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

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

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

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

Introduction:

Reef fishes, including Gray 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 Gray 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 Gray Snapper (MaxN, or the maximum number of Gray Snapper observed on a single video frame). When video conditions allowed, individual Gray 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 1299 samples available for Gray Snapper video analyses from 2010-2015. Annual video effort varied from 146 – 286 video deployments per year (Table 2; Fig. 2; Appendix A). Gray Snapper observed on video ranged from 164-558 mm FL, although most were between 200 and 400 mm FL (Figure 3).

Standardization of Response Variable:

For the video index of Gray Snapper we modeled the MaxN, or maximum number of Gray 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 15 explanatory variables in the model analysis: year, month, depth, latitude, vertical relief, presence of algal growth, presence of hard corals, presence of soft corals, presence of seagrass, presence of sponge, presence of unknown sessile organisms, presence of rock, turbidity, side scan geoform, and SEAMPA statistical zone

Year (*Y*) – Year was included since standardized catch rates by year are the objective of the analysis. We modeled data from 2010-2015, 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. 3).

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. 3).

Latitude (*LatQ*) – The latitude of video samples was included as a spatial parameter in the model (Table 2; Fig. 3) and was treated as a quantile factor in the models.

Turbidity (*TurbQ*) – 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 as a quantile factor in our model.

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.

Statistical Zone (*statz*)- The SEAMAP sampling statistical zone (Fig.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+TurbQ+statz+geoform*

However, due to linear dependencies preventing model convergance, the geoform variable had to be dropped, leaving a initial model with the following structure:

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

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 Gray Snapper in the Eastern Gulf of Mexico. Results of the likelihood ratio test indicate that the two zero-inflated models were most appropriate, and with similar log likelihood values (Table 3). The fitted values of the full zero-inflated negative binomial model (ZINB) better matched the MaxN values than the similar Poisson model, as such we moved forward with the ZINB distribution (Fig. 6).

A backwards step-wise model selection procedure was used to exclude unnecessary parameters from the null model (2) formulation. The optimum Gray Snapper model formulation (3) was determined by backwards selection and comparisons of model AIC values (Zuur et al. 2009). The final (best) model is given by:

(3) *MaxN = Y+DQ+LatQ+Rel+Alg+Sgr+Spo*

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 against original data distribution (Fig. 9) indicates a good fit between the model and original data. Confidence intervals were determined by bootstrapping the model fitting over 5000 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 Gray Snapper in the Eastern Gulf of Mexico, including coefficients of variation, are presented in Table 4. The model CV's indicate a good fit, aside from high CV values in 2010, indicating a high level of variation in the MaxN that year. This is likely related to the lower proportion of sites observing Gray Snapper for that year. The relative nominal video counts for Gray Snapper varied somewhat from the standardized index in 2014-2015, however in general the two indices show a similar pattern (Fig. 10). In general, indices show an increasing trend from 2010-2012, with a slight drop in abundance in 2013. Following that year, both the standardized index and nominal index show an increase in 2014 with the nominal index showing a higher increase. The nominal index then drops in 2015 but the standardized index remains similar. Interestingly, the FWRI inshore index for age-0 and age-1 Gray Snapper indicated a pulse in recruitment in 2012 and 2013 a trend that is seen by this offshore, adult index with a year or two delay. This fits currently known ontogeny of this species.

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Table 1. Annual total number of video samples included in the analysis and range of spatial and environmental variables included.

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	146	11 - 102	26.025 – 27.986	July - August
2011	222	12 - 84	26.064 – 27.984	June – Sept.
2012	237	11 - 104	26.020 – 27.975	June – Sept.
2013	184	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.

Table 3. Full model likelihood ratio comparisons.

	Df	Likelihood	χ^2	*p*-value
Poisson	43	-2688.5		
Negative Binomial	44	-1317.5	2742.02	<2.2e-16
Zero-inflated Poisson	42	-1583.4	531.89	<2.2e-16
Zero-Inflated NB	43	-1222.9	721.08	<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	0.315	146	0.034	0.597	0.859
2011	0.617	222	0.153	0.538	0.260
2012	0.873	237	0.126	0.855	0.239
2013	1.108	184	0.271	0.968	0.199
2014	1.790	286	0.335	1.393	0.152
2015	1.517	224	0.321	1.647	0.167

