Indices of abundance for Red Snapper (*Lutjanus campechanus*) from the Florida Fish and Wildlife Research Institute (FWRI) video survey on the West Florida Shelf

Kevin A. Thompson, Theodore S. Switzer, Sean F. Keenan, and James P. McDermott

SEDAR52-WP-02

27 July 2017

Please cite this document as:

Thompson, Kevin A., Theodore S. Switzer, Sean F. Keenan, and James P. McDermott. 2017. Indices of abundance for Red Snapper (*Lutjanus campechanus*) from the Florida Fish and Wildlife Research Institute (FWRI) video survey on the West Florida Shelf. SEDAR52-WP-02. SEDAR, North Charleston, SC. 24 pp.

Indices of abundance for Red Snapper (*Lutjanus campechanus*) from the Florida Fish and Wildlife Research Institute (FWRI) video survey on the West Florida Shelf

Kevin A. Thompson, Theodore S. Switzer, Sean F. Keenan, and James P. McDermott
Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 8th Avenue SE, St. Petersburg, FL 33701

Introduction:

Reef fishes, including Red Snapper, are targeted commercially and recreationally along the West Florida Shelf (WFS). Historically, the assessment and management of reef fishes in the Gulf of Mexico has relied heavily on data from fisheries-dependent sources, although limitations and biases inherent to these data are admittedly a major source of uncertainty in current stock assessments. Additionally, commercial, headboat, and recreational landings data are restricted to harvestable-sized fish, and thus are highly influenced by regulatory changes (i.e., size limits, recreational bag limits, and seasonal closures). These limitations render it difficult to forecast potential stock recovery associated with strong year classes entering the fishery. There has been a renewed emphasis in recent years to increase the availability of fisheries-independent data on reef fish populations in the Gulf of Mexico because these data reflect the status of fish populations as a whole, rather than just the portion of the population taken in the fishery. To meet this need for fisheries-independent reef fish data, the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI) has been working collaboratively with scientists from the National Marine Fisheries Service (NMFS) to expand regional monitoring capabilities and provide timely fisheries-independent data for a variety of state- and federally-managed reef fishes. Results for Red Snapper are summarized from fisheries-independent reef fish surveys conducted by FWRI along the West Florida Shelf.

Survey Design and Sampling Methods:

The FWRI reef fish survey includes a portion of the WFS bounded by 26° and 28° N latitude and depths from 10 – 110 m (Fig. 1). The boundaries of the WFS sampling universe were chosen to compliment ongoing NMFS reef-fish surveys. To assure adequate spatial sampling coverage, the WFS survey area was subdivided into four sampling zones comprised of two NMFS statistical zones (Tampa Bay: NMFS statistical zone 5; Charlotte Harbor: NMFS statistical zone 4) and two depth zones (Nearshore: 10 – 37 m; Offshore: 37 – 110 m; Fig. 1). Prior to conducting exploratory sampling in 2008, the WFS survey area was subdivided into 1 km x 1 km sampling units. Results from 2008 indicated that the 1 km x 1 km spatial scale was too large in relation to the small-scale habitat features characteristic of the WFS; accordingly, from 2009 onward the WFS survey area was subdivided into 0.1 nm x 0.3 nm sampling units (E/W by N/S). Overall sampling effort (annual goal of 200 sampling units) was proportionally allocated among the four sampling zones (TBN: Tampa Bay Nearshore; TBO: Tampa Bay Offshore; CHN: Charlotte Harbor Nearshore; CHO: Charlotte Harbor Offshore) based on habitat availability, and specific sampling units were selected randomly within each sampling zone.

Very little is known regarding the fine-scale distribution of reef habitat throughout much of the WFS, and due to anticipated cost and time requirements, mapping the entire WFS survey area was not feasible prior to initiating the WFS reef fish survey. For the 2008 reef fish survey, the identification of sampling units with an increased probability of containing reef habitat (and inclusion in the sampling frame for the reef-fish survey) was based on bottom rugosity calculated from 100-m-resolution interpolated bathymetry data. An examination of results from the 2008 survey indicated that a high proportion of sampling effort occurred at sites with no reef habitat (i.e., unconsolidated sediment). Accordingly, the sampling universe was updated in 2009 to include habitat information provided by commercial fishermen as well as published literature. Further, we implemented an adaptive strategy where a three-pass acoustic survey was conducted covering an area of 1 nm to the east and west of the pre-selected sampling unit prior to sampling. In 2009 and part of 2010, the acoustic survey was conducted using the research vessel echo sounder, whereas for part of 2010 and 2011 onward the acoustic survey was conducted using an L3- Klein 3900 side scan sonar. If these acoustic surveys produced evidence of reef habitat in a nearby sampling unit, but not in the pre-selected sampling unit, sampling effort was randomly relocated to the nearby sampling unit.

Incorporation of side-scan sonar into the site selection process led to a higher rate of sites set on reef habitat from 2010 onward compared to 2008-2009. Accordingly, we limited this index to data from 2010-2015. Habitats observed via side-scan sonar were classified as geoforms following the NOAA Coastal and Marine Ecological Classification Standards (CMECS 2012) geoform and surface geological component classifications. Geoforms identified via side-scan sonar are coded as categorical variables with 36 potential values (Table 1) and included as a potential explanatory variable in the index model.

At each sampling station, 1 – 2 stationary underwater camera arrays (SUCAs) were deployed based on the quantity and distribution of identified reef habitat. SUCA deployments and collection and processing of field data followed established NMFS protocols. Each SUCA consisted of a pair of stereo imaging system (SIS) units positioned at an angle of 180º from one another to maximize the total field of view. Each SIS unit consisted of an underwater housing containing a digital camcorder to record video and a pair of stereo cameras to capture still images at a rate of one per second. Each SUCA was baited (generally Atlantic Mackerel) and deployed for thirty minutes to assure that twenty minutes of continuous video and stereo images were recorded. Video data from one SIS per SUCA deployment were processed to quantify the relative abundance of Red Snapper (MaxN, or the maximum number of Red Snapper observed on a single video frame). When video conditions allowed, individual Red Snapper were measured using stereo still images using Vision Measurement System software (VMS) or SeaGIS software; measurements obtained could best be described as fork length (FL). All individual gear deployments were spaced a minimum of 100 m apart.

Data Treatment and Standardization:

Data Summary:

We excluded any videos that were considered unreadable by an analyst, or where predictor variables of interest were not recorded or standardized sampling methods were not followed, leaving 1489 samples available for Red Snapper video analyses from 2010-2016. Annual video effort varied from 146 – 286 video deployments per year (Table 2; Fig. 2; Appendix A). Red Snapper observed on video ranged from 161-891 mm FL, although most were between 300 and 550 mm FL (Figure 3).

Standardization of Response Variable:

For the video index of Red Snapper we modeled the MaxN, or maximum number of Red Snapper observed during an individual frame across the 20 minute video read. MaxN has previously been used as the response variable for estimation of abundance from reef fish video surveys in the Gulf of Mexico.

Explanatory Variables:

We considered 14 explanatory variables in the model analysis:

Year (*Y*) – Year was included since standardized catch rates by year are the objective of the analysis. We modeled data from 2010-2016, annual summaries of data points considered are presented in Table 2.

Month (*M*) – A temporal parameter based on month of sampling (range shown in Table 2; Fig. 4).

Depth (*DQ*) – Water depth may be an important component affecting the distribution of reef fish and we included all depths sampled and treated it as a quantile factor (Table 2; Fig. 4).

Latitude (*LatQ*) – The latitude of video samples was included as a spatial parameter in the model (Table 2; Fig. 4) and was treated as a quantile factor in the models.

Turbidity (*Turb*) – Due to the effect of turbidity on both species distribution and the ability of our video analysts to process video samples accurately, we included a turbidity factor in the models.

Side-scan geoform (*Geoform*) – The observed geoform from side-scanning used in site selection for camera deployment. Geoform was included as a categorical variable with potential values shown in Table 1.

Vertical Relief (*Rel*) – Habitat type and quantity can influence the distribution and abundance of reef fish. As such the presence or absence of vertical relief, as determined by video reads, was included as a binary habitat descriptor in the model. The following habitat variables are similar methodologically.

Algae (*Alg*) – A binary habitat descriptor of the presence or absence of benthic algal growth.

Hard Coral (*Hcor*) - A binary habitat descriptor of the presence or absence of benthic hard coral.

Soft Coral (*Scor*) – A binary habitat descriptor of the presence or absence of benthic soft coral.

Seagrass (*Sgr*) - A binary habitat descriptor of the presence or absence of seagrass.

Sponges (Spo) - A binary habitat descriptor of the presence or absence of sponges.

Unknown Sessile Organisms (*Usess*) - A binary habitat descriptor of the presence or absence of unknown sessile organisms.

Rock (*Rock*) - A binary habitat descriptor of the presence or absence of exposed rock.

Model Selection and Diagnostics:

Video surveys produce count data that do not conform to assumptions of normality. As such distributions of count data are often modeled using Poisson or negative binomial error distributions. Further, there is evidence that our video data may have a disproportionate number of zero counts that may differ from the standard error distributions used for count data (Fig. 5). These data distributions are referred to as “zero-inflated” and are fairly common in ecologically based count data. Due to the count nature of the data, and the possibility of inflation of the zero counts we used four different error distribution models to construct preliminary evaluation models (i.e., Poisson, Negative Binomial, Zero-inflated Poisson, Zero-inflated Negative Binomial). The zero inflated approaches model the zero counts using two different processes, a binomial and a count process (Zuur et al. 2009).

