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Indices of abundance for Red Grouper (*Epinephelus morio*) from the Florida Fish and Wildlife Research Institute (FWRI) chevron trap survey on the West Florida Shelf

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Introduction:

Reef fishes, including Red Grouper, 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 data for reef fishes, 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 Grouper 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 (Figure 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). 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.

At each sampling station, 1 – 4 chevron traps were deployed based on the quantity and distribution of identified reef habitat. Each chevron trap (1.76m x 1.52m x 0.61m; 28cm throat diameter; 3.81cm vinyl-clad mesh) was baited with fresh Atlantic Mackerel prior to deployment, and allowed to soak for a target of 90 minutes prior to retrieval. All Red Grouper captured were counted and measured to the nearest mm standard length (SL) and total length (TL); results are summarized by SL. In addition to the total number of Red Grouper captured, geographic coordinates, depth, physiochemical conditions (e.g., temperature, salinity, dissolved oxygen, pH), and time of day were generally recorded at each sampling site. All sampling was conducted from June to October, and although overnight trap sets were conducted during the first two years of the survey, our analyses only included those sets conducted during daylight hours.

Data Treatment and Standardization:

Data Subsetting:

Prior to conducting statistical analyses, data from overnight trap sets were removed, as were any trap set that was over four hours in duration. In total, this excluded 281 traps from subsequent analyses.

Overall, 2,186 chevron trap survey deployments were evaluated for developing indices of relative abundance for Red Grouper during the six year sampling period (2008-2013). We excluded any data points where variables of interest were not recorded or standardized sampling methods were not followed. Of the 2,186 trap samples considered for inclusion in the modeling analysis, only four were removed based on the data subsetting approach described, leaving 2,184 samples available for Red Grouper trap analyses from 2008-2013. Annual trapping effort varied from 291 – 506 traps per year (Table 1; Figures 2 – 7). Red Grouper caught in traps ranged from 147 – 709 mm SL, although most were between 200 and 500 mm SL (Figure 8).

Explanatory Variables:

The response variable for the trap data is the total number of Red Grouper captured per trap set. We considered nine explanatory variables in the model analysis: year, month, depth, latitude, temperature, dissolved oxygen, salinity, soak time, and presence/absence of Sand Perch, *Diplectrum formosum* (a habitat proxy to account for improved ability at targeting reef habitat through time). Temperature, dissolved oxygen and salinity were immediately dropped from the analysis since these variables were sporadically recorded during the early portion of the sampling time frame, leaving six candidate explanatory variables for consideration in the model.

Year (*Y*) – Year was included since standardized catch rates by year are the objective of the analysis. We modeled data from 2008-2013, annual summaries of data points considered are presented in Table 1.

Month (*M*) – A temporal parameter based on month of sampling (Table 1; Figure 9).

Depth (*D*) – Water depth may be an important component affecting the distribution of Red Grouper and we included all depths sampled (Table 1; Figure 9). Depth was treated as a quantile factor.

Latitude (*Lat*) – The latitude of trap samples was included as a spatial parameter in the model (Figure 9). Latitude was treated as a quantile factor in the models.

Soak Time (*Eff*) – The amount of time the trap is actively fishing could influence the total catch rate of Red Grouper and was included as a covariate in the model formulation as a quantile factor.

Habitat Proxy (*Df*) – Physical habitat descriptors were unavailable for the trap deployments, therefore we tested the presence/absence of Sand Perch, a species with a known preference for sandy bottom, as a habitat proxy.

Model Selection:

Trap 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 trap data may have a disproportionate number of zero counts that may differ from the standard error distributions used for count data (Figure 10). These data distributions are referred to as “zero-inflated” and are fairly common in ecologically based count data. Zero-inflation is considered a special case of over dispersion that cannot be easily addressed using tradition transformation procedures (Hall 2000). 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 null models were considered utilizing both a Poisson (P) and Negative binomial (NB) error distribution (1), and both Zero-inflated Poisson (ZIP) and zero inflated Negative Binomial (ZINB) formulations (2).

(1) $Total\ RG = Y + M + D + Lat + Eff + Df$

and

(2) *Total RG = Y + M + D + Lat + Eff + Df | Y + M + D + Lat + Eff + Df*

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 trap index for Red Grouper in the Eastern Gulf of Mexico. The likelihood ratio tests (Table 2; Figure 11) showed strong support for application of a ZINB formulation, and we selected this as the most probable model to continue analyses.

A backwards step-wise model selection procedure was used to exclude unnecessary parameters from the null model (2) formulation. The optimum Red Grouper model formulation (3) was determined using a combination of AIC and likelihood ratio tests (Zuur et al. 2009) and excluded month and soak time from the count portion of the model and presence/absence of Sand Perch (habitat proxy) from the binomial component of the model (Table 3).

(3) *Tot RG = Y + D + Lat + Df | Y + M + D + Lat + Eff*

Model diagnostics showed no discernible patterns of association between Pearson residuals and fitted values or the fitted values and the original data (Figure 12). An examination of residuals for the spatial and environmental model parameters (Figure 13) 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 (Figure 14) indicates a good fit between the model and original data.

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 pscle package (Jackman 2008), available from the Comprehensive R Archive Network (CRAN).

Results:

Annual standardized index values for Red Grouper in the Eastern Gulf of Mexico, including coefficients of variation are presented in Table 4. The relative nominal trap CPUE for Red Grouper reflected the standardized index of abundance with only the 2009 nominal value falling outside the 2.5% and 97.5% confidence intervals of the standardized index (Figure 15). The standardized index does slightly overestimate abundance in 2009. Due to a somewhat short temporal extent of the index, limited inferences can be discerned concerning patterns of Red Grouper abundance, nevertheless the index does indicate an overall increasing trend in trap catches from 2008-2013 with a peak in 2011.

Literature Cited:

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

Year	N	Depth Range (m)	Latitude Range	Month Range
2008	291	10 - 108	26.024 – 27.744	July - August
2009	432	7 - 105	26.000 – 27.990	June – Sept.
2010	303	10 - 102	26.028 – 27.985	July – August
2011	315	7 - 83	26.060 – 27.989	June – Sept.
2012	335	11 - 103	26.021 – 27.975	June – Sept.
2013	506	7 - 93	26.007 – 27.998	July – Oct.

Table 2. Preliminary model formulation comparisons.

	df	Likelihood	*df*	χ^2	*p*-value
Poisson	20	-3754.3			
Negative Binomial	21	-2673.4	1	2161.7	<0.001
ZIP	40	-2885.2			
ZINB	41	-2580.6	1	609.19	<0.001

Table 3. Model selection results for Zero-Inflated Negative Binomial model of Red Grouper observed during FWRI trap surveys on the West Florida Shelf, 2008-2013

	Removed Term						
Step	Count Process	Binomial Process	*df*	AIC	χ^2	*df*	*p* - value
Null	<none>	<none>	41	5243.14			
1	Eff	<none>	38	5238.99	1.849	3	0.604
2	Eff, M	<none>	34	5241.39	10.407	4	0.034
3	<none>	Df	33	5239.78	0.387	1	0.534

Table 4. Relative nominal CPUE, number of Red Grouper captured (N), proportion of positive sets, standardized index, and CV for FWRI Red Grouper trap index of the West Florida Shelf, 2008-2013.

