# Index of abundance for Red Grouper (*Epinephelus morio*) from the Florida Fish and Wildlife Research Institute (FWRI) repetitive time drop survey in the eastern Gulf of Mexico

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**Index of abundance for Red Grouper (*Epinephelus morio*) from the Florida Fish and Wildlife Research Institute (FWRI) repetitive time drop survey in the eastern Gulf of Mexico**

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## Introduction:

Reef fishes, including Red Grouper (*Epinephelus morio*), are targeted commercially and recreationally along the shelf of the eastern Gulf of Mexico (GOM) off the Florida coastline. Historically, the assessment and management of reef fishes in the GOM 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 GOM 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 Grouper are summarized from fisheries-independent reef fish surveys conducted by FWRI throughout the eastern GOM using time-series that vary in space, time, and habitats sampled.

## Survey Design and Sampling Methods:

In 2014 and 2015 sampling was conducted in the NFMS statistical zones 4, 5, 9, and 10 as part of fisheries-independent surveys conducted by FWRI in the eastern GOM. In 2016 and 2017, sampling was widened to include reef habitat spanning the entire Gulf coast of Florida (NMFS statistical zones 2-10; (Figure 1). Sampling locations were selected using a stratified-random sampling design with sampling effort proportional to available habitat within each statistical zone and depth stratum (nearshore, 4-36 m;

offshore, 37-109 m; and deep, 110-180 m). An annual summary of sampling effort by year is illustrated in Table 1.

Very little is known regarding the fine-scale distribution of reef habitat throughout much of the eastern GOM, and due to anticipated cost and time requirements, mapping all of the reef habitat of the Gulf coast of Florida was not feasible prior to initiating this survey. Instead, an adaptive strategy was adopted 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. Acoustic surveys were 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. 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 were coded as categorical variables and were included as a potential explanatory variable in the index model. Geoforms were grouped as Artificial or Natural, then Natural geoforms were further classified into having relief, no relief or potholes (Table 2).

Repetitive time drop (RTD) sampling was conducted using powered (12V DC) Elec-tra-mate® rigs (model 940XP) outfitted with a Penn 115L 9/0 (Senator model) reel equipped with 45 kg test monofilament mounted onto a heavy-duty fiberglass fishing pole ~ 2.1 m in length. A barrel swivel was attached to the mainline from the reel. Each fishing rig contained two short leads ~ 0.20 m long, tied along the length of a ~ 1.8 m section of monofilament leader (36 or 45 kg test). Three hook sizes were used at each sampling station: one angler fished two 8/0 hooks, another fished with two 11/0 hooks, and a third fished with two 15/0 hooks (Mustad circle hooks-Ref 39960D). At the base of each rig was a lead weight (225-510 g). All hooks were baited with Atlantic Mackerel cut proportional to hook size. At each sampling station, three anglers simultaneously dropped their rigs to the bottom and actively fished for no more than two minutes. If an angler hooked a fish before two minutes had elapsed the angler would retrieve, identify and measure the fish, rebait their hooks and wait until the next team drop before redeploying. Simultaneous team drops were repeated ten times at each station. Standard, fork, and total length were measured (mm) for all Red Grouper.

**Data Treatment and Standardization:**

*Standardization of Response Variable:*

To create the longest consistent time series for the RTD index of Red Grouper, we only included data sampled in zones 4, 5, 9, and 10 from 2014-2017. Since effort was the same across all stations sampled

(number of team drops and number of hooks), we modeled the total catch at each station as fish captured from all hook sizes at a station combined.

*Explanatory Variables:*

We considered six explanatory variables in the original model. Potential variables are listed below. Variables that were included in all models are shown in **bold**:

**Year (*Y*)** – Year was included since standardized catch rates by year are the objective of the analysis. We modeled data from 2014-2017.

**Depth (*DQ*)** – Water depth may be an important component affecting the distribution of reef fish. All depths sampled (9-173 m) were included and treated as a quantile factor.

Latitude (*LatQ*) – The latitude of sampling location was included as a spatial parameter in the model and treated as a quantile factor.

Longitude (*LonQ*) – The longitude of sampling location was included as a spatial parameter in the model and treated as a quantile factor.

**Statistical Zone (*Zone*)** – National Marine Fisheries Service statistical zones 4, 5, 9, and 10 were included based on the zone in which a sample was collected.

**Geoform (*Geo*)-** The observed geoform from side-scan sonar used in site selection for repetitive time drop sampling. Geoforms were included as a categorical variable and grouped as shown in Table 2.

**Model Selection and Diagnostics:**

The total number of Red Grouper captured represents count data and therefore does not conform to assumptions of normality. Therefore, the data were modeled using the Poisson and negative binomial distributions to fit the data. Additionally, catch data often has a disproportionate number of zero counts that may differ from the standard error distributions used for count data. To address the excess zeros the zero-inflated Poisson and zero-inflated negative binomial models were also fit to the data. These approaches model the zero counts using two different processes, a binomial and a count process (Zuur et al. 2009).

