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

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Indices of abundance for Red Snapper (*Lutjanus campechanus*) from the NFWF-expanded Florida Fish and Wildlife Research Institute (FWRI) video 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 of 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 time-series that vary in space, time, and habitats sampled.

Survey Design and Sampling Methods:

The FWRI reef fish survey was initially conducted on natural reef habitats in an area of the west Florida shelf (WFS) bounded by 26° and 28° N latitude and depths from 10 – 110 m, which corresponded to the SEAMAP statistical zones 4 and 5 (Figure 1). The time series for the video survey in these zones starts in 2010 and has already contributed to assessments of reef fish in the GOM, both as an independent index and combined with video surveys carried out by the NMFS Pascagoula and Panama City labs. Starting in 2014, due to NFWF-funded expansion of the video survey, SEAMAP zones 9 and 10 were sampled, which corresponds to the western edge of the Florida Panhandle. In 2014, the FWRI survey also began incorporating artificial reef habitats into the survey, whereas previous years focused on natural (geologic and biogenic) reef habitats. Finally, in 2016 sampling was further expanded into all SEAMAP statistical zones along the Florida coastline (from 2-10), and area that is bounded in the southern portion by the Florida Keys and Dry Tortugas and extend to the Florida/Alabama border (Figure 1; Appendix A, B). 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 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 with 36 potential values (Table 2) 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 Red Snapper (MaxN, or the maximum number of Red Snapper observed on a single video frame). When video conditions allowed, individual Red 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. In this paper we are presenting three alternative indices of abundance based on different site criteria. The first is the zone 4/5 only index which was taken from an already developed index used in assessments as those habitats are the longest possible time series (only 2014-2016 shown here). To illustrate potential changes in trends in estimated abundance by including sites derived from the NFWF expansion we included two indices with additional data. The first additional index was limited to natural bottom habitats only similar to the 4/5 index, but with the addition of samples from zones 9 and 10. The other index included data from all zones (4/5 and 9/10 only for 2014 and 2015) and all habitat types (natural and artificial) for the three year period. Final sample sizes for each index are in Table 3.

Standardization of Response Variable:

For the video index of Red Snapper we modeled the MaxN, or maximum number of Red 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 18 explanatory variables in the original, zone 4/5 model analysis, however, due to time limitations, not all variables were available for each zone for each year. Potential variables are listed below, with ones included in all potential models (could be used in the indices for 9/10 and all zones as well) 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

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

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

Longitude (*LonQ*) – The longitude of video samples was included as a spatial parameter in the model and was treated as a quantile factor in the models

Statistical Zone (*statz*) – The SEAMAP statistical zone in which a sample was collected

Turbidity (*Turb*) – 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 in the models

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 2.

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.

Region (Reg) – A categorical variable to describe if a site was off of the Florida Panhandle (zones 7-10) or the peninsular region (zones 2-6)

Project (Project) – A categorical variable to describe if a site was on a natural bottom (WM) or artificial (Art) structure.

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. These data distributions are referred to as "zero-inflated" and are fairly common in ecologically based count data. In all index models, the zero-inflated negative binomial model was determined to be the most appropriate and was subsequently used for model selection and fitting. The zero inflated approaches model the zero counts using two different processes, a binomial and a count process (Zuur et al. 2009).

A backwards step-wise model selection procedure was used to exclude unnecessary parameters from the full model formulations. The optimum Red Snapper model formulation was determined by backwards selection and comparisons of model AIC values (Zuur et al. 2009). Due to correlations and models not converging in the index with zones 9/10 latitude and longitude had to be dropped. For the all zones model, stat zone couldn't be used due to correlations with Lat and Lon similarly. For both models geoform couldn't be included due to not enough samples of each geoform type in each zone, quartile value of depth and space to allow for bootstrapped CV's and confidence intervals. The final index models for each dataset are given by the following equations:

(1: Zones 4/5-Natural) *MaxN = Y+DQ+LatQ+Rel+Alg+Hcor+Scor+Sgr+Spo+Uses+Rock+geoform*

(2: Zones 4/5/9/10-Natural) *MaxN = Y+DQ+statz*

(1: All zones All habitats) *MaxN = Y+DQ+LatQ+LonQ+project*

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 and environmental 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 3.0.2 (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 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). The CV's indicate a good fit and decrease every year (Table 3; Figure 3). Interestingly, the CVs are lower for each subsequent index, indicating that the variation in the data is decreasing with increased sample sizes. Furthermore, the increased sampling throughout the eastern GOM, rather than just the central portion of Florida, may be assessing a more complete picture of eastern Gulf of Mexico populations in terms of overall size or habitat associations.

