Indices of abundance for Red Snapper (*Lutjanus campechanus*) on natural reefs in the eastern Gulf of Mexico using combined data from multiple video surveys

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Revised indices of abundance for Red Snapper (*Lutjanus campechanus*) on natural reefs in the eastern Gulf of America using combined data from multiple video surveys

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Introduction

Historically, three independent stationary video surveys were conducted for reef fishes in the Gulf of America (GOA). The SouthEast Area Monitoring and Assessment Program Reef Fish Video survey (SRFV), conducted by NMFS Mississippi Laboratories (beginning in 1992), focused primarily on high-relief banks along the shelf break throughout the Gulf. The NMFS – Panama City survey (beginning in 2005) was developed to complement the SRFV survey by targeting shallow reef habitats on the inner shelf of the northeast Gulf (5-60 m depth). More recently (beginning in 2008), the FWRI survey was developed to complement both surveys by targeting reef habitats of the central West Florida Shelf. While the surveys use standardized deployment, camera field of view, and fish abundance methods to assess fish abundance on reef or structured habitat, there are variations in survey design and habitat characteristics collected in addition to the time period and area sampled. Traditionally the surveys have submitted independent indices for each survey, however, combining indices across datasets likely increases predictive capabilities by allowing for the largest possible sample sizes in model fitting and encompassing a greater proportion of the distribution of the stock. Previous research has indicated that combining data across changing spatial areas and surveys and using a year only model, can yield spurious conclusions regarding stock abundance (Campbell 2004; Ye et al. 2004). As such, a habitat-based approach was used to combine relative abundance data for generating annual trends for Red Snapper (*Lutjanus campechanus*) throughout the eastern GOA for the Central and East regions as defined in the Stock ID (SEDAR 2021) process for this assessment. Following the SEDAR 98 in-person data workshop, we identified discrepancies in 2023 data, therefore updated indices of abundance were developed with revised data using identical analytical methodologies initially approved at the workshop.

Survey Comparisons

Survey design

The SFRV survey primarily targets high-relief topographic features along the continental shelf from south Texas to south Florida. Sites are selected using a stratified, random design with strata determined by region and total proportion of reef area in a sampling block (10 minute latitude X 10 minute longitude blocks). Sites are selected at random from known reef areas identified through habitat mapping (multi-beam and side-scan sonar). This survey was truncated to include only data from the Central and East regions (Fig. 1 & Fig. 2.)

The Panama City video survey targets the inner shelf of the northeast GOA (5-60 m depth) ranging from NMFS, SEFSC statistical zone 6 through 10 (Fig. 1 & Fig. 2). Survey design has changed through time, but since 2010 a two-stage unequal probability design has been used. Blocks are 5 minutes x 5 minutes in size with sites randomly, proportionally allocated by region, sub-region and depth. Two known reef sites, a minimum of 250 m apart within each selected block are randomly selected. Sites are described using side-scanning before video deployment (Gardner et al. 2017).

The FWRI survey initially focused on the regions offshore of Tampa Bay and Charlotte Harbor, FL (NMFS statistical zones 4 and 5) with habitats either inshore (10-36 m depth) or offshore (37-110 m depth). The survey has since expanded to also include NMFS, SEFSC statistical zones 9 and 10 off the Florida Panhandle in 2014 with additional sites added in 2016 to cover the entirety of the West Florida Shelf from statistical zones 2-10 (Fig. 1 & Fig. 2; FWRI/NFWF). Sites are initially randomly selected and mapped using side scan sonar over a 2.1 km^2 area (Switzer et al. 2020). Video deployment sites are then randomly assigned proportionally across region and depth zones (Thompson et al. 2017).

Beginning in 2020, Gulf-wide video survey efforts were integrated under a single, novel survey design as the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER) program (Switzer et al. 2023). A stratified-random approach to survey design was adopted based on both spatial and habitat stratification, as other reef fish surveys have utilized this approach to subdivide the survey domain into homogeneous strata and partition population variance (Smith et al. 2011). To do so, a retrospective analysis of data on reef fish assemblages and their habitats was conducted to (1) delineate biologically relevant spatial and habitat strata, and (2) define optimal allocation of sampling effort based on a combination of habitat availability and managed species richness. Spatially, the Gulf survey domain was subdivided into three depth strata (10–25 m, >25–50 m, >50–180 m) and six regional strata (Texas, west Louisiana, east Louisiana, north-central Gulf, Big Bend, and southwest Florida). For both natural and artificial reefs, habitat strata were delineated based on relative relief (low, medium, high) and size of the individual reef feature, although delineation of reef scale differed markedly between natural (<100 m^2, 100–1000 m^2, >1000 m^2) and artificial habitat strata (<25 m^2, 25–100 m^2, >100 m^2). Under the new G-FISHER design, approximately 2,000 reef fish stations are sampled annually with stereo-baited remote underwater video (S-BRUV) camera arrays designed to characterize benthic habitats and provide data on abundance and size composition of reef fishes observed.

Video reads

All surveys use paired stereo-imaging cameras at each site. All videos are read to identify the maximum number of individuals of each species viewed in a single frame within a 20-minute time frame (i.e. MaxN, MinCount). Habitat characteristics on video are also noted with the percentage or presence/absence of abiotic and biotic habitat types that may contribute to fish biomass (e.g. sponge, algae, and corals), although some categories are not shared among all labs (Campbell et al. 2017; Gardner et al. 2017; Thompson et al. 2017).

Fish length measurement

Fish length measurements have varied through time for the surveys. Beginning in 1995, fish lengths were measured from video using parallel lasers attached on the camera system (Campbell et al. 2017). Subsequently years from (2008 in Pascagoula and FWRI and 2010 in Panama City), surveys used a stereo-video approach to provide size data. Vision Measurement System (VMS, Geometrics Inc.) was used to estimate size of fish up to 2014 for all three surveys, and SeaGIS software (SeaGIS Pty. Ltd.) was used to provide size estimates from 2015 – present. Length measurements are typically taken at the point in the video where the most number of fish are measurable, and often there are some individuals observed that are not measurable.

Data reduction

For all surveys, video reads were excluded if they were unreadable due to high turbidity or deployment errors. For the SRFV survey, data included in this index are from 1993 and on. The entire spatial extent of the Panama City data was used from 2006 on with 2005 excluded because of an incomplete survey. For the FWRI data from prior to 2010 because side scan sonar was not used to determine potential sampling sites prior to 2010. Following SEDAR 74, the decision was made to truncate the overall time series for the East region due to very low catch rates in the SFRV survey initially and the small footprint of the PC survey in that region (Fig. 1 & Fig. 2). Therefore, the East index was limited to 2010-2023. Final sample sizes by survey and year can be found in Table 1 and spatial coverage is shown in Figure 1 and Figure 2. Data were separated into Central (zones 7-11) and East (zones 2-6) regions following the stock ID workshop and analyses were completed for each of these regions independently. The same data reduction procedures were applied to the video length data set such that annual size composition vectors were generated solely from stations used to generate standardized indices for each region. Individual measurements subsequently assigned to 1 cm size bins ranging from 1 to 120 cm fork length.

Index Construction

Habitat models

To develop a single index of abundance for Red Snapper from all surveys, a common habitat variable was created that included each of the separate survey individual variables that could be applied to all the data. This was done so final index models can account for changing sampling effort and habitat allocation through time rather than limiting the model to be predicted only by year and survey. We first determined the percentage of sites that occurred with High, Medium, or Low (H, M, or L) proportion positive for each survey and region independently. For this we used a classification and regression tree approach (CART) because this method accounts for correlations among variables and allows both continuous and categorical data to be included. It has been previously demonstrated to be a useful tool in fisheries ecology and specifically in describing fish-habitat associations (De'Ath and Fabricus 2000; Yates et al. 2016, Thompson et al. 2022).

For these initial analyses, MaxN for each site was reduced to a presence and absence variable and was used as the response variable for habitat designations. Predictor variables included the habitat metrics coded on the video reads (reduced to presence/absence), the latitude and longitude of each site and depth for all four survey sets. For G-FISHER and FWRI, side-scan geoform was also included as a landscape-level habitat variable, with values derived using a modified version of the Coastal and Marine Ecological Classification Standard (CMECS) classification approach. Geoform was not included as a predictor variable for the analysis of SRFV survey data because the habitat mapping for that survey has primarily been conducted utilizing multibeam sonar. At present, comparable habitat classification between side-scan and multibeam is not possible due to differences in scale and differences in the underlying data itself (particularly for low relief strata). We first used a random forest approach to reduce the number of potential variables to be selected from in the final model for each lab's dataset to reduce redundant or correlated variables used in the final indexing model. For the random forest analysis, each survey was modeled separately for the entirety of that dataset. The random forest analysis fitted 2000 CARTS to the data and then determined each variables importance, a scale-less number used to indicate the number of final models each variable occurred in and its significance therein. An example of output is given in Fig. 3 for the FWRI survey dataset.

From the random forest analysis, approximately 50% of the potential variables were retained for each survey given by the importance values for a final CART model. The final model was created by fitting the presence of Red Snapper at a site to the independent variables for a training dataset of 80% of the data. The remaining 20% of the data were retained in a test dataset to determine misclassification rates for each of the three models. The proportion of sites with positive Red Snapper catches at each terminal node was then evaluated to determine the habitat characteristics defining High, Medium, or Low habitat. Terminal nodes with 1.25 times the overall proportion of positive catches for a dataset were assigned a High habitat code. Low sites were identified as those determined by proportion positives that were at least half (50%) of the overall proportion positive and were generally approaching zero. The remaining sites were deemed Medium and included the range of the overall proportion positive. All analyses were carried out using R version 4.1.0 (R Core Team 2021) and the Party package for CART (Hothorn et al. 2006).

CART results varied by survey and region with respect to the final variables chosen. Red Snapper habitat models indicated an association with factors commonly attributed to reef or rugose habitats, including rock, relief, soft coral, seawhips, and spatial parameters such as latitude, longitude, and depth (Figs. 4-11). Red Snapper were found to be in a relatively higher proportion of sites in the Central region with occurrence rates of 54% (FWRI), 58% (GF), 52% (PC), and 33% (SFRV). Alternatively, the East sites had lower percent positives; 18% (FWRI), 16% (GF), 45% (PC), and 5% (SFRV).

The site characteristics that define each node and habitat code were then used to create a habitat variable (i.e., 'hab' and coded as: H or M or L) that was then back applied to each site for each of the three survey datasets. The datasets were then combined for the index model. The final proportion of sites in the three habitat categories for each individual survey set and year are shown in Table 2 and Table 3 for each region.

Index model fitting and diagnostics

The final model used to index abundance was fit using a negative binomial with the formula:

*MaxN = Y*Hab *Survey*

Where Hab is the CART derived habitat code and survey represents the survey that collected the data for each site. Backwards variable selection was used and indicated that the full model performed best, given by AIC, compared to models with only one or two of the potential variables.

The index was fit in SAS using the Proc GLIMMX procedure. To account for the variation in survey area, differences in area mapped with known habitat, and the distribution of High, Medium, and Low proportion positive habitats by survey, the estimated MaxN means provided by the GLM were then adjusted. The known potential survey universe for each of the three was first multiplied by the proportion of habitat microgrids that had reef habitat to provide an area weight. This was then multiplied by each year * Survey * hab combination, providing a weighting factor for each of the mean estimates. Area weighting factors are provided in Table 4. Weighted index values were then standardized to the grand mean.

Compilation of length data

Similar to the habitat weighting approach used to generate indices of abundance, annual length compositions were weighted by the habitat class proportion and area weights. This was accomplished by first calculating the annual bin proportions for each survey and habitat class combination such that length data were placed on comparable scales. The resulting relative frequencies for each survey were then multiplied by their respective habitat and area weights to generate annual length compositions which account for both differences in habitat classes sampled by each survey and the overall survey footprints.

Results and Discussion:

Annual standardized index values for Red Snapper in the Central and East regions including coefficients of variation, are presented in Table 5 and Table 6. The model CV's indicate a good model fit, with high values in earlier years but steadily decreasing CV's as additional surveys are added and continue with CV's for the final years in the range of ~10% for the Central and ~16% in the East. CVs and confidence limits were found to be highest before in 1997 in the Central model. Original results, along with results from updated analyses using corrected 2023 data, are presented in Figures 12 and 13. Biomass trends for Red Snapper in the Central region show low and variable numbers early in the time series, followed by peaks in abundance in 2009 and 2021 with recent decreases in 2022 and 2023 (Table 5; Fig. 12). In the East region, relative abundance is low and stable initially in the time series, with a steady increase starting in 2014 through a peak in the population in 2016 and subsequent declines through 2023 (Table 6, Fig. 13).

The combined length frequencies across years were similar among surveys for the Central region, which suggests selectivity/catchability is similar among surveys (Fig. 14). Length frequencies from the East region were more variable among surveys (Fig. 15), however this appears to be the result of large disparities in sample sizes among surveys (Table 8). The FWRI survey region encompasses a greater depth range compared with the PC survey, which mostly samples nearshore sites, and the SRFV, which predominately samples offshore habitats. When survey data is partitioned into nearshore (≤ 37m) and offshore (> 37m) depths, the length compositions are more similar among surveys (Fig. 16).

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Table 1. Summary of sample sizes by year for each of the four included video surveys, Florida Fish and Wildlife Research Institute (FWRI), SEAMAP Reef Fish Video Survey (SRFV), NMFS Panama City (PC), and Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER) for both the Central (zones 7-11) and South (zones 2-6) regions. No data were available or used from any survey from 1998-2001; 2003.

	Central Region					East Region				
year	FWRI	PC	SFRV	GF	Total	FWRI	PC	SFRV	GF	Total
1993			27		27					
1994			30		30					
1995			17		17					
1996			40		40					
1997			41		41					
2002			62		62					
2004			62		62					
2005			126		126					
2006		84	117		201					
2007		43	173		216					
2008		81	67		148					
2009		99	96		195					
2010		106	117		223	49	32	111		192
2011		120	160		280	211	30	177		418
2012		114	103		217	214	34	178		426
2013		75	74		149	183	11	89		283
2014		142	92		234	277	28	138		443
2015		129	63		192	233	26	92		351
2016	258	127	65		450	461	29	140		630
2017	224	123	59		406	397	24	163		584
2018	229	57	82		368	464	19	138		621
2019	353	76	127		556	546	18	159		723
2020				163	163				598	598
2021				331	331				667	667
2022				364	364				571	571
2023				371	371				561	561
Total	1064	1376	1800	1229	5469	3035	251	1388	2397	7071

Table 2. Proportion of sites for each habitat level (High, Medium, Low) as determined by individual survey categorical regression trees (CARTs) for Red Snapper presence in the Central region. Note the gap in sampling for the SFRV survey (1998-2001 and 2003).

