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Indices of abundance for Gulf Gray Triggerfish (*Balistes capriscus*) using data from multiple video surveys

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Introduction

Historically, three different stationary video surveys were conducted in the northern Gulf of America (GOA) to derive abundance estimates of important reef fish stocks. The longest running survey was the SEAMAP reef fish video (SRFV) survey initiated by the NMFS Mississippi Laboratory in 1992, followed in 2005 by the NMFS Panama City Laboratory (PC) survey, and finally the Florida Fish and Wildlife Research Institute (FWRI) video survey, which started in 2010. Each survey used standardized sampling and data processing procedures. However, subtle variations in video annotation procedures as well as survey design and spatial coverage presented challenges from an assessment perspective. As such, a new survey initiative was undertaken, the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER) program, using funds provided by the NOAA RESTORE science program to integrate the three historic surveys under a single, unified design from 2020 onward (Switzer et al 2023).

The initial approach to integrate data from these independently conducted surveys was to generate independent indices for each; however, combining indices across datasets likely increases predictive capabilities by allowing for the largest possible sample sizes in model fitting. Previous research 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). As such, a habitat-based approach was developed (Thompson et al 2022) to combine relative abundance data for generating annual trends of Gray Triggerfish (*Balistes capriscus*). Specifically, Gray Triggerfish are found throughout the GOA, which is considered a single stock based on its prolonged, indeterminate larval stage. However, the stock was historically divided into eastern and western GOA components at the Mississippi River to allow the application of area-specific life history characteristics, catch statistics, and survey indices. As such, this report provides indices of abundance for the East GOA (EGOA, > -89° longitude), West GOA (WGOA; < -89° longitude), and Gulf-wide GOA (GOA) regions as defined in the Stock ID process (SEDAR 9).

Survey Comparisons

Survey design

The SRFV survey primarily targeted high-relief topographic features along the continental shelf from

south Texas to south Florida. Site selection followed a stratified random design with strata determined by region and total proportion of reef area in a sampling block of 10 minute latitude x 10 minute longitude. Sites were selected at random from known areas identified through habitat mapping either with multi-beam or side-scan sonar (Campbell et al 2017). Historic indices developed from this survey designated the Mississippi river delta as a geographic feature separating the west and east regions of the GOA (Campbell et al. 2017). As a result, the survey was split into SFRV East and SFRV West for the EGOA and WGOA indices, respectively. Both surveys were included in the GOA index.

The PC survey targeted the inner shelf (5 - 60 m depth) of the northeast GOA (NMFS statistical zones 6 - 10). Survey design has changed through time, but since 2010 a two-stage unequal probability design was 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 were randomly selected. Sites were described using side-scan sonar before video deployment (Overly et al. 2020). Historic indices developed from this survey had a spatial footprint east of -89° longitude. As a result, the PC survey was included in the EGOA and GOA indices.

The FWRI survey initially focused on the regions offshore of Tampa Bay and Charlotte Harbor, FL (NMFS statistical zones 4 and 5) which were partitioned into inshore or offshore depth strata (depth ranges of 10 - 36 m and 37 - 110 m, respectively). The survey expanded in 2014 to include NMFS, SEFSC statistical zones 9 and 10 off the Florida Panhandle with additional sites added in 2016 to cover the entirety of the West Florida Shelf from statistical zones 2 - 10 (Fig. 1, Fig. 2). Historic indices developed from this survey had a spatial footprint east of -89° longitude. As a result, the FWRI survey was included in the EGOA and GOA indices.

Beginning in 2020, Gulf-wide video survey efforts were integrated under a single, novel survey design under the 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 natural 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 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. As the G-FISHER survey footprint spans both east and west of -89° longitude, the survey was split into G-FISHER East and G-FISHER West for the EGOA and WGOA indices, respectively. Both surveys were included in the GOA index.

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, often referred to as MaxN or 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). While some categories were not historically recorded by all three labs (Campbell et al. 2017; Gardner et al. 2017; Thompson et al. 2017), the habitat annotation procedures adopted by G-FISHER are more comprehensive and include habitat variables recorded during any of the three prior surveys.

Fish length measurements

The methods employed to gather fish length data from video have also evolved through time. Length measurements from the SRFV and PC surveys were initially estimated using parallel lasers attached to the camera system (Campbell et al. 2017; Gardner et al. 2017). However, the fixed mounted lasers resulted in very few usable laser contacts needed to obtain individual length measurement while also mitigating repeated measurements of the same individual. Therefore, both surveys adopted stereo-video methods (2008 and 2010 for SRFV and PC surveys, respectively). The FWRI survey used stereo-video methods to obtain length measurements from the onset. Length estimates from all three historic surveys were obtained from Vision Measurement System (VMS, Geometrics Inc.) through 2014. From 2015 to present, all length measurements are obtained from the SeaGIS software (SeaGIS Pty. Ltd.). Length measurements are typically taken at the point in the video where the greatest 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 low visibility or deployment errors. Data from the SRFV survey collected in 1992 were excluded from the EGOA, WGOA and GOA index calculations because of differences in counting methods in this first year, and no survey data are available for years 1998-2001 and 2003. Additionally, Panama City survey data from 2005 was excluded because of an incomplete survey. Due to COVID restrictions on field sampling, no data were collected in the WGOA in 2020. As a result, 2020 data were excluded from analysis in the WGOA index. Final sample sizes by region, survey and year can be found in Table 1 and spatial coverage is shown in Figures 1 and 2. Data were separated into EGOA (zones 2-11) and WGOA (zones 13-21) and GOA (zones 2-21) regions following the Stock ID identified in SEDAR 9, 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 stock. Individual measurements subsequently assigned to 2 cm size bins ranging from 10 - 88 cm fork length.

Index Construction

Overview

To develop the three indices for Gray Triggerfish (EGOA, WGOA, and GOA), the historical surveys and the

G-FISHER survey were partitioned at the -89° longitude line. This division resulted in the following data groupings:

1. EGOA Index: This index includes data from the SRFV East, PC, FWRI, and G-FISHER East surveys.

2. WGOA Index: This index includes data from the SRFV West and G-FISHER West surveys.

3. GOA Index: This index includes all of the surveys listed above, representing the entire study area.

Habitat models

To develop indices of abundance from all surveys for each Gray Triggerfish stock (region), 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 the final index models can account for changing sampling effort and habitat allocation through time rather than limiting the model to be predicted by only 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 survey sets, and within each region. For G-FISHER and FWRI, side-scan sonar designated 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. GenHab, a video derived habitat variable that generally describes the type of habitat represented by the observed substrates, attached biota types, and relief was included for PC. 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 (RF) analysis fitted 2000 CARTS to the data and then determined each variable's 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 Figure 3 for the SRFV East survey dataset.

From the RF 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 Gray Triggerfish 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 Gray Triggerfish catches at each terminal node was then evaluated to determine the habitat characteristics defining each survey habitat class. For the surveys, generally terminal nodes were partitioned among three classes, defined as High, Medium, or Low; although some surveys may be missing classes depending on overall proportion positive. Terminal nodes with two times the mean of positive catches for a dataset were assigned a High habitat code. Low sites were identified as those determined by proportion positives that were less than 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. Because this habitat classification procedure was performed independently for each video survey, they are not directly comparable across surveys. All analyses were carried out using R version 4.5.0 (R Core Team 2025) and the partykit package for RF and CART model fitting (Hothorn and Zeileis. 2015).

CART results varied by survey and region with respect to the final variables chosen. In the EGOA, Gray Triggerfish were found to be at 23% of all sampled stations. The highest proportion of occurrence was PC sites at 40%, followed by G-FISHER East at 29%, FWRI at 19% and SRFV East at 15% (Fig. 4 - 7). In the WGOA, Gray Triggerfish were found to be at 11% of all sampled stations, with proportion positives of 8% for SRFV West, and 12% for G-FISHER West (Fig. 8 – 9). Finally, in the GOA, Gray Triggerfish were found to be at an overall proportion positive of 20% (Fig. 10 – 15). In the EGOA, longitude and latitude were shared among the four survey models. In the WGOA, depth was shared among the two survey models. Finally, in the GOA no variables were shared among all of the six survey models, however depth, latitude, and longitude were significant in most. Overall Gray Triggerfish habitat models indicated an association with factors commonly attributed to reef or rugose habitats, including rock, relief, soft coral, sponge, and spatial parameters such as latitude, longitude, and depth (Fig. 4 - 15). 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 survey datasets for each region. The datasets were then combined for each region-specific index model. The final proportion of sites in the three habitat categories for each individual survey set and year are shown in Table 2 – 4, for each region.

Index model fitting and diagnostics

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

$$MaxN = Year \times Survey \times Hab$$

Where Hab is the CART derived habitat class and survey represents the survey that collected the data for each site.

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. The survey area weighting factors used to generate the EGOA, WGOA and GOA Gulf Gray Triggerfish indices are provided in Table 5 - 7 for each region. Note that the area estimates are only used to establish a universal scale from which the relative proportion of reef habitat among surveys can be estimated. They should not be interpreted in an absolute sense. Weighted index values were then standardized to the grand mean.

Compilation of Length Data

As with the habitat-area weighting approach above, annual length compositions were weighted by the habitat class proportion and area weights for each stock. 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 Gray Triggerfish in the EGOA, WGOA, and GOA regions are presented in Table 8 – 10, along with their coefficients of variation (CV). The model's CVs indicate a good to very good fit across all three regions. While CV values were higher in earlier years, they steadily decreased as additional surveys were incorporated. For the final years, CVs are in the range of 7–10% for the EGOA and GOA, and approximately 22% for the WGOA.

The EGOA index, as depicted in Figure 16, experienced an initial decline in from the SRFV survey, a trend that continued until 2005. Following this low point, abundance generally increased until 2009, then experienced a sharp decrease in the following years. From 2014 to the final year of 2023, abundance shows a general recovery with an upward trend, though with some year-to-year variability (Table 8, Fig. 16). The WGOA index indicates variable abundance from 1993 to 1997, followed by a sharp increase in 1997. After this peak, abundance generally declined from 1997 to 2023, with current levels being low (Table 9, Fig. 17). The GOA index shows lower abundance from 1993 – 1996, with an increase in 1997. Abundance then declined from 1997 – 2005, followed by a general increase from 2005 to 2009. Another decrease occurred from 2009 to 2013, before abundance began an increasing trend from 2013 to the terminal year of 2023 (Table 10, Fig. 18).

The combined length frequencies across years were similar among surveys for all three regions (EGOA, WGOA, and GOA), which suggests similar selectivity and catchability across the surveys (Fig. 19). Fork lengths ranged from 10 – 88 cm in the EGOA and GOA, and 16 – 68 cm in the WGOA. The fewer fish measured in the WGOA likely accounts for the smaller range in length for that region (Table 11).

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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 the EGOA (zones 2-11) and WGOA (zones 13-21) and GOA (zones 2-21) regions. No data were available or used from any survey from 1998 - 2001; 2003. No data were available from G-FISHER in WGOA in 2020 due to field sampling restrictions.

	EGOA Region					**WGOA Region**			**GOA Region**				
Year	SFRV	PC	FWRI	G-FISHER	Total	SFRV	G-FISHER	Total	SFRV	PC	FWRI	G-FISHER	Total
1993	115				115	45		45	160				160
1994	97				97	45		45	142				142
1995	52				52	37		37	89				89
1996	133				133	165		165	298				298
1997	162				162	127		127	289				289
2002	168				168	93		93	261				261
2004	149				149	49		49	198				198
2005	275				275	136		136	411				411
2006	280	87			367	136		136	416	87			503
2007	332	44			376	158		158	490	44			534
2008	212	83			295	125		125	337	83			420
2009	264	104			368	165		165	429	104			533
2010	229	138	49		416	98		98	327	138	49		514
2011	337	150	211		698	103		103	440	150	211		801
2012	281	148	214		643	200		200	481	148	214		843
2013	163	86	183		432	133		133	296	86	183		565
2014	230	169	338		737	113		113	343	169	338		850
2015	155	155	378		688	54		54	209	155	378		742
2016	205	156	719		1080	167		167	372	156	719		1247
2017	222	147	622		991	193		193	415	147	622		1184
2018	221	76	694		991	186		186	407	76	694		1177
2019	286	94	899		1279	262		262	548	94	899		1541
2020				764	764		0	0				764	764
2021				1000	1000		285	285				1285	1285
2022				936	936		309	309				1245	1245
2023				938	938		281	281				1219	1219

Table 2. Proportion of sites for each habitat level (High, Medium, Low) as determined by individual survey classification and regression trees (CARTs) for Gray Triggerfish in the EGOA region. Surveys conducted in the East region (> -89° longitude) are denoted with a "_E". Note the gap in sampling for the SFRV_E survey (1998-2001 and 2003).