Backwards step-wise model selection and comparisons of AIC values were used to determine the optimal model. Due to correlations and models not converging latitude and longitude had to be dropped. Including

geoform also caused the models to not converge so this variable was removed. The final index model is given by the following equation:

$$Total = Y + DQ + Zone$$

Model diagnostics showed no discernible patterns of association between Pearson residuals and fitted values or the fitted values and the original data (Figure 2). An examination of residuals for the spatial and environmental model parameters showed no clear patterns of association, indicating correspondence to underlying model assumptions (Zuur et al. 2009) (Figure 3). Lastly, a comparison of predicted values from the best model against original data distribution indicates a good fit of the zero-inflated data structure (Figure 4). Confidence intervals were determined by bootstrapping the model fitting over 1,000 iterations. The relative nominal total was calculated as the mean catch per year. The proportion of positive sets was calculated as the proportion of stations that caught at least one Red Grouper. The estimated index values were then standardized to one by dividing by the overall predicted mean for the entire time series.

All data manipulation and analysis were conducted using R version 3.5.0 (R Core Team 2018). Modeling was conducted using the zeroinfl function of the pscl package (Jackman 2008), available from the Comprehensive R Archive Network (CRAN).

**Results:**

A total of 387 stations were sampled from 2014 to 2017 (Appendix A). Annual standardized index values for Red Grouper in the eastern GOM, including coefficients of variation, are presented in Table 3. The standardized index values indicated there was an overall decreasing trend, with a slight increase from 2015 to 2016. All CVs indicated a good fit (Table 3, Figure 5). Due to the relatively short temporal extent of the index, limited inferences can be discerned concerning patterns of overall Red Grouper population abundance.

**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.

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. 2018. 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. Annual total number of repetitive time drop (RTD) samples included in the analysis and range of spatial and environmental variables included.

| Year | # of RTD samples | Depth Range (m) | Latitude Range | Longitude Range |
|---|---|---|---|---|
| 2014 | 108 | 13 - 97 | 26.176 to 30.253 | -87.359 to -82.749 |
| 2015 | 105 | 9 - 134 | 26.022 to 30.250 | -87.388 to -82.326 |
| 2016 | 98 | 11 - 105 | 26.116 to 30.258 | -87.472 to -82.583 |
| 2017 | 76 | 10 -173 | 26.372 to 30.264 | -87.513 to -82.533 |

Table 2. List of the geoforms used to describe potential reef fish habitats observed using side-scan sonar and sampled using repetitive time drop.

| Habitat Type | Geoforms | Habitat Type | Geoforms |
|---|---|---|---|
| Relief | | Anthropogenic | |
| | Aggregate Coral Reef | | Artificial Reef Unknown |
| | Boulder/Boulder Field | | Chicken Coop |
| | Fragmented HB | | Construction Materials |
| | Ledge | | Large Vessel/Barge |
| | Mixed HB | | Military Tanks |
| | Pinnacle | | Reef Modules |
| | Reef Rubble | | Small Vessel |
| | Fracture | | Tires |
| Pothole | | No Relief | |
| | Pothole | | Flat HB |
| | | | Pavement |

Table 3. Relative nominal total, number of stations sampled (N), proportion of positive sets, standardized index, and coefficient of variation (CV) for Red Grouper collected during the FWRI repetitive time drop survey in the eastern Gulf of Mexico, 2014-2017.

| Year | Nominal total | N | Proportion positive | Standardized Index | CV |
|---|---|---|---|---|---|
| 2014 | 2.30 | 108 | 0.42 | 1.49 | 0.13 |
| 2015 | 1.01 | 105 | 0.33 | 0.84 | 0.19 |
| 2016 | 1.46 | 98 | 0.49 | 1.10 | 0.14 |
| 2017 | 0.76 | 76 | 0.34 | 0.58 | 0.22 |