Year	Relative Nominal CPUE	N	Proportion positive	Standardized Index	CV
2008	0.138	291	0.044	0.083	0.786
2009	0.492	432	0.197	0.774	0.149
2010	0.667	303	0.228	0.561	0.192
2011	2.600	315	0.627	2.539	0.077
2012	0.993	335	0.423	0.953	0.101
2013	1.111	506	0.447	1.089	0.098

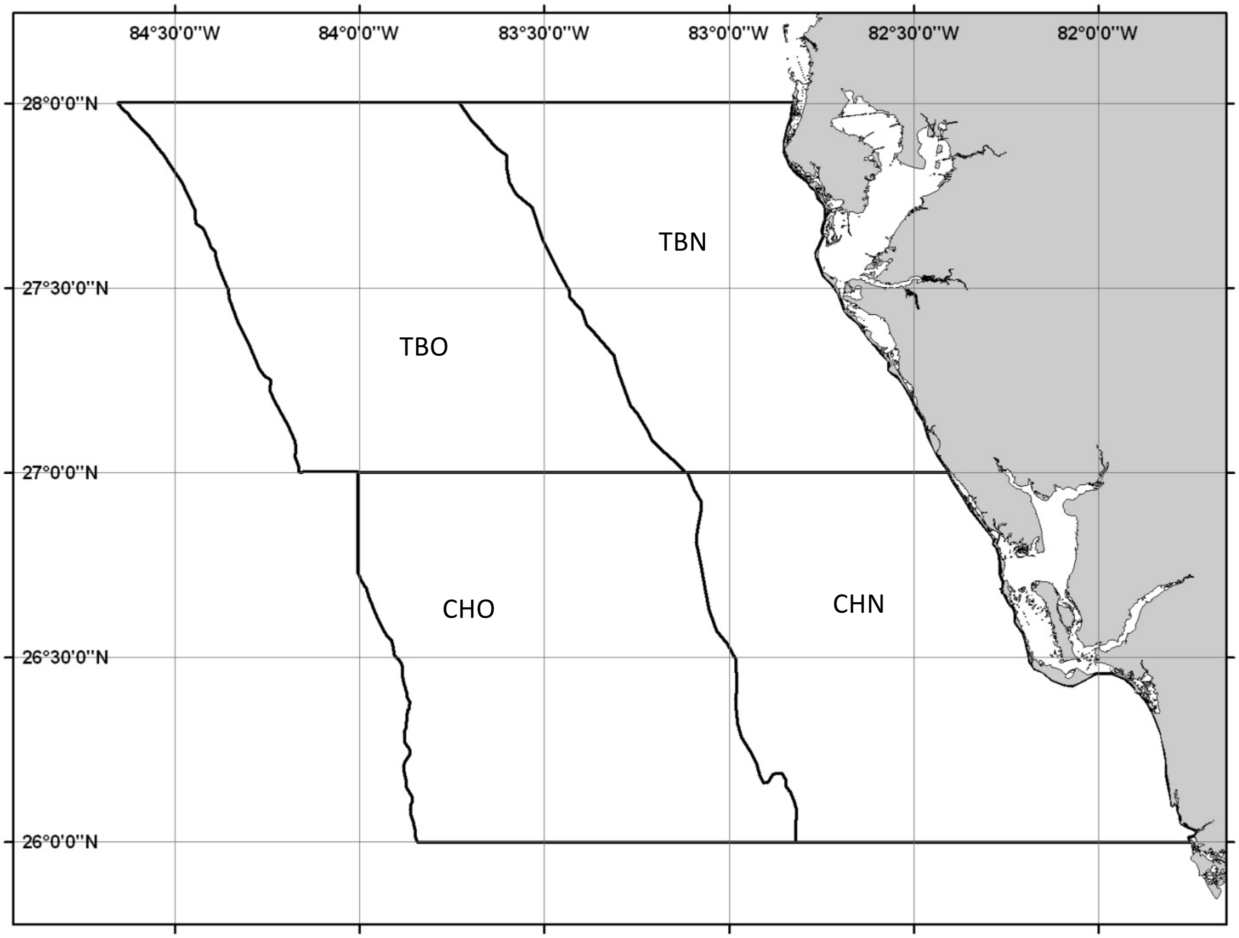

Figure 1. The West Florida Shelf survey area. The 20fa (37m) contour separates nearshore (i.e., TBN and CHN) and offshore (TBO and CHO) sampling zones. The sampling area includes waters 10m – 110m.

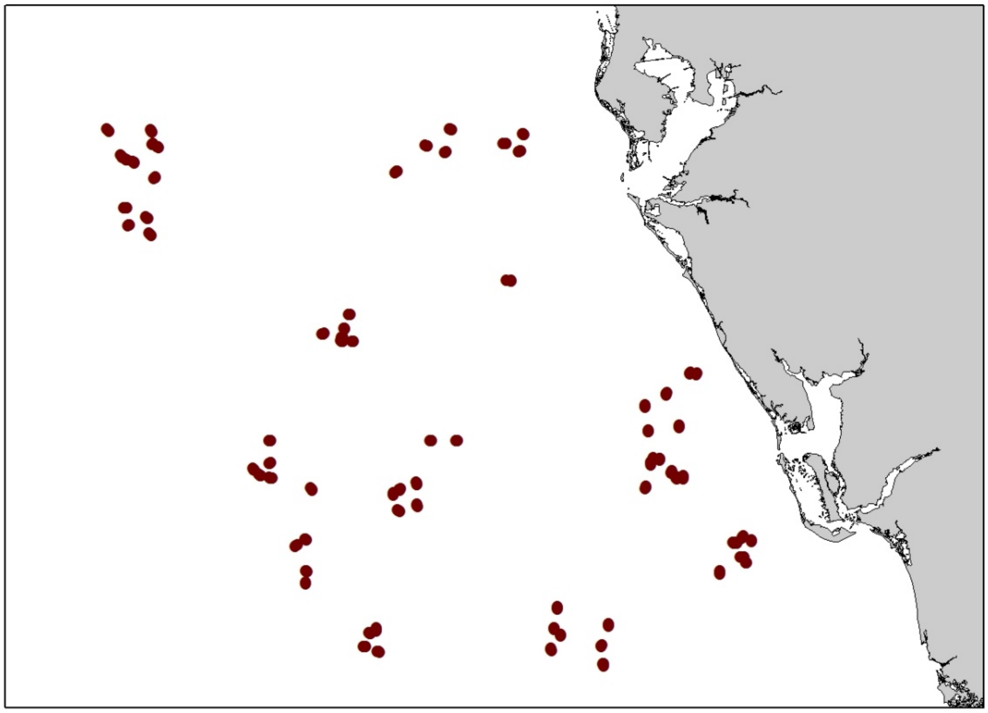

Figure 2. Map of sampling locations where chevron traps were deployed in 2008.