Initially, four full (all potential variables) models were considered utilizing both a Poisson (P) and Negative binomial (NB) error distribution and both Zero-inflated Poisson (ZIP) and zero inflated Negative Binomial (ZINB) formulations.

(1) *MaxN = Y+DQ+M+LatQ+Rel+Alg+Hcor+Scor+Sgr+Spo+Uses+Rock+Turb+geoform*

We compared the variance structure of each model formulation using likelihood ratio tests (Zuur et al. 2009) and Aikaike’s information theoretic criterion (AIC; Zuur et al. 2009) to determine the most appropriate model formulation for the development of a video index for Red Snapper in the Eastern Gulf of Mexico. Results of the likelihood ratio test indicate that the two negative binomial models were most appropriate, and with similar log likelihood values (Table 3). The fitted values of both negative binomial models matched the MaxN values similarly, but the AIC score indicated that the ZINB distribution was most appropriate and was used for the final index model (Table 3, Fig. 6).

A backwards step-wise model selection procedure was used to exclude unnecessary parameters from the null model (2) formulation. The optimum Red Snapper model formulation (3) was determined by backwards selection and comparisons of model AIC values (Zuur et al. 2009). Two variables, Month and Turbidity were dropped, with the final (best) model of:

(2) *MaxN = Y+DQ+LatQ+Rel+Alg+Hcor+Scor+Sgr+Spo+Uses+Rock+geoform*

Model diagnostics showed no discernible patterns of association between Pearson residuals and fitted values or the fitted values and the original data (Fig. 7). An examination of residuals for the spatial and environmental model parameters (Fig. 8) showed no clear patterns of association, indicating correspondence to underlying model assumptions (Zuur et al. 2009). Lastly, a comparison of predicted values from the best model against original data distribution (Fig. 9) indicates a good fit of the zero-inflated data structure. Confidence intervals were determined by bootstrapping the model fitting over 1000 iterations.

All data manipulation and analysis was conducted using R version 3.0.2 (R Core Team 2014). Modeling was conducted using the zeroinfl function of the pscl package (Jackman 2008), available from the Comprehensive R Archive Network (CRAN).

Results:

Annual standardized index values for Red Snapper in the Eastern Gulf of Mexico, including coefficients of variation, are presented in Table 4. The model CV's indicate a good fit, CV values between 14-25% with only the first year with a CV above 30%, indicating a higher level of variation in the MaxN that year, likely related to the lower proportion of sites observing Red Snapper that year. The relative nominal video counts for Red Snapper tracks the same pattern seen with the standardized, model predicted abundance estimates (Fig. 10). In general, Red Snapper catches were low, with the proportion of sites with individuals observed between 8-16% for most years, except for the terminal year of 2016 in which Red Snapper were observed at 30% of sites. The standardized index shows two peaks above a CPUE of 1, one in 2013 and a larger peak in abundance in 2016 with estimated abundance double that of earlier years in the survey (Fig. 10).

Literature Cited:

CMECS. 2012. Coastal and Marine Ecological Classification Standard. Marine and Coastal Data Subcommittee, Federal Geographic Data Committee, FGDC-STD-018-2012. url: https://coast.noaa.gov/digitalcoast/training/cmecs-pub.html

Hall, D. B. 2000. Zero-Inflated Poisson binomial regression with random effects: a case study. Biometrics, 56: 1030-1039.

Jackman, S. 2008. Pack: Classes and methods for R developed in the political science computational laboratory, Stanford University. Department of Political Science, Stanford University, Stanford, CA.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. URL: http://www.R-project.org/.

Zuur, A.F., E.N. Ieno, N.J. Walkder, A.A. Saveliev, and G.M. Smith. 2009. Mixed effects models and extensions in ecology with R. Spring Science and Business Media, LLC, New York, NY.

Table 1. List of the Geoforms used to describe potential reef fish habitats observed using side scan sonar. Habitats in bold were those observed with side scan and had videos deployed that had sufficient sample sizes to be included in subsequent analyses.

Habitat Type	Geoforms	Habitat Type	Geoforms
Geologic		Anthropogenic	
	Ledge		Aircraft
	Pothole		Cable
	Fragmented HB		Construction Materials
	Boulder/Boulder Field		Dredged Channel
	Spring Sink		Chicken Coop
	Pavement		Military Tanks
	Pinnacle		Artificial Reef Unknown
	Flat HB		Dredge Deposit
	Mixed HB		Marine Wreckage
	Rubble Field		Oil Platform Material
	Fracture		Pipeline Area
	Escarpment		Reef Modules
Biogenic			Rock Piles
	Aggregate Coral Reef		Tires
	Aggregate Patch Reef		Vehicles Other
	Individual Patch Reef		Large Vessel/Barge
	Reef Rubble		Small Vessel
	Seagrass	Other	
	Spur Groove		**Unknown**

Table 2. Annual total number of video samples included in the analysis and range of spatial and environmental variables included.

Year	# of video samples	Depth Range (m)	Latitude Range	Month Range
2010	145	11 - 102	26.025 – 27.986	July – Aug.
2011	221	12 - 84	26.064 – 27.984	June – Sept.
2012	237	11 - 104	26.020 – 27.975	June – Sept.
2013	183	7 - 93	26.010 – 27.996	July – Oct.
2014	286	8 - 103	26.020 – 27.975	June – Oct.
2015	224	8 - 107	26.011 – 27.988	June – Oct.
2016	193	10 - 88	26.336 – 27.980	May – Aug.

Table 3. Full model likelihood ratio comparisons.

	Df	Likelihood	χ^2	AIC	*p*-value
Poisson	33	-1474.38		3014.755	
Negative Binomial	34	-926.79	1095.18	1921.576	<2.2e-16
Zero-inflated Poisson	66	-988.05	122.52	2108.095	1.60e-12
Zero-Inflated NB	67	-869.36	237.37	1872.727	<2.2e-16

Table 4. Relative nominal MaxN, number of stations sampled (N), proportion of positive sets, standardized index, and CV for FWRI Gray Snapper video index of the West Florida Shelf, 2008-2013.

Year	Nominal MaxN	N	Proportion positive	Standardized Index	CV
2010	0.186207	145	0.08219178	0.383410	0.3455919
2011	0.171946	221	0.1040724	0.428600	0.2447148
2012	0.261603	237	0.1181435	0.547538	0.2512152
2013	0.628415	183	0.1521739	1.392327	0.2253685
2014	0.402098	286	0.1358885	0.979539	0.2543073
2015	0.433036	224	0.1607143	0.828299	0.2144147
2016	1.222798	193	0.3041237	2.440288	0.1486021

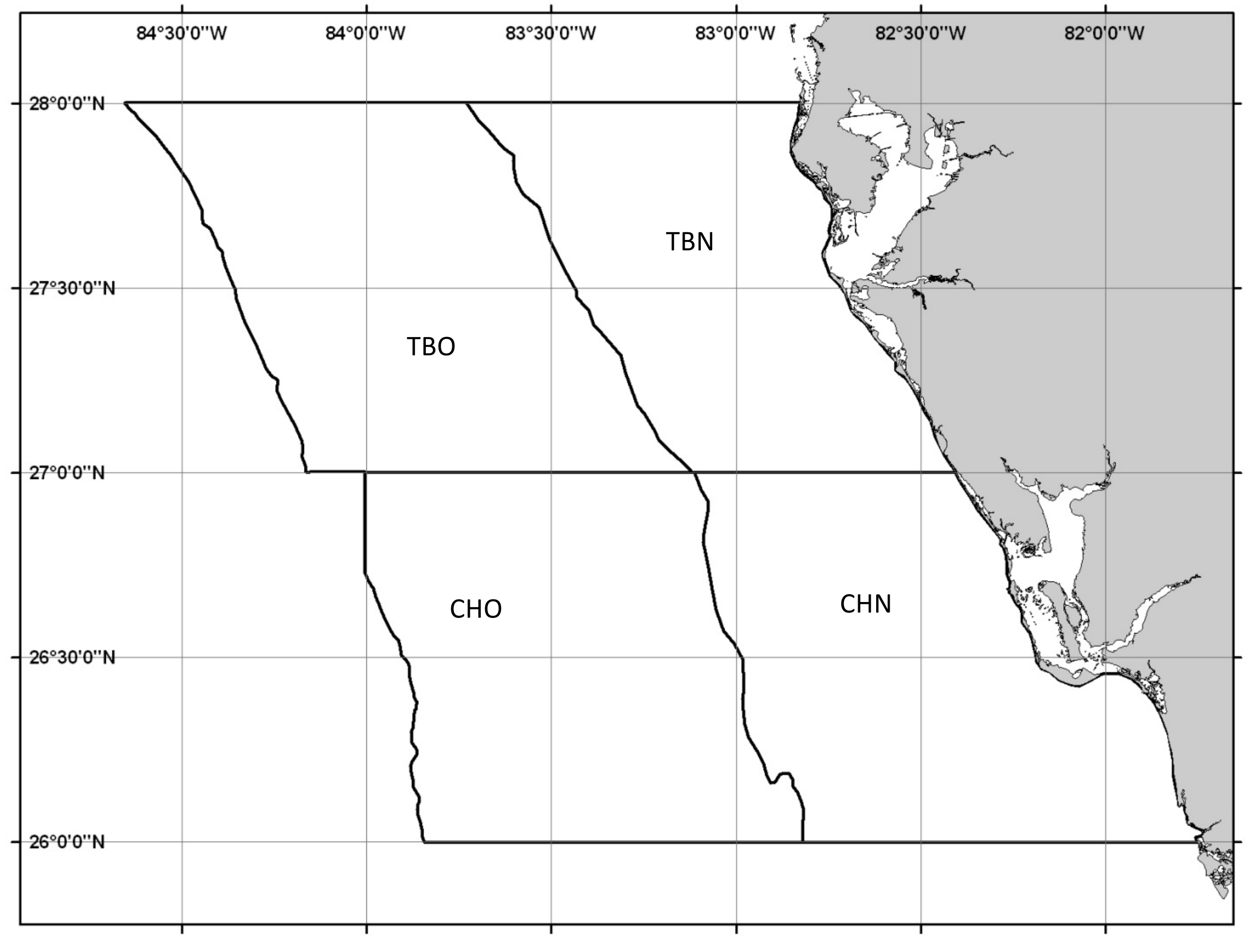


Figure 1. The West Florida Shelf survey area. The 20fa (37m) contour separates nearshore (i.e., TBN and CHN) and offshore (TBO and CHO) sampling zones. The sampling area includes waters 10m – 110m.