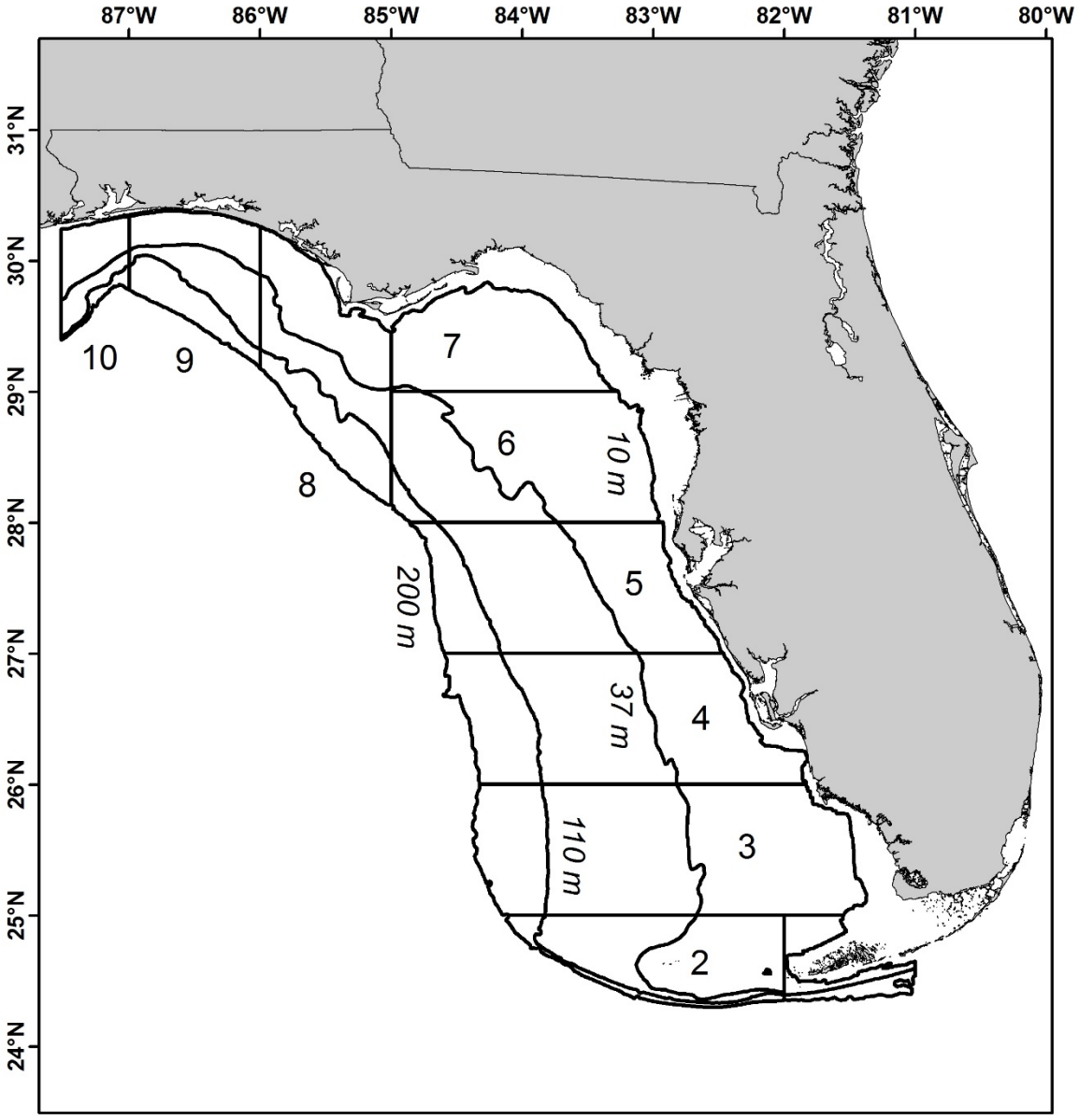


Figure 1. The FWRI repetitive time drop survey area in the eastern Gulf of Mexico. Sampling effort was allocated among NMFS statistical zones (4, 5, 9, and 10) as well as nearshore (9 – 36 m), offshore (37 – 109 m), and deep (110-180 m) depth strata.

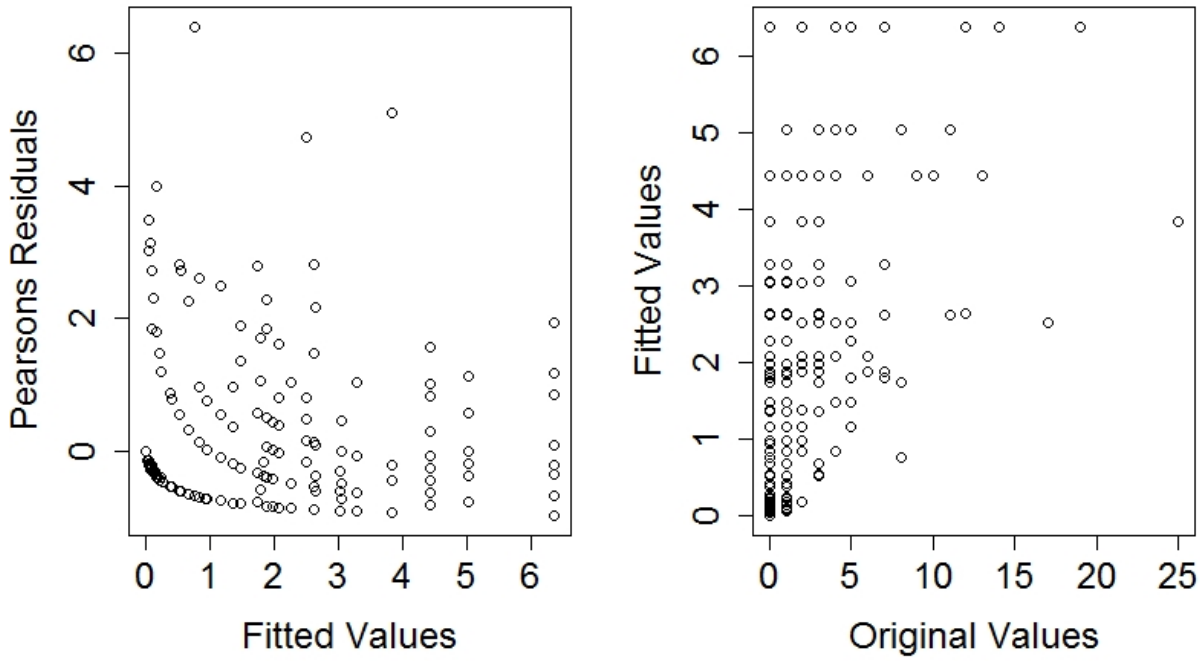


Figure 2. Model diagnostic plots showing fitted best model values against Pearson residuals (left panel) and fitted values plotted against original data values (right panel).

