Red snapper *Lutjanus campechanus* Findings from the NMFS Panama City Laboratory Camera & Trap Fishery-Independent Survey 2004-2016

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Red snapper *Lutjanus campechanus* Findings from the NMFS Panama City Laboratory Camera & Trap Fishery-Independent Survey 2004-2016

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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 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 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 (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 (2015-2016). 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 snapper have been consistently and commonly been observed with stationary video gear and captured in chevron traps across the inner and mid-West Florida shelf west of Cape San Blas and in waters deeper than 18m east 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 often forms small to medium sized schools, with approximately 89% of positive observations being 10 fish or less (Fig. 6). Red snapper were rarely observed or captured at depths less than 18m with positive occurrence in video only 9% and 6% in traps vs 67% in video and 52% in traps in depths ≥18 m (Tables 1, 2 and 3; Figures 7, 8, 9, and

16). Because of the rarity or absence of red snapper in shallower depths, data summaries are presented for collections from all depths and collections from depths ≥ 18 m. Red snapper displayed a very slight positive correlation between depth and fork length (Fig. 25) both east and west of the Cape, with a wide range of sizes at all depths sampled. However, an even stronger positive correlation between age and depth ($p<.0001$, $R^2=.82$) was observed (Fig. 27).

Encounter rates

Red snapper distribution and abundance on the inner and mid shelf have consistently and noticeably differed east and west of Cape San Blas since the Panama City survey began in 2004/5 (Tables 1 and 2, Figures 5 and 9)(DeVries et al. 2008, 2009), with significantly higher frequency of occurrence in video and trap samples in the west ($\bar{x}$ =.86 ±.07 vs .33±.09, p<.0001 video and $\bar{x}$ =.68 ±.14 vs $\bar{x}$ =.18 ±.07, p<.0001 trap) (Tables 1 and 2). Red snapper have been, by far, the most commonly encountered exploited reef fish west of Cape San Blas (the Cape) every year, occurring in 21 – 90 % ($\bar{x}$ ± 95% CL: .70 ±.14) of trap catches and 72 – 100 % ($\bar{x}$ =.88 ±.07) of video samples (Tables 1 and 2; Fig. 9). In contrast, east of the Cape, red snapper have been much less common, especially during 2004-08, when they occurred in 0-11 % ($\bar{x}$ =.07±.05) of trap sets and 11-55 % ($\bar{x}$ =.17±.22) of video samples. However, when sites shallower than 18m are excluded in the east, the % occurrences increased to 0-67% ($\bar{x}$ =.37±.11) for traps and 29-62% ($\bar{x}$ =.48±.08) for video (Tables 1 and 2; Figures 9 and 16). Some of the increase reflects 1) the difference in the distribution of depths sampled in each area, e.g., only a small proportion of sites <18 m have been sampled west of the Cape, while in the east through 2009, very few sites >18 m were sampled; as well as 2) the expansion of sampling to deeper depths over time (Fig. 3). Figure 8 clearly shows that red snapper east of Cape San Blas were rarely observed in depths <18 m. Although the sampling depth differences and changes likely explain some of the increases in occurrence, it also appears to reflect an expansion of the population into Apalachee Bay, as occurrence increased noticeably even in shallow (<18 m) areas, especially an area in northwest Apalachee Bay in 2009 and 2010 (Fig. 12) that was not as prevalent again until 2016. The region west of Cape San Blas did not have any samples shallower than 16m and red snapper were observed throughout the entire depth range. This difference in sampling between regions is attributed to the shallower slope of the West Florida Shelf in the east, which hosts a large amount of hard bottom habitat.

Abundance trends

Not surprisingly, estimates of relative abundance for red snapper displayed overall similar patterns to those seen in proportion positives. A significant decline in mean nominal video min counts was observed on the west side of Cape San Blas in 2008 ($\bar{x}$ =10.35 to 6.57, p=.028 followed by a sharp increase in 2009 ($\bar{x}$ =6.57 to 10.7, p=.016) (Table 1, Figures 10 and 20). Following 2009, video relative abundance counts in the west declined steadily until 2012, while only showing a slight decline in proportion positive for video samples (Table 1). From 2006-2007 and 2009-2012 video relative abundance data (Mean min count or MaxN) displayed much higher values west compared to the east of the cape for both all depths and those collected ≥ 18m (p<.0001). In the eastern region, video relative abundance increased steadily from 2012, and from 2013-2016 displayed similar abundance estimates as those in the west in both the total depth range as well as the ≥ 18m zone (Table 1). Trap catch per trap hour closely mirrored the

abundance trends displayed in the video survey with generally higher catches in the west for 2004-2012 with the exception of 2010, where trap catches declined dramatically in the west (Figures 17 and 20). From 2013-2016, there were no significant differences in trap CPUE on either side of the cape or in either depth zone. This matches video estimates of relative abundance decreasing in the west, but being relatively stable since 2012 (Tables 1 and 2; Fig. 20).
Geographic patterns of trends in relative abundance in video min counts (2006-2016) and nominal trap catches (2004-2016) are displayed in annual GIS plots in Figures 12 and 19.

Size and age

Red snapper caught in the trap survey ranged from ages 1 to 15 yr with a mean age of 3.3±0.1 yr and broad mode of 2-6 yr (Fig. 28). Modal and mean ages were similar both east and west of the Cape. Annual age structure data of red snapper from the trap catches showed evidence of a strong year classes in 2006, 2007, 2011, 2012, and 2014 as steady progressions in the age structure are present each year 2009-2016 (Fig. 28). Such periodic strong year classes characterize populations of co-occurring reef fish such as gag, red grouper, and vermilion snapper on the northern West Florida Shelf. Overall annual modal ages varied from 2 to 6 yr between 2005 and 2016, and red snapper ages 1 and >6 yr have been rare in the survey since age samples started being retained in 2005 (Fig. 26). There was a slight positive relationship between red snapper age and depth. Although the regression of age on depth was significant ($p<.0001$), it only explained 12% of the variance (Fig. 27). This is likely due to the wide range of ages seen throughout the depth range.
Trap caught red snapper sizes displayed a normal distribution (Fig. 21) and overall modal size of was fairly stable 2005-2007, ranging from 300 to 350 mm FL, then steadily increased through 2011, when it was 375 to 425 mm FL (Fig. 23). Along with this increase in modal size, the lower (left hand) tail of the distribution also shifted, increasing from around 200-225 mm in 2005 to about 325 mm in 2011. Part of this shift may reflect the expansion of the sampling depth range west of the Cape during those years, as a comparison of size structure in depths < and > 30 m (Fig. 25) clearly showed smaller average sizes in shallower depths. However, the shift in size structure co-occurred with increasingly restrictive management measures and mirrored the steady increases in average sizes (and catch rates) of recreationally harvested fish in the area, which suggests it shows a real trend in the population and is not just an artifact of changes in sampling depths. In 2012, the distribution shifted back to the left, with modal size decreasing to around 275-300 mm FL. However, the larger fish were still common and displayed regular progression and a wide range of sizes from 2013-2016 both east and west of Cape San Blas.

Not surprisingly, a comparison of size data from trap catches with that from stereo images indicated that the traps do select against most red snapper >650 mm FL, although fish that large appear to be uncommon in the survey area based on the few stereo measurements obtained (Fig. 22). For the most part, in 2009-2016, the size distributions were surprisingly similar between the two gears, except for the rare large fish detected only with the video gear.

Red snapper lengths calculated from stereo cameras during 2009-2016 displayed normal distributions both east and west of Cape San Blas (Figures 13 and 14). Mean lengths were similar on both sides of the Cape ($\bar{x}$ ± 95% CL: 409 ± 15 vs 419 ±11 mm FL)(Table 4). The overall modal size of red snapper was smaller in the east vs west (352 vs 402 mm

FL). In years with overlap between stereo cameras and traps (2009-2016), mean sizes were similar between both gears and regions, however, measurements from stereo cameras in the west had a larger mode (402 vs 336 mm FL east). This is likely due to the traps selecting against the red snapper greater than 650 mm FL. Annual size distributions displayed shifted to greater lengths (although sample sizes were small) each year from 2009 to 2011, and then dropped noticeably in 2013 to a median size of ~380 mm from 467 mm the year before, suggesting recruitment into the region of a new year class noticeably larger than those in the previous two years (Figures 15 and 24). In 2015 in both the trap and video data, a larger proportion of small fish was observed, with a mode ~225-250 mm, suggesting another recruitment pulse (Figures 15 and 23).

The regression of fork length on depth from the video survey was not significant for both regions combined (p=.99) as well as individual regions (p=.99 east, p=.86 west). However, the trap data showed a moderate positive correlation between FL and depth for data regions individually as well as combined (p<.0001). This only accounted for ~2% of the variation in the regression in each case and a wide range of lengths were observed across the entire depth range (Fig. 25).

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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 snapper east and west of Cape San Blas, 2006-2016, for all depths (A) and for depths ≥18 m (B). Estimates calculated using censored data sets (see Methods).

A. <u>All depths included</u>

	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	48	23	71	0.27	1.00	0.50	0.83	7.77	3.01	0.35	1.22	0.59
2007	29	23	52	0.14	1.00	0.52	0.34	10.35	4.77	0.22	1.54	0.97
2008	56	29	85	0.11	0.97	0.40	0.70	6.34	2.62	0.61	0.83	0.57
2009	62	37	99	0.45	1.00	0.66	1.45	10.70	4.91	0.29	1.54	0.75
2010	92	51	143	0.48	0.94	0.64	1.35	7.08	3.39	0.19	0.92	0.42
2011	99	57	156	0.26	0.91	0.50	0.52	5.49	2.33	0.10	0.67	0.32
2012	101	49	150	0.23	0.86	0.43	0.42	2.88	1.22	0.09	0.56	0.21
2013	34	60	94	0.26	0.75	0.57	1.00	2.50	1.96	0.42	0.44	0.32
2014	85	69	154	0.31	0.80	0.53	1.07	2.10	1.53	0.34	0.26	0.22
2015	98	58	156	0.36	0.72	0.49	2.51	2.09	2.35	0.63	0.41	0.43
2016	119	62	181	0.55	0.78	0.64	2.97	3.02	2.93	0.53	0.68	0.40
Total	**823**	**518**	**1341**	**0.33**	**0.86**	**0.54**	**1.32**	**4.65**	**2.62**	**0.13**	**0.26**	**0.13**

B. <u>Depths ≥ 18 m</u>

	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	17	21	38	0.59	1.00	0.82	2.12	8.00	5.37	0.93	1.26	0.93
2007	11	23	34	0.36	1.00	0.79	0.91	10.35	7.29	0.55	1.54	1.30
2008	16	28	44	0.38	1.00	0.77	2.44	6.57	5.07	2.11	0.82	0.96
2009	31	36	67	0.61	1.00	0.82	2.10	10.89	6.82	0.49	1.58	1.02
2010	68	51	119	0.62	0.94	0.76	1.76	7.08	4.04	0.23	0.92	0.48
2011	65	56	121	0.40	0.91	0.64	0.78	5.57	3.00	0.15	0.68	0.39
2012	78	49	127	0.29	0.86	0.51	0.54	2.88	1.44	0.12	0.56	0.25
2013	17	60	77	0.53	0.75	0.70	2.00	2.50	2.39	0.77	0.44	0.38
2014	56	68	124	0.45	0.79	0.64	1.61	2.00	1.82	0.50	0.24	0.26
2015	75	58	133	0.45	0.72	0.57	3.27	2.09	2.75	0.81	0.41	0.49
2016	80	65	145	0.63	0.78	0.70	3.63	3.00	3.34	0.64	0.67	0.46
Total	**514**	**515**	**1029**	**0.48**	**0.86**	**0.67**	**1.99**	**4.66**	**3.32**	**0.19**	**0.26**	**0.17**

Table 2: Annual chevron trap sample sizes, proportion positive occurrences, mean nominal catch/trap hr, and standard errors of red snapper east and west of Cape San Blas, 2004-2016, for all depths (A) and for depths ≥18 m (B).