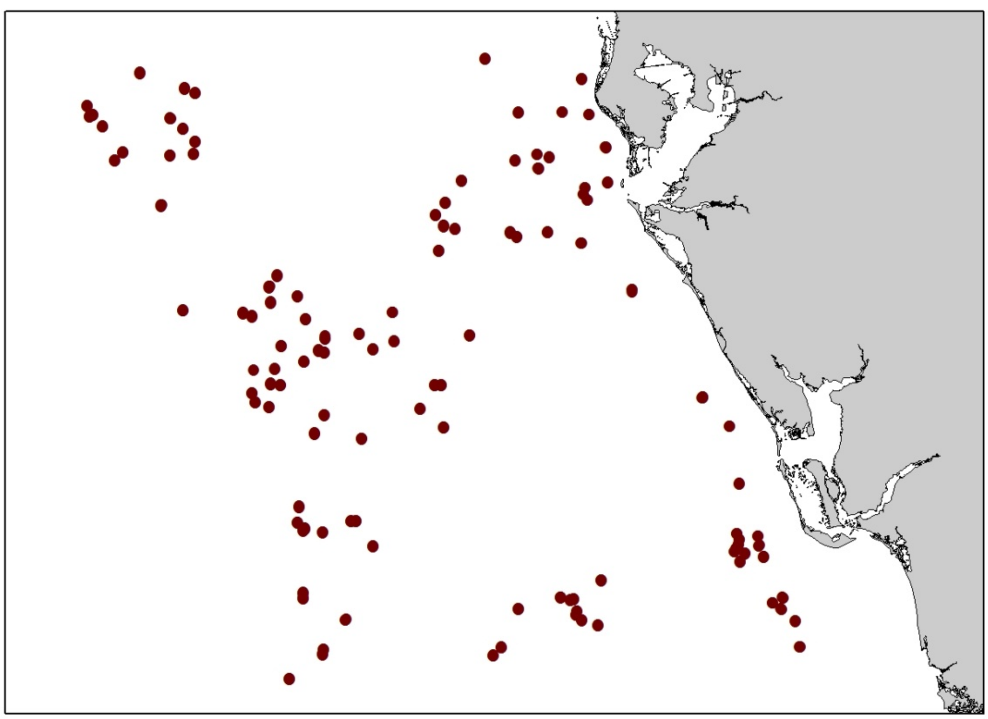

Figure 3. Map of sampling locations where chevron traps were deployed in 2009.

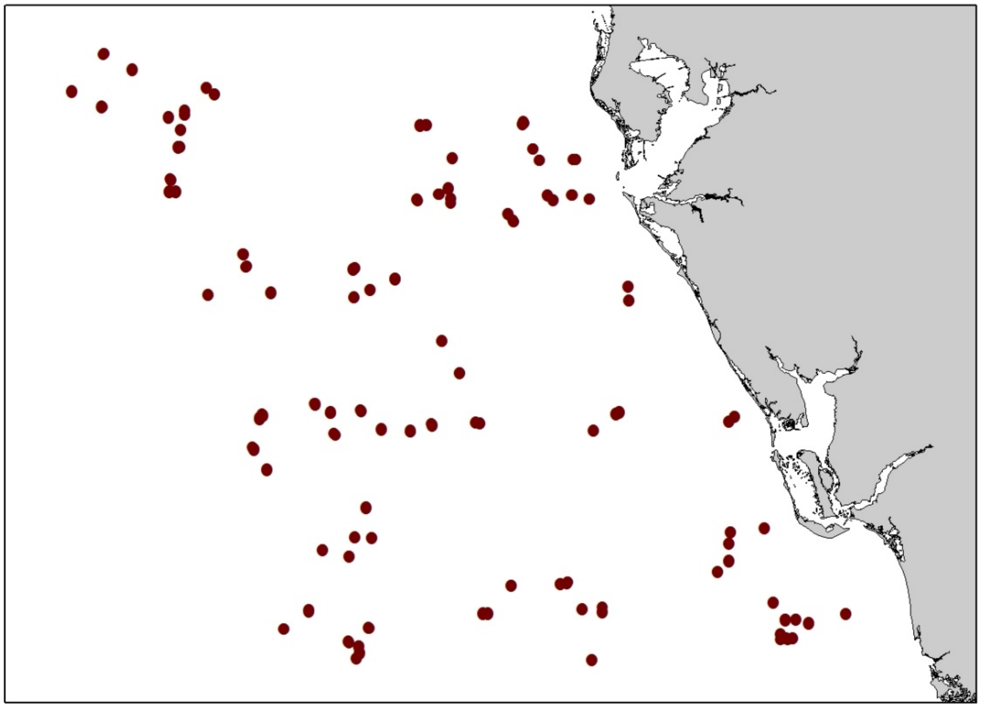

Figure 4. Map of sampling locations where chevron traps were deployed in 2010.

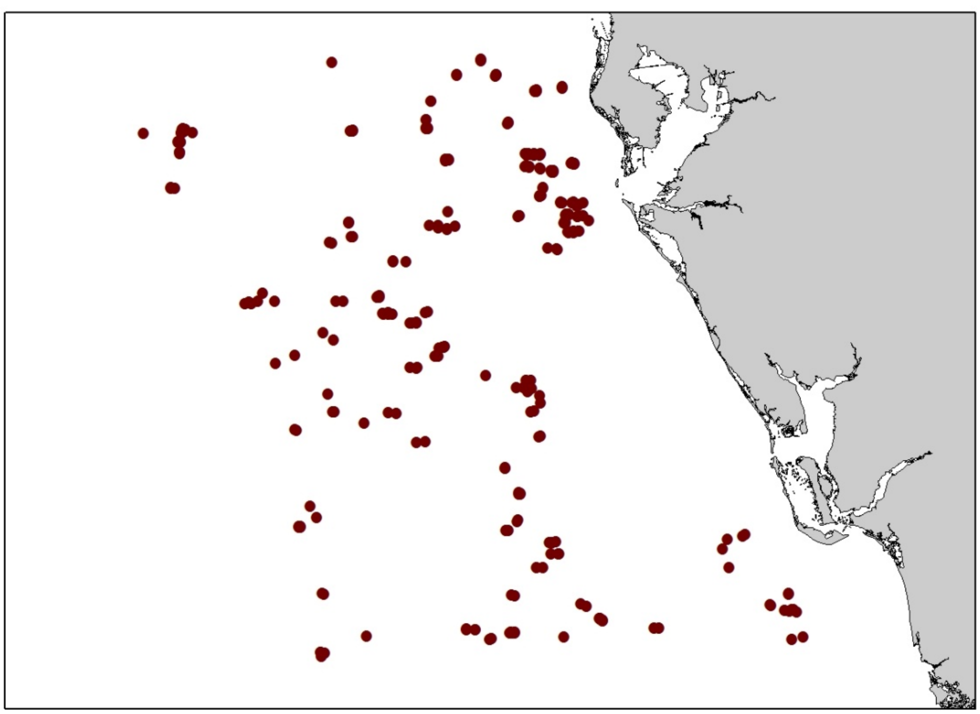

Figure 5. Map of sampling locations where chevron traps were deployed in 2011.

