Indices of abundance for Red Snapper (*Lutjanus campechanus*) from the Florida Fish and Wildlife Research Institute (FWRI) vertical longline survey in the eastern Gulf of Mexico

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Indices of abundance for Red Snapper (*Lutjanus campechanus*) 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 Snapper, 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 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 throughout the eastern GOM using vertical longlines.

Survey Design and Sampling Methods:

In 2014 and 2015 sampling was conducted in the National Marine Fisheries Service (NFMS) statistical reporting zones 4, 5, 9, and 10 as part of fisheries-independent surveys conducted by FWRI in the eastern Gulf of Mexico. In 2016, sampling effort was expanded to include the entire Florida coastline including 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 (4-180 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 the entire west Florida Shelf (WFS) survey area was not feasible prior to initiating the WFS reef fish survey. A variety of methods were initially used to target reef habitat throughout the GOM, but from 2010 onward 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. 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, potholes, or fracture (Table 2).

Established Southeast Area Monitoring and Assessment Program's (SEAMAP) protocols were followed at stations fished with the vertical longline (VLL) method. Each VLL rig consisted of, a monofilament (181 kg test) back-bone 7.3 m long, equipped with 10 evenly-spaced (every 0.61 m) crimped t-swivels. A gangion was attached to each of the 10 t-swivels. A gangion consisted of a snap swivel with a length (0.46 m) 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 vertical longlines were fished simultaneously at each sampling site, each rigged with 10 identical hooks. Two hook sizes, 8/0, 11/0, or 15/0 (Mustad 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. Hooks were baited with Atlantic Mackerel cut proportional to the hook size and the gear fished passively for five minutes prior to retrieval using a bandit reel. Standard length, fork length, and total length were measured for all captured Red Snapper.

Data Treatment and Standardization:

Standardization of Response Variable:

For the VLL index of Red Snapper we modeled the total catch at each station. Fish captured from all hook sizes were combined to determine total catch per station. Only two hook sizes were fished at each station, therefore a presence/absence variable was created for each hook size.

Explanatory Variables:

We considered 10 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 2014-2016.

Month (*M*) – A temporal parameter based on month of sampling. Sampling occurred from June to October.

Depth (*DQ*) – Water depth may be an important component affecting the distribution of reef fish. All depths sampled (4-142 m) were included and treated as a quantile factor.

Latitude (*Lat*) – The latitude of sampling location was included as a spatial parameter in the model.

Longitude (*Lon*) – The longitude of sampling location was included as a spatial parameter in the model.

Region (*Zone*) – National Marine Fisheries Service statistical zones were combined into three regions: Region 1 (Zones 2, 3, and 4); Region 2 (Zones 5, 6, and 7); and Region 3 (Zones 8, 9, and 10) 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 Snapper 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). Parameters that were not significant and did not improve model fit were removed from the analysis. Including latitude and longitude caused the model to not converge, so these variables were therefore 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. An examination of residuals for the spatial model parameters 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 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 3.3.2 (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 3. The standardized index values indicate an overall increasing trend in estimated mean abundance for the years 2014-2016 (Figure 2). 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, limited inferences can be discerned concerning overall patterns of Red Snapper population abundance.

Literature Cited:

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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	Month Range
2014	131	13 - 98	26.076 – 30.243	-87.492 to -82.750	Sept. – Oct.
2015	122	8 - 142	26.021 – 30.169	-87.389 to -82.282	June – Oct.
2016	265	9 - 105	24.466 – 31.000	-87.492 to -81.808	June – Sept.

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
Pothole			Small Vessel
	Pothole		Tires
No Relief		Fracture	
	Flat HB		Fracture
	Pavement		

Table 3. Relative nominal total, number of stations sampled (N), proportion of positive sets, standardized index, and coefficient of variation (CV) for FWRI Red Snapper vertical longline survey of the West Florida Shelf, 2014-2016.