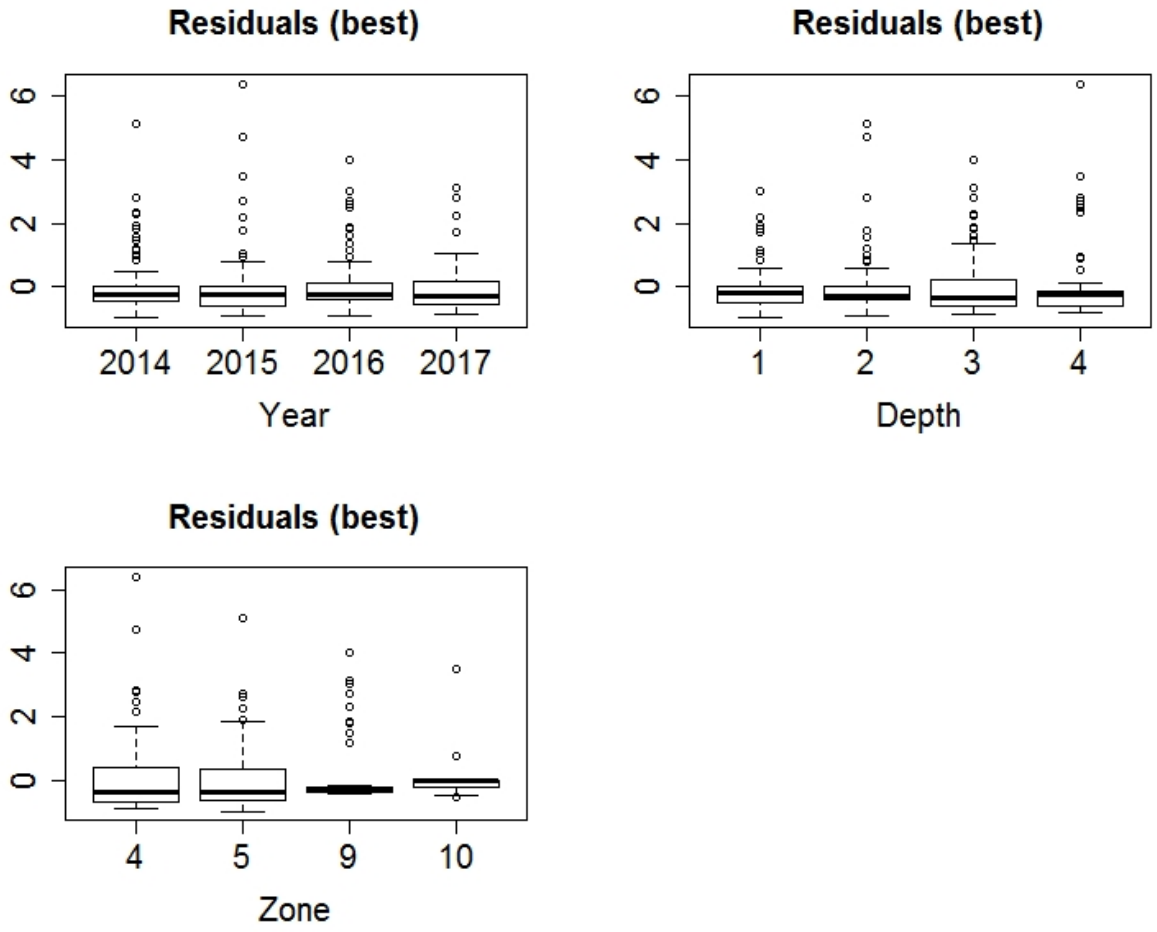


Figure 3. Model diagnostic plots showing Pearson residuals for the final (best) model plotted against spatiotemporal and environmental model parameters.

