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

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SEDAR61-WP-10

16 August 2018

Please cite this document as:

Christiansen, Heather M., Brent L. Winner, and Theodore S. Switzer. 2018. Index of abundance for Red Grouper (*Epinephelus morio*) from the Florida Fish and Wildlife Research Institute (FWRI) vertical longline survey in the eastern Gulf of Mexico. SEDAR61-WP-10. SEDAR, North Charleston, SC. 16 pp.

Index of abundance for Red Grouper (*Epinephelus morio*) from the Florida Fish and Wildlife Research Institute (FWRI) vertical longline 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 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 effort was expanded 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; 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 survey area 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 are 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).

Protocols established by the Southeast Area Monitoring and Assessment Program (SEAMAP) were followed at stations fished with the vertical longline (VLL) method. Each VLL rig consisted of a 7.3-m monofilament (181 kg test) backbone equipped with 10 evenly spaced (every 0.61 m) crimped t-swivels. A gangion was attached to each t-swivel; consisting of a snap swivel with a length of 45-kg-test monofilament and a single Mustad circle hook attached to each end. A lead weight (4-7 kg), depending on current and sea conditions was attached at the base of the backbone. Two or three vertical longlines, depending on vessel size, were fished simultaneously at each sampling site, each rigged with 10 hooks of the same size. For vessels that used two vertical longlines two hook sizes, either 8/0, 11/0, or 15/0 (Mustad circle hooks, Ref # 39960D), were randomly selected at the first station of the day and rotated by hook size throughout the day to ensure equal sampling effort during a cruise. Hooks were baited with Atlantic Mackerel cut proportional to the hook size and the gear fished passively for five minutes before it was retrieved with a bandit reel. Standard, fork, and total length were measured (mm) for all Red Grouper.

Data Treatment and Standardization:

Standardization of Response Variable:

To create the longest comparable time series for the VLL index of Red Grouper, we only included data sampled in zones 4, 5, 9, and 10 from 2014-2017. We modeled the total catch at each station as fish

captured from all hook sizes combined. For the majority of stations only two hook sizes were fished at each station, therefore a presence/absence variable was created for each hook size.

Explanatory Variables:

We considered 9 explanatory variables in the original models. 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 (8-178 m) were included and treated as a quartile 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.

Small (sm)- The size of the hook used may be a limiting factor in whether a fish is captured. Recorded as a binary factor of the presence or absence of 8/0 hooks.

Medium (md)- The size of the hook used may be a limiting factor in whether a fish is captured. Recorded as a binary factor of the presence or absence of 11/0 hooks.

Large (lg)- The size of the hook used may be a limiting factor in whether a fish is captured. Recorded as a binary factor of the presence or absence of 15/0 hooks.

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 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 (Zuur et al. 2009). Geoform could not be included in the model due to not enough samples of each geoform type in each zone. Due to correlations and models not converging latitude and longitude were removed. While including depth, zone, sm, and lg gave the best model fit according to AIC value, to allow for bootstrapped CV's and confidence intervals to be calculated they were removed. Therefore, the model was reduced to year only as in the following equation:

$$Total = Y$$

Model diagnostics showed no discernible patterns of association between Pearson residuals and fitted values or the fitted values and the original data (Figure 2). 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 3). 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 390 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 indicate an overall decreasing trend in estimated mean abundance for the years 2014-2017 (Figure 4). All CVs indicated a good fit and generally decreased with increasing sample size (Table 3). Due to the relatively short temporal extent of the index and general sparseness of Red Grouper catch, limited inferences can be discerned concerning overall patterns of Red Grouper population abundance.

Literature Cited:

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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.

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Table 1. Annual total number of vertical longline (VLL) samples included in the analysis and range of spatial and environmental variables included.

Year	# of VLL samples	Depth Range (m)	Latitude Range	Longitude Range
2014	114	13 - 98	26.076 to 30.243	-87.435 to -82.750
2015	100	8 - 142	26.021 to 30.124	-87.389 to -82.365
2016	95	11 - 105	26.130 to 30.259	-87.490 to -82.879
2017	81	10 - 178	26.034 to 30.298	-87.514 to -82.533

Table 2. List of the geoforms used to describe potential reef fish habitats observed using side-scan sonar and sampled by vertical longline.

