SEAMAP Vertical Line Survey: Relative Indices of Abundance of Gulf of Mexico - Red Snapper

Matthew D. Campbell, Ted Switzer, John Mareska, Jill Hendon, Jeff Rester, Chloe Dean, Fernando Martinez-Andrade

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SEAMAP Vertical Line Survey:
Relative Indices of Abundance of Gulf of Mexico - Red Snapper

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Matthew D. Campbell[1], Ted Switzer[2], John Mareska[3],
Jill Hendon[4], Jeff Rester[5], Chloe Dean[6], Fernando Martinez-Andrade[7]

PARTICIPATING INSTITUTIONS

1 - Southeast Fisheries Science Center, Mississippi Laboratories, Pascagoula, MS
2 - Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL
3 – Alabama MRD, Dauphin Island, Al.
4 – Mississippi DNR, Ocean Springs, MS
5 – Gulf States Marine Fisheries Commission, Ocean Springs, MS
6 – Louisiana Department of Wildlife and Fisheries, Cocodrie, LA
7 – Texas Parks and Wildlife Department, Austin, TX

INTRODUCTION

The primary purpose of the SEAMAP Vertical Line Survey is to characterize the spatial and temporal distribution, age and size distributions, and analyze relative abundances of commercially and recreationally important reef fish species in the coastal waters of the Gulf of Mexico. The vertical line gear used in this survey is often referred to as bandit reels and the gear has been in use in the commercial fishery for a long period of time (Scott-Denton et al. 2011). Use of the vertical line as a fishery-independent survey tool has a less extensive history but is becoming more popular in the last decade. NMFS Mississippi Laboratories (MS Labs) began conducting standardized sampling with vertical line gear in 2005 to sample oil production platforms in Mississippi and Louisiana (Table 1, Moser et al. 2012). Due to the ease of deployment and the number of samples that can quickly obtained MS Labs replaced traps with vertical line gears as a piggyback component of the SEAMAP reef fish video survey in 2010 and as a primary gear used during the Congressional Supplemental Sampling Program in 2011 (Campbell et al. 2015, Karnouskas et al. 2017). The primary intent of the gear for the SEAMAP reef fish video survey is to collect otoliths and gonads as supplemental data that otherwise cannot be obtained from video. The original experimental design that made use of three hook sizes, and is still in use today, was focused on collecting hook selectivity data (Moser et al. 2012, Campbell et al. 2015). In 2010 standardized sampling was initiated by Alabama MRD to sample coastal waters in their region and that sampling effort has used similar gears and standardized approaches as the previous NMFS efforts (Gregalis et al. 2012). Louisiana began vertical line sampling in 2011, Florida started in 2014 and Texas started in 2015. By 2012 all groups sampling with vertical line were following the gear standardization and deployment protocols established by the SEAMAP vertical line subcommittee with several minor exceptions covered in the methods section. All biological data are submitted to the SEAMAP data management system and managed by Gulf States Marine Fisheries Commission.

Objectives

- Create a standardized survey using vertical-line gear to provide a time-series data set for evaluation of changes in relative abundances of various reef fish of the Gulf of Mexico.
- Characterize reef fish assemblages by depth strata and habitat types utilizing currently approved and standardized SEAMAP protocols.
- Provide reef fish life-history information.
- Quantify and characterize habitats within depth strata of the Gulf of Mexico using remote sensing technologies and video toward a comprehensive goal of creating a Gulf-wide habitat map.

Historical and Current Station Selection

Previous to 2016 each state was conducting surveys using standardized gear and deployment methods however each state was using their own survey design. In 2016 due to concerns about the utility of data collected under disparate sampling designs the SEAMAP subcommittee collaborated to create a single unified sampling design that will serve to select sites in a given year to sample. The history of changes are presented below by state and year, and highlight the changes to the design when they took place.

Alabama
2010-2013. From 2010-2012 a total of 12 grids were fished per survey: two structure and two non-structure were randomly chosen and proportionally allocated across three depth strata: 20-40 m, 40-60 m and 60-100 m. In 2013 the total number of grids was increased to 18.