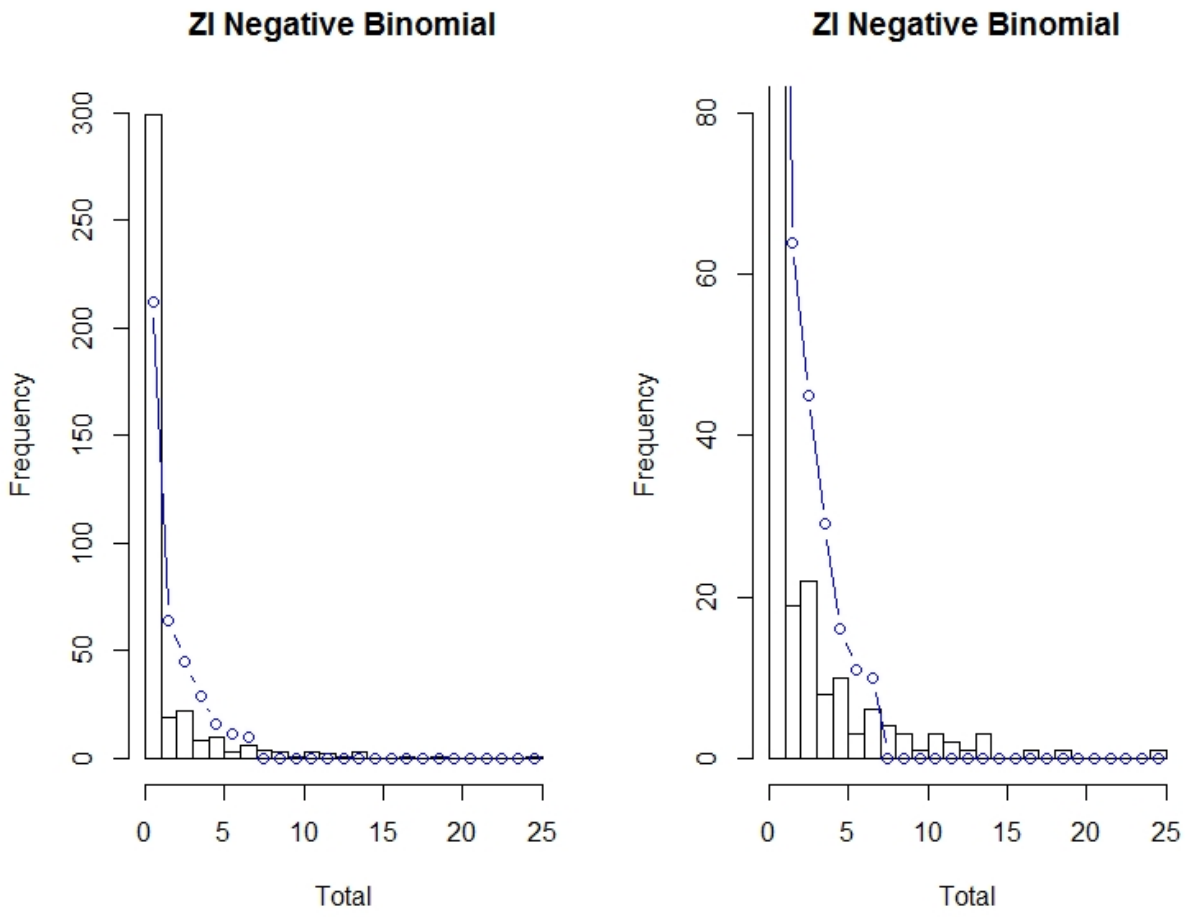


Figure 4. Model diagnostic plots of fitted model values (blue line) against the original data distribution. Full distribution view (left panel) and limited y-axis view (right panel).

