Red grouper *Epinephelus morio* Findings from the NMFS Panama City Laboratory Camera & Trap Fishery-Independent Survey 2004-2017

C.L. Gardner and K.E. Overly

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C.L. Gardner and K.E. Overly
Riverside Technology
(Contracting for the National Marine Fisheries Service)
Panama City Laboratory
3500 Delwood Beach Rd.
Panama City, FL 32408

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Panama City Laboratory
Contribution 18-17

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 186 video samples per year. Sample sizes per year are displayed in Tables 1 and 2. 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 November, but primarily during June through August (Fig. 4)

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 to 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 (HD) 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 HD 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 (2015-2017). Beginning in 2011, a second SIS facing 180º from the other was added, reducing the number of HDs to two; and both SIS's were also upgraded with HD, color MPEG cameras. In 2012 the two digital video cameras were replaced with HD 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 HD 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 HD video cameras were scanned and the one with the best view of the reef was analyzed. Starting in 2010, all 4 cameras – the HDs 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 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 video 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.

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.

Results

Since the Panama City lab reef fish survey began in 2004/5, red grouper have been 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 overall frequency distribution of min counts suggests that the species is often solitary or small groups, with approximately 81% of positive observations being 1 fish and 99% of observations being 3 fish or less (Fig. 6). Red grouper displayed a positive correlation between depth and fork length ($p<.0001$, $R^2=.11$) (Fig. 24) both east and west of the Cape, with a wide range of sizes at all depths sampled. A positive correlation between age and depth ($p<.0001$, $R^2=.31$) was observed providing evidence for an ontogenetic shift offshore (Fig. 26).

Encounter rates

The annual percent of positive video samples ranged from 11 to 72 % east of Cape San Blas during 2006-2017 ($\bar{x}$ =.35), and 4 to 72 % west of the Cape during 2006-2017 ($\bar{x}$ =.37) (Table 1, Fig. 9). The annual percent of positive red grouper trap catches during 2004-2017 ranged from 13 to 62 % east of Cape San Blas and 5 to 52 % west of the Cape

(Table 2). 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 12 m, then were fairly uniform to depths of 50m (Table 3, Figs. 7 and 8). Increases in encounter rates corresponded with the emergence of strong year classes that were often detected at age 2-3 and occasionally at age 1 (Tables 1 and 2, Figs. 9 and 27). High proportion positive occurrences occurred in 2008-2011 both east and west of Cape San Blas then decreased from 2012-2016. This correlates with two strong year classes (2006 and 2007) followed by several years of lower recruitment. Although sample sizes are small in recent years, red grouper spawned in 2015 are commonly being detected by the survey in 2016 and 2017 (Figs. 23 and 27).

Trends in the trap catch closely mirrored those in the video data, with the exception of 2009 and 2010, where occurrence in the trap data was down in the area west of Cape San Blas. This could possibly be attributed to heavier fishing pressure offshore of Panama City and Destin and removing fish of legal size.

Abundance trends

Not surprisingly, estimates of relative abundance for red grouper displayed overall similar patterns to those seen in proportion positives. This is especially apparent due to red groupers tendencies to appear as single fish or small groups. Significant increases in mean min count were displayed from 2007-2009 on both sides of the cape ($\bar{x}$ =0.23 to 0.61 to 1.09, p<.0001) (Table 1, Fig.11). The overall mean nominal min count declined after 2009 each year until 2012 ($\bar{x}$ =0.83 to 0.64 to 0.42, p=.04) where it remained relatively constant ($\bar{x}$ =0.16 to 0.29) until 2016. An overall significant increase was observed in 2017 ($\bar{x}$ =0.34, p<.001). These variations in relative abundance from video data appear to be directly correlated with the emergence of strong year classes showing up in the survey. Measurements from stereo cameras start in 2009 (the year of highest abundance observed in this survey), however those data as well as the trap catches display a large number of smaller fish that also are present in the age data as fish from the 2006 and 2007 year classes (Table 1, Figs.15, 23, and 27). These advance throughout the years and either move offshore where they are not detected by the survey or are subject to fishing pressure or natural mortality.

When abundance trends are viewed by region, very similar patterns are displayed on both sides of Cape San Blas, strongly suggesting that only one stock of red grouper dominates the survey area (Table 1, Fig. 10). However, in 2015, the western region showed a significantly greater nominal mean min count ($\bar{x}$ =0.36 vs.012, p=.001). This trend changed abruptly in 2016, with a lower count in the west ($\bar{x}$ =0.04 vs 0.24, p=.001) and continued into 2017. However, mean min counts in both regions were on the rise in 2016 and 2017. This again can be attributed to an influx of smaller fish being captured by the survey, especially in the region east of Cape San Blas, where fish as small as 150-200 mm FL were observed (Fig. 15). The noisier trap data did not track each as closely, especially prior to 2011. CPUE from these trap data are not recommended for use as a relative abundance index due to wide variability in catches. However, it is very useful for obtaining size and age data.

Geographic patterns of trends in relative abundance in video min counts (2006-2017) and nominal trap catches (2004-2017) are displayed in annual GIS plots in Figures 5A, 12, 18 and 19. An interpolated surface map displaying relative abundance from video min counts is available in Figure 5B.

Size and age

The survey strongly targeted pre-recruit red grouper, especially east of Cape San Blas, where 80% of trap-caught fish were below the minimum legal size limit of 487 mm FL, compared to 45% west of the Cape. East of the Cape, 22% of the fish were <350 mm and only 5% were >600 mm, while in the west only 6% were <350 mm but 19% were >600 mm. This pattern can also be clearly seen in the annual length composition data from 2005-2009 (Fig. 23), the years when the distribution of depths sampled was quite different east and west of Cape San Blas (Fig. 3).

Red grouper taken in chevron traps during 2004-2017 ranged from 200 to 801 mm FL, with a modal size of ~390-482 mm FL, and a mean of 448 mm FL. Those observed with stereo cameras, 2009-2017, ranged from ranged from 181 to 885 mm FL, with a modal size of roughly 450-500 mm FL, and a mean of 497 mm (Table 4). A comparison of size data from trap catches with that from stereo images from the same years (2009-2017) indicated that the two gears sample the same overall size ranges. However, the traps do select against most red grouper >775 mm FL, although fish that large are much less common in the survey area based on the few stereo measurements obtained (Fig. 22). The stereo camera gear is also selective, but it tends to select against small (<250 mm FL) red grouper, which tend to be much more cryptic than larger individuals and less likely to be visible to camera gear.

Red grouper lengths calculated from stereo cameras during 2009-2017 displayed normal distributions both east and west of Cape San Blas (Figures 13 and 14). Mean lengths were greater on the west side of the Cape ($\bar{x}$ ± 95% CL: 550 ± 31.7 vs 473 ±21.9 mm FL, p=.00017) (Table 4). The overall modal size of red grouper was smaller in the east vs west as well (451 vs 497 mm FL). One factor in the differences between mean length east and west of Cape San Blas is the availability of hard bottom reefs in the shallow water in the East. The reefs sampled in the western region start around 18m depth, but in the eastern region, approximately 35% of the samples are shallower than that depth (Table 3). Once similar depths are compared in both regions and both gears, the values are much more similar ($\bar{x}$ ± 95% CL: 464 ± 22.9 vs 500± 34.39 mm FL) (Table 4 B) and difference in means is not significant.

The correlation of depth on fork length from the video and trap data was significant for both regions combined (p<.0001) as well as individual regions (p<.0001). However, both trap and video data showed a wide range of sizes across depth ranges and the regression accounted for ~11% (video) and ~27% (trap) of the variation (Fig 24). Ages from trap caught red grouper also displayed a wide range across depth and a significant correlation with depth and age (p<.0001, R^2=.31) (Fig. 26). These patterns with size and age reflect probable ontogenetic movements and decreasing fishing mortality rates with distance from shore.

As expected, given the regional differences observed in size structure, red grouper were also younger east of the Cape than west (p<.0001), with individuals caught in the trap survey ranging from ages 1 to 11 yr, with mean 3.9 ±0.2 yr, of a mode of 3-4 yr (Figs. 25 and 27). West of the Cape, red grouper ranged from ages 1 to 19 yr, although most were 1-10 yr, with a mean of 6.3±0.4 yr, and modal age was 5-6. 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. 27). 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 2016. 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. No evidence of any subsequent good recruitment years until 2016 when the 2015 cohort appeared in trap catches in the east. This cohort was also apparent in the 2017 sampling in the east, but was not detected in the west.

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. 23). 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 2016. Another group was detected in 2016 in the east with a mode ~225 mm FL. 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, detecting the group in the east in 2016 and 2017 as well.

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Tables

Table 1: Annual video survey sample sizes, proportion positive occurrences, mean nominal video min counts, and standard errors of red grouper east and west of Cape San Blas, 2006-2017. Estimates calculated using censored data sets (see Methods).

	Total sites sampled			Proportion positive occurrences			Mean nominal min count			Standard error		
Year	East	West	Total	East	West	Total	East	West	Total	East	West	Total
2006	78	22	100	0.32	0.27	0.31	0.42	0.27	0.39	0.08	0.10	0.06
2007	45	19	64	0.24	0.16	0.22	0.24	0.21	0.23	0.06	0.12	0.06
2008	55	32	87	0.42	0.69	0.52	0.49	0.81	0.61	0.09	0.12	0.07
2009	65	39	104	0.72	0.72	0.72	1.15	0.97	1.09	0.14	0.13	0.10
2010	92	51	143	0.63	0.59	0.62	0.88	0.75	0.83	0.09	0.12	0.07
2011	99	58	157	0.43	0.64	0.51	0.58	0.76	0.64	0.08	0.09	0.06
2012	101	49	150	0.35	0.39	0.36	0.42	0.43	0.42	0.06	0.08	0.05
2013	38	65	103	0.21	0.26	0.24	0.29	0.29	0.29	0.11	0.06	0.06
2014	85	71	156	0.20	0.25	0.22	0.20	0.27	0.23	0.04	0.06	0.04
2015	104	59	163	0.11	0.36	0.20	0.12	0.36	0.20	0.03	0.06	0.03
2016	102	70	172	0.20	0.04	0.13	0.24	0.04	0.16	0.05	0.02	0.03
2017	99	49	148	0.37	0.20	0.32	0.40	0.20	0.34	0.06	0.06	0.04
Total	**963**	**584**	**1547**	**0.35**	**0.37**	**0.35**	**0.45**	**0.43**	**0.44**	**0.02**	**0.03**	**0.02**

Table 2: Annual chevron trap sample sizes, proportion positive occurrences, mean nominal catch/trap hr, and standard errors of red grouper east and west of Cape San Blas, 2004-2017.

	Total sites sampled			Proportion positive occurrences			Mean nominal catch/trap hr			Standard error		
Year	East	West	Total	East	West	Total	East	West	Total	East	West	Total
2004	16	25	41	0.50	0.36	0.41	1.38	1.66	1.55	0.45	0.69	0.45
2005	47	20	67	0.36	0.45	0.39	0.84	1.12	0.92	0.23	0.50	0.22
2006	67	24	91	0.13	0.29	0.18	0.12	0.23	0.15	0.04	0.09	0.04
2007	44	20	64	0.14	0.05	0.11	0.09	0.15	0.11	0.03	0.15	0.05
2008	50	31	81	0.36	0.52	0.42	0.48	0.91	0.64	0.12	0.27	0.13
2009	53	30	83	0.53	0.33	0.46	1.00	0.74	0.91	0.18	0.29	0.16
2010	52	17	69	0.58	0.24	0.49	1.24	0.44	1.04	0.22	0.30	0.19
2011	50	31	81	0.62	0.52	0.58	1.54	1.05	1.35	0.28	0.26	0.20
2012	59	30	89	0.29	0.23	0.27	0.39	0.37	0.38	0.11	0.15	0.09
2013	14	37	51	0.14	0.16	0.16	0.10	0.22	0.19	0.06	0.10	0.07
2014	47	33	80	0.26	0.21	0.24	0.26	0.18	0.22	0.08	0.07	0.05
2015	29	34	63	0.14	0.12	0.13	0.14	0.10	0.11	0.08	0.05	0.04
2016	57	38	95	0.23	0.13	0.19	0.26	0.13	0.21	0.07	0.06	0.05
2017	45	19	64	0.29	0.00	0.20	0.40	0.00	0.28	0.11	0.00	0.08
Total	**630**	**389**	**1019**	**0.33**	**0.26**	**0.30**	**0.58**	**0.51**	**0.55**	**0.05**	**0.07**	**0.04**

Table 3: Video survey sample sizes and proportion positive occurrences of red grouper by depth zone east and west of Cape San Blas, 2006-2017 all years combined.

