-35	36	30	66	0.89	0.47	0.70
35-37	32	34	66	0.69	0.21	0.44
37-39	18	23	41	0.72	0.26	0.46
39-41	12	17	29	0.50	0.24	0.34
41-43	7	7	14	0.57	0.14	0.36
43-45	3	3	6	0.33	0.00	0.17
45-47	3	13	16	1.00	0.23	0.38
47-49	7	10	17	0.57	0.00	0.24
49-51	4	1	5	0.50	0.00	0.40
51-53		1	1		0.00	0.00
53-55						
55-57		2	2		0.50	0.50
57-59		1	1		0.00	0.00
59-61						
Total	**744**	**457**	**1201**	**0.41**	**0.41**	**0.41**

Table 4: Descriptive statistics of gray snapper sizes obtained from stereo camera measurements (fork length mm) 2009-2015.

	East	**West**	**Total**
Min.	170	199	170
1st Qu.	308	349	314
Median	351	405	368
Mean	373	408	384
Confidence Level on Mean (95%)	10	14	8
3rd Qu.	429	464	446
Max.	647	633	647
Count	358	157	515

Table 5: Summary of backward selection procedure for building delta-lognormal submodels for gray snapper Panama City Video Survey index of relative abundance from 2006 to 2015.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 5119.7)*						*Lognormal Submodel Type 3 Tests (AIC 1295.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	1152	42.03	4.67	<.0001	<.0001	9	466	7.49	<.0001
Depth	1	1152	41.21	41.21	<.0001	<.0001	1	466	2.76	0.0973
Month	6	1152	27.59	4.60	0.0001	0.0001	6	466	1.23	0.2877
Region	1	1152	5.99	5.99	0.0144	0.0146	1	466	3.41	0.0655
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 5119.7)*						*Lognormal Submodel Type 3 Tests (AIC 1293.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	1152	42.03	4.67	<.0001	<.0001	9	472	7.35	<.0001
Depth	1	1152	41.21	41.21	<.0001	<.0001	1	472	2.47	0.1165
Month	6	1152	27.59	4.60	0.0001	0.0001		Dropped		
Region	1	1152	5.99	5.99	0.0144	0.0146	1	472	0.96	0.3279
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 5119.7)*						*Lognormal Submodel Type 3 Tests (AIC 1290.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	1152	42.03	4.67	<.0001	<.0001	9	473	7.37	<.0001
Depth	1	1152	41.21	41.21	<.0001	<.0001	1	473	2.99	0.0843
Month	6	1152	27.59	4.60	0.0001	0.0001		Dropped		
Region	1	1152	5.99	5.99	0.0144	0.0146		Dropped		
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 5119.7)*						*Lognormal Submodel Type 3 Tests (AIC 1285.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	1152	42.03	4.67	<.0001	<.0001	9	474	7.40	<.0001
Depth	1	1152	41.21	41.21	<.0001	<.0001		Dropped		
Month	6	1152	27.59	4.60	0.0001	0.0001		Dropped		
Region	1	1152	5.99	5.99	0.0144	0.0146		Dropped		

Table 6: Indices of gray snapper abundance developed using the delta-lognormal (DL) model for the Panama City Video Survey from 2006-2015. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per video-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2006	0.43662	71	2.90999	1.39257	0.20282	0.93202	2.08070
2007	0.50980	51	1.03139	0.49357	0.20848	0.32673	0.74560
2008	0.41176	85	4.11678	1.97008	0.20291	1.31830	2.94412
2009	0.50505	99	3.52291	1.68589	0.15876	1.22967	2.31136
2010	0.48951	143	2.60384	1.24607	0.15538	0.91492	1.69708
2011	0.33974	156	1.43427	0.68637	0.17941	0.48080	0.97984
2012	0.41333	150	1.36794	0.65463	0.18579	0.45288	0.94625
2013	0.27660	94	1.12251	0.53718	0.25892	0.32275	0.89407
2014	0.40244	164	1.46350	0.70036	0.17238	0.49738	0.98617
2015	0.41401	157	1.32335	0.63329	0.18160	0.44172	0.90795

Table 7: Summary of the factors used in constructing the gray snapper abundance index from the Panama City Video Survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
MONTH	May	117	57	0.48718	2.02564
MONTH	June	354	119	0.33616	1.68362
MONTH	July	359	171	0.47632	2.16992
MONTH	August	162	61	0.37654	2.70370
MONTH	September	107	43	0.40187	1.50467
MONTH	October	59	27	0.45763	2.54237
MONTH	November	12	6	0.50000	2.08333
REGION	East	713	298	0.41795	2.25245
REGION	West	457	186	0.40700	1.70678
YEAR	2006	71	31	0.43662	2.60563
YEAR	2007	51	26	0.50980	0.56863
YEAR	2008	85	35	0.41176	4.50588
YEAR	2009	99	50	0.50505	3.21212
YEAR	2010	143	70	0.48951	2.58741
YEAR	2011	156	53	0.33974	1.23718
YEAR	2012	150	62	0.41333	1.40000
YEAR	2013	94	26	0.27660	1.42553
YEAR	2014	164	66	0.40244	1.62195
YEAR	2015	157	65	0.41401	1.89809

Figures

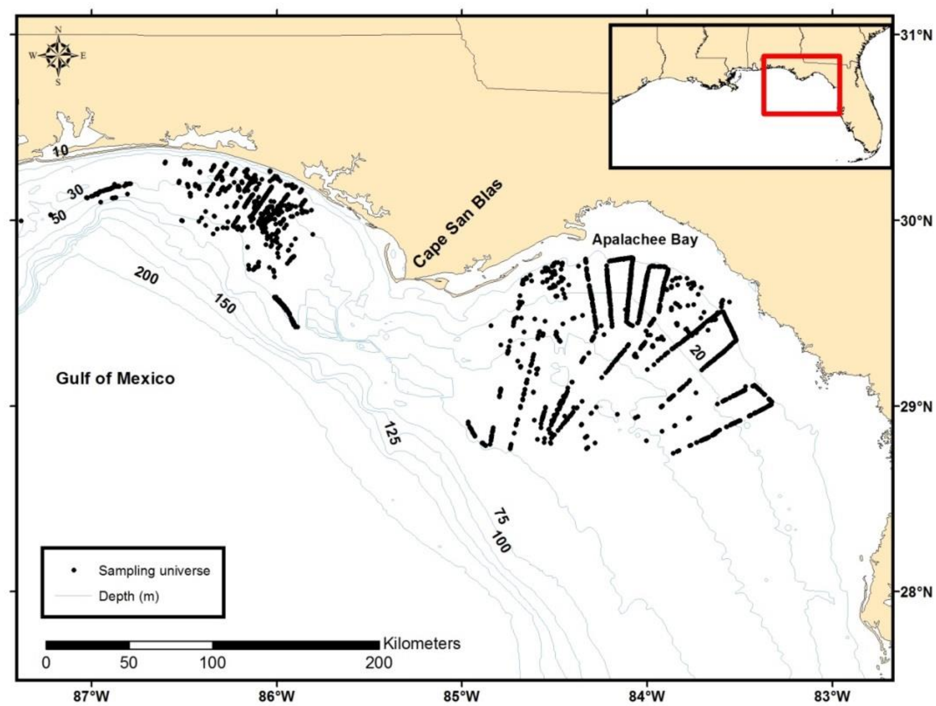

Figure 1. Locations of all natural reefs in the sampling universe of the Panama City NMFS reef fish video survey as of January 2017. Total sites: 3241 – 1362 west, and 1879 east, of Cape San Blas. Isobaths are in meters.