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Table 1. List of total video samples conducted by zone and year for both natural and artificial reef types.

Natural Habitats				
	Year			
Stat Zone	2014	2015	2016	Total
2			83	83
3			74	74
4	142	90	83	315
5	144	134	130	408
6			87	87
7			69	69
8			66	66
9	68	88	67	223
10	22	55	54	131
Total	376	367	713	1456

Artificial Habitats				
	Year			
Stat Zone	2014	2015	2016	Total
2				
3				
4		13	6	19
5		12	8	20
6			3	3
7			8	8
8			24	24
9	12	7	15	34
10	21	12	19	52
Total	33	44	83	160

Table 2. List of the Geoforms used to describe potential reef fish habitats observed using side scan sonar. Habitats in bold were those observed with side scan and had videos deployed that had sufficient sample sizes to be included in subsequent analyses.

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 3. Relative nominal MaxN, number of stations sampled (N), proportion of positive sets, standardized index, and CV for FWRI Red Snapper video index of the West Florida Shelf, 2014-2016.

Zones 4/5 Natural

Year	Nominal MaxN	N	Proportion positive	Standardized Index	CV
2014	0.402098	286	0.1358885	0.979539	0.254307
2015	0.433036	224	0.1607143	0.828299	0.214415
2016	1.222798	193	0.3041237	2.440288	0.148602

Zones 4/5/9/10 Natural

Year	Nominal MaxN	N	Proportion positive	Standardized Index	CV
2014	0.6542553	376	0.143617021	0.6951193	0.14129
2015	0.7520436	367	0.182561308	0.8253484	0.111889
2016	1.3443114	334	0.221556886	1.4795323	0.076105

All Zones-All Habitats

Year	Nominal MaxN	N	Proportion positive	Standardized Index	CV
2014	0.9731051	409	0.180929095	0.831665	0.129218
2015	0.7323601	411	0.172749392	0.6609285	0.108519
2016	2.2286432	796	0.248743719	1.5074065	0.067138