	Total sites sampled			Proportion positive occurrences		
Depth (m)	East	West	Total	East	West	Total
5-7	1		1	1.00		1.00
7-9	13		13	0.00		0.00
9-11	68		68	0.10		0.10
11-13	64		64	0.16		0.16
13-15	107		107	0.22		0.22
15-17	85	1	86	0.35	0.00	0.35
17-19	95	6	101	0.51	0.17	0.49
19-21	91	14	105	0.35	0.21	0.33
21-23	62	52	114	0.31	0.44	0.37
23-25	48	48	96	0.42	0.38	0.40
25-27	33	50	83	0.33	0.40	0.37
27-29	52	51	103	0.44	0.33	0.39
29-31	52	68	120	0.38	0.41	0.40
31-33	34	85	119	0.62	0.32	0.40
33-35	40	44	84	0.48	0.25	0.36
35-37	42	54	96	0.45	0.30	0.36
37-39	28	32	60	0.46	0.50	0.48
39-41	17	26	43	0.41	0.50	0.47
41-43	8	7	15	0.25	0.57	0.40
43-45	3	6	9	0.33	0.33	0.33
45-47	6	17	23	0.50	0.41	0.43
47-49	10	15	25	0.40	0.40	0.40
49-51	4	3	7	0.25	0.00	0.14
51-53		1	1		0.00	0.00
53-55		1	1		1.00	1.00
55-57		2	2		0.00	0.00
57-59		1	1		1.00	1.00
Total	**963**	**584**	**1547**	**0.35**	**0.37**	**0.35**

Table 4 A: Descriptive statistics of red grouper sizes (fork length mm) obtained from chevron traps (2004-2017) and stereo camera measurements (2009-2017).

	Trap Caught Fish			Stereo Camera		
	East	West	Total	East	West	Total
Min.	200	224	200	151	242	151
1st Qu.	353	430	367	393	460	405
Median	396	502	429	457	522	477
Mode	390	482	390	451	497	491
Mean	415	508	448	473	550	497
Confidence Level on Mean (95%	7.7	12.8	7.4	21.9	31.7	18.5
3rd Qu.	465	579	515	540	638	568
Max.	735	801	801	885	881	885
Count	559	304	863	158	75	233

Table 4 B: Descriptive statistics of red grouper sizes (fork length mm) obtained from chevron traps and stereo camera measurements for overlapping years (2009-2017).

	Trap Caught Fish			Stereo Camera		
	East	West	Total	East	West	Total
Min.	200	270	200	151	242	151
1st Qu.	367	438	385	393	460	405
Median	418	534	438	457	522	477
Mode	425	400	425	451	497	491
Mean	432	539	460	473	550	497
Confidence Level on Mean (95%	9.7	19.4	9.6	21.9	31.7	18.5
3rd Qu.	485	645	524	540	638	568
Max.	735	801	801	885	881	885
Count	393	144	537	158	75	233

Figures

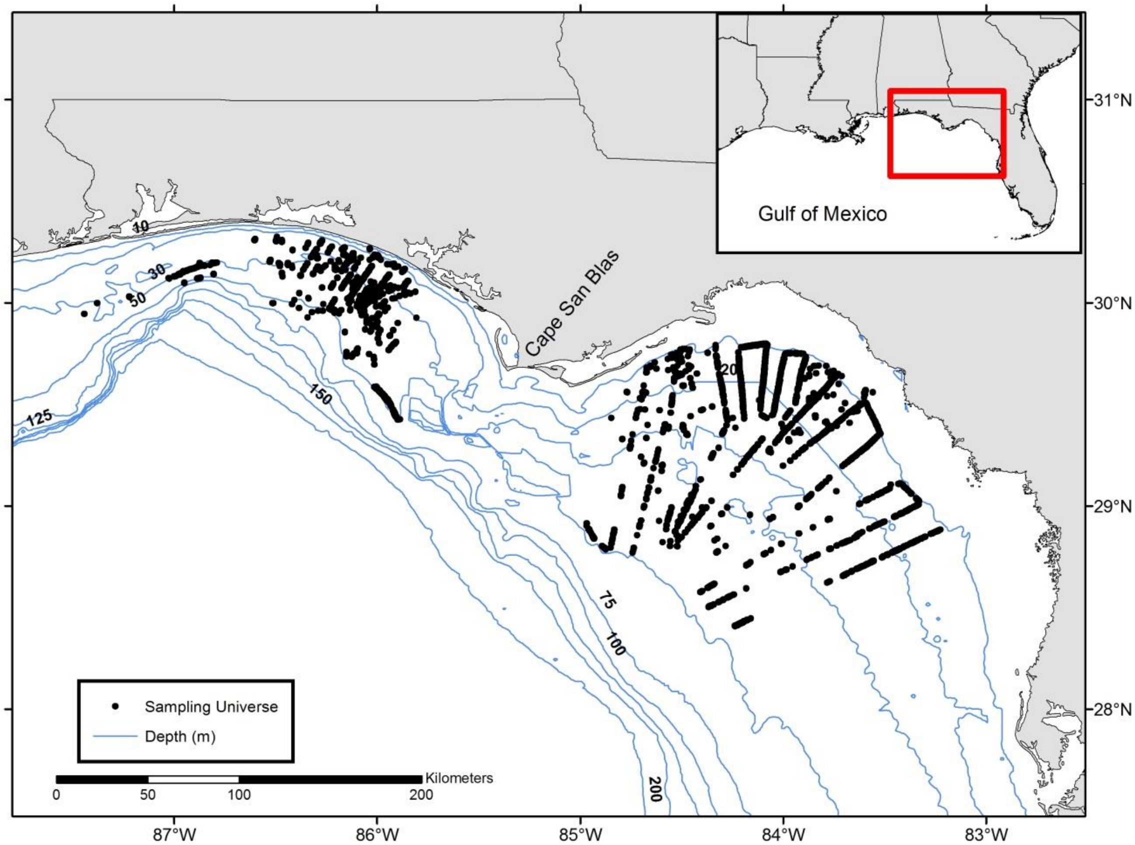

Figure 1. Locations of all natural reefs in the sampling universe of the Panama City NMFS reef fish video survey as of November 2017. Total sites: 4026 – 1360 west, and 2666 east, of Cape San Blas. Isobaths are in meters.

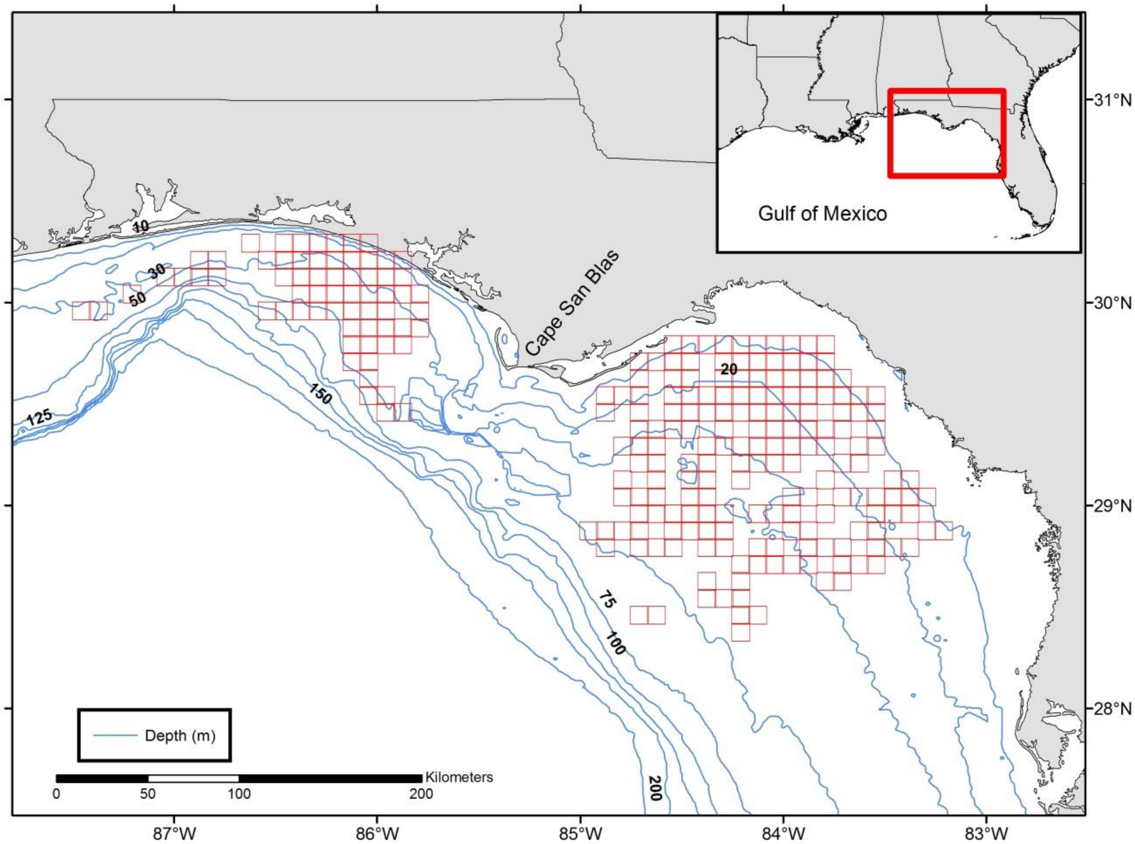

Figure 2. Sampling blocks (5 min lat. x 5 min. long.) of the Panama City reef fish survey. Blocks in red contain known hard bottom reefs and are subject to being selected for sampling. Isobaths are in meters.

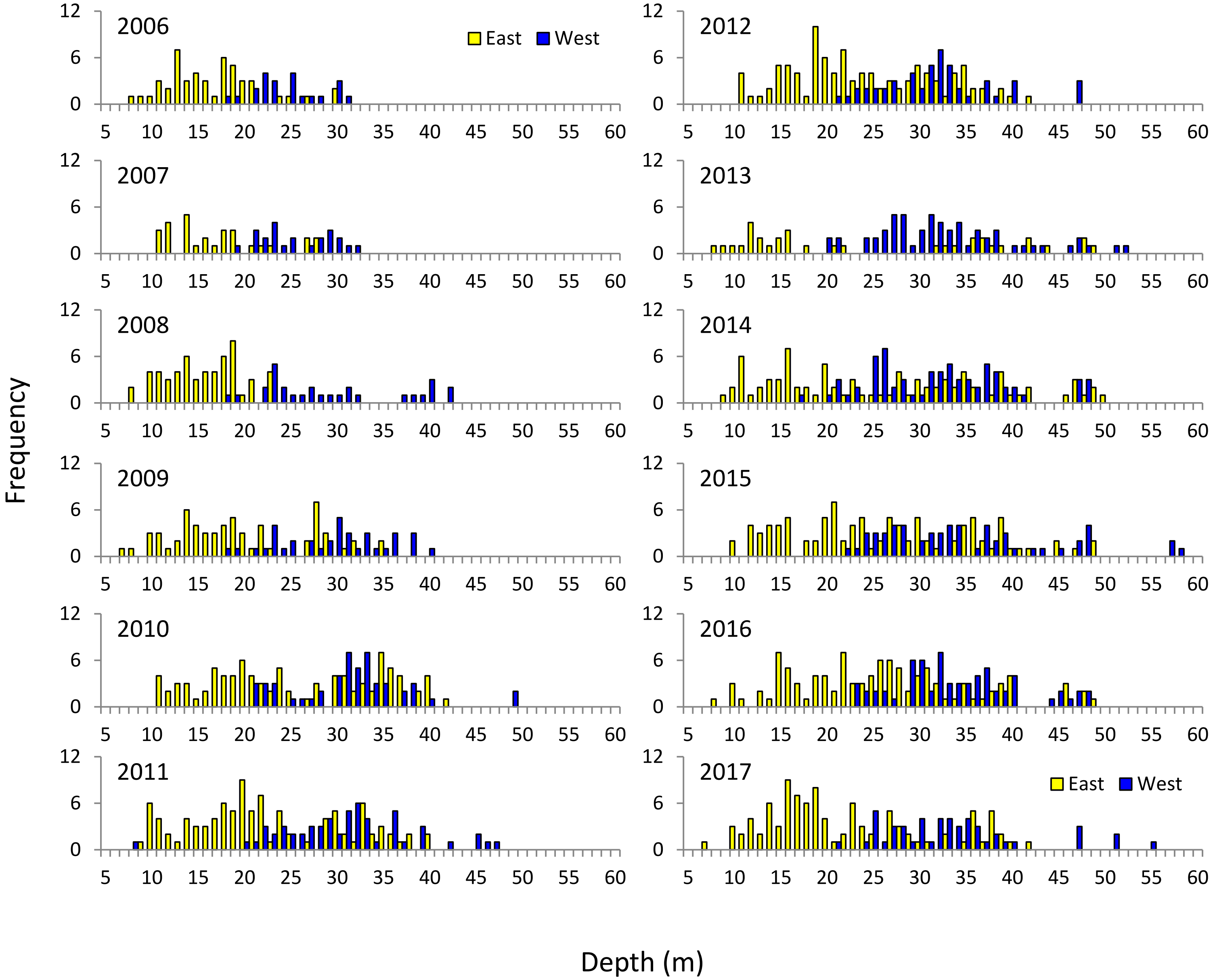

Figure 3. Annual depth distribution of Panama City reef fish survey video sample sites east and west of Cape San Blas, 2006-2017.