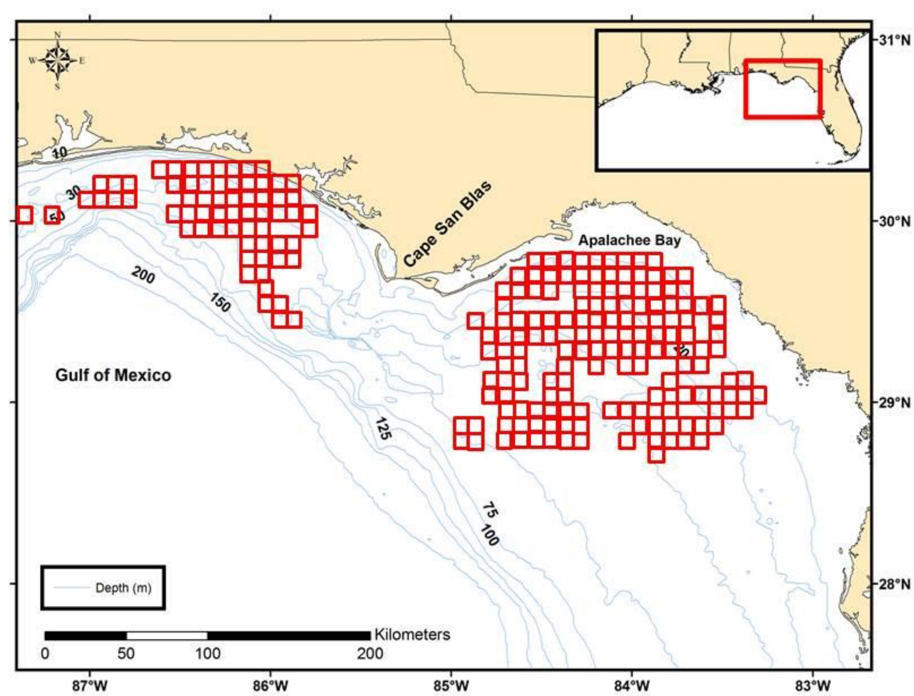

Figure 2. Sampling blocks (5 min lat. x 5 min. long.) of the Panama City reef fish survey. Blocks in red contain known hard bottom reefs and are subject to being selected for sampling.

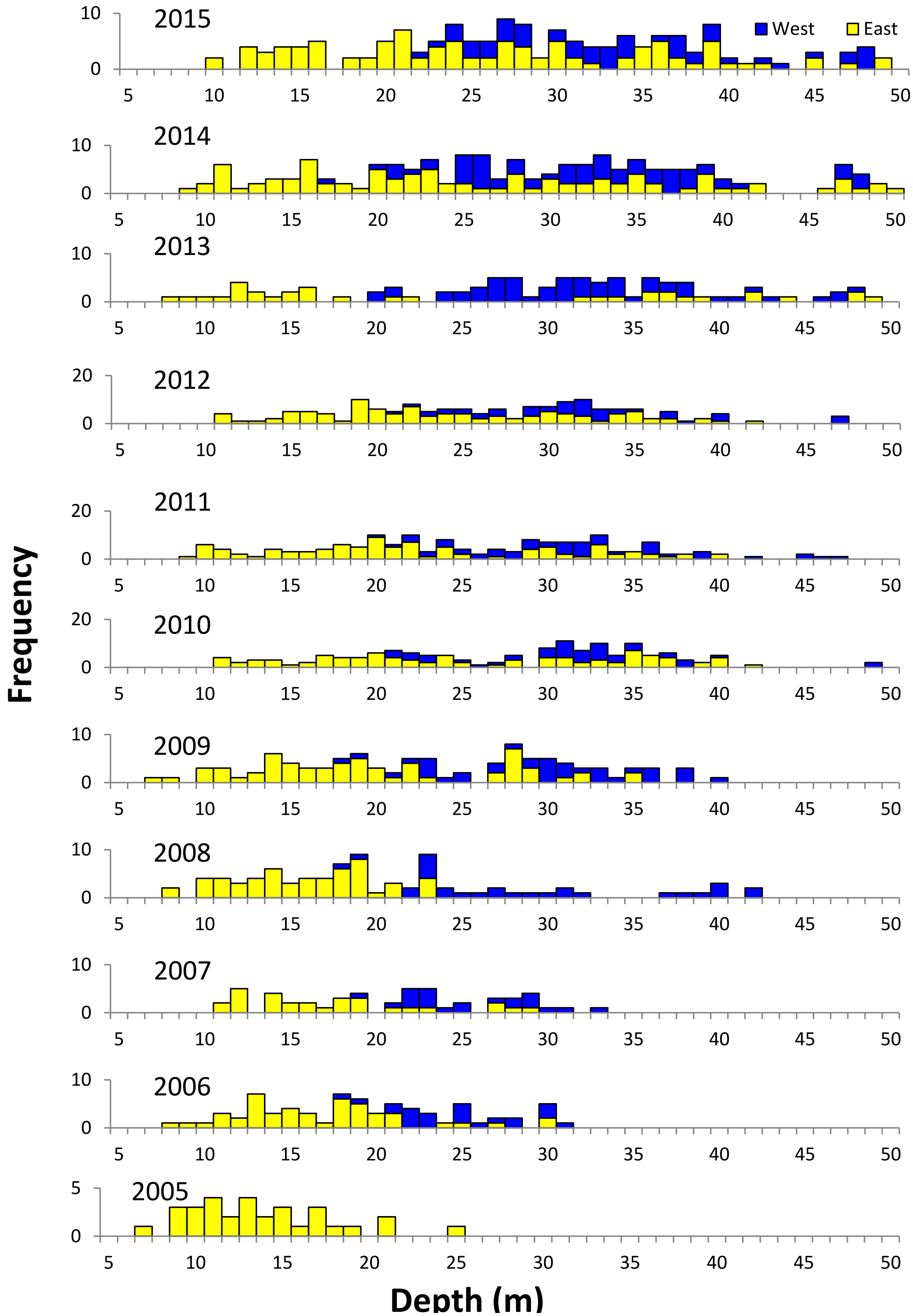

Figure 3. Annual depth distribution of Panama City reef fish survey video sample sites east and west of Cape San Blas, 2005-2015.