Habitat Type	Geoforms	Habitat Type	Geoforms
Relief		Anthropogenic	
	Aggregate Coral Reef		Artificial Reef Unknown
	Boulder/ Boulder Field		Chicken Coop
	Escarpment		Construction Materials
	Fragmented HB		Large Vessel/Barge
	Ledge		Marine Wreckage
	Mixed HB		Military Tanks
	Pinnacle		Oil Platform Material
	Reef Rubble		Reef Modules
	Rubble Field		Rock Piles
	Fracture		Small Vessel
Pothole			Tires
	Pothole	No Relief	
			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 vertical longline survey in the eastern Gulf of Mexico, 2014-2017.

Year	Nominal total	N	Proportion positive	Standardized Index	CV
2014	0.25	114	0.15	1.41	0.22
2015	0.19	100	0.09	1.06	0.34
2016	0.19	95	0.15	1.05	0.26
2017	0.08	81	0.04	0.48	0.60

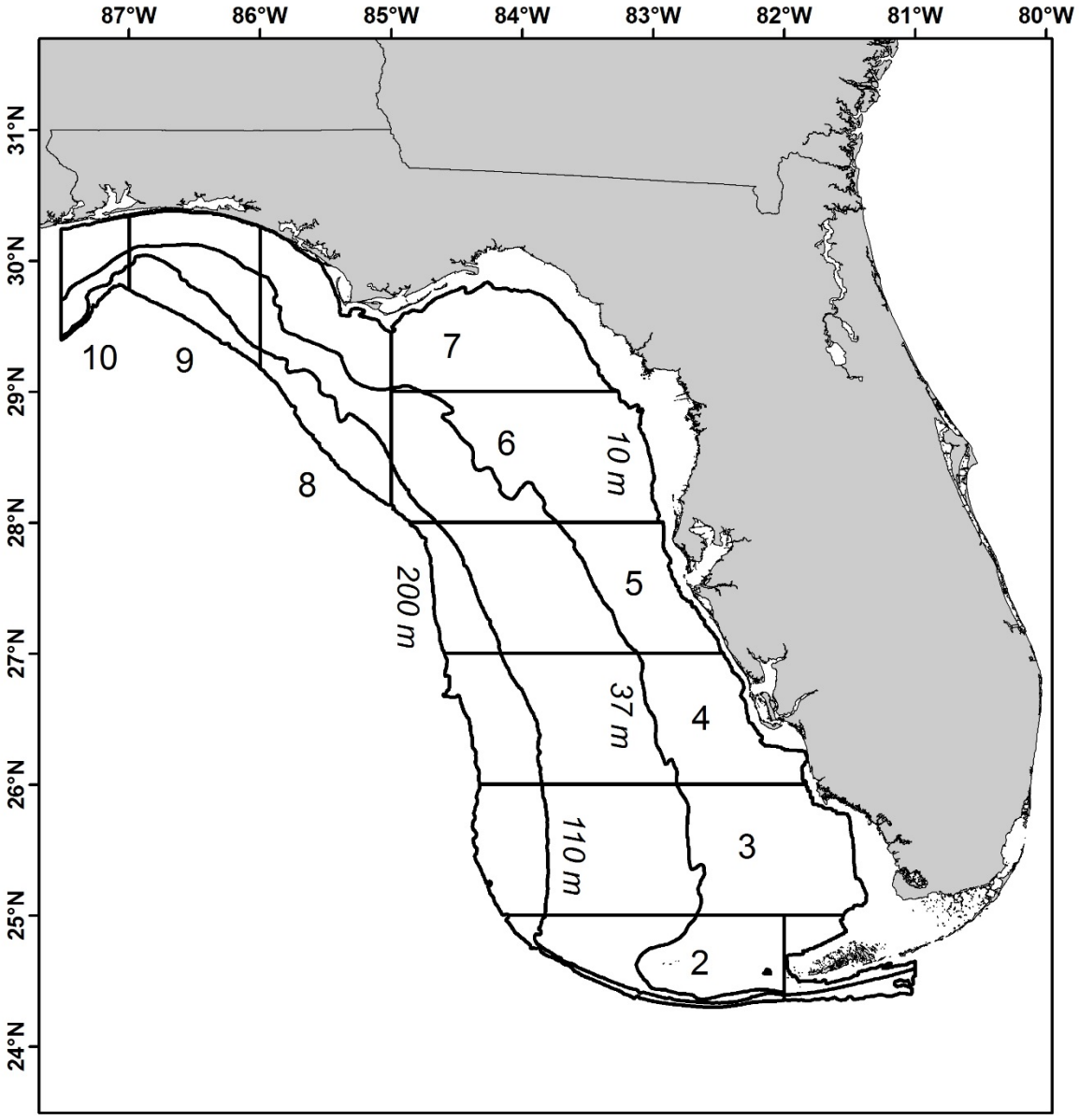

Figure 1. The FWRI vertical longline survey area in the eastern Gulf of Mexico. Sampling effort was allocated among NMFS statistical zones (4, 5, 9, and 10) as well as nearshore (10 – 36 m), offshore (37 – 109 m), and deep (110-180 m) depth strata.

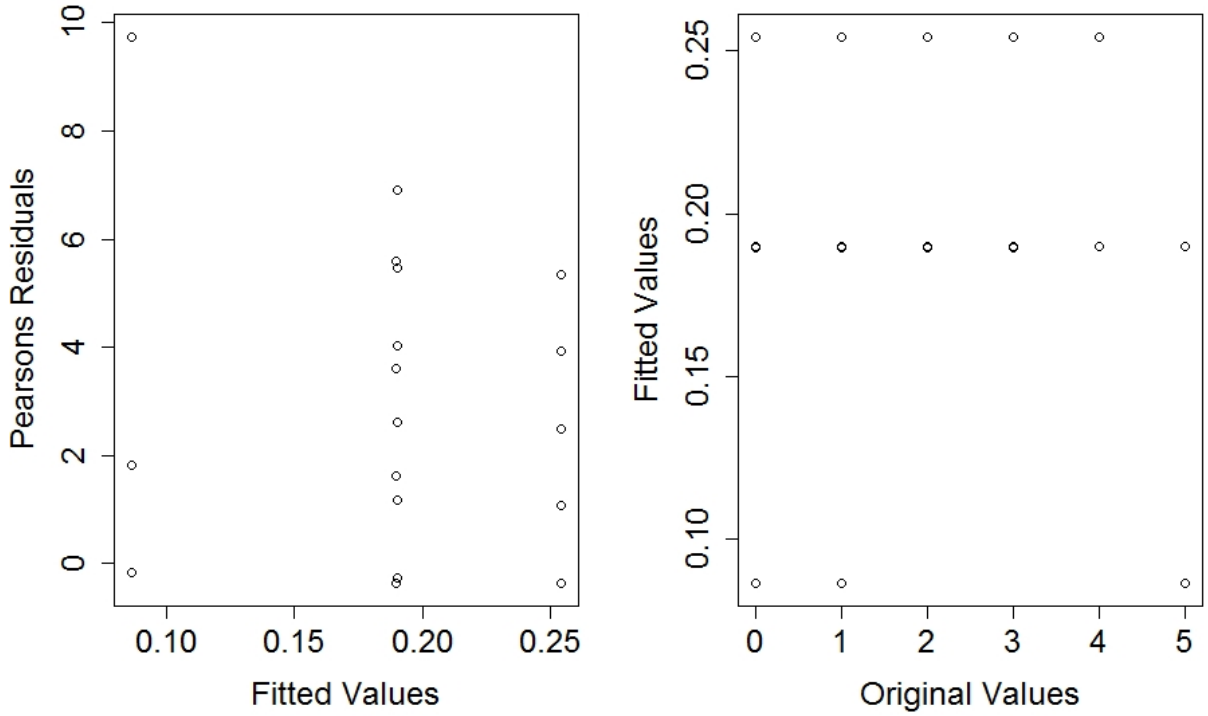

Figure 2. Model diagnostic plots showing fitted best model values against Pearson residuals (left panel) and fitted values plotted against original data values (right panel).