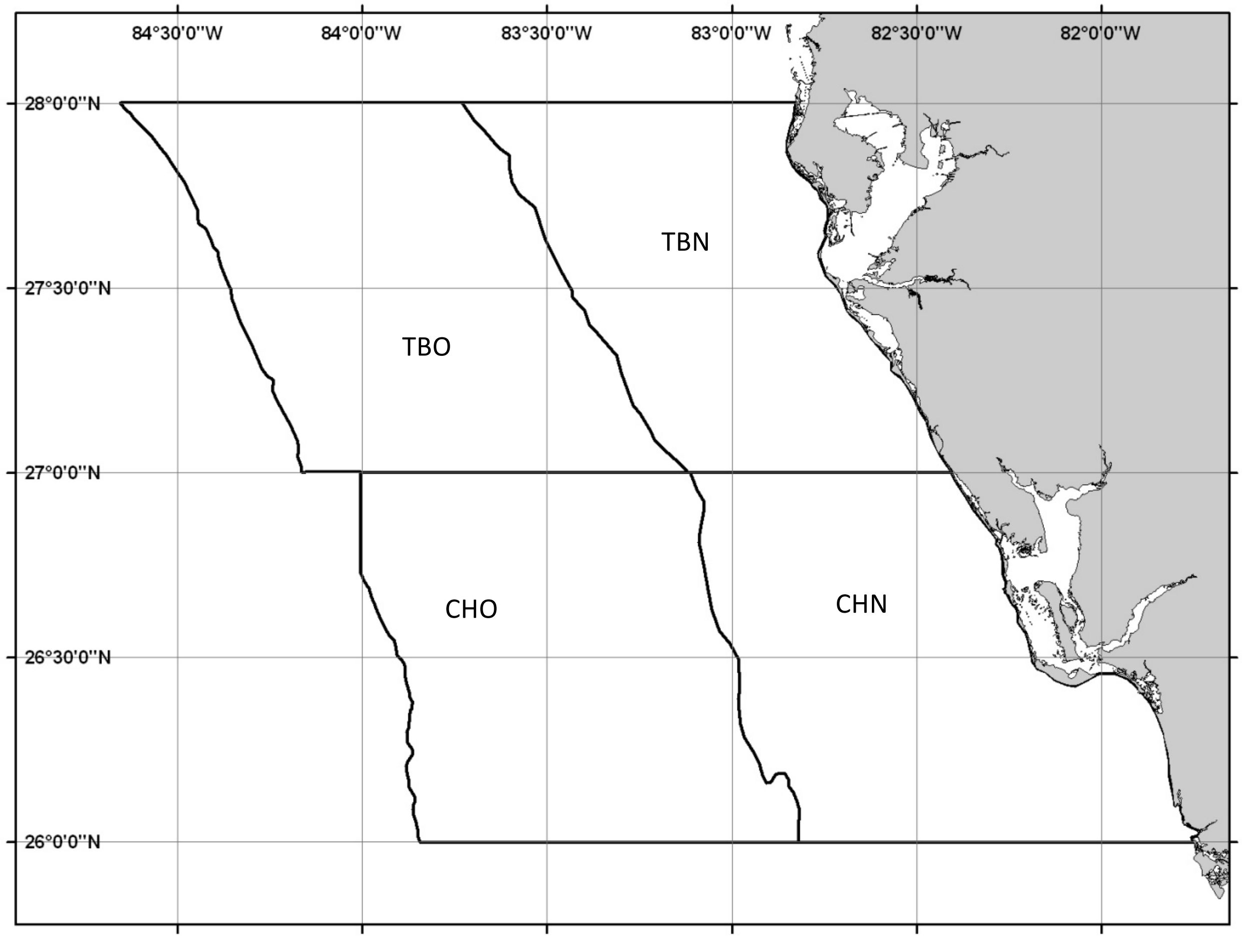


Figure 1. The West Florida Shelf survey area. The 20fa (37m) contour separates nearshore (i.e., TBN and CHN) and offshore (TBO and CHO) sampling zones. The sampling area includes waters 10m – 110m.

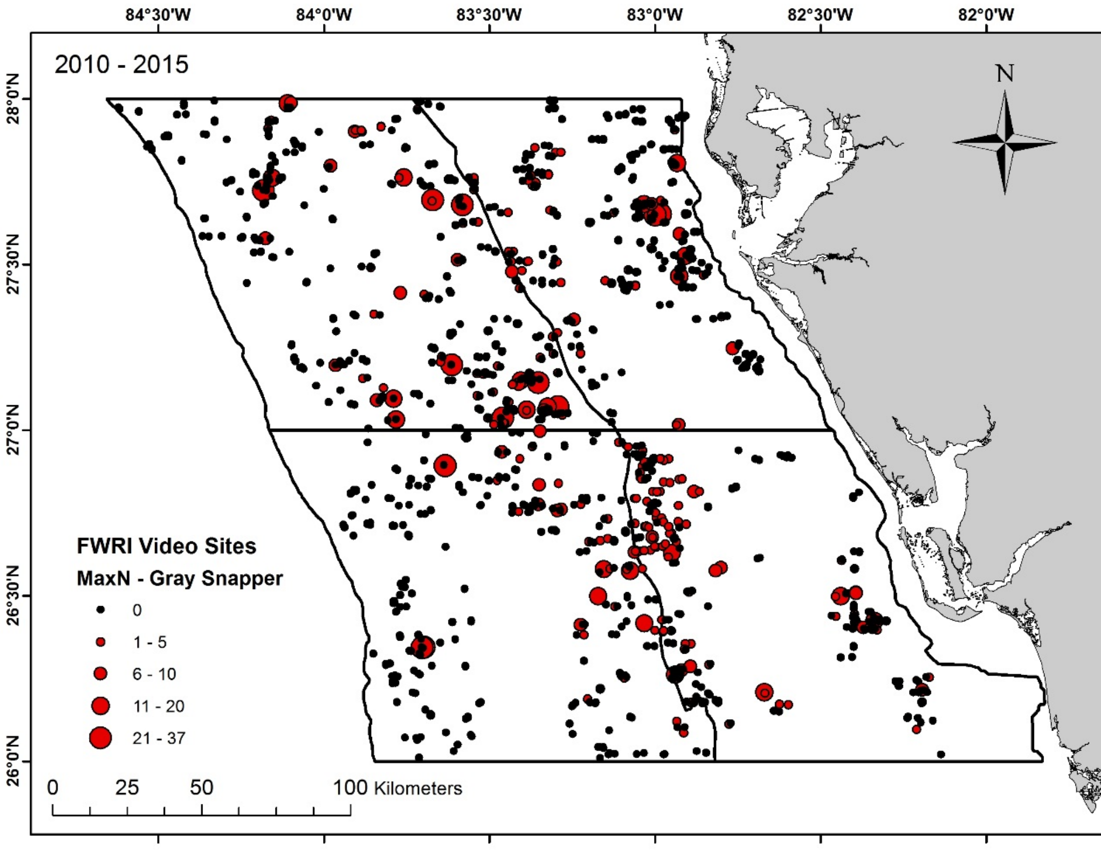


Figure 2. Stations sampled from 2010 – 2015 during the FWRI reef fish video survey. Symbols represent MaxN, or the maximum number of gray snapper observed on a single screen shot during each video.

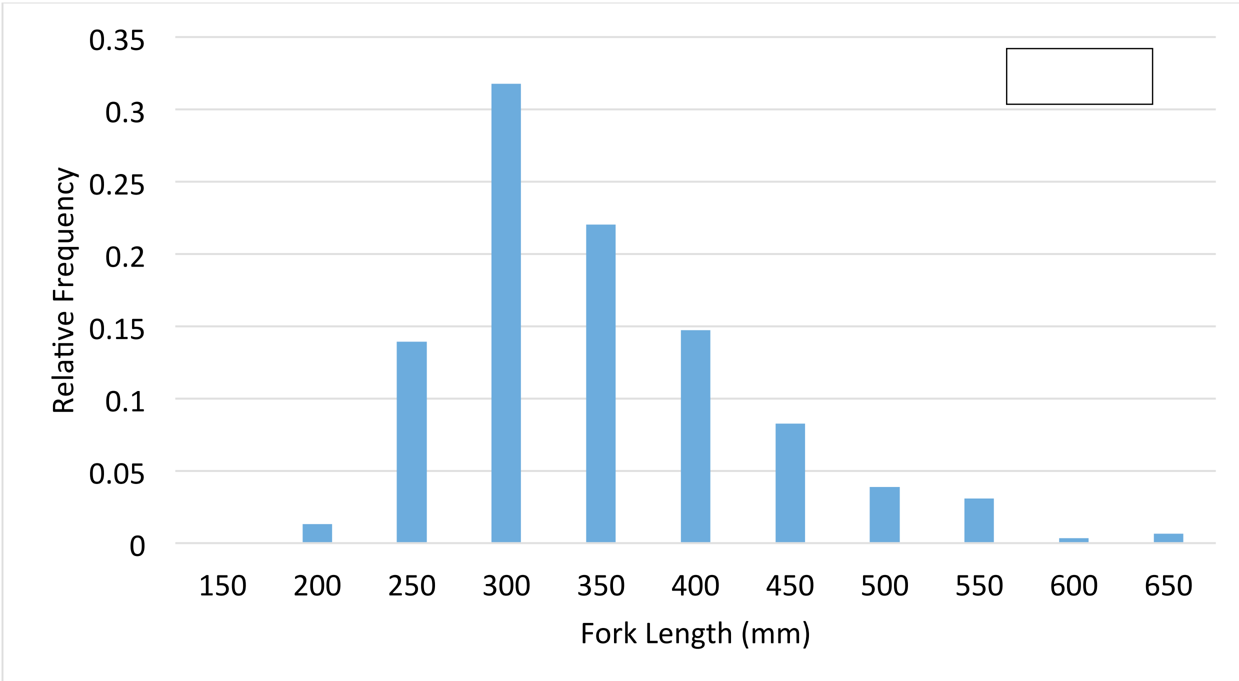


Figure 3. Length frequency distribution of Gray Snapper observed on SUCAs and measures using Vision Measurement System software.