EGOA	SRFV_E			PC_E			FWRI_E			G-FISHER_E		
Year	High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
1993	26	60	29									
1994	21	36	40									
1995	9	22	21									
1996	27	59	47									
1997	42	63	57									
2002	32	76	60									
2004	24	71	54									
2005	24	97	154									
2006	32	104	144	0	50	37						
2007	10	127	195	0	30	14						
2008	19	65	128	0	61	22						
2009	29	89	146	0	73	31						
2010	10	98	121	0	84	54	0	42	7			
2011	27	142	168	0	80	70	0	188	23			
2012	32	74	175	0	79	69	0	178	36			
2013	18	66	79	0	72	14	0	151	32			
2014	19	83	128	0	107	62	46	267	25			
2015	22	47	86	0	90	65	63	284	31			
2016	16	73	116	0	95	61	61	532	126			
2017	11	76	135	0	79	68	57	416	149			
2018	12	66	143	0	19	57	68	430	196			
2019	23	78	185	0	57	37	117	579	203			
2020										58	582	124
2021										124	732	144
2022										152	668	116
2023										168	621	149

Table 3. Proportion of sites for each habitat level (High, Medium, Low) as determined by individual survey classification and regression trees (CARTs) for Gray Triggerfish in the WGOA region. Surveys conducted in the West region (< -89° longitude) are denoted with a "_W". Note the gap in sampling for the SFRV_W survey (1998-2001, 2003), and G-FISHER_W (2020).

WGOA	G-FISHER_W			SRFV_W		
Year	High	Medium	Low	High	Medium	Low
1993				0	43	2
1994				2	41	2
1995				0	33	4
1996				0	154	11
1997				14	79	34
2002				1	43	49
2004				10	17	22
2005				18	65	53
2006				7	72	57
2007				10	70	78
2008				16	63	46
2009				17	77	71
2010				14	59	25
2011				18	41	44
2012				24	106	70
2013				28	62	43
2014				19	55	39
2015				0	23	31
2016				23	71	73
2017				35	80	78
2018				52	85	49
2019				22	112	128
2021	73	0	212			
2022	78	0	231			
2023	75	0	206			

Table 4. Proportion of sites for each habitat level (High, Medium, Low) as determined by individual survey classification and regression trees (CARTs) for Gray Triggerfish in the GOA region. Note the gap in sampling for the SFRV_E and SFRV_W survey (1998-2001 and 2003), and G-FISHER_W (2020). Surveys conducted in the East region (> -89° longitude) are denoted with a "_E", surveys conducted in the West region (< -89° longitude) are denoted with a "_W".

GOA	SRFV_E			SRFV_W			PC_E			FWRI_E			G-FISHER_E			G-FISHER_W		
Year	High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
1993	27	50	38	0	43	2												
1994	21	33	43	2	41	2												
1995	9	18	25	0	33	4												
1996	31	49	53	0	154	11												
1997	45	54	63	14	79	34												
2002	39	56	73	1	43	49												
2004	24	65	60	10	17	22												
2005	25	86	164	18	65	53												
2006	33	83	164	7	72	57	0	58	29									
2007	10	107	215	10	70	78	0	37	7									
2008	19	47	146	16	63	46	0	64	19									
2009	29	78	157	17	77	71	0	79	25									
2010	10	86	133	14	59	25	0	112	26	0	42	7						
2011	27	125	185	18	41	44	0	109	41	0	185	26						
2012	32	63	186	24	106	70	0	114	34	0	178	36						
2013	18	54	91	28	62	43	0	74	12	0	151	32						
2014	20	70	140	19	55	39	0	138	31	51	253	34						
2015	23	36	96		23	31	0	129	26	90	238	50						
2016	16	55	134	23	71	73	0	132	24	171	394	154						
2017	12	52	158	35	80	78	0	100	47	161	289	172						
2018	15	42	164	52	85	49	0	36	40	168	287	239						
2019	24	59	203	22	112	128	0	76	18	257	376	266						
2020													58	601	105			
2021													122	748	130	73	0	212
2022													147	684	105	78	0	231
2023													164	638	136	75	0	206

Table 5. The habitat weighting used with the annual distribution of High, Medium, Low for Gray Triggerfish habitats to adjust estimated model means to account for sampling variation across surveys for the EGOA region.

EGOA	Survey					
	SRFV East (1993-2019)	PC (2006-2019)	FWRI (2010-2013)	FWRI (2014-2015)	FWRI (2016-2019)	G-FISHER East (2020-2023)
Total Universe Area (km^2)	37278	22105	46286	58970	144403	159028
Area x Proportion of mapped with reef	6428	5124	9820	11160	29000	30374
Time Period Weighting Values						
1993-2005	1.00	--	--	--	--	--
2006-2009	0.56	0.44	--	--	--	--
2010-2013	0.30	0.24	0.46	--	--	--
2014-2015	0.28	0.23	--	0.49	--	--
2016-2019	0.16	0.13	--	--	0.71	--
2020-2023	--	--	--	--	--	1.00

Table 6. The habitat weighting used with the annual distribution of High, Medium, Low for Gray Triggerfish habitats to adjust estimated model means to account for sampling variation across surveys for the WGOA region.

WGOA	Survey	
	SRFV West (1993-2019)	G-FISHER West (2021-2023)
Total Universe Area (km^2)	31258	31258
Area x Proportion of mapped with reef	11565	11565
Time Period Weighting Values		
1993-2005	1.0	--
2006-2009	1.0	--
2010-2013	1.0	--
2014-2015	1.0	--
2016-2019	1.0	--
2020	--	--
2021-2023	--	1.0

Table 7. The habitat weighting used with the annual distribution of High, Medium, Low for Gray Triggerfish habitats to adjust estimated model means to account for sampling variation across surveys for the GOA region.

GOA	Survey							
	SRFV East (1993-2019)	SRFV West (1993-2019)	PC (2006-2019)	FWRI (2010-2013)	FWRI (2014-2015)	FWRI (2016-2019)	G-FISHER East (2021-2023)	G-FISHER West (2021-2023)
Total Universe Area (km^2)	37278	31258	22105	46286	58970	144403	159028	31258
Area x Proportion of mapped with reef	6428	11565	5124	9820	11160	29000	30374.38	11565
Time Period Weighting Values								
1993-2005	0.36	0.64	--	--	--	--	--	--
2006-2009	0.28	0.50	0.22	--	--	--	--	--
2010-2013	0.20	0.35	0.16	0.30	--	--	--	--
2014-2015	0.19	0.34	0.15	--	0.33	--	--	--
2016-2019	0.12	0.22	0.10	--	--	0.56	--	--
2020-2023	--	--	--	--	--	--	0.72	0.28

Table 8. Number of stations sampled (N Sites) and number of Gray Triggerfish (N Fish) by survey and year, proportion of positive sets (PPOS), standardized index (Std. Index), nominal index (Std. Nominal), upper and lower 95% confidence level (LCL, UCL, respectively), and CV for the annual Gray Triggerfish combined video index of the EGOA region.

Year	N Sites	PPOS	N Fish	Std. Index	Std. Nominal	LCL	UCL	CV
1993	115	0.304	66	0.768664862	1.223418434	0.63679624	0.90053348	0.198
1994	97	0.320	61	0.923363571	1.340562374	0.73566309	1.11106406	0.234
1995	52	0.250	30	0.961284985	1.229834965	0.69301898	1.22955099	0.322
1996	133	0.293	54	0.651514807	0.865507915	0.53826362	0.76476599	0.200
1997	162	0.315	79	0.831542826	1.039539513	0.70459253	0.95849312	0.176
2002	168	0.190	61	0.538688535	0.77401518	0.44600202	0.63137505	0.198
2004	149	0.188	40	0.432993003	0.572272198	0.34848236	0.51750365	0.225
2005	275	0.156	62	0.551895746	0.480604597	0.46524325	0.63854824	0.181
2006	367	0.256	179	1.555498504	1.039718787	1.33393884	1.77705817	0.164
2007	376	0.154	97	1.386452885	0.549936841	1.13192508	1.64098069	0.212
2008	295	0.214	120	1.105630695	0.867137873	0.94675264	1.26450875	0.166
2009	368	0.307	282	2.132814209	1.633541659	1.87497733	2.39065109	0.139
2010	416	0.161	166	0.681176002	0.85063585	0.59645101	0.765901	0.143
2011	698	0.181	206	0.665739896	0.629130475	0.59654288	0.73493691	0.120
2012	643	0.129	126	0.471502508	0.417723105	0.41813341	0.52487161	0.131
2013	432	0.144	101	0.461266056	0.498386824	0.4071391	0.51539302	0.135
2014	737	0.164	228	0.661945976	0.659471883	0.60097707	0.72291488	0.106
2015	688	0.238	364	1.136682145	1.127825398	1.04182014	1.23154415	0.096
2016	1080	0.269	685	1.433037899	1.352059304	1.34653389	1.51954191	0.070
2017	991	0.234	438	1.089281235	0.942170237	1.01283024	1.16573223	0.081
2018	991	0.168	497	1.196007782	1.06908358	1.08391189	1.30810368	0.108
2019	1279	0.197	535	1.052933355	0.89168644	0.97758061	1.1282861	0.083
2020	764	0.188	403	1.296986329	1.124451201	1.17269183	1.42128083	0.111
2021	1000	0.266	648	1.255585531	1.381350632	1.16775559	1.34341547	0.081
2022	936	0.333	770	1.410275482	1.753653561	1.32357915	1.49697182	0.071
2023	938	0.339	742	1.347235174	1.686281175	1.26815272	1.42631763	0.068

Table 9. Number of stations sampled (N Sites) and number of Gray Triggerfish (N Fish) by survey and year, proportion of positive sets (PPOS), standardized index (Std. Index), nominal index (Std. Nominal), upper and lower 95% confidence level (LCL, UCL, respectively), and CV for the annual Gray Triggerfish combined video index of the WGOA region.

Year	N Sites	PPOS	N Fish	Std. Index	Std. Nominal	LCL	UCL	CV
1993	45	0.067	3	0.25910652	0.14958586	0.105	0.194	0.625
1994	45	0.178	11	0.95005722	1.45993198	0.896	2.024	0.812
1995	37	0.054	3	0.31512955	0.1949149	0.136	0.254	0.638
1996	165	0.085	24	0.56532331	0.33413983	0.296	0.372	0.240
1997	127	0.228	102	3.12151943	3.19257537	2.781	3.604	0.271
2002	93	0.097	19	0.79403609	1.76459581	0.959	2.57	0.960
2004	49	0.163	24	1.9036397	1.2476545	0.954	1.541	0.495
2005	136	0.103	38	1.08596113	1.06583993	0.896	1.236	0.335
2006	136	0.044	16	0.45724679	0.91153643	0.667	1.156	0.563
2007	158	0.082	24	0.59036927	0.98896717	0.799	1.179	0.405
2008	125	0.168	41	1.27480405	1.28347641	1.081	1.486	0.331
2009	165	0.097	20	0.47110275	0.56864187	0.473	0.664	0.353
2010	98	0.122	36	1.42772978	1.26143716	1.024	1.499	0.396
2011	103	0.175	59	2.22630355	1.77474861	1.499	2.05	0.326
2012	200	0.180	88	1.710103	1.7861391	1.556	2.017	0.271
2013	133	0.150	51	1.4903495	0.99117002	0.86	1.122	0.279
2014	113	0.133	27	0.92865609	0.82612414	0.712	0.94	0.291
2015	54	0.056	4	0.28789613	0.3277555	0.236	0.419	0.586
2016	167	0.102	32	0.74473729	0.7324146	0.625	0.839	0.307
2017	193	0.140	72	1.44992247	1.17040359	1.043	1.298	0.229
2018	186	0.134	42	0.87761884	0.72663462	0.651	0.802	0.218
2019	262	0.031	12	0.17801211	0.24180617	0.204	0.279	0.328
2021	285	0.074	50	0.68185925	0.72867509	0.652	0.805	0.220
2022	309	0.074	40	0.50311945	0.5448173	0.486	0.604	0.228
2023	281	0.089	51	0.70539674	0.72601405	0.65	0.802	0.220

Table 10. Number of stations sampled (N Sites) and number of Gray Triggerfish (N Fish) by survey and year, proportion of positive sets (PPOS), standardized index (Std. Index), nominal index (Std. Nominal), upper and lower 95% confidence level (LCL, UCL, respectively), and CV for the annual Gray Triggerfish combined video index of the GOA region.