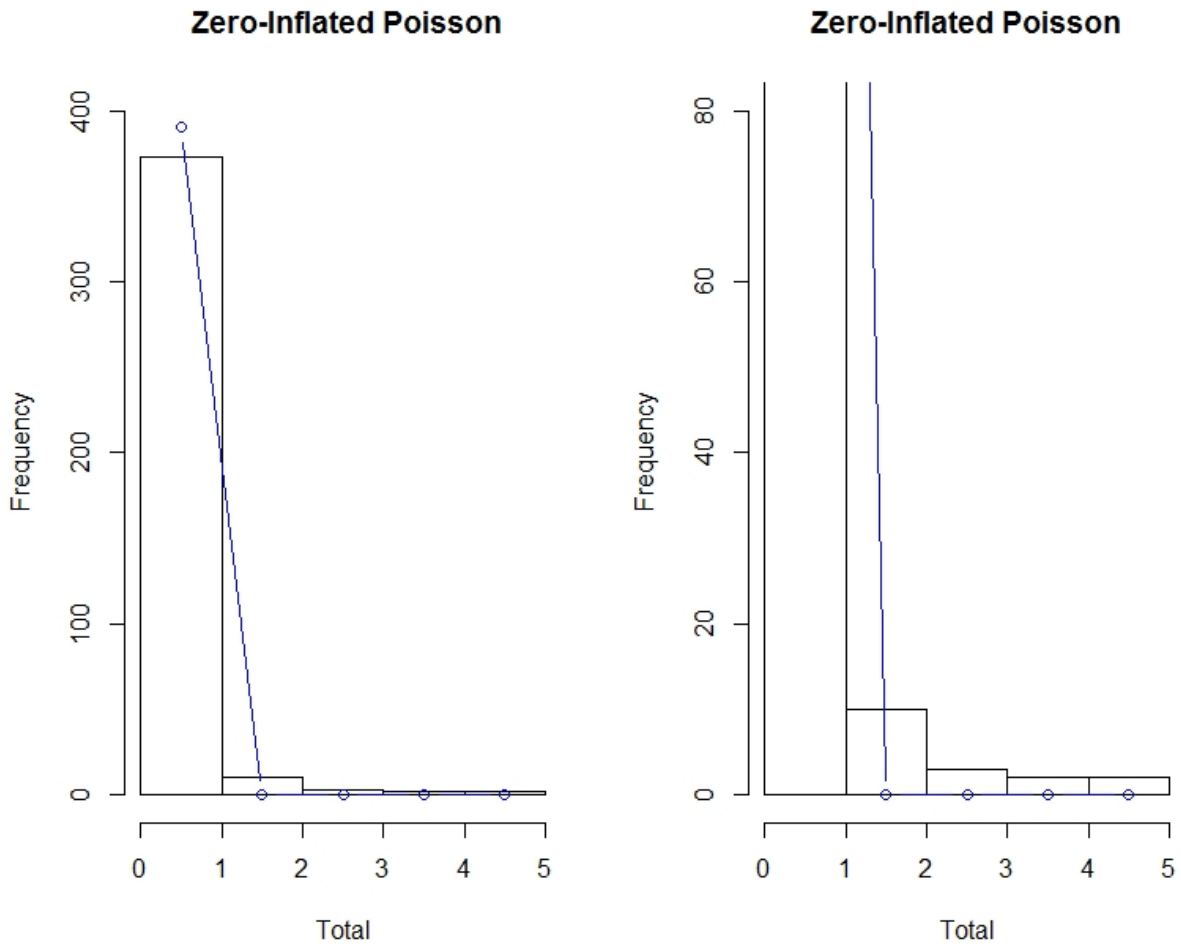

Figure 3. Model diagnostic plots of fitted model values (blue line) against the original data distribution. Full distribution view (left panel) and limited y-axis view (right panel).