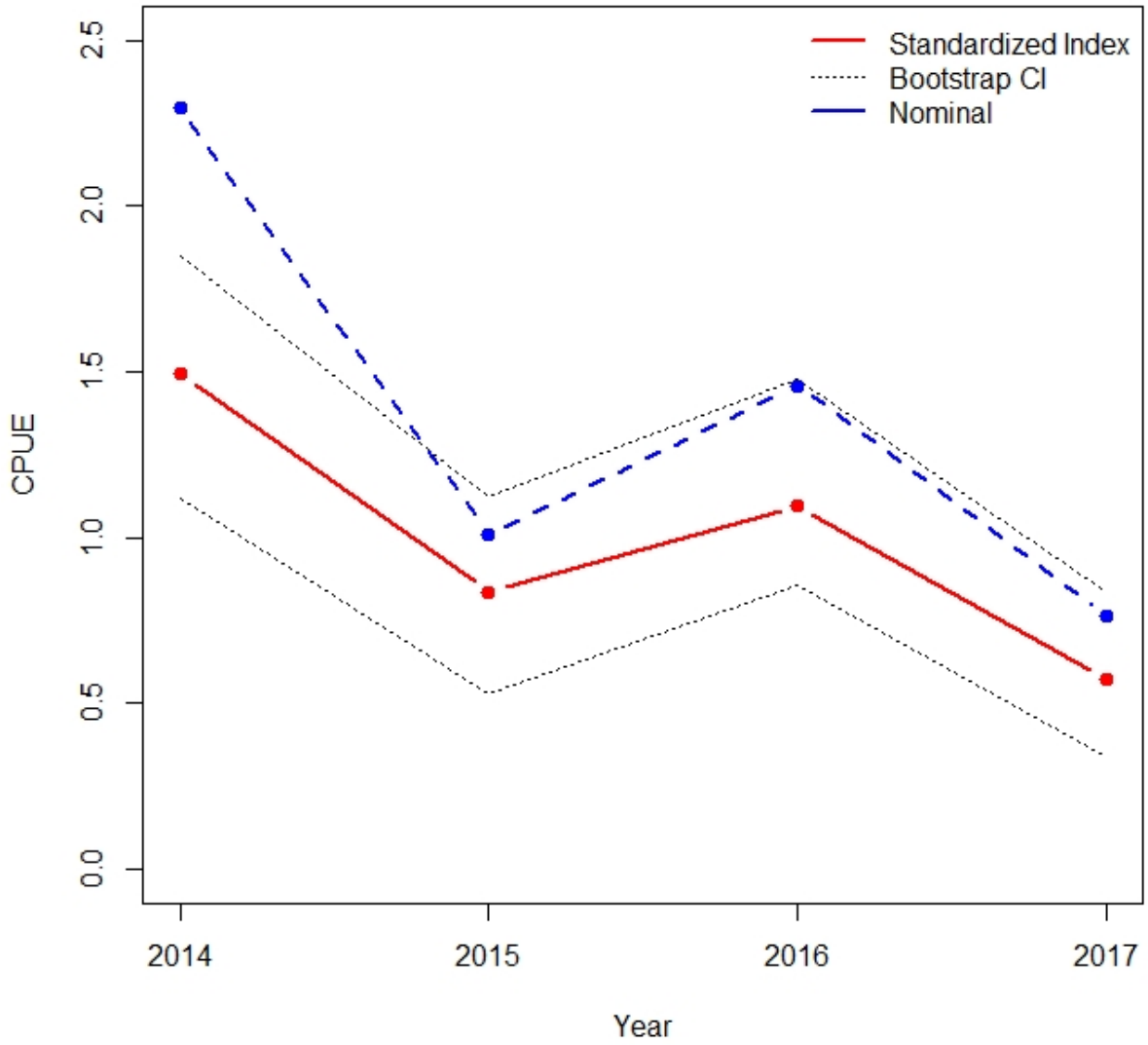


Figure 5. Relative standardized index (solid red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and the nominal CPUE (blue hashed line) for Red Grouper caught in the FWRI repetitive time drop survey.

**Appendix A:**

Figures A1-A4. Annual distribution of stations sampled (2014 – 2017) during the FWRI repetitive time drop sampling of reef fish in the eastern Gulf of Mexico.

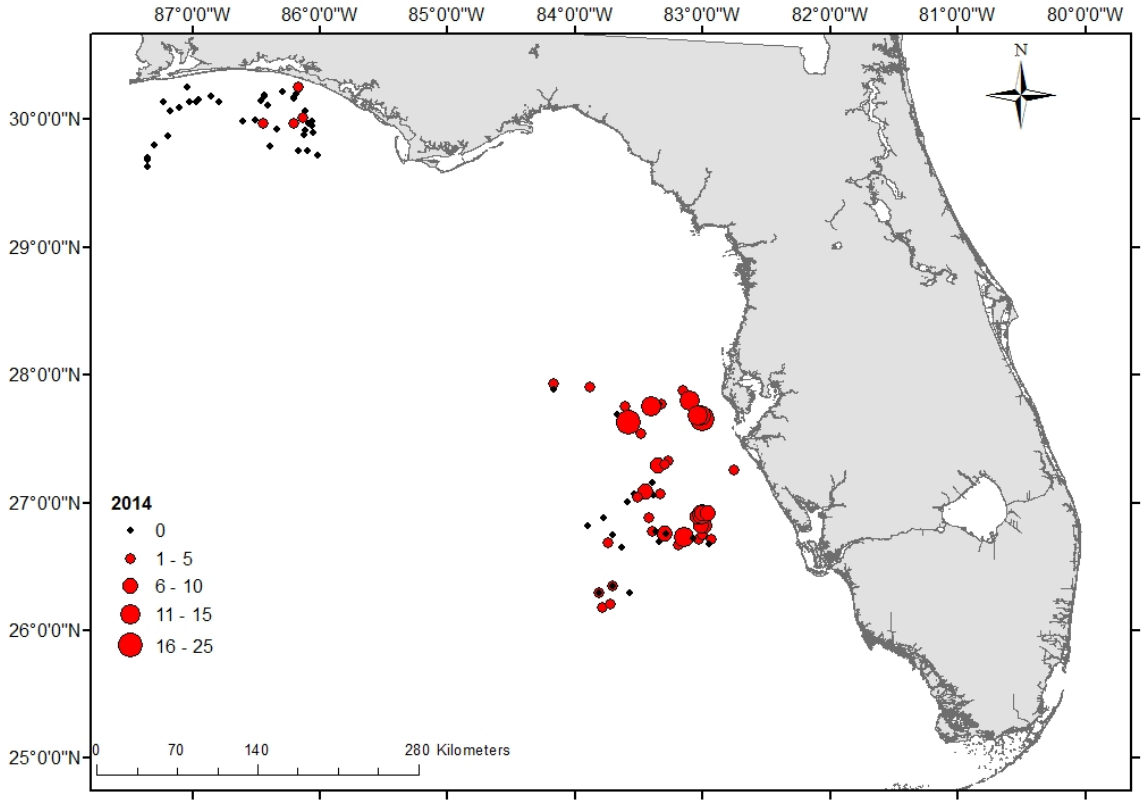


Figure A1. Stations sampled in 2014 during FWRI repetitive time drop survey. Symbols are scaled to represent total abundance of Red Grouper caught at each station.