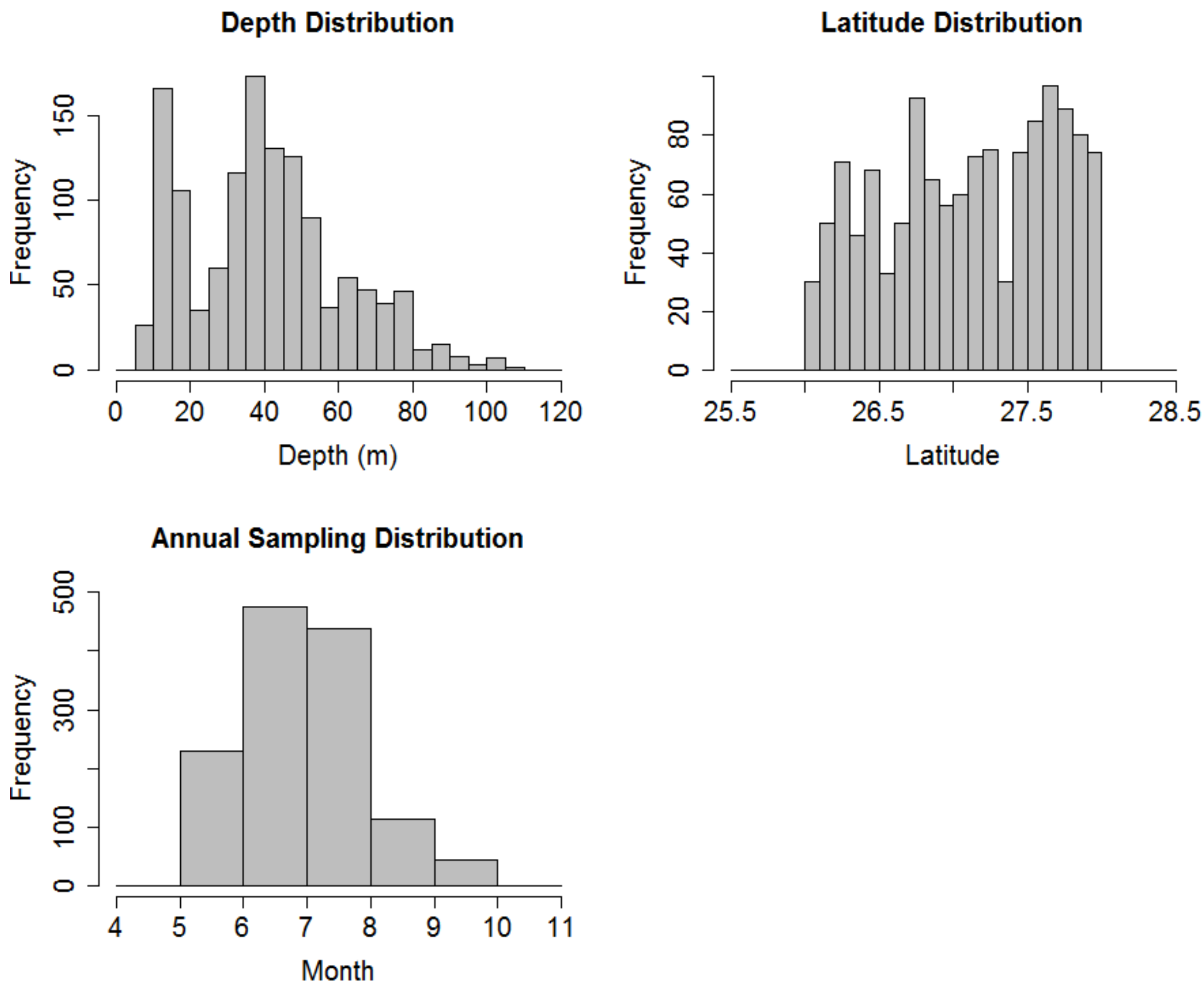


Figure 4. Sample distribution for the original continuous variables.