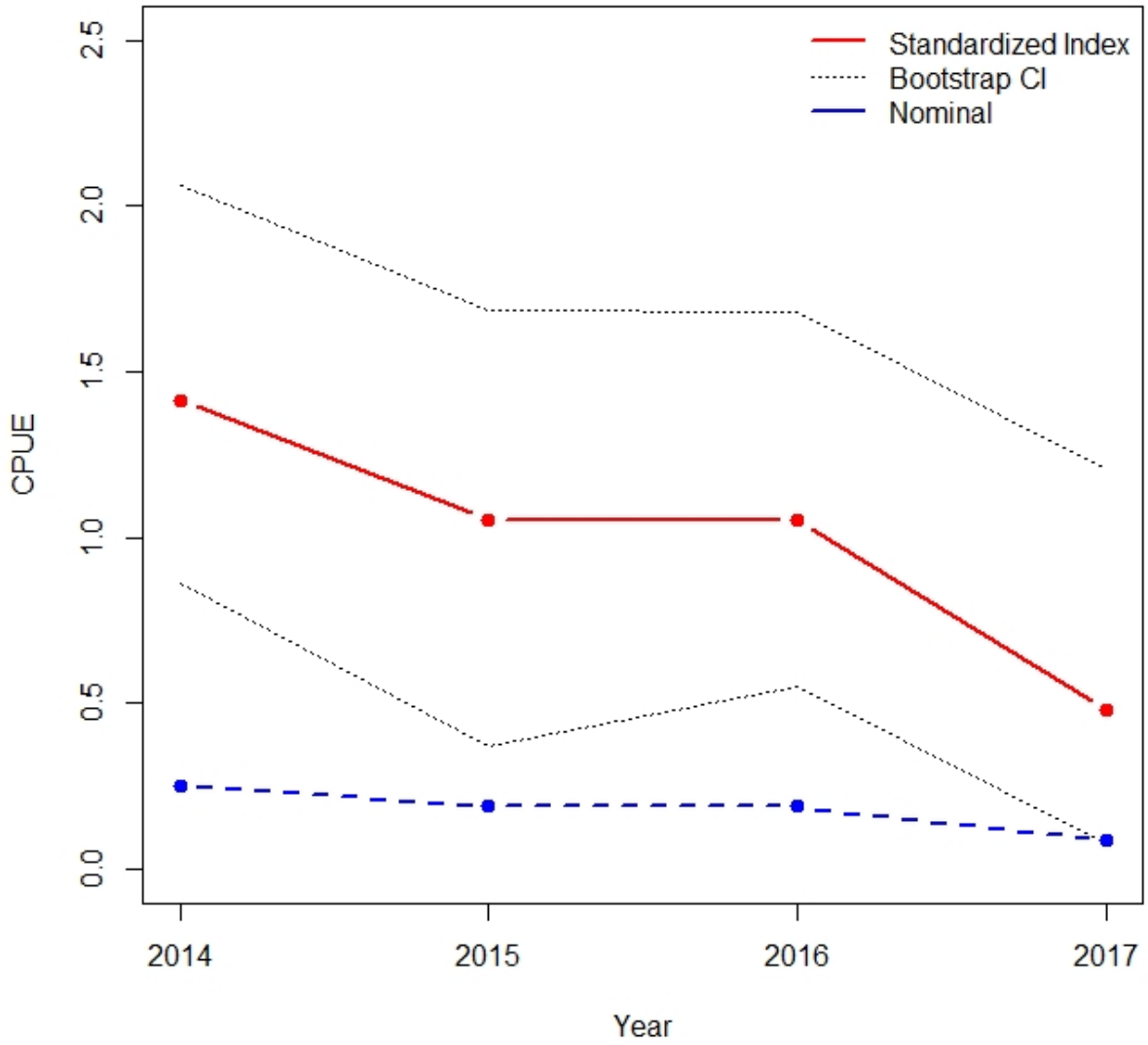

Figure 4. Relative standardized index (solid red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and the nominal CPUE (blue hashed line) for Red Grouper caught in the FWRI vertical longline survey.

Appendix A:

Figures A1-A4. Annual distribution of stations sampled (2014 – 2017) during the FWRI vertical longline survey of reef fish in the eastern Gulf of Mexico.