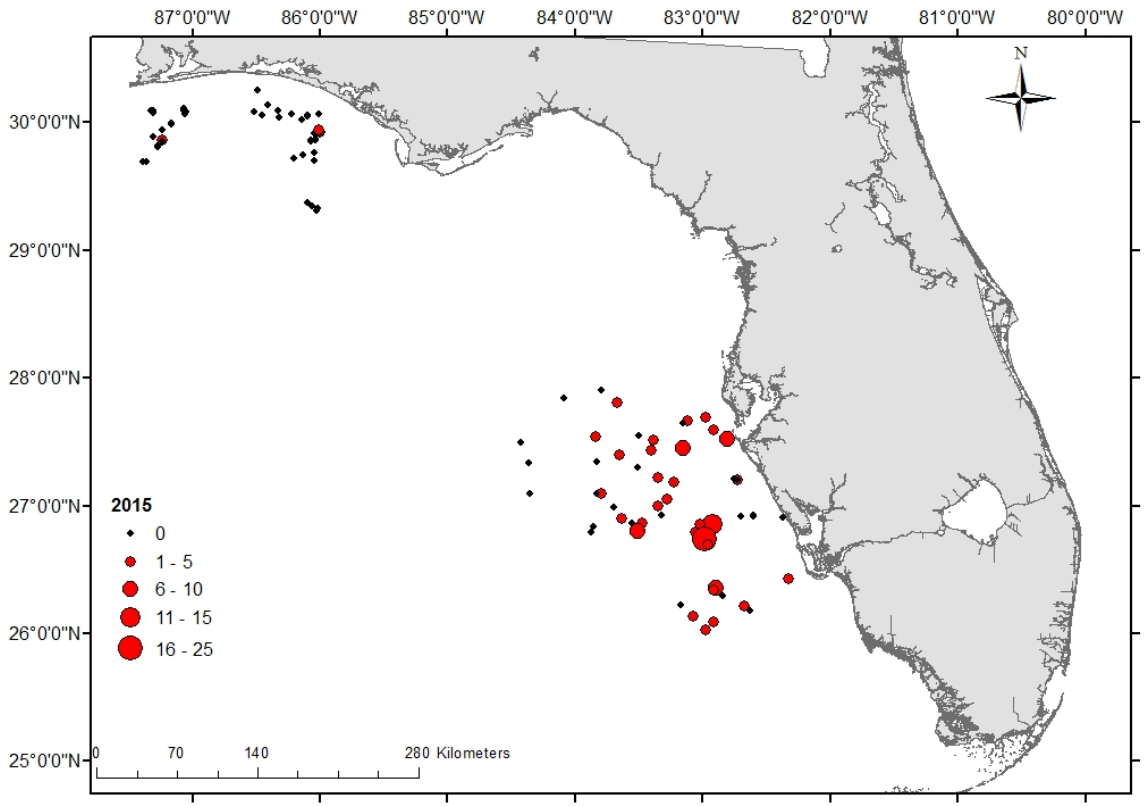


Figure A2. Stations sampled in 2015 during FWRI repetitive time drop survey. Symbols are scaled to represent total abundance of Red Grouper caught at each station.