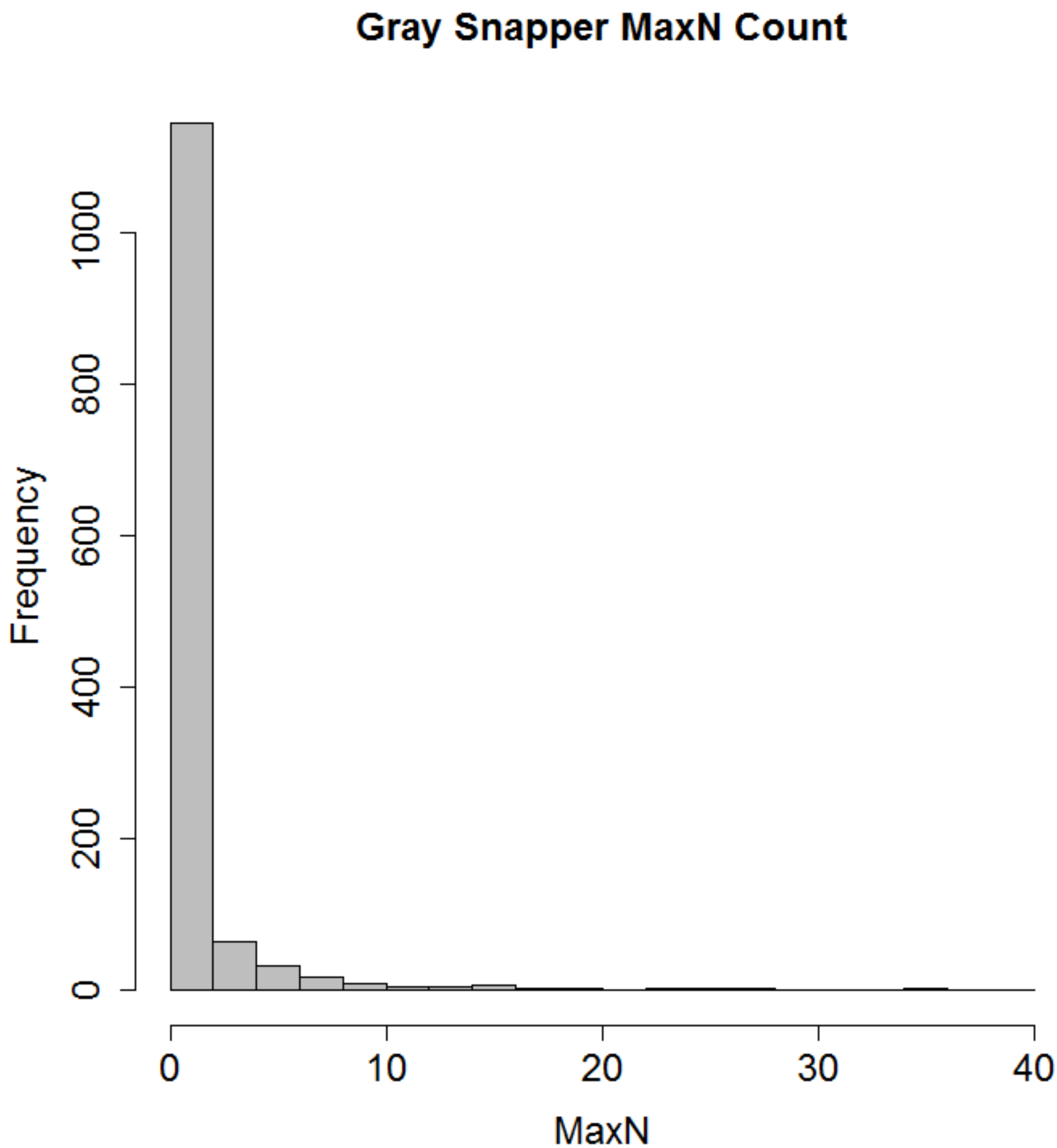


Figure 5. MaxN count distribution for Gray Snapper FWRI video surveys on the West Florida Shelf.

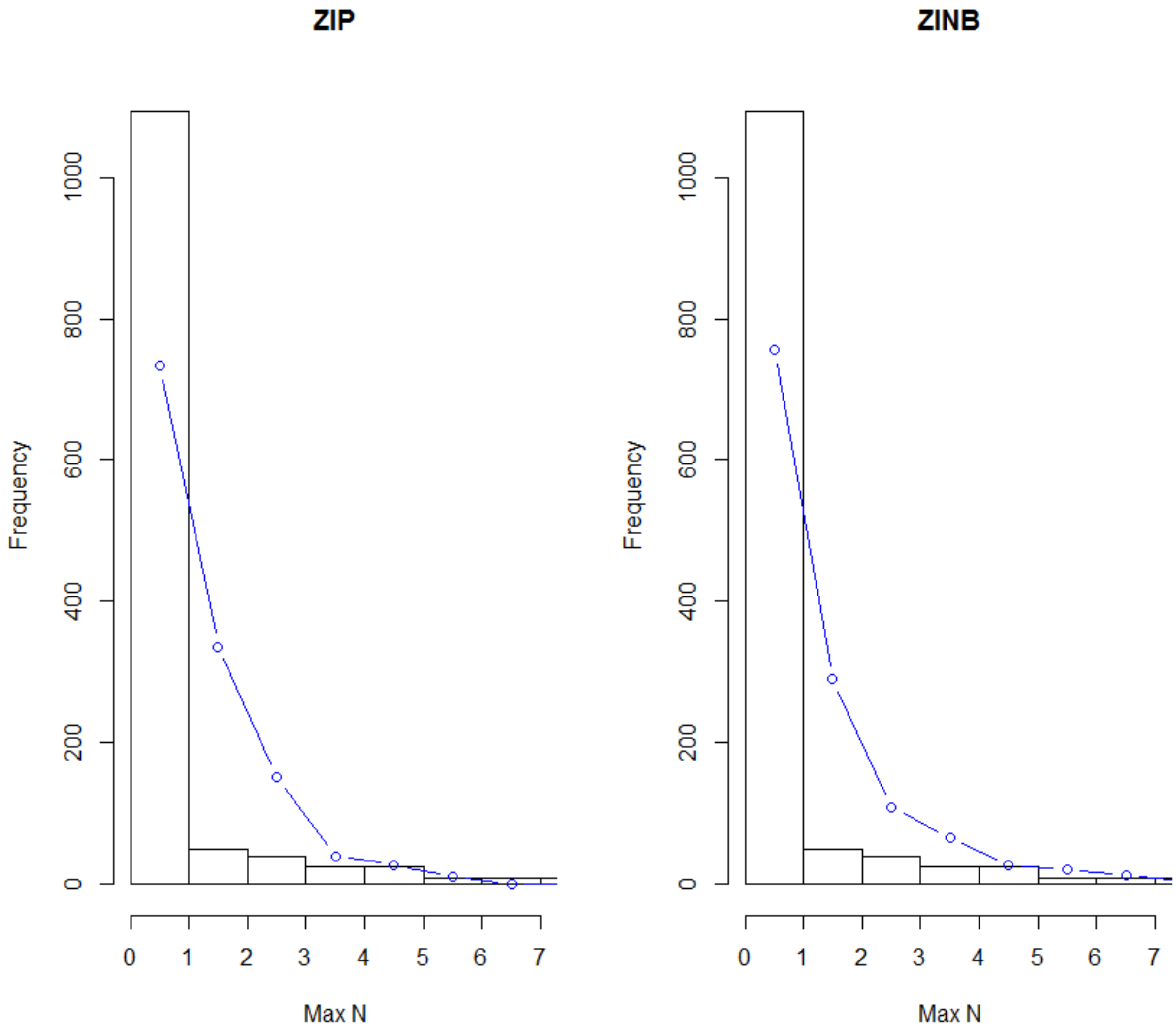


Figure 6. Full model formulation comparison, with zero-inflated Poisson and negative binomial fitted values plotted against the original data distribution.