Year	N Sites	PPOS	N Fish	Std. Index	Std. Nominal	LCL	UCL	CV
1993	160	0.238	69	0.41426914	1.03174649	0.35259792	0.47594036	0.190
1994	142	0.275	72	0.93300574	1.2130761	0.57915863	1.28685284	0.485
1995	89	0.169	33	0.46713077	0.88709029	0.35686983	0.57739171	0.302
1996	298	0.178	78	0.37548244	0.62621322	0.32895347	0.4220114	0.158
1997	289	0.277	181	1.57759992	1.49838917	1.3258802	1.82931964	0.204
2002	261	0.157	80	0.90019129	0.73331974	0.41342491	1.38695767	0.691
2004	198	0.182	64	0.65234591	0.77331899	0.47270646	0.83198537	0.352
2005	411	0.139	100	0.62786816	0.58210599	0.52046094	0.73527539	0.219
2006	503	0.199	195	1.20005392	0.92749274	1.0322311	1.36787675	0.179
2007	534	0.133	121	1.04437441	0.54211073	0.88630084	1.20244797	0.194
2008	420	0.200	161	1.08549593	0.91710799	0.95078001	1.22021185	0.159
2009	533	0.242	302	1.48863003	1.35557524	1.32662512	1.65063495	0.139
2010	514	0.154	202	0.74128445	0.94022576	0.64770879	0.8348601	0.161
2011	801	0.180	265	0.84048286	0.79151154	0.7400275	0.94093821	0.153
2012	843	0.141	214	0.68846512	0.60733749	0.6067654	0.77016483	0.152
2013	565	0.145	152	0.56801678	0.64363408	0.50839956	0.62763401	0.134
2014	850	0.160	255	0.66649705	0.71773669	0.61146254	0.72153157	0.106
2015	742	0.225	368	0.85879688	1.18655482	0.79398964	0.92360411	0.096
2016	1247	0.246	717	1.26641618	1.37561403	1.20038042	1.33245193	0.067
2017	1184	0.219	510	1.07275399	1.0305341	1.01063739	1.1348706	0.074
2018	1177	0.162	539	1.04126886	1.09561053	0.97258746	1.10995027	0.084
2019	1541	0.169	547	0.90520755	0.84923636	0.84908318	0.96133191	0.079
2020	764	0.188	403	1.55628887	1.26198903	1.36813829	1.74443944	0.155
2021	1285	0.223	698	1.65395858	1.29955956	1.52208034	1.78583681	0.102
2022	1245	0.269	810	1.74844967	1.5565374	1.62473548	1.87216386	0.090
2023	1219	0.281	793	1.62566553	1.55637188	1.52220458	1.72912647	0.081

Table 11. Total of measurements (N) and sampling sites (Sites) where measurements were obtained by year and survey for the GOA. Surveys conducted in the East region (> -89° longitude) are denoted with a "_E", surveys conducted in the West region (< -89° longitude) are denoted with a "_W".

GOA	SRFV_E		SRFV_W		PC_E		FWRI_E		G-FISHER_E		G-FISHER_W	
Year	**Sites**	**N**	**Sites**	**N**	**Sites**	**N**	**Sites**	**N**	**Sites**	**N**	**Sites**	**N**
1995	1	3	1	1	0	0	0	0	0	0	0	0
1996	18	47	3	10	0	0	0	0	0	0	0	0
1997	8	19	15	54	0	0	0	0	0	0	0	0
2002	19	63	4	10	0	0	0	0	0	0	0	0
2004	24	126	6	86	0	0	0	0	0	0	0	0
2005	23	62	13	157	0	0	0	0	0	0	0	0
2006	23	88	6	68	0	0	0	0	0	0	0	0
2007	14	39	8	30	0	0	0	0	0	0	0	0
2008	17	24	11	17	0	0	0	0	0	0	0	0
2009	28	33	5	6	29	47	0	0	0	0	0	0
2010	1	1	6	11	12	13	1	1	0	0	0	0
2011	35	44	13	21	22	28	5	5	0	0	0	0
2012	17	20	14	15	27	32	12	13	0	0	0	0
2013	13	13	12	23	16	19	13	16	0	0	0	0
2014	1	1	10	16	11	15	38	51	0	0	0	0
2015	12	16	2	2	14	14	66	105	0	0	0	0
2016	19	27	10	14	31	31	163	297	0	0	0	0
2017	10	14	14	18	17	17	136	201	0	0	0	0
2018	1	2	1	9	5	5	98	202	0	0	0	0
2019	0	0	0	0	14	36	147	259	0	0	0	0
2020	0	0	0	0	0	0	0	0	123	241	0	0
2021	0	0	0	0	0	0	0	0	192	277	4	17
2022	0	0	0	0	0	0	0	0	255	425	4	23
2023	0	0	0	0	0	0	0	0	258	397	2	9

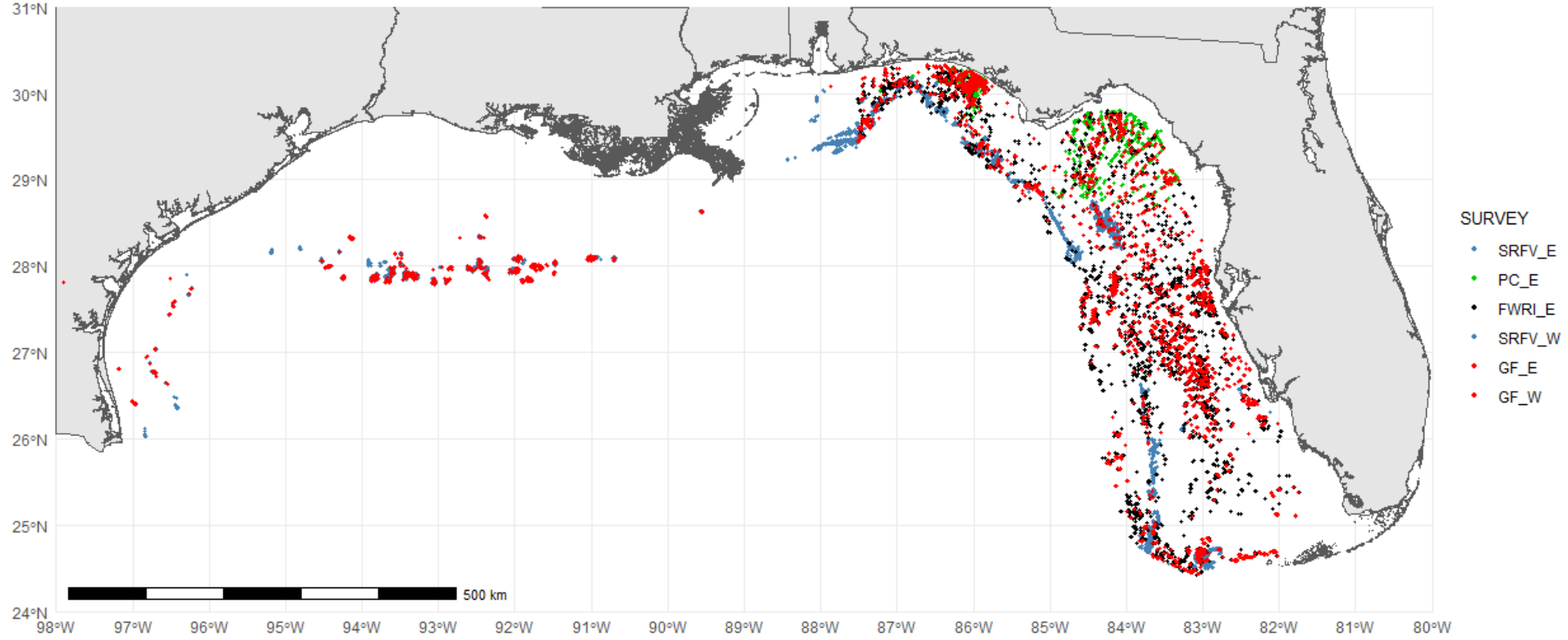

Figure 1. Map of all video sites included in the GOA index for each survey across all years 1993-2023.

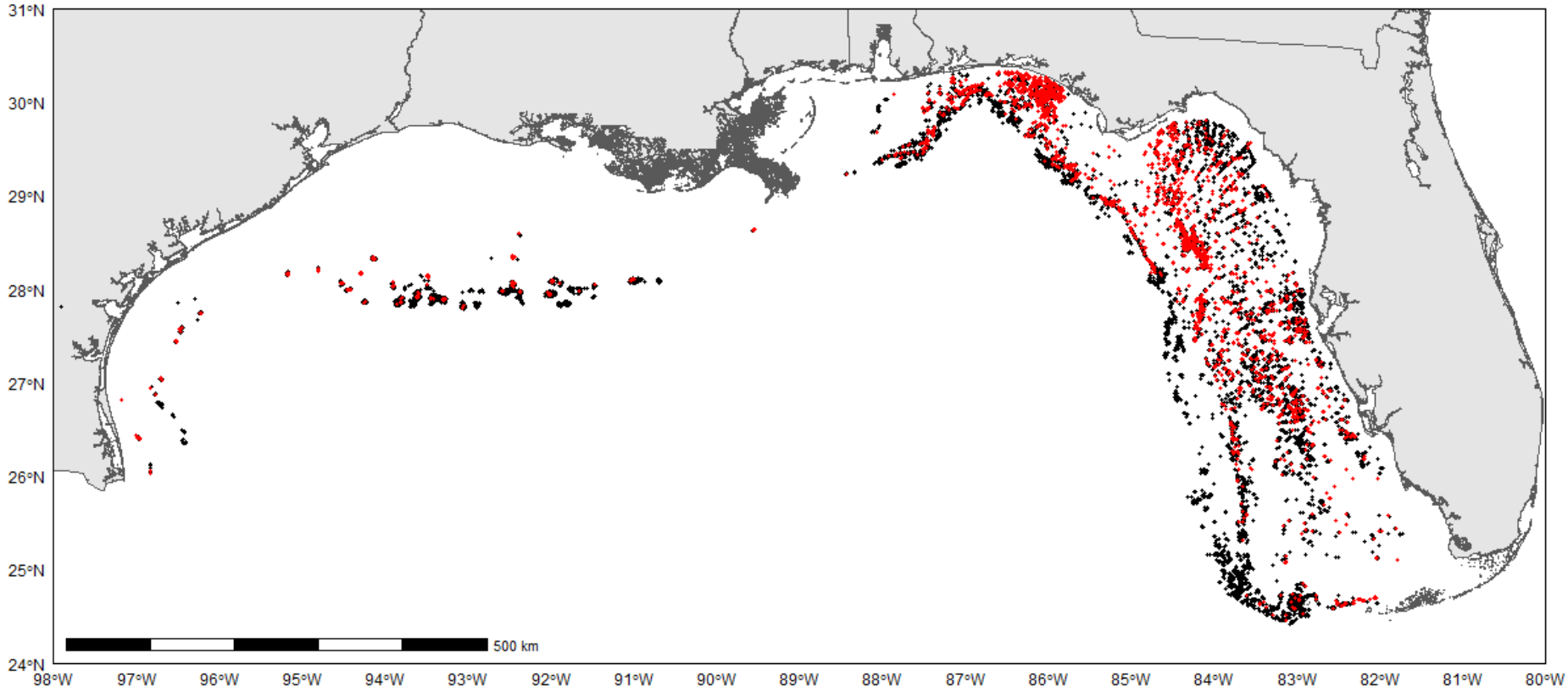

Figure 2. Presence/absence of Gray Triggerfish in the GOA sampled by the G-FISHER video survey on natural reefs from 1993-2023. Red points denote presence, black points denote absence.

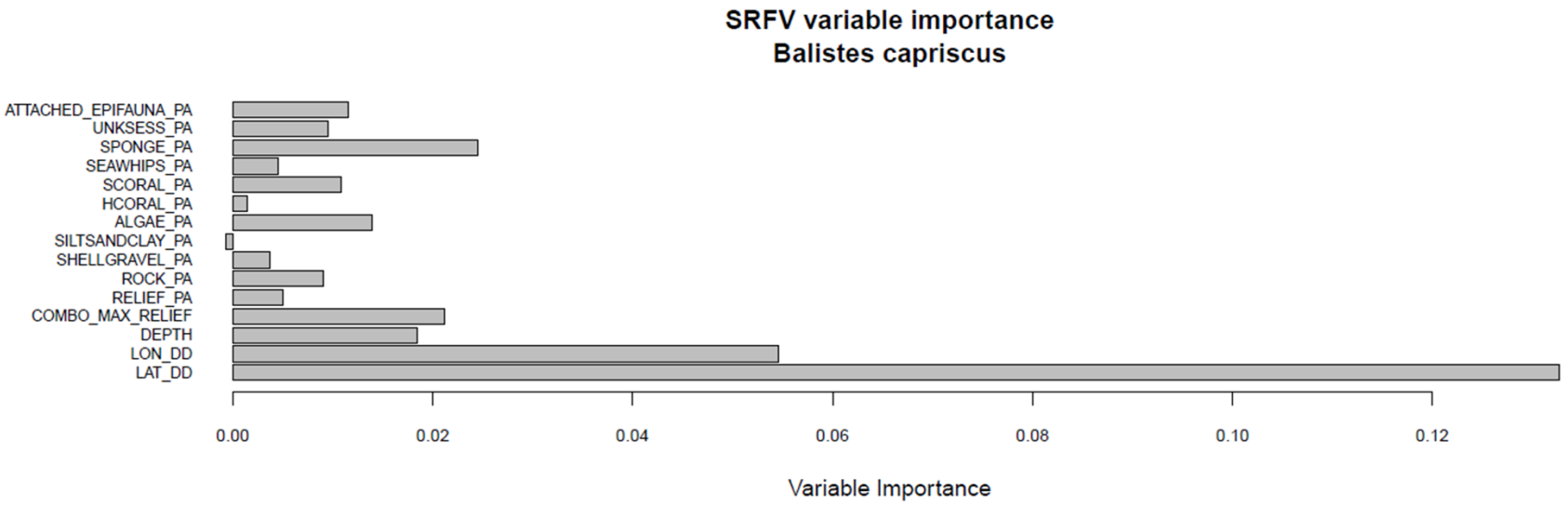

Figure 3. Random Forest generated variable importance for Gray Triggerfish presence using the EGOA SRFV East survey data.