	SRFV			PC			FWRI			GF		
	High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
1993	0.370	0.037	0.593									
1994	0.300	0.000	0.700									
1995	0.059	0.412	0.529									
1996	0.200	0.325	0.475									
1997	0.341	0.244	0.415									
2002	0.565	0.145	0.290									
2004	0.597	0.113	0.290									
2005	0.532	0.040	0.429									
2006	0.427	0.060	0.513	0.321	0.024	0.655						
2007	0.503	0.075	0.422	0.372	0.093	0.535						
2008	0.567	0.045	0.388	0.432	0.012	0.556						
2009	0.510	0.115	0.375	0.475	0.081	0.444						
2010	0.470	0.077	0.453	0.575	0.066	0.358						
2011	0.575	0.069	0.356	0.517	0.042	0.442						
2012	0.417	0.029	0.553	0.500	0.096	0.404						
2013	0.470	0.024	0.506	0.655	0.000	0.345						
2014	0.457	0.043	0.500	0.585	0.070	0.345						
2015	0.286	0.095	0.619	0.535	0.116	0.349						
2016	0.477	0.077	0.446	0.449	0.205	0.346	0.112	0.709	0.178			
2017	0.407	0.017	0.576	0.463	0.089	0.447	0.192	0.549	0.259			
2018	0.244	0.000	0.756	0.158	0.035	0.807	0.188	0.594	0.218			
2019	0.197	0.008	0.795	0.513	0.079	0.408	0.246	0.626	0.127			
2020										0.331	0.466	0.202
2021										0.411	0.435	0.154
2022										0.549	0.283	0.168
2023										0.593	0.270	0.137

Table 3. Proportion of sites for each habitat level (High, Medium, Low) as determined by individual survey categorical regression trees (CARTs) for Red Snapper presence in the East region.

	SRFV			PC			FWRI			GF		
YEAR	High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
2010	0.378	0.000	0.622	0.000	0.813	0.188	0.571	0.143	0.286			
2011	0.143	0.000	0.857	0.000	0.833	0.167	0.441	0.104	0.455			
2012	0.517	0.000	0.483	0.000	0.853	0.147	0.537	0.028	0.435			
2013	0.837	0.000	0.163	0.000	1.000	0.000	0.656	0.115	0.230			
2014	0.408	0.000	0.592	0.000	0.857	0.143	0.585	0.116	0.300			
2015	0.826	0.000	0.174	0.000	0.962	0.038	0.605	0.112	0.283			
2016	0.571	0.000	0.429	0.000	0.966	0.034	0.577	0.128	0.295			
2017	0.620	0.000	0.380	0.000	0.917	0.083	0.504	0.096	0.401			
2018	0.674	0.000	0.326	0.000	0.789	0.211	0.474	0.050	0.476			
2019	0.642	0.000	0.358	0.000	1.000	0.000	0.484	0.086	0.430			
2020										0.222	0.358	0.420
2021										0.220	0.369	0.411
2022										0.205	0.384	0.412
2023										0.226	0.371	0.403

Table 4. The habitat weighting used with the annual distribution of High, Medium, Low for Red Snapper habitats to adjust estimated model means to account for sampling variation across surveys for the Central and East Regions.

Central Region

	FWRI	PC	SRFV	G-FISHER
Total Universe Area (km2)	52392	15757	22855	52392
Area x Proportion of mapped with reef	1717	92	328	1717
Time Period Weighting Values				
1993-2005			1	
2006-2015		0.56	0.44	
2016-2019	0.55	0.25	0.20	
2020-2023				1

East Region

	FWRI (2010-2015)	FWRI (2016+)	PC	SRFV	G-FISHER
Total Universe Area (km2)	46286	106636	6348	14423	106636
Area x Proportion of mapped with reef	10160.65	22083.16	1431.20	3536.70	22083.16
Time Period Weighting Values					
2010-2015	0.66		0.10	0.24	
2016-2019		0.82	0.05	0.13	
2020-2023					1

Table 5. Number of stations sampled (N) by survey and year, proportion of positive sets, standardized index, and CV for the annual Red Snapper combined video index of the Central region.

Year	N	Prop pos	Std. Nominal	Std. Index	Lower 95% CI	Upper 95% CI	CV
1993	27	0.111	0.093	0.096	-0.100	0.292	0.615
1994	30	0.067	0.063	0.087	-0.123	0.297	0.731
1995	17	0.059	0.037	0.006	-0.016	0.028	1.122
1996	40	0.075	0.078	0.045	-0.077	0.168	0.814
1997	41	0.098	0.244	0.220	-0.046	0.485	0.366
2002	62	0.274	0.444	0.360	0.072	0.649	0.242
2004	62	0.419	1.222	1.247	0.316	2.177	0.226
2005	126	0.365	0.855	0.735	0.350	1.119	0.158
2006	201	0.264	0.863	1.408	0.327	2.489	0.232
2007	216	0.282	0.760	1.564	0.019	3.108	0.299
2008	148	0.385	1.312	1.333	0.594	2.071	0.168
2009	195	0.528	1.933	1.941	0.943	2.939	0.156
2010	223	0.565	1.511	1.374	0.789	1.959	0.129
2011	280	0.543	1.496	1.346	0.790	1.902	0.125
2012	217	0.433	0.805	0.789	0.417	1.162	0.143
2013	149	0.497	0.967	0.693	0.349	1.037	0.150
2014	234	0.440	0.827	0.691	0.404	0.978	0.126
2015	192	0.401	0.842	0.736	0.394	1.079	0.141
2016	450	0.529	1.539	1.455	1.061	1.849	0.082
2017	406	0.542	1.546	1.471	1.067	1.876	0.083
2018	368	0.432	1.154	1.245	0.745	1.745	0.122
2019	556	0.480	1.258	1.251	0.892	1.610	0.087
2020	163	0.540	1.360	1.471	0.749	2.192	0.148
2021	331	0.659	1.985	1.888	1.321	2.455	0.091
2022	364	0.547	1.674	1.577	1.131	2.023	0.086
2023	371	0.563	1.133	0.970	0.686	1.254	0.089

Table 6. Number of stations sampled (N) by survey and year, proportion of positive sets, standardized index, and CV for the annual Red Snapper combined video index of the East region.

Year	N	Proportion positive	Std. Nominal	Std. Index	Lower 95% CI	Upper 95% CI	CV
2010	192	0.130	0.541	0.482	0.311	0.652	0.331
2011	418	0.110	0.624	0.580	0.446	0.713	0.215
2012	426	0.092	0.377	0.443	0.337	0.549	0.223
2013	283	0.138	0.935	0.833	0.631	1.037	0.227
2014	443	0.108	0.571	0.544	0.443	0.644	0.172
2015	351	0.168	1.302	1.295	0.881	1.710	0.299
2016	630	0.217	2.695	2.547	2.141	2.952	0.148
2017	584	0.199	1.665	1.813	1.499	2.126	0.161
2018	621	0.166	1.304	1.509	1.208	1.811	0.186
2019	723	0.162	1.022	1.173	0.949	1.397	0.178
2020	598	0.154	0.787	0.744	0.626	0.862	0.148
2021	667	0.168	0.706	0.657	0.548	0.767	0.156
2022	571	0.135	0.680	0.658	0.533	0.782	0.176
2023	561	0.175	0.790	0.722	0.594	0.851	0.166

Table 7. Total of measurements (N) and sampling sites where measurements were obtained by year and survey for the Central region of the eGOM.

Central								
YEAR	SRFV		PC		FWRI		GF	
	N	Sites	N	Sites	N	Sites	N	Sites
1996	5	2						
1997	17	5						
2002	81	12						
2004	734	25						
2005	210	40						
2006	95	14						
2007	336	35						
2008	19	11						
2009	19	14	118	48				
2010	32	13	60	34				
2011	108	51	116	43				
2012	49	28	53	39				
2013	24	15	77	26				
2014	26	13	10	4				
2015	19	11	44	29				
2016	35	20			356	119		
2017	35	18	49	32	380	114		
2018	69	6	20	11	315	110		
2019	37	7	49	18	564	185		
2020							218	77
2021							377	165
2022							423	179
2023							323	178

Table 8. Total of measurements (N) and sampling sites where measurements were obtained by year and survey for the East region of the eGOM.

East								
YEAR	SRFV		PC		FWRI		GF	
	N	Sites	N	Sites	N	Sites	N	Sites
2010			22	15	3	3		
2011	36	11	11	6	10	6		
2012	3	2	8	7	18	14		
2013	3	2	3	2	36	21		
2014	3	3	3	3	58	29		
2015	5	4	25	10	67	36		
2016	1	1			424	118		
2017	18	10	26	9	259	84		
2018	51	3	16	8	219	77		
2019	31	2	4	3	201	85		
2020							181	87
2021							127	73
2022							107	60
2023							160	80

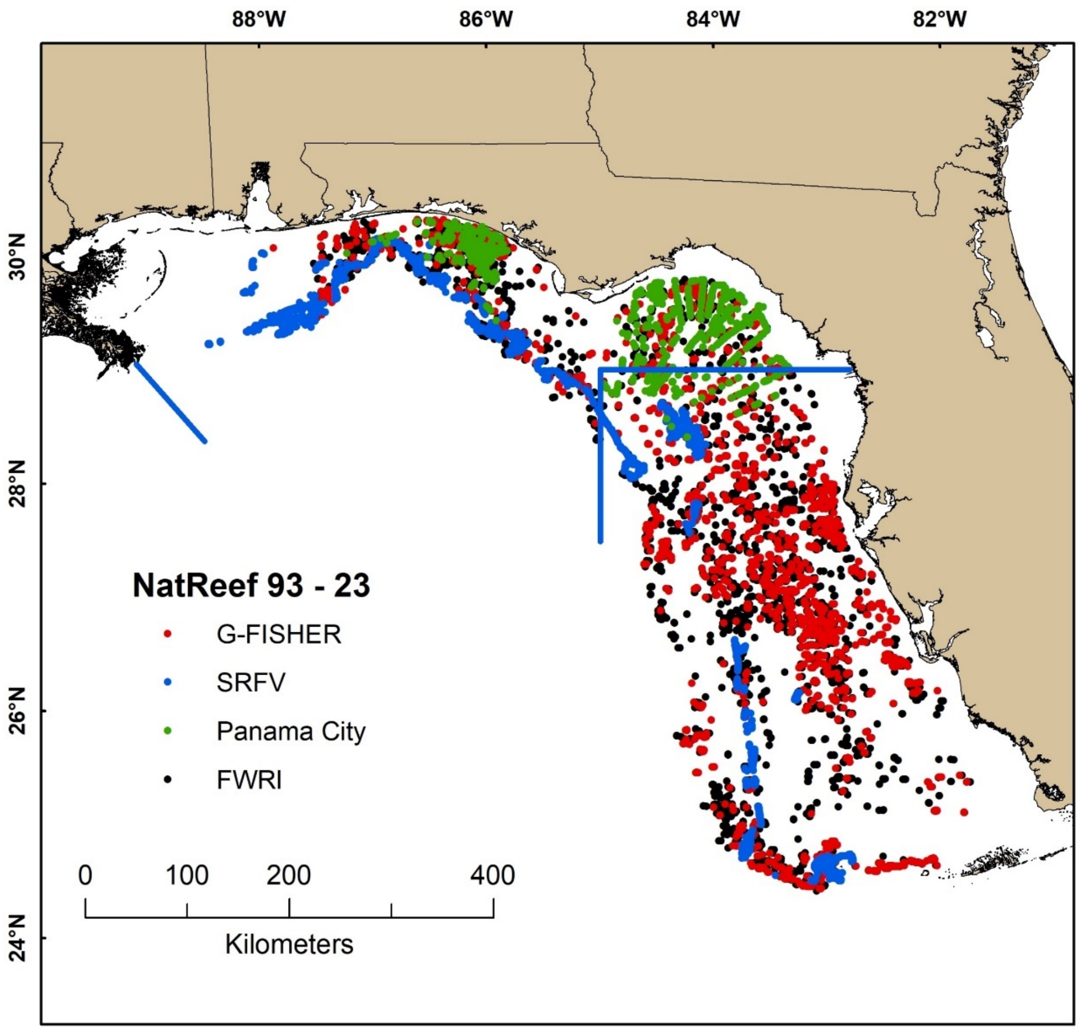
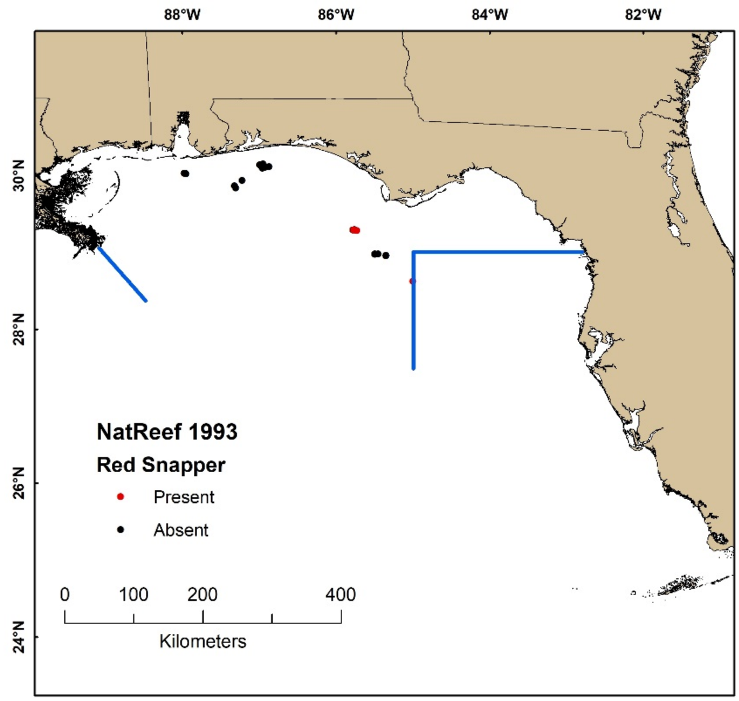
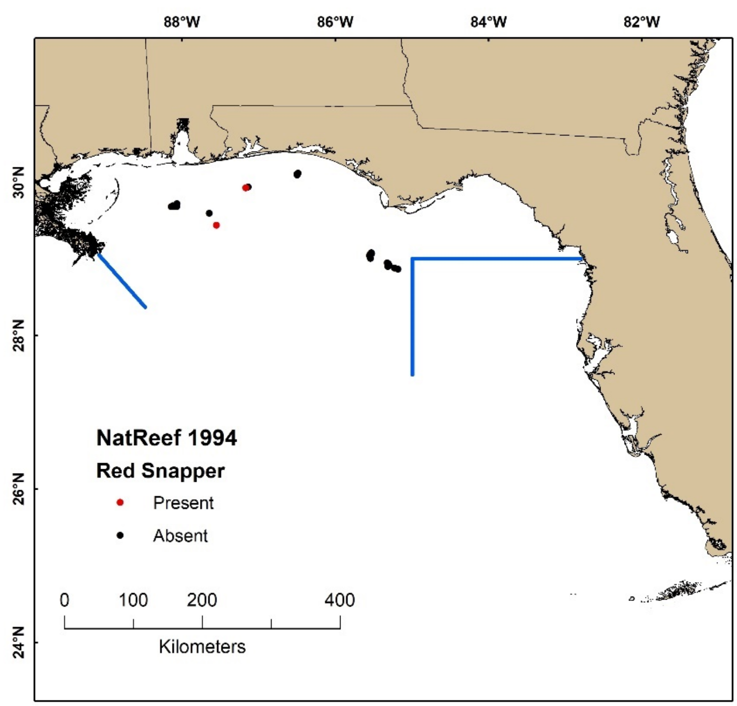
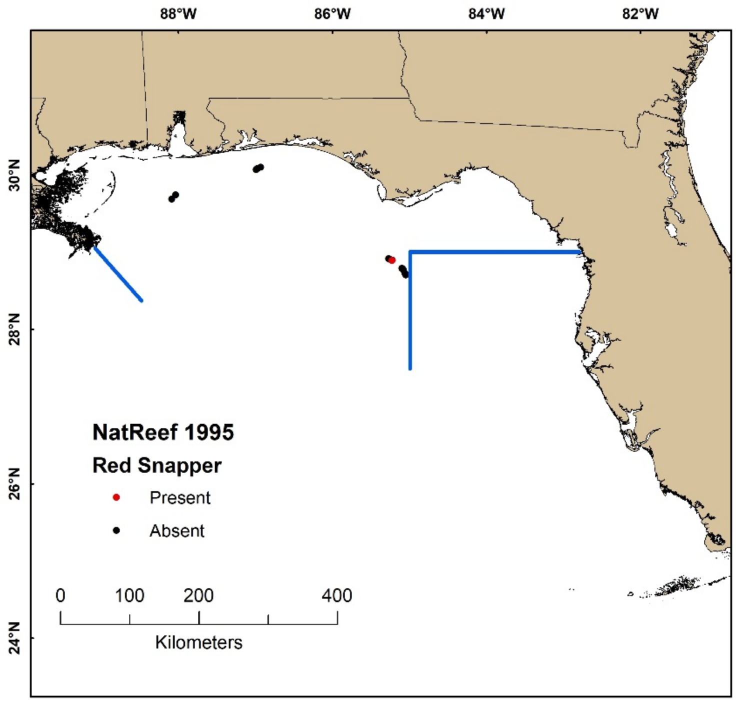


Figure 1. Map of all video sites included in the index for each survey across all years 1993-2023. The break at zone 6/7 is shown to illustrate the Central and East regions for Red Snapper.