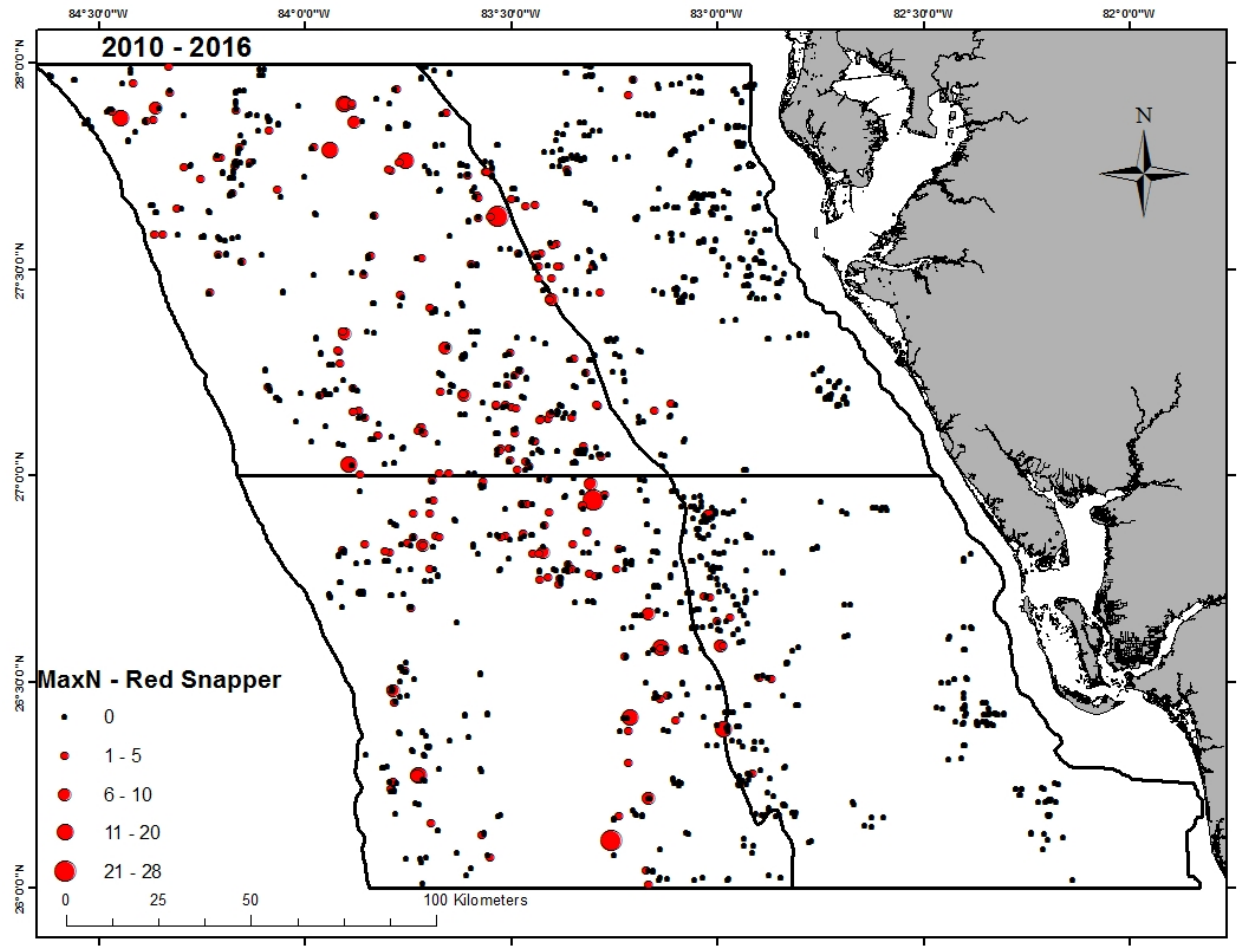


Figure 2. Stations sampled from 2010 – 2015 during the FWRI reef fish video survey. Symbols represent MaxN, or the maximum number of gray snapper observed on a single screen shot during each video.

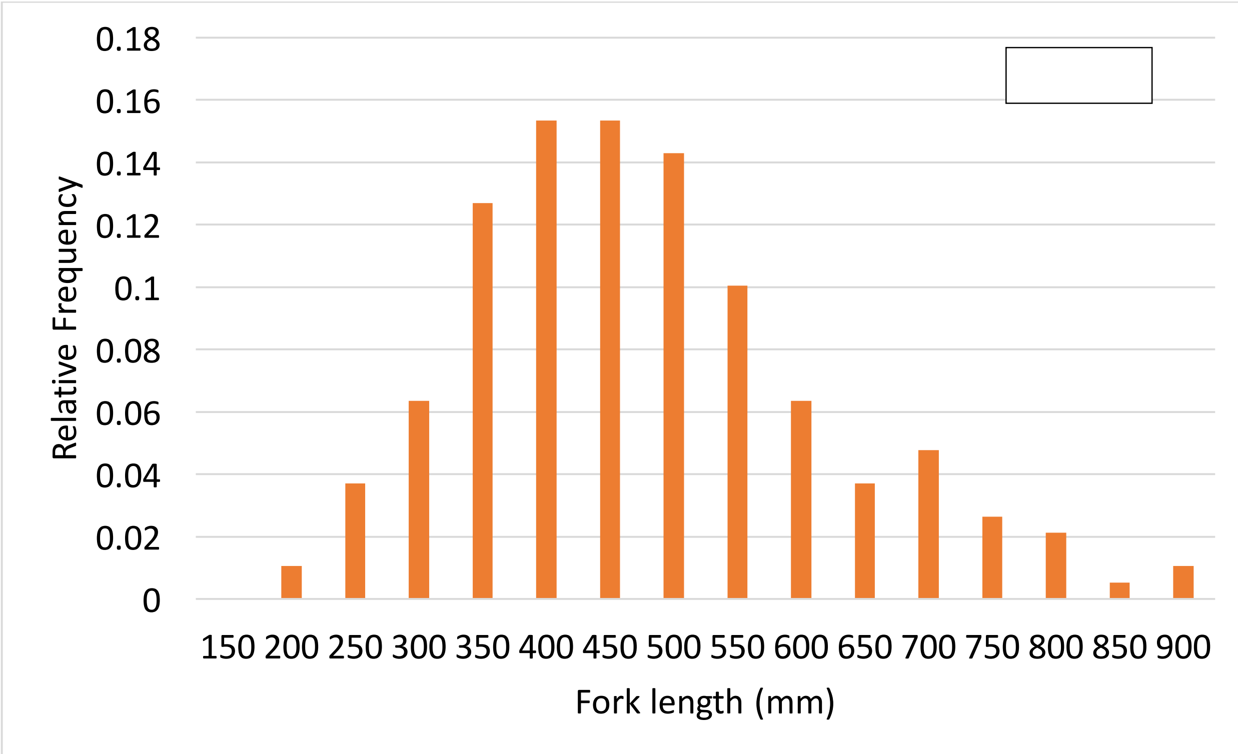


Figure 3. Length frequency distribution of Red Snapper observed on SUCAs included in the index and measures using Vision Measurement System software and SeaGIS from 2010-2015.