2014. Sampling effort was increased relative to previous years to provide more data in support of the red snapper (*Lutjanus campechanus*) stock assessment. This increase in effort included sampling effort outside Alabama Artificial Reef Permit Zone (RPZ). Stations were randomly chosen and allocated proportionally across three depth strata: nine stations in 20-40 m, six stations in 40-60 m and three stations in 60-120 m and nine stations (across nine grids) outside the reef permit zone. Across these 48 stations, three different treatments were applied, as follows:

- Treatment 1 (n=12, all inside RPZ): 1) ROV, then 2) fish six drops with GoPro cameras attached to vertical longline backbone, then 3) ROV again unless no catch.
- Treatment 2 (n=12, all inside RPZ): 1) ROV, then 2) fish three drops with GoPro cameras on the vertical longline backbone.
- Treatment 3 (n=24): 1) Fish three drops with GoPro cameras on the vertical longline backbone. No ROV deployment. This treatment is applied to structure sites in the Reef Permit Zone (n=12), no structure sites in the Reef Permit Zone (n=3), and no-structure sites outside the Reef Permit Zone (n=9).

2015. Eighteen grids were selected and stations were randomly chosen proportional to three depth strata: eighteen stations in 20-40 m, fourteen stations in 40-60 m and seven stations in 60-120 m. Two different treatments were applied, as follows:

- Treatment 1 (n=24, all inside the reef permit zone): First ROV, then fish three drops. GoPro cameras were used at these stations.
- Treatment 2 (n=12+3 no structure per strata, all inside the reef permit zone): Fish three drops. No ROV. GoPro cameras were used at these stations.

Louisiana
2011-2015. The sampling universe was divided into three equidistant longitudinal zones (Eastern zone: 89.00°- 89.39°, Central zone: 89.40°- 90.19°, and Western zone: 90.20°- 91.00°), with the water depth ranging between 60' to 360'. Each block was sampled quarterly in rotation. Within each sampling block there are 40 different corridors (separated by minutes in longitude) which are randomly selected with an allowance of + / - 3 minutes. The sites are randomly selected within the corridor boundary and sampled at the chief scientist's discretion (concerning safety). The sites roughly consist of 23% Artificial Reefs, 3% Natural Bottom, 74% Petroleum Production Platforms, and the depths at which the sites are selected from is 60'-120' (54%), 120'-180 (27%), and 180'-360' (19%).

Texas
2015. Stations were randomly selected by field party chiefs from known habitat in statistical zones 17-21 and within 10-40 m water depth. Habitat predominantly consisted of oil and gas platforms.

SEAMAP – Unified Design.
In 2016 the SEAMAP Subcommittee initiated a unified research design for station selection to improve the utility of the survey at assessment. Within each state the offshore waters between 10 and 150m were divided into 150x150m grid blocks across three depth strata (10-20 m, 20-40 m, and 40-150m). Area occupied by five habitat types within region/depth zone is then calculated and which include natural reef (hard bottom), presumed reef (either natural or artificial), oil/gas platforms, artificial reefs, and unknown. Sites are then randomly selected in proportion to the area occupied within a region/depth zone and further allocated proportional to the habitat types within that region/depth zone. SEAMAP partners are provided with coordinates and information on the selected sampling target station prior to the sampling year.

NMFS
2010-present. Vertical line sampling is piggy-backed onto the SEAMAP reef fish video survey of natural hard bottom habitats of the GOM. The survey uses a two-stage sampling design that is based on four regional strata (South Florida, Northeast Gulf, Louisiana-Texas Shelf, and South Texas). Within regional strata 10 minute by 10 minute longitude blocks are characterized as containing two levels of reef area (≤ 20 km^2 of reef and > 20 km^2 reef). The area occupied by each region/reef strata relative to the total area of known reef is then calculated and blocks within each strata are then selected proportional