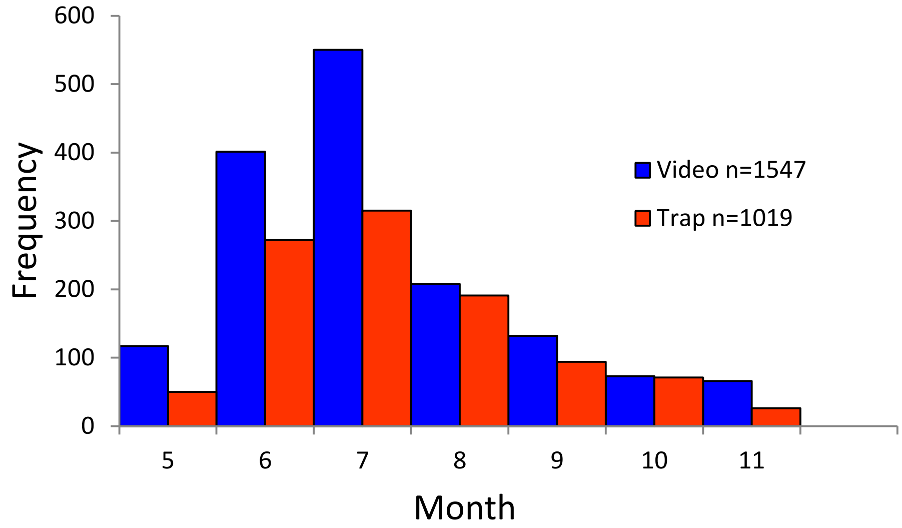

Figure 4. Overall monthly distribution of Panama City reef fish survey video and trap samples (censored data sets only), 2006-2017 (video) and 2004-2017 (trap).

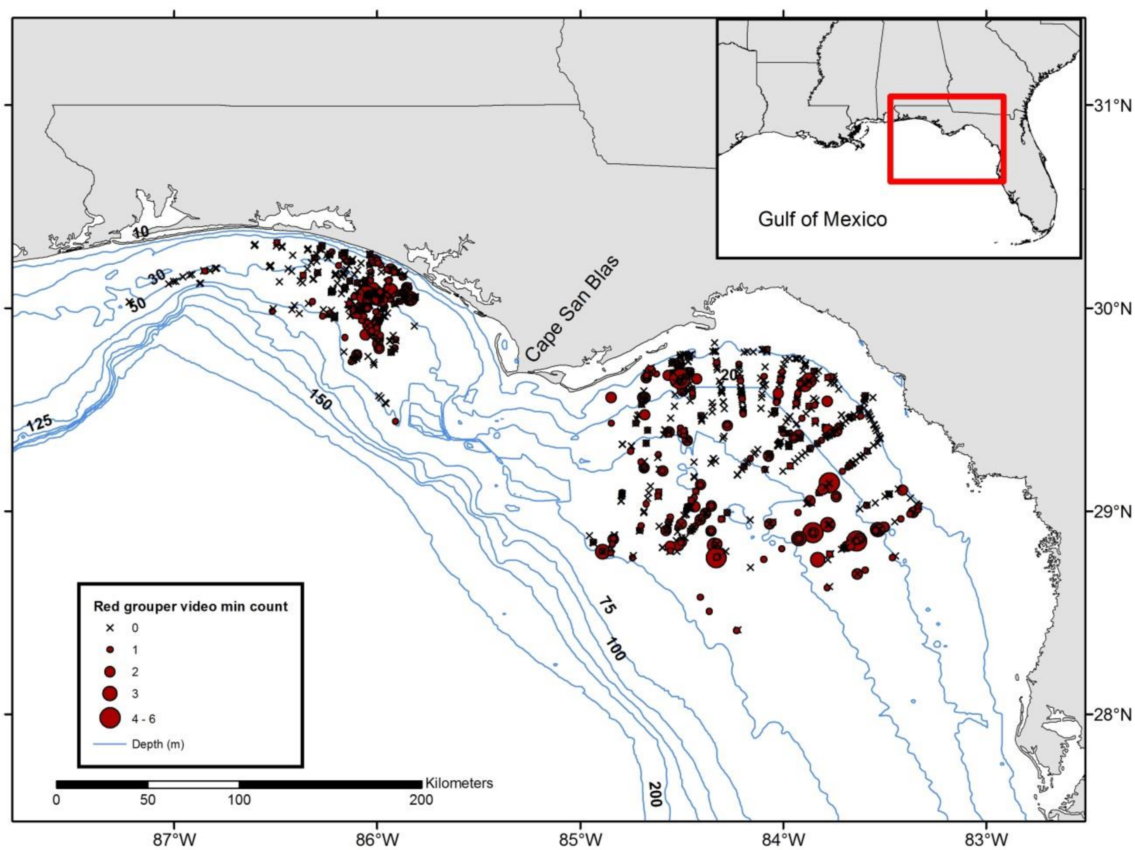

Figure 5 A. Distribution and relative abundance of red grouper observed with stationary, high definition video or MPEG cameras (min counts) in the Panama City NMFS reef fish survey, 2006-2017. X's are sites sampled, but where no red grouper were observed.

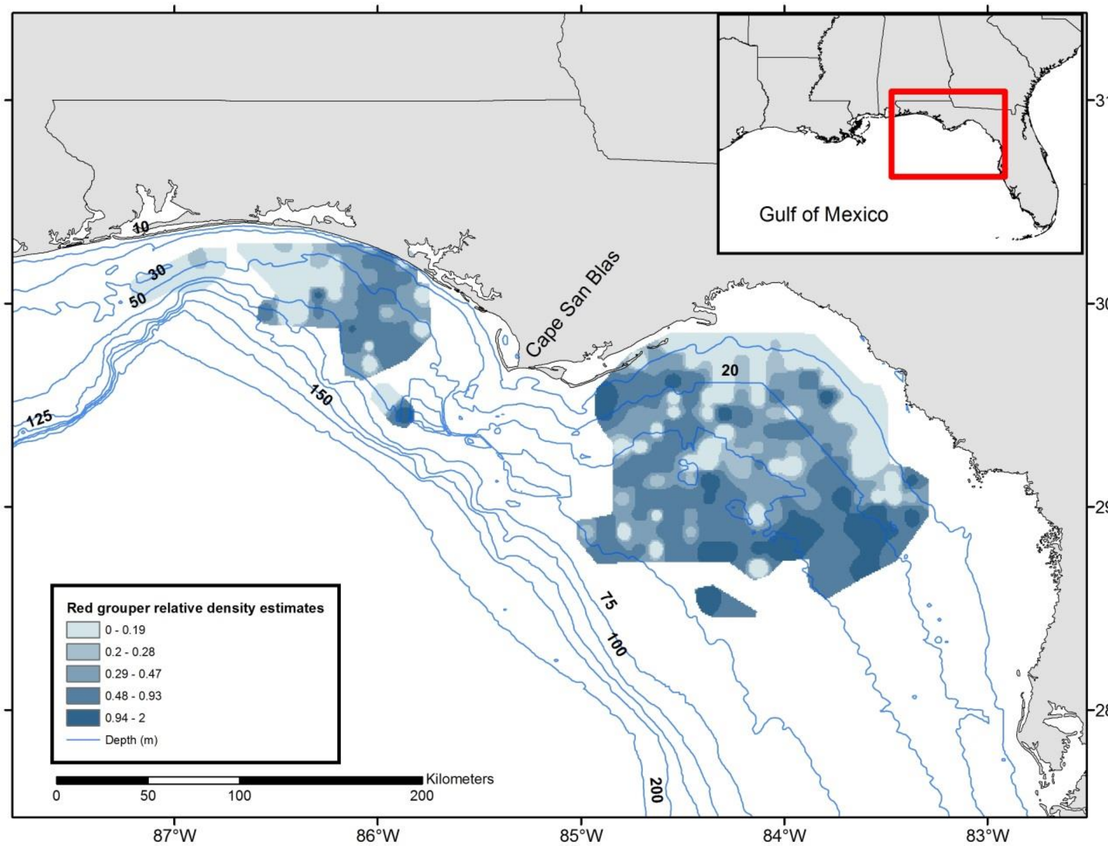

Figure 5 B. Overall relative density plot of red grouper based on count data (min-counts, also called maxN) from video collected with stationary camera arrays in annual surveys, 2006-2017. Mean min counts per were standardized by 5 min latitude x 5 min longitude sampling block, then inverse distance weighting estimates were calculated each block and weighted by effort (See Fig. 2).

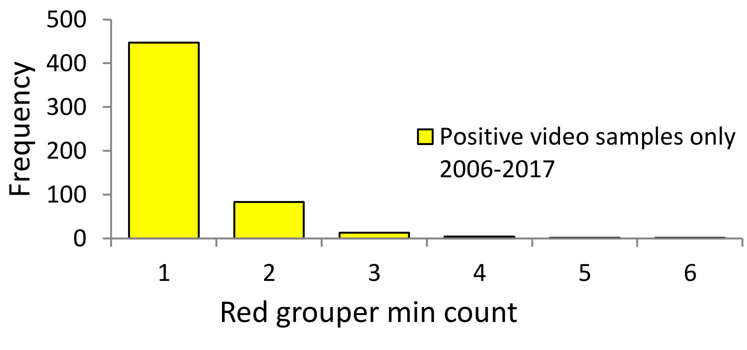

Figure 6. Frequency distribution of non-zero min counts of red grouper from Panama City reef fish video samples, 2006-2017.

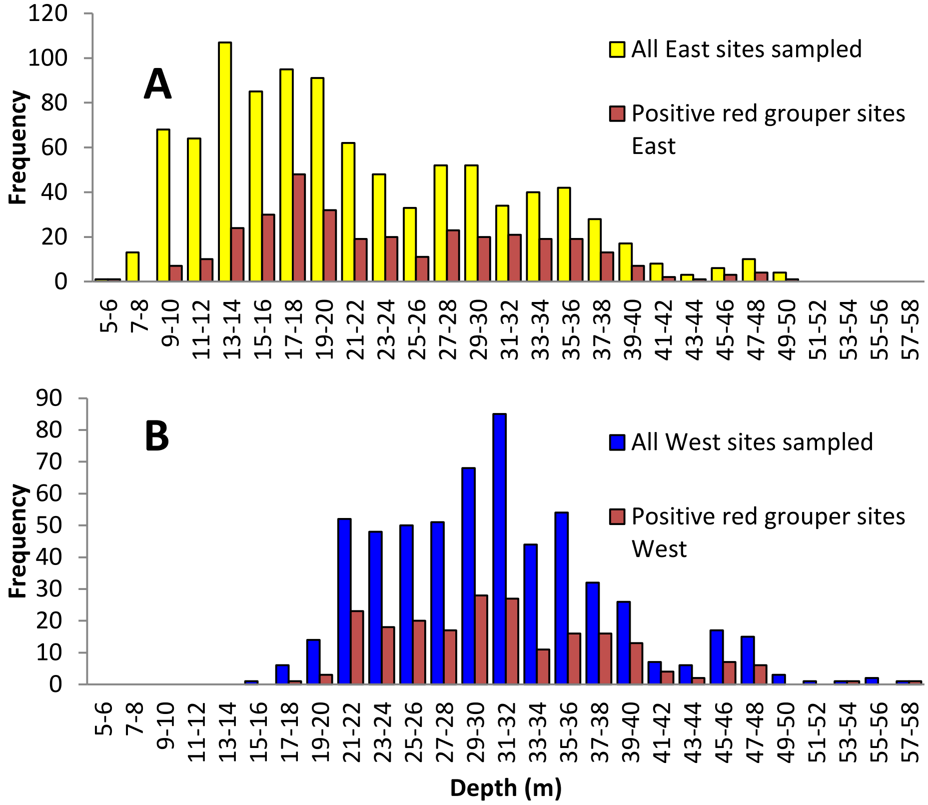

Figure 7. Depth distributions of all video (A) and trap (B) sample sites vs only sites positive for red grouper (2006-2017, video; 2004-2017, trap).