A. <u>All depths included</u>

	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	25	41	0.06	0.84	0.54	0.42	13.50	8.40	0.42	3.16	2.17
2005	47	20	67	0.11	0.90	0.34	1.87	10.28	4.38	1.20	2.00	1.13
2006	67	24	91	0.10	0.88	0.31	0.26	7.05	2.05	0.13	1.38	0.49
2007	44	20	64	0.09	0.90	0.34	0.18	8.67	2.84	0.13	1.82	0.75
2008	50	31	81	0.00	0.87	0.33	0.00	7.18	2.75		1.59	0.72
2009	53	30	83	0.36	0.87	0.54	1.16	8.96	3.98	0.34	1.58	0.73
2010	52	17	69	0.19	0.47	0.26	0.70	1.38	0.87	0.31	0.59	0.28
2011	50	31	81	0.20	0.87	0.46	0.23	5.01	2.06	0.08	0.85	0.42
2012	59	30	89	0.17	0.80	0.38	0.27	3.52	1.37	0.11	0.73	0.30
2013	14	37	51	0.14	0.46	0.37	2.62	1.85	2.06	2.01	0.49	0.64
2014	47	33	80	0.13	0.21	0.16	0.33	0.32	0.33	0.24	0.14	0.15
2015	29	34	63	0.31	0.50	0.41	0.76	1.02	0.90	0.25	0.23	0.17
2016	57	38	95	0.39	0.55	0.45	1.13	2.21	1.56	0.24	0.39	0.22
Total	**585**	**370**	**955**	**0.18**	**0.68**	**0.37**	**0.66**	**5.03**	**2.35**	**0.12**	**0.40**	**0.19**

B. <u>Depths ≥ 18 m</u>

	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	2	23	25	0.50	0.87	0.84	3.33	14.10	13.24	3.33	3.39	3.17
2005	7	20	27	0.57	0.90	0.81	12.34	10.28	10.81	7.22	2.00	2.31
2006	18	23	41	0.39	0.87	0.66	0.96	7.24	4.48	0.47	1.43	0.96
2007	12	18	30	0.33	0.89	0.67	0.67	8.86	5.58	0.45	2.02	1.42
2008	14	30	44	0.00	0.90	0.61	0.00	7.42	5.06	0.00	1.62	1.22
2009	20	30	50	0.50	0.87	0.72	1.80	8.96	6.10	0.68	1.58	1.10
2010	36	17	53	0.25	0.47	0.32	0.99	1.38	1.12	0.44	0.59	0.35
2011	37	30	67	0.27	0.87	0.54	0.31	5.02	2.42	0.11	0.88	0.49
2012	44	30	74	0.23	0.80	0.46	0.36	3.52	1.64	0.14	0.73	0.35
2013	3	37	40	0.67	0.46	0.48	12.22	1.85	2.63	8.02	0.49	0.80
2014	33	33	66	0.18	0.21	0.20	0.47	0.32	0.40	0.34	0.14	0.18
2015	20	34	54	0.40	0.50	0.46	1.07	1.02	1.04	0.35	0.23	0.19
2016	43	38	81	0.47	0.55	0.51	1.43	2.21	1.80	0.31	0.39	0.25
Total	**289**	**363**	**652**	**0.31**	**0.68**	**0.52**	**1.22**	**5.03**	**3.34**	**0.24**	**0.41**	**0.26**

Table 3: Video survey sample sizes and proportion positive occurrences of red snapper by depth zone snapper east and west of Cape San Blas, 2006-2016 all years combined.

	Total sites sampled			Proportion positive occurrences		
Depth (m)	East	West	Total	East	West	Total
5-7	1		1	0.00		0.00
7-9	10		10	0.10		0.18
9-11	52		52	0.06		0.06
11-13	50		50	0.04		0.04
13-15	78		78	0.06		0.06
15-17	69	1	70	0.09	1.00	0.10
17-19	78	7	85	0.24	0.86	0.29
19-21	79	14	93	0.37	0.79	0.43
21-23	56	52	108	0.32	0.94	0.62
23-25	40	41	81	0.38	0.90	0.64
25-27	30	47	77	0.60	0.91	0.78
27-29	45	47	92	0.51	0.89	0.71
29-31	46	63	109	0.65	0.90	0.80
31-33	31	75	106	0.55	0.83	0.75
33-35	38	36	74	0.63	0.81	0.72
35-37	36	42	78	0.83	0.79	0.81
37-39	21	28	49	0.57	0.83	0.72
39-41	18	21	39	0.61	0.95	0.79
41-43	7	7	14	0.00	0.86	0.43
43-45	3	6	9	0.00	1.00	0.67
45-47	6	16	22	0.17	0.63	0.50
47-49	10	12	22	0.50	0.75	0.64
49-51	4	1	5	0.50	0.00	0.40
51-53		1	1		0.00	0.00
53-55		2	2		1.00	1.00
55-57		1	1		0.00	0.00

Table 4: Descriptive statistics of red snapper sizes (fork length mm) obtained from chevron traps (2004-2016) and stereo camera measurements (2009-2016).

	Trap caught fish			Stereo camera		
	East	West	Total	East	West	Total
Min	158	192	158	161	217	161
1st Qu.	298	303	301	336	351	346
Median	332	333	333	395	405	405
Mode	298	330	330	353	402	402
Mean	342	344	343	409	419	415
Confidence Level on Mean (95%)	5.2	2.4	2.2	15.3	10.5	8.7
3rd Qu.	368	373	372	472	469	470
Max.	692	773	773	841	845	845
Count	824	3038	3862	241	385	626

Figures

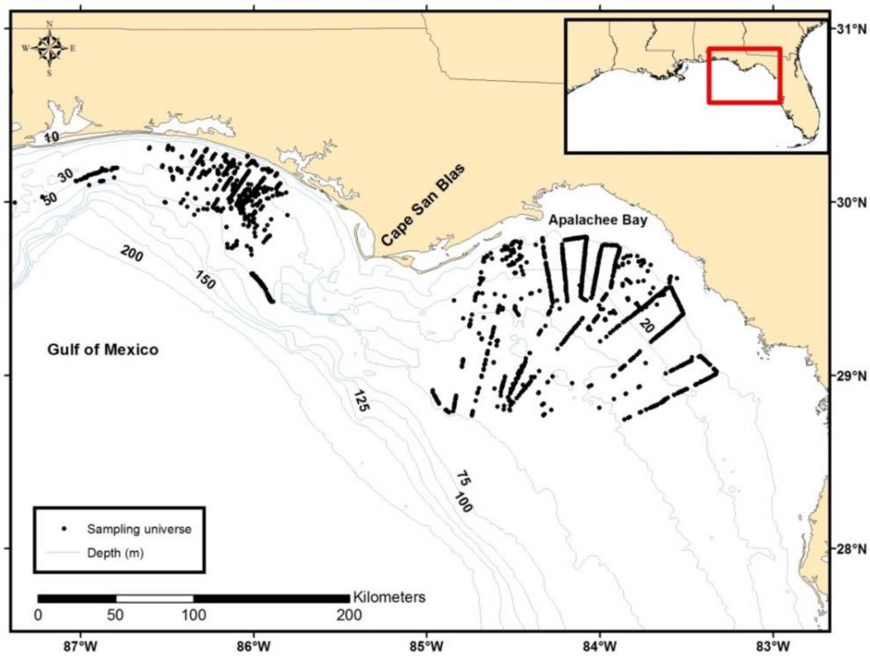


Figure 1. Locations of all natural reefs in the sampling universe of the Panama City NMFS reef fish video survey as of October 2016. Total sites: 3241 – 1362 west, and 1879 east, of Cape San Blas. Isobaths are in meters.

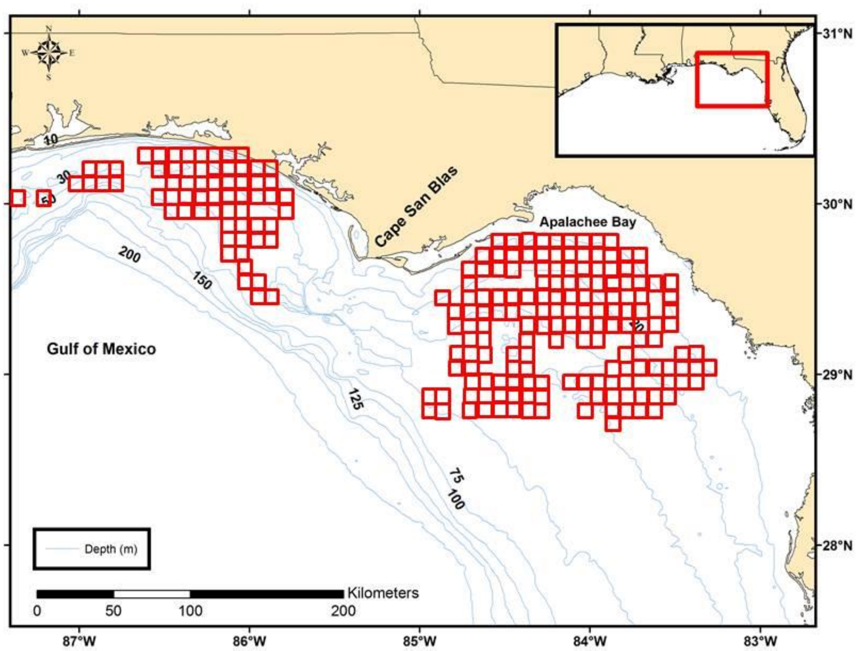


Figure 2. Sampling blocks (5 min lat. x 5 min. long.) of the Panama City reef fish survey. Blocks in red contain known hard bottom reefs and are subject to being selected for sampling. Isobaths are in meters.

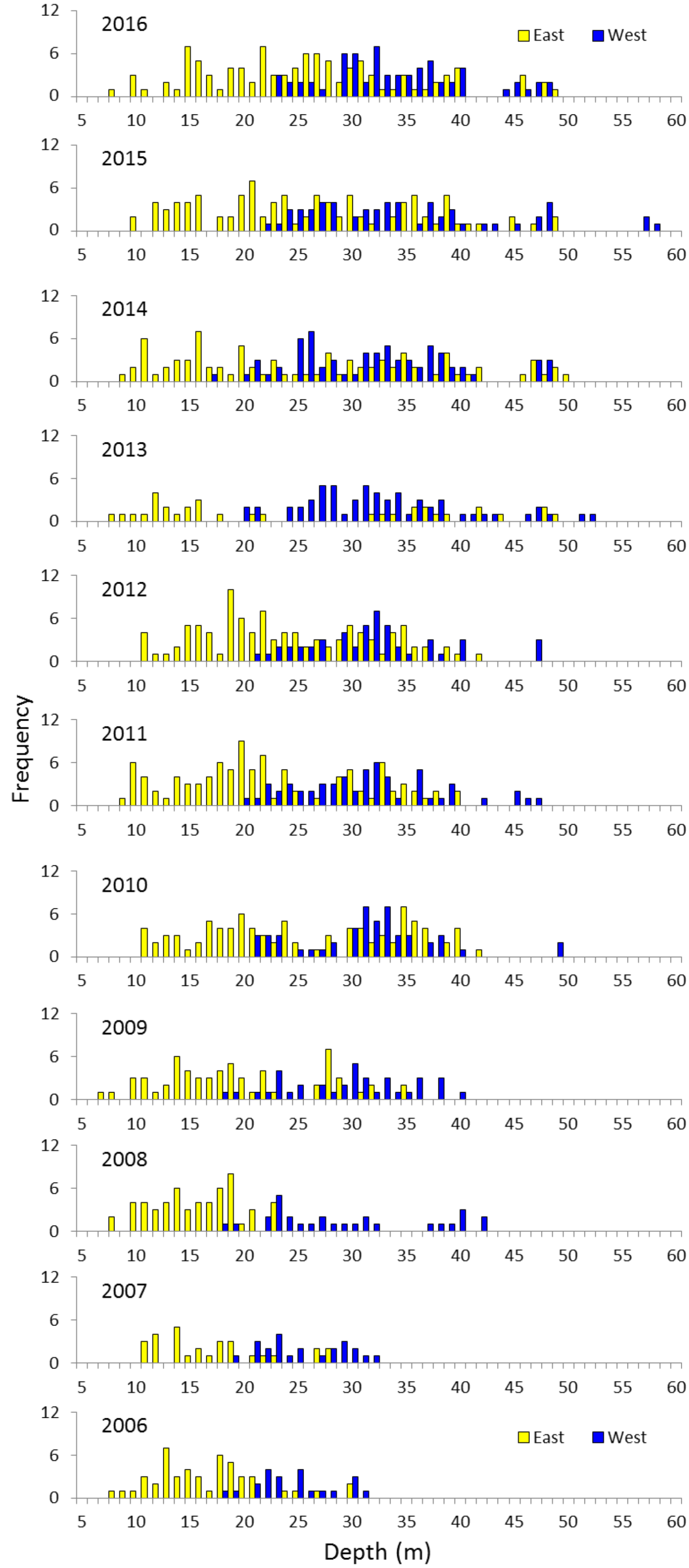


Figure 3. Annual depth distribution of Panama City reef fish survey video sample sites east and west of Cape San Blas, 2006-2016.

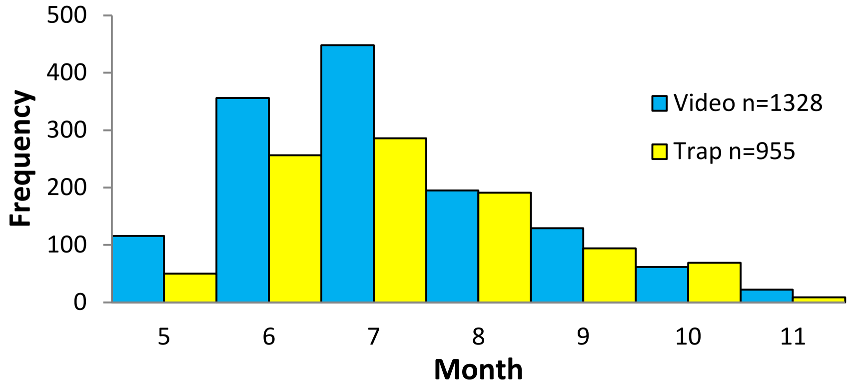


Figure 4. Overall monthly distribution of Panama City reef fish survey video and trap samples (censored data sets only), 2006-2016.