Figure 2. Annual maps of sampling effort on natural reef habitats by the G-FISHER video survey. Blue lines designate boundaries of Central and East Red Snapper stocks.



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NatReef 1995
Red Snapper
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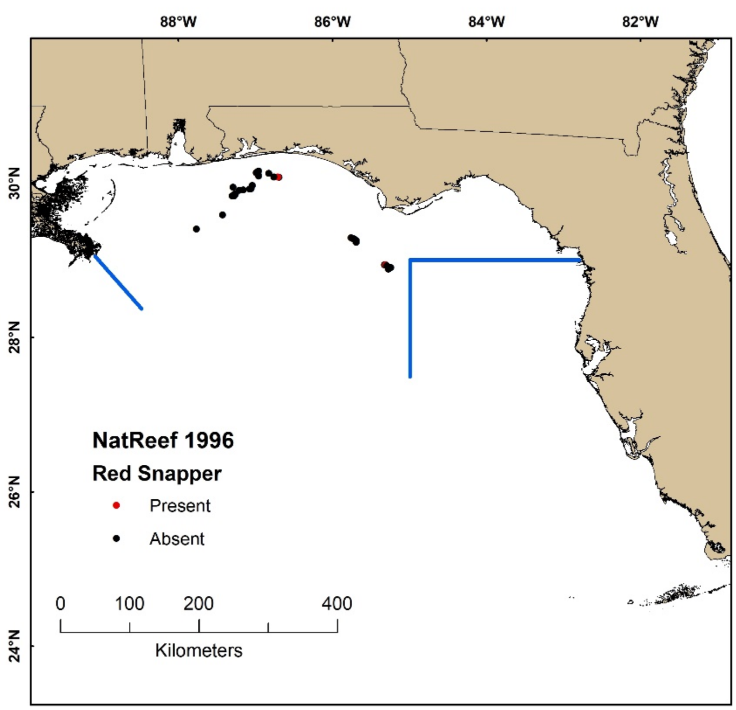
Kilometers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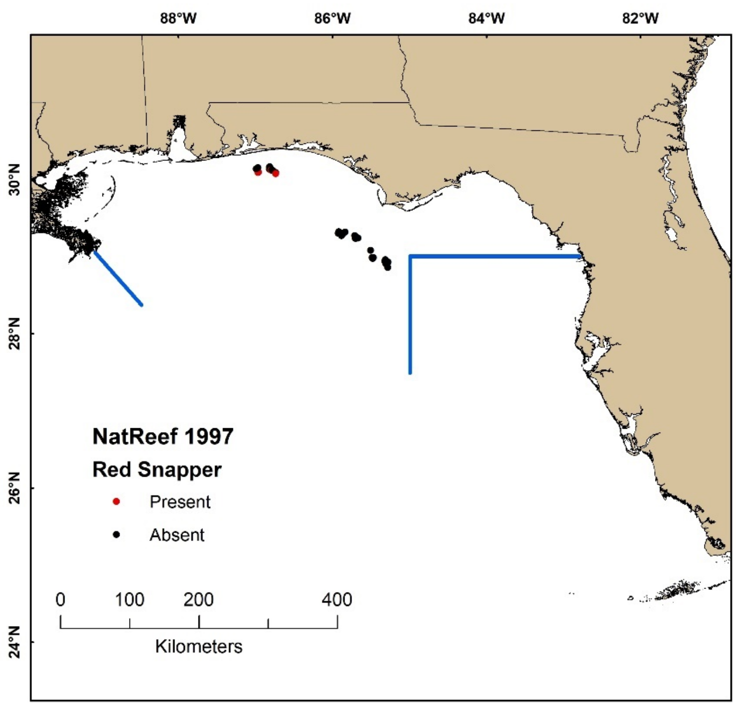
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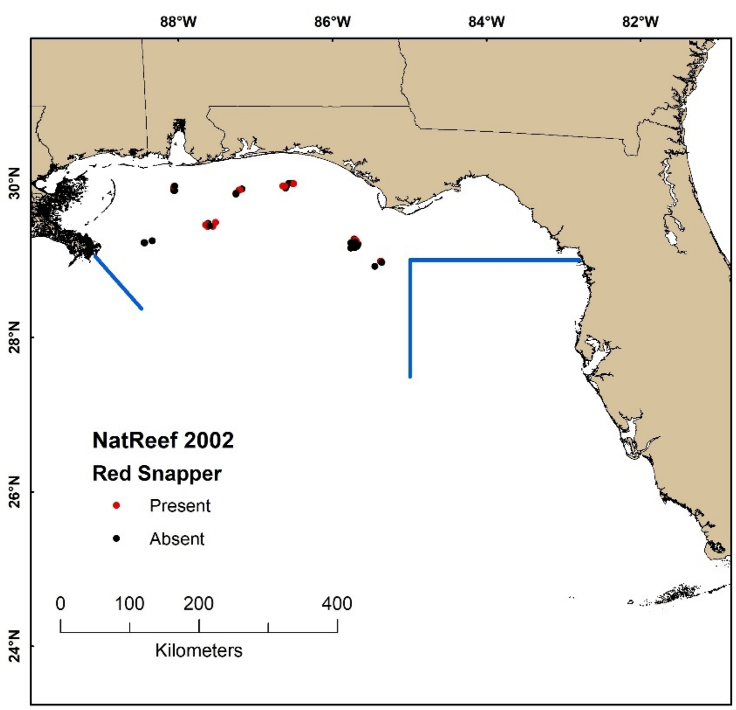
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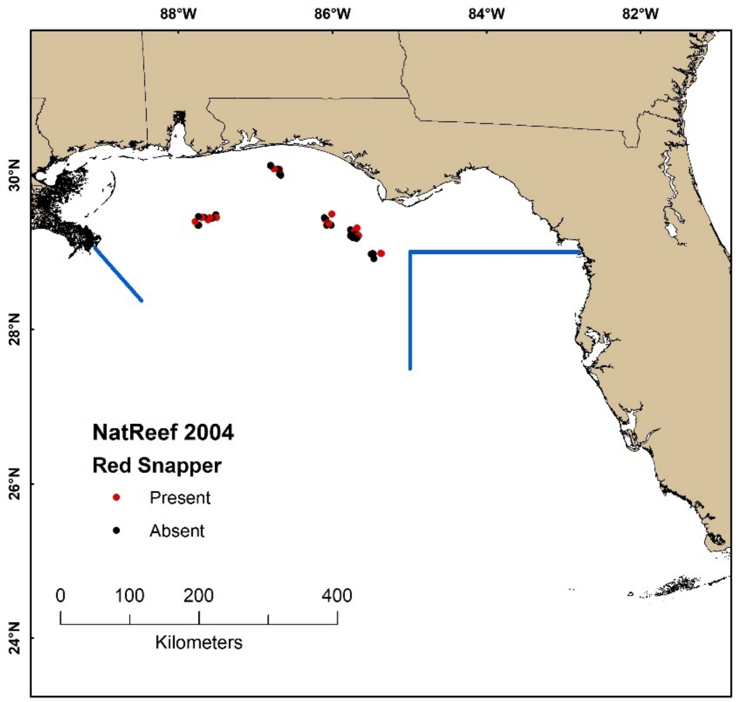
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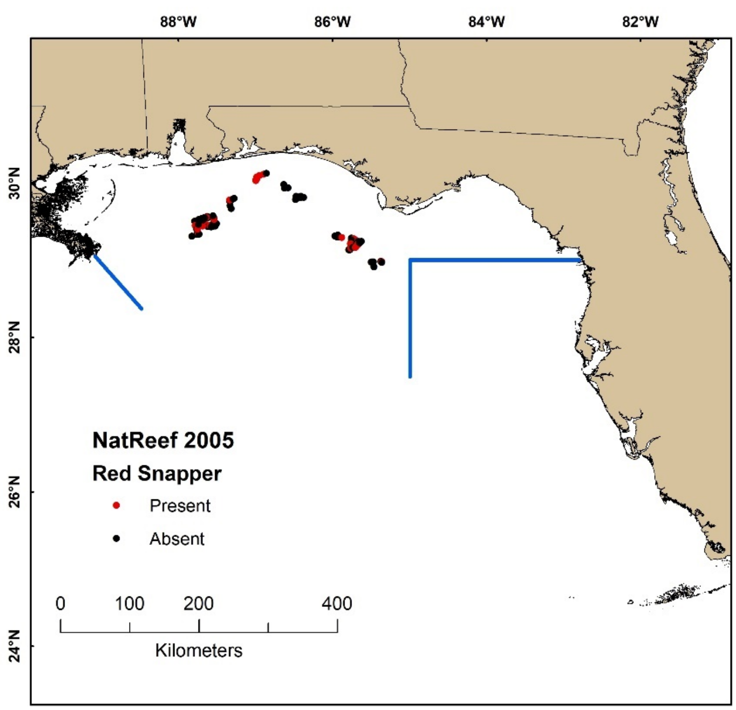
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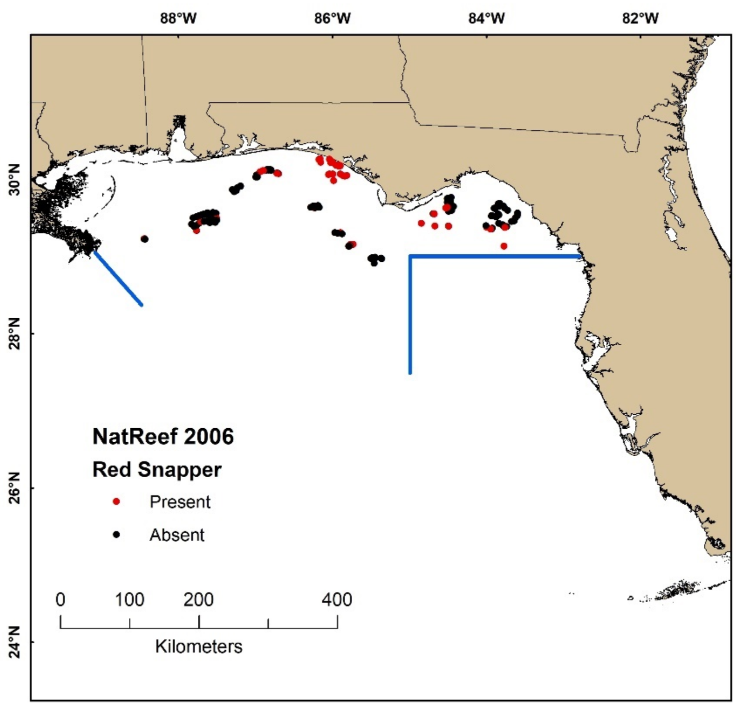