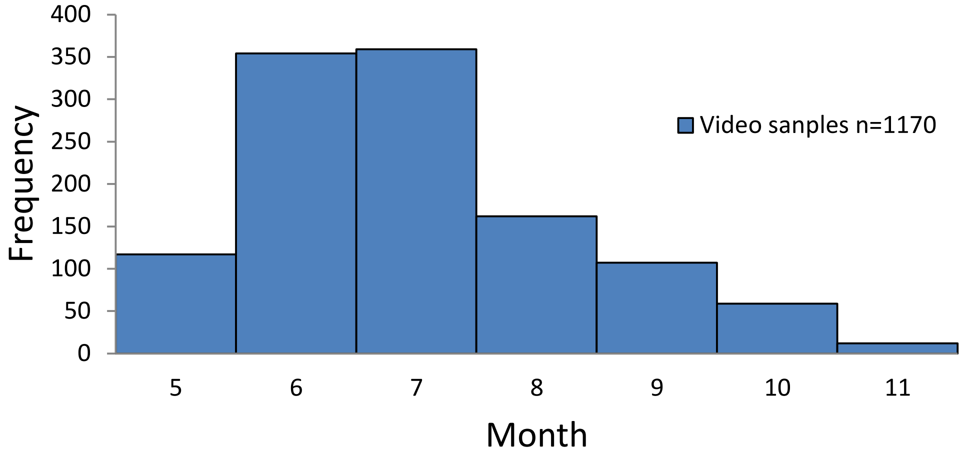

Figure 4. Overall monthly distribution of Panama City reef fish survey video and trap samples (censored data sets only), 2006-2015.

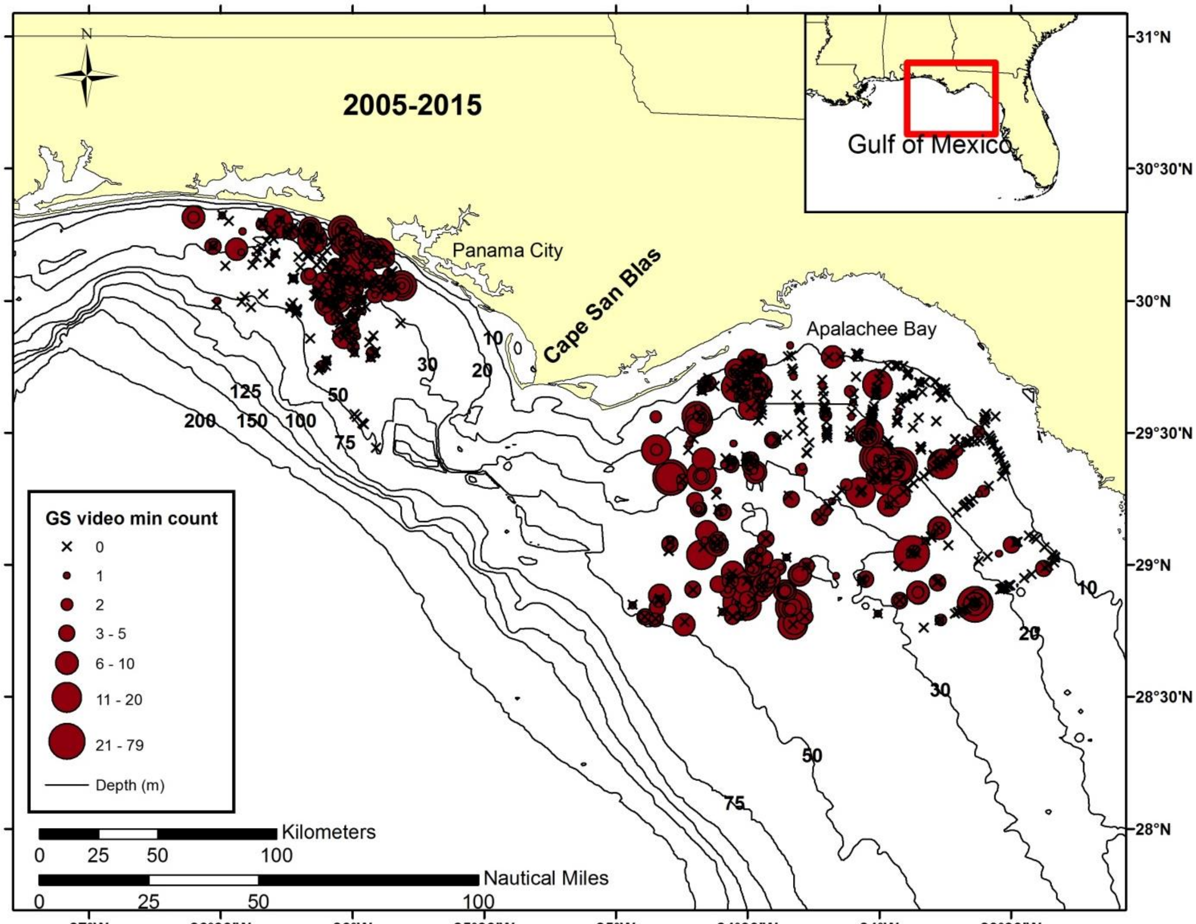

Figure 5 A. Distribution and relative abundance of gray snapper observed with stationary, high definition video or mpeg cameras (min counts) in the Panama City NMFS reef fish survey, 2005-2015. X's are sites sampled, but where no gray snapper were observed.