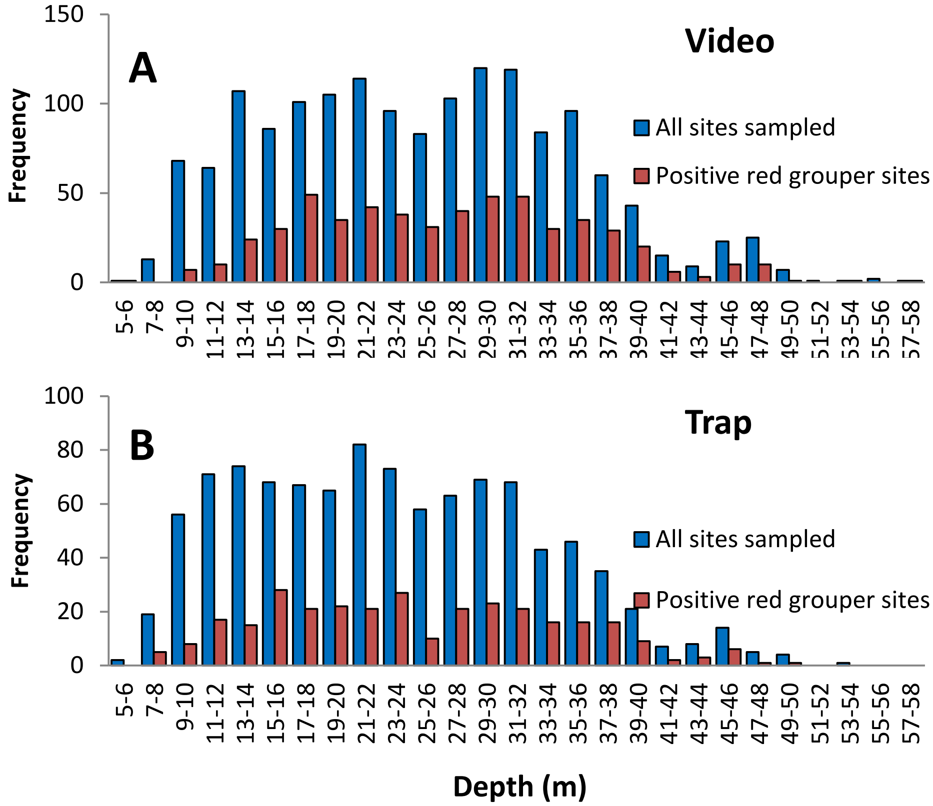

Figure 8. Depth distributions of all video sample sites vs only sites positive for red grouper for east of Cape San Blas (A) and west of Cape San Blas (B).

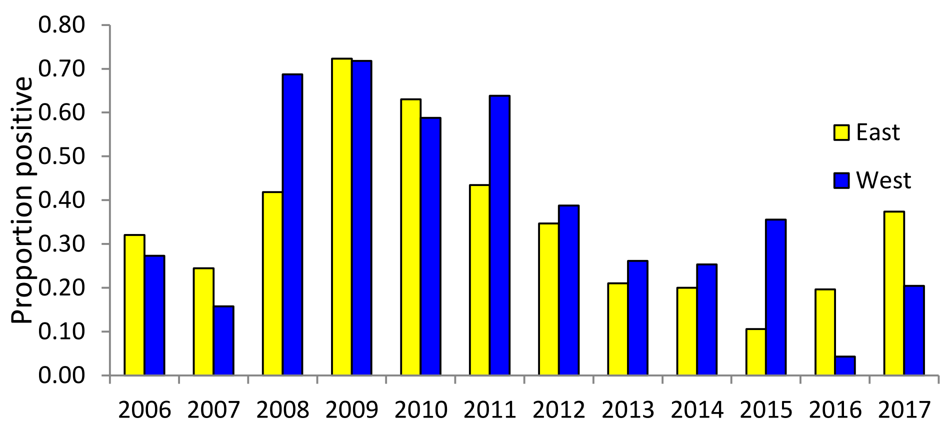

Figure 9. Annual proportions of positive red grouper video samples, 2006-17 east and west of Cape San Blas.

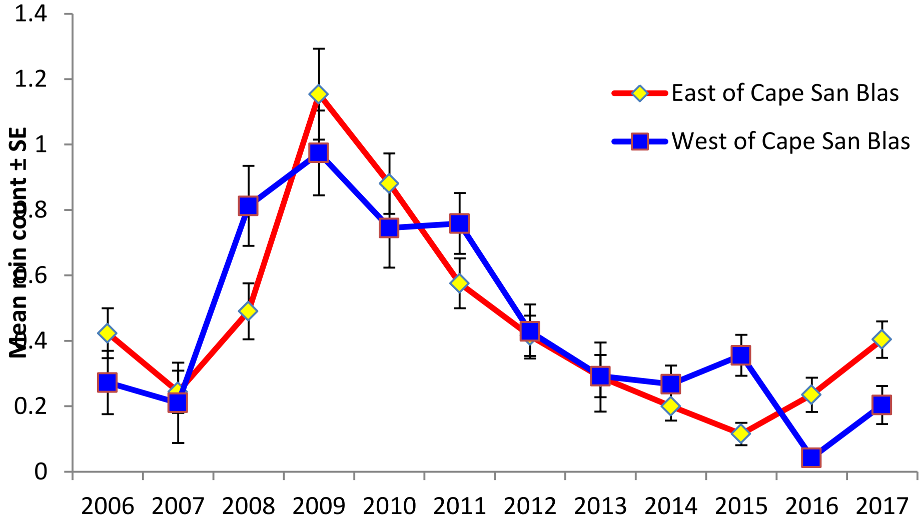

Figure 10. Mean annual nominal video min counts (MaxN) and standard errors of red grouper east and west of Cape San Blas, 2006-2017.

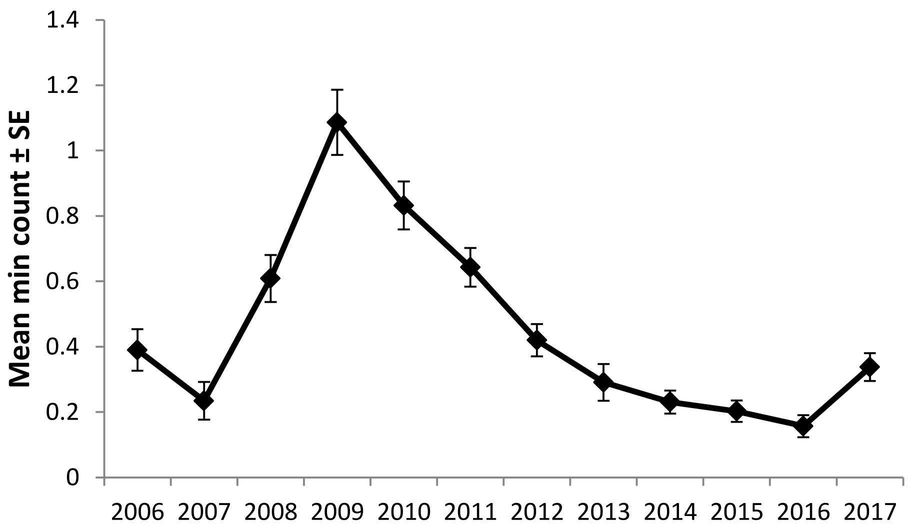

Figure 11. Overall (east + west of Cape San Blas) mean annual nominal video min counts (MaxN) and standard errors of red grouper, 2006-2017.

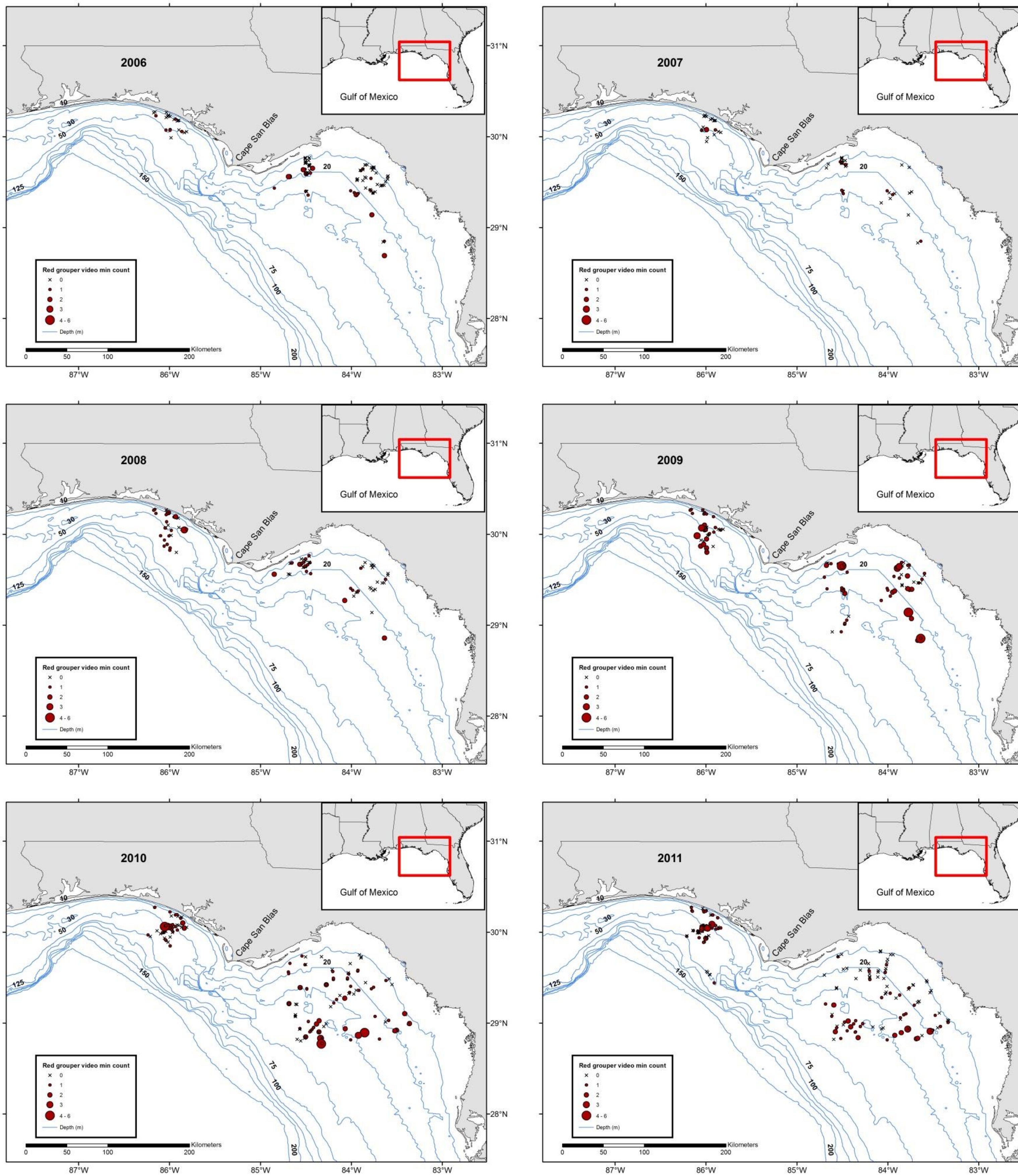

Figure 12. Annual distribution and relative abundance of red grouper observed with stationary, high definition video or MPEG cameras (min counts) in the Panama City NMFS reef fish survey, 2006-2017. Sites sampled, but where no red grouper were observed, are indicated with an X.