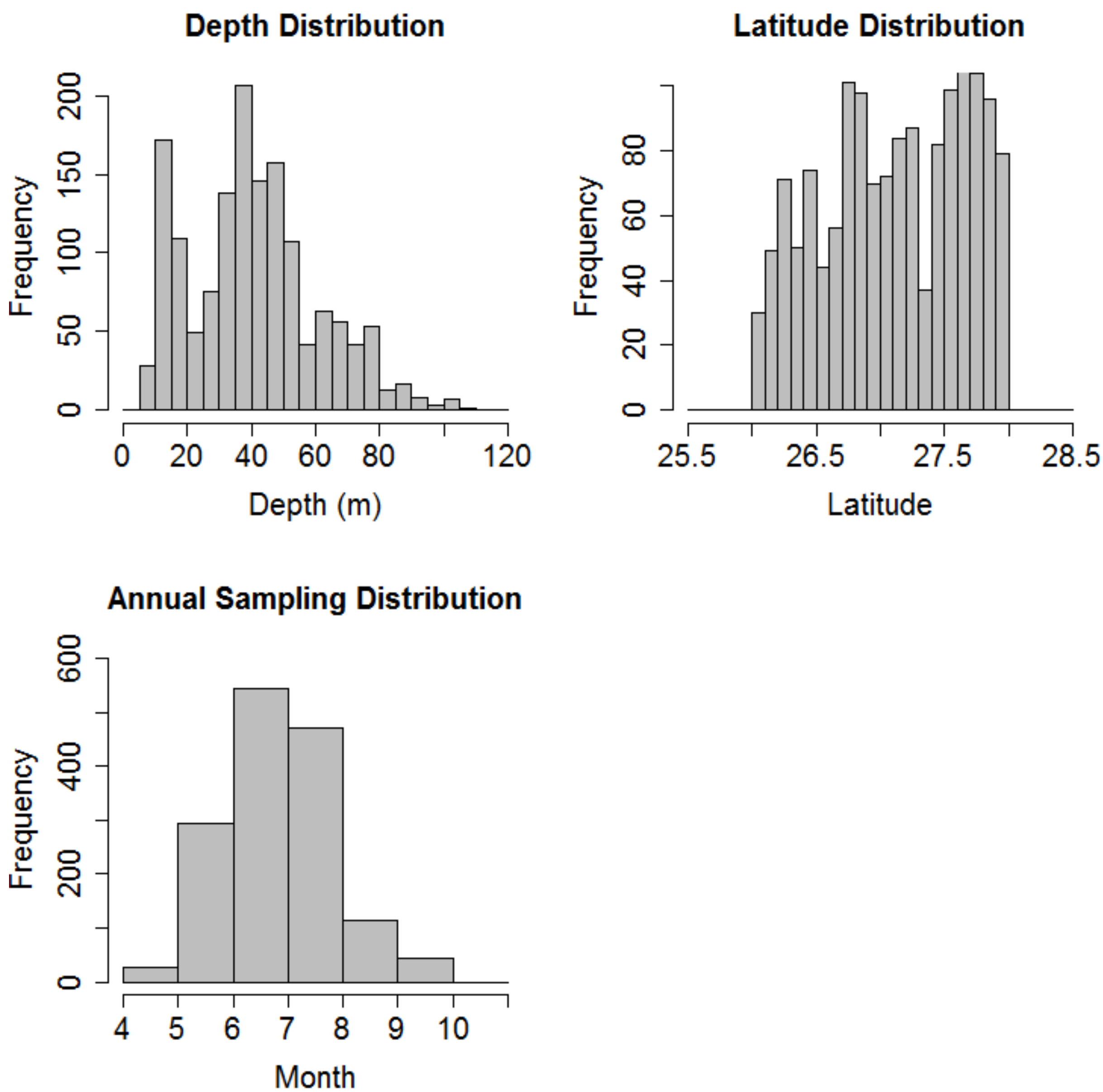


Figure 4. Sample distribution for the original continuous variables.

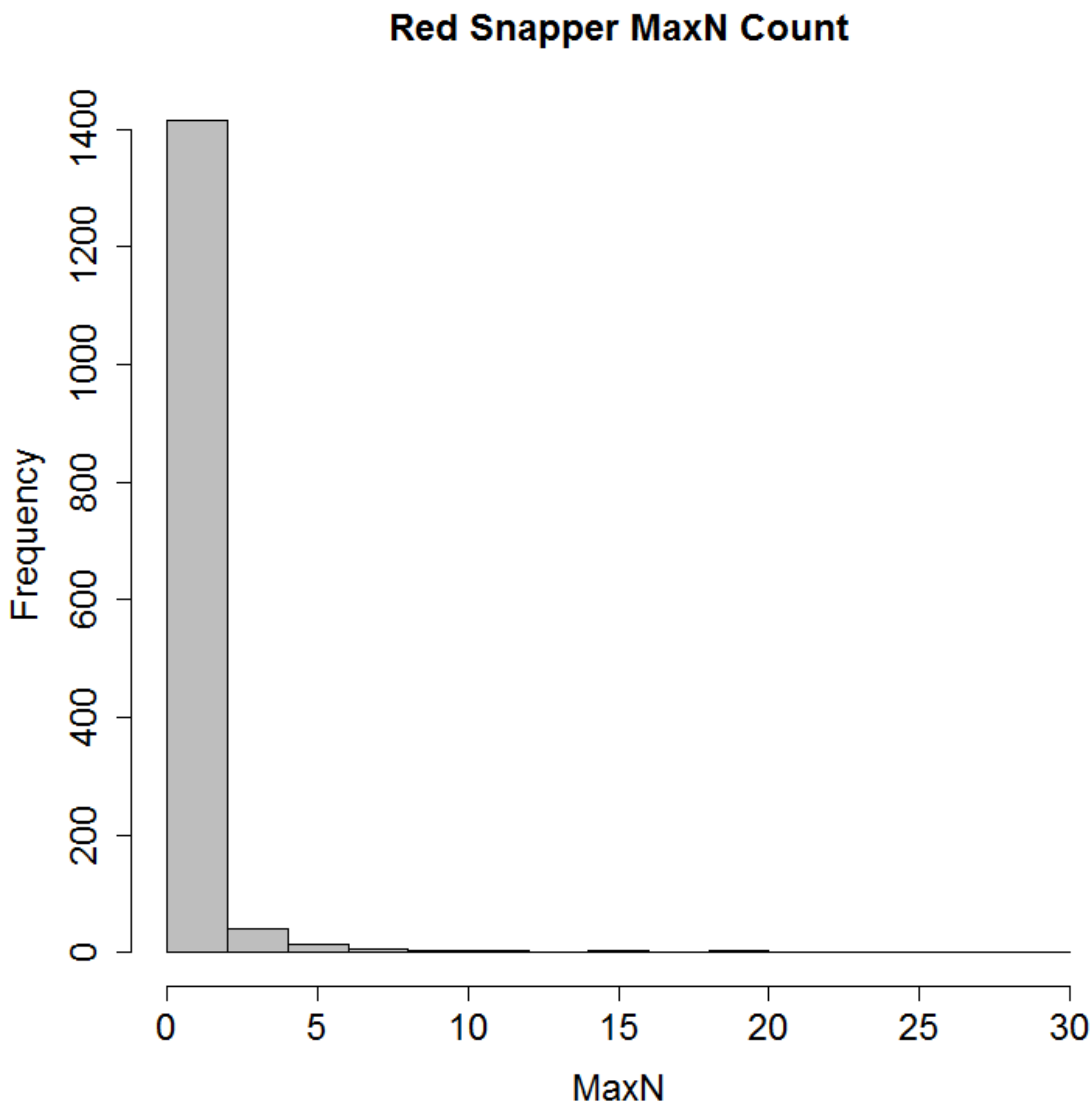


Figure 5. MaxN count distribution for Gray Snapper FWRI video surveys on the West Florida Shelf.

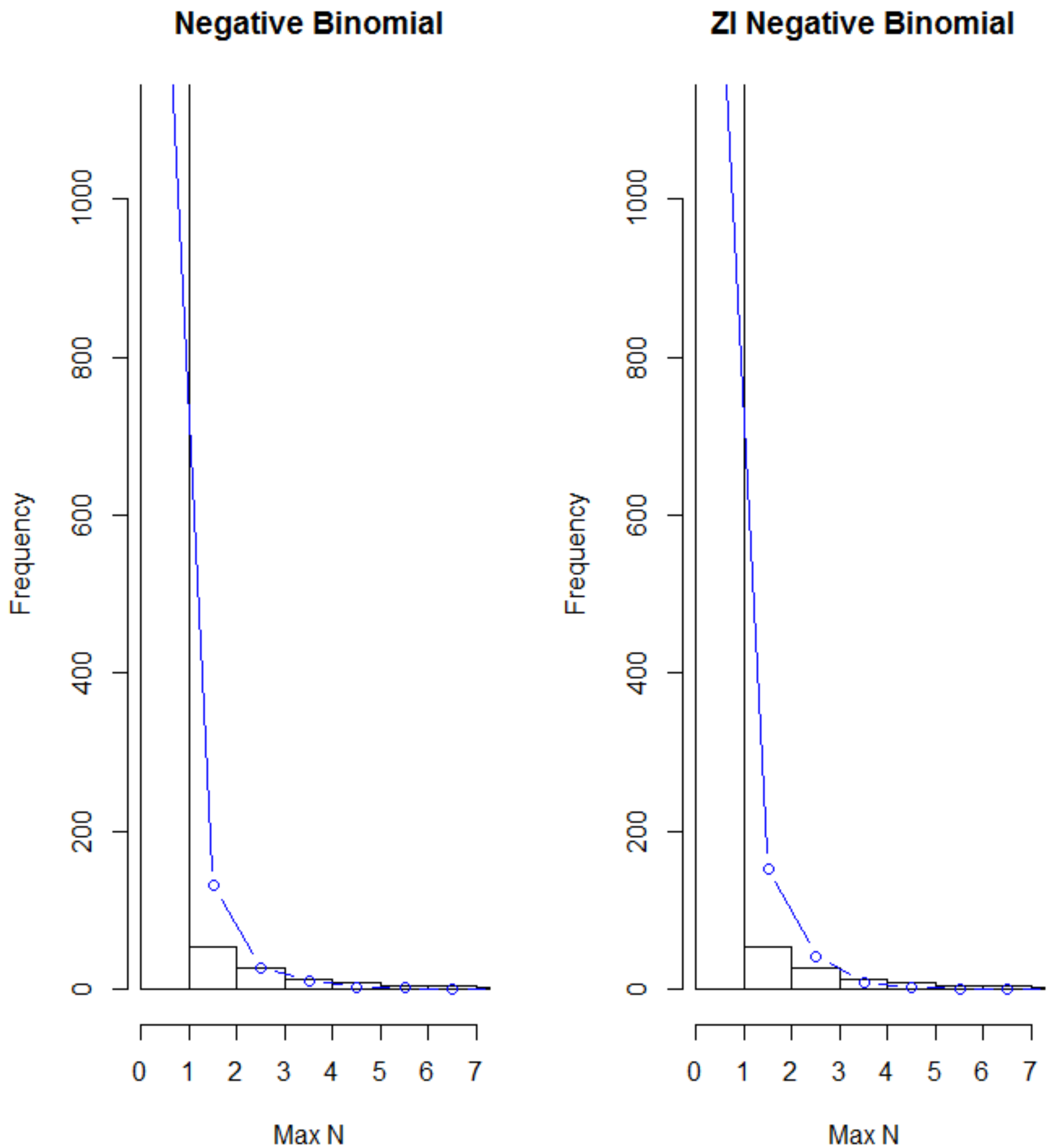


Figure 6. Full model formulation comparison, with the two best model distributions based on AIC: negative binomial and zero-inflated negative binomial. Blue lines indicate the model predicted MaxN frequencies plotted against the original data distribution.