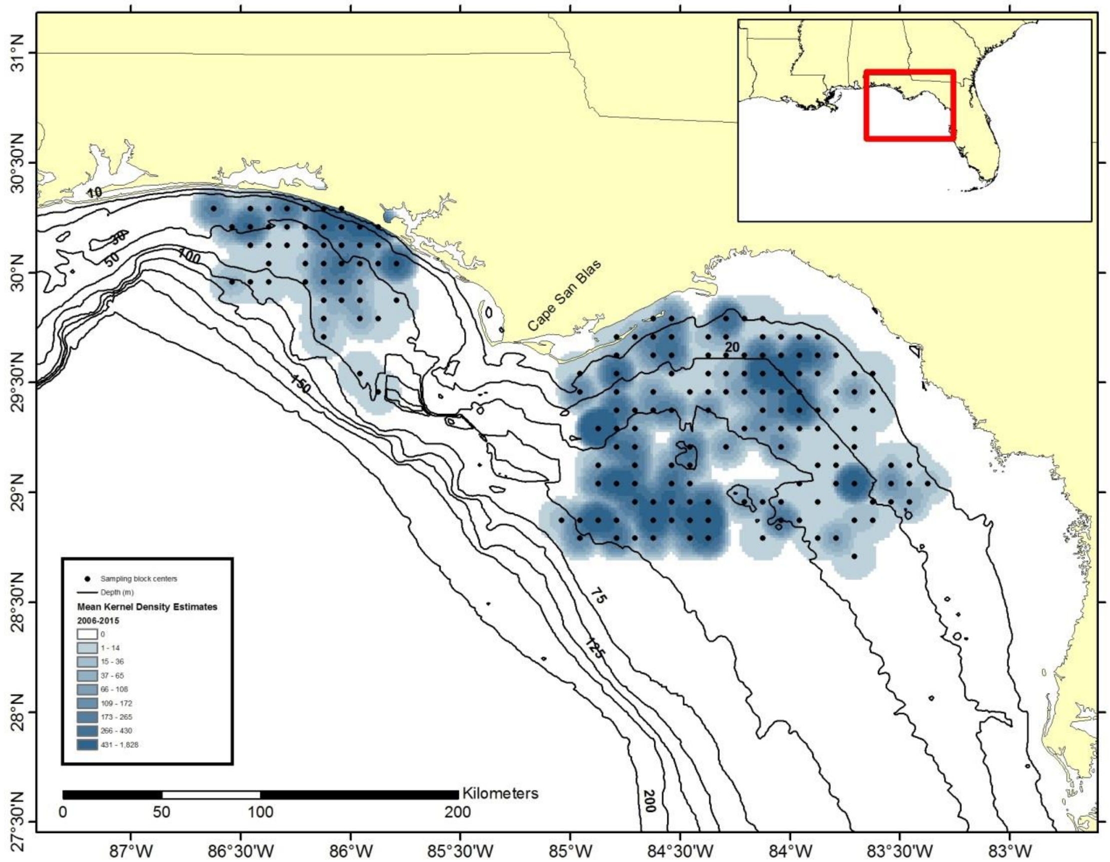

Figure 5 B. Overall relative density plot of gray snapper based on count data (min-counts, also called maxN) from video collected with stationary camera arrays in annual surveys, 2006-2015. Min counts were standardized by 5 min latitude x 5 min longitude sampling block, and kernel density estimates were calculated from the mid-point (black dots in the figure) of each block (See Fig. 2).

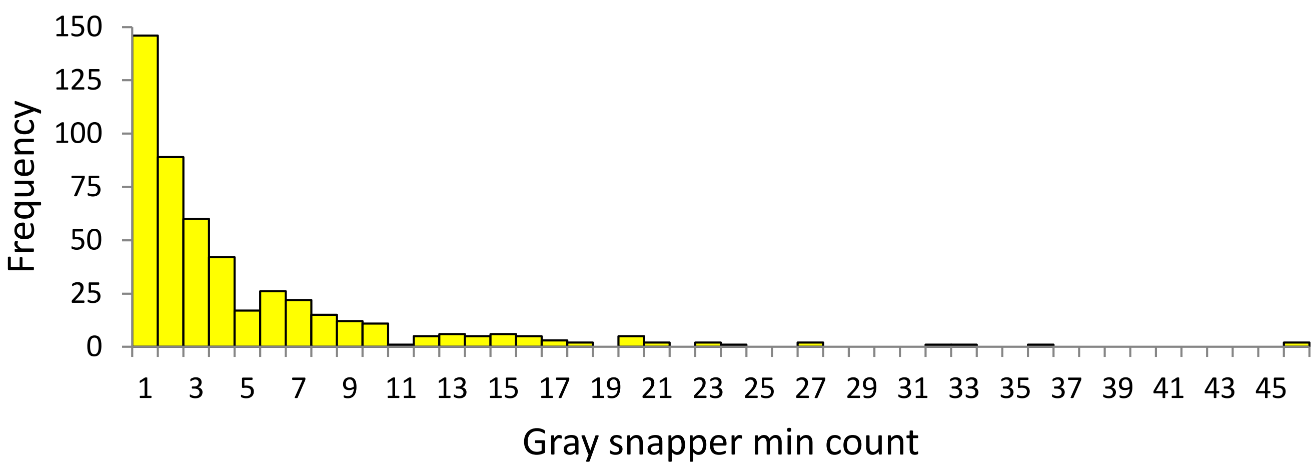

Figure 6. Frequency distribution of non-zero min counts of gray snapper from Panama City reef fish video samples, 2005-2015. One sample with a min count of 79 is not shown.

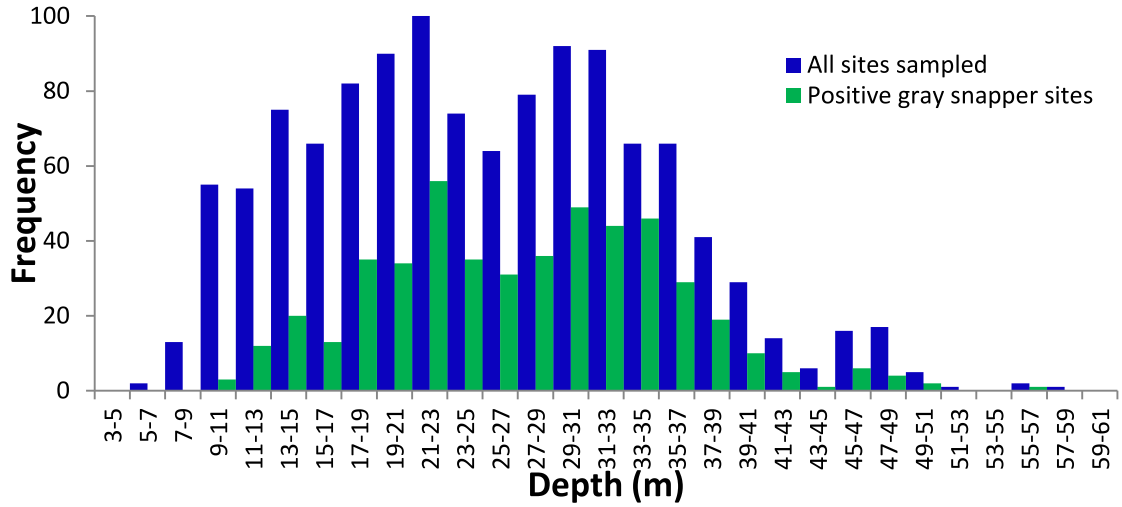

Figure 7. Depth distributions of all video (2006-2015) sample sites vs only sites positive for gray snapper.