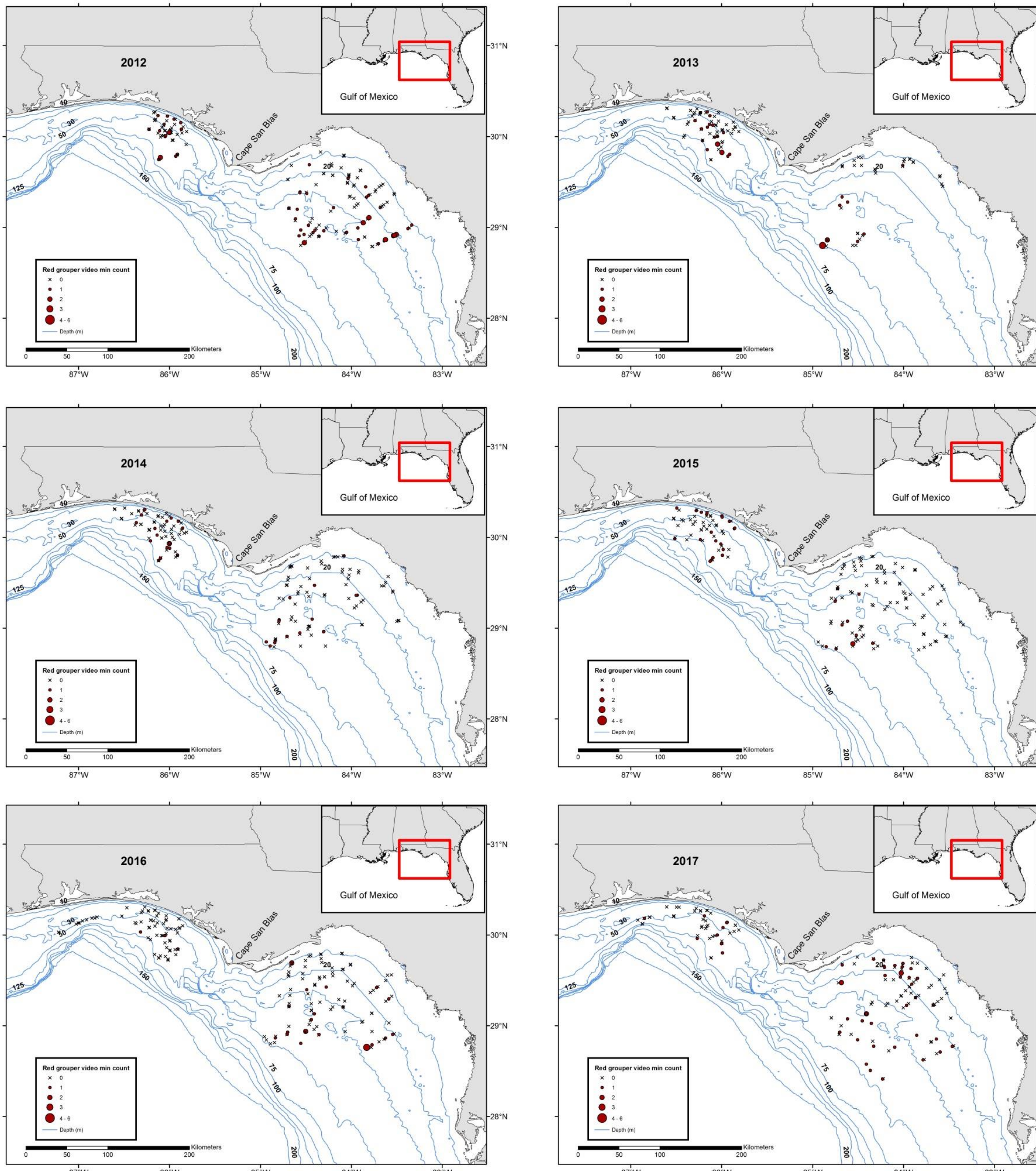

Figure 12 cont. Annual distribution and relative abundance of red grouper observed with stationary, high definition video or MPEG cameras (min counts) in the Panama City NMFS reef fish survey, 2006-2017. Sites sampled, but where no red grouper were observed, are indicated with an X.

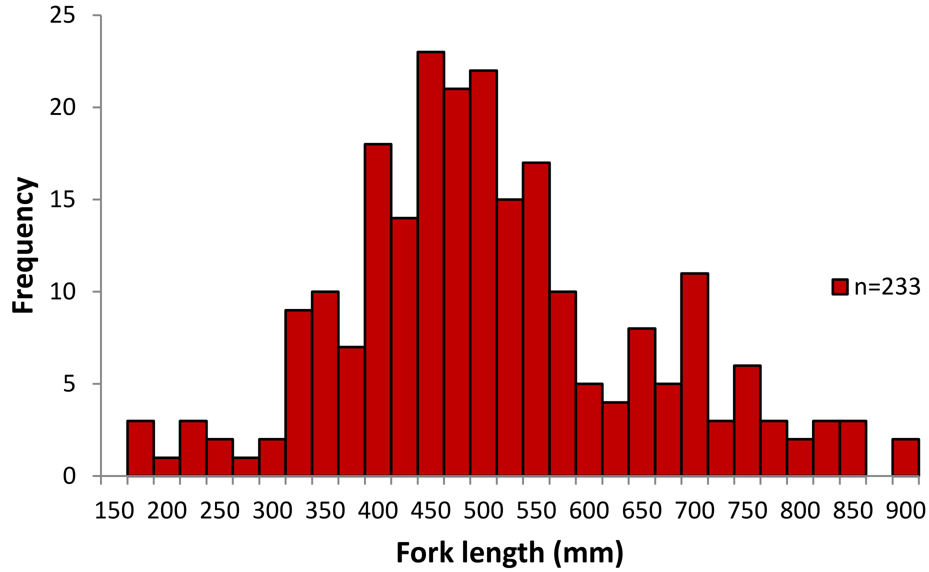

Figure 13. Overall size distributions of all red grouper measured from stereo images, 2009-2017.

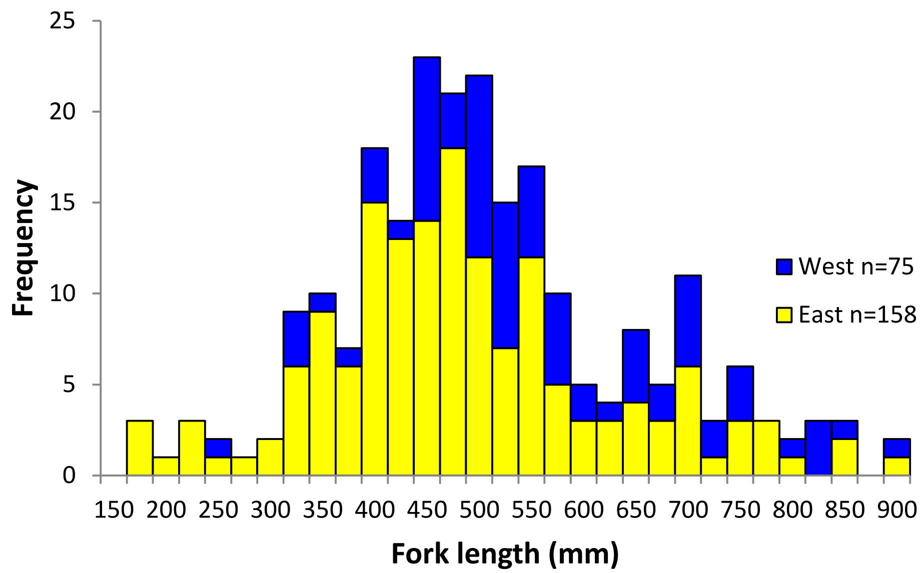

Figure 14. Overall size distributions of red grouper east and west of Cape San Blas observed with stereo cameras, 2009-2016.

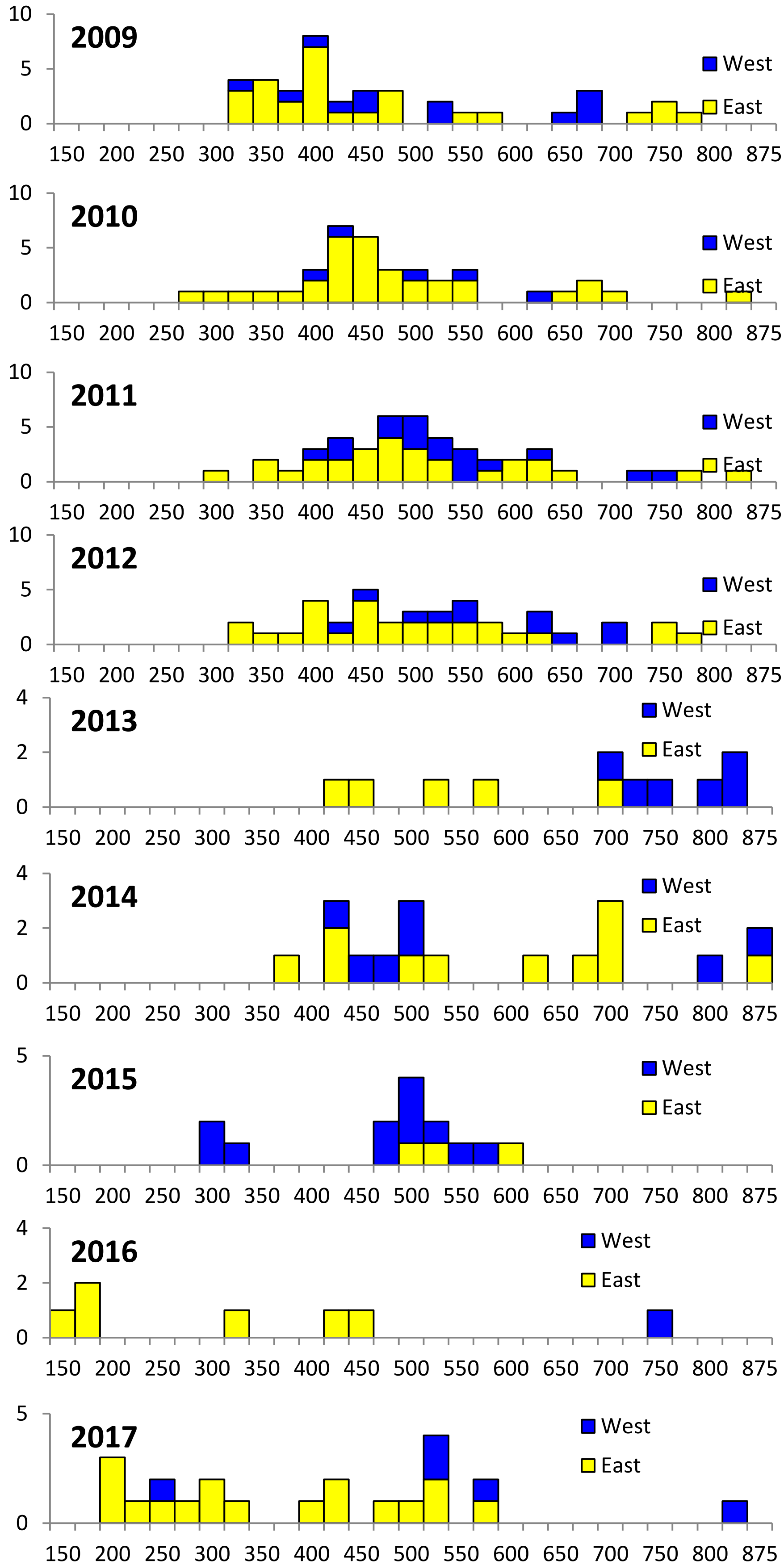

Figure 15. Annual size distributions of red grouper observed with stereo cameras, 2009-2017 east and west of Cape San Blas.

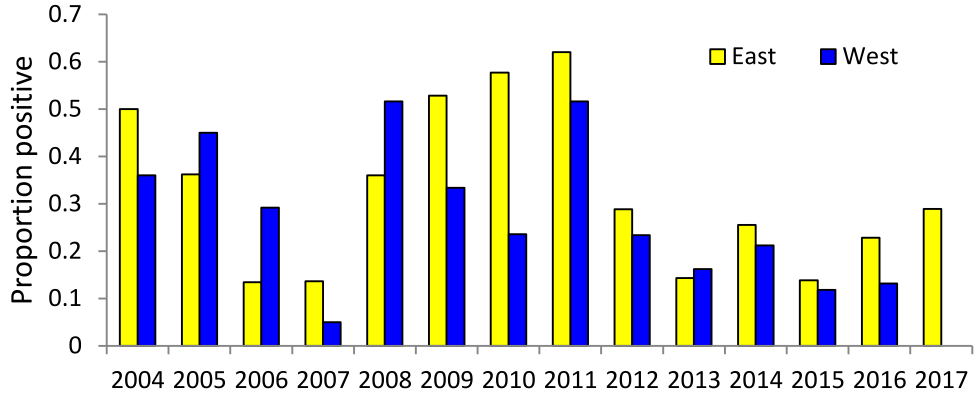

Figure 16. Annual proportions of positive red grouper trap catches, 2004-17 east and west of Cape San Blas.