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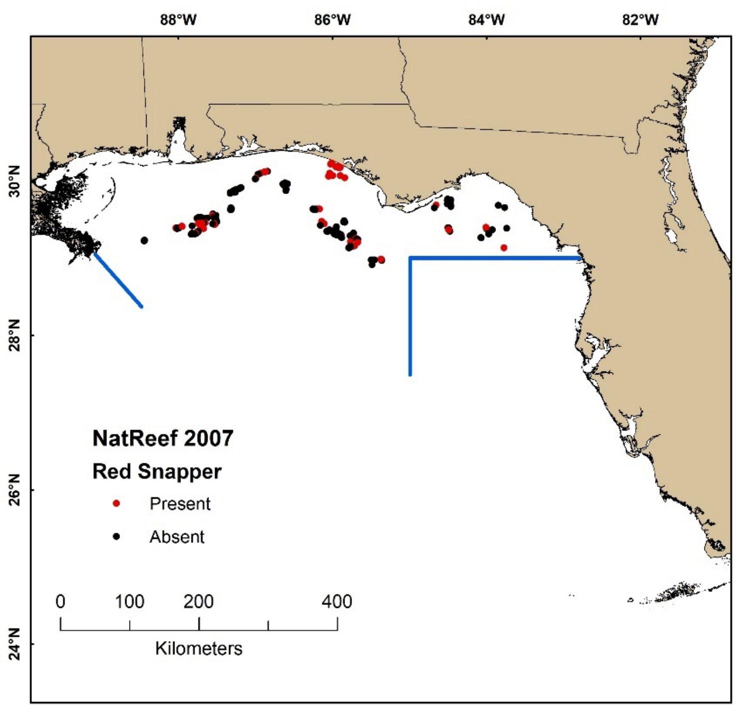
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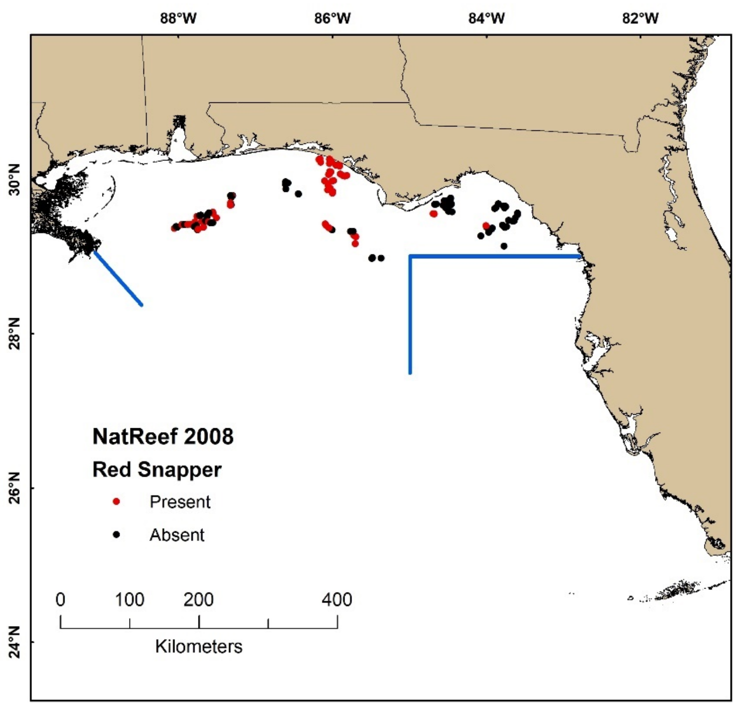
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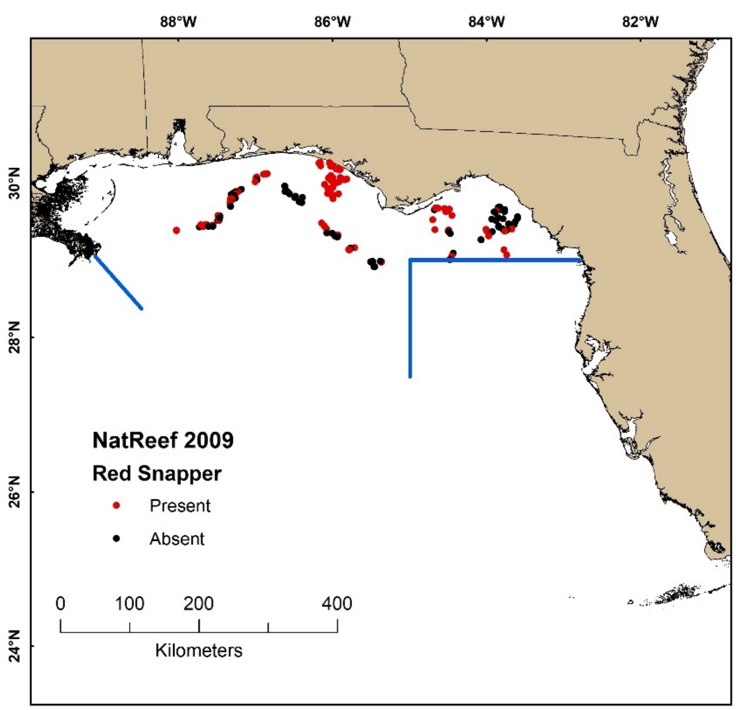
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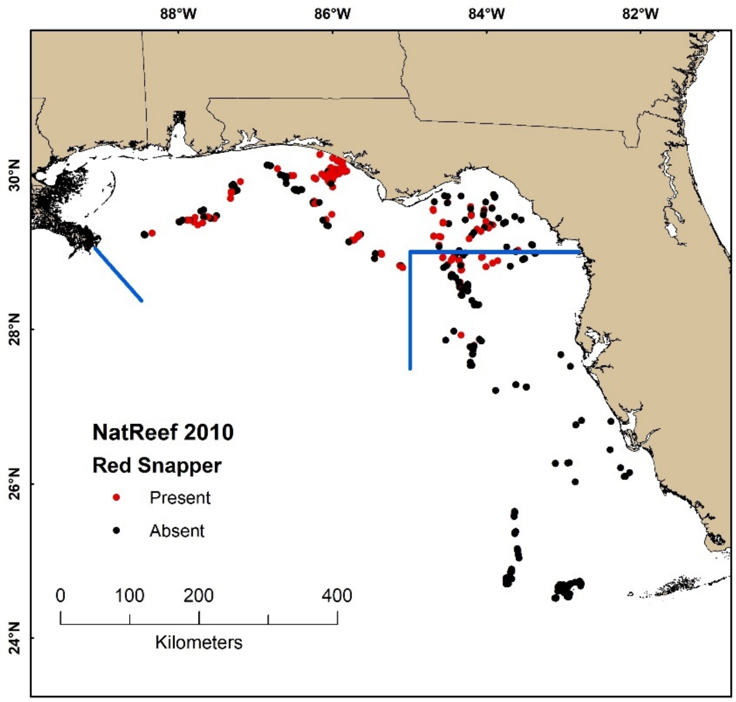
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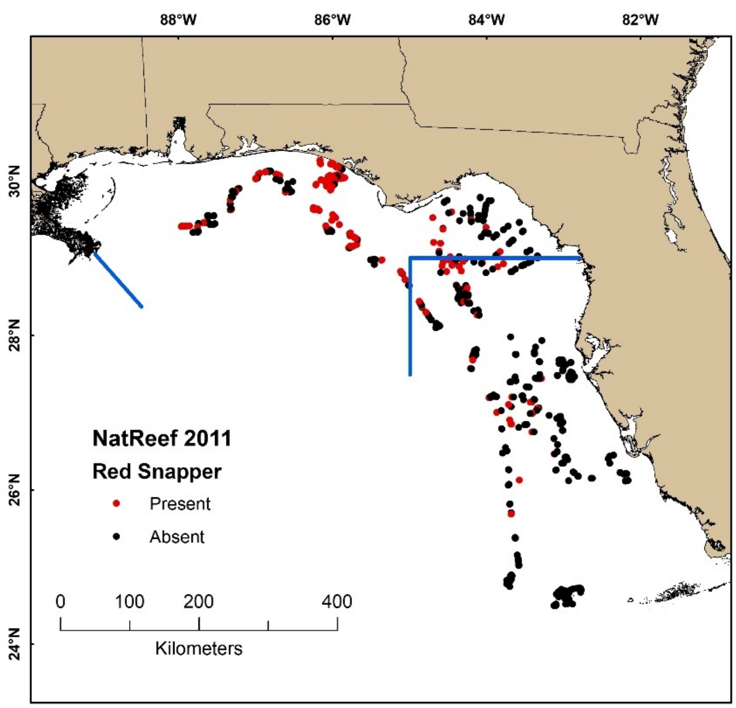
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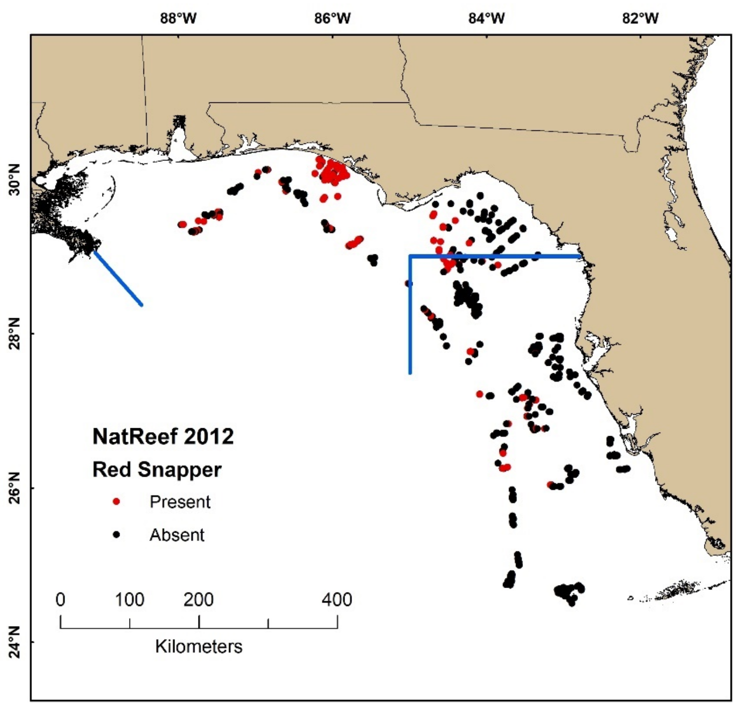
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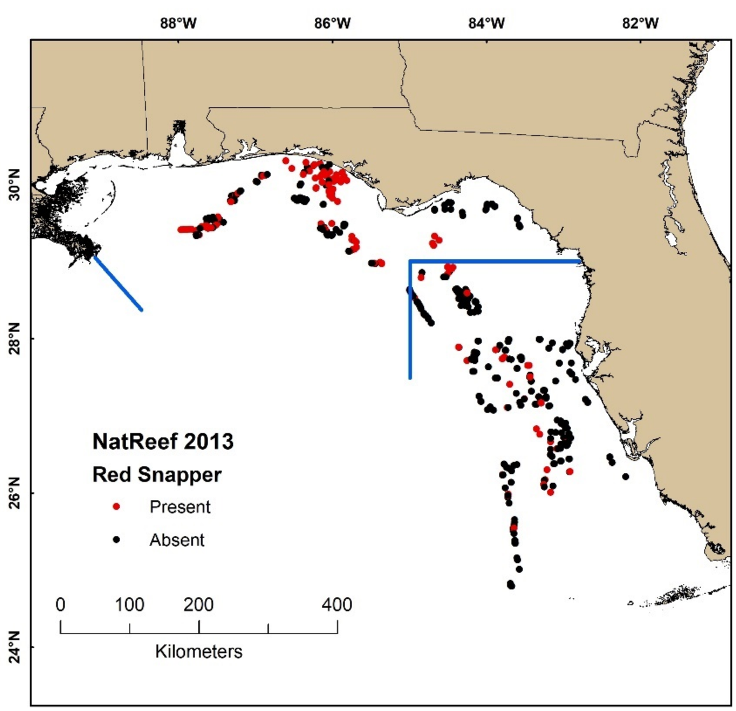
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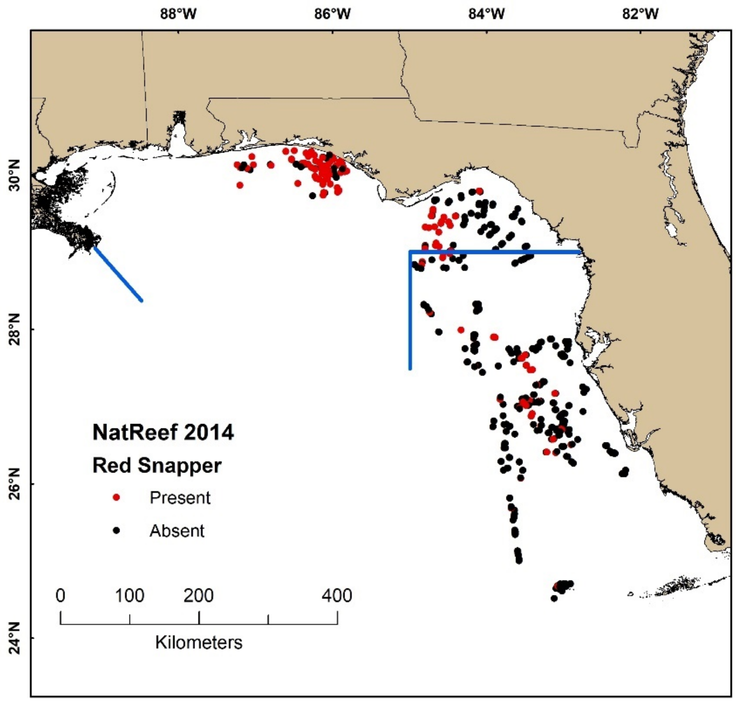
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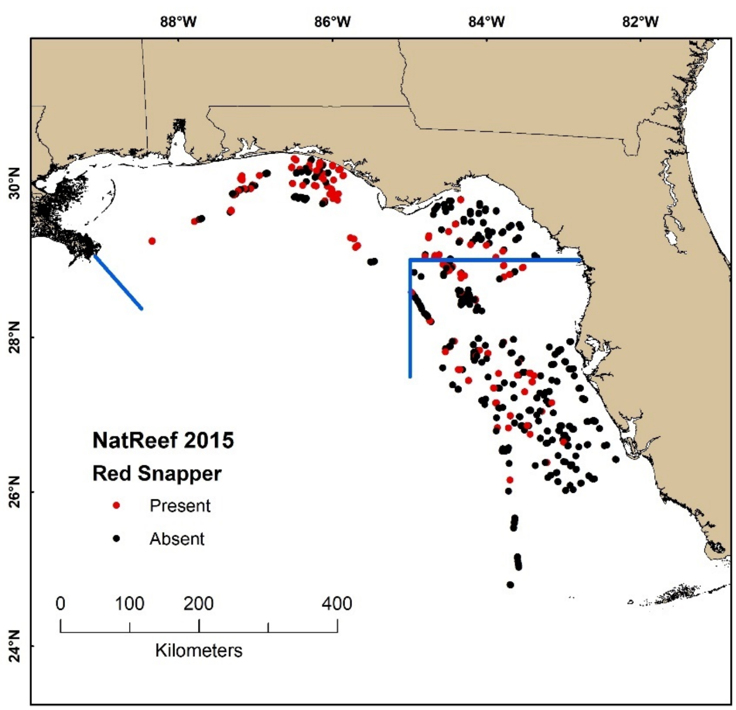