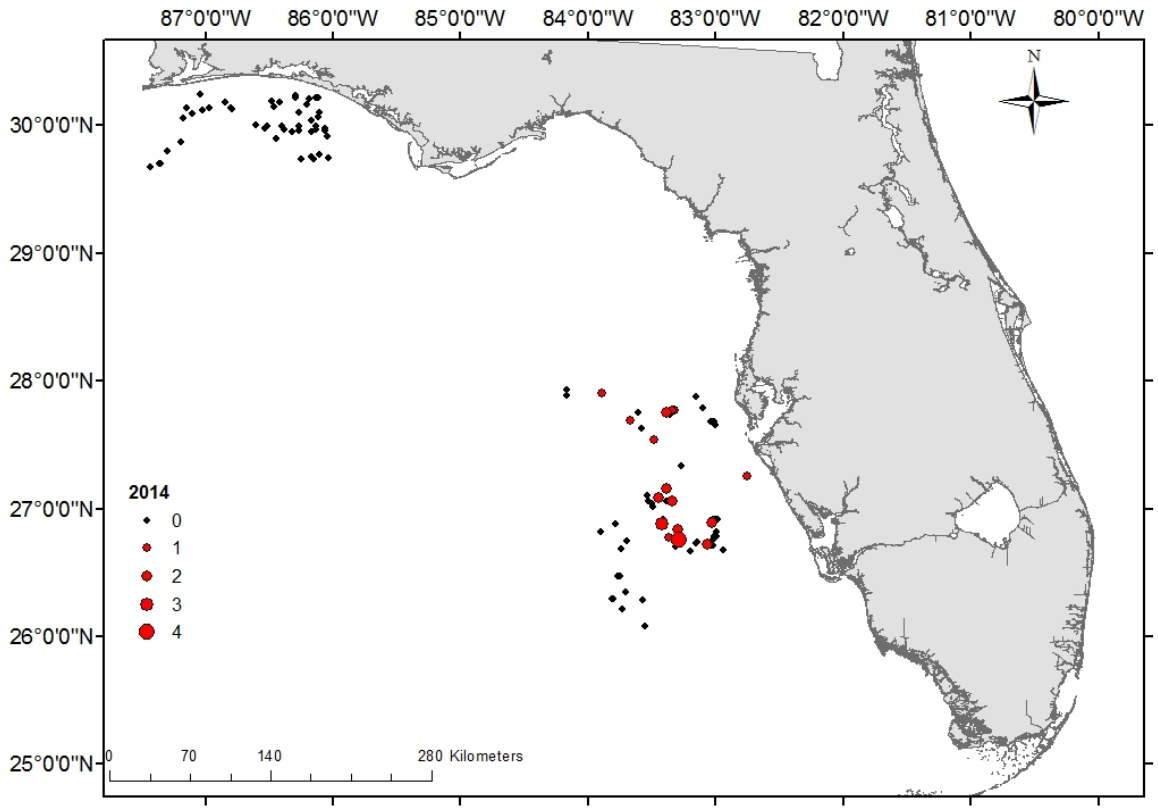

Figure A1. Stations sampled in 2014 during the FWRI vertical longline survey. Symbols are scaled to represent total number of Red Grouper caught at each station.