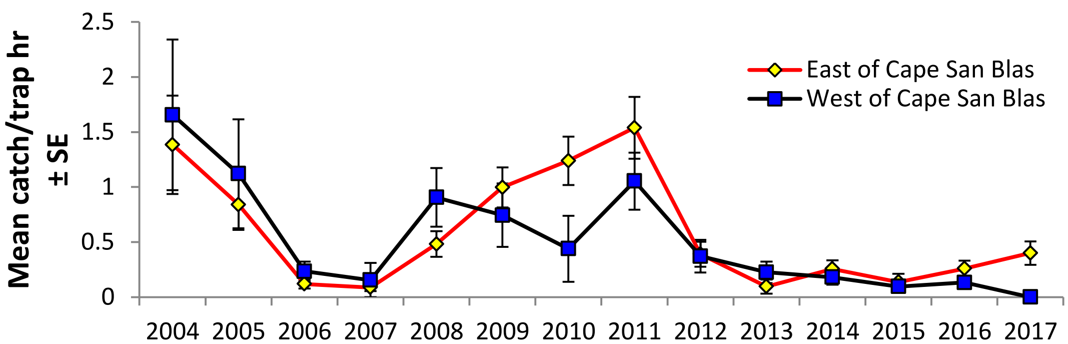

Figure 17. Mean catch per trap hr and standard errors of red grouper east and west of Cape San Blas, 2004-2017.

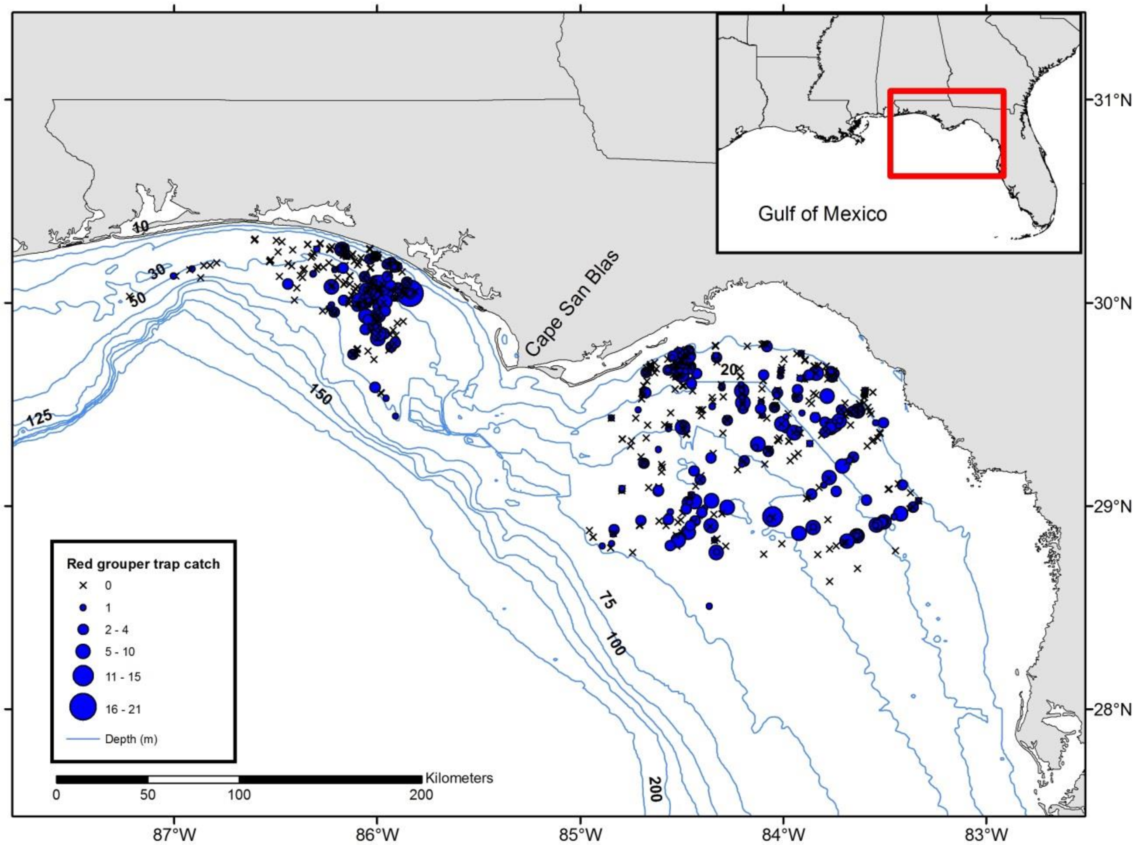

Figure 18. Distribution and relative abundance of red grouper caught in chevron traps in the Panama City NMFS reef fish survey, 2004-2017. X's are sites sampled, but where no red grouper were caught.

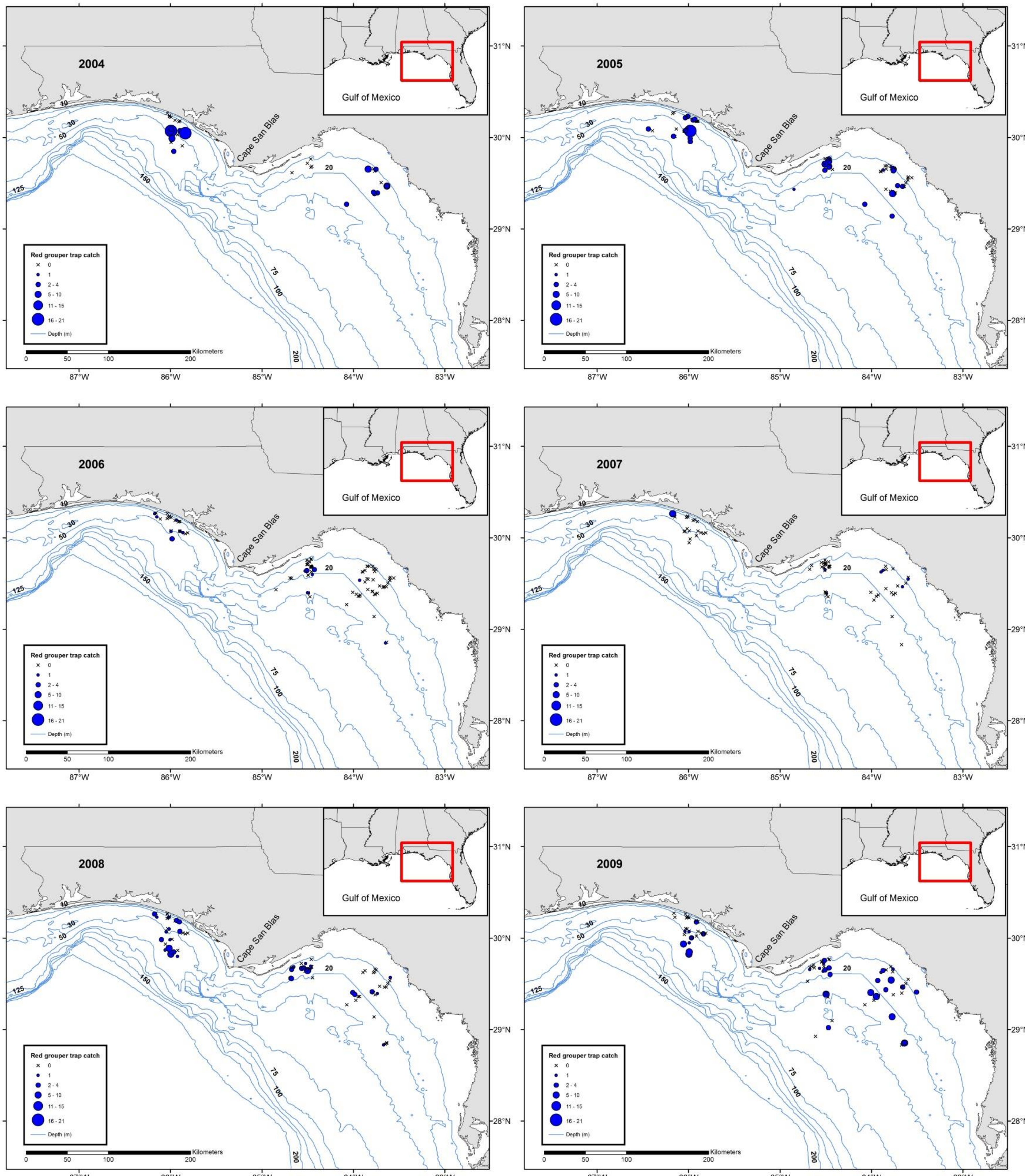

Figure 19. Annual distribution and relative abundance of red grouper caught in chevron traps in the Panama City NMFS reef fish survey, 2004-2017. X's are sites sampled, but where no red grouper were caught.

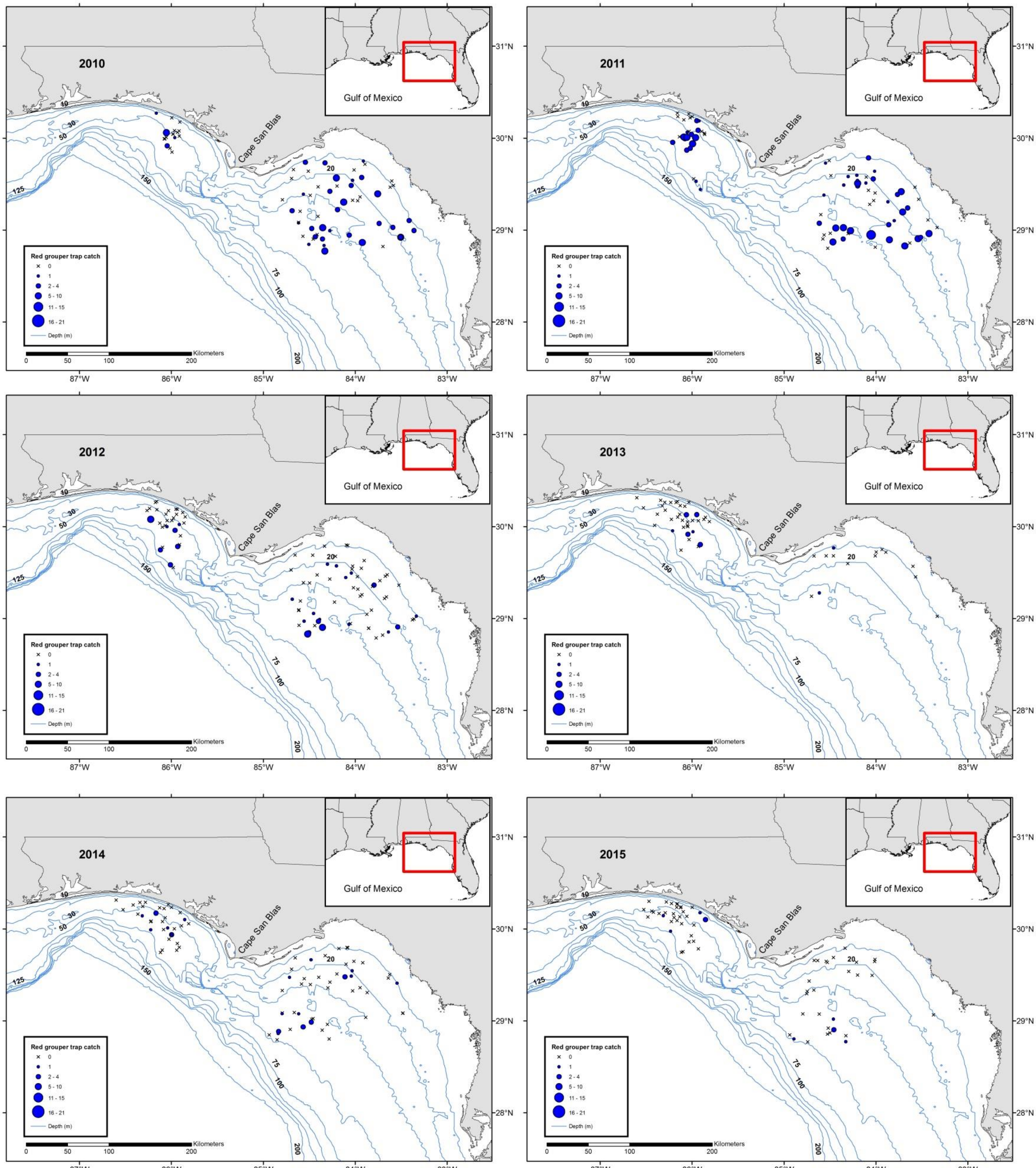

Figure 19 cont. Annual distribution and relative abundance of red grouper caught in chevron traps in the Panama City NMFS reef fish survey, 2004-2017. X's are sites sampled, but where no red grouper were caught.