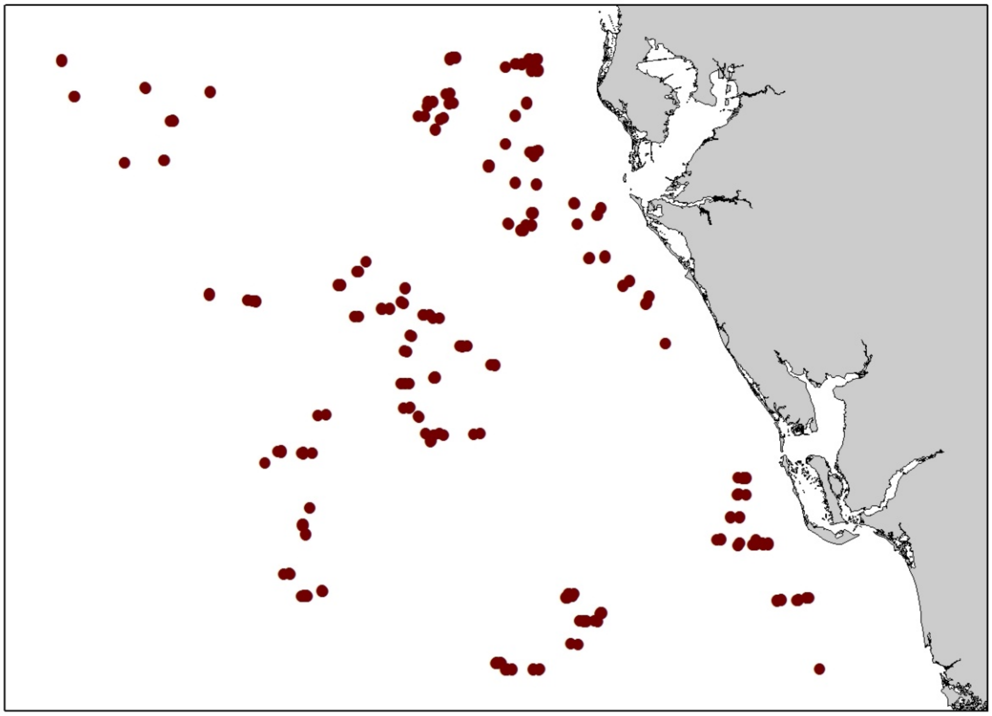

Figure 6. Map of sampling locations where chevron traps were deployed in 2012.

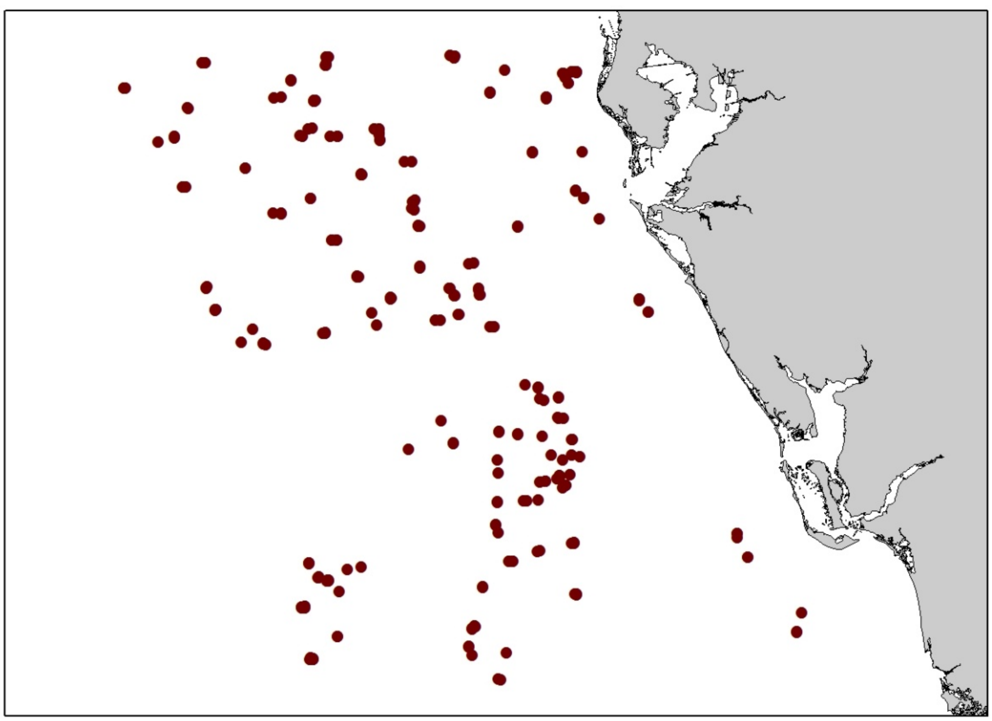

Figure 7. Map of sampling locations where chevron traps were deployed in 2013.

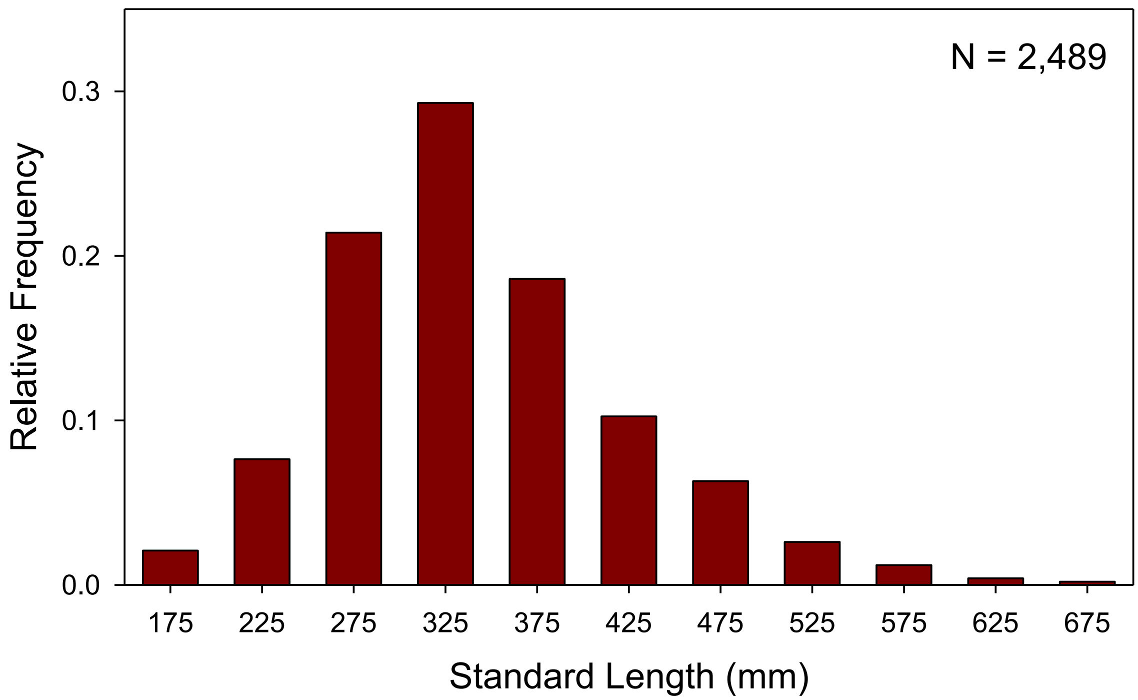

Figure 8. Length frequency distribution of Red Grouper captured in chevron traps.