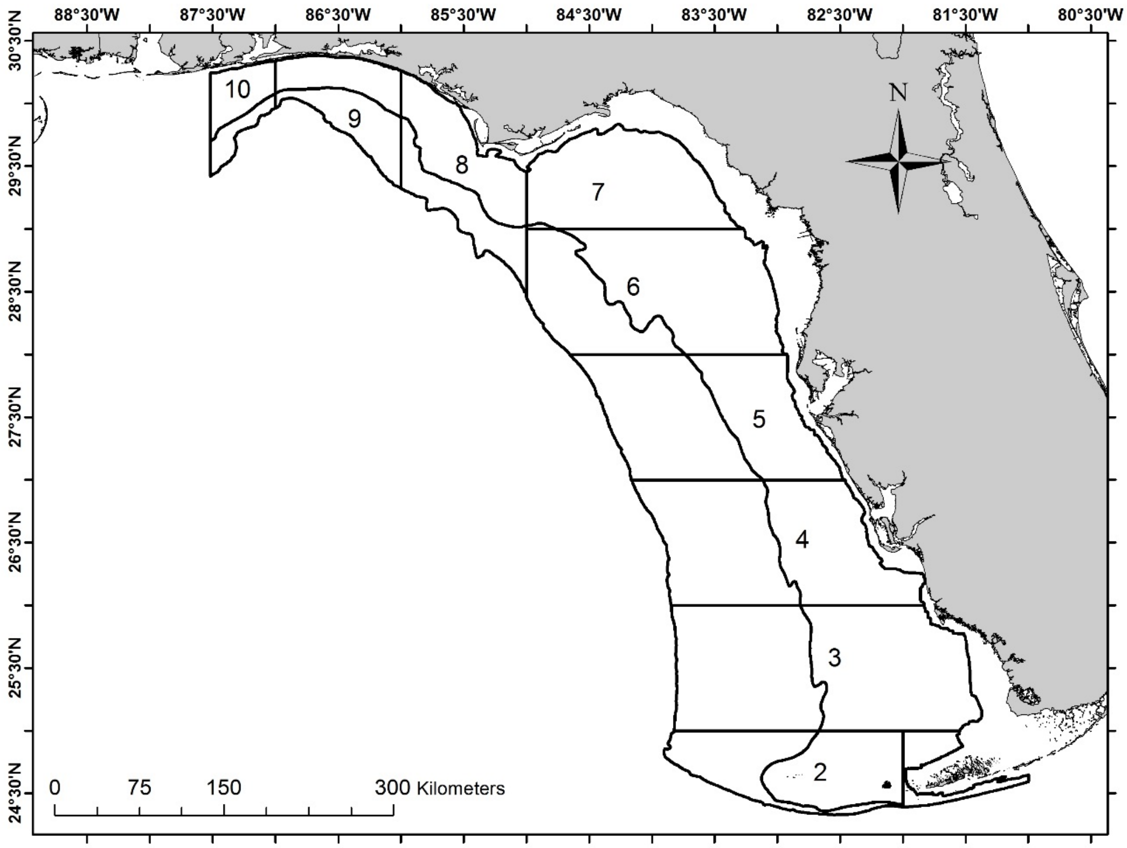


Figure 1. The eastern Gulf of Mexico survey area. Sampling effort is allocated among NMFS statistical reporting zones (2 – 10) as well as nearshore (10 – 37 m) and offshore (37 – 110 m) sampling strata.

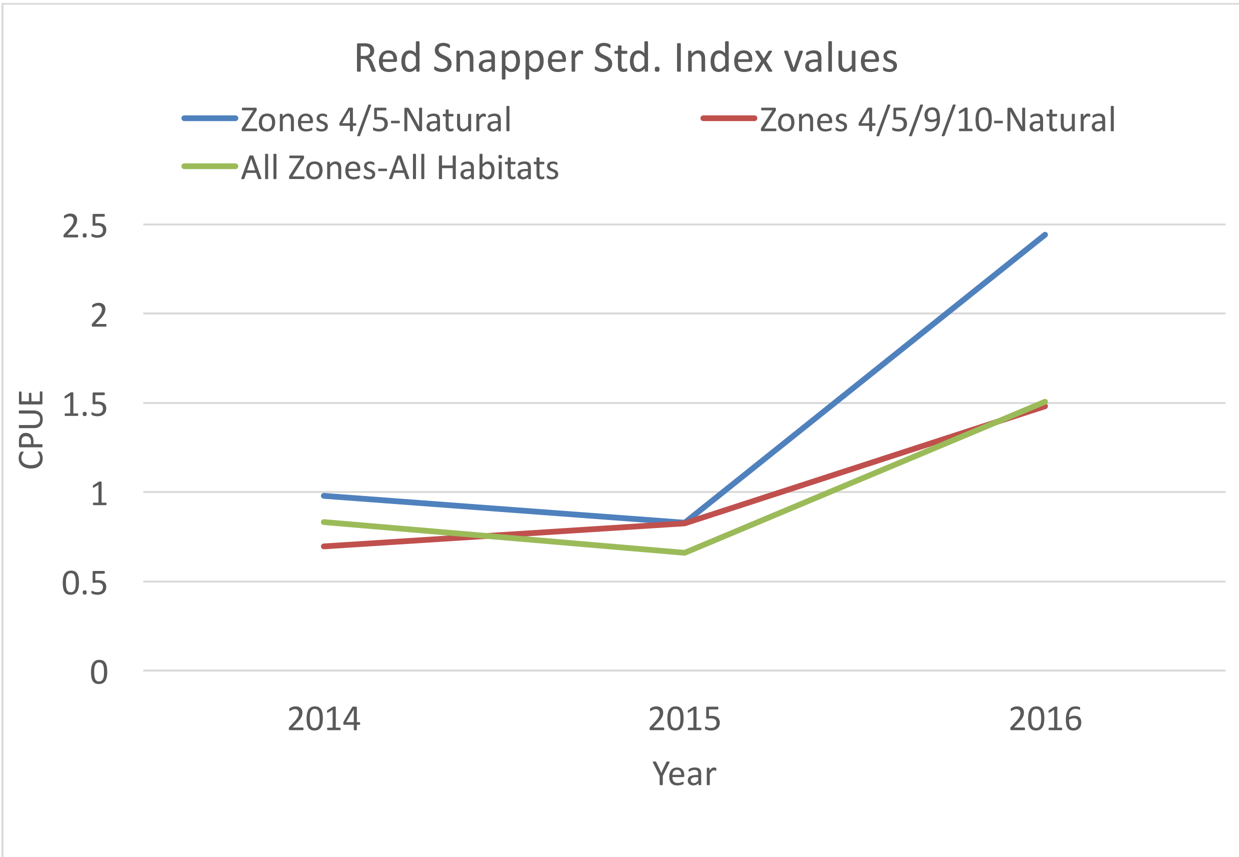


Figure 2. Relative standardized CPUE for Red Snapper for the three alternate indices in the FWRI eastern Gulf of Mexico video survey. Indices differ in SEAMAP statistical zones included, with the all zones-all habitats encompassing zones 2-10 for both natural and artificial habitats.