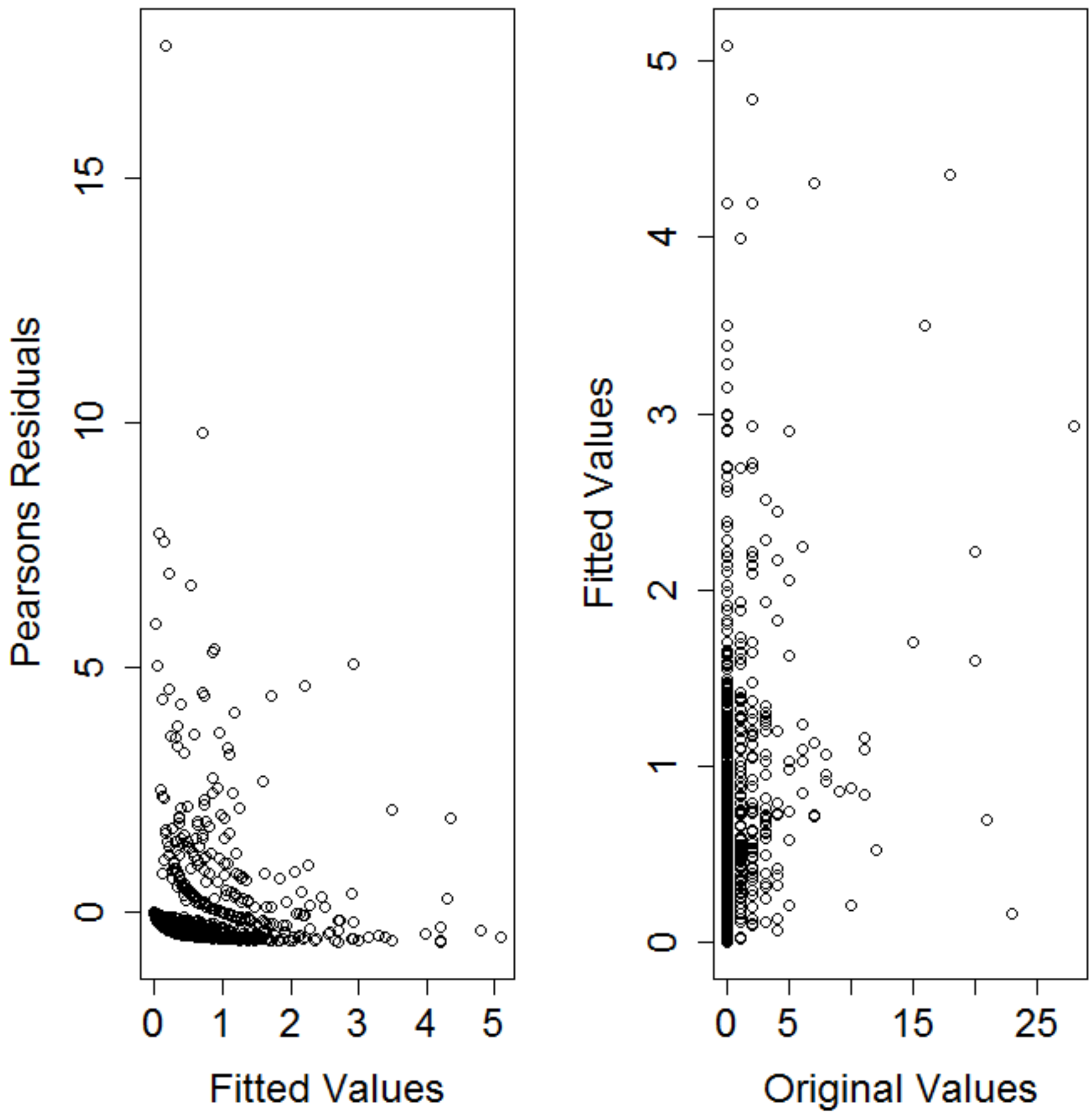
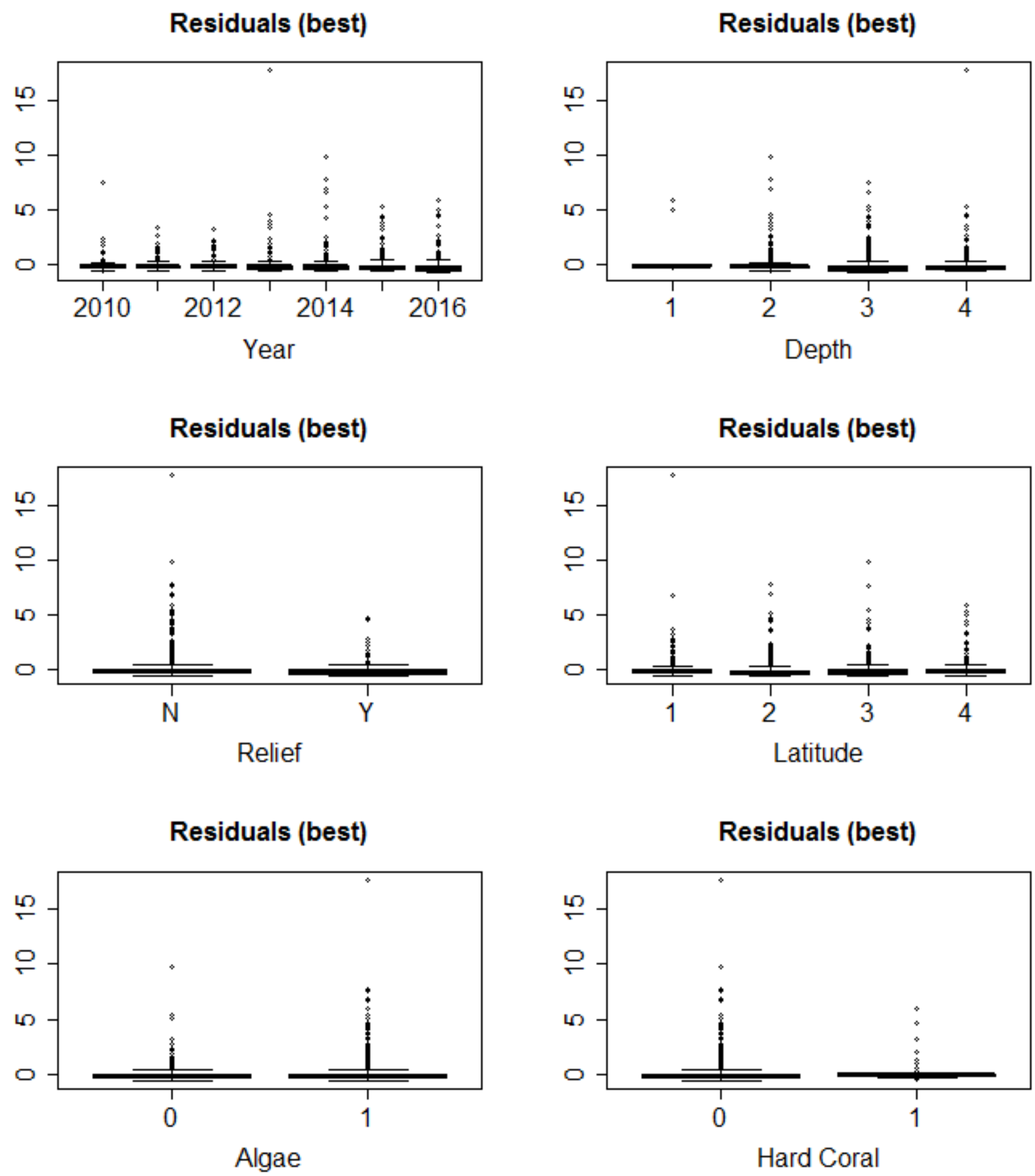


Figure 7. Model diagnostic plots showing fitted best model values against Pearson residuals (left panel) and fitted values plotted against original data values (right panel).