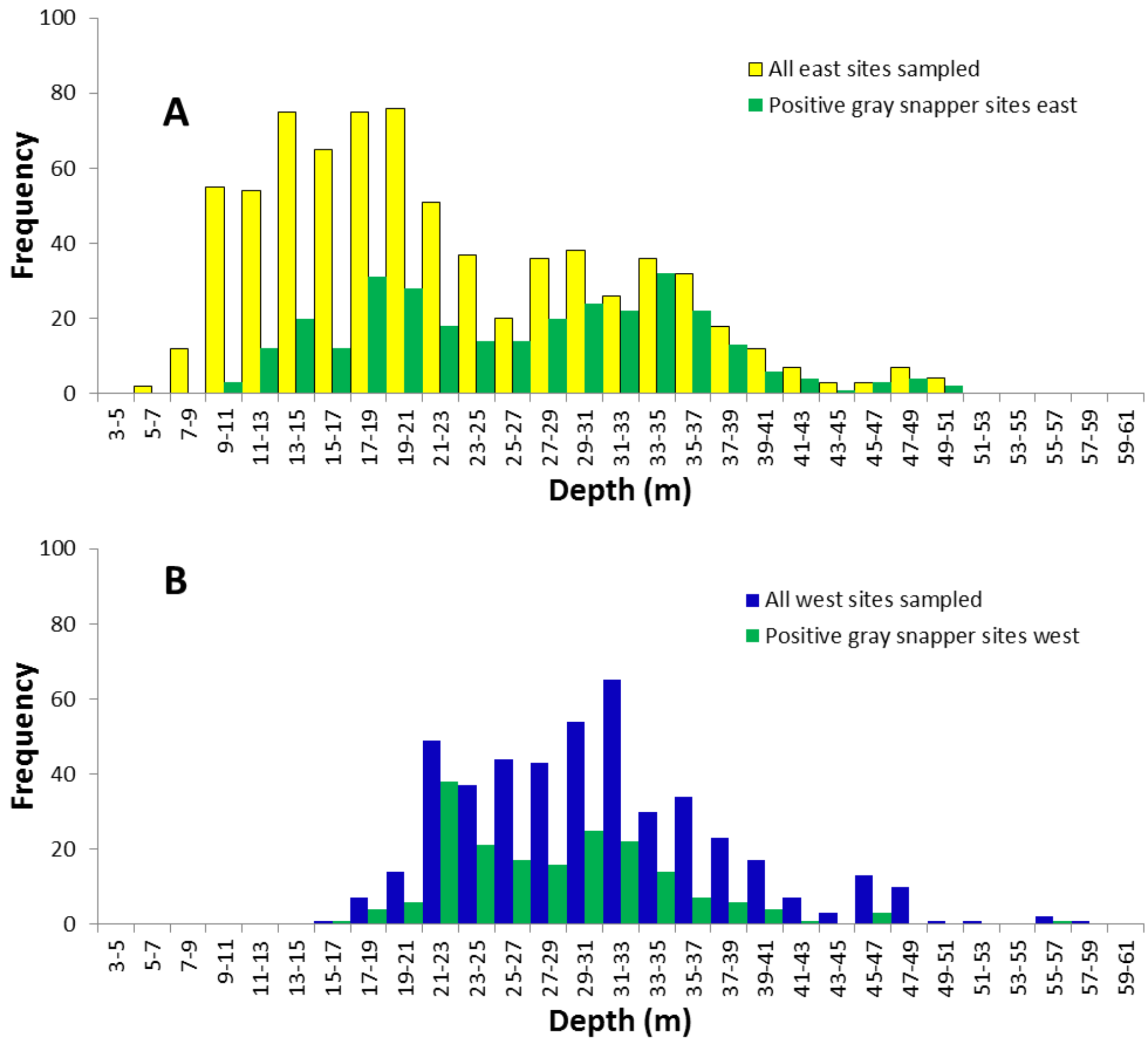

Figure 8. Depth distributions of all video sample sites vs only sites positive for gray snapper for east of Cape San Blas (A) and west of Cape San Blas (B).

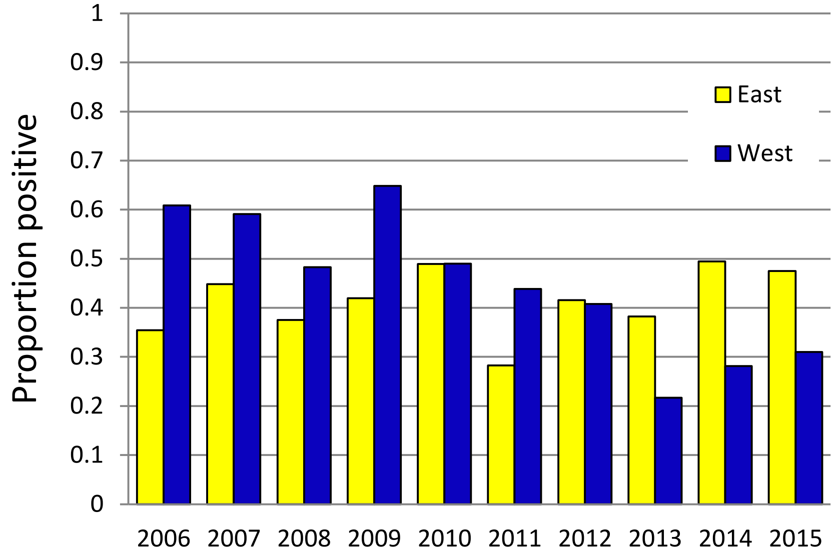

Figure 9. Annual proportions of positive gray video samples, 2006-14, east and west of Cape San Blas.

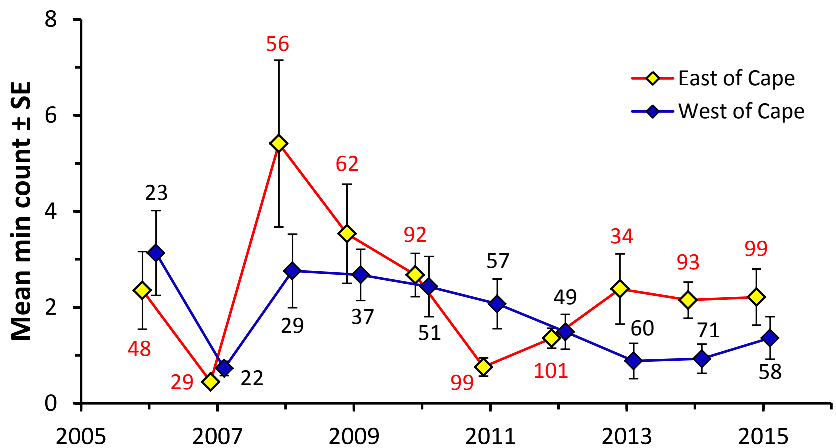

Figure 10. Mean annual nominal video min counts (MaxN) and standard errors of gray snapper east and west of Cape San Blas, 2006-2015. Numbers within the plots are sample sizes for each year.

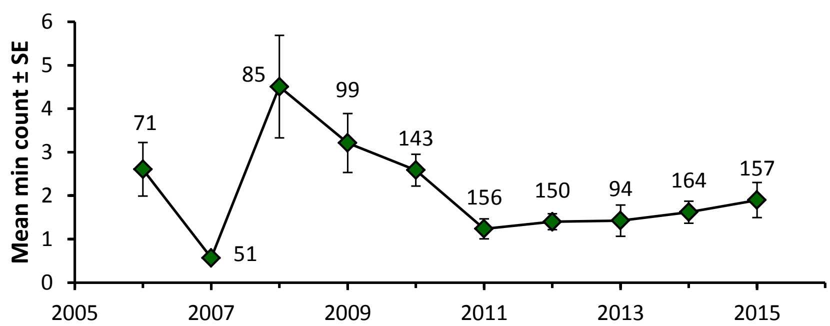

Figure 11. Overall (east + west of Cape San Blas) mean annual nominal video min counts (MaxN) and standard errors of gray snapper, 2006-2015. Numbers within the plots are sample sizes for each year.