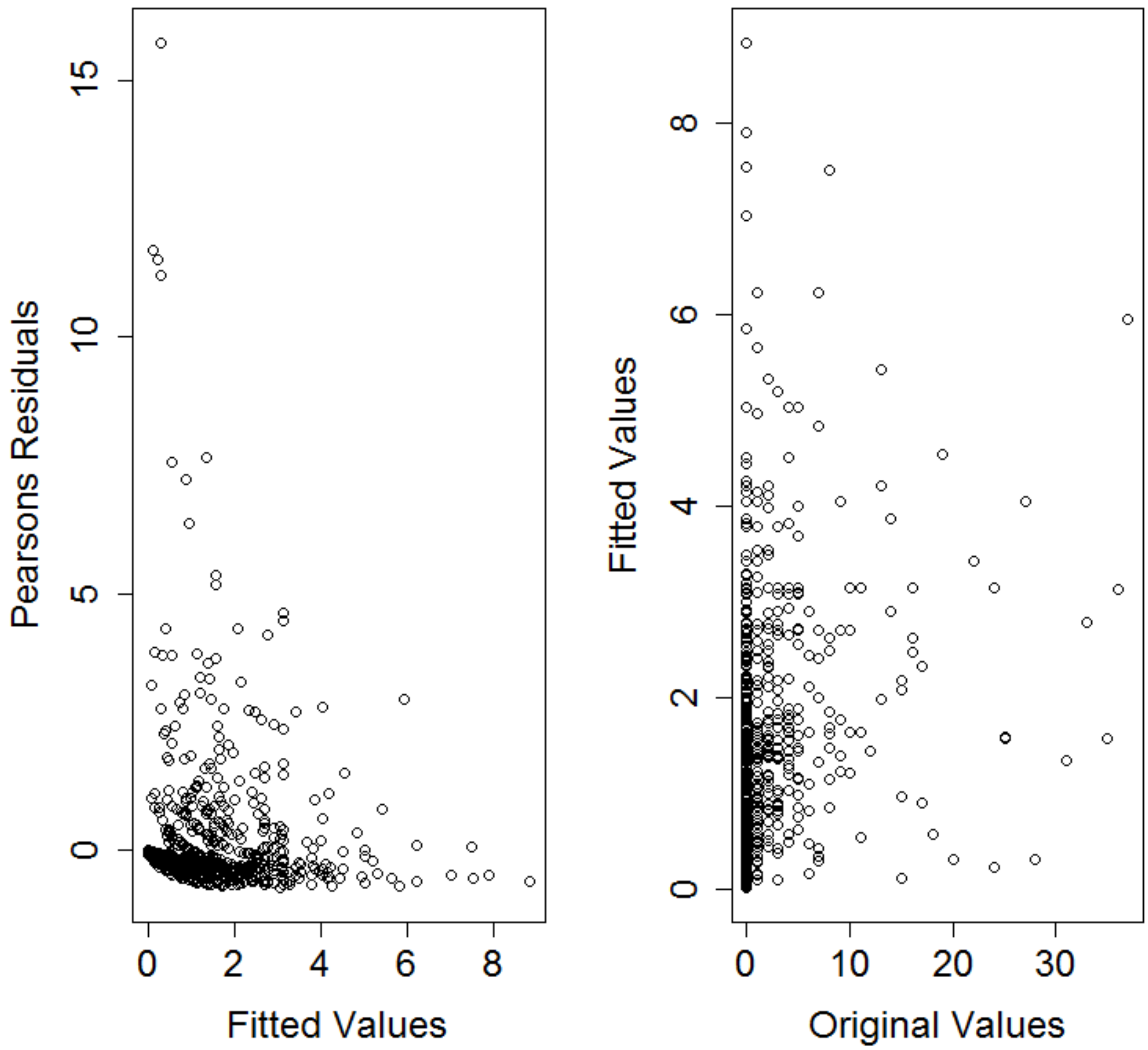


Figure 7. Model diagnostic plots showing fitted best model values against Pearson residuals (left panel) and fitted values plotted against original data values (right panel).

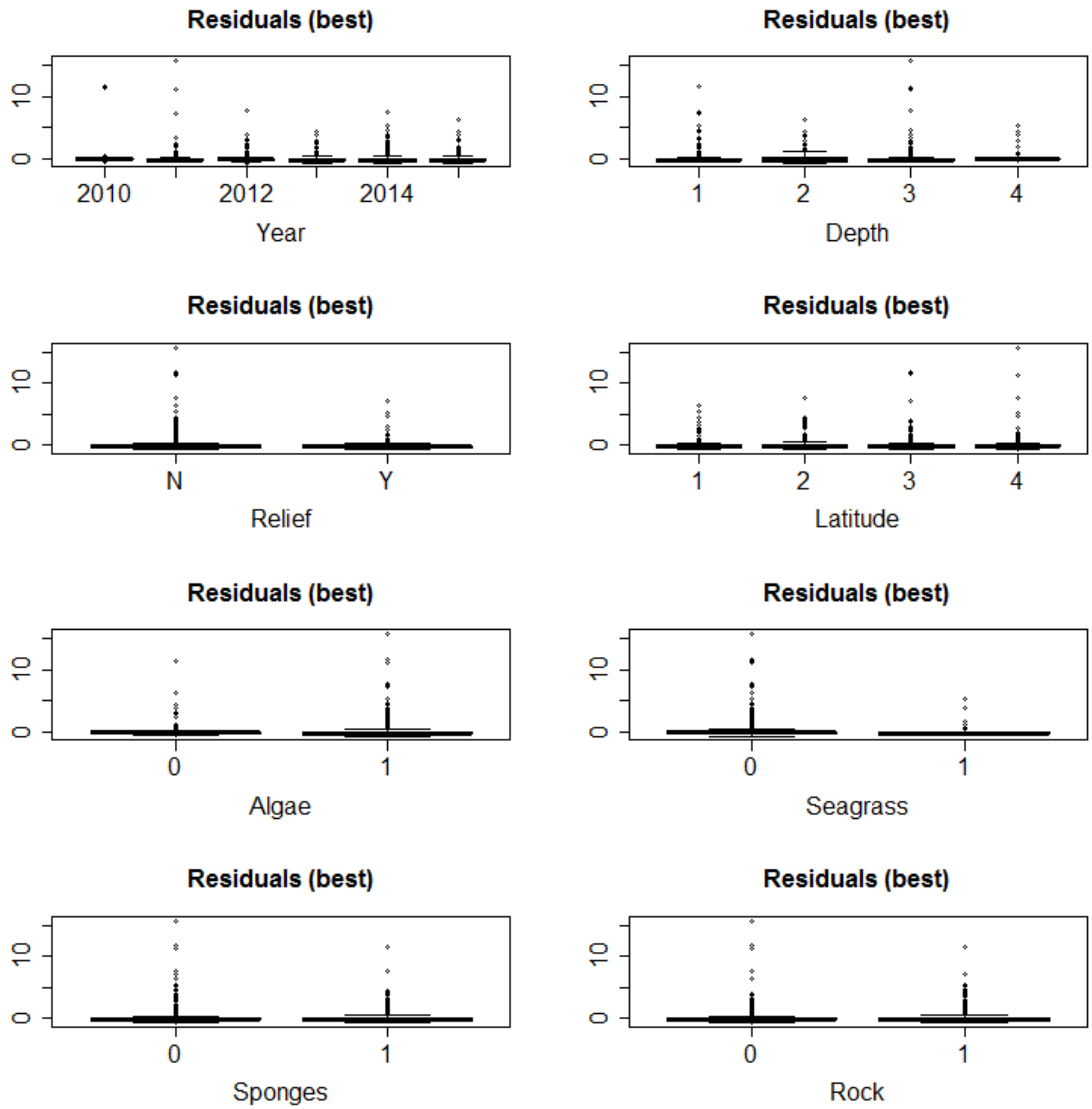


Figure 8. Model diagnostic plots showing Pearson residuals for the final (best) model plotted against spatiotemporal and environmental model parameters.