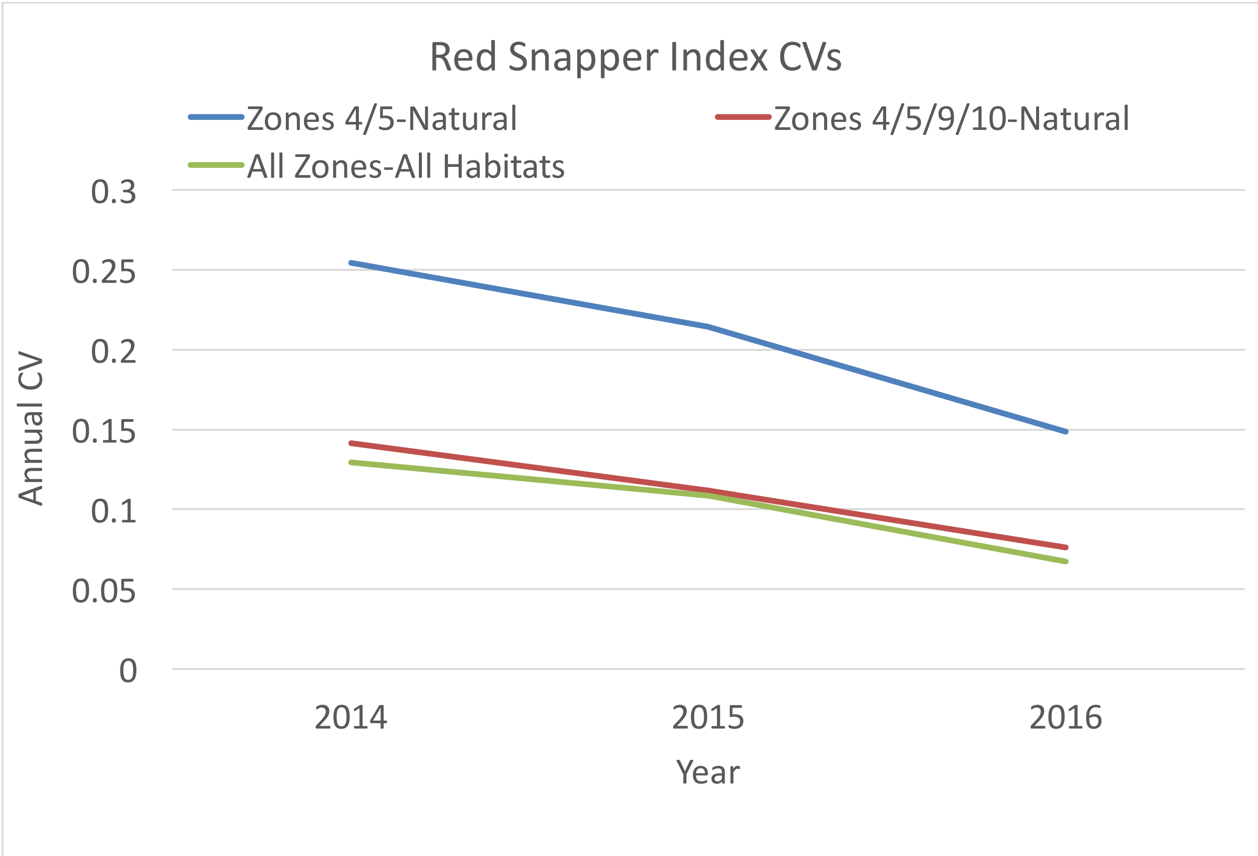
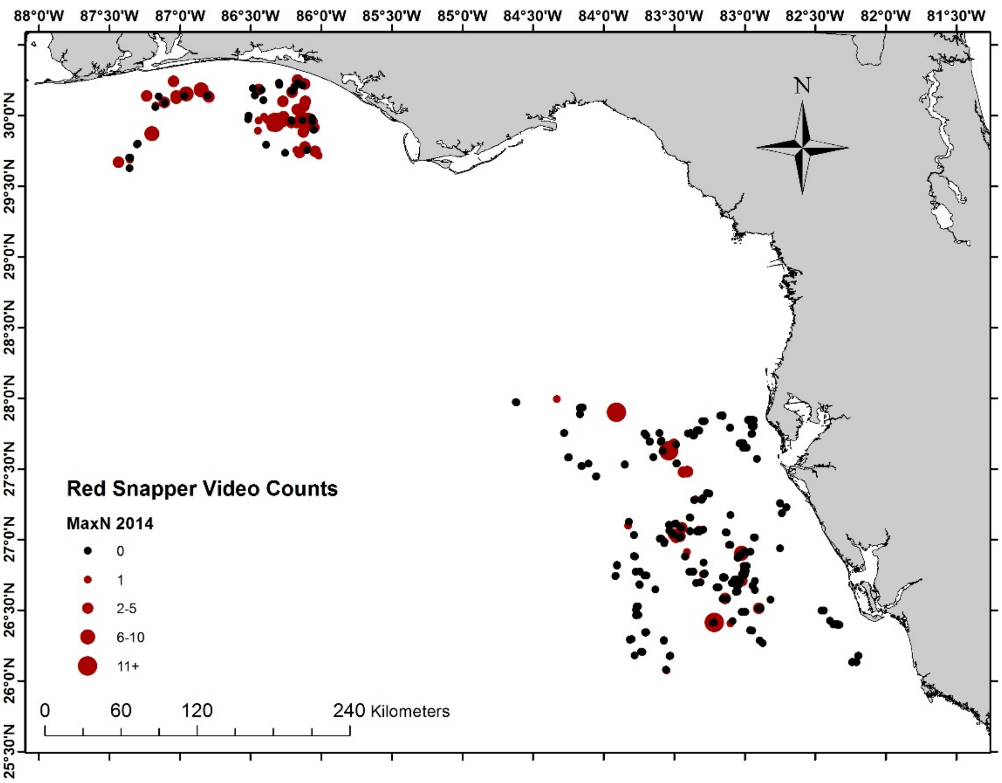