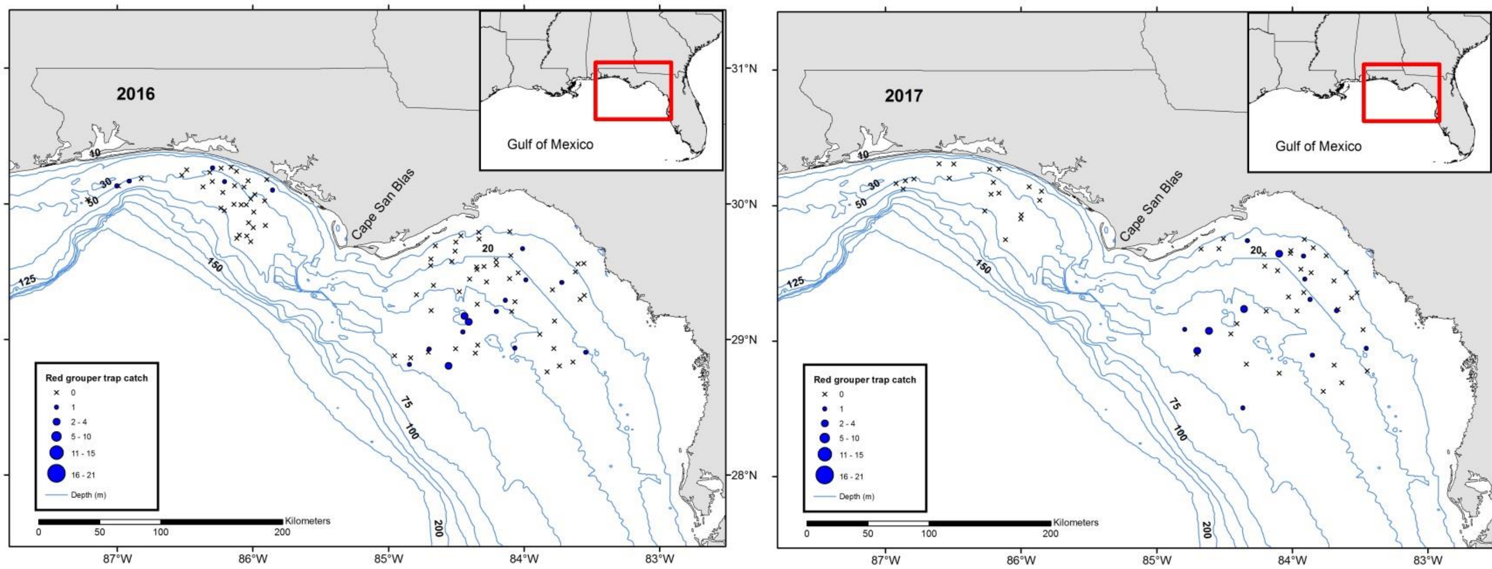

Figure 19 cont. Annual distribution and relative abundance of red grouper caught in chevron traps in the Panama City NMFS reef fish survey, 2004-2017. X's are sites sampled, but where no red grouper were caught.

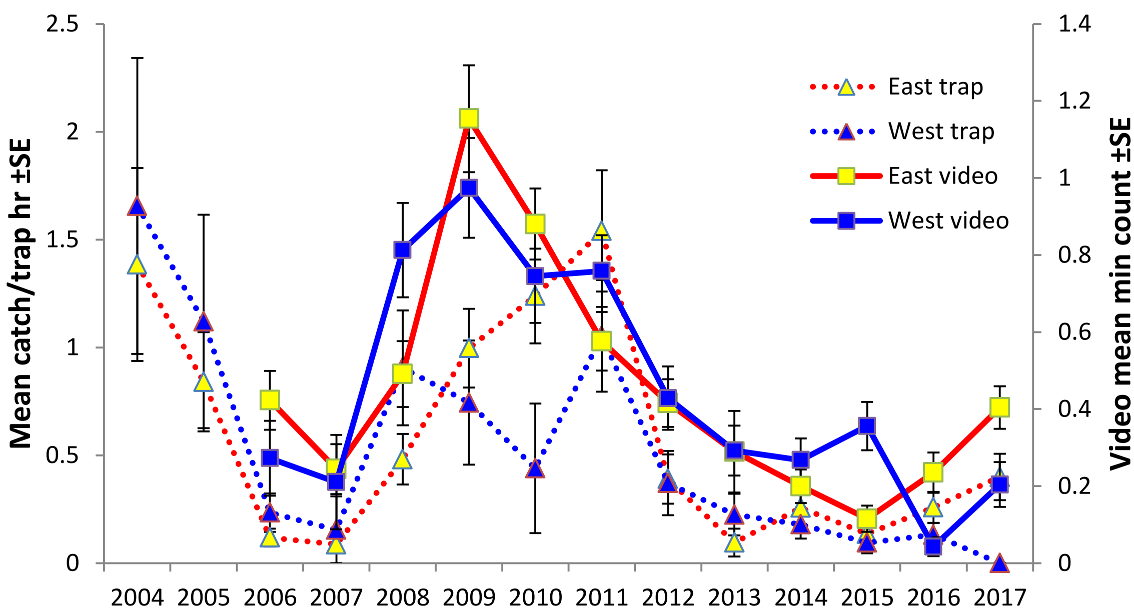

Figure 20. Annual trap (2004-2017) CPUE ±SE and video (2006-2017) mean min count ±SE of red grouper east and west of Cape San Blas.

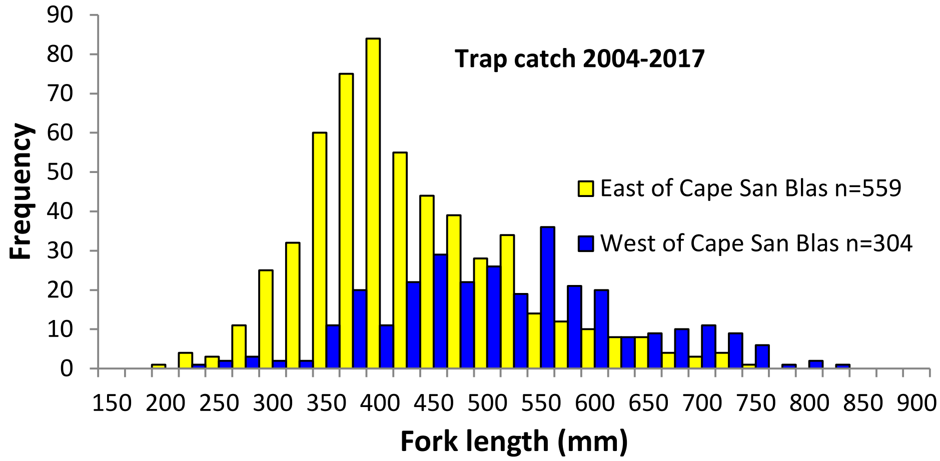

Figure 21. Overall size distributions of red grouper east and west of Cape San Blas caught in chevron traps, 2004-2017.

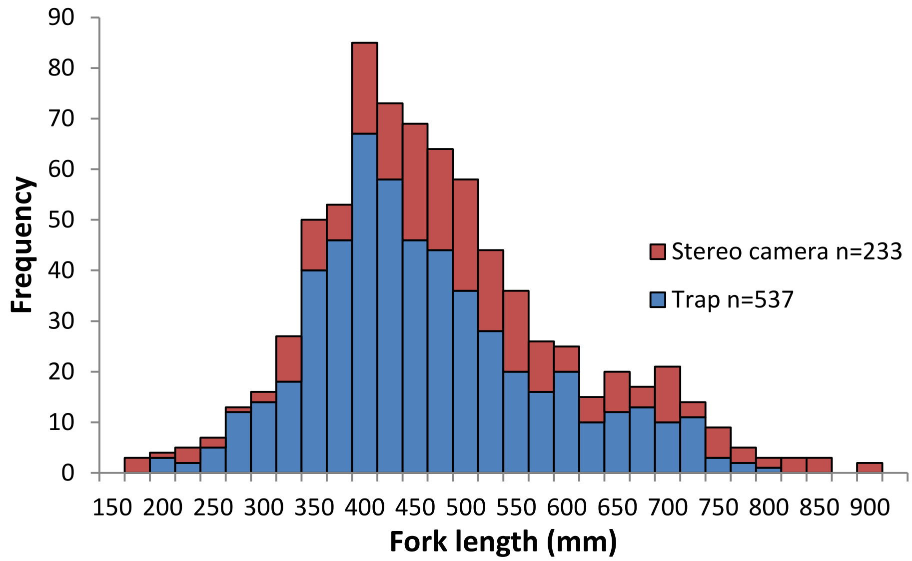

Figure 22. Overall size distributions of all red grouper collected in chevron traps and measured in stereo images, 2009-2017.

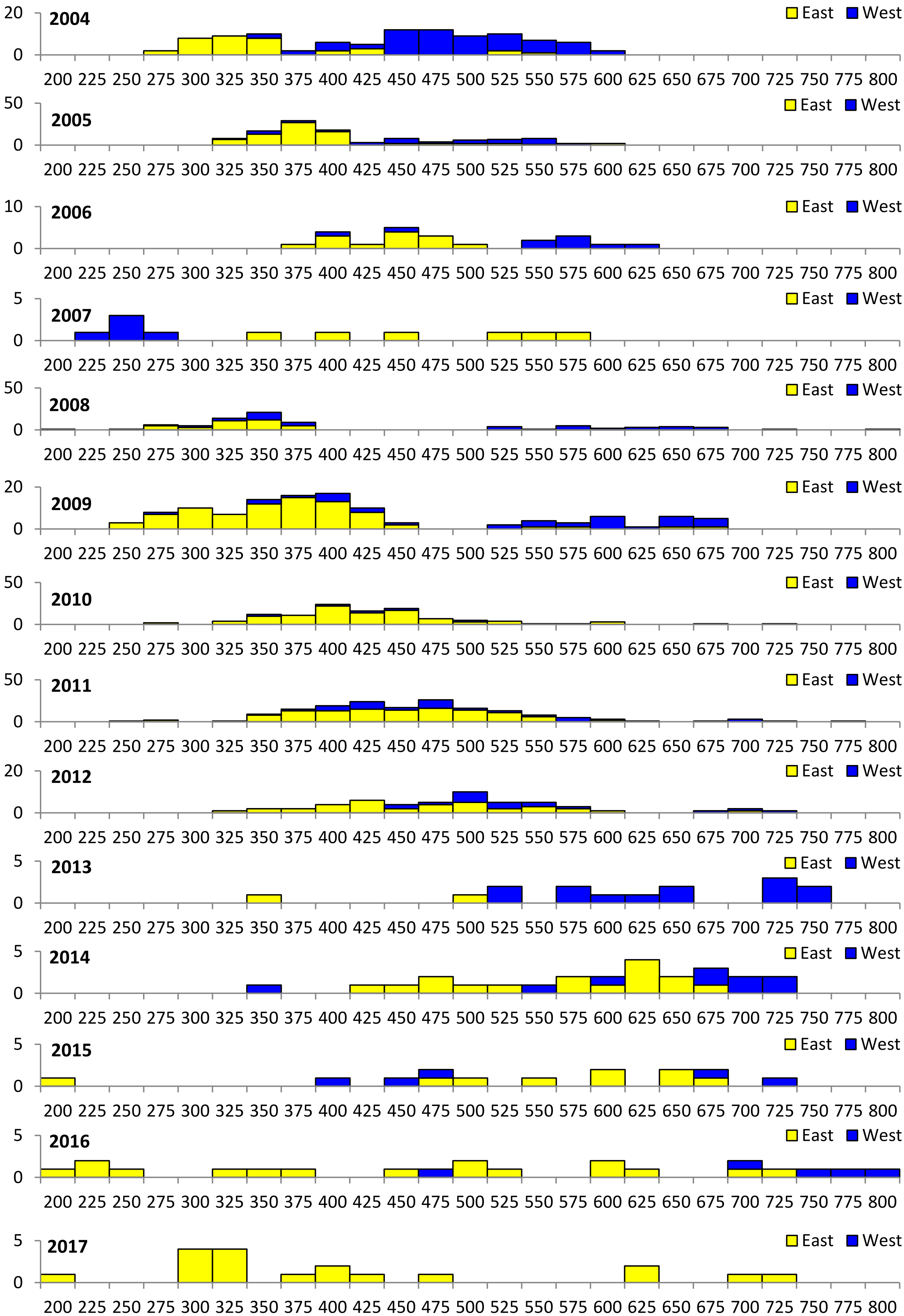

Figure 23. Annual size distributions of red grouper collected in chevron traps, 2004-2017, east and west of Cape San Blas.