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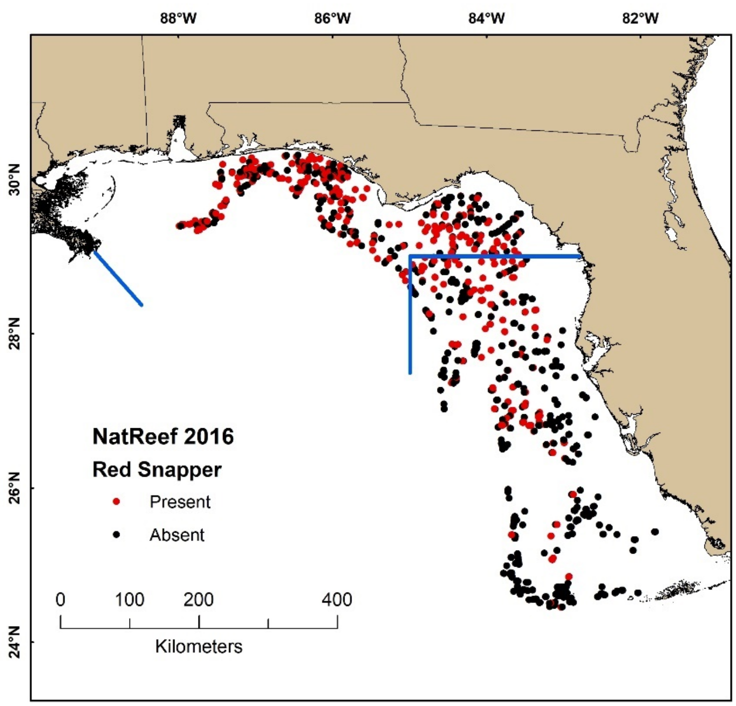
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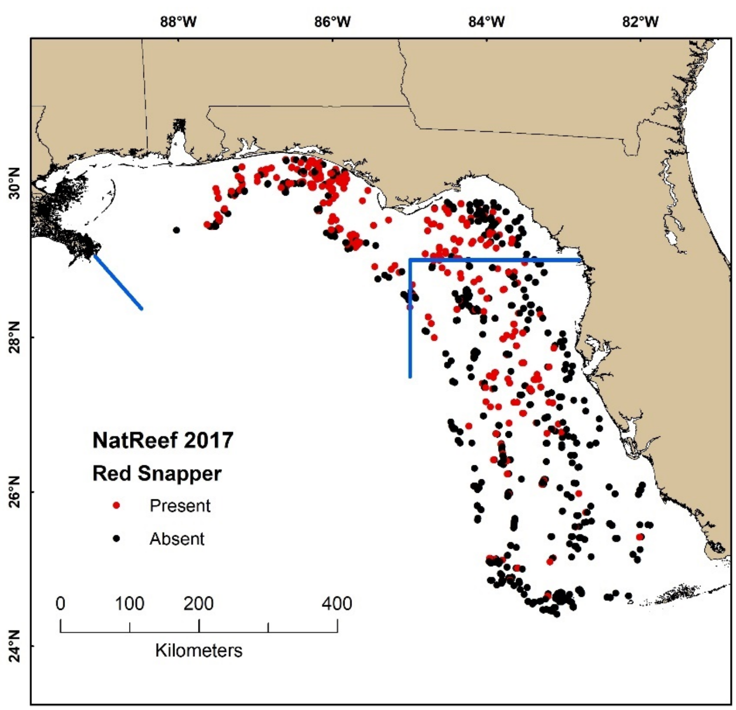
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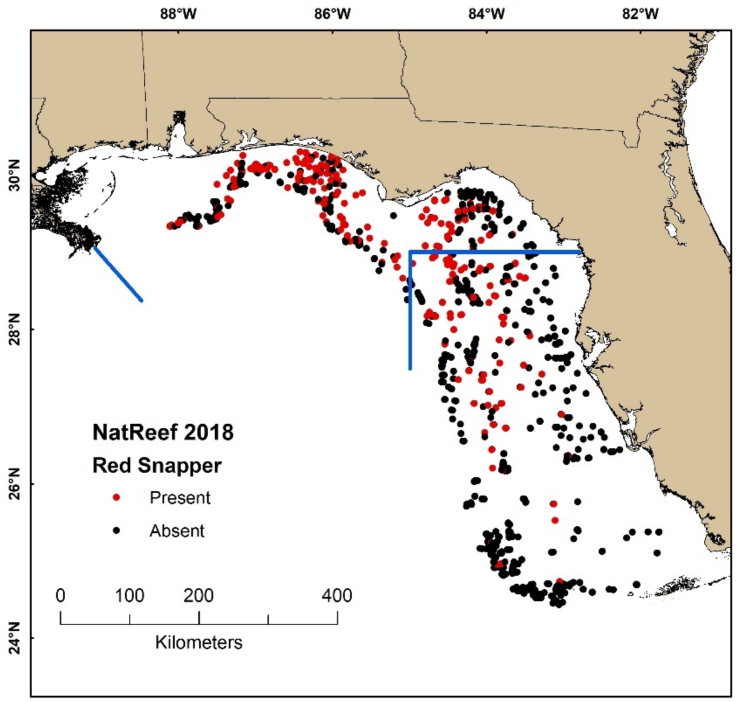
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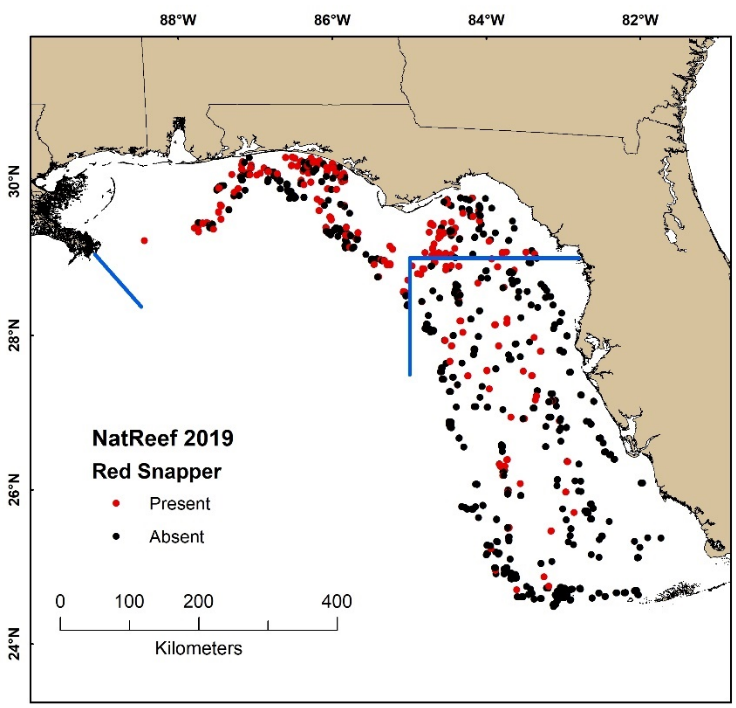
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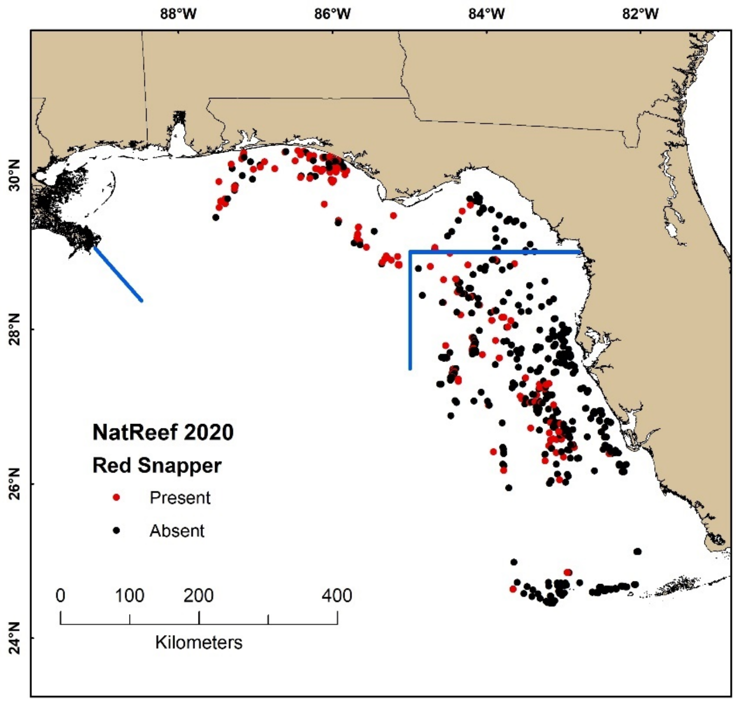
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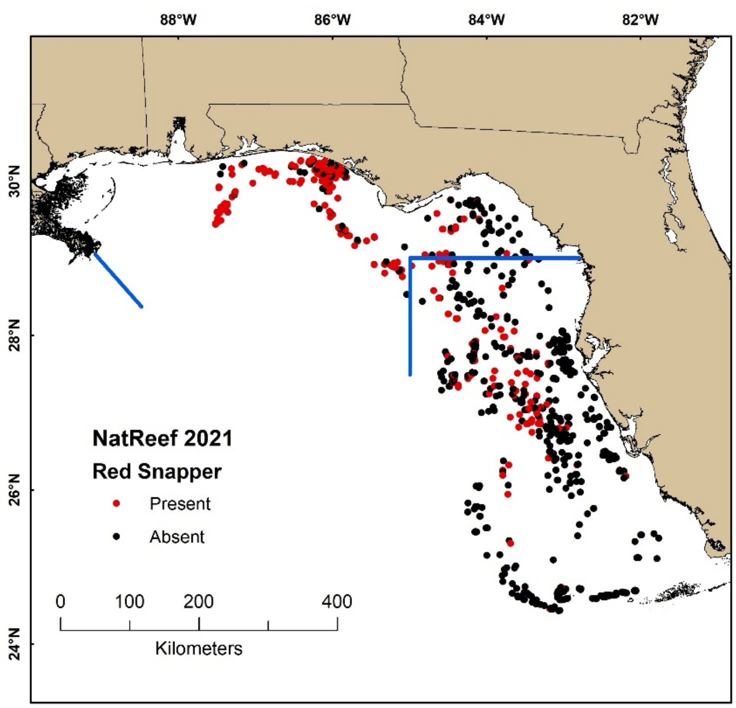
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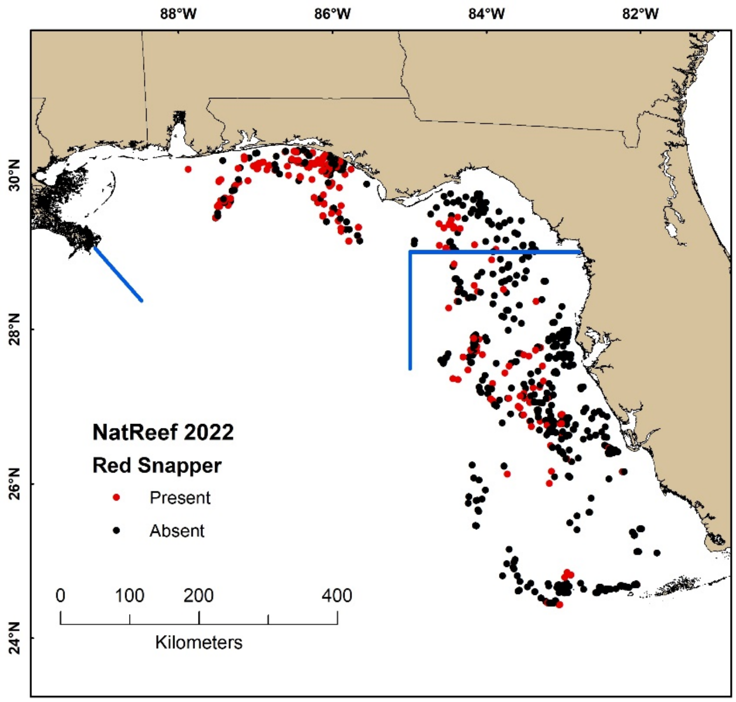
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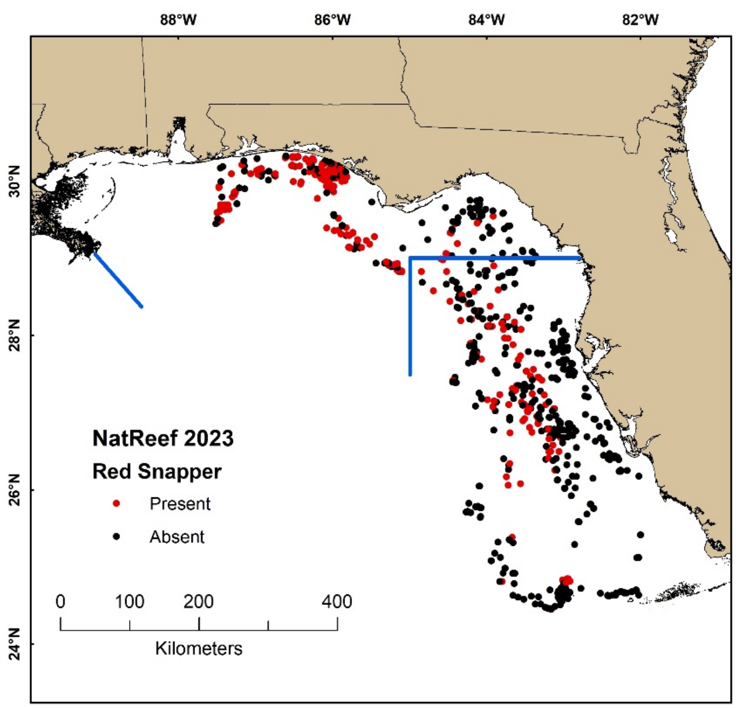
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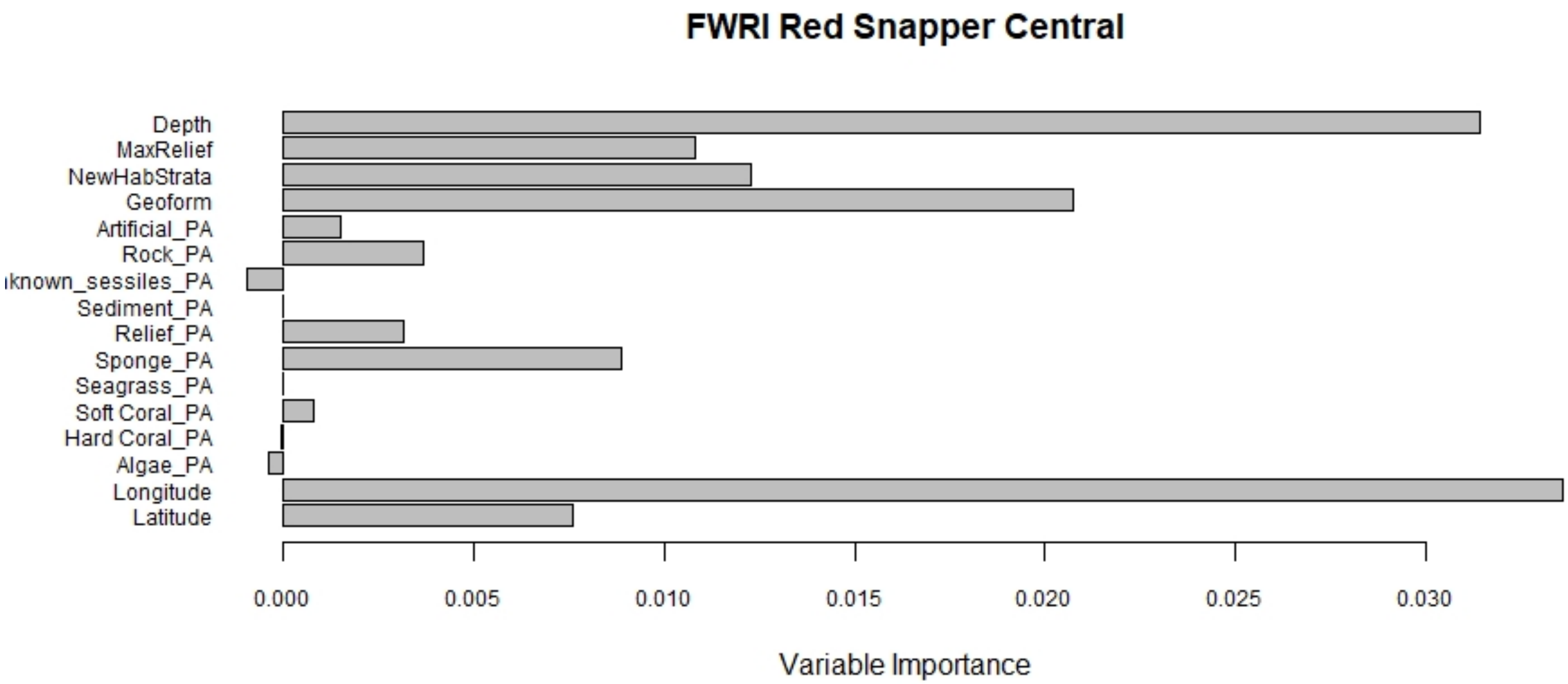