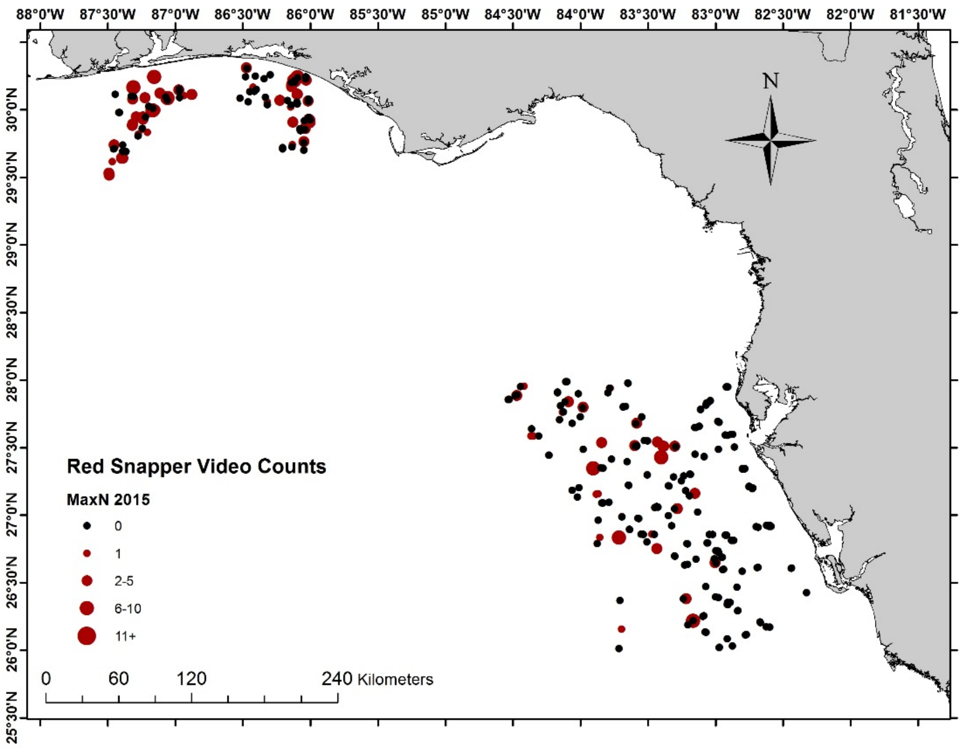