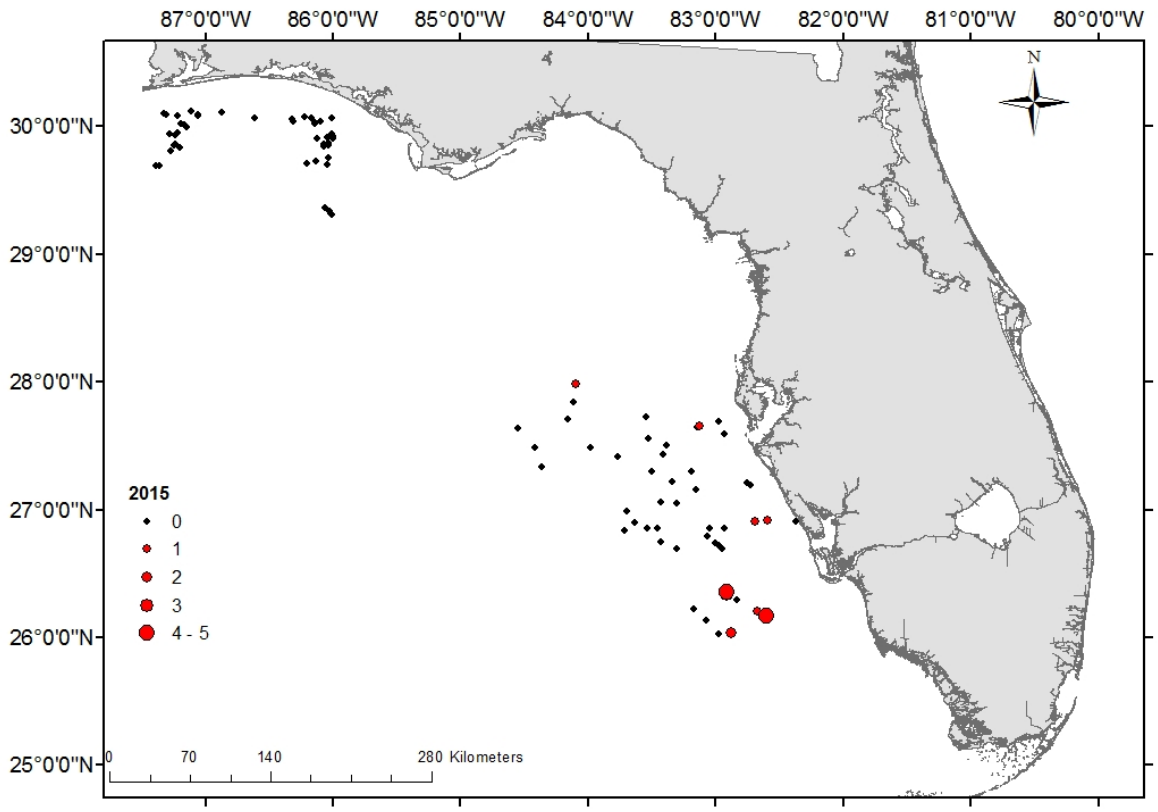

Figure A2. Stations sampled in 2015 during the FWRI vertical longline survey. Symbols are scaled to represent total number of Red Grouper caught at each station.