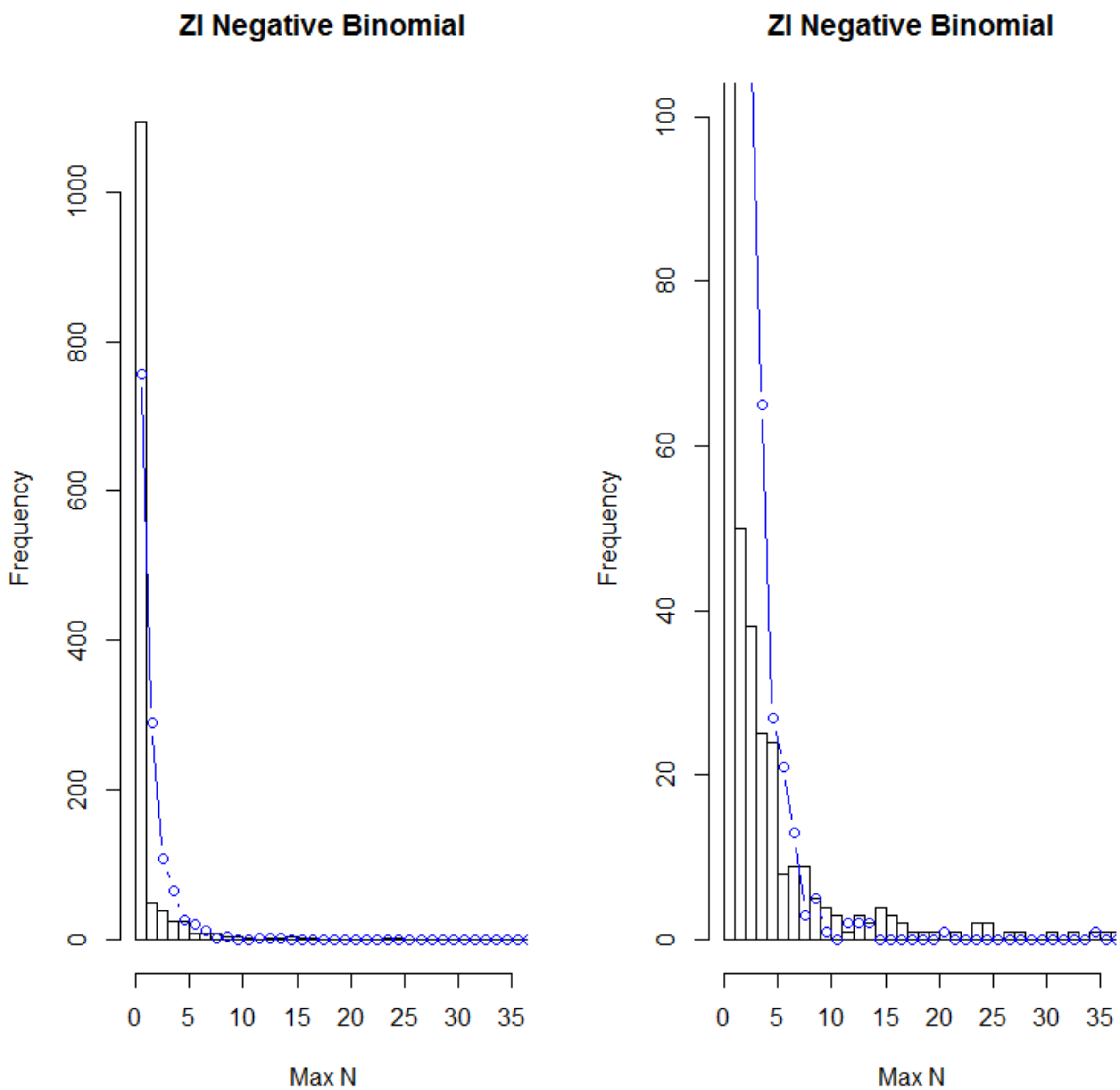


Figure 9. Model diagnostic plots of fitted model values (blue line) against the original data distribution. Full distribution view (left panel) and limited y-axis view (right panel).