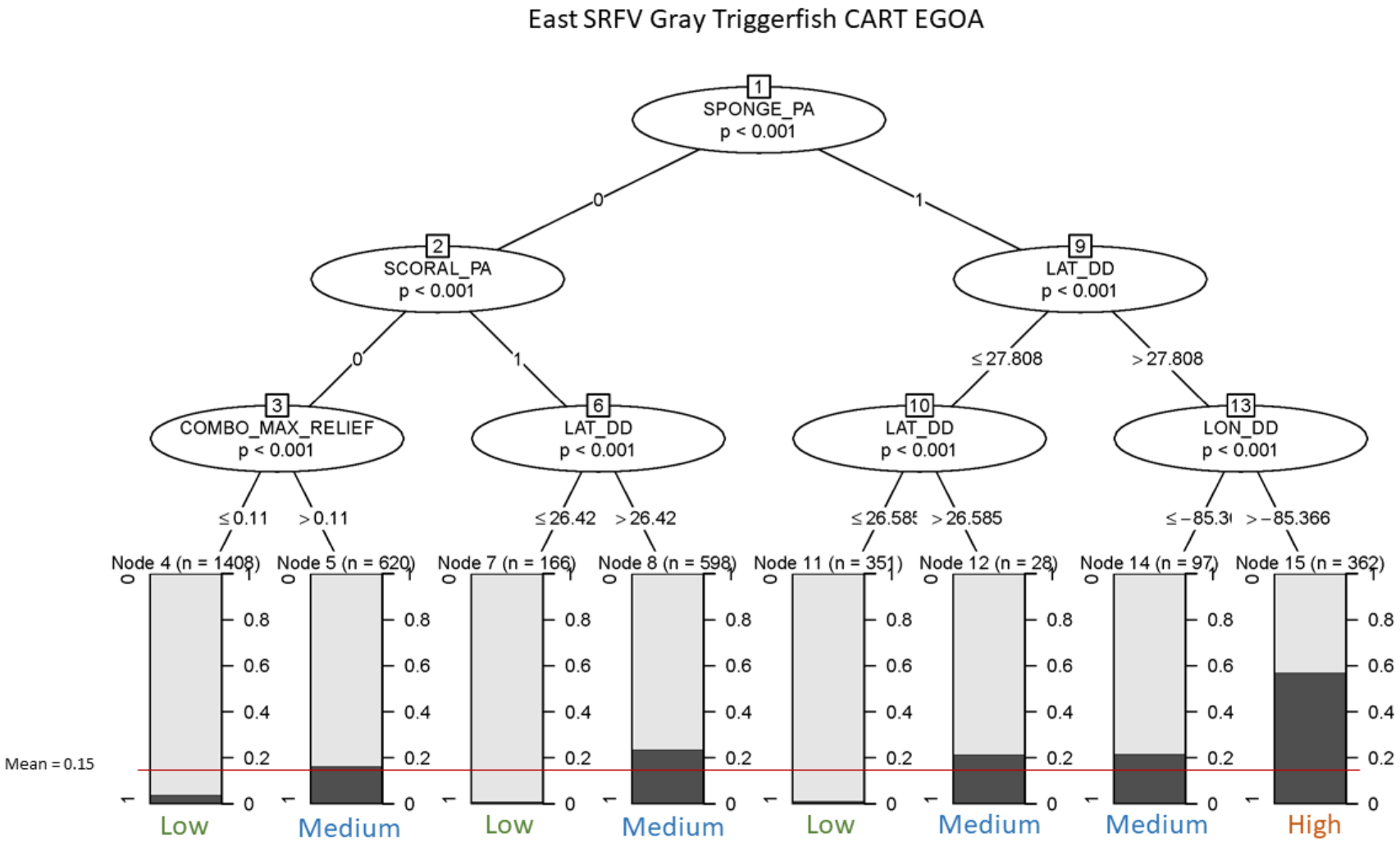

Figure 4. CART results for Gray Triggerfish for the SRFV East survey for the EGOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

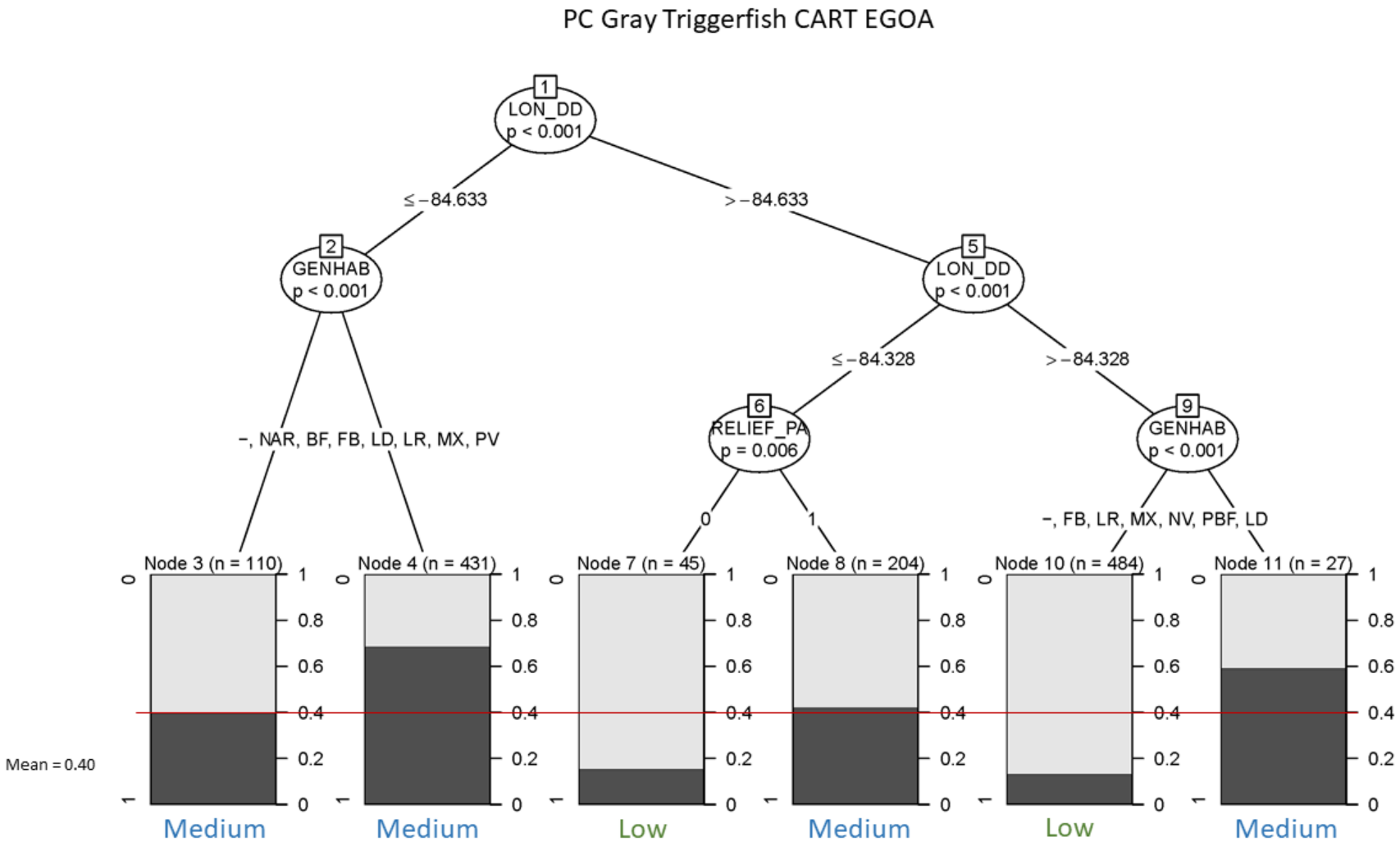

Figure 5. CART results for Gray Triggerfish for the PC survey for the EGOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

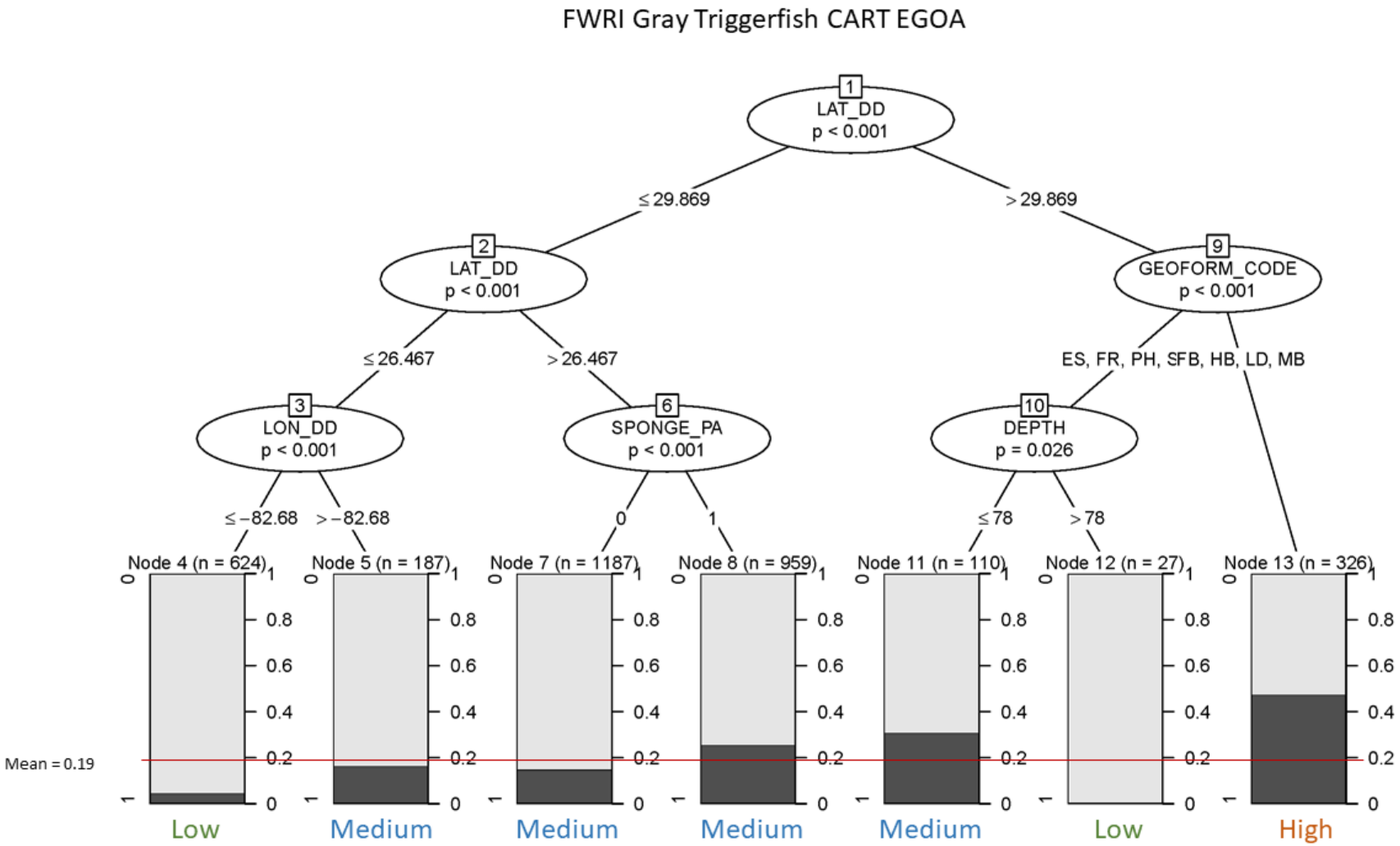

Figure 6. CART results for Gray Triggerfish for the FWRI survey for the EGOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