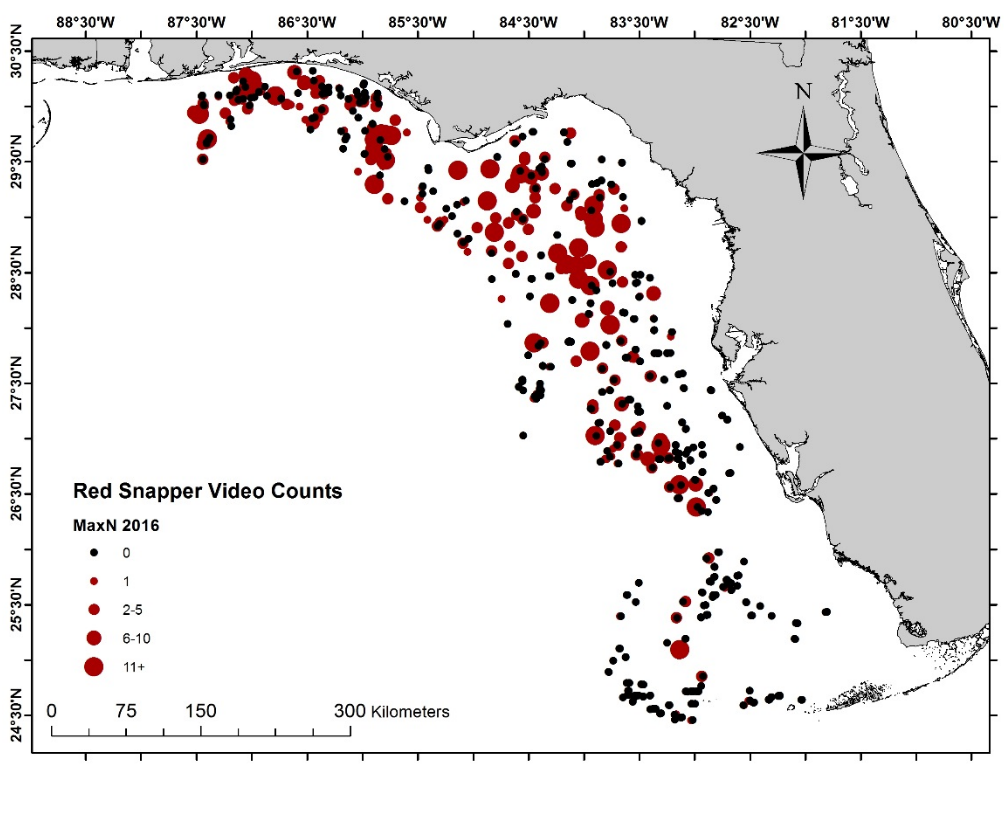
Figure 3. Relative standardized index CVs for Red Snapper for the three alternate indices in the FWRI eastern Gulf of Mexico video survey. Indices differ in SEAMAP statistical zones included, with the all zones-all habitats encompassing zones 2-10 for both natural and artificial habitats.