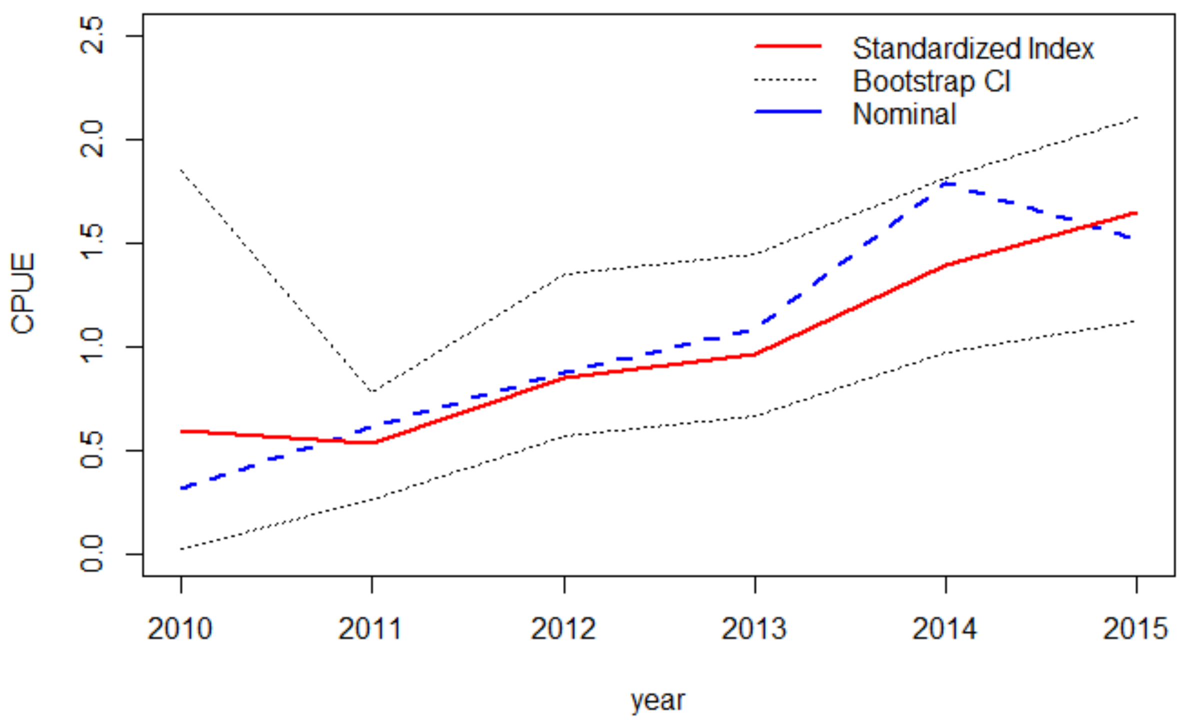
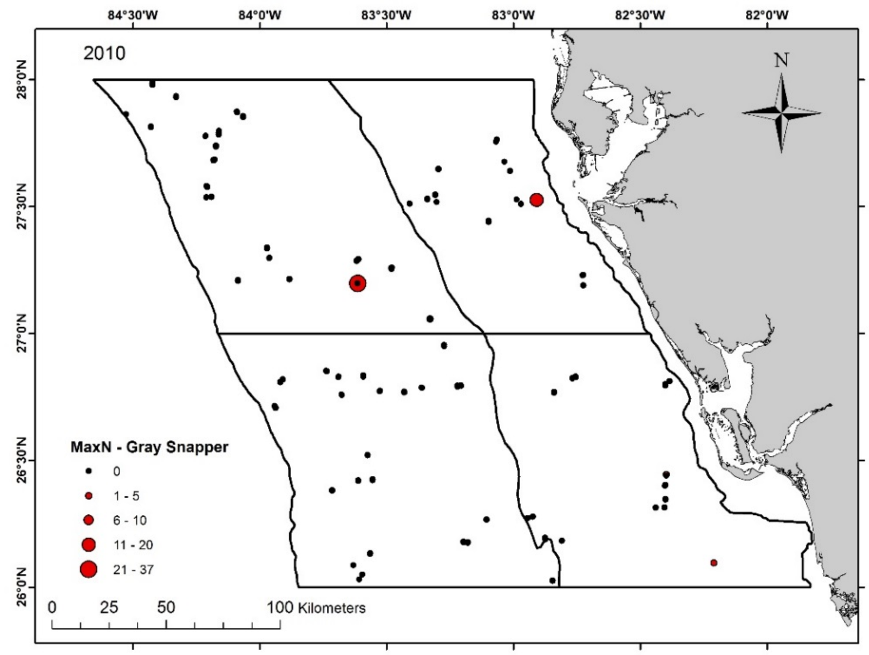
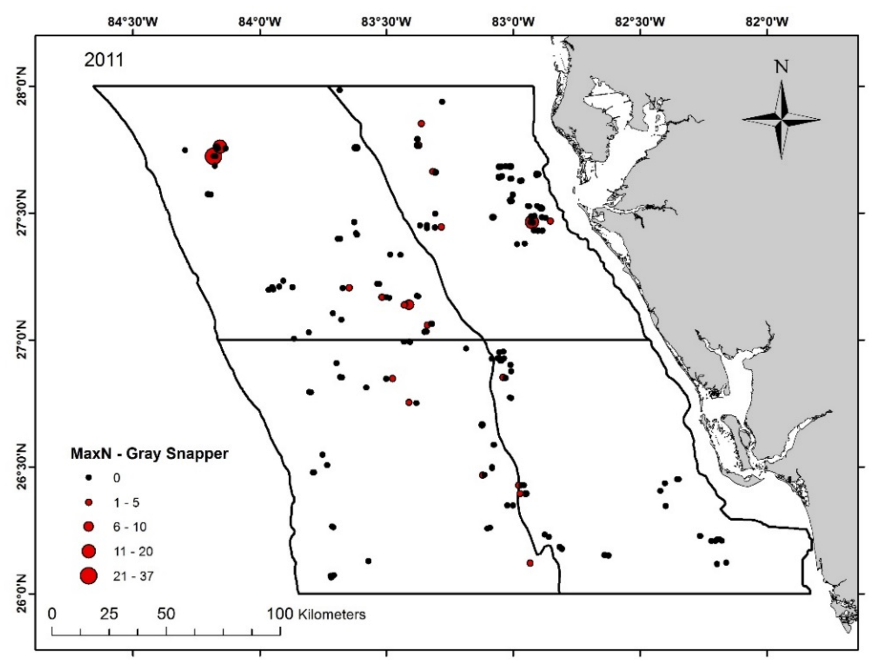


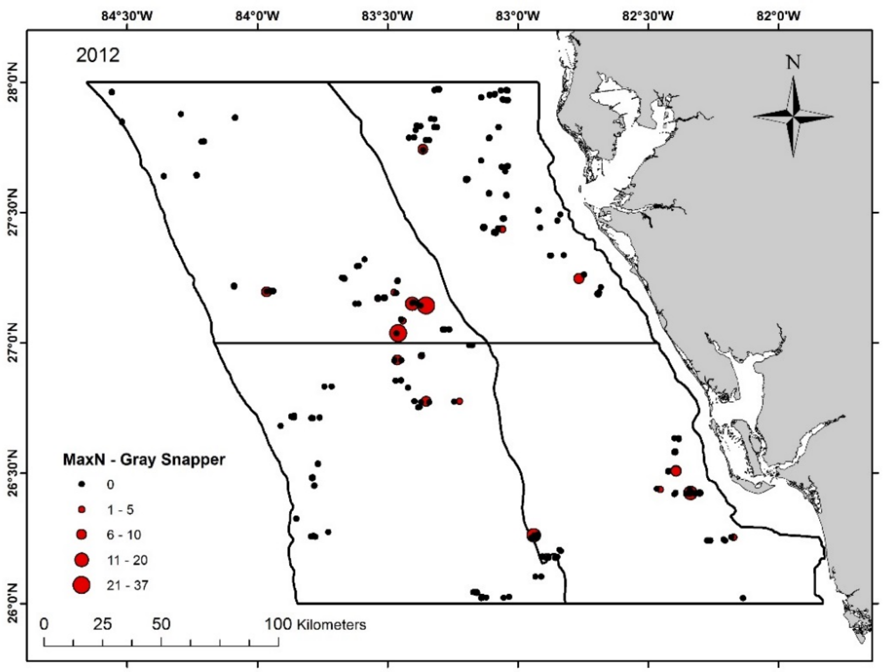
Figure 10. Relative standardized index (solid red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and the nominal index (blue hashed line) for Gray Snapper CPUE in the FWRI West Florida Shelf Video Survey.