Year	Nominal total	N	Proportion positive	Standardized Index	CV
2014	0.3511450	131	0.1450382	0.8636869	0.2502677
2015	0.2868852	122	0.1311475	0.8987452	0.2739246
2016	0.4656489	262	0.148855	1.2375678	0.1852334

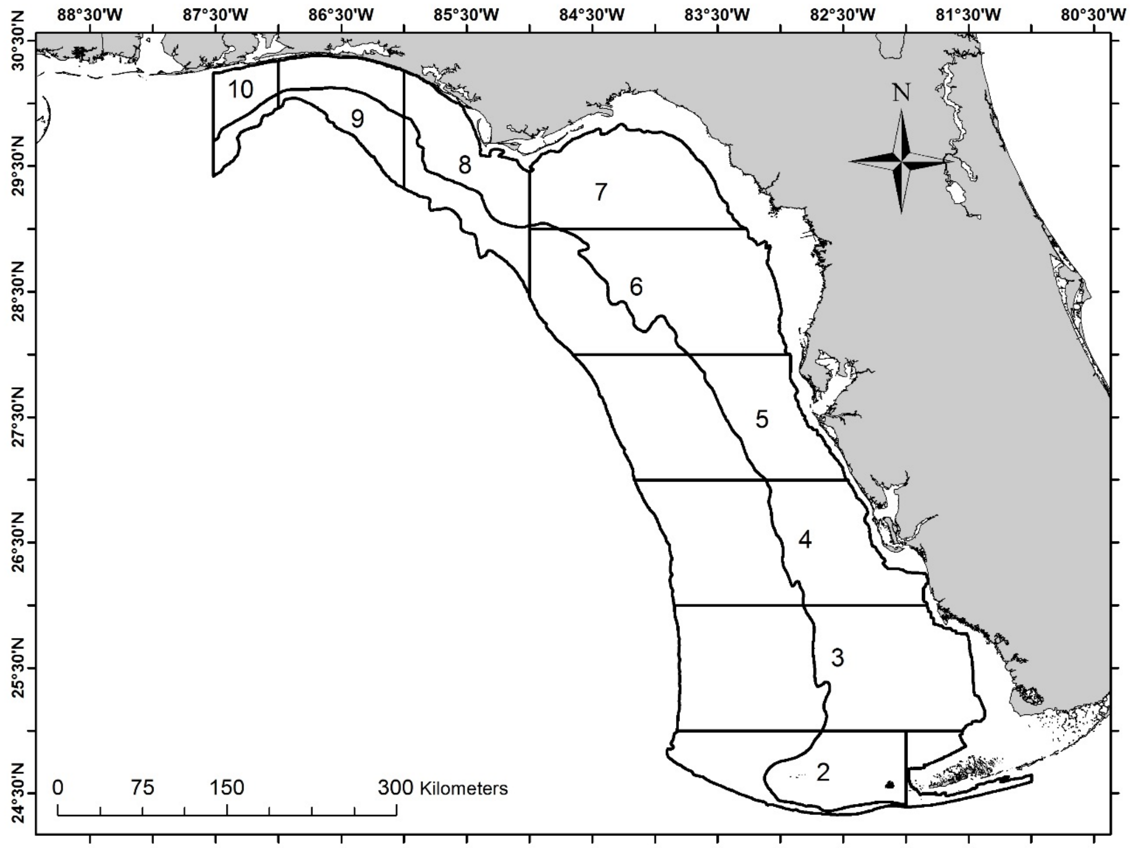

Figure 1. The eastern Gulf of Mexico survey area. Sampling effort is allocated among NMFS statistical reporting zones (2 – 10) as well as nearshore (10 – 37 m) and offshore (37 – 180 m) depth strata.