Residuals (best)
Year
Residuals (best)
Depth
Residuals (best)
Relief
Residuals (best)
Latitude
Residuals (best)
Algae
Residuals (best)
Hard Coral

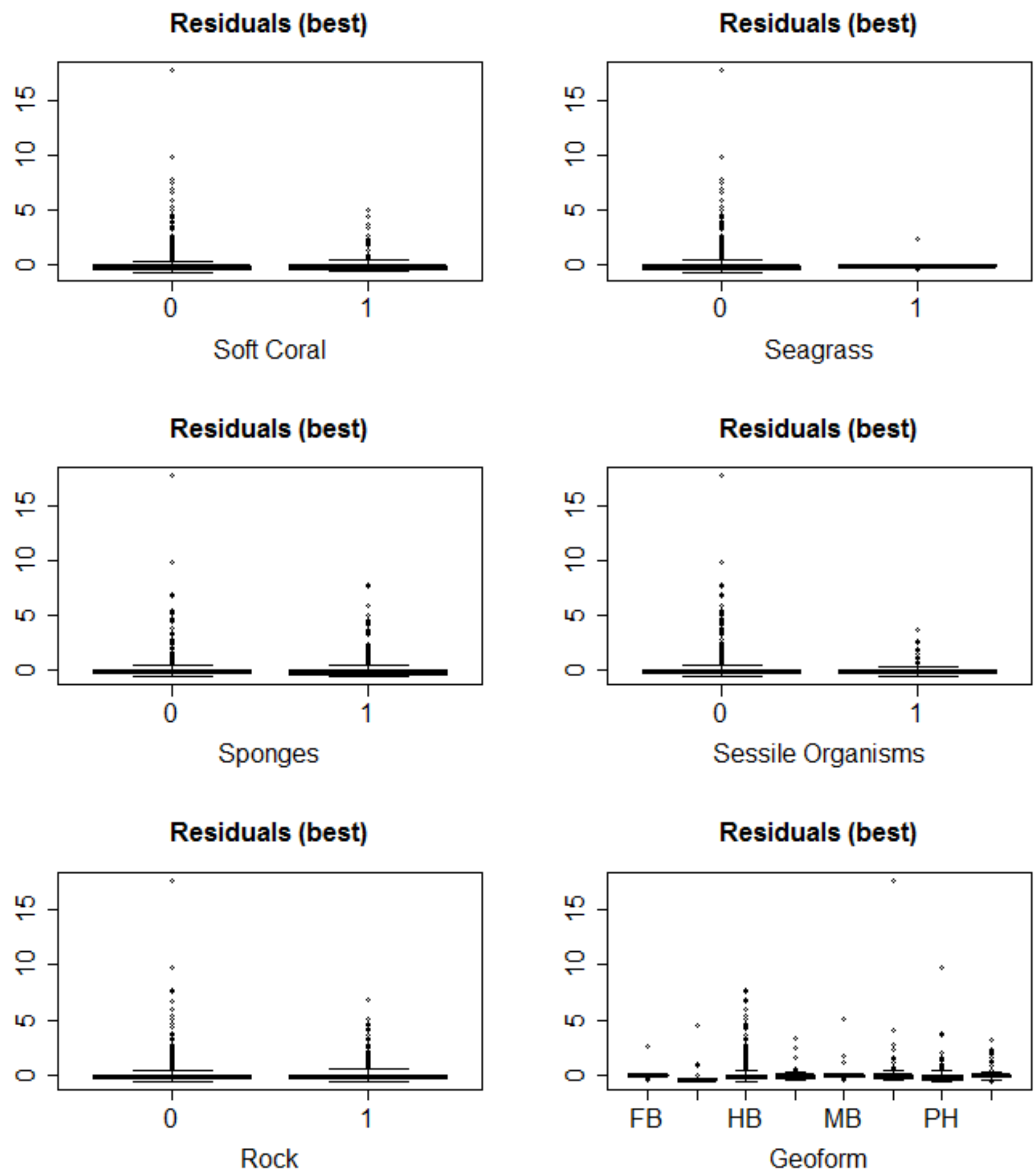


Figure 8. Model diagnostic plots showing Pearson residuals for the final (best) model plotted against spatiotemporal and environmental model parameters.

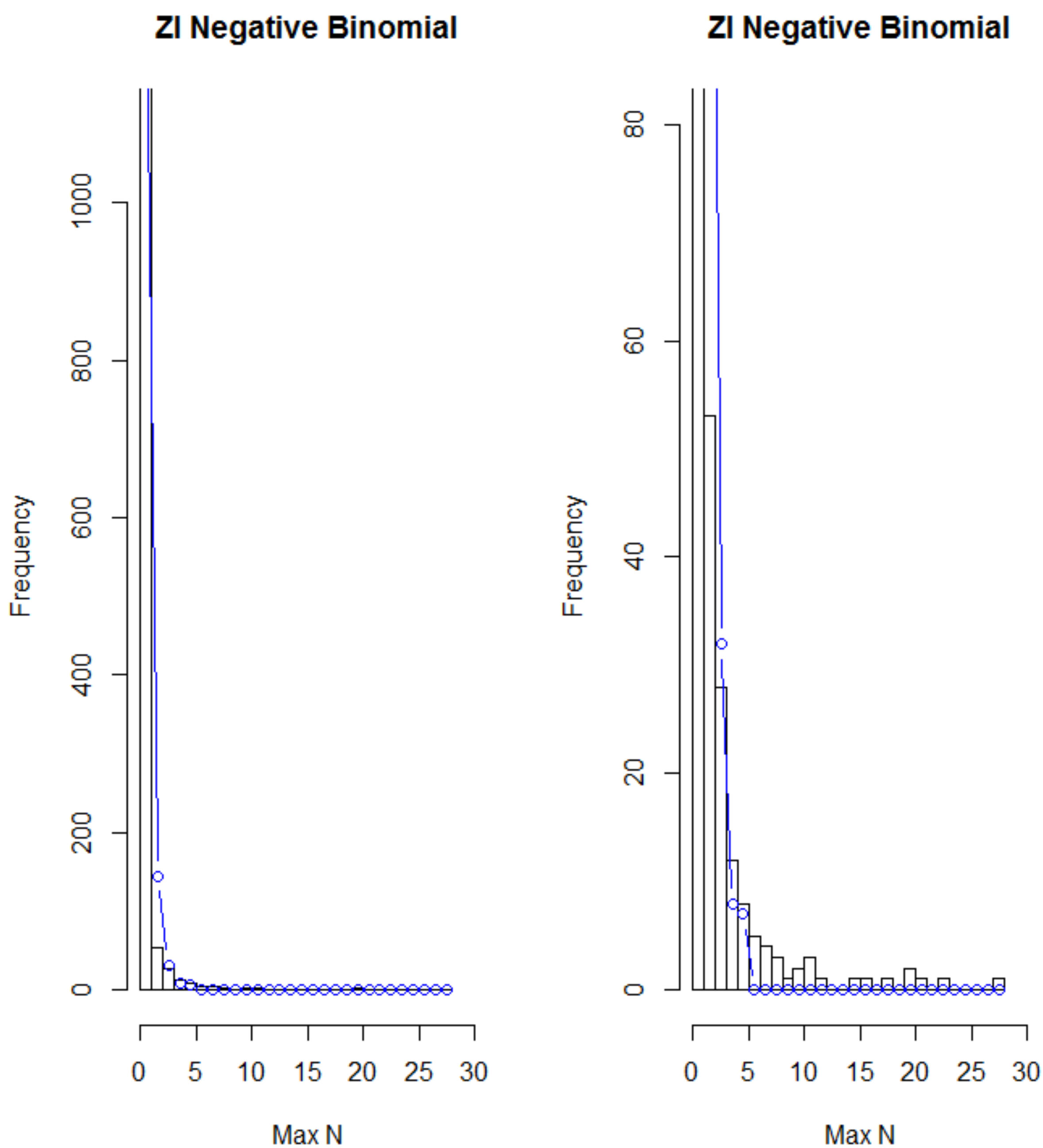


Figure 9. Model diagnostic plots of fitted model values (blue line) against the original data distribution. Full distribution view (left panel) and limited y-axis view (right panel).