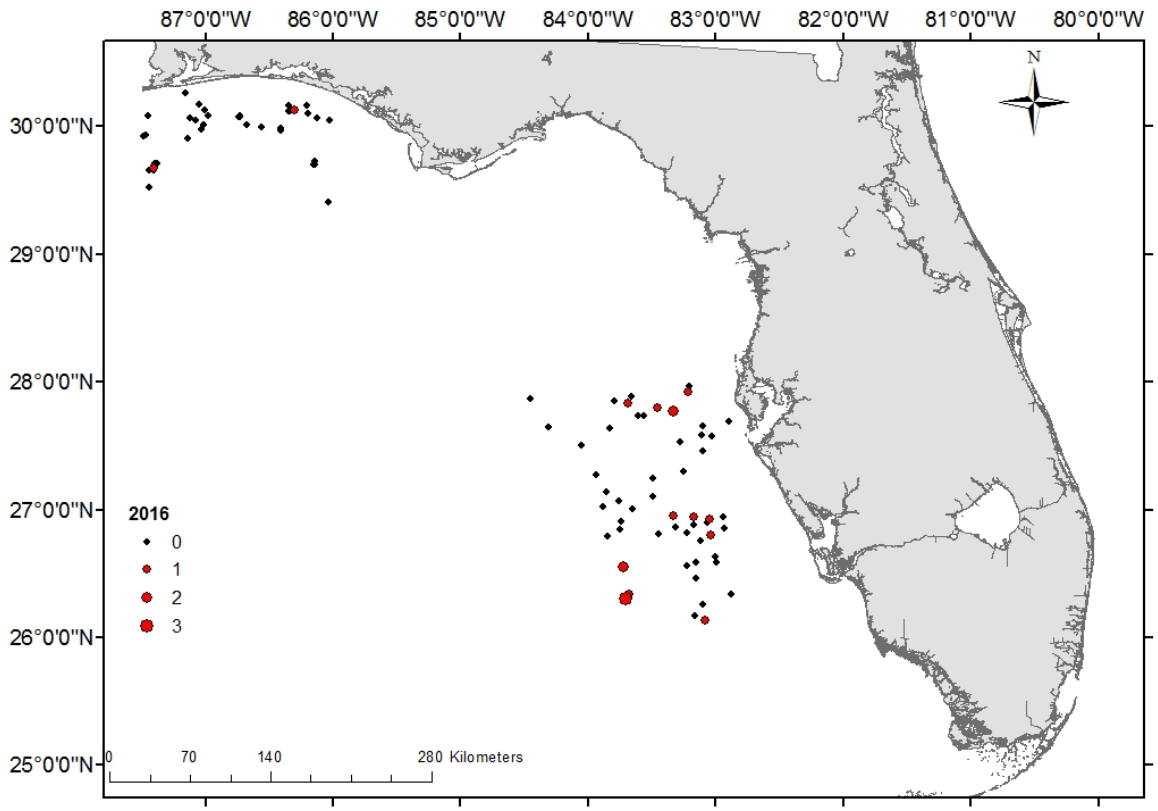

Figure A3. Stations sampled in 2016 during the FWRI vertical longline survey. Symbols are scaled to represent total number of Red Grouper caught at each station.

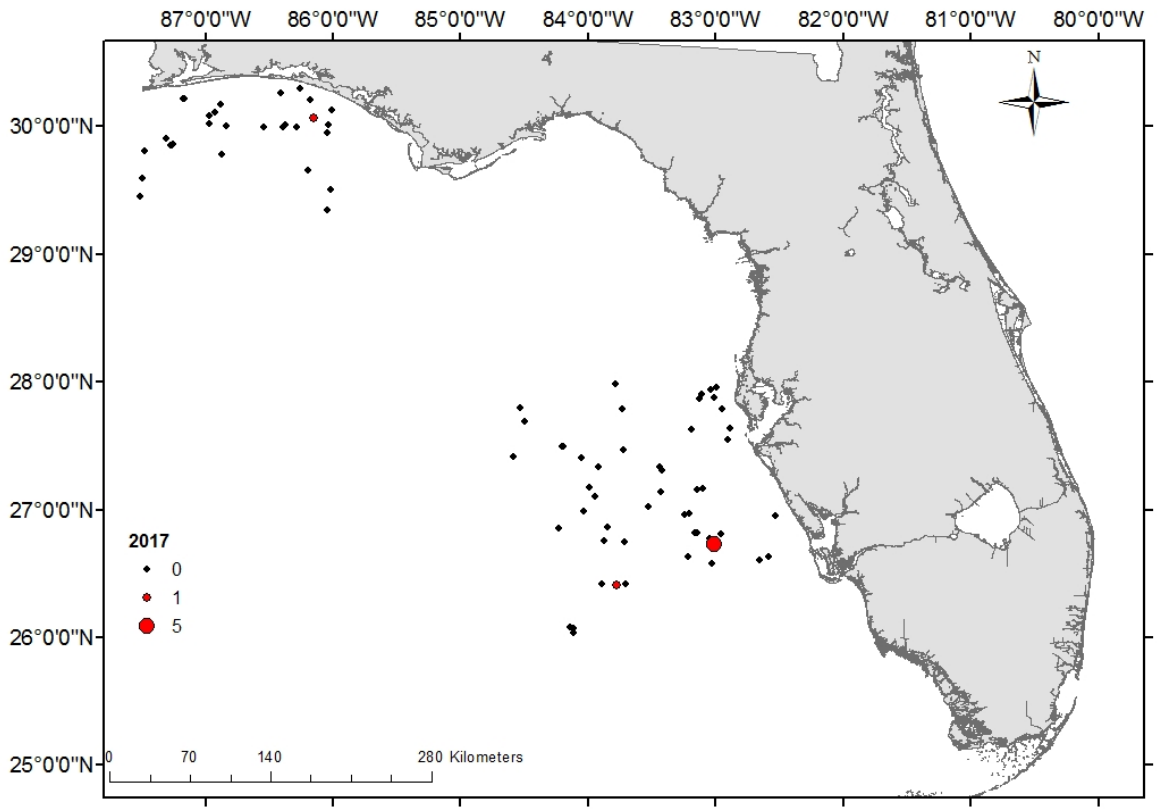

Figure A4. Stations sampled in 2017 during the FWRI vertical longline survey. Symbols are scaled to represent total number of Red Grouper caught at each sampling location.