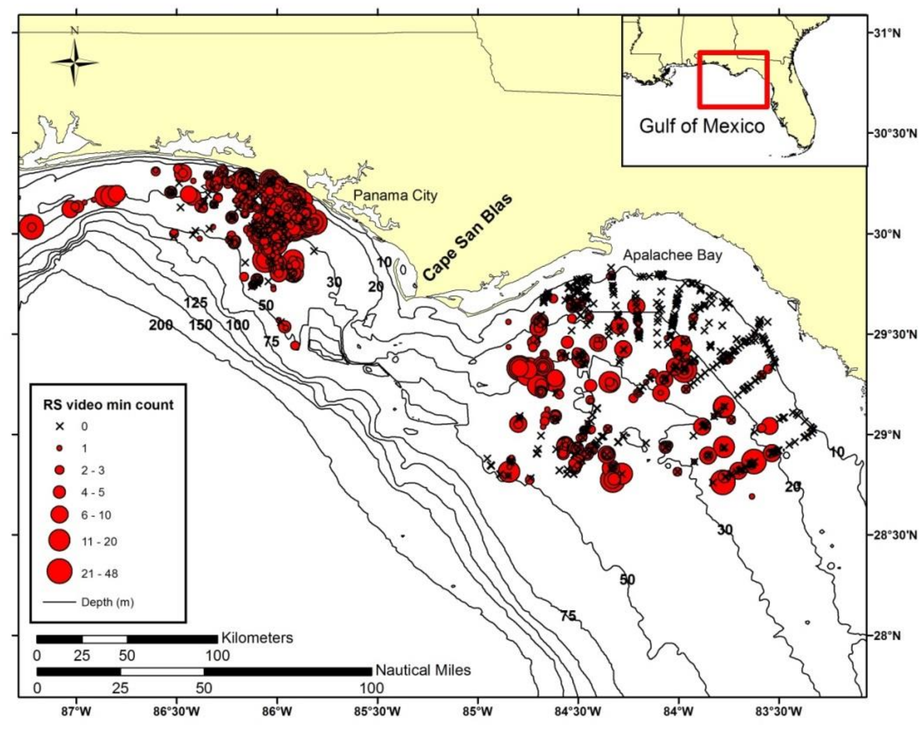


Figure 5 A. Distribution and relative abundance of red snapper observed with stationary, high definition video or MPEG cameras (min counts) in the Panama City NMFS reef fish survey, 2006-2016. X's are sites sampled, but where no red snapper were observed.

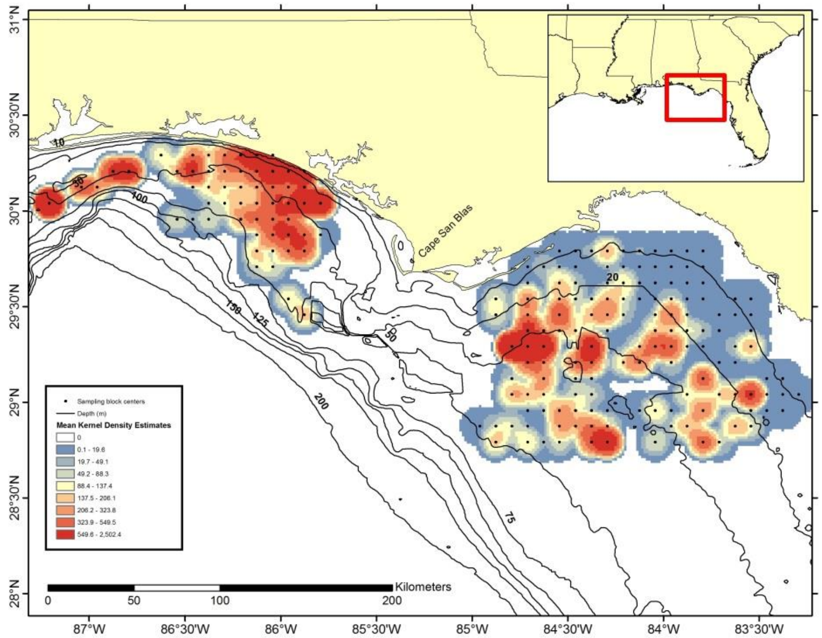


Figure 5 B. Overall relative density plot of red snapper based on count data (min-counts, also called maxN) from video collected with stationary camera arrays in annual surveys, 2006-2016. Min counts were standardized by 5 min latitude x 5 min longitude sampling block, and kernel density estimates were calculated from the mid-point (black dots in the figure) of each block (See Fig. 2).

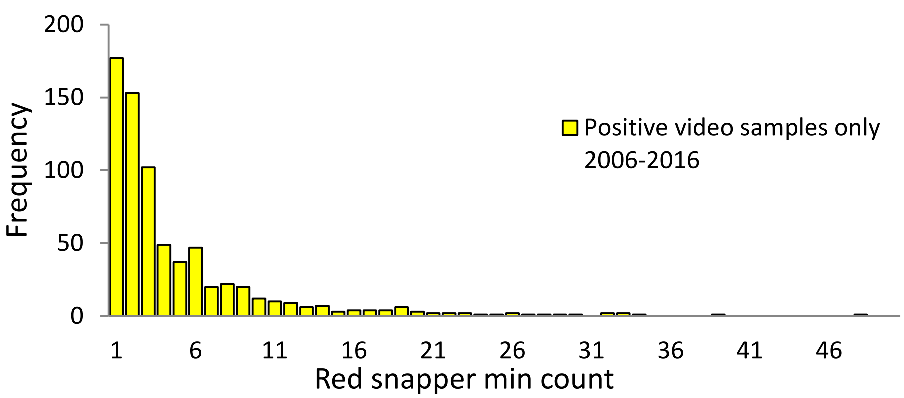


Figure 6. Frequency distribution of non-zero min counts of red snapper from Panama City reef fish video samples, 2006-2016.

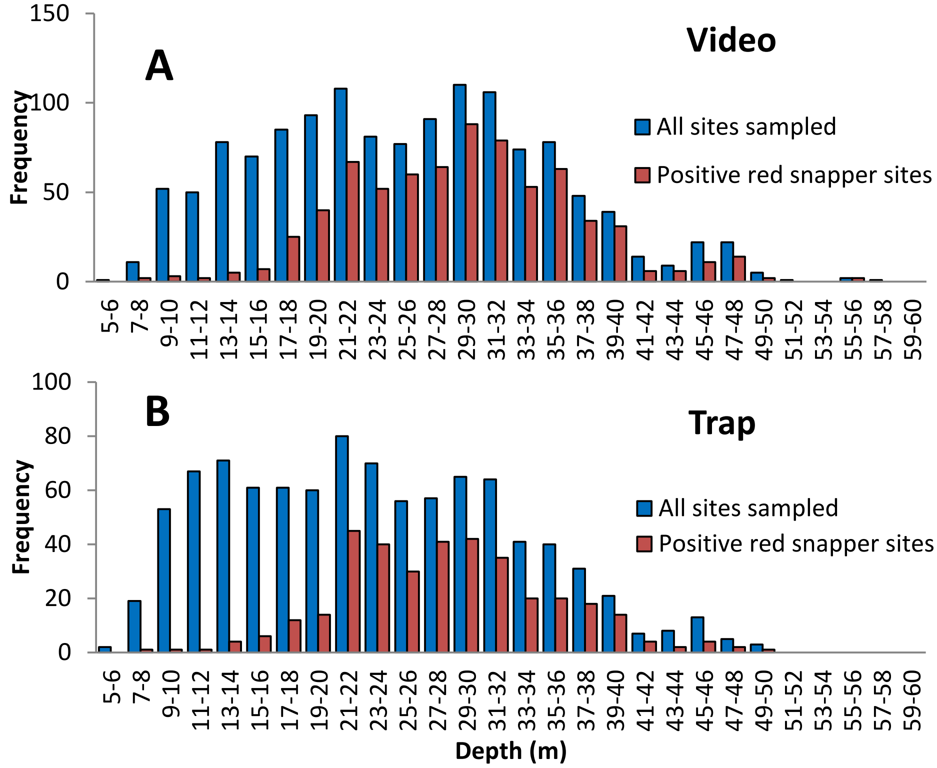


Figure 7. Depth distributions of all video (A) and trap (B) (2006-2016) sample sites vs only sites positive for red snapper.

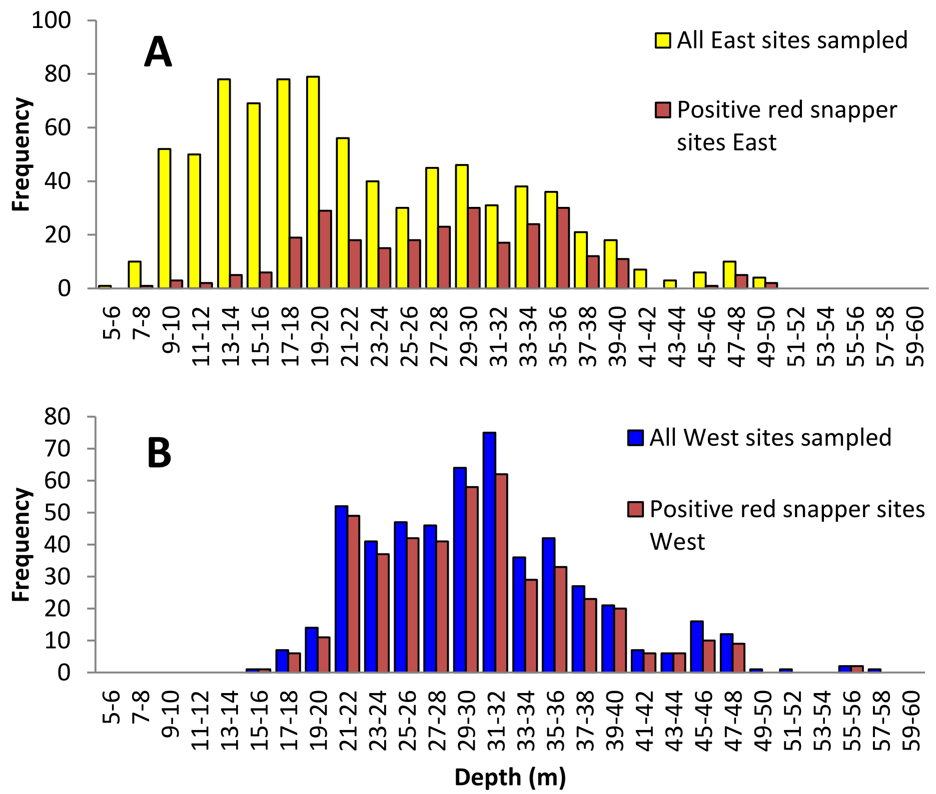


Figure 8. Depth distributions of all video sample sites vs only sites positive for red snapper for east of Cape San Blas (A) and west of Cape San Blas (B).

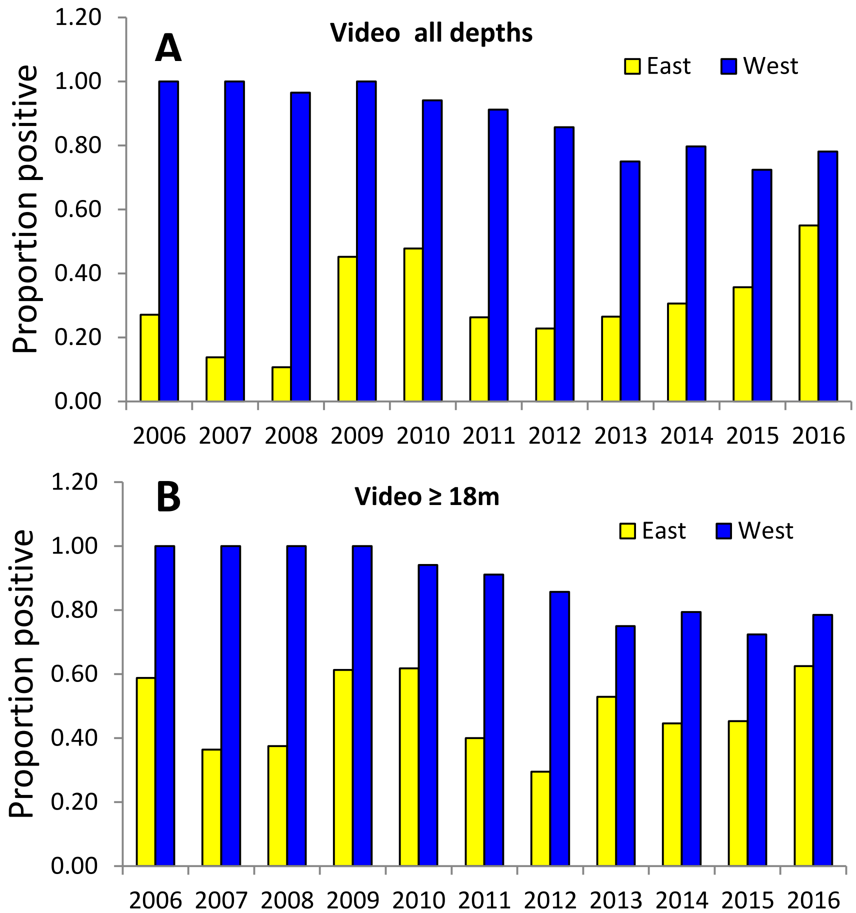


Figure 9. Annual proportions of positive red snapper video samples, 2006-16 east and west of Cape San Blas, for all depths (A) and for depths ≥18 m (B).