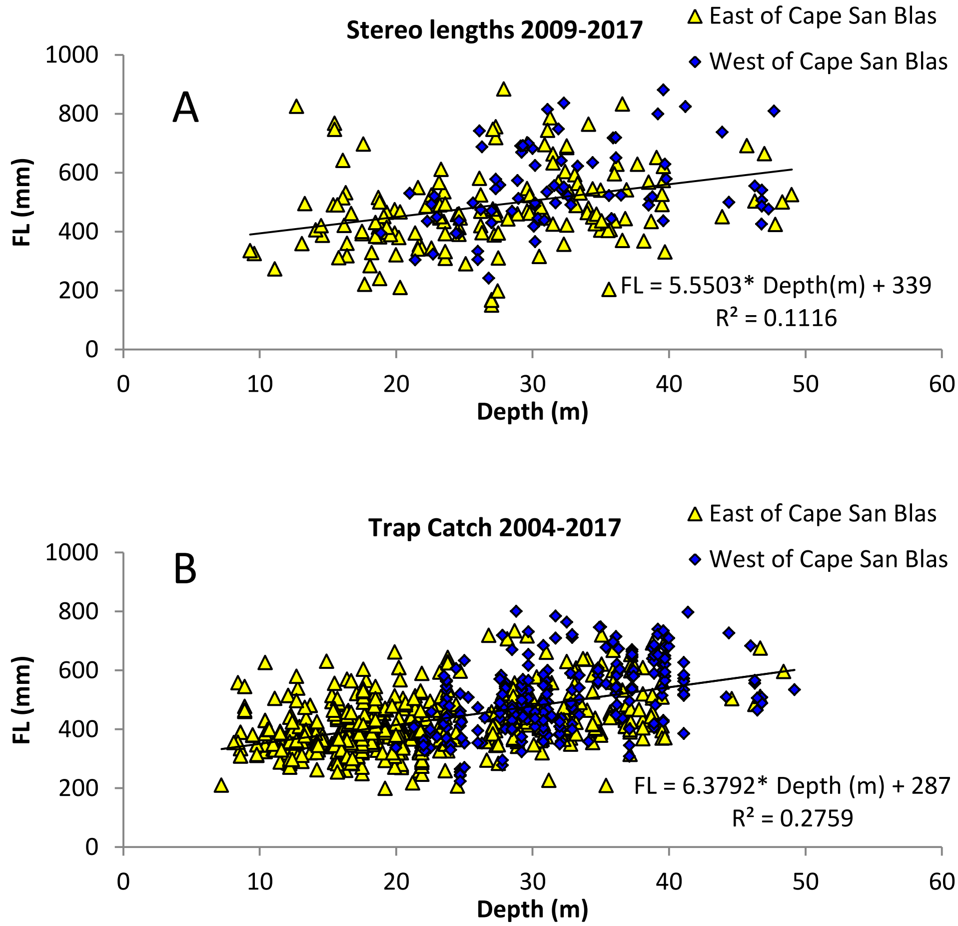

Figure 24. Fork length vs. depth relationship of red grouper observed with stereo cameras (A) east and west of Cape San Blas, 2009-2017, and collected with chevron traps (B), 2004-2017.

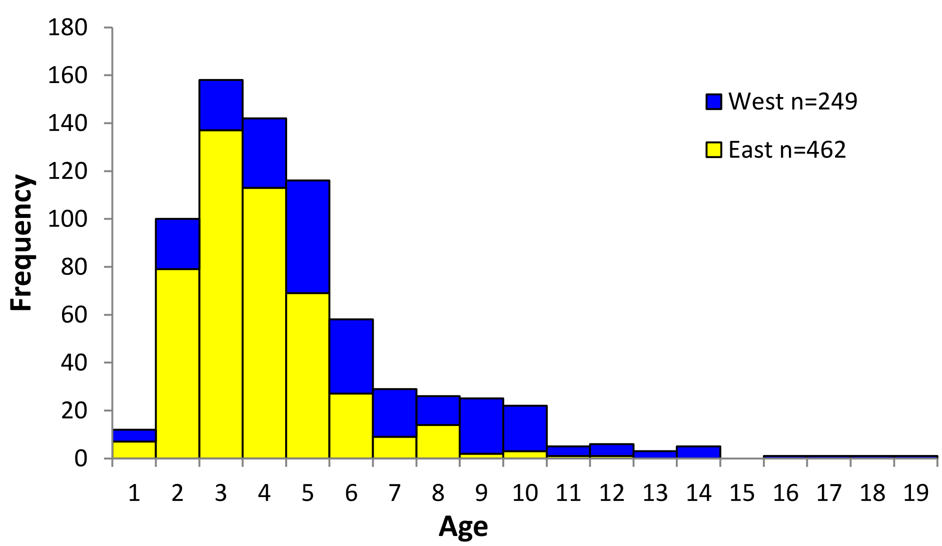

Figure 25. Overall age structure of trap-caught red grouper, east and west of Cape San Blas, 2004-2017.

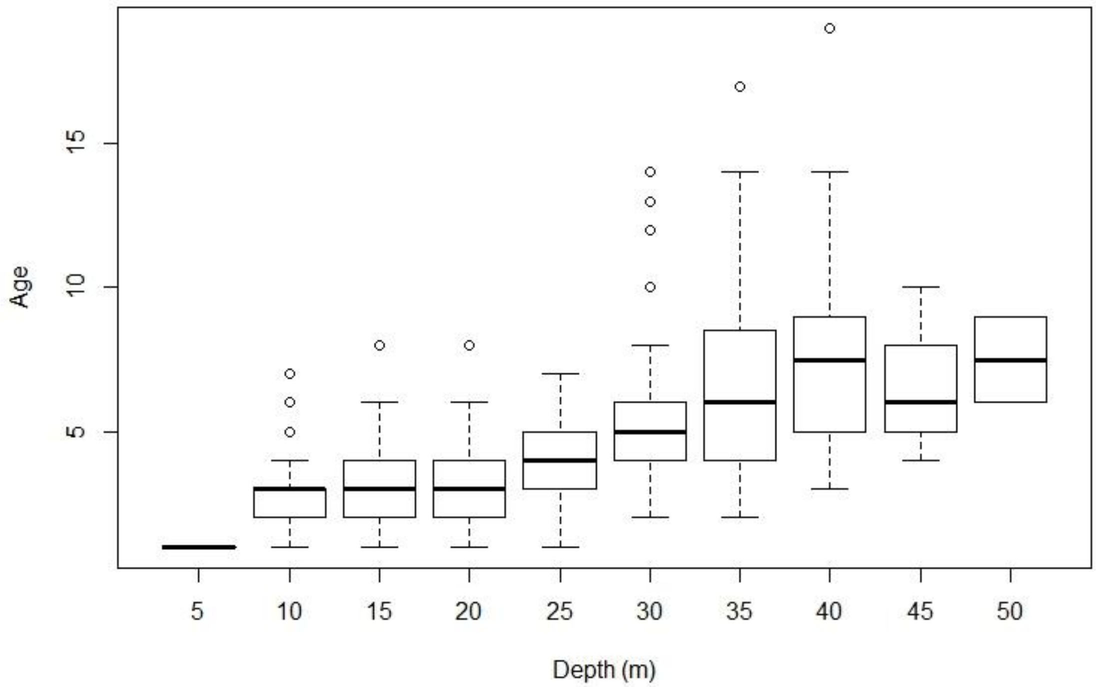

Figure 26. Age vs depth relationship of red grouper caught in chevron traps, 2004-2017, in the Panama City reef fish survey.

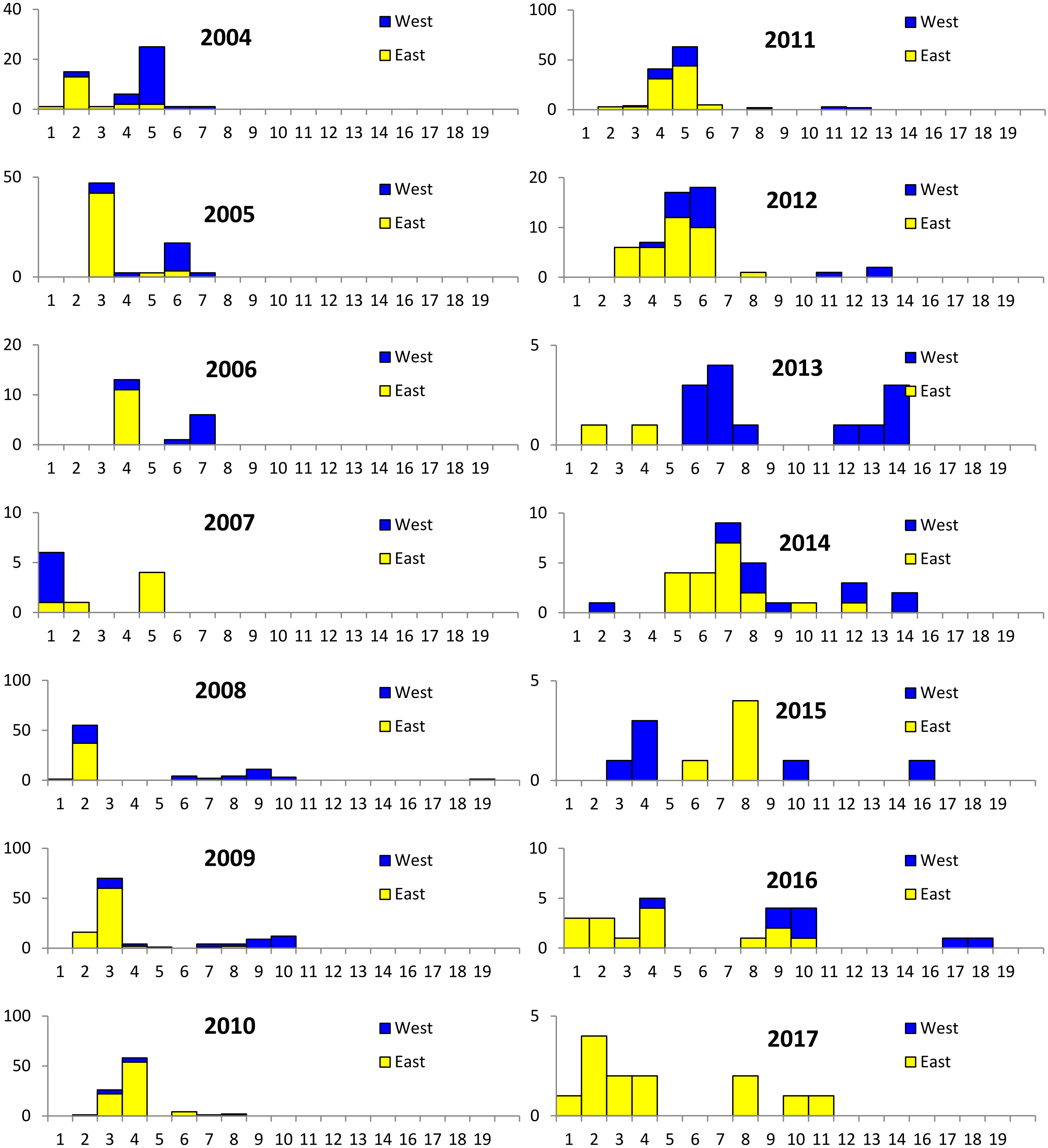

Figure 27. Annual age structure of red grouper caught in chevron traps in the NOAA Panama City lab reef fish survey, 2004-2017, by region.