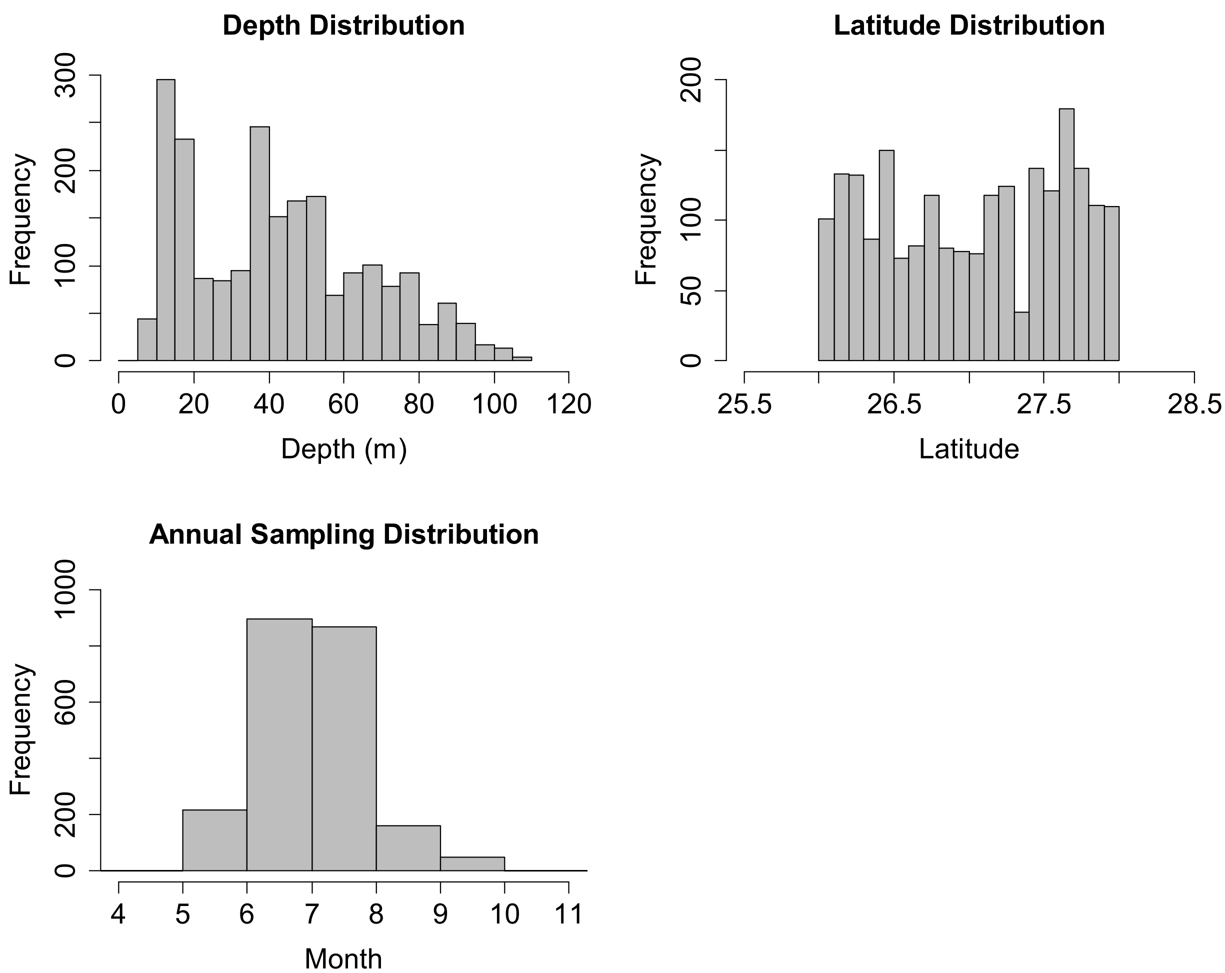

Figure 9. Sample distribution for the original continuous variables.