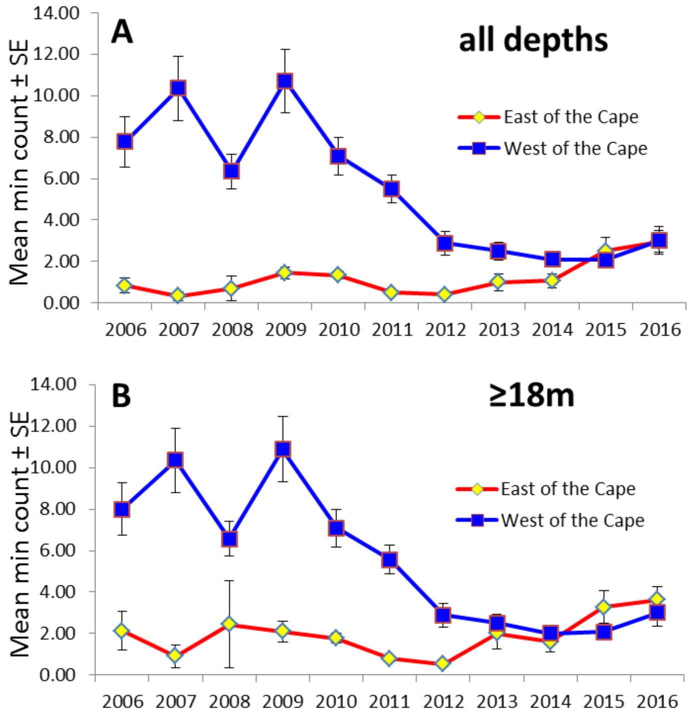


Figure 10. Mean annual nominal video min counts (MaxN) and standard errors of red snapper east and west of Cape San Blas, 2006-2016, for all depths (A) and for depths ≥18 m (B).

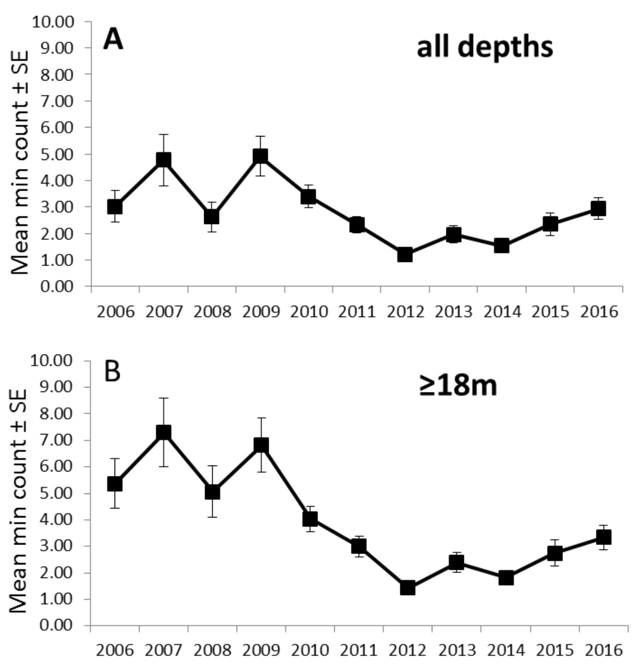


Figure 11. Overall (east + west of Cape San Blas) mean annual nominal video min counts (MaxN) and standard errors of red snapper, 2006-2016, for all depths (A) and for depths ≥18 m (B).

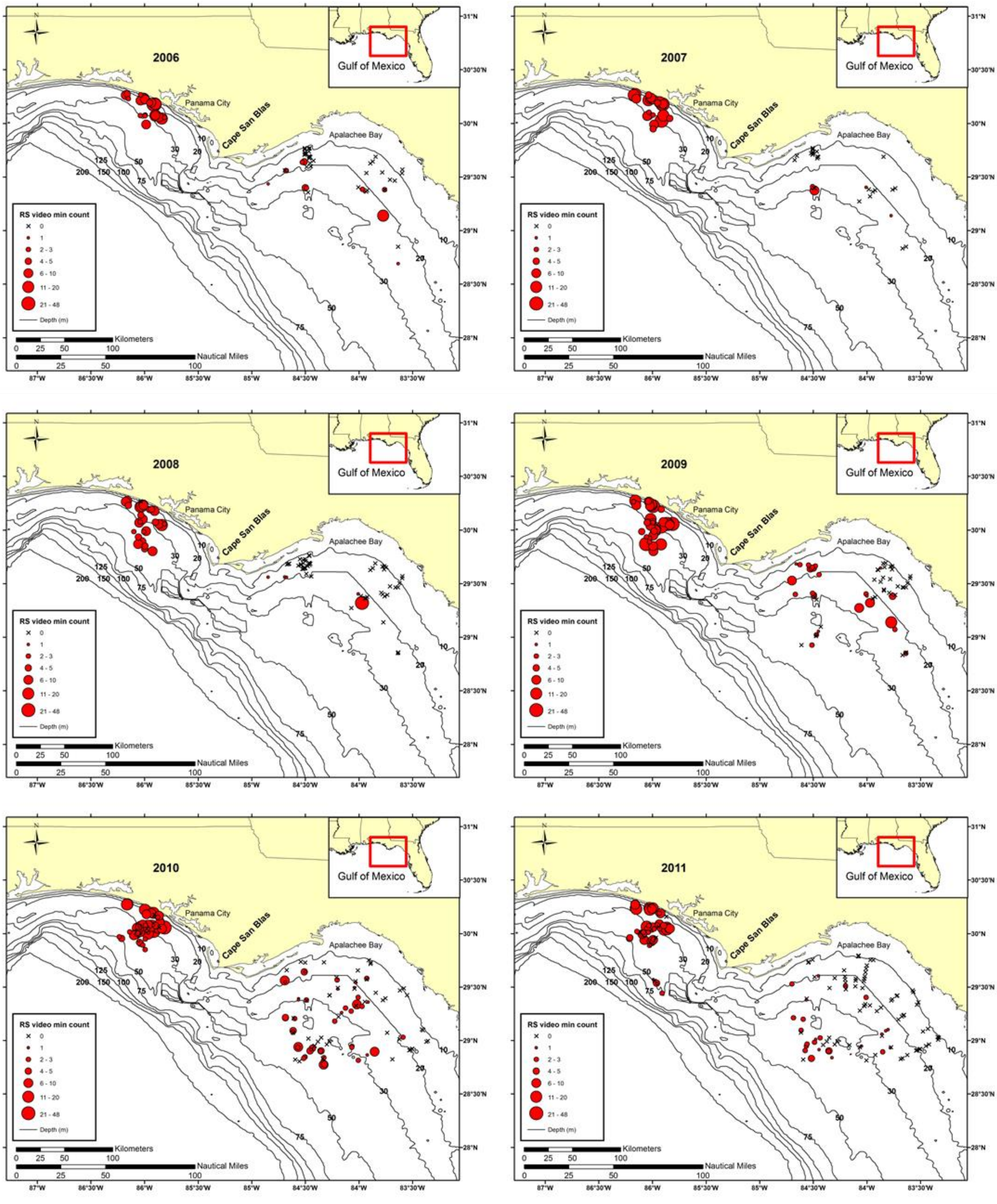


Figure 12. Annual distribution and relative abundance of red snapper observed with stationary, high definition video or MPEG cameras (min counts) in the Panama City NMFS reef fish survey, 2006-2016. Sites sampled, but where no red snapper were observed, are indicated with an X.

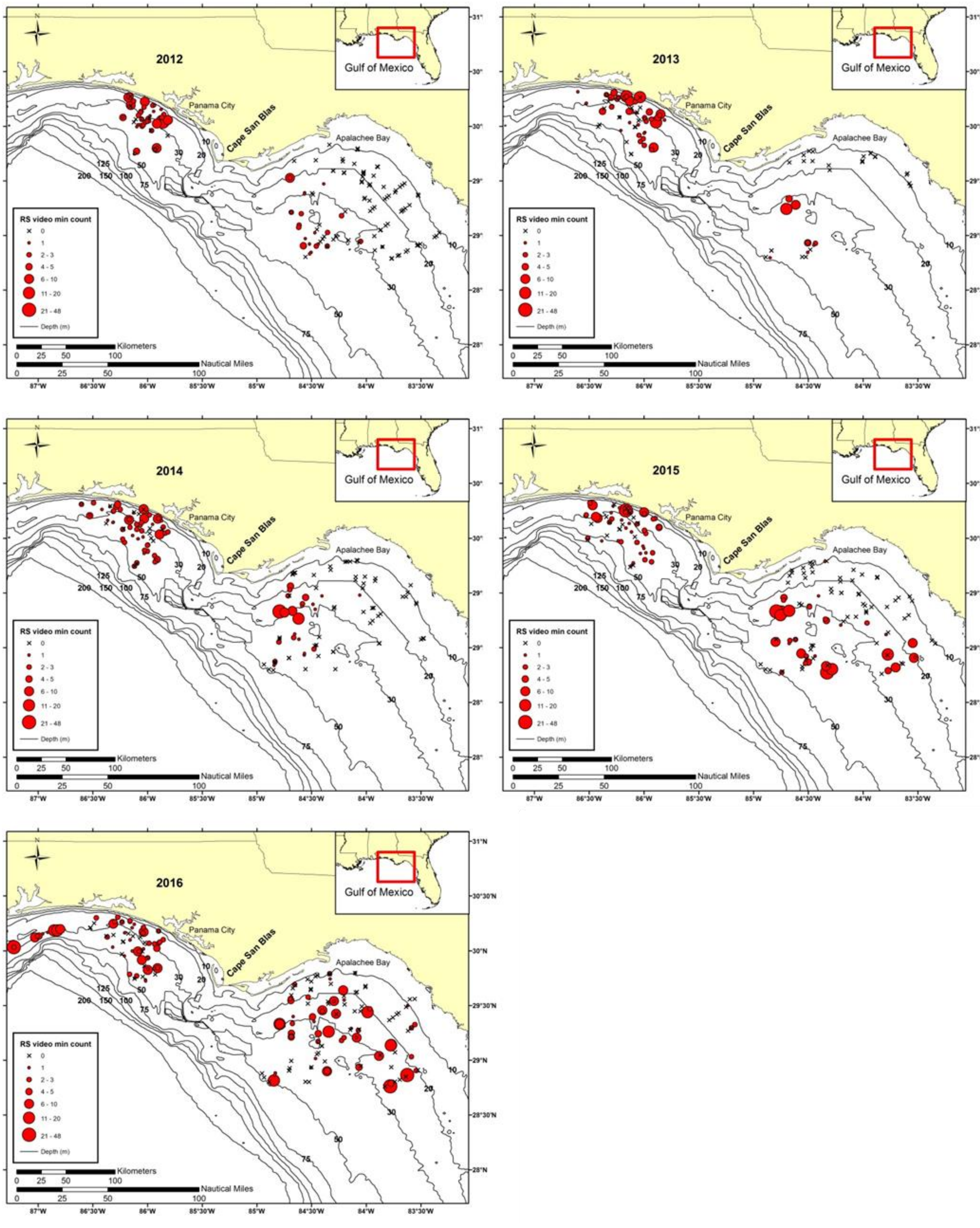


Figure 12 cont. Annual distribution and relative abundance of red snapper observed with stationary, high definition video or MPEG cameras (min counts) in the Panama City NMFS reef fish survey, 2006-2016. Sites sampled, but where no red snapper were observed, are indicated with an X.