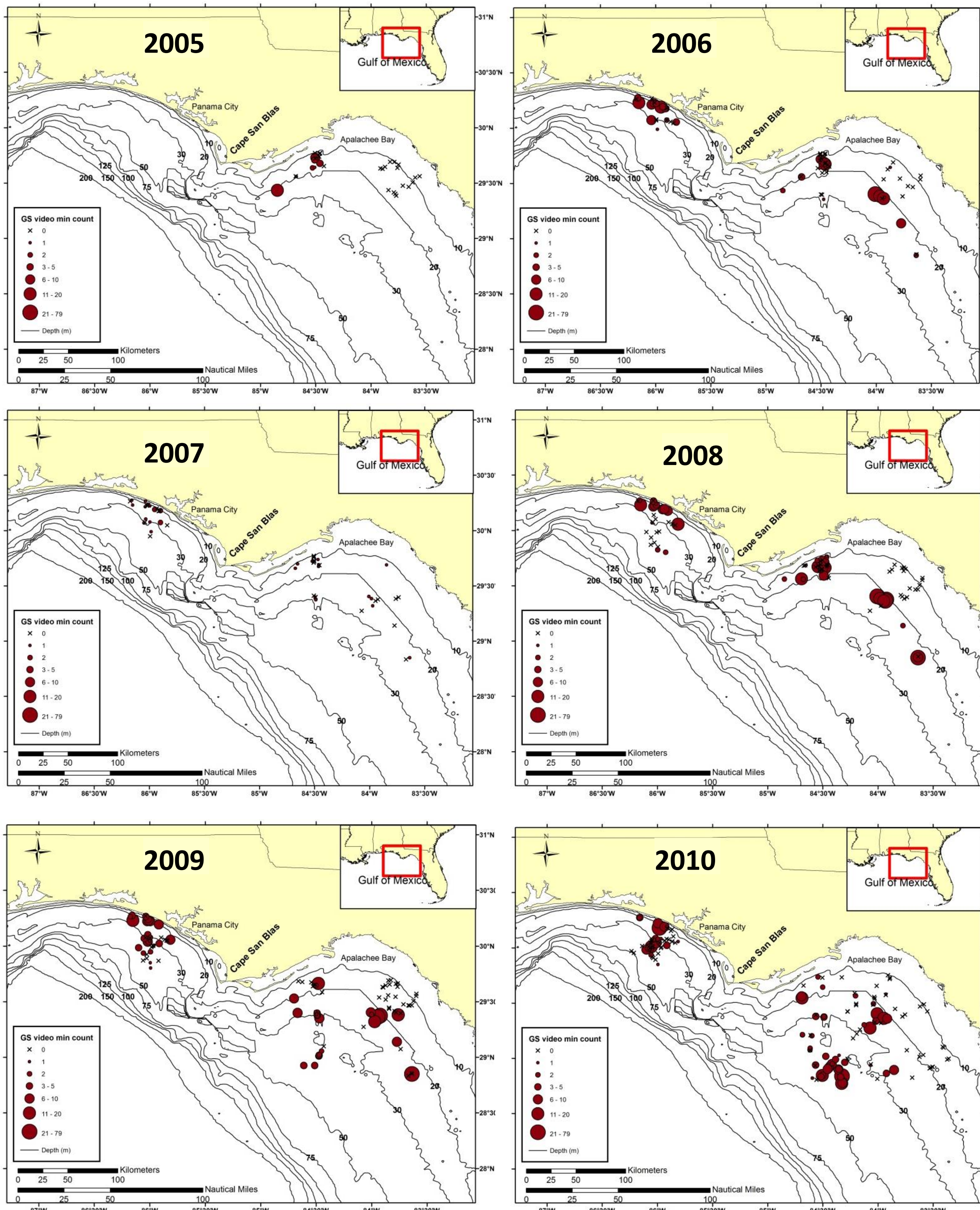

Figure 12. Annual distribution and relative abundance of gray snapper observed with stationary, high definition video or mpeg cameras (min counts) in the Panama City NMFS reef fish survey, 2005-2015. Sites sampled, but where no gray snapper were observed, are indicated with an X.

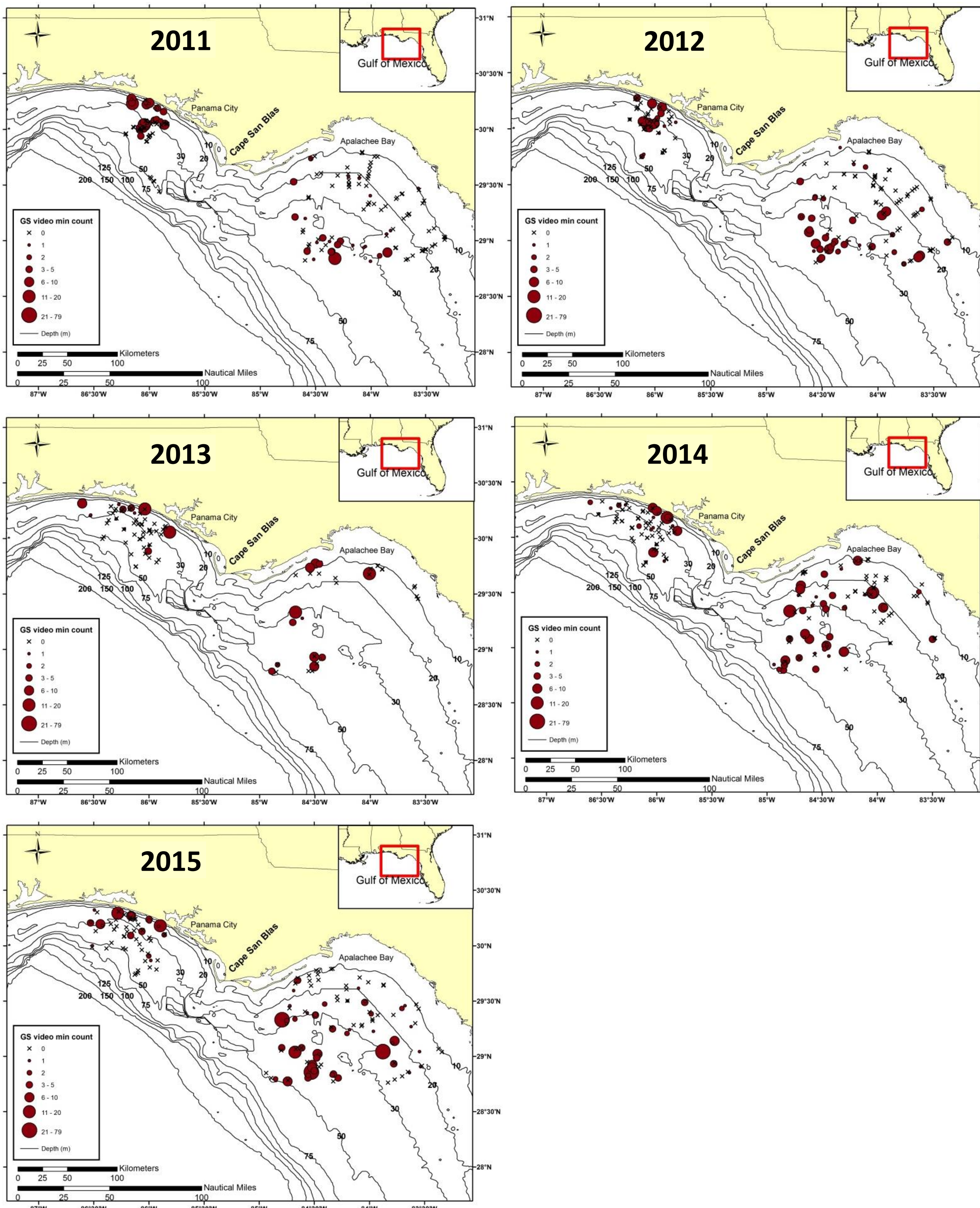

Figure 12 cont. Annual distribution and relative abundance of gray snapper observed with stationary, high definition video or mpeg cameras (min counts) in the Panama City NMFS reef fish survey, 2005-2015. Sites sampled, but where no gray snapper were caught or observed, are indicated with an X.