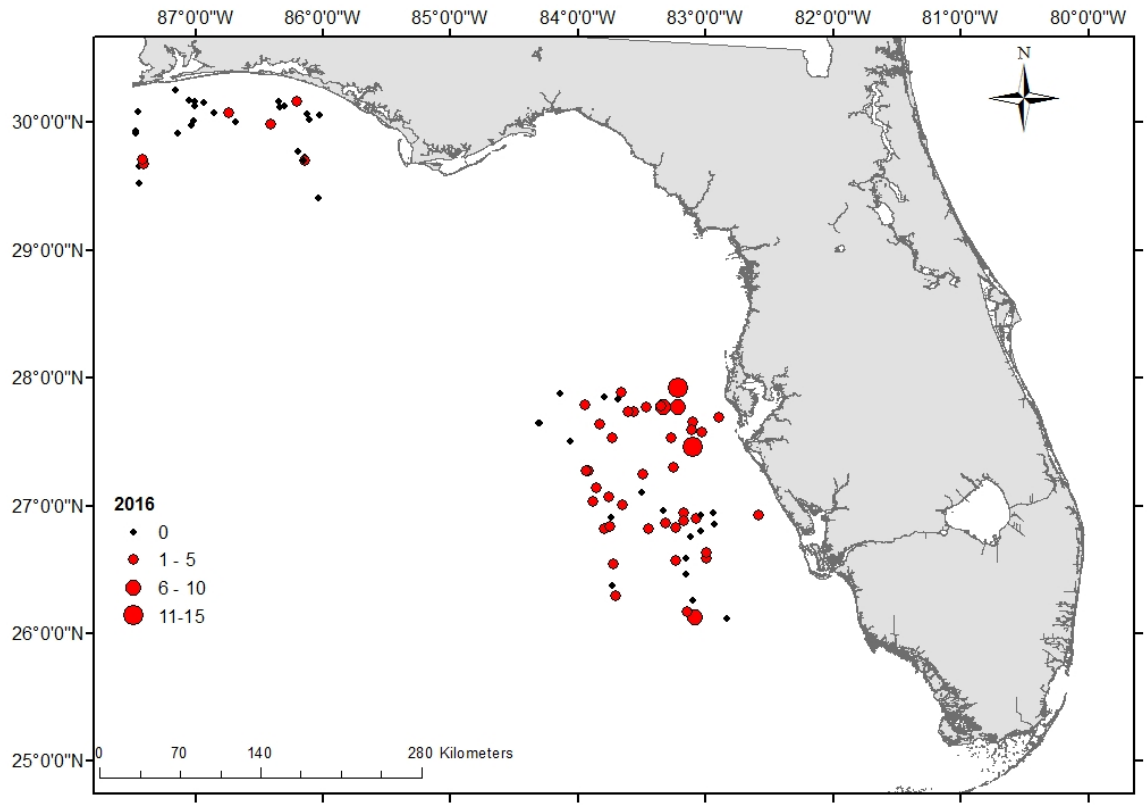


Figure A3. Stations sampled in 2016 during FWRI repetitive time drop survey. Symbols are scaled to represent total abundance of Red Grouper caught at each station.

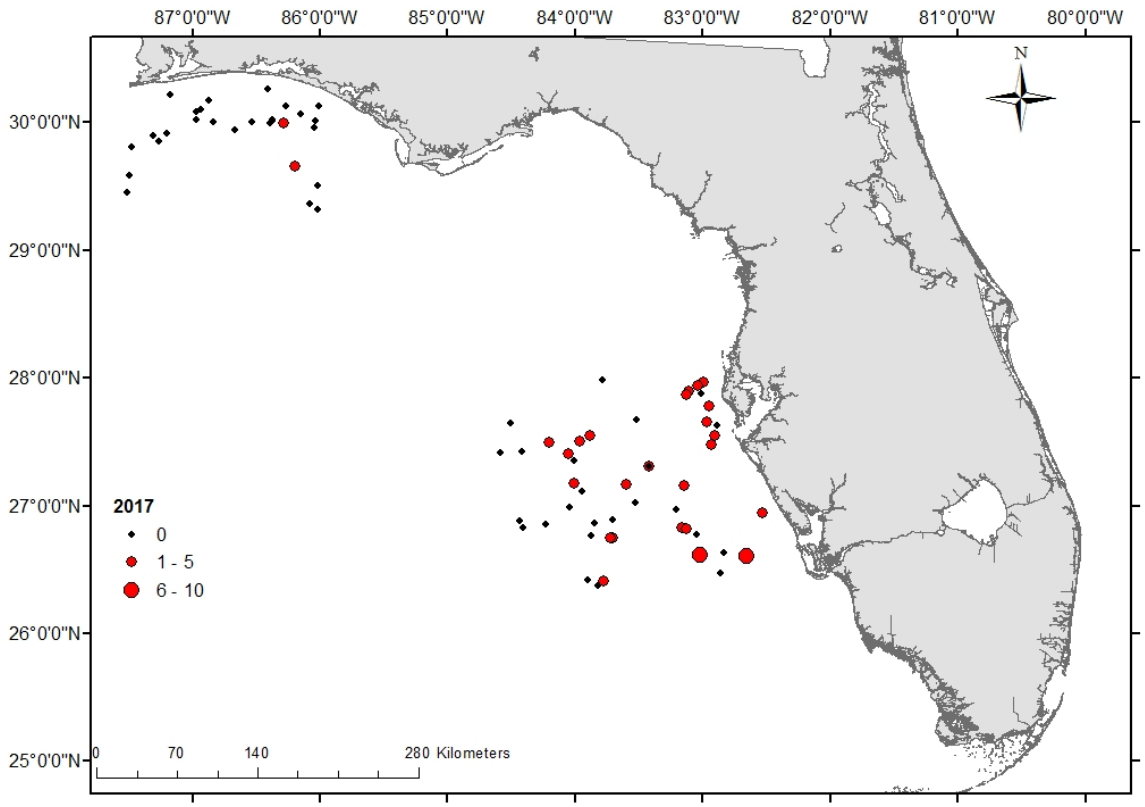


Figure A4. Stations sampled in 2017 during FWRI repetitive time drop survey. Symbols are scaled to represent total abundance of Red Grouper caught at each station.