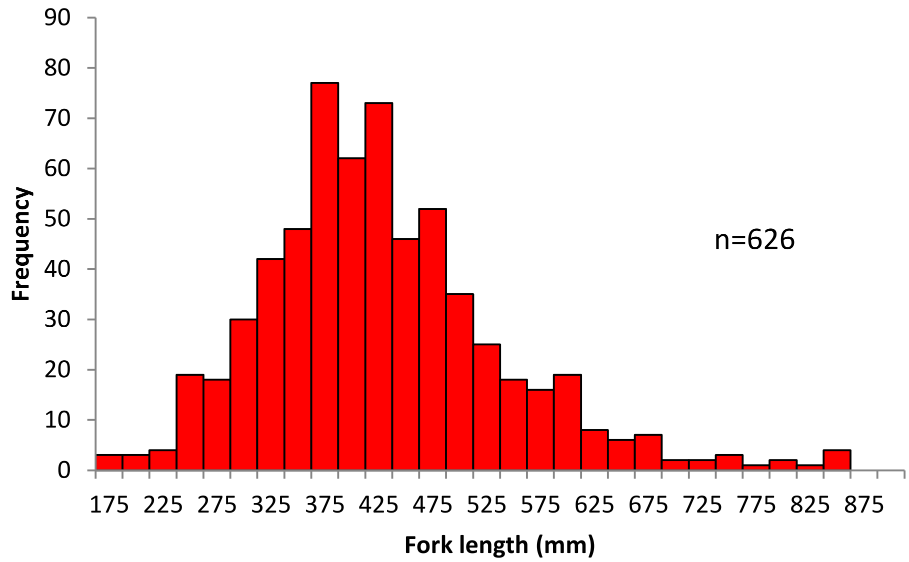


Figure 13. Overall size distributions of all red snapper measured from stereo images, 2009-2016.

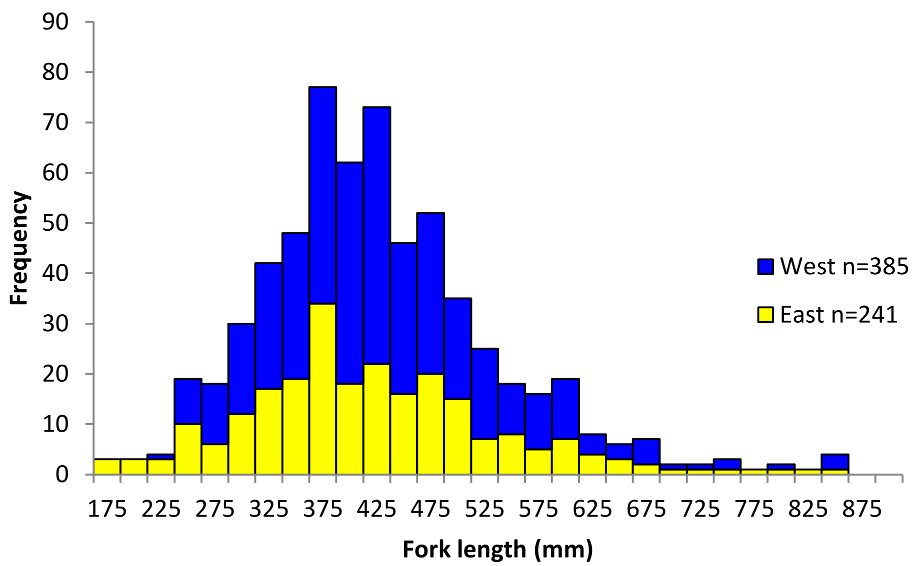


Figure 14. Overall size distributions of red snapper east and west of Cape San Blas observed with stereo cameras, 2009-2016.

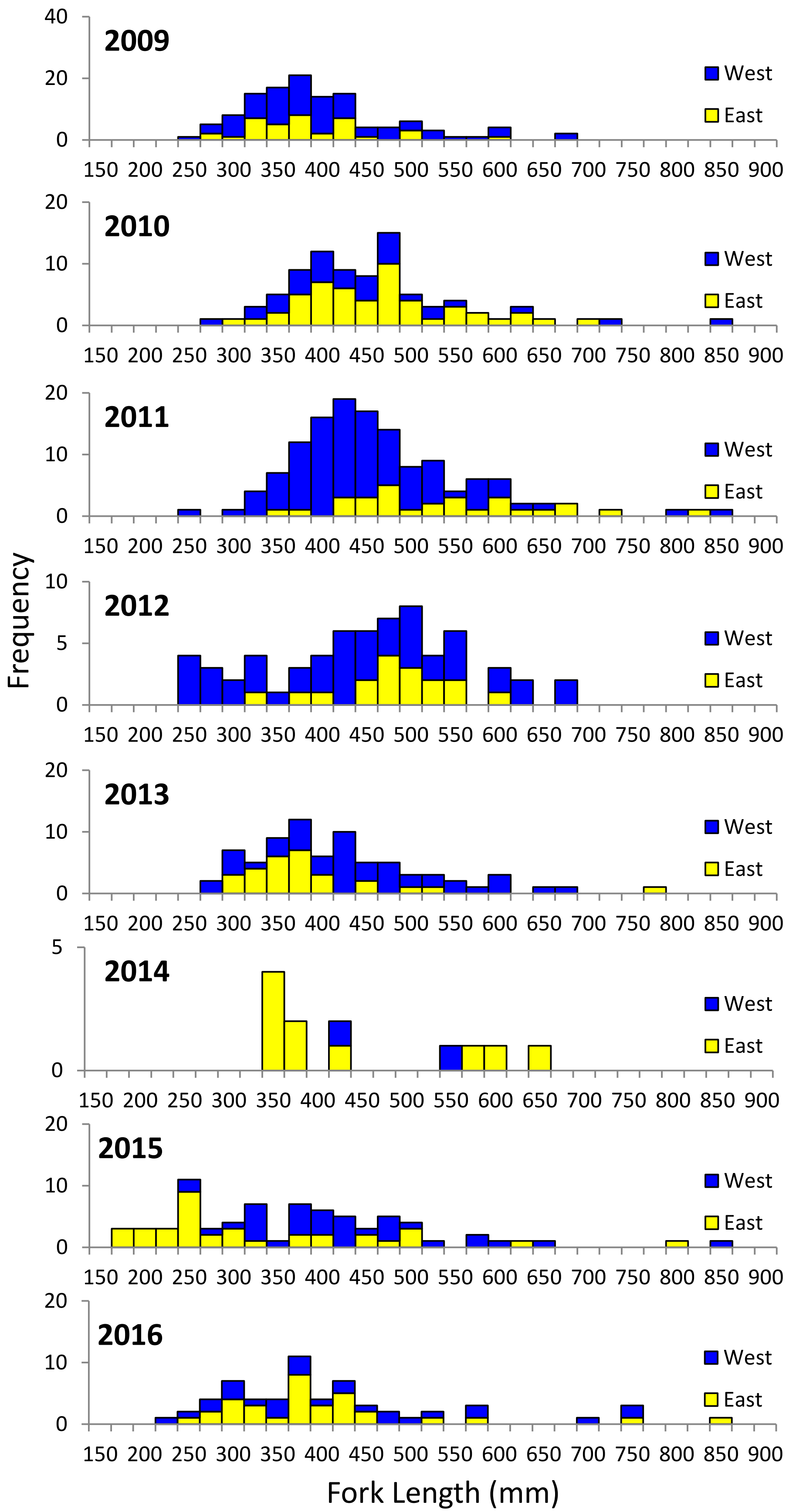


Figure 15. Annual size distributions of red snapper observed with stereo cameras, 2009-2016 east and west of Cape San Blas. 2014 had low numbers of measurements because of technical issues with the cameras.

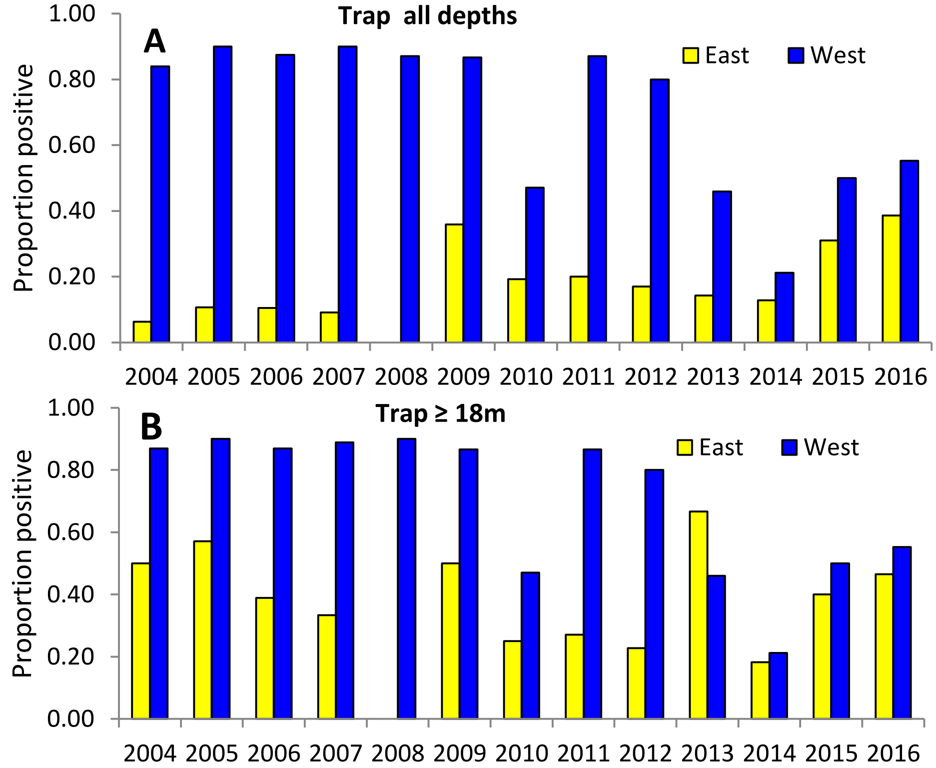


Figure 16. Annual proportions of positive red snapper trap catches, 2004-16 east and west of Cape San Blas, for all depths (A) and for depths ≥18 m (B).

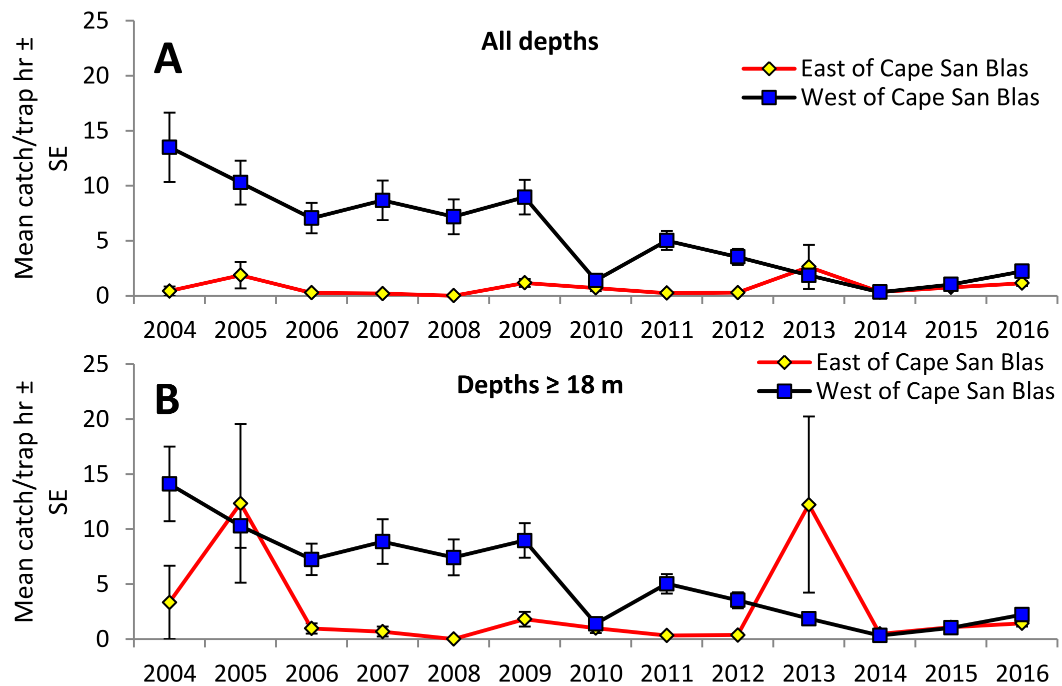


Figure 17. Mean catch per trap hr and standard errors of red snapper east and west of Cape San Blas, 2004-2016, for all depths (A) and for depths ≥18 m (B). Sampling east of Cape San Blas in 2013 was greatly reduced (down ~66%) and done later than normal (Oct. and Nov.) because of late receipt of funding, ship mechanical issues, and weather delays.