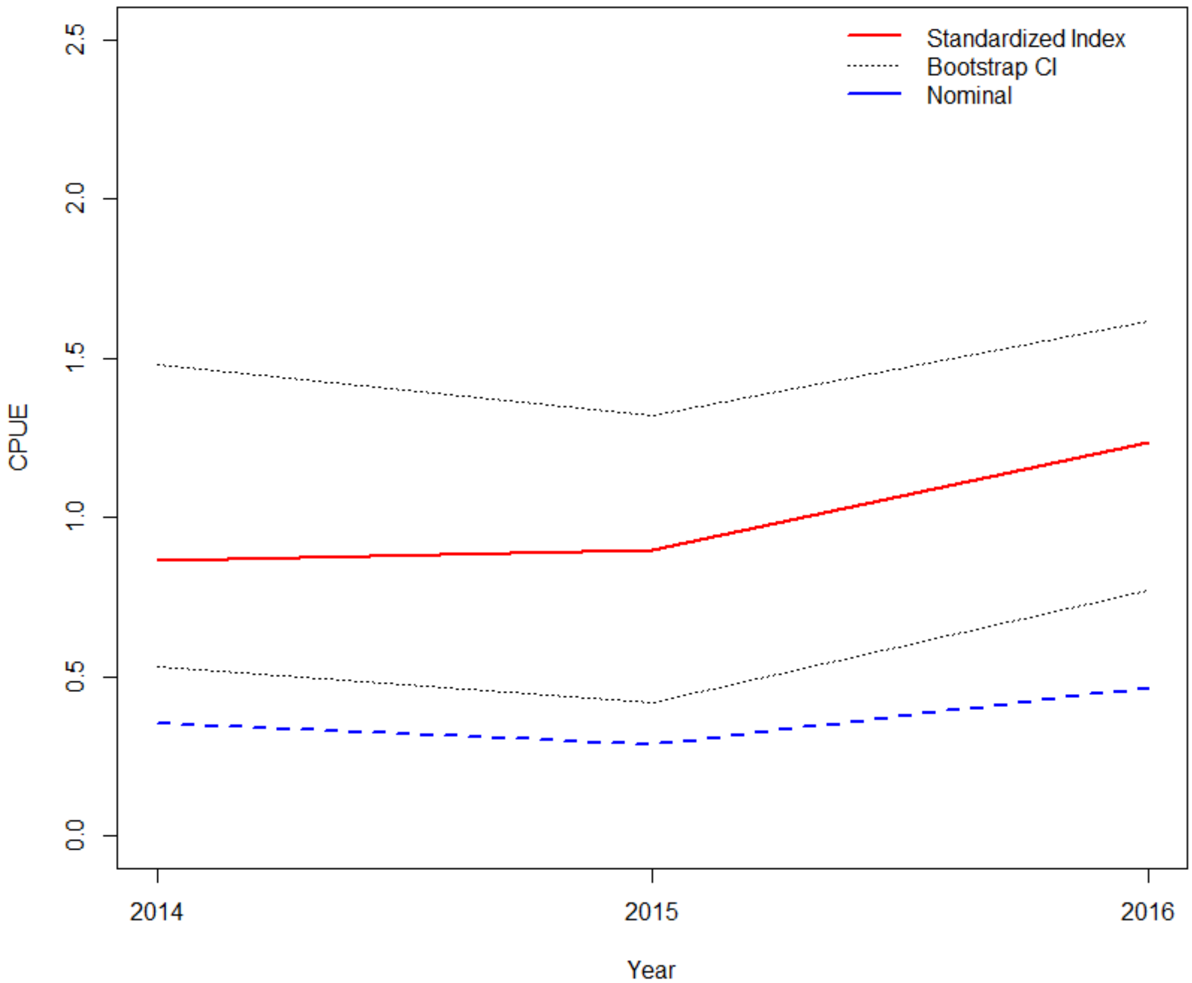

Figure 2. Relative standardized index (solid red line) with 2.5% and 97.5% confidence intervals (black dotted lines) and the nominal CPUE (blue hashed line) for Red Snapper CPUE in the FWRI vertical longline survey.

Appendix A

Figures A1-A3. Annual distribution of stations sampled (2014 – 2016) during the FWRI reef fish vertical longline survey of reef fish along the West Florida Shelf.