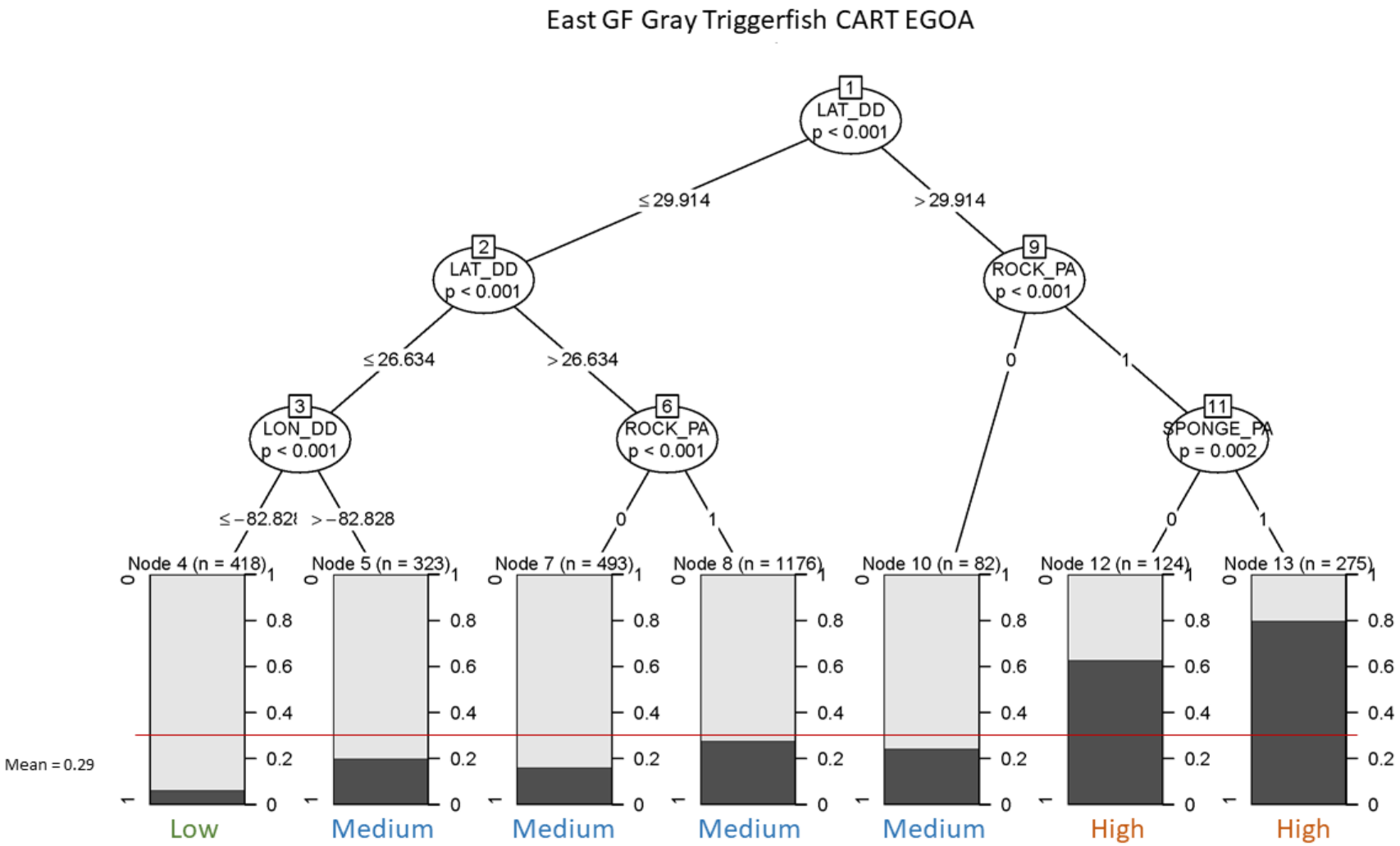

Figure 7. CART results for Gray Triggerfish for the G-FISHER East (East GF) survey for the EGOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

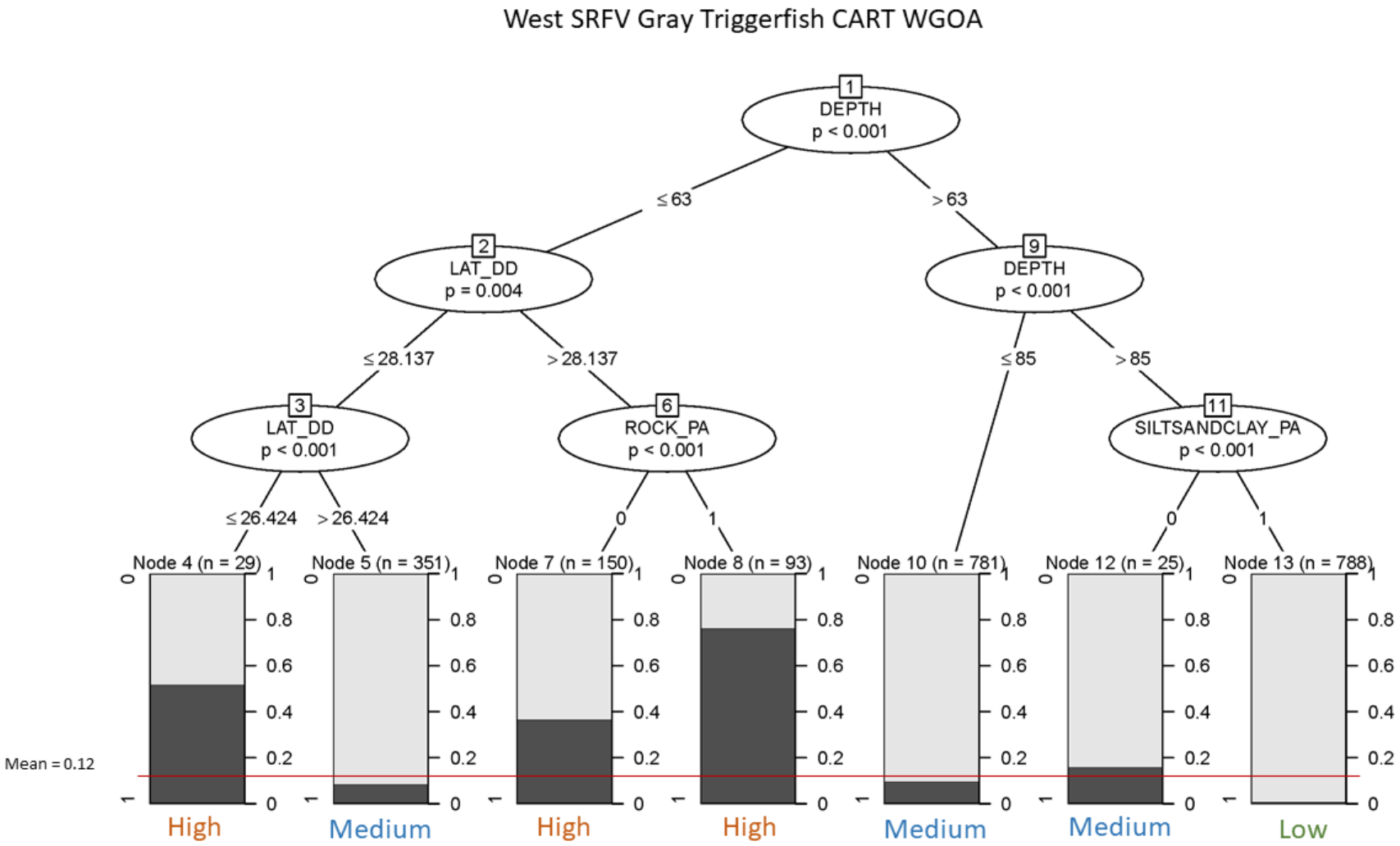

Figure 8. CART results for Gray Triggerfish for the SRFV West survey for the WGOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

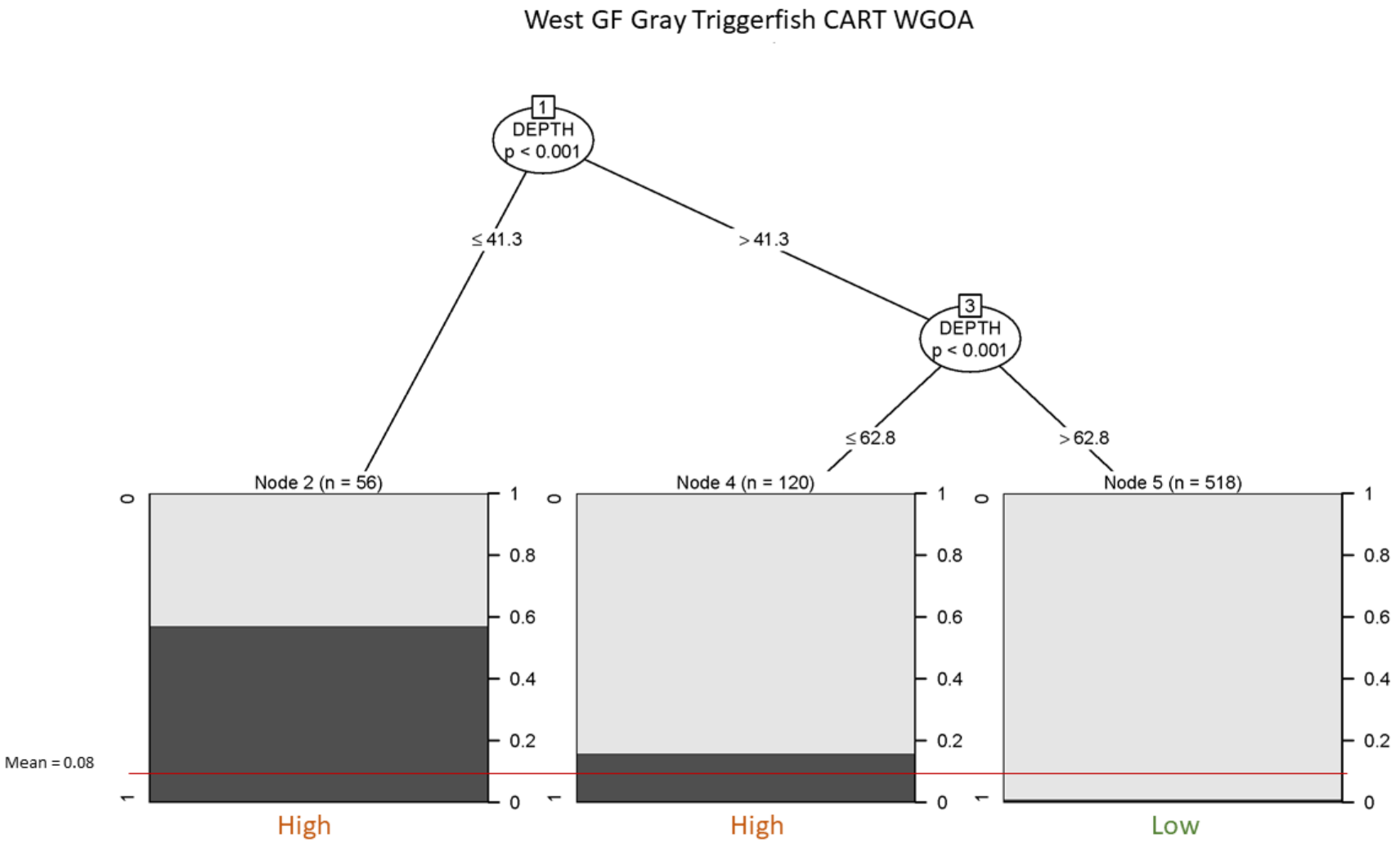

Figure 9. CART results for Gray Triggerfish for the G-FISHER West (West GF) survey for the WGOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