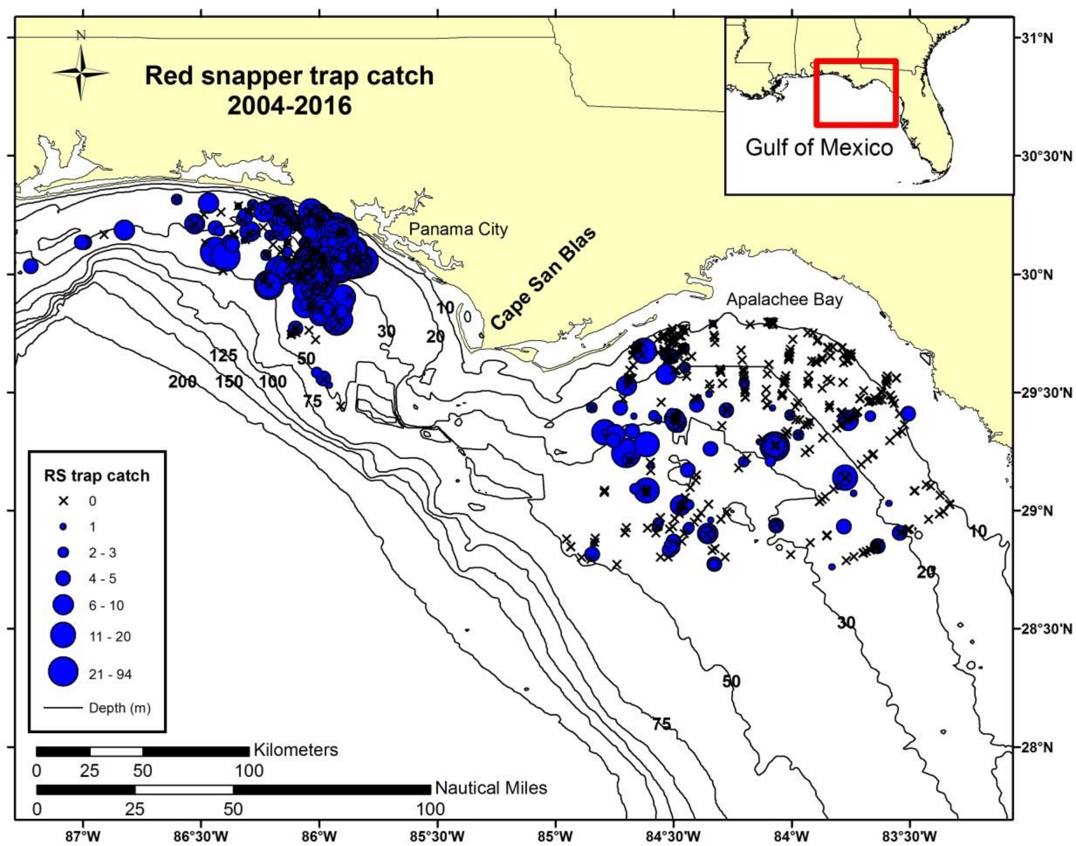


Figure 18. Distribution and relative abundance of red snapper caught in chevron traps in the Panama City NMFS reef fish survey, 2004-2016. X's are sites sampled, but where no red snapper were caught.

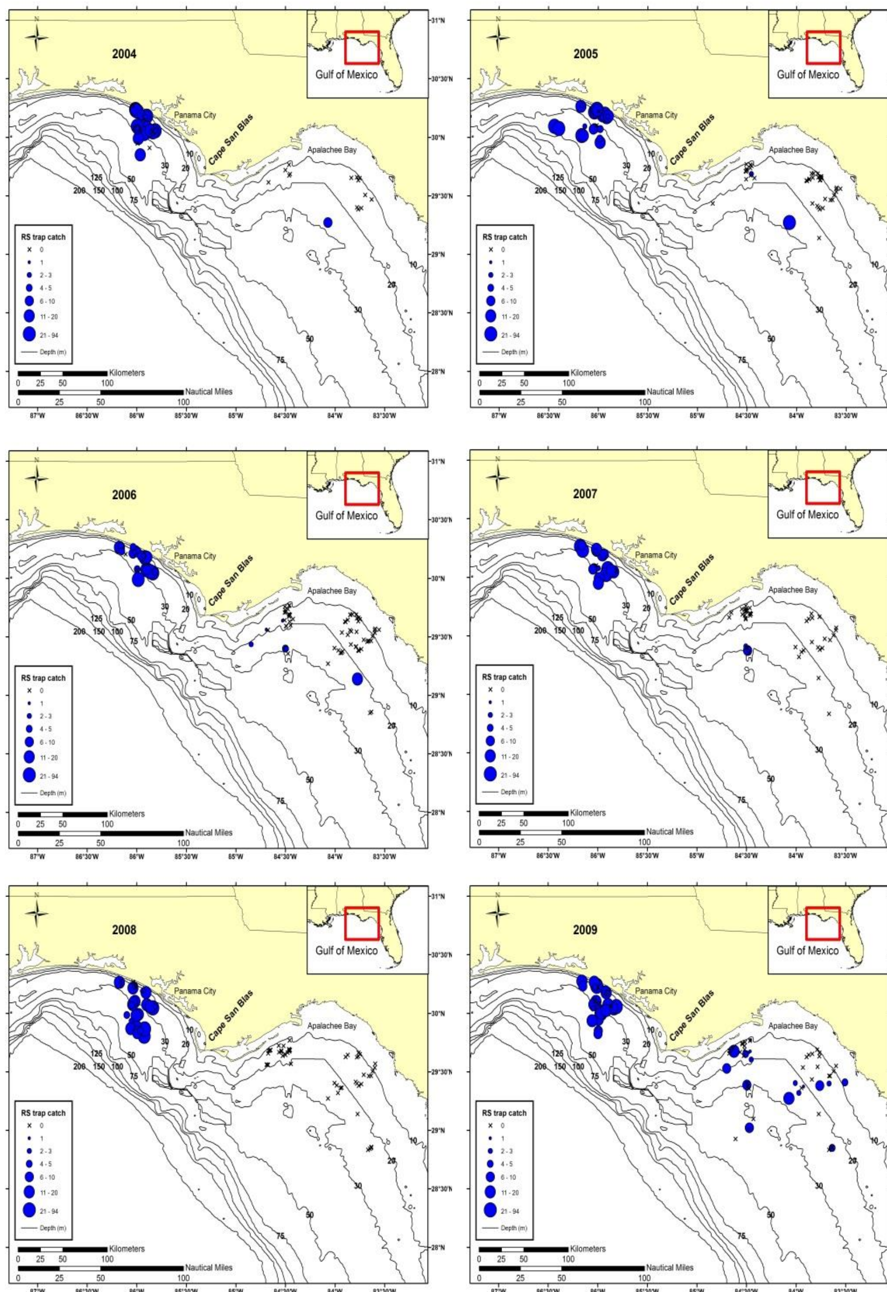


Figure 19. Annual distribution and relative abundance of red snapper caught in chevron traps in the Panama City NMFS reef fish survey, 2004-2016. X's are sites sampled, but where no red snapper were caught.

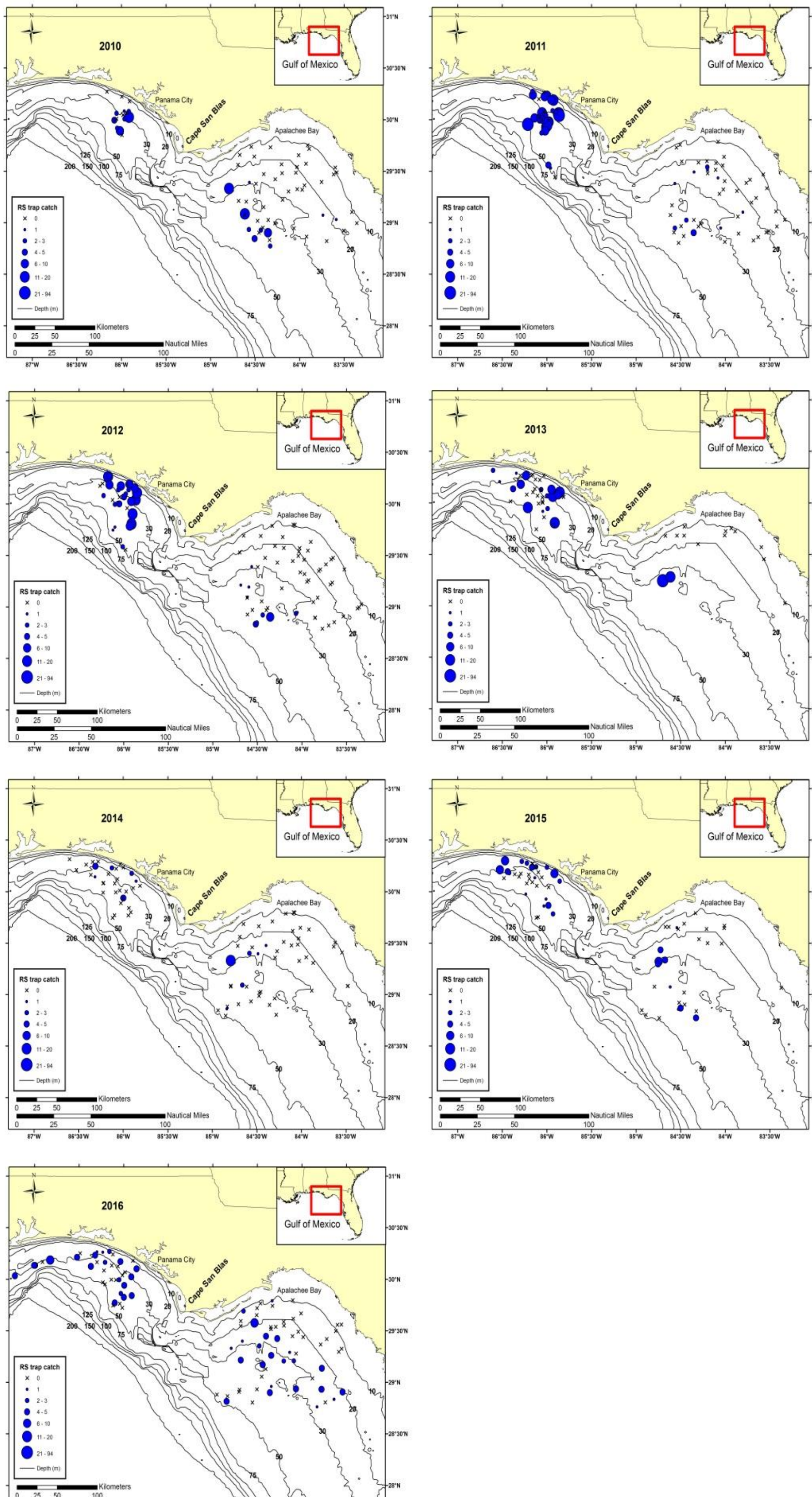
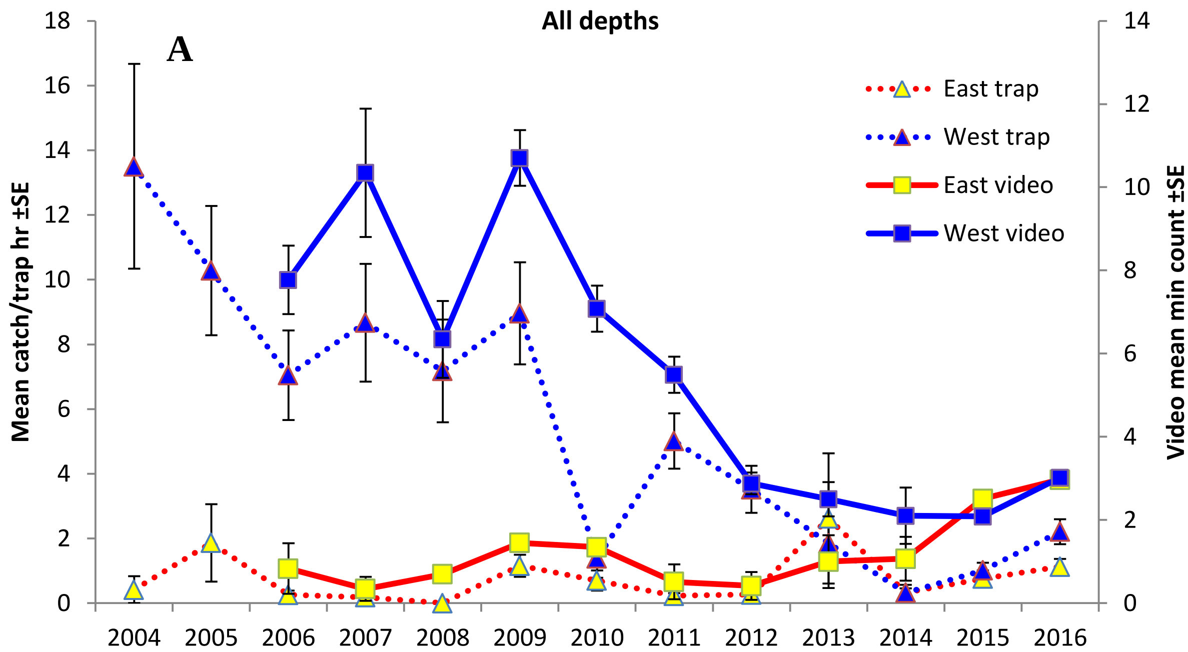


Figure 19 cont. Annual distribution and relative abundance of red snapper caught in chevron traps in the Panama City NMFS reef fish survey, 2004-2016. X's are sites sampled, but where no red snapper were caught.