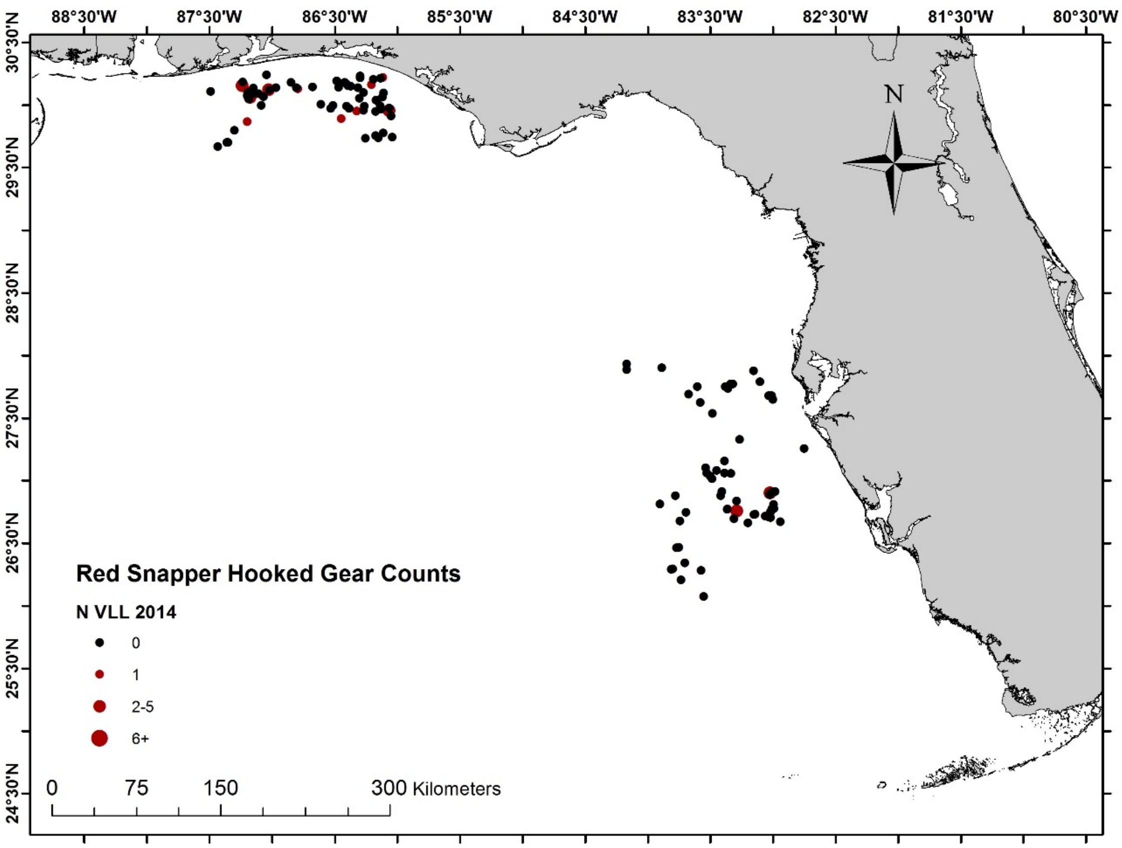

Figure A1. Stations sampled from 2014 during the FWRI vertical longline survey. Symbols represent total number of Red Snapper captured at each sampling location.