Figure 3. Random Forest generated variable importance for Red Snapper presence using the Central FWRI survey data.

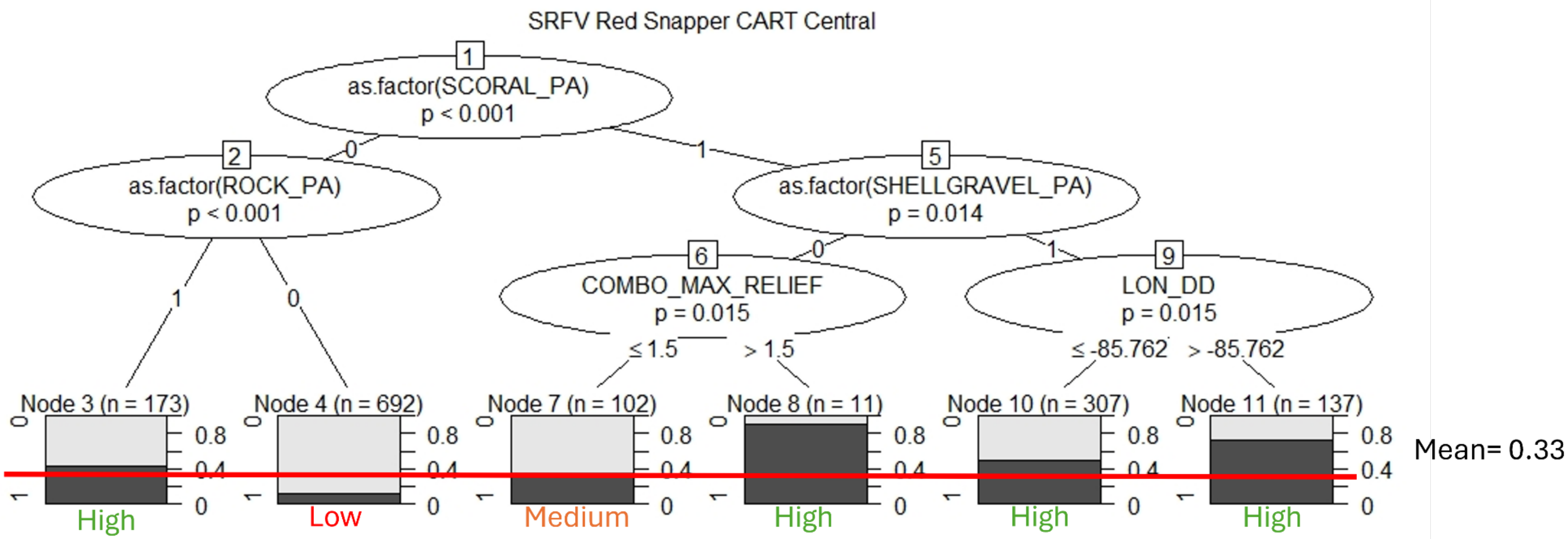

Figure 4. CART results for Red Snapper for SRFV survey for the Central region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

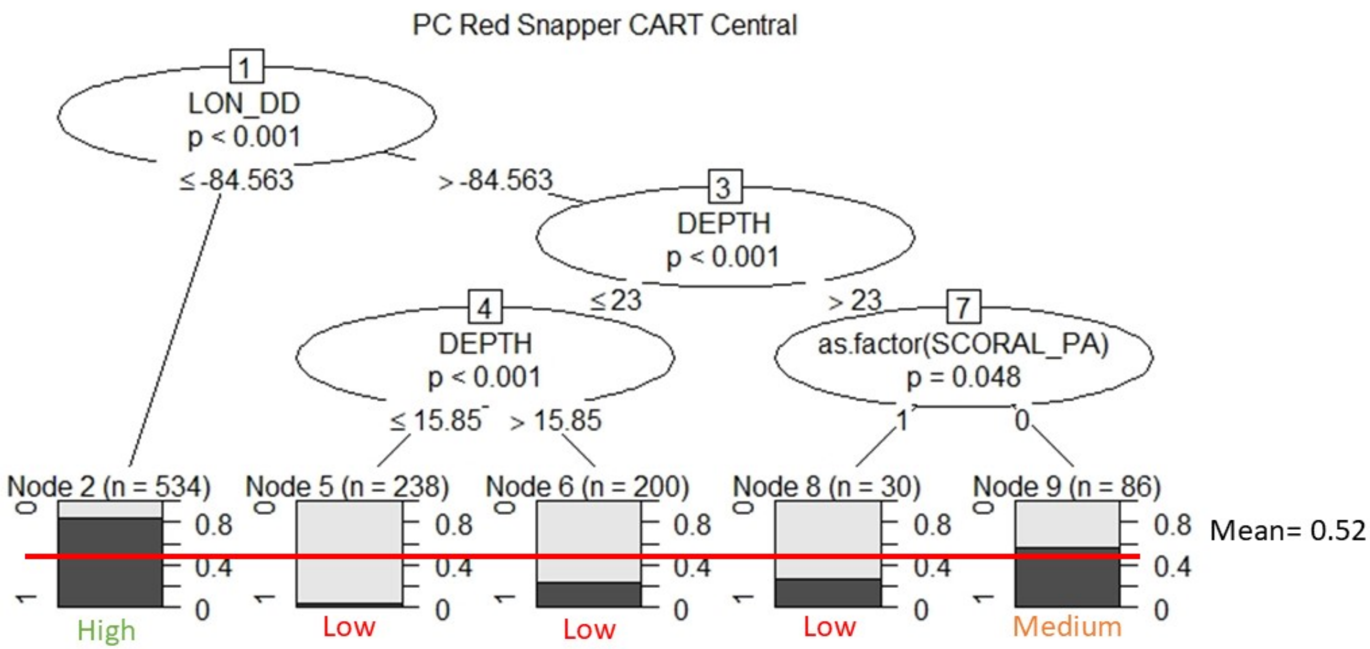

Figure 5. CART results for Red Snapper for PC survey for the Central region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

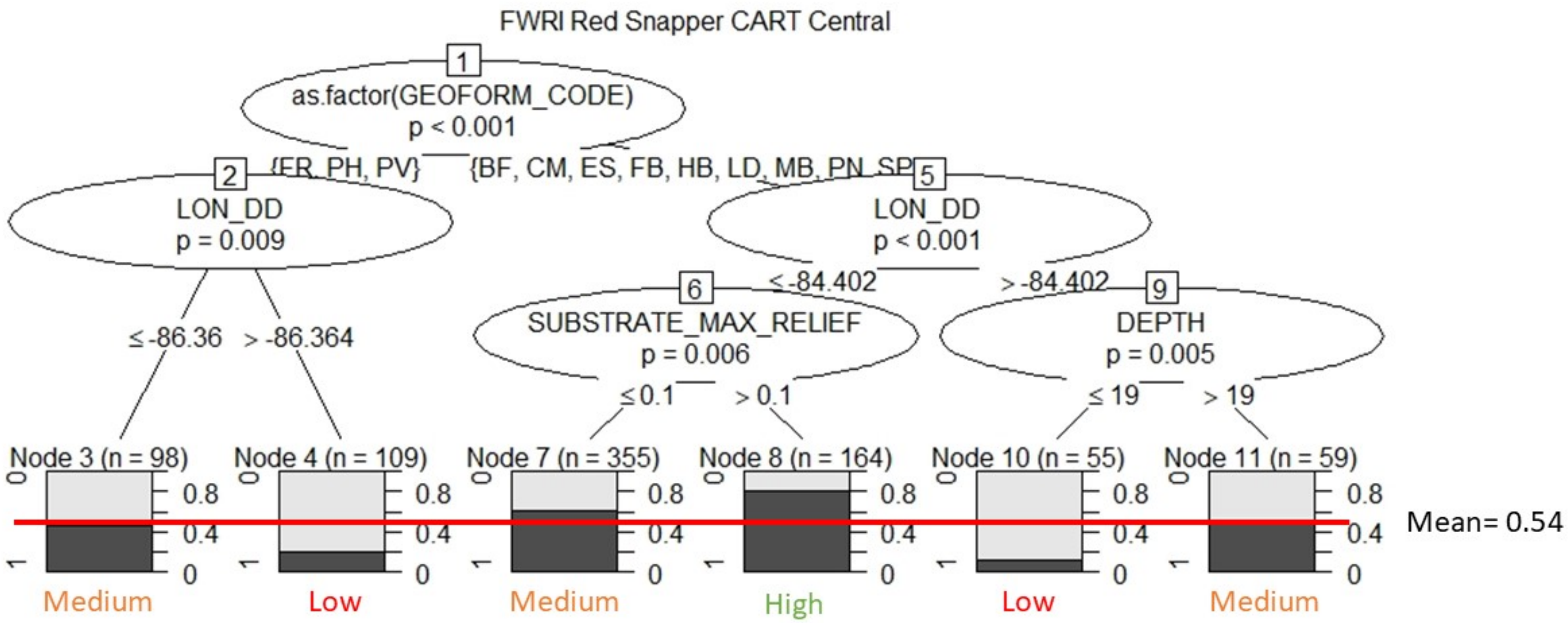

Figure 6. CART results for Red Snapper for FWRI survey for the Central region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

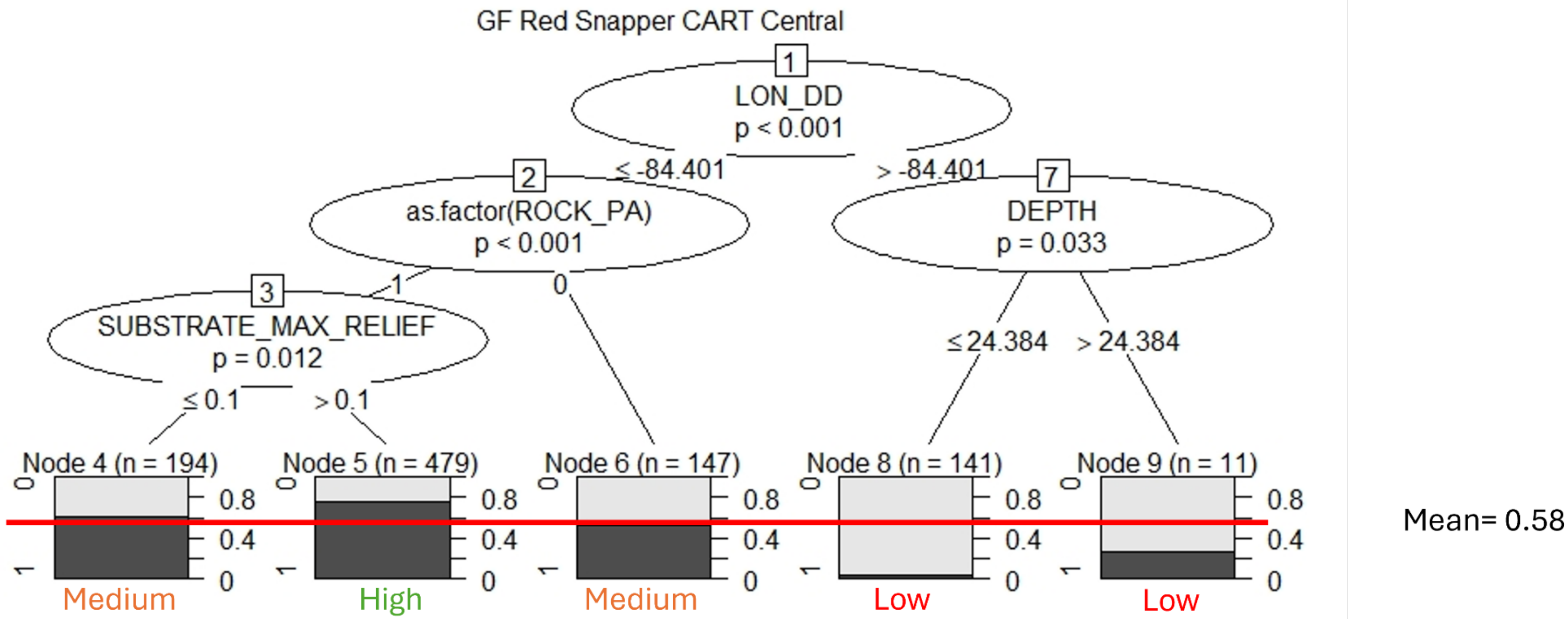

Figure 7. CART results for Red Snapper for G-FISHER survey for the Central region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

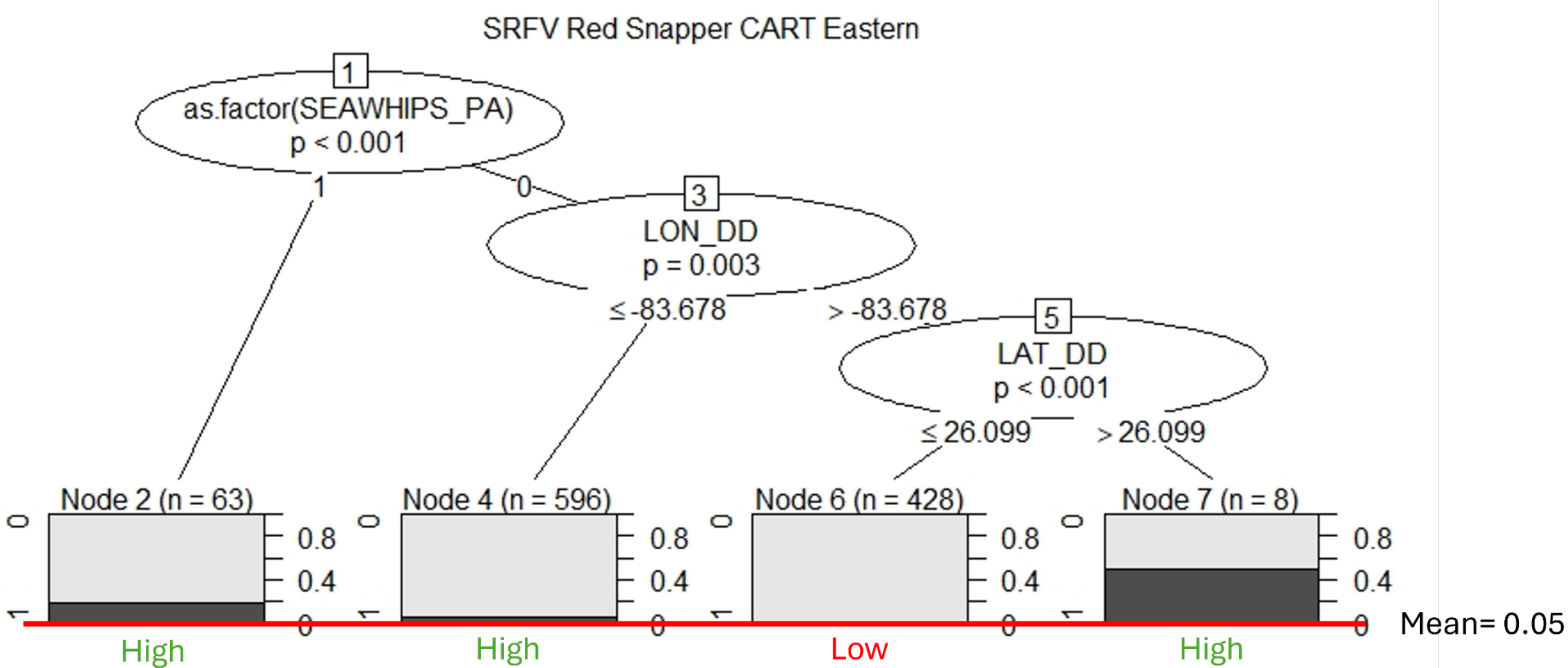

Figure 8. CART results for Red Snapper for SRFV survey for the East region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