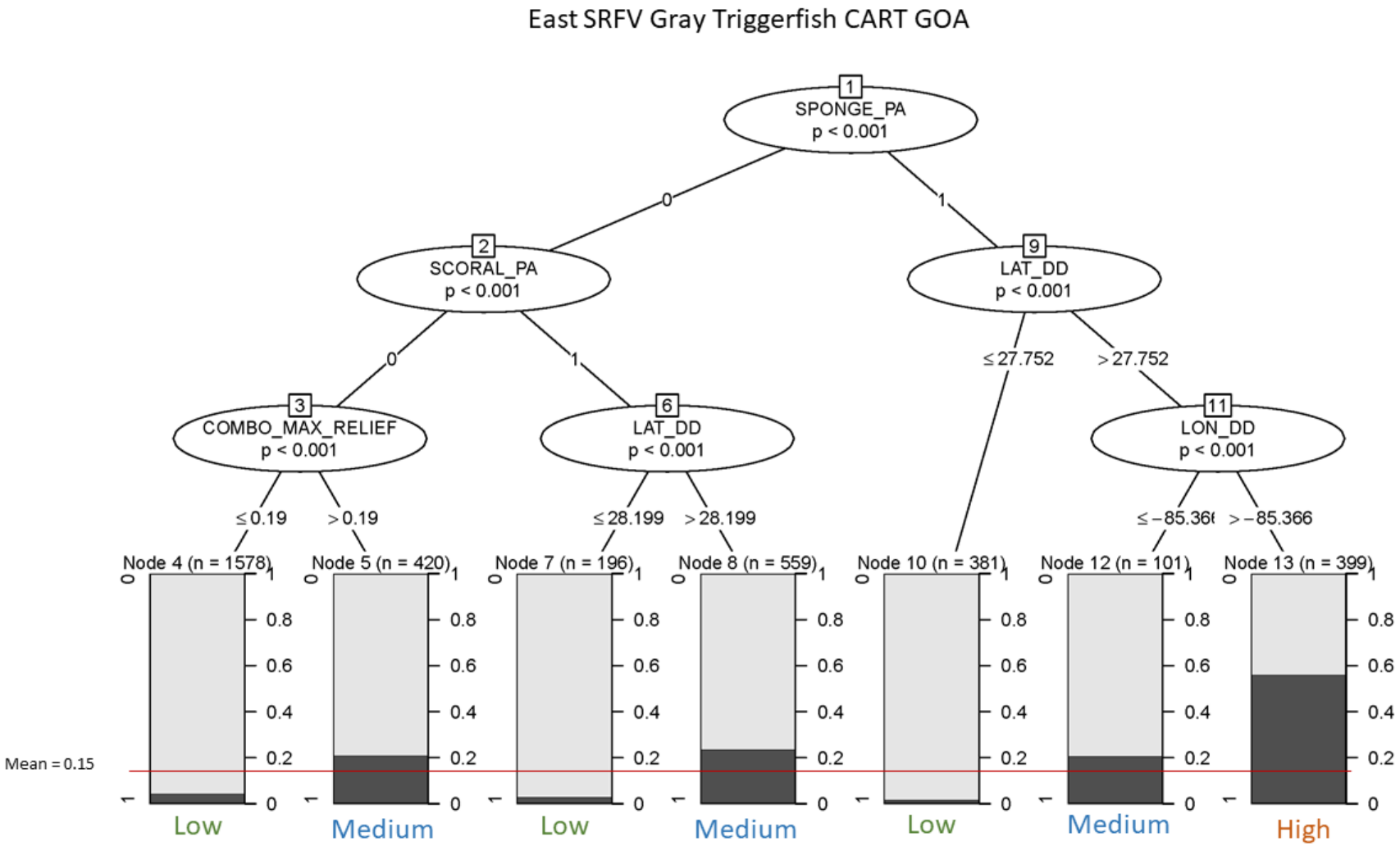

Figure 10. CART results for Gray Triggerfish for the SRFV East survey for the GOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

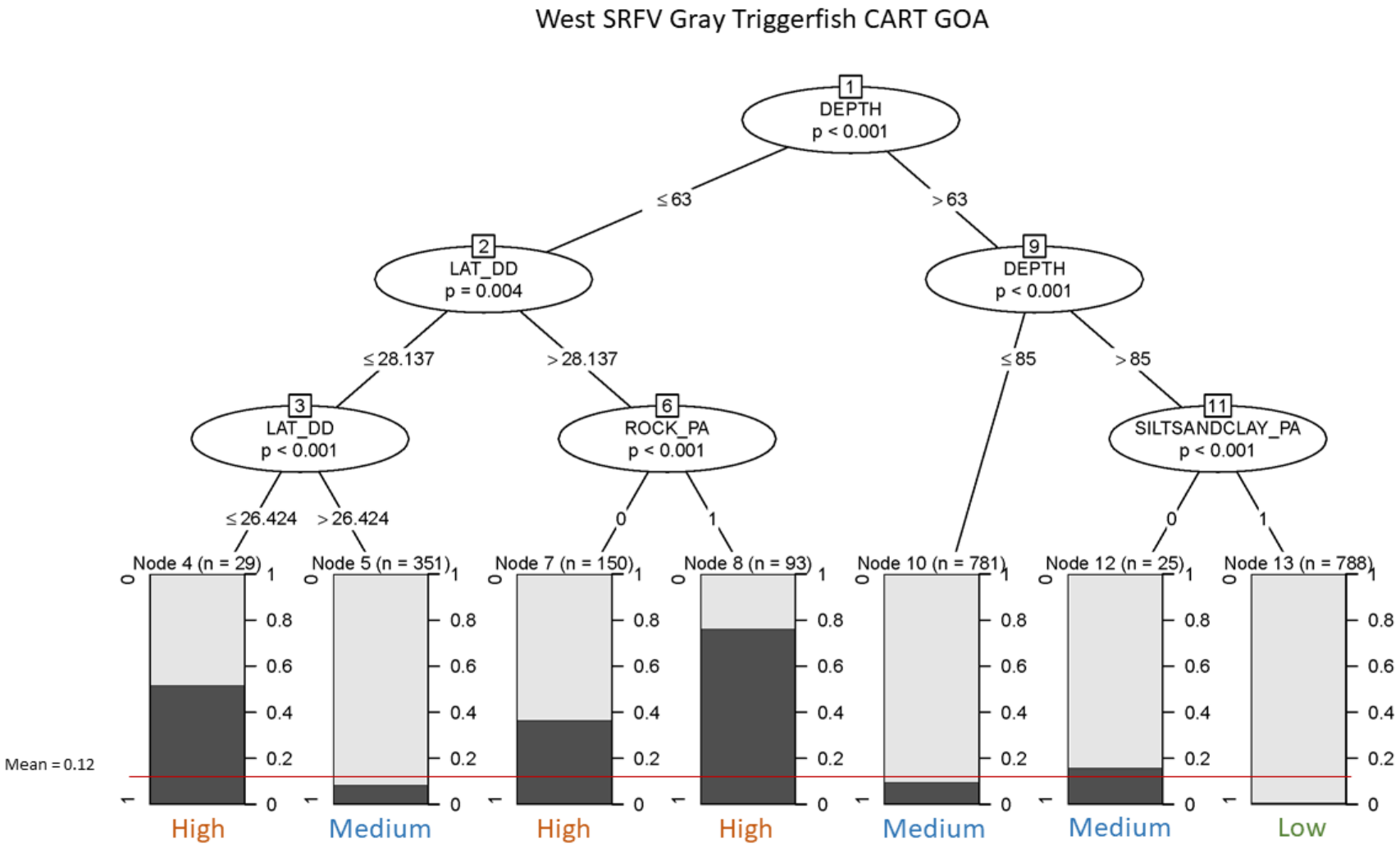

Figure 11. CART results for Gray Triggerfish for the SRFV West survey for the GOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

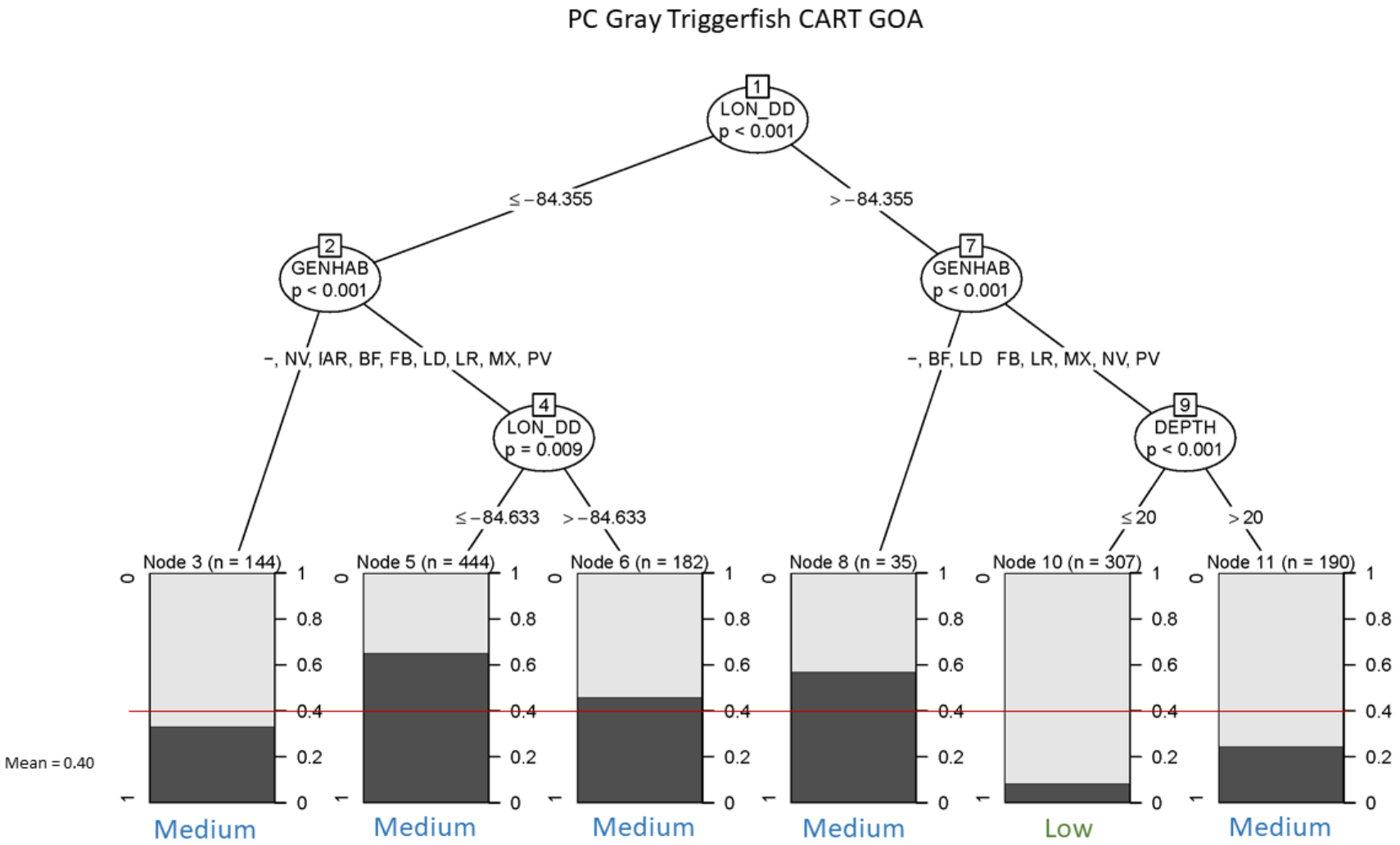

Figure 12. CART results for Gray Triggerfish for the PC survey for the GOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