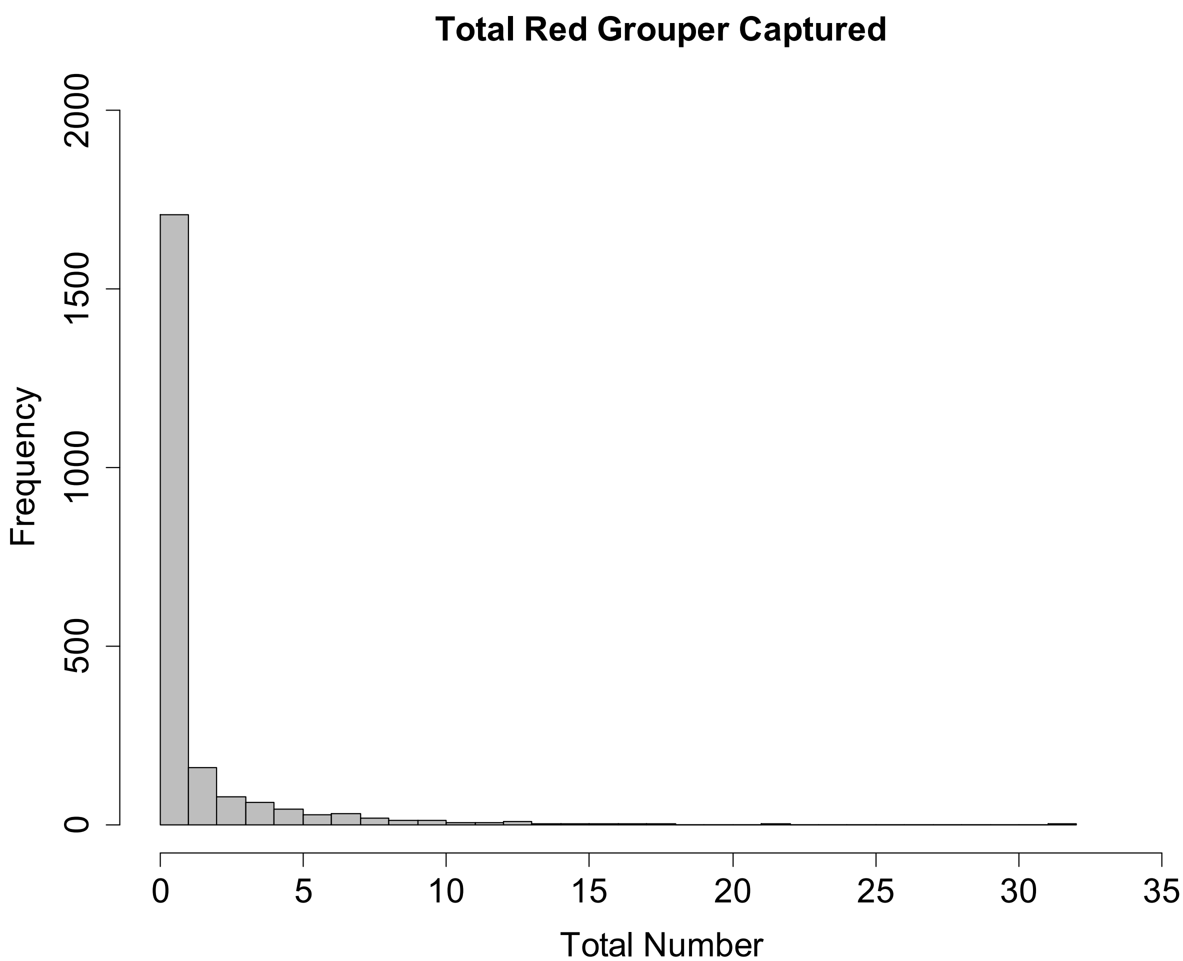

Figure 10. Total count distribution for Red Grouper FWRI trap surveys on the West Florida Shelf.

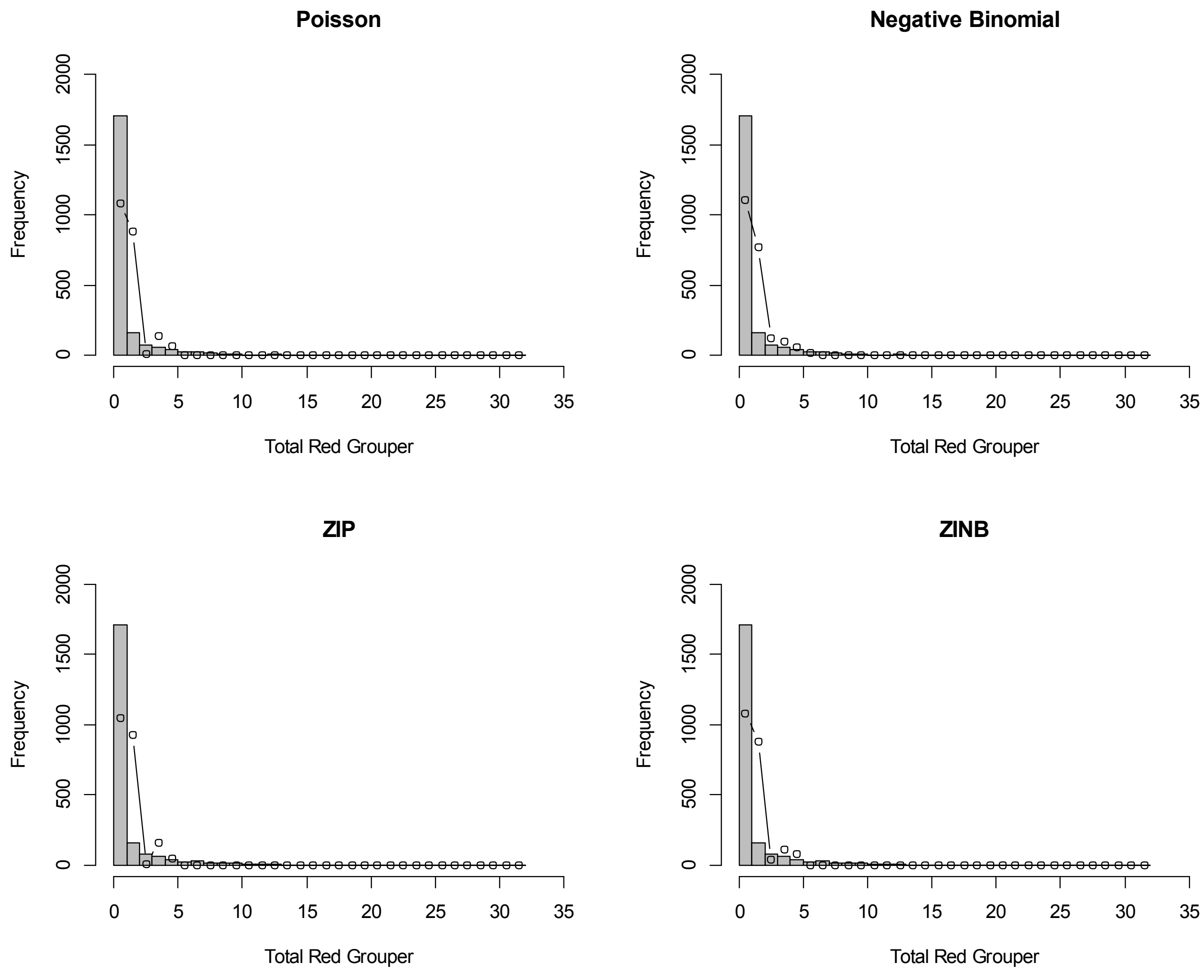

Figure 11. Model formulation comparison, with Poisson (top left), negative binomial (top right), ZIP (bottom left) and ZINB (bottom right) fitted values plotted against the original data distribution.