Appendix A

Figures A1-A3. Annual distribution of stations sampled (2014 – 2016) during the FWRI reef fish video survey on **natural reef habitats**. Symbols represent MaxN, or the maximum number of Red Snapper observed on a single screen shot during each video. Only zones 4/5 and 9/10 were sampled all three years, the remaining SEAMAP zones were only sampled in 2016.

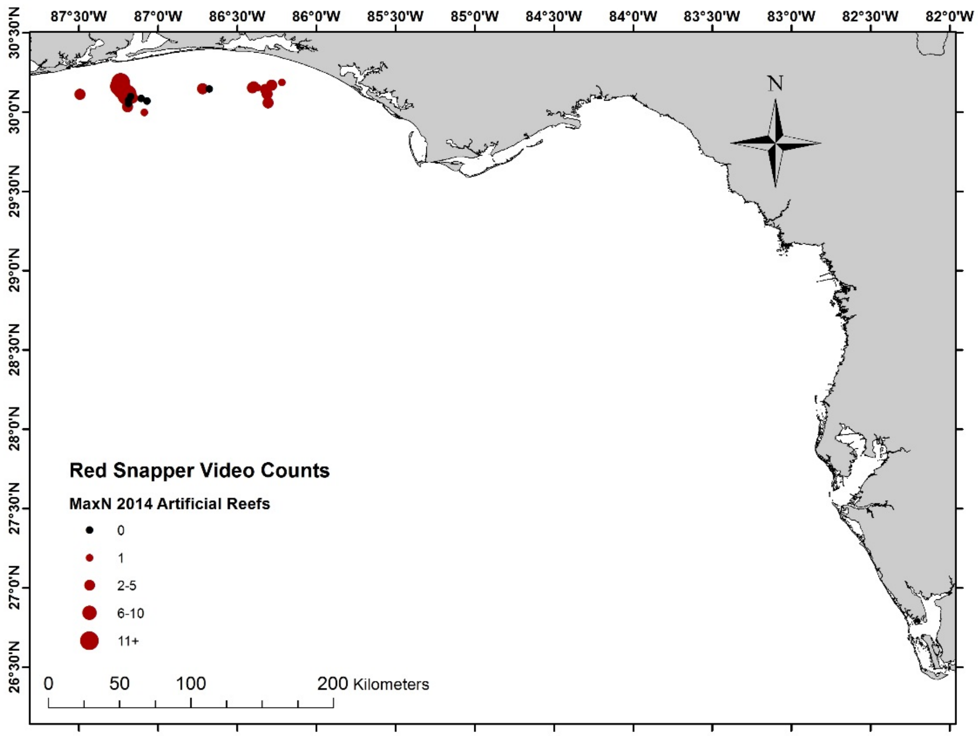


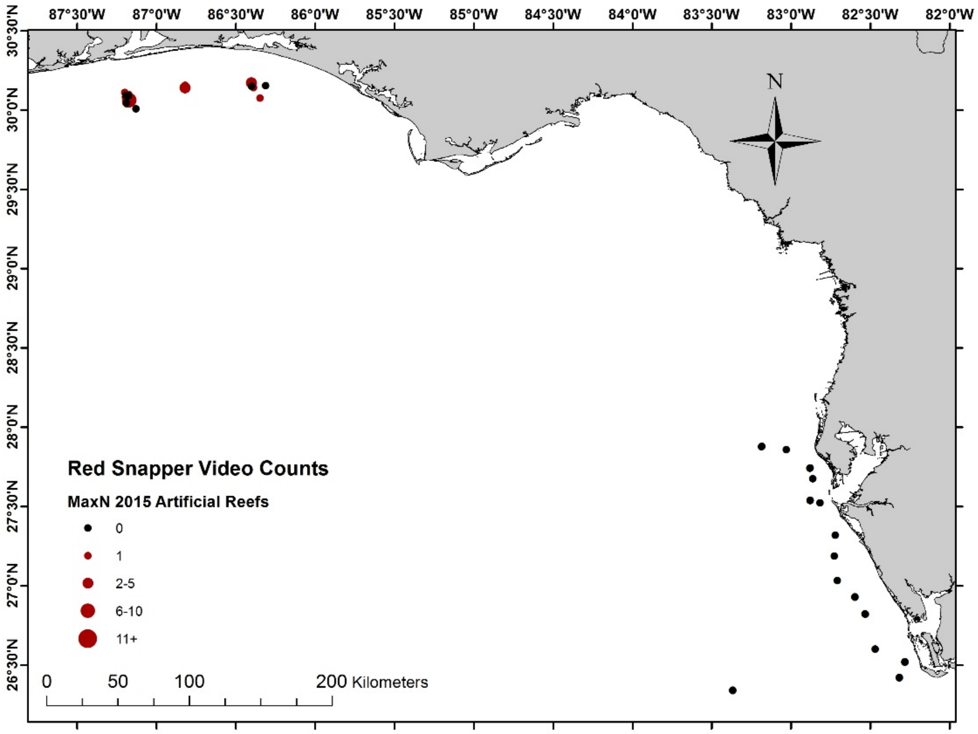

88°0'W
87°30'W
87°0'W
86°30'W
86°0'W
85°30'W
85°0'W
84°30'W
84°0'W
83°30'W
83°0'W
82°30'W
82°0'W
81°30'W
30°0'N
29°30'N
29°0'N
28°30'N
28°0'N
27°30'N
27°0'N
26°30'N
26°0'N
25°30'N
N
Red Snapper Video Counts
MaxN 2015
0
1
2-5
6-10
11+
0 60 120 240 Kilometers