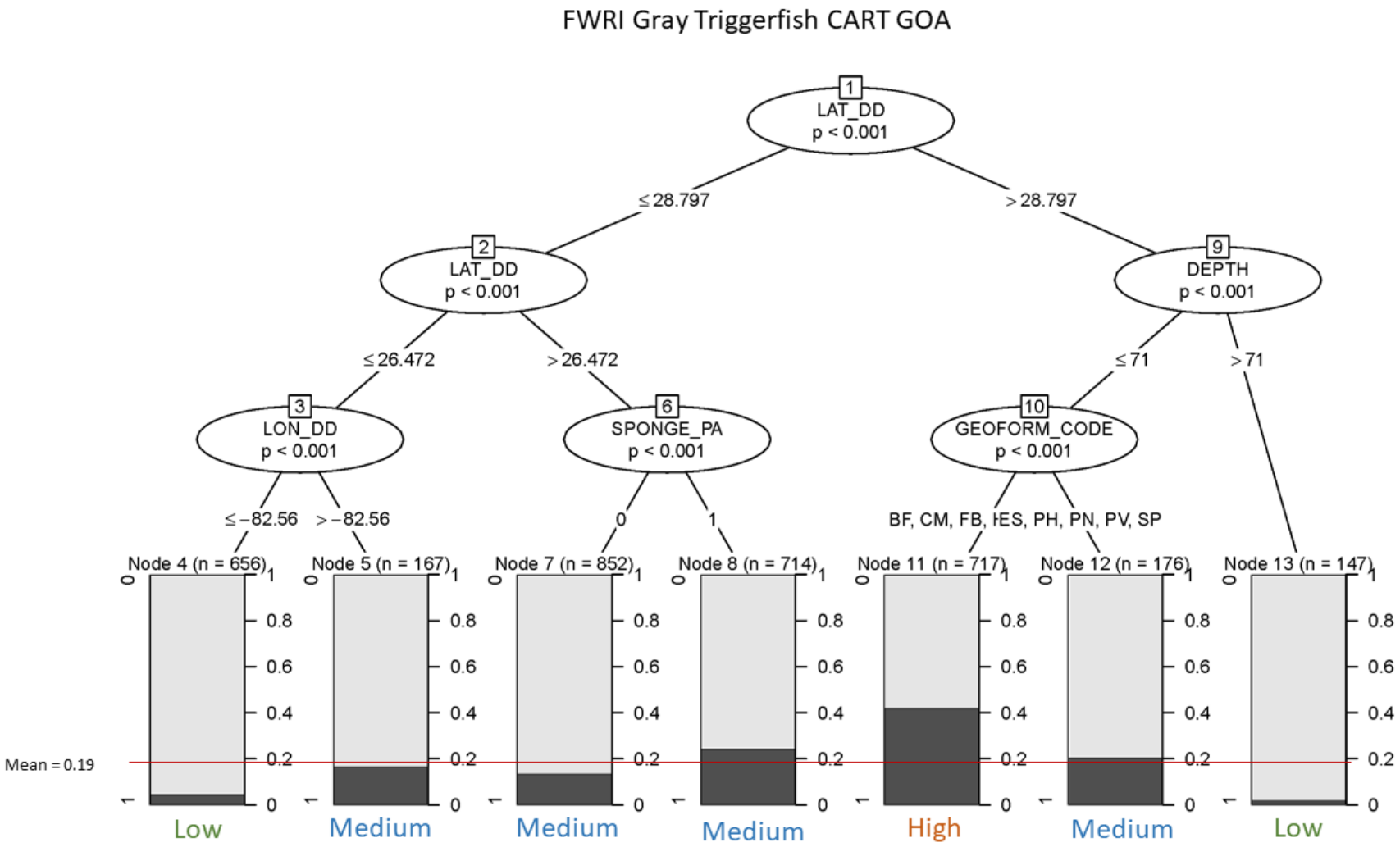

Figure 13. CART results for Gray Triggerfish for the FWRI survey for the GOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

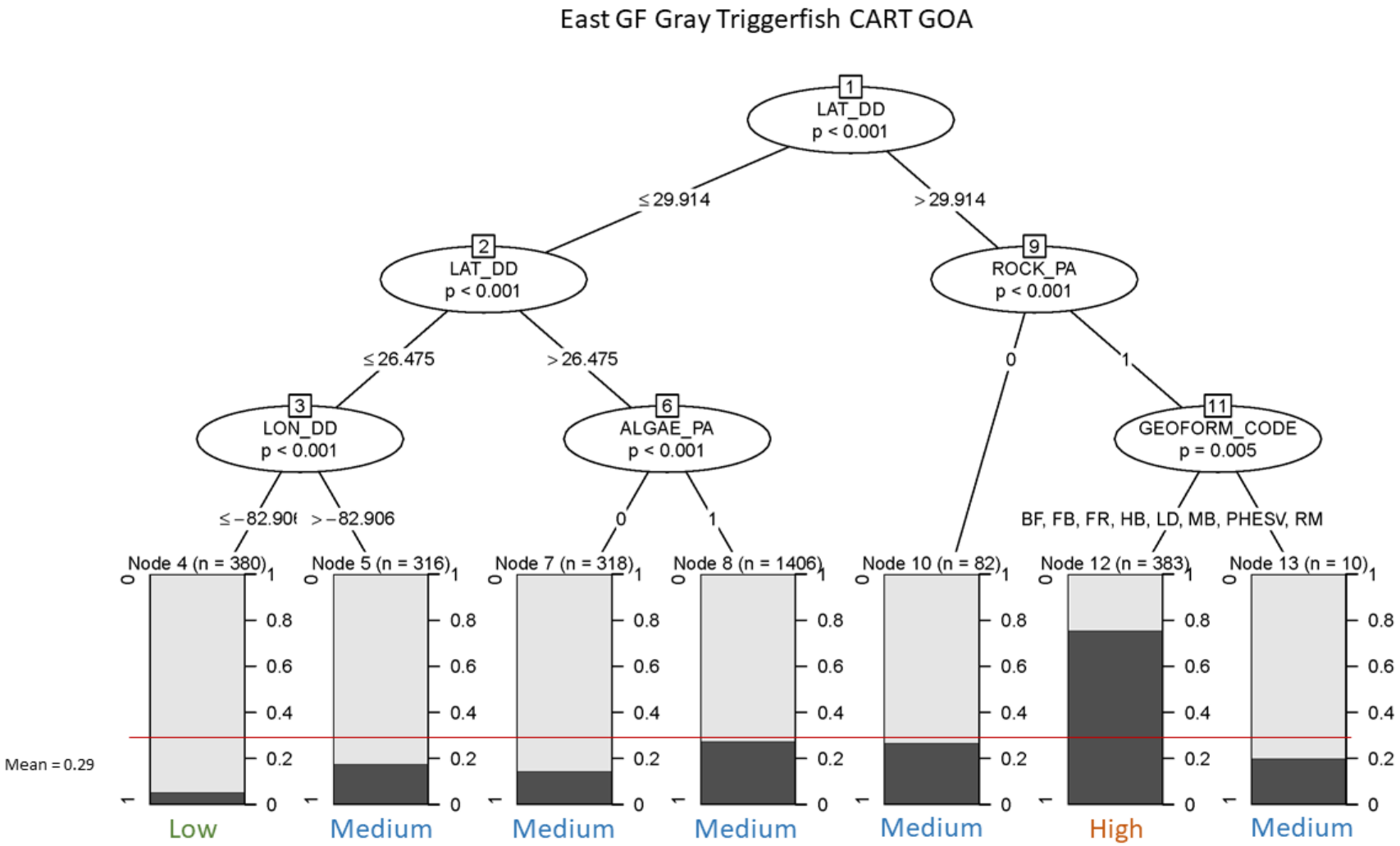

Figure 14. CART results for Gray Triggerfish for the G-FISHER East (East GF) survey for the GOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

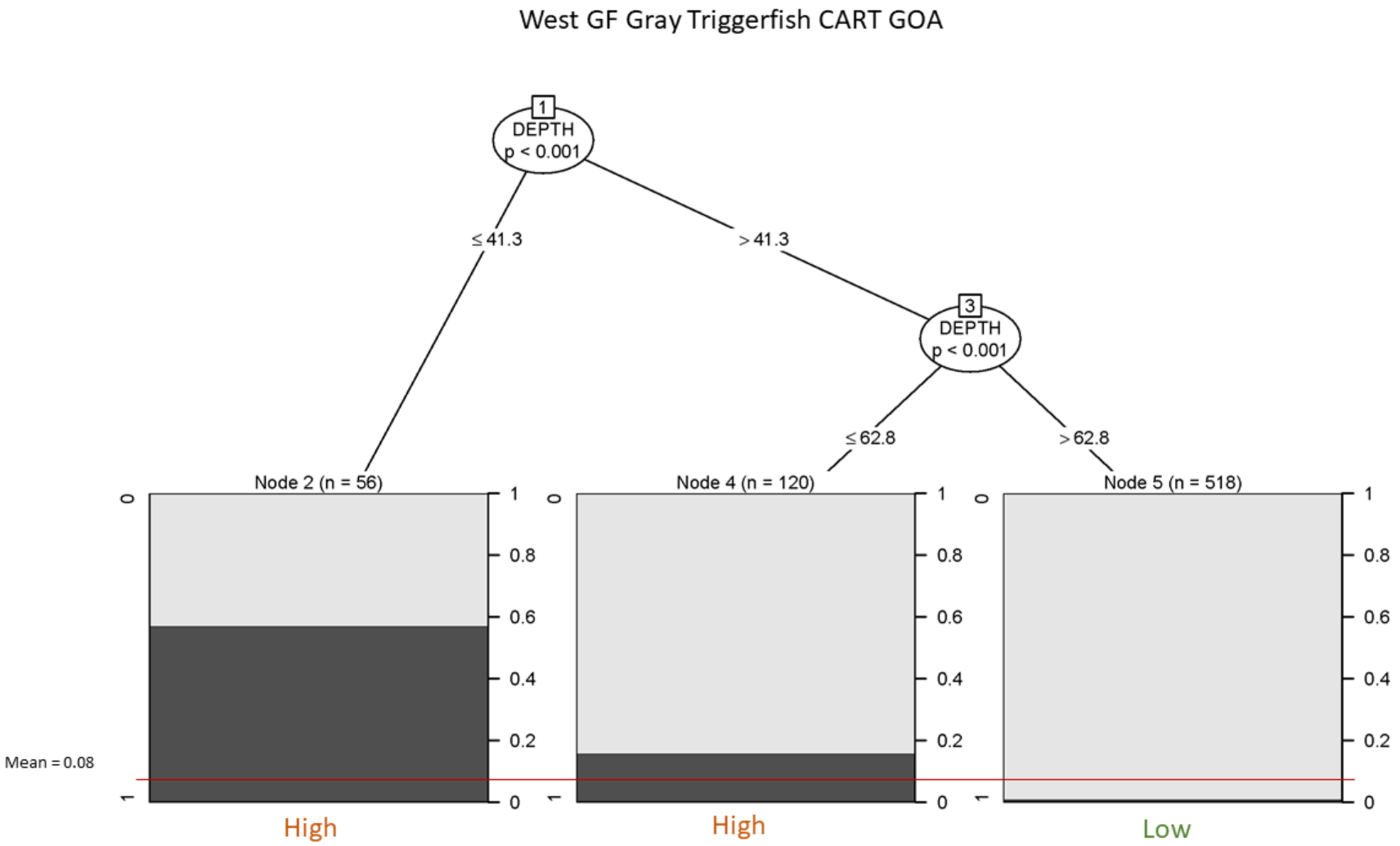

Figure 15. CART results for Gray Triggerfish for the G-FISHER West (West GF) survey for the GOA region. Shaded portion of the plots indicate proportion of sites given by a node where Gray Triggerfish were observed. Overall proportion positive is noted in the bottom left.

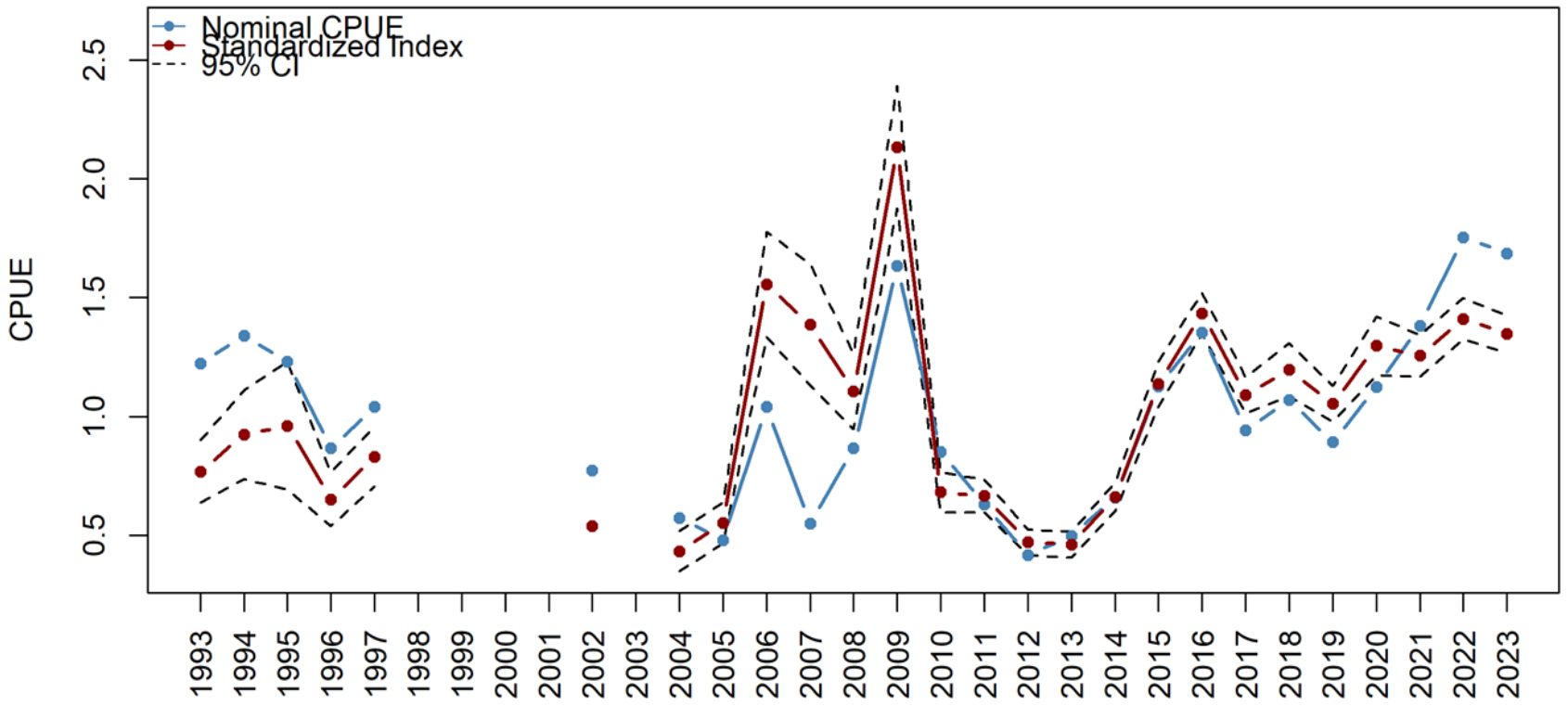

Figure 16. Relative standardized index (red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and relative nominal index (blue line) for Gray Triggerfish CPUE (MaxN) using the integrated G-FISHER combined survey data in EGOA.