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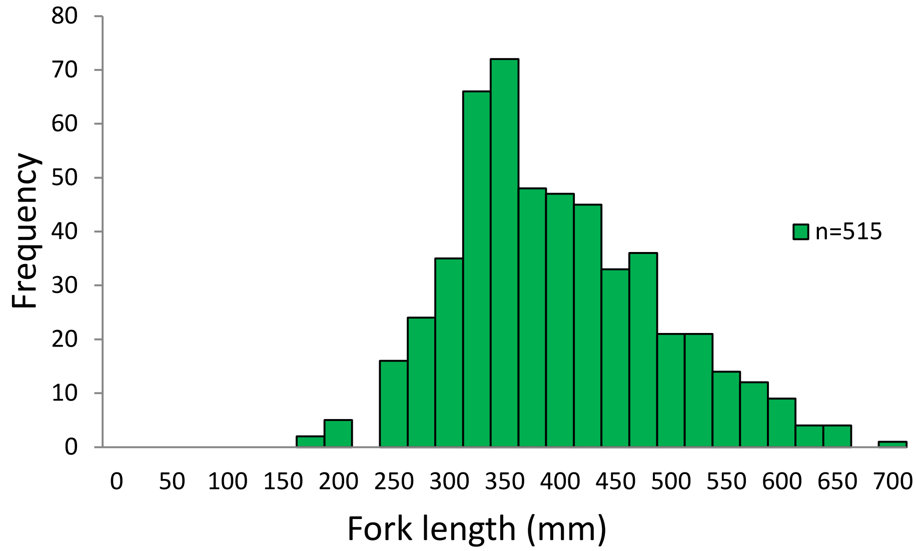

Figure 13. Overall size distributions of all gray snapper measured from stereo images, 2009-2015.

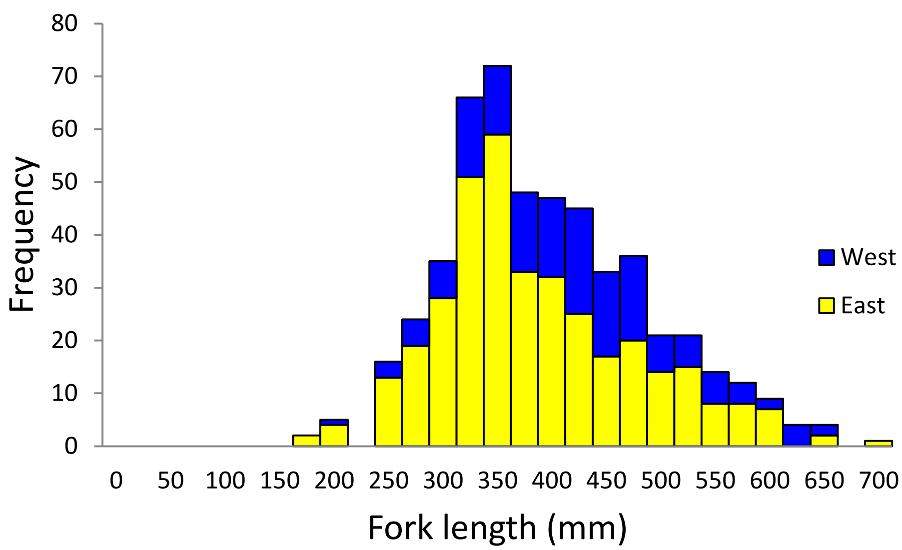

Figure 14. Overall size distributions of gray snapper east and west of Cape San Blas observed with stereo cameras, 2009-2015.

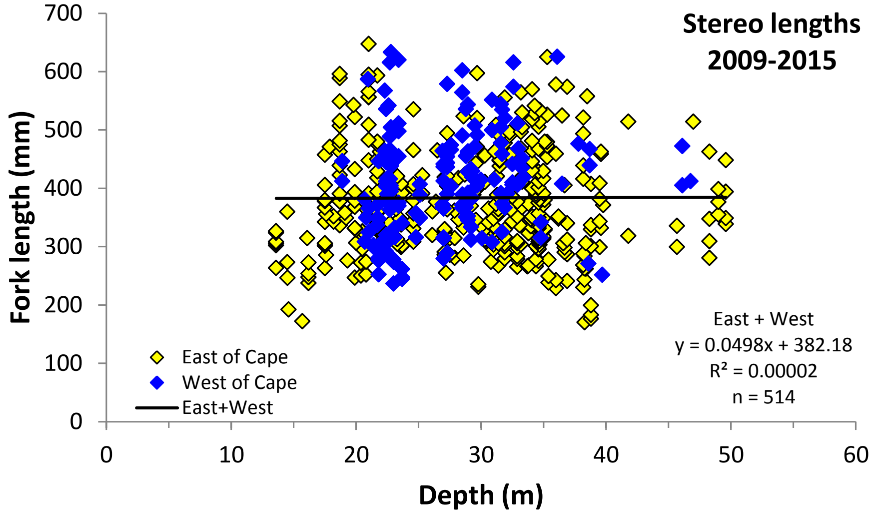

Figure 15. Fork length vs. depth relationship of gray snapper observed with stereo cameras east and west of Cape San Blas, 2009-2015.