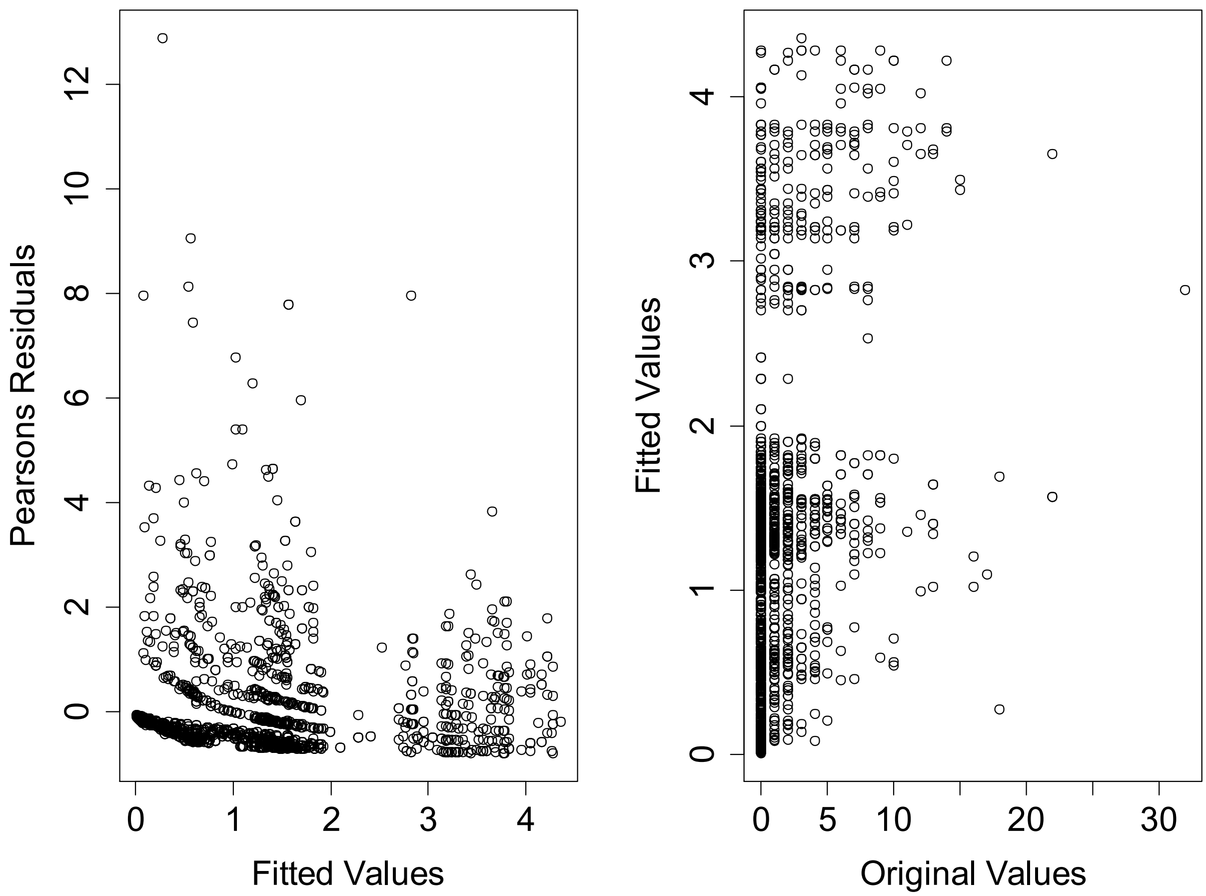

Figure 12. Model diagnostic plots showing fitted model values against Pearson residuals (left panel) and fitted values plotted against original data values (right panel).

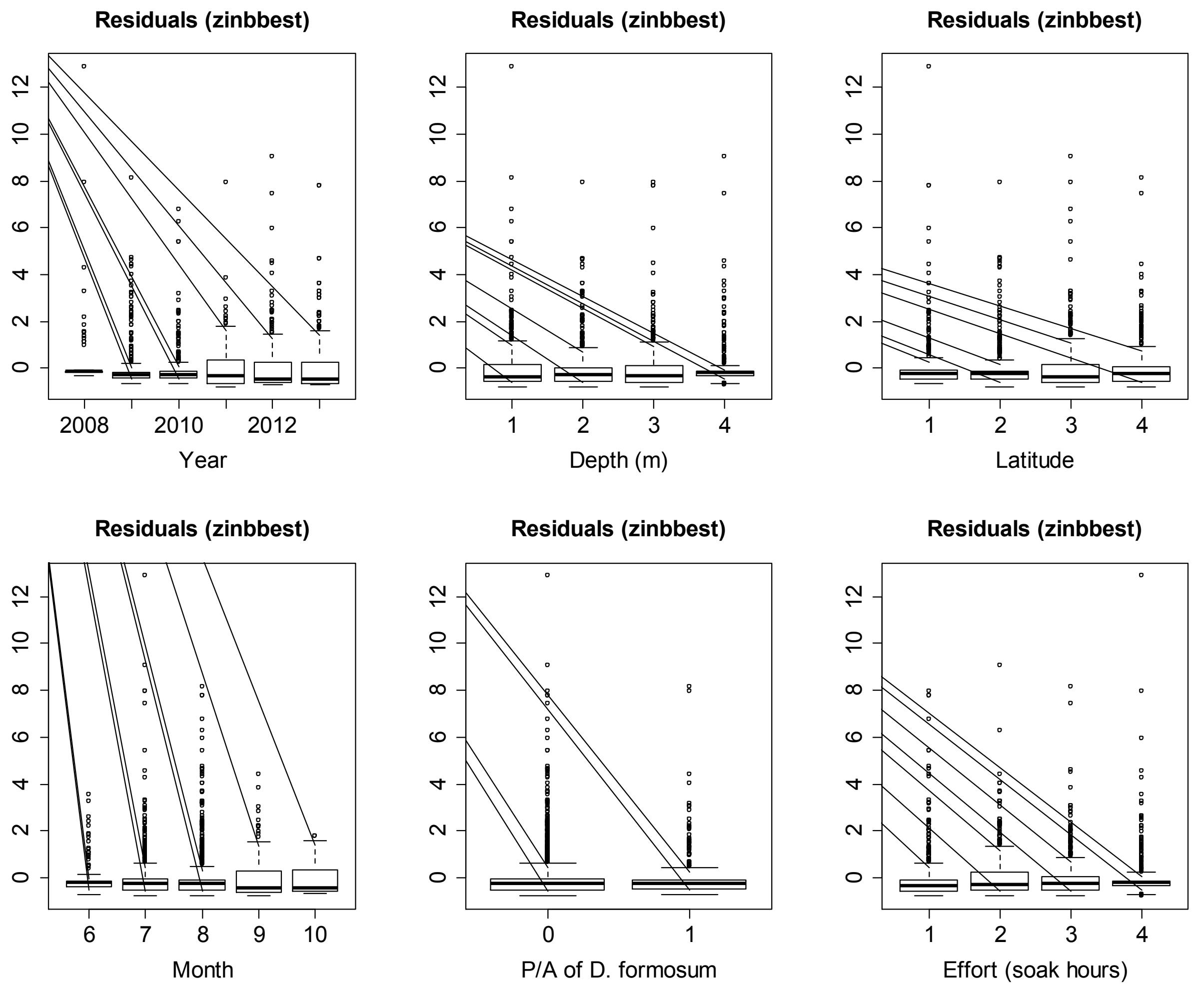

Figure 13. Model diagnostic plots showing Pearson residuals for the final model plotted against spatiotemporal and environmental model parameters.