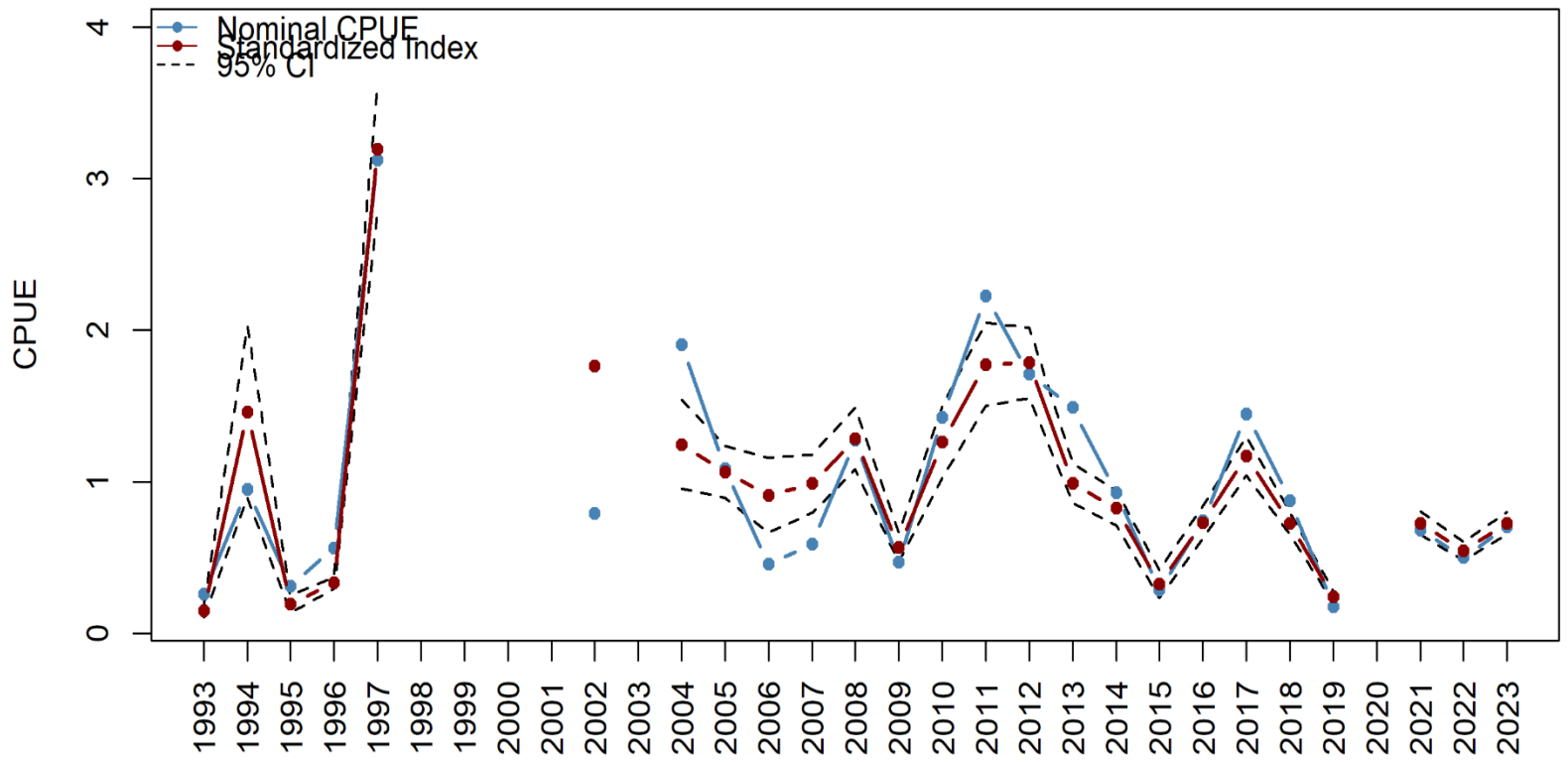

Figure 17. Relative standardized index (red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and relative nominal index (blue line) for Gray Triggerfish CPUE (MaxN) using the integrated G-FISHER combined survey data in WGOA.

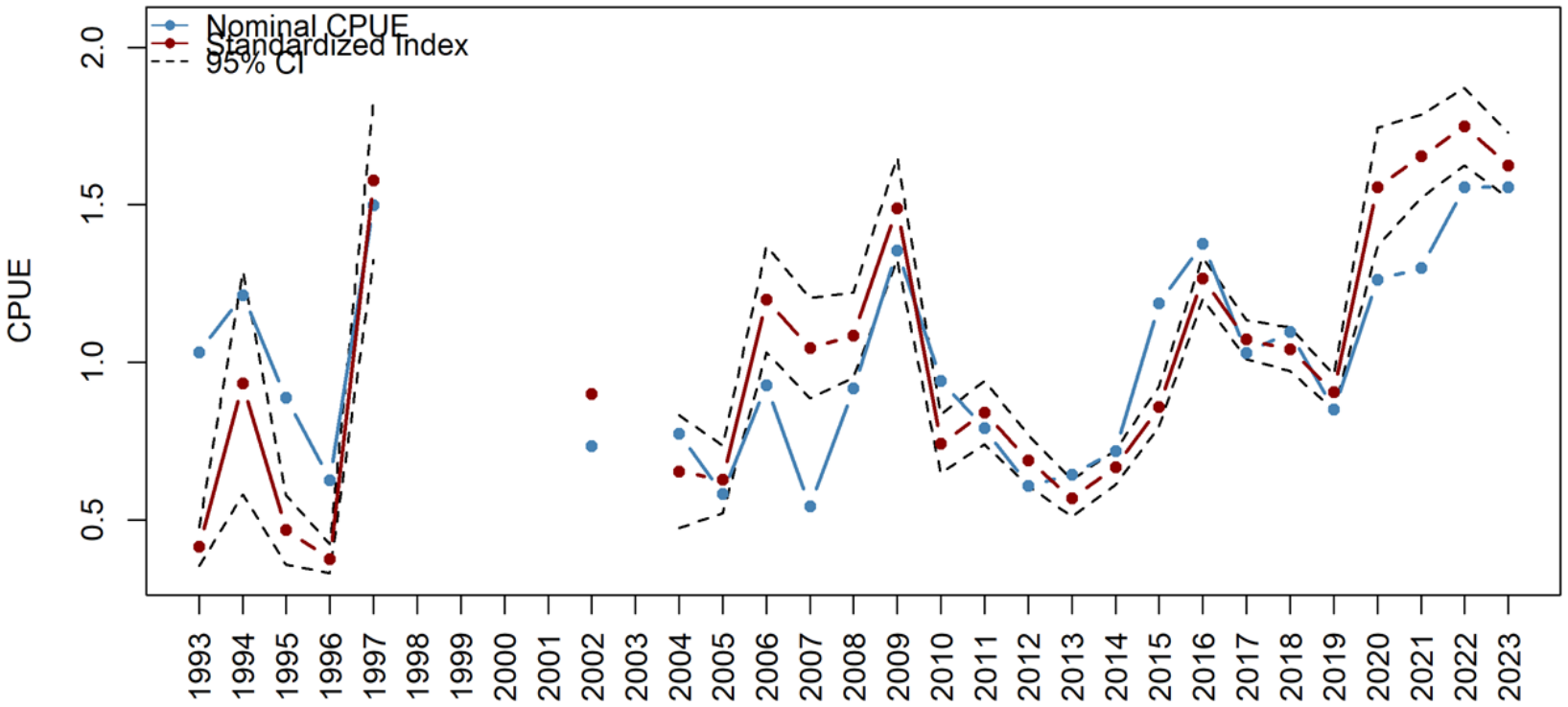

Figure 18. Relative standardized index (red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and relative nominal index (blue line) for Gray Triggerfish CPUE (MaxN) using the integrated G-FISHER combined survey data in GOA.

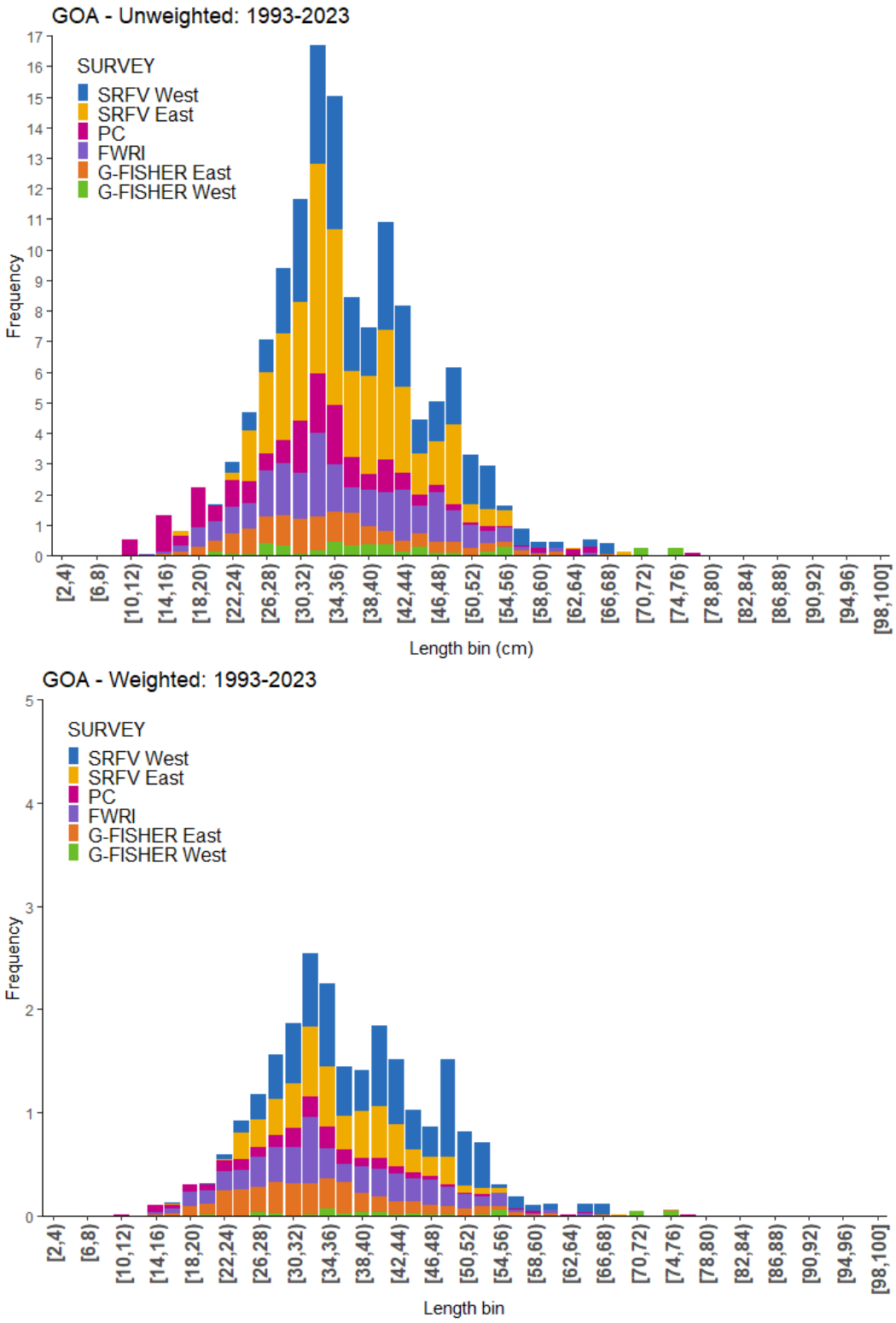

Figure 19. Raw (top panel) and weighted (bottom panel) relative frequency distributions (2 cm length bins) for Gray Triggerfish in the GOA region by survey for all years sampled.