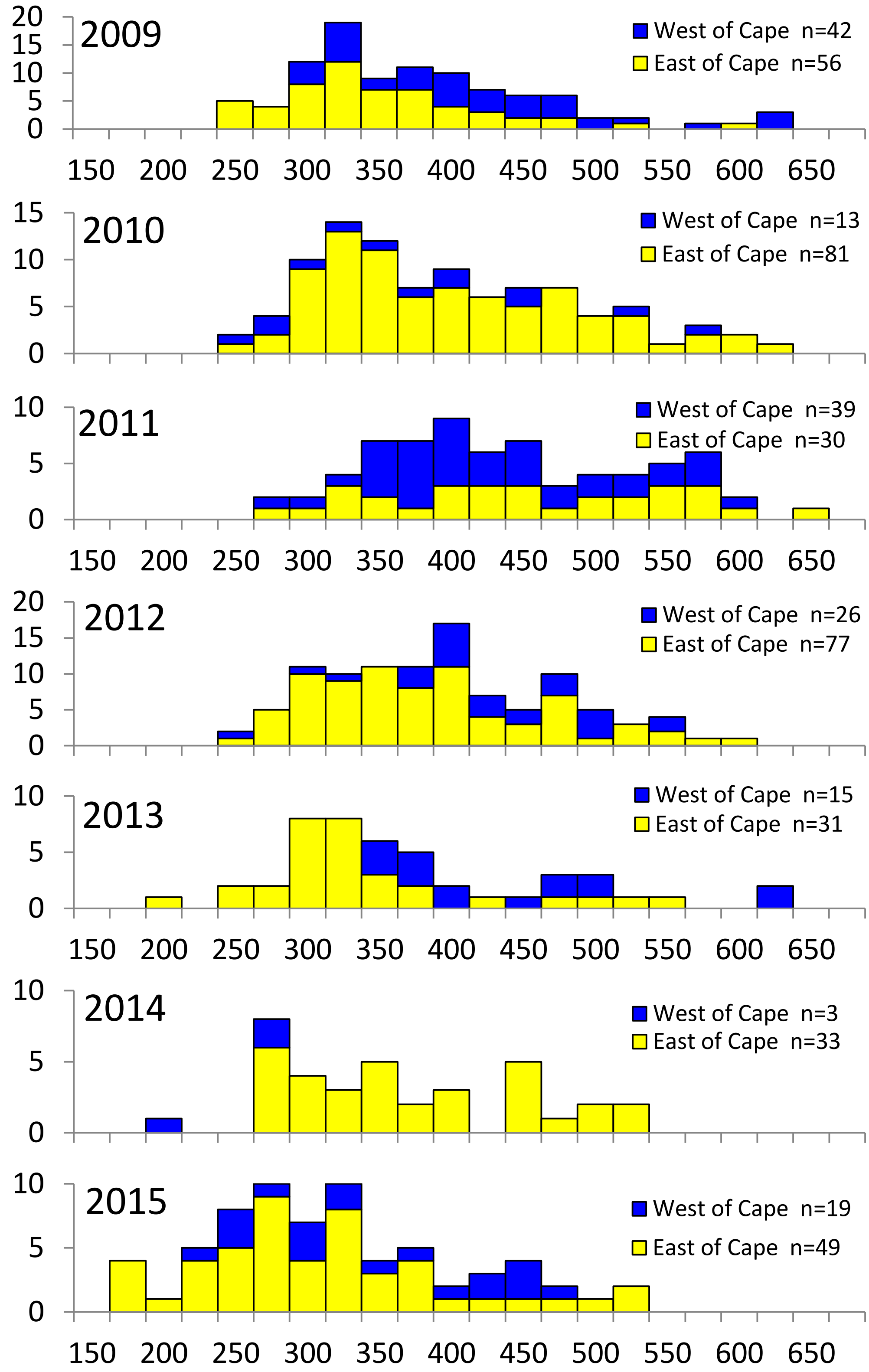

Figure 16. Annual size distributions of gray snapper observed with stereo cameras, 2009-15, east and west of Cape San Blas.

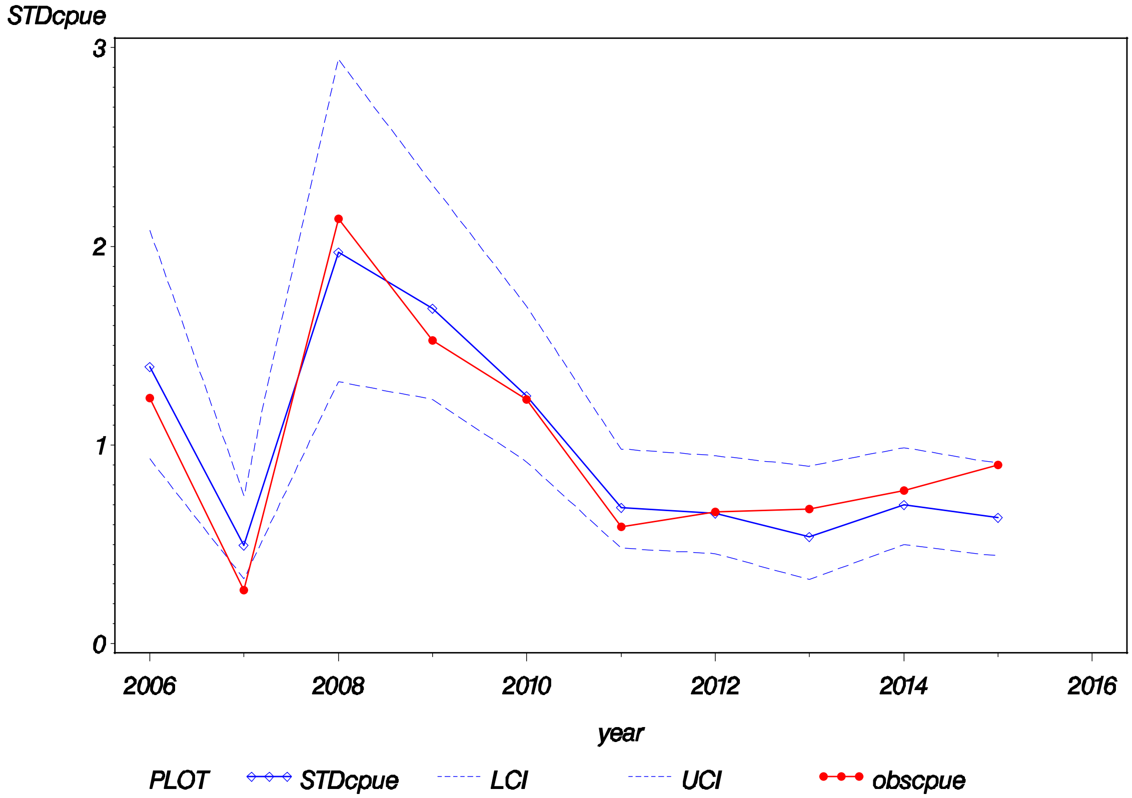

Figure 17: Annual index of abundance for gray snapper from the Panama City Video Survey from 2006 – 2015. STDcpue is the index scaled to a mean of one over the time series. Obscpue is the average nominal CPUE, and LCI and UCI are 95% confidence limits for the scaled index. In the table above, the *frequency* 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.

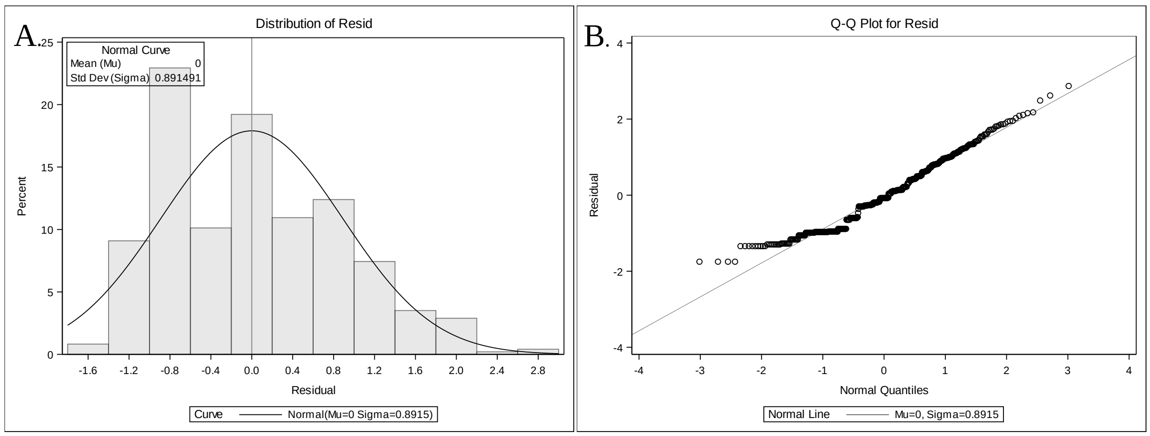

Figure 18. Diagnostic plots for lognormal component of the gray snapper Panama City Video Survey model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).