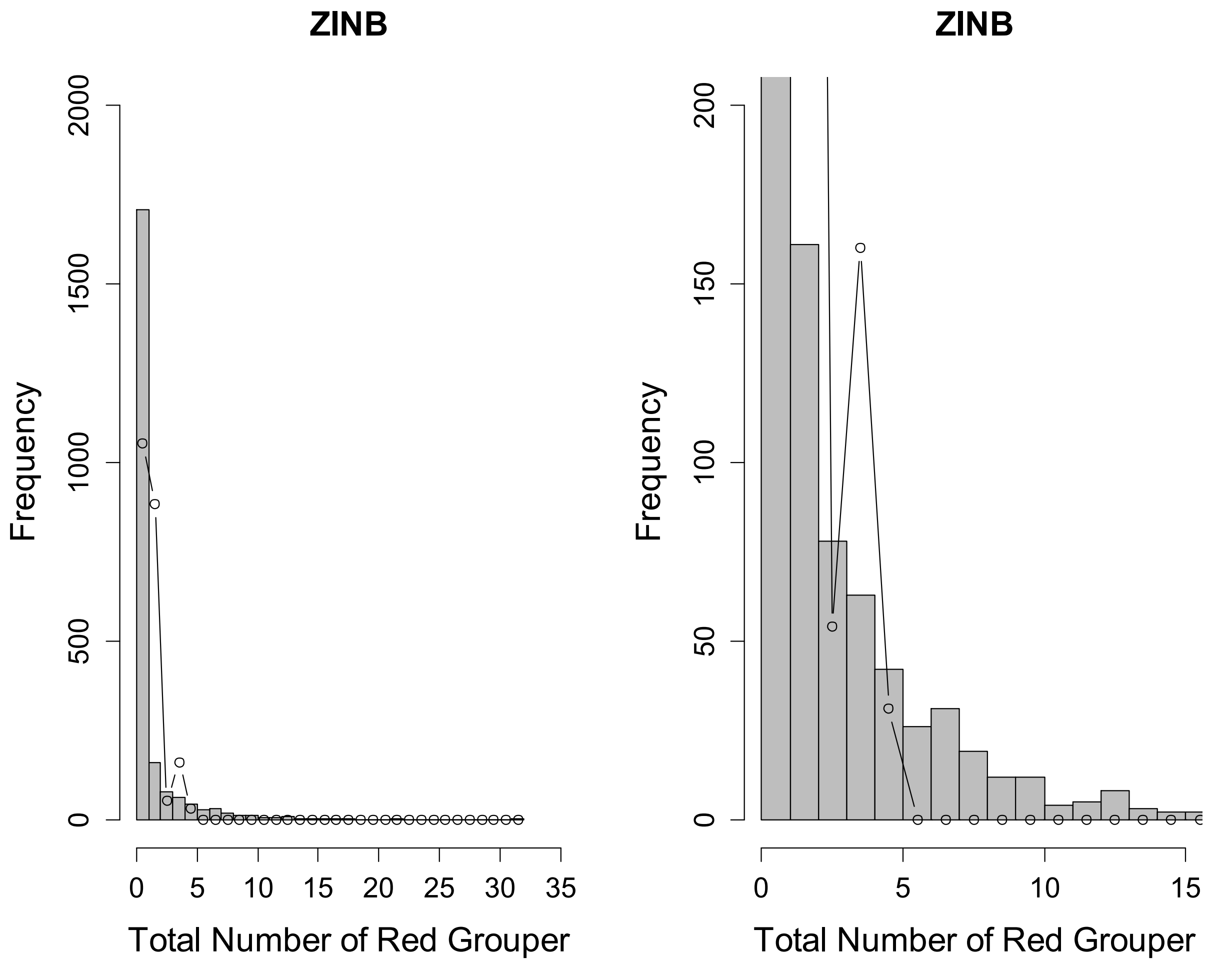

Figure 14. Model diagnostic plots of fitted model values (black line) against the original data distribution. Full distribution view (left panel) and limited x/y-axis view (right panel).

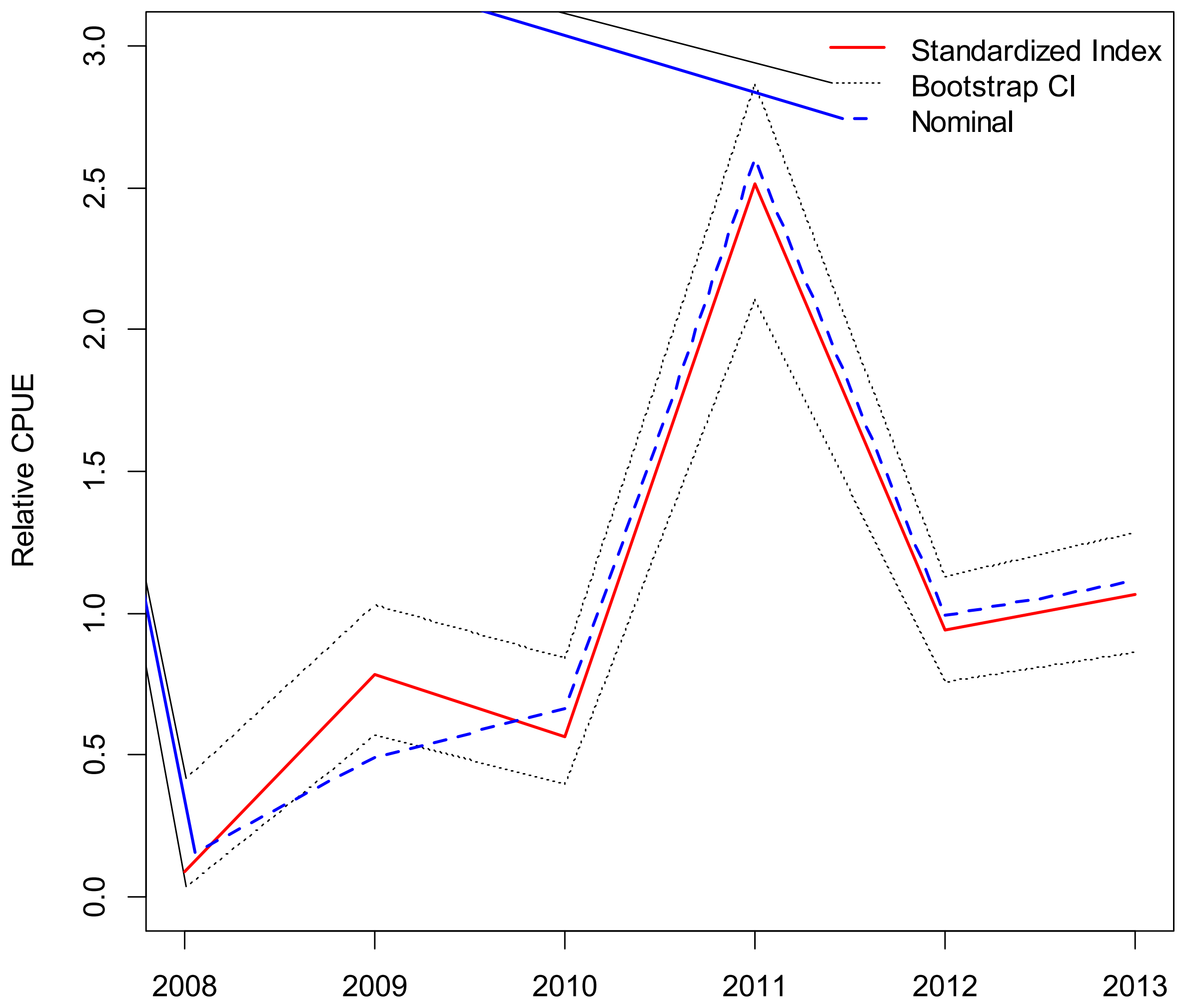

Figure 15. Relative standardized index (solid red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and the relative nominal index (blue hashed line) for Red Grouper CPUE in the FWRI West Florida Shelf trap survey.