88°30'W
87°30'W
86°30'W
85°30'W
84°30'W
83°30'W
82°30'W
81°30'W
80°30'W
30°30'N
29°30'N
28°30'N
27°30'N
26°30'N
25°30'N
24°30'N
N
Red Snapper Video Counts
MaxN 2016
0
1
2-5
6-10
11+
0 75 150 300 Kilometers

Appendix B

Figures B1-B3. Annual distribution of stations sampled (2014 – 2016) during the FWRI reef fish video survey on **artificial reef habitats**. Symbols represent MaxN, or the maximum number of Red Snapper observed on a single screen shot during each video. Only zones 4/5 and 9/10 were sampled all three years, the remaining SEAMAP zones were only sampled in 2016.




87°30'W
87°0'W
86°30'W
86°0'W
85°30'W
85°0'W
84°30'W
84°0'W
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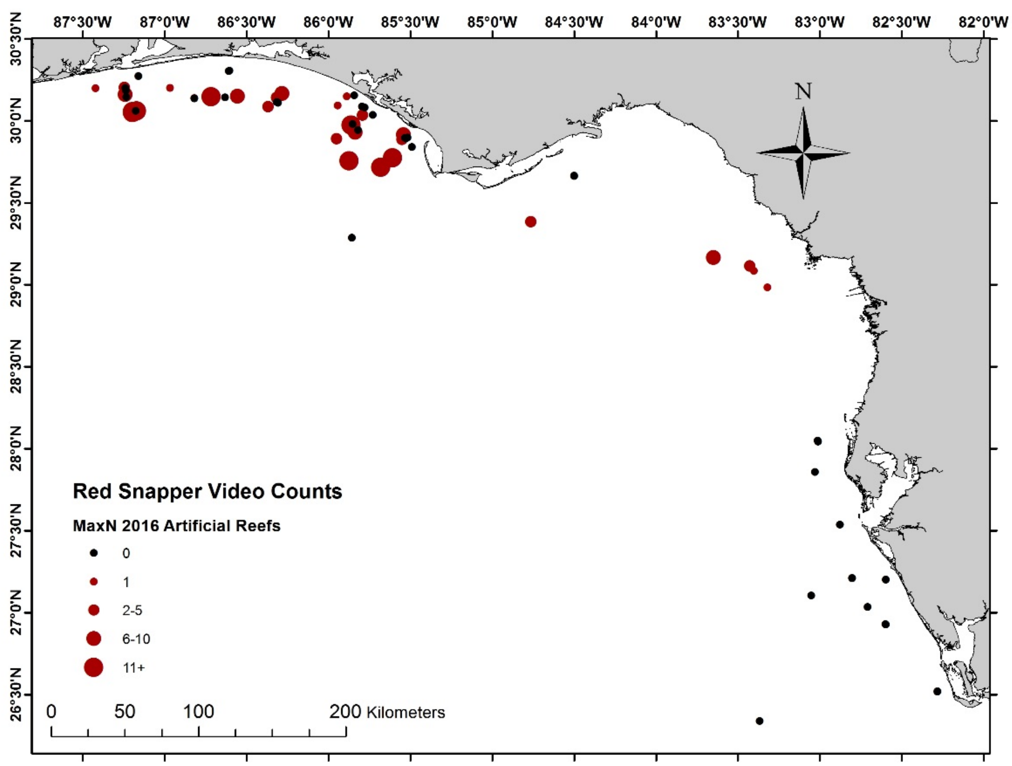
83°0'W
82°30'W
82°0'W
30°30'N
30°0'N
29°30'N
29°0'N
28°30'N
28°0'N
27°30'N
27°0'N
26°30'N
N
Red Snapper Video Counts
MaxN 2015 Artificial Reefs
0
1
2-5
6-10
11+
0
50
100
200 Kilometers


87°30'W
87°0'W
86°30'W
86°0'W
85°30'W
85°0'W
84°30'W
84°0'W
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83°0'W
82°30'W
82°0'W
30°30'N
30°0'N
29°30'N
29°0'N
28°30'N
28°0'N
27°30'N
27°0'N
26°30'N
N
Red Snapper Video Counts
MaxN 2016 Artificial Reefs
0
1
2-5
6-10
11+
0
50
100
200 Kilometers