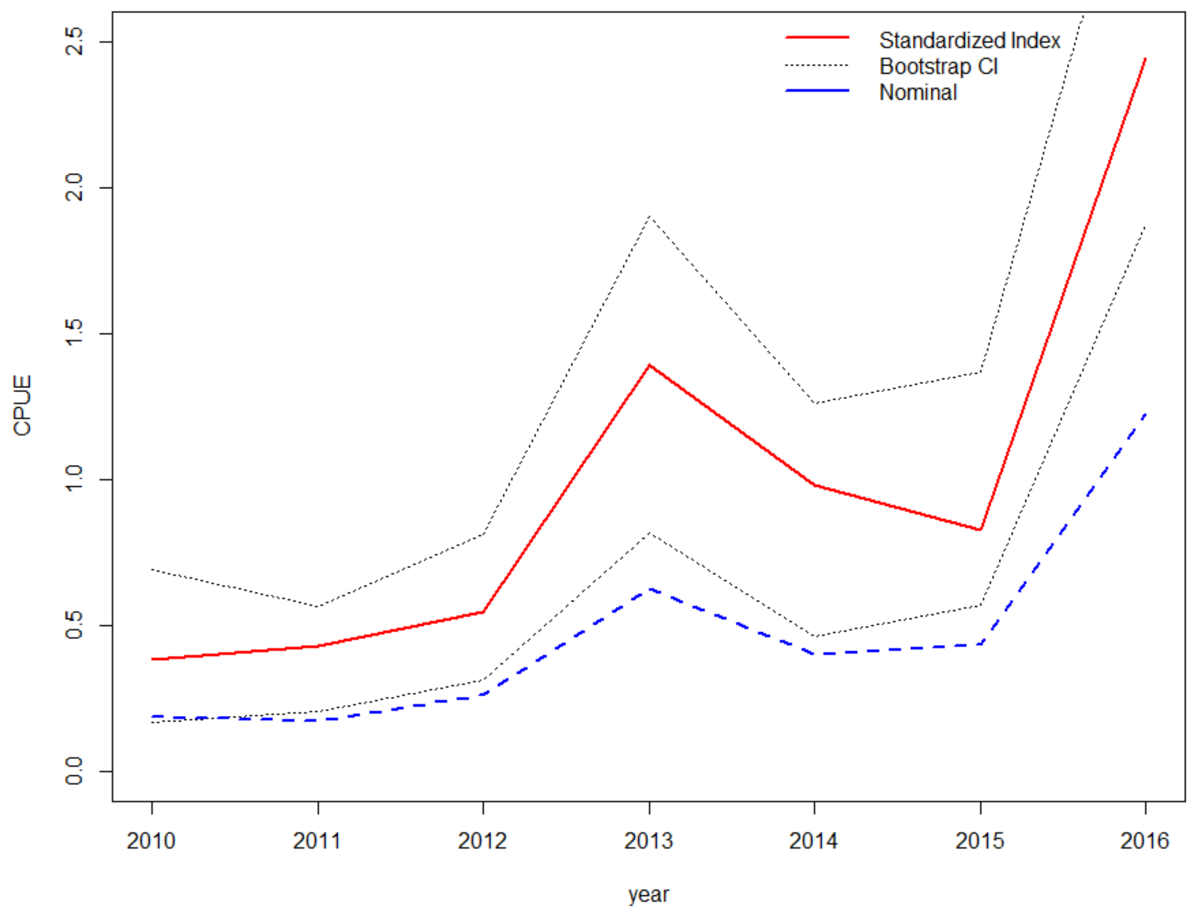
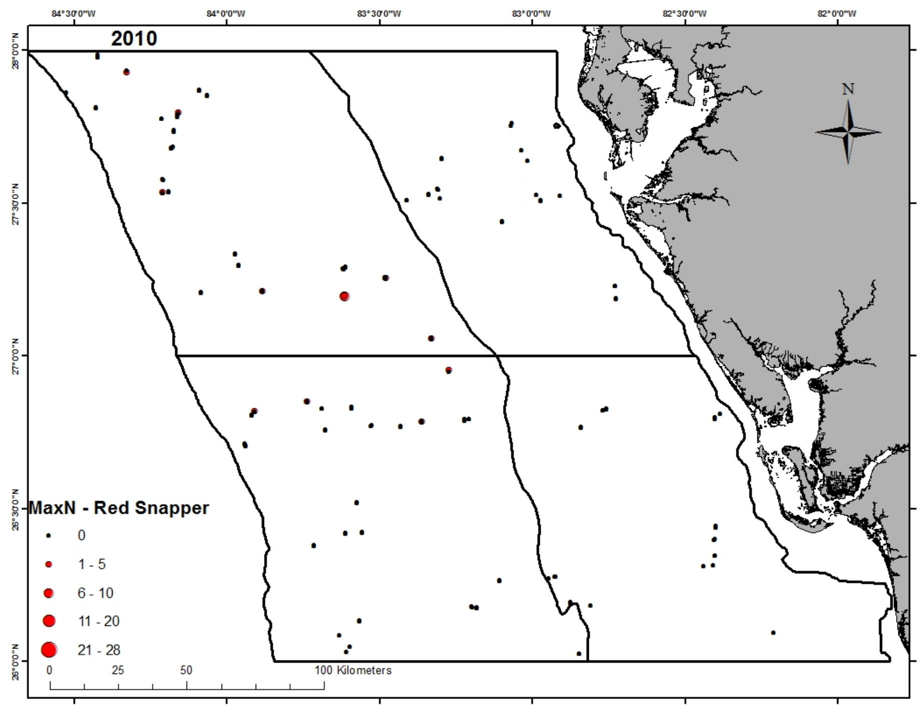
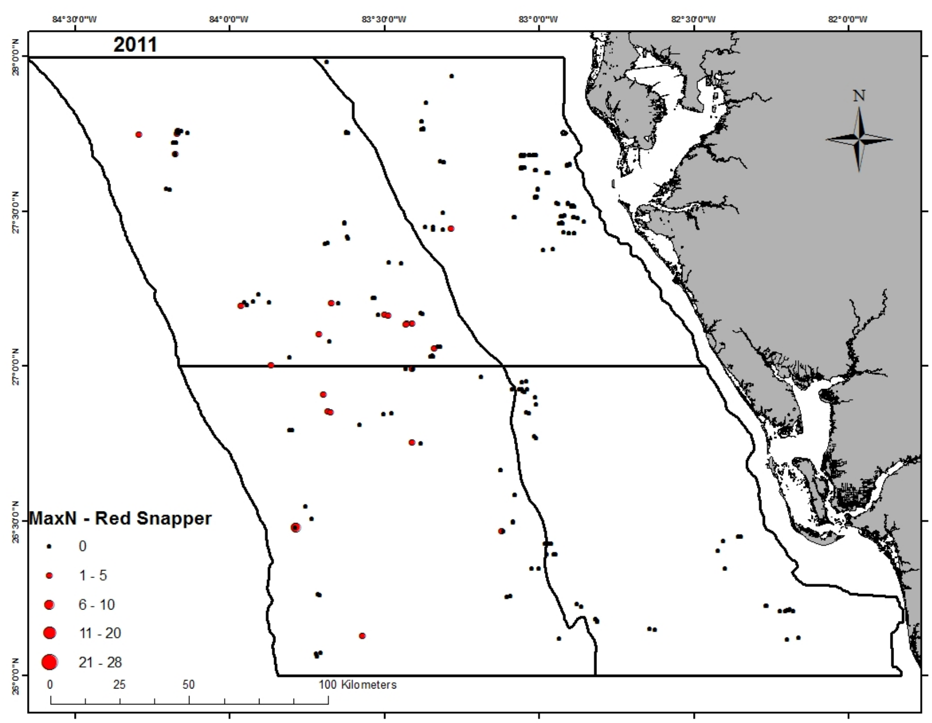


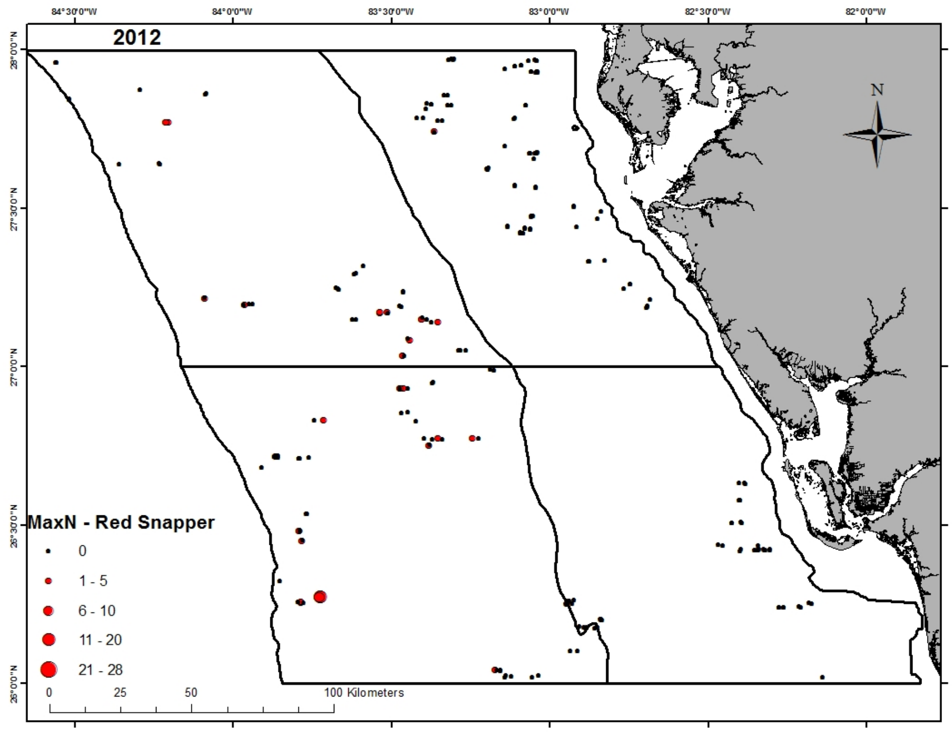
Figure 10. Relative standardized index (solid red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and the nominal CPUE (blue hashed line) for Red Snapper CPUE in the FWRI West Florida Shelf Video Survey.

Appendix A

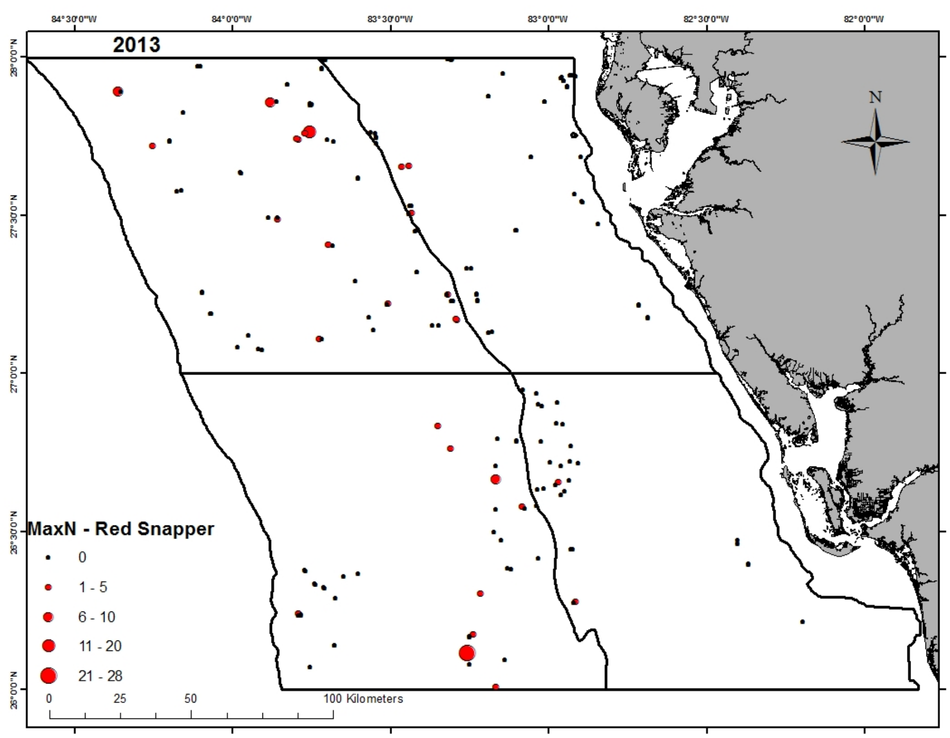
Figures A1-A7. Annual distribution of stations sampled (2010 – 2016) during the FWRI reef fish video survey. Symbols represent MaxN, or the maximum number of gray snapper observed on a single screen shot during each video.