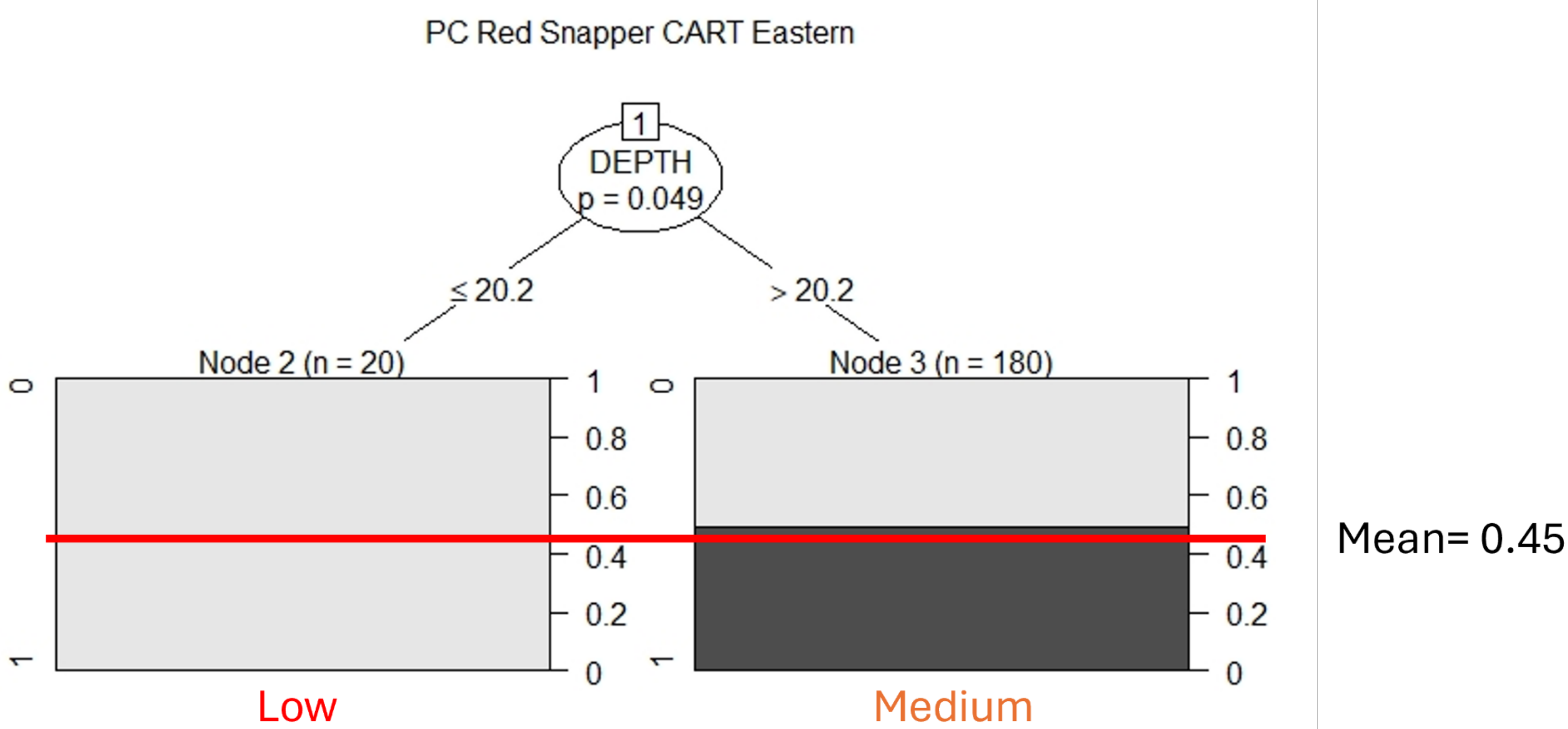

Figure 9. CART results for Red Snapper for PC survey for the East region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

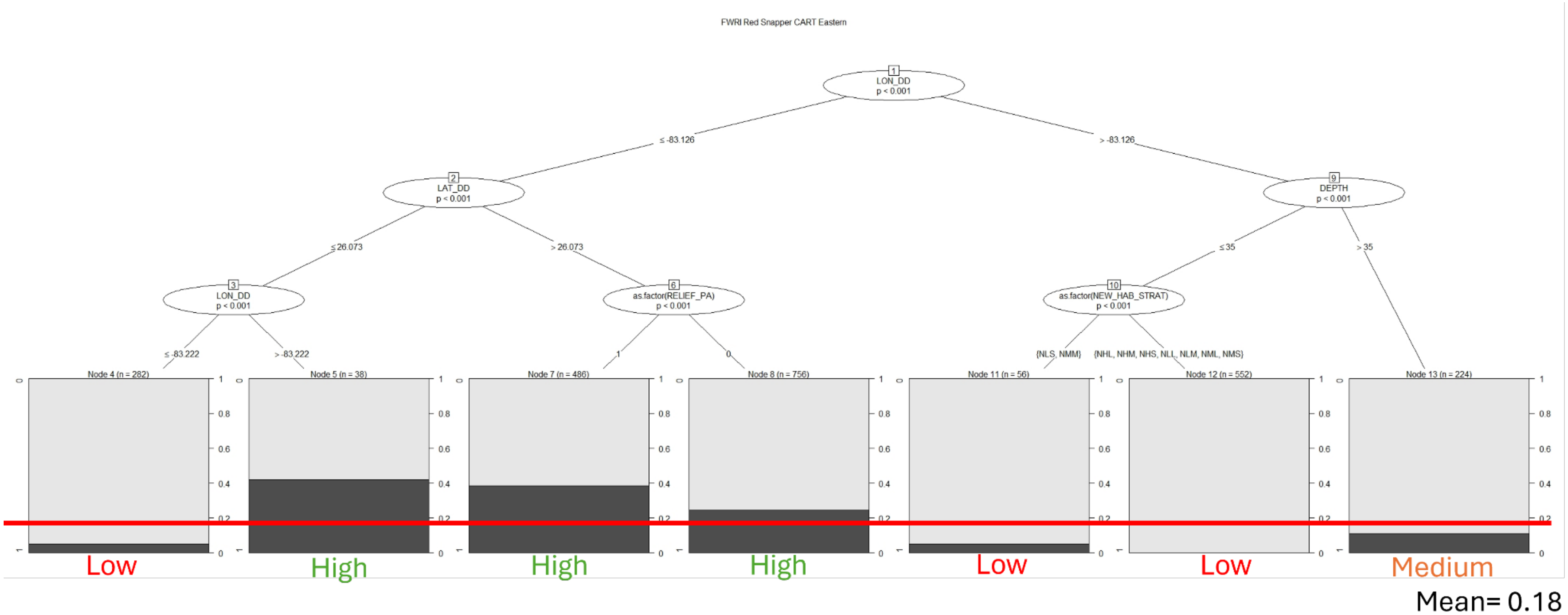

Figure 10. CART results for Red Snapper for FWRI survey for the East region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

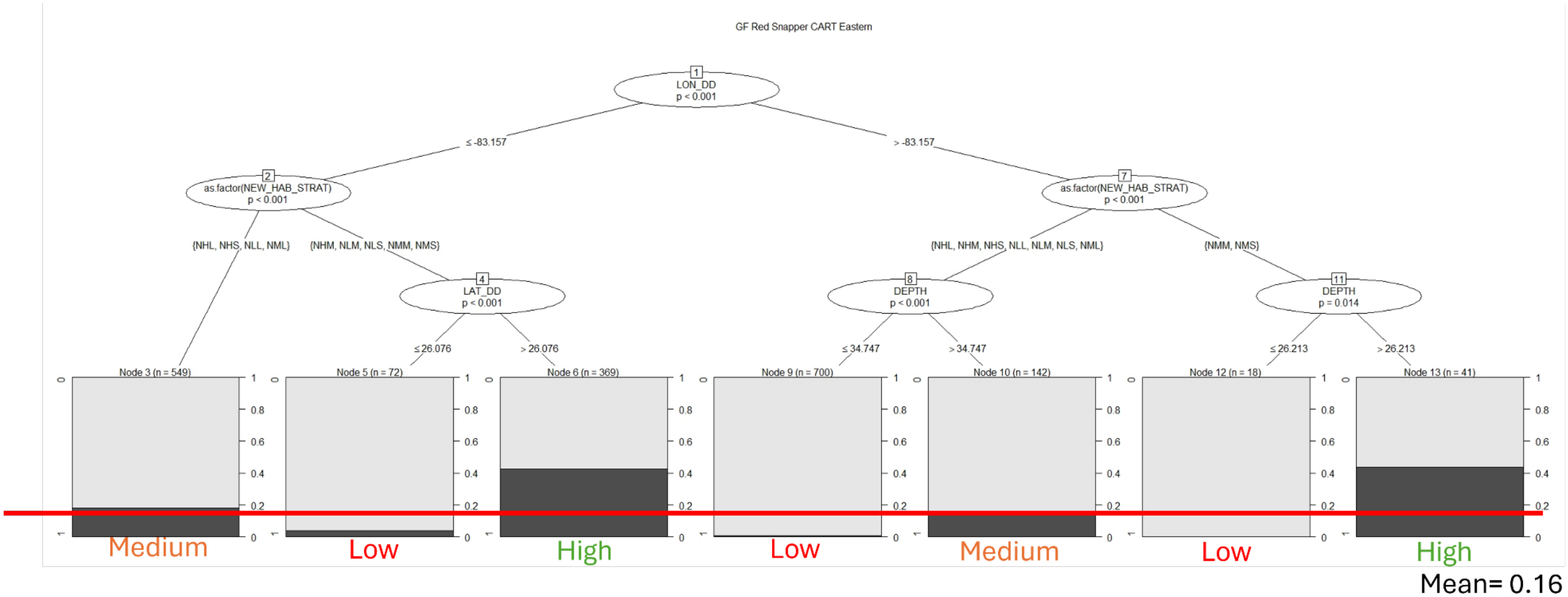

Figure 11. CART results for Red Snapper for G-FISHER survey for the East region. Shaded portion of the plots indicate proportion of sites given by a node where Red Snapper were observed.

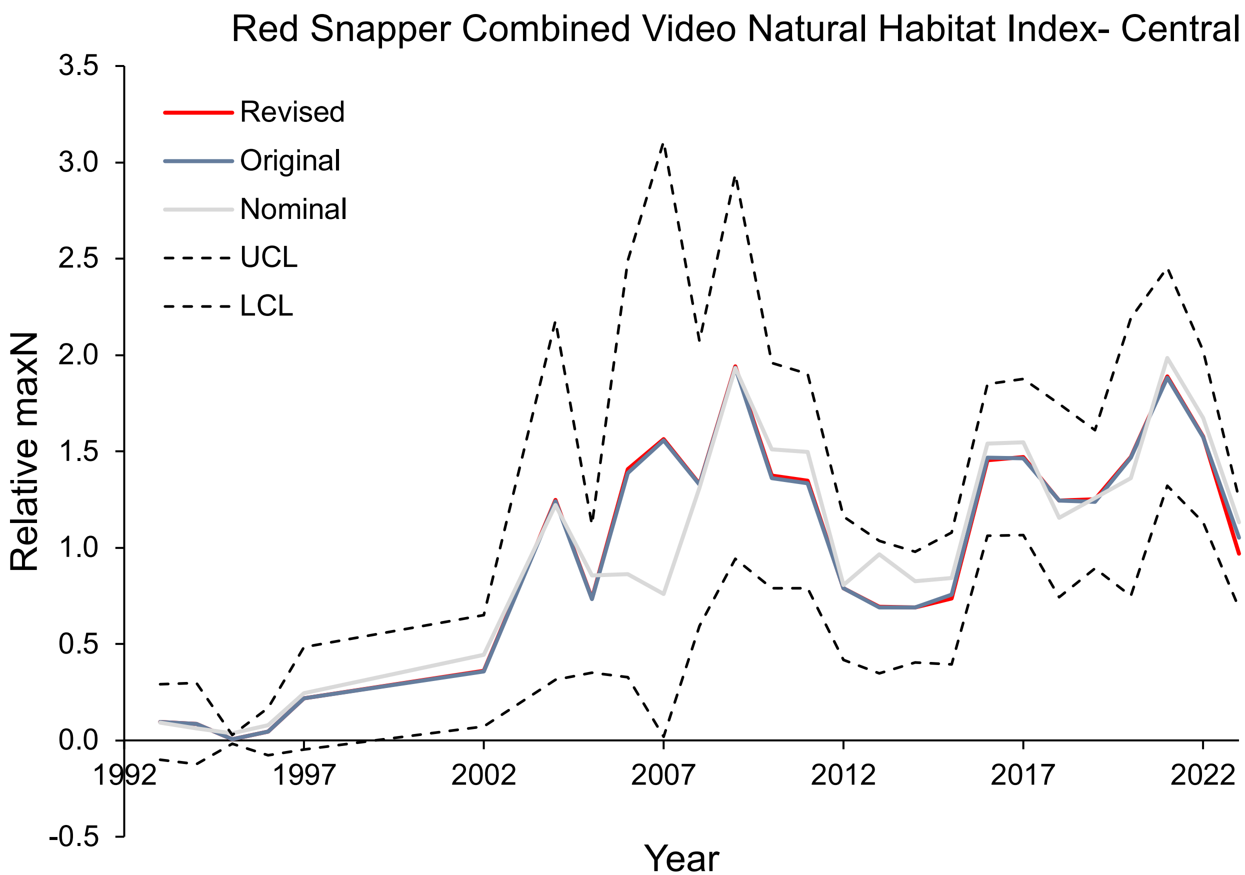

Figure 12. Standardized index with 2.5% and 97.5% confidence intervals and nominal index for relative Red Snapper CPUE (MaxN) using the integrated West Florida Shelf video data for the Central Region.