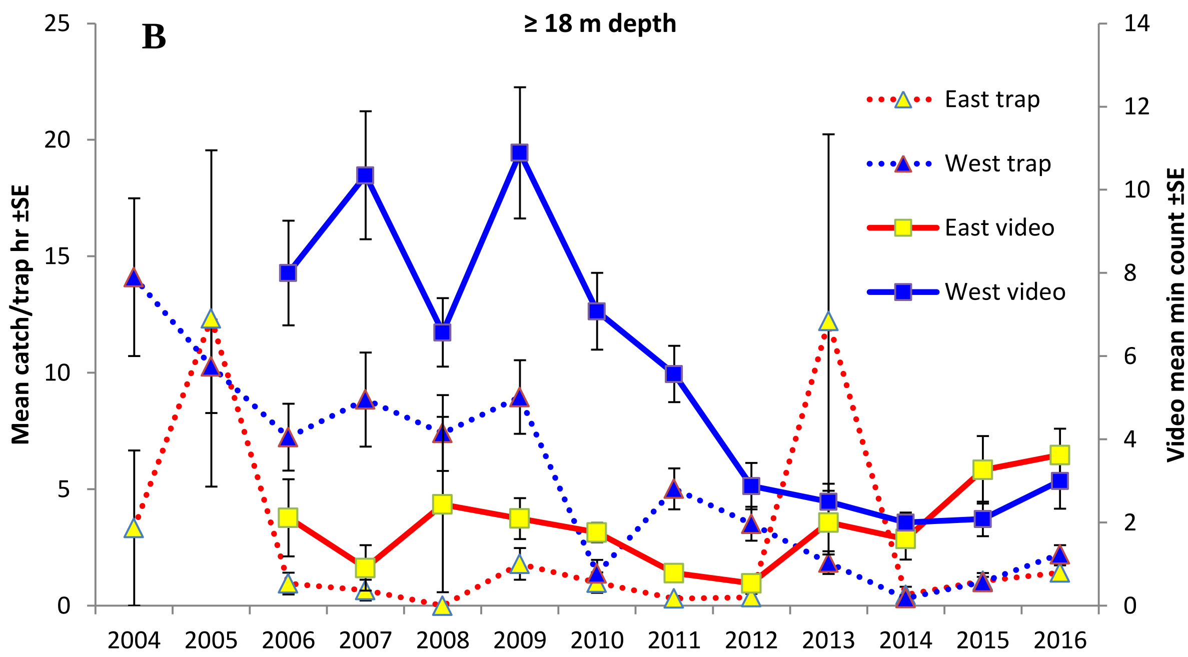


Figure 20. Annual trap (2004-2016) CPUE ±SE and video (2006-2016) mean min count ±SE of red snapper east and west of Cape San Blas for all depths (A) and ≥ 18m (B).

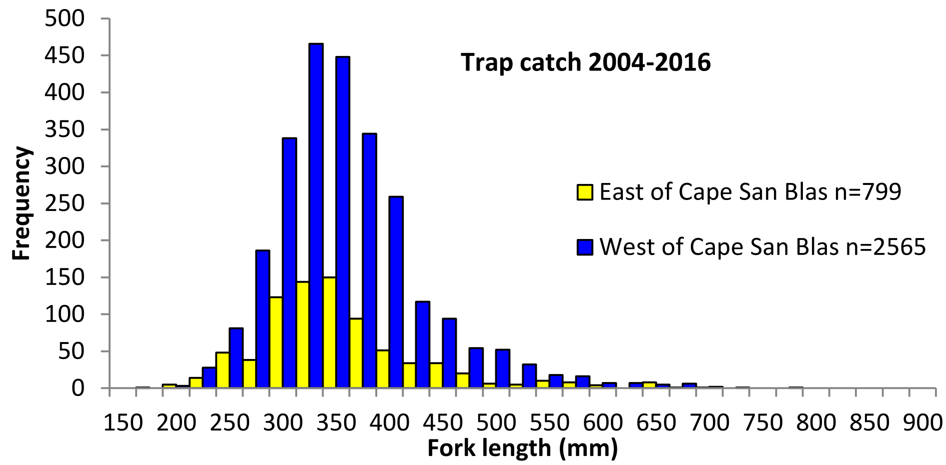


Figure 21. Overall size distributions of red snapper east and west of Cape San Blas caught in chevron traps, 2004-2016.

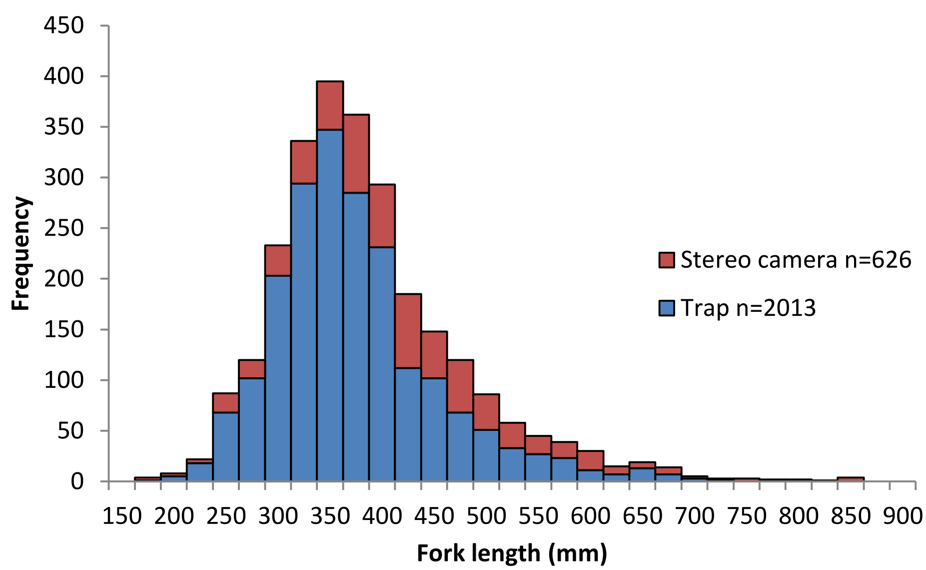


Figure 22. Overall size distributions of all red snapper collected in chevron traps and measured in stereo images, 2009-2016.

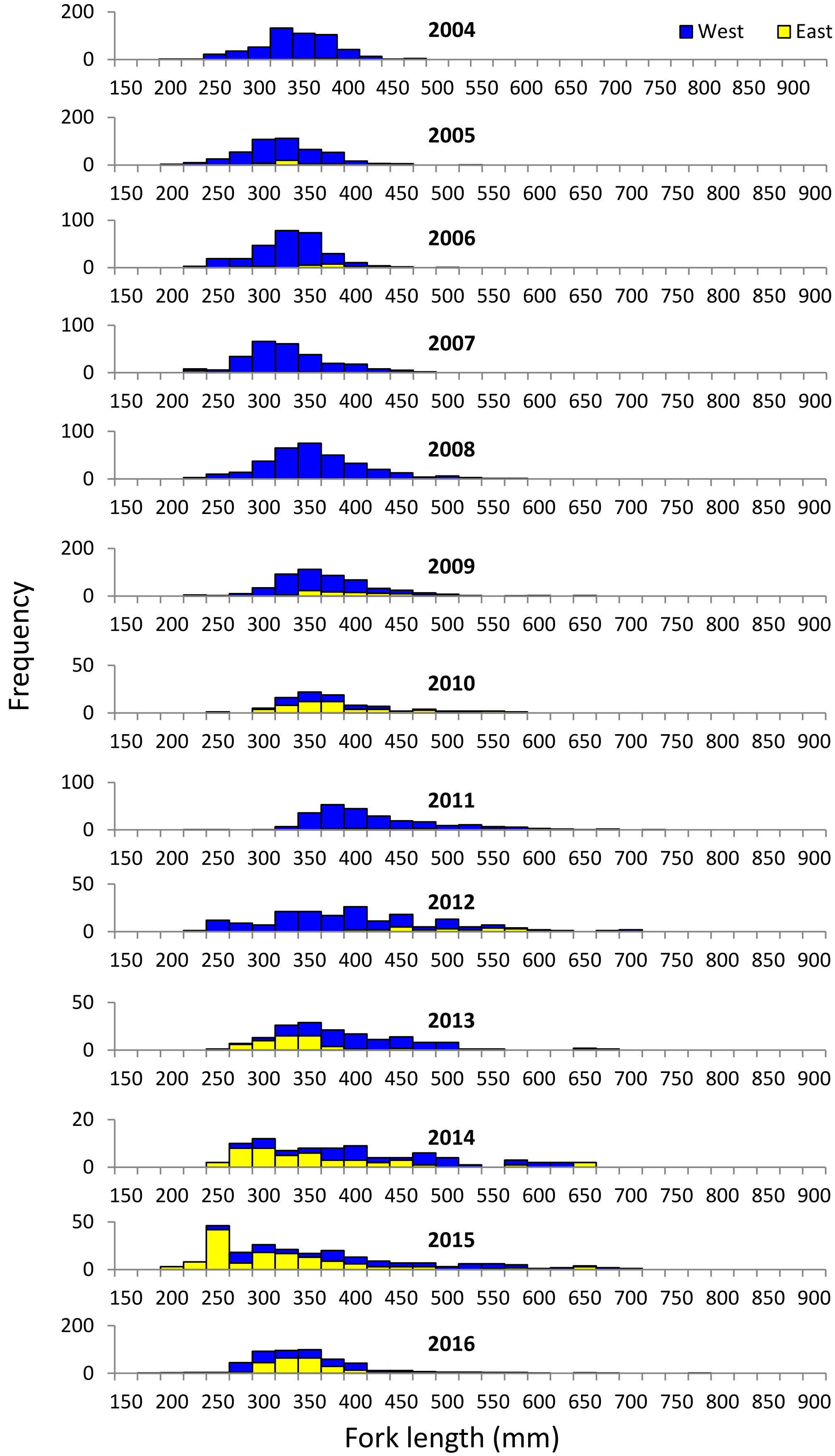


Figure 23. Annual size distributions of red snapper collected in chevron traps, 2004-2016, east and west of Cape San Blas.

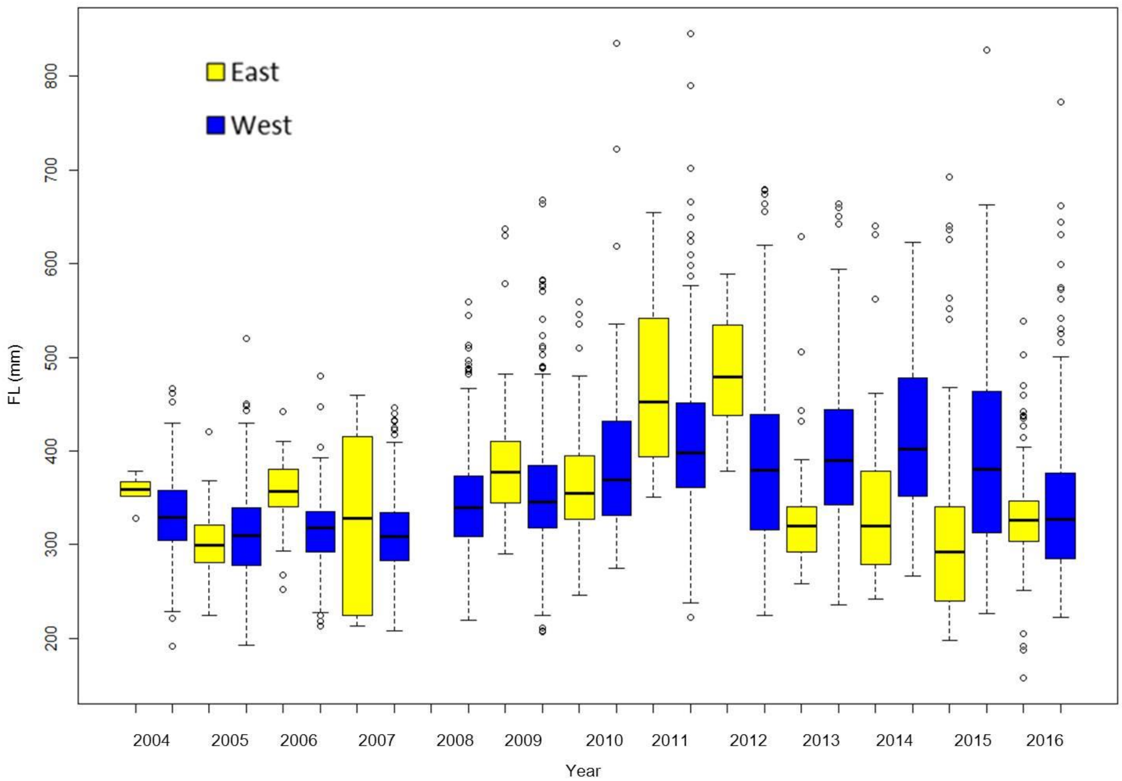


Figure 24. Annual fork length distributions of red snapper caught in traps 2004-2016 and observed from stereo images 2009-2016 east and west of Cape San Blas.