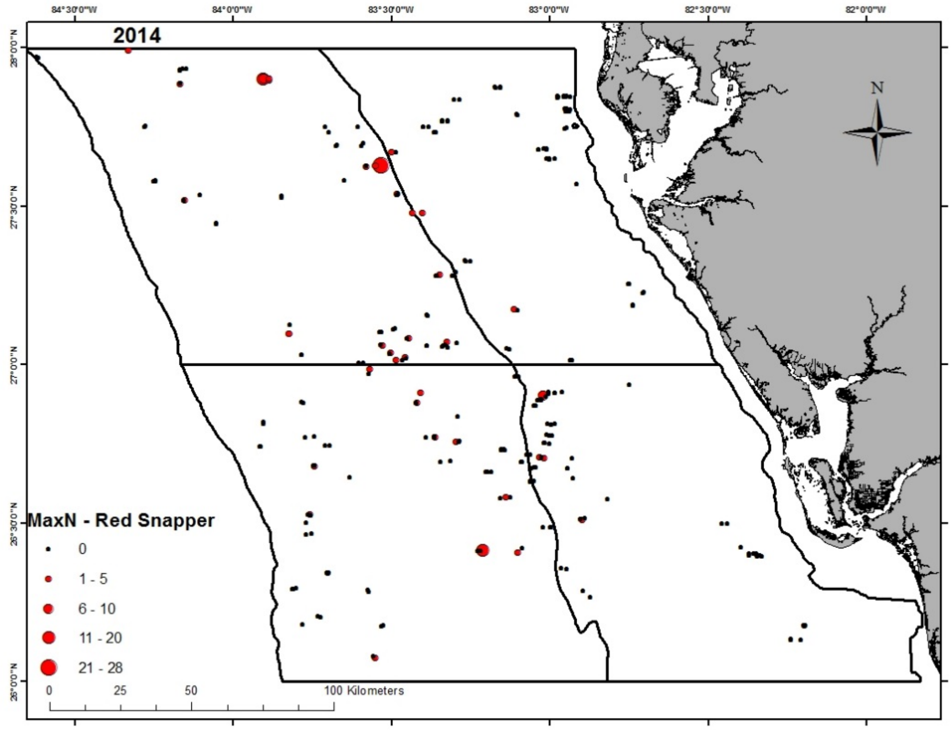




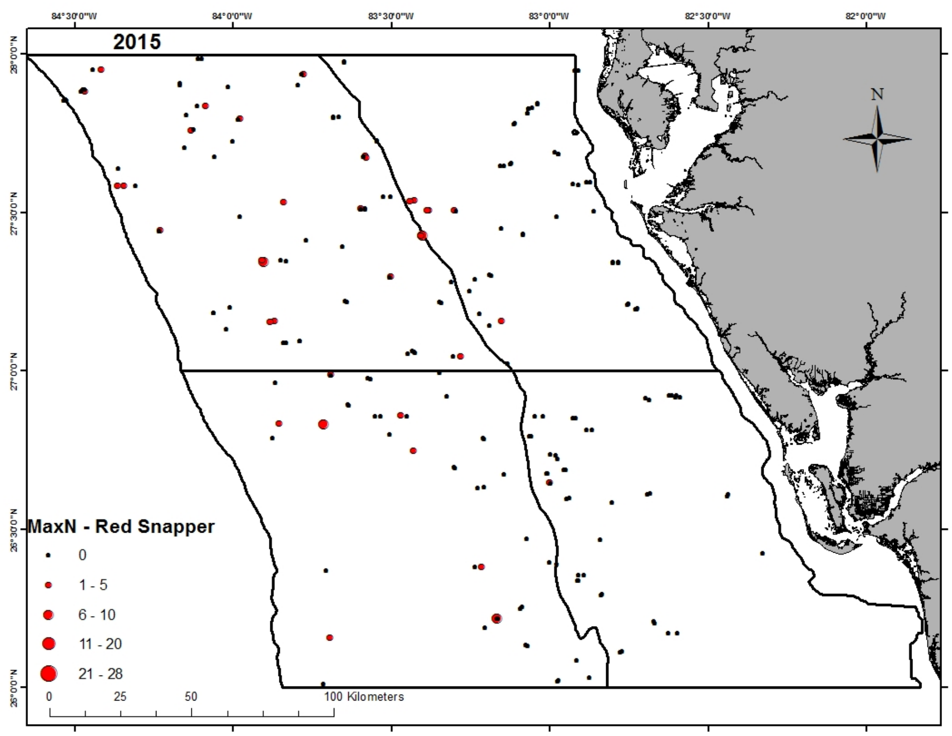
84°30'0"W
84°0'0"W
83°30'0"W
83°0'0"W
82°30'0"W
82°0'0"W
2012
28°0'0"N
27°30'0"N
27°0'0"N
26°30'0"N
26°0'0"N
N
MaxN - Red Snapper
0
1 - 5
6 - 10
11 - 20
21 - 28
0 25 50 100 Kilometers



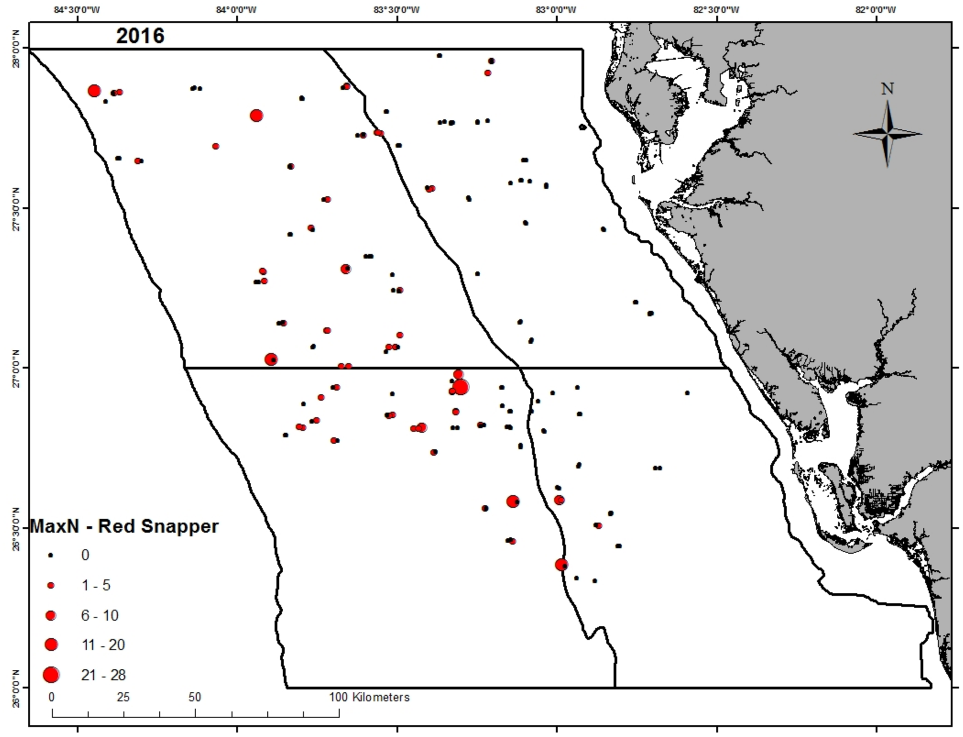
84°30'0"W
84°0'0"W
83°30'0"W
83°0'0"W
82°30'0"W
82°0'0"W
2013
28°0'0"N
27°30'0"N
27°0'0"N
26°30'0"N
26°0'0"N
N
MaxN - Red Snapper
0
1 - 5
6 - 10
11 - 20
21 - 28
0 25 50 100 Kilometers



2014
84°30'0"W
84°0'0"W
83°30'0"W
83°0'0"W
82°30'0"W
82°0'0"W
28°0'0"N
27°30'0"N
27°0'0"N
26°30'0"N
26°0'0"N
N
MaxN - Red Snapper
0
1 - 5
6 - 10
11 - 20
21 - 28
0 25 50 100 Kilometers



2015
84°30'0"W
84°0'0"W
83°30'0"W
83°0'0"W
82°30'0"W
82°0'0"W
28°0'0"N
27°30'0"N
27°0'0"N
26°30'0"N
26°0'0"N
N
MaxN - Red Snapper
0
1 - 5
6 - 10
11 - 20
21 - 28
0 25 50 100 Kilometers


84°30'0"W
84°0'0"W
83°30'0"W
83°0'0"W
82°30'0"W
82°0'0"W
28°0'0"N
27°30'0"N
27°0'0"N
26°30'0"N
26°0'0"N
2016
N
MaxN - Red Snapper
0
1 - 5
6 - 10
11 - 20
21 - 28
0
25
50
100 Kilometers