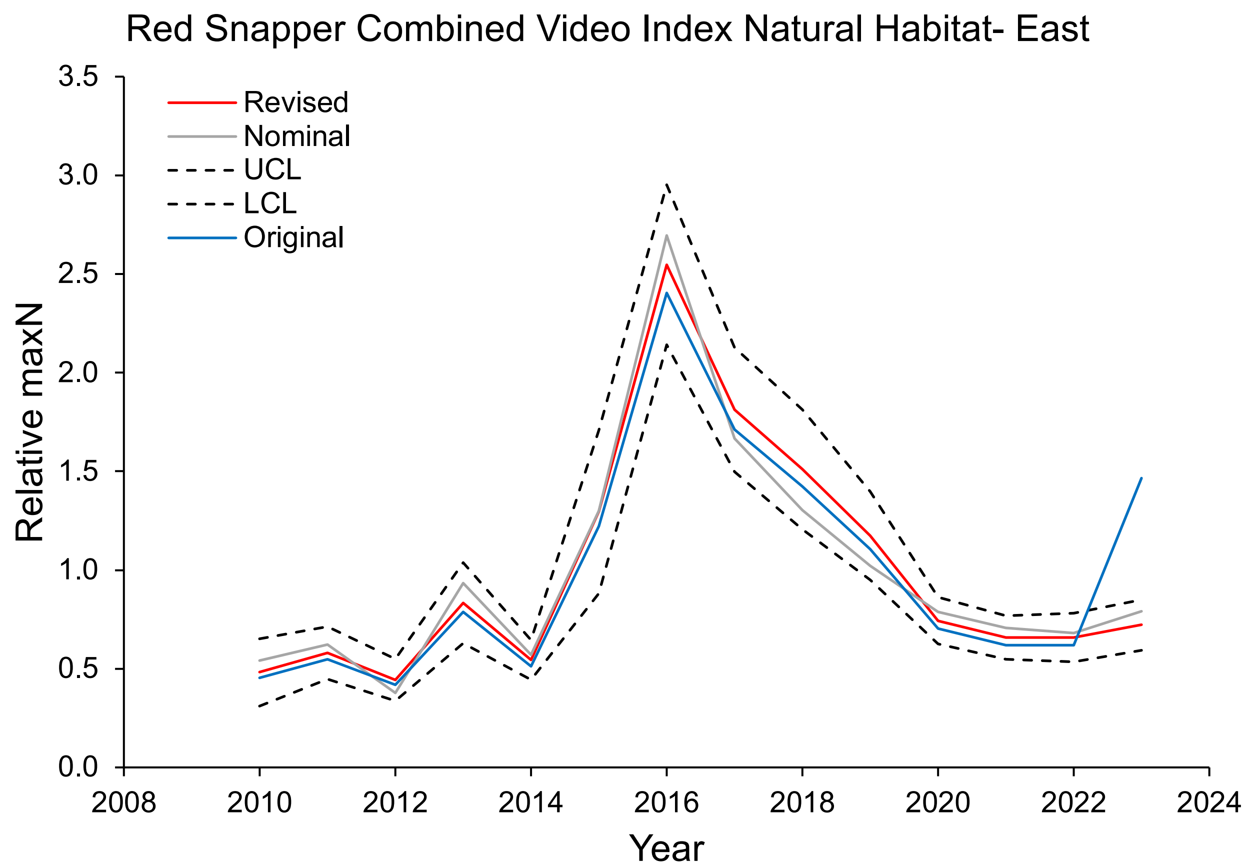

Figure 13. Standardized index with 2.5% and 97.5% confidence intervals and nominal index for relative Red Snapper CPUE (MaxN) using the integrated West Florida Shelf video data for the East Region.

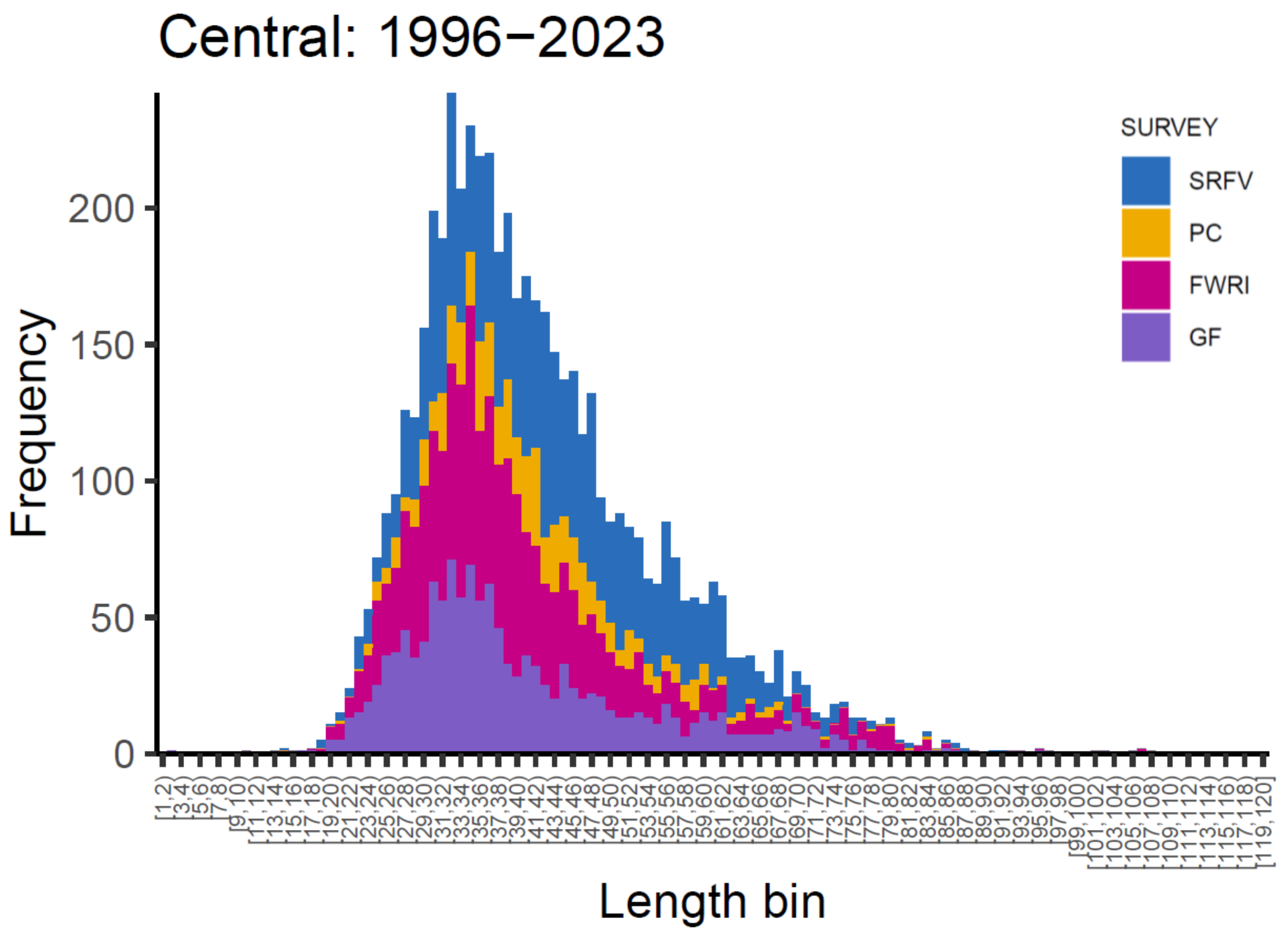

Figure 14. Combined length frequencies of Red Snapper in the Central region by survey for all years sampled.

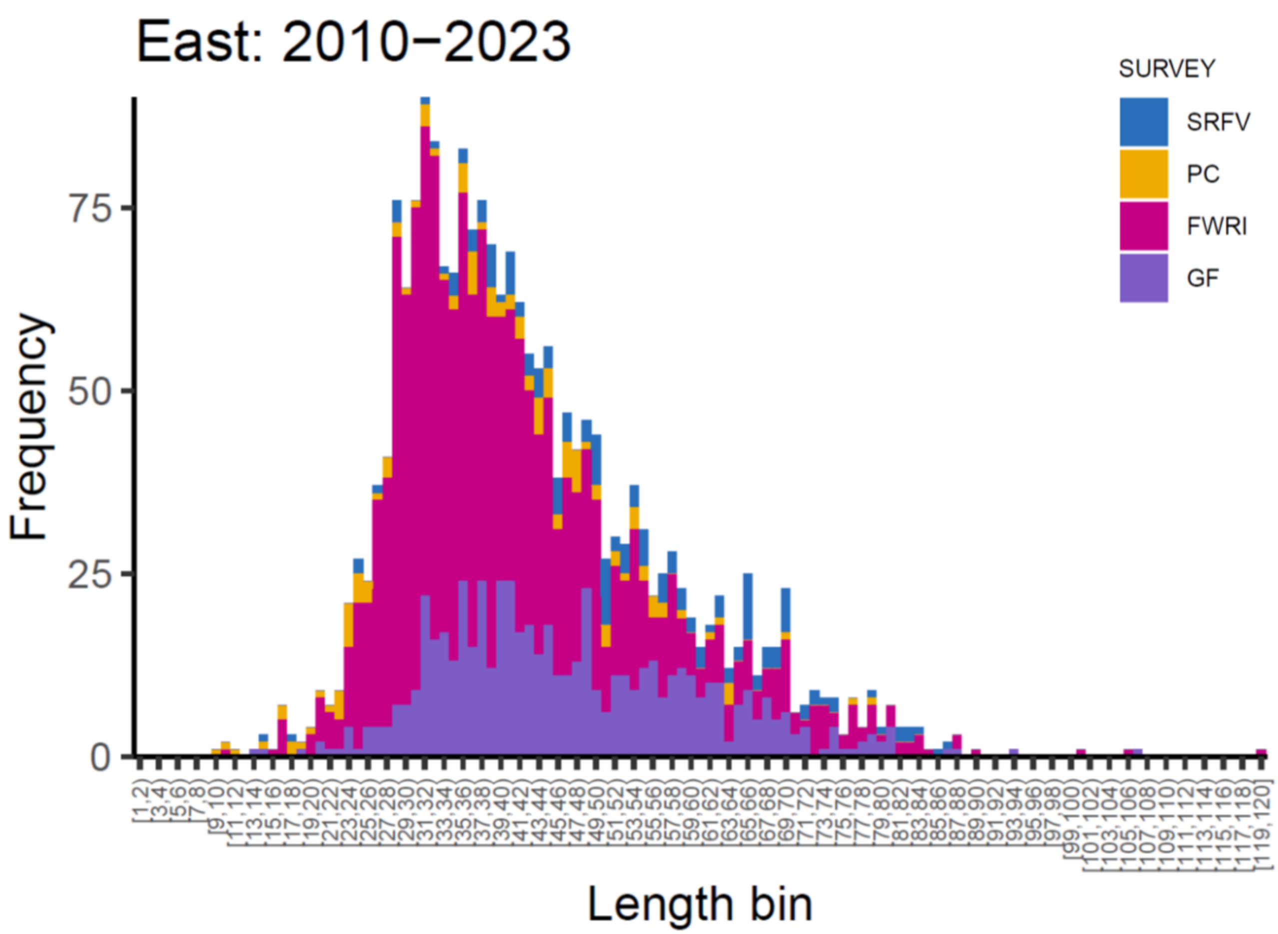

Figure 15. Combined length frequencies of Red Snapper in the South region by survey for all years sampled.

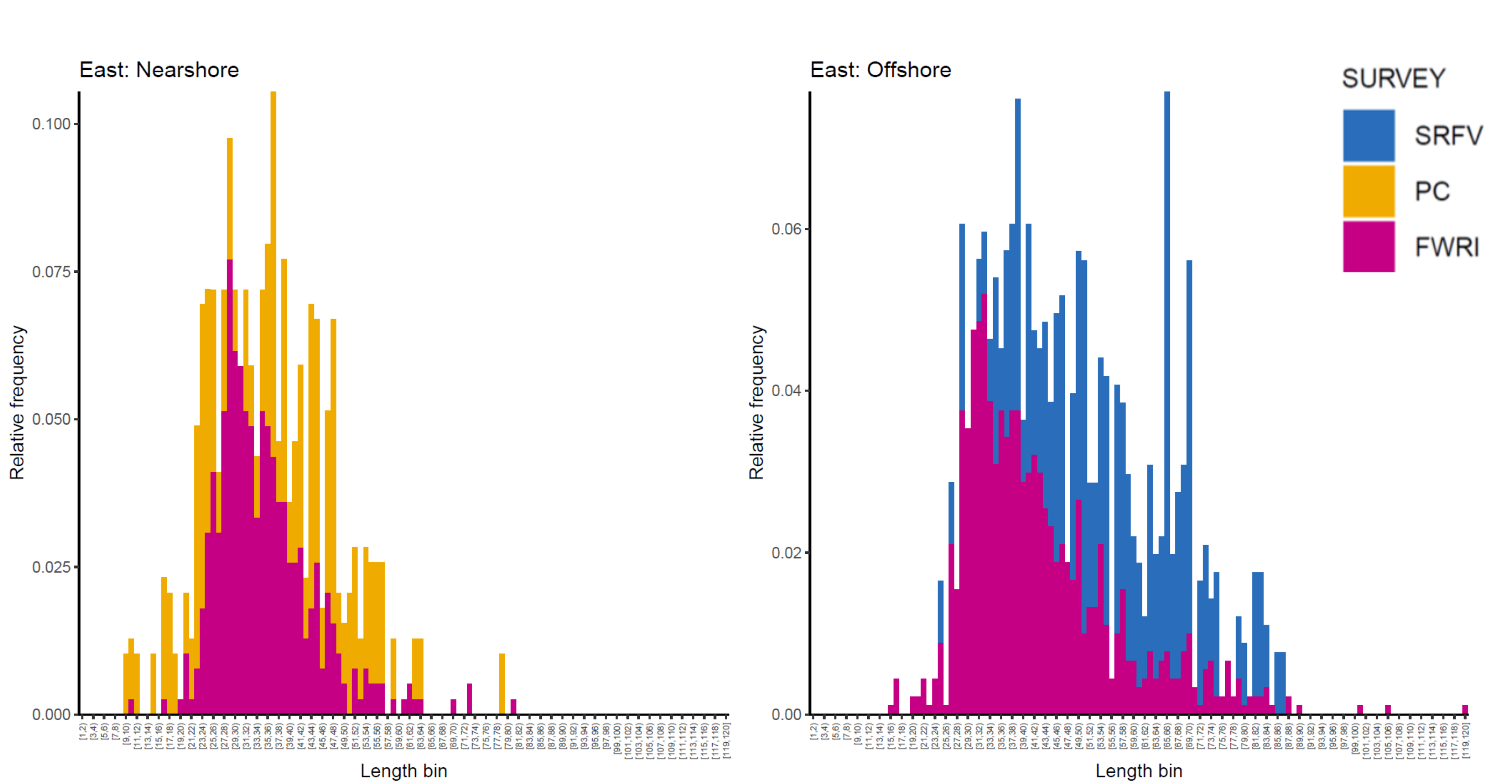

Figure 16. Combined length frequencies of Red Snapper in the South region by survey for all years sampled separated into nearshore (< 37m) and offshore (> 37m) depth strata.