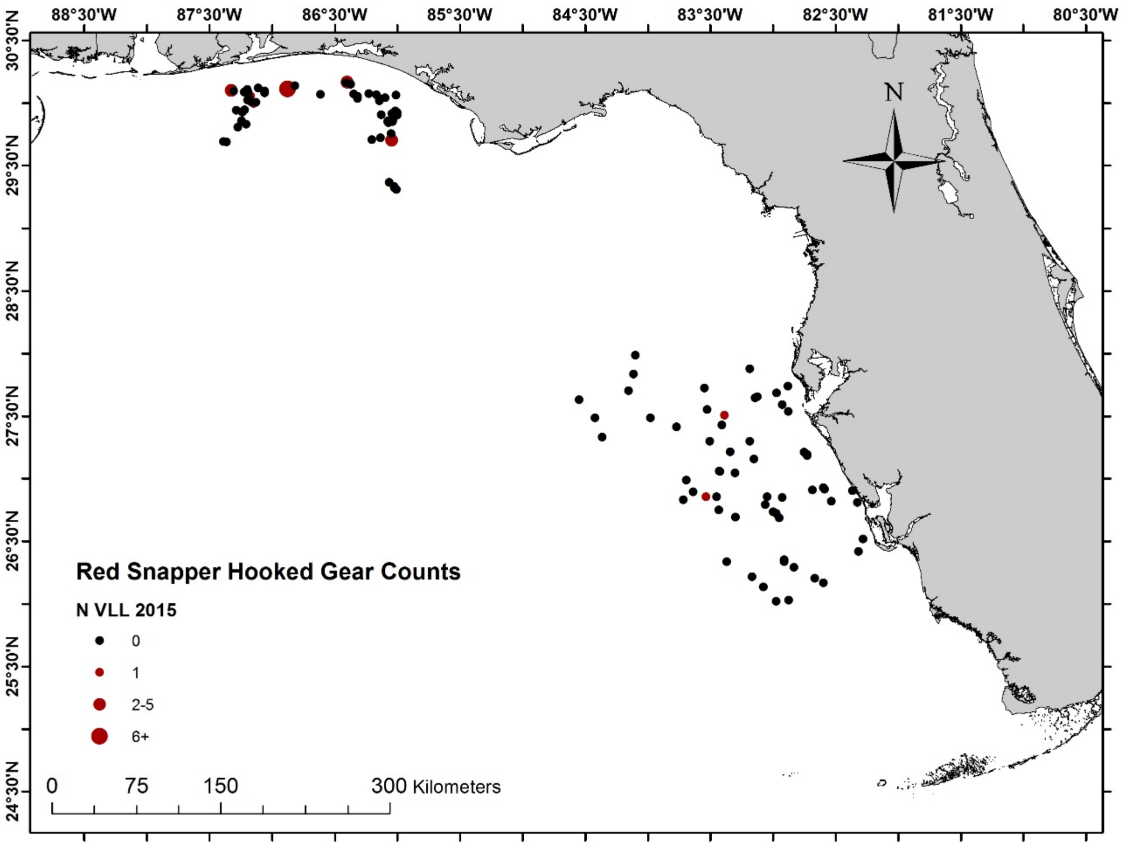

Figure A2. Stations sampled from 2015 during the FWRI vertical longline survey. Symbols represent total number of Red Snapper captured at each sampling location.

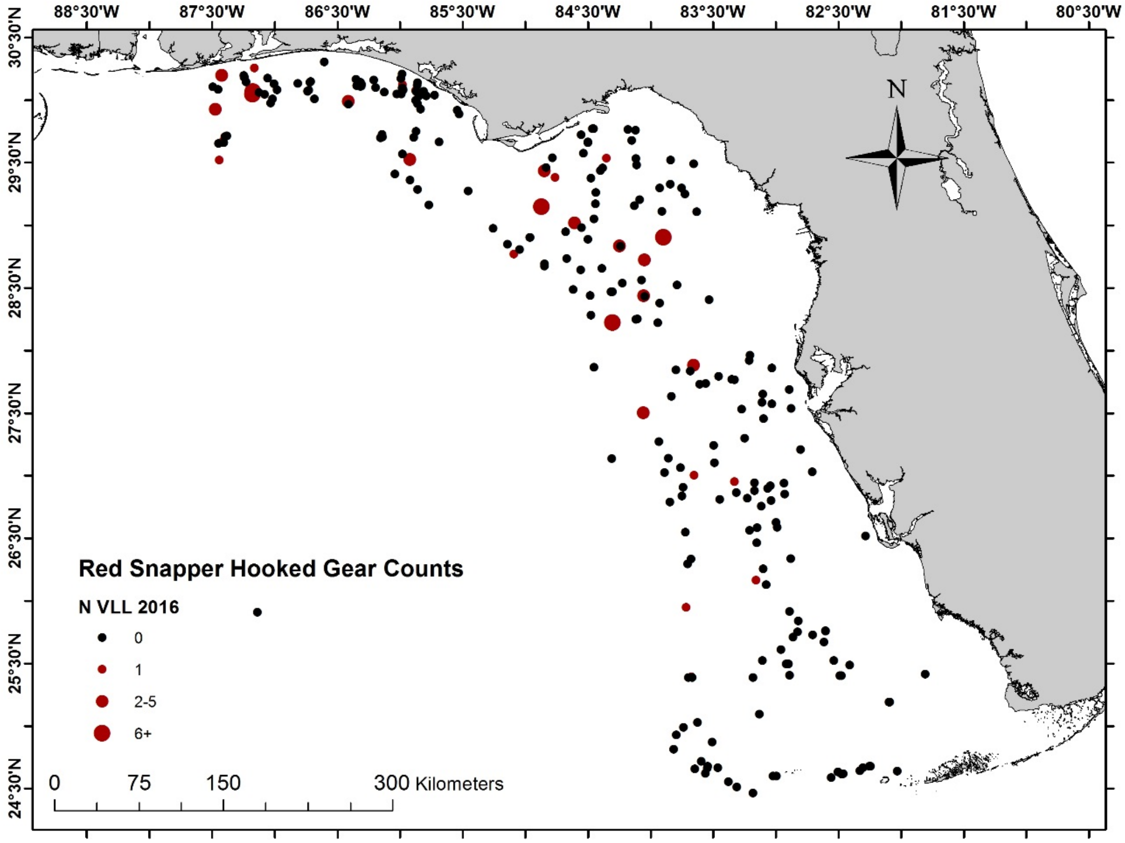

Figure A3. Stations sampled from 2016 during the FWRI vertical longline survey. Symbols represent total number of Red Snapper captured at each sampling location.