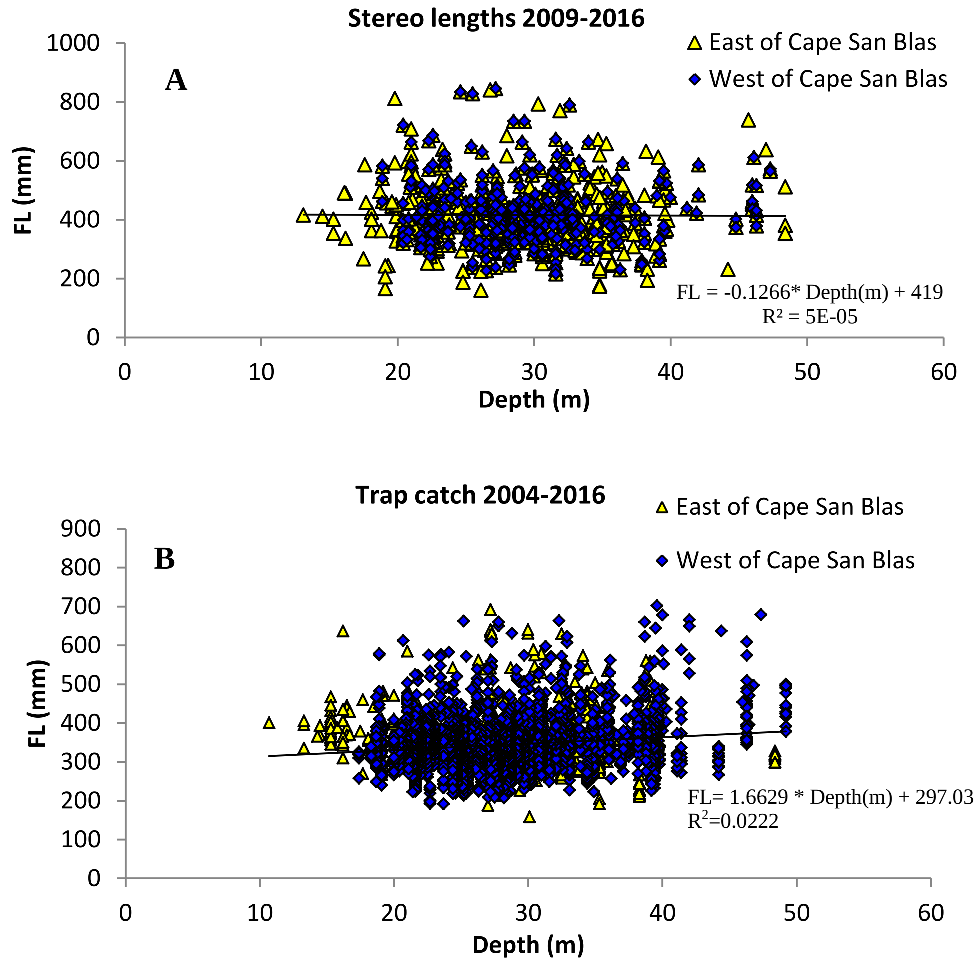


Figure 25. Fork length vs. depth relationship of red snapper observed with stereo cameras (A) east and west of Cape San Blas, 2009-2016, and collected with chevron traps (B), 2004-2016.

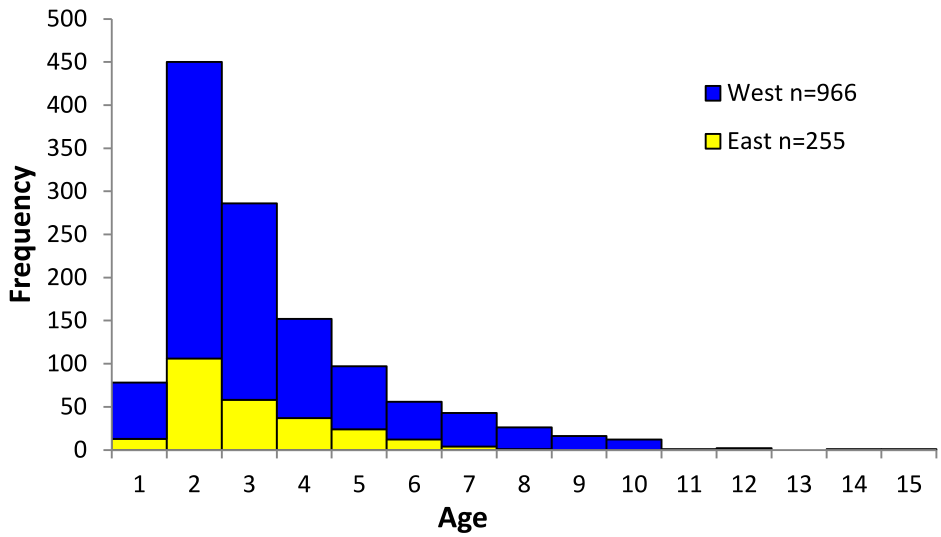


Figure 26. Overall age structure of trap-caught red snapper, east and west of Cape San Blas, 2005-2016.

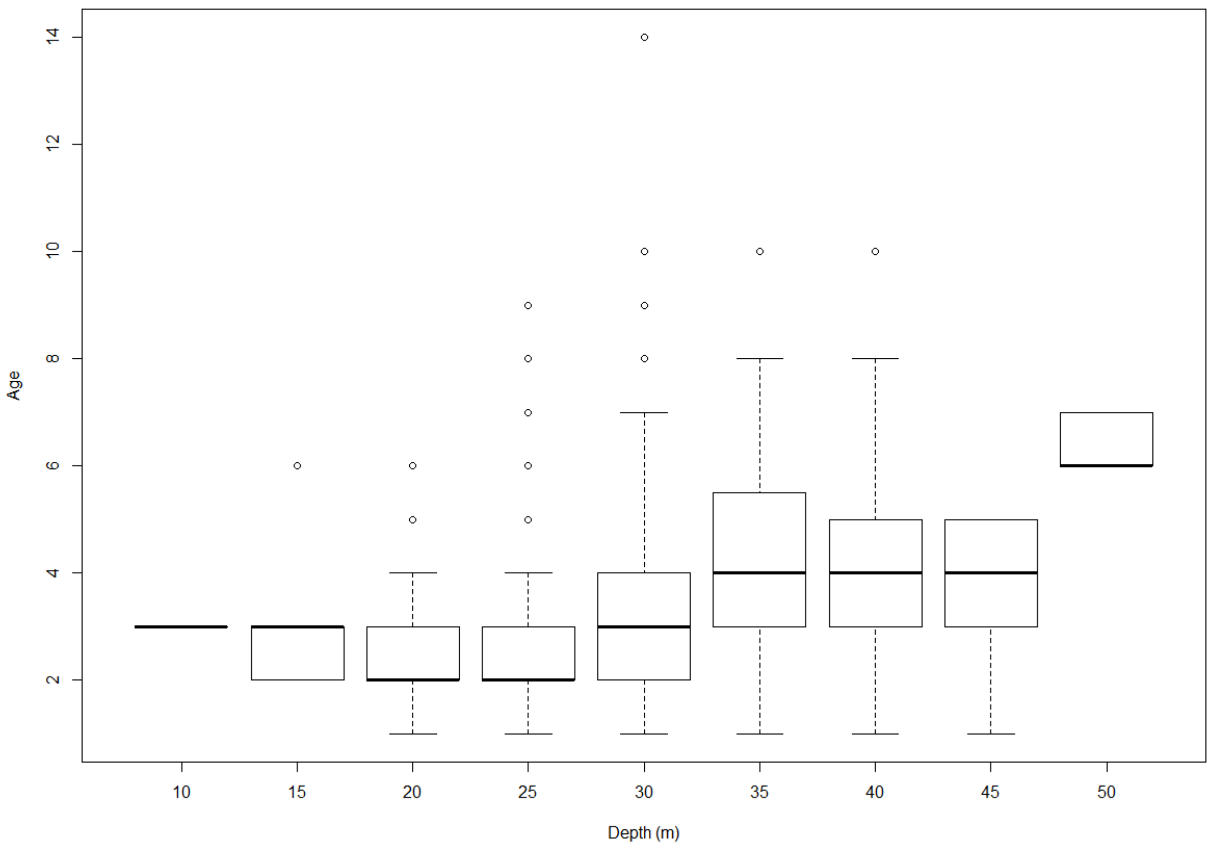


Figure 27. Age vs depth relationship of red snapper caught in chevron traps, 2005-2016, in the Panama City reef fish survey.

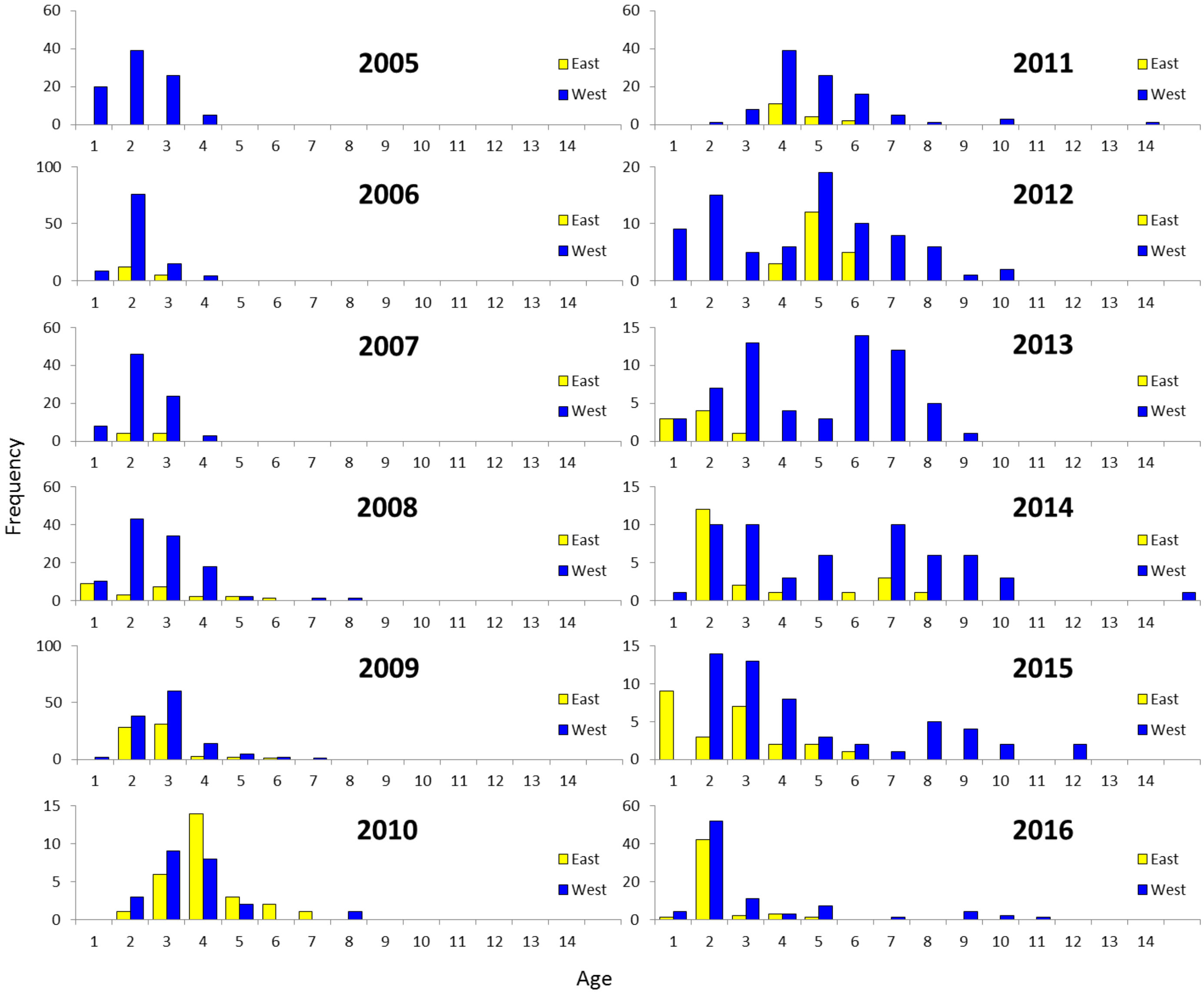


Figure 28. Annual age structure of red snapper caught in chevron traps in the NOAA Panama City lab reef fish survey, 2005-2016, by region.