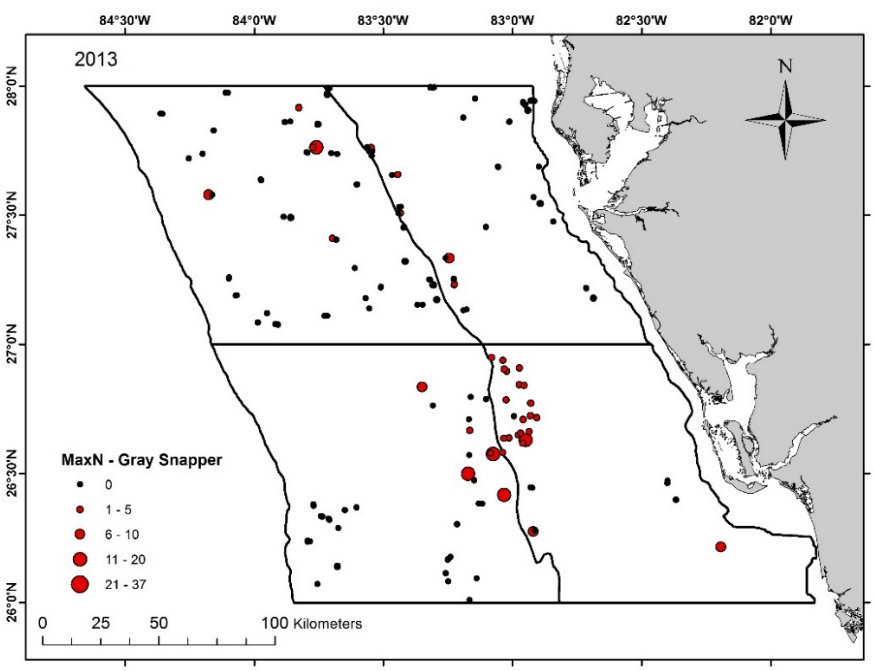
Appendix A

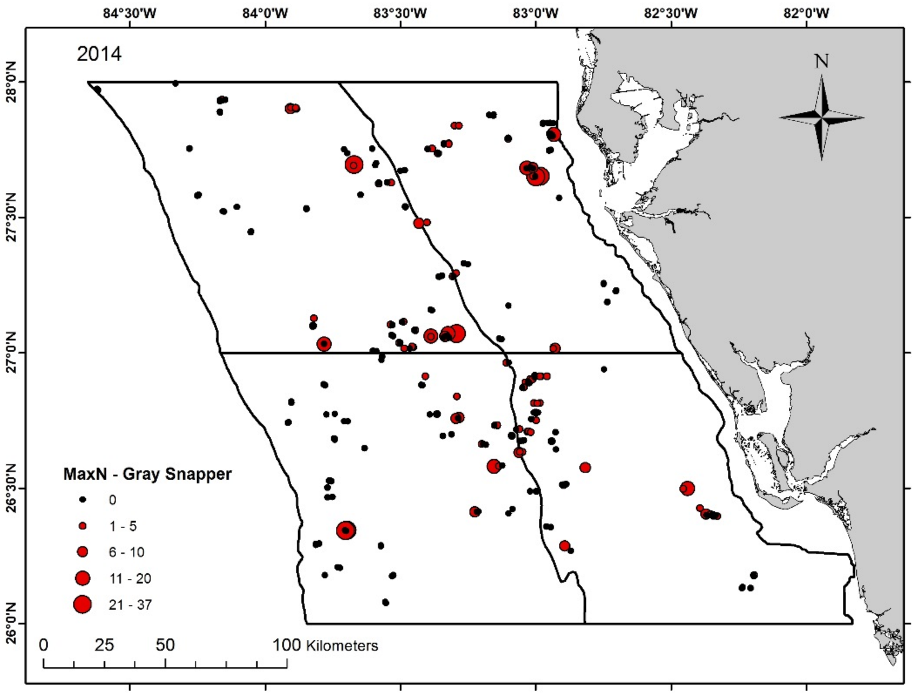
Figures A1-A6. Annual distribution of stations sampled (2010 – 2015) during the FWRI reef fish video survey. Symbols represent MaxN, or the maximum number of gray snapper observed on a single screen shot during each video.

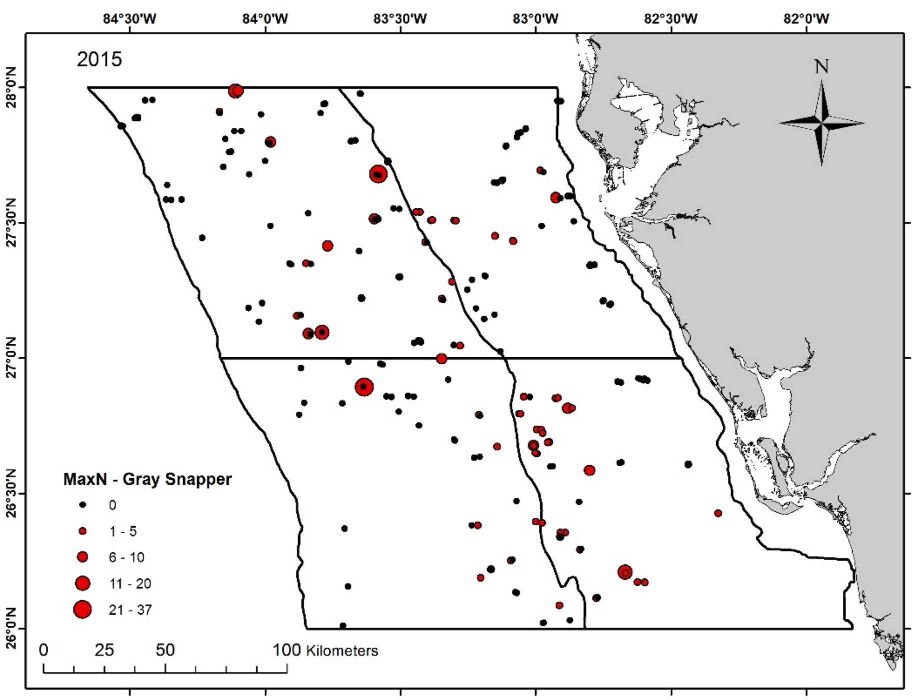





84°30'W
84°0'W
83°30'W
83°0'W
82°30'W
82°0'W
2012
28°0'N
27°30'N
27°0'N
26°30'N
26°0'N
N
MaxN - Gray Snapper
0
1 - 5
6 - 10
11 - 20
21 - 37
0 25 50 100 Kilometers


84°30'W
84°0'W
83°30'W
83°0'W
82°30'W
82°0'W
2013
28°0'N
27°30'N
27°0'N
26°30'N
26°0'N
N
MaxN - Gray Snapper
0
1 - 5
6 - 10
11 - 20
21 - 37
0 25 50 100 Kilometers


84°30'W
84°0'W
83°30'W
83°0'W
82°30'W
82°0'W
28°0'N
27°30'N
27°0'N
26°30'N
26°0'N
2014
N
MaxN - Gray Snapper
0
1 - 5
6 - 10
11 - 20
21 - 37
0 25 50 100 Kilometers


84°30'W
84°0'W
83°30'W
83°0'W
82°30'W
82°0'W
28°0'N
27°30'N
27°0'N
26°30'N
26°0'N
2015
N
MaxN - Gray Snapper
0
1 - 5
6 - 10
11 - 20
21 - 37
0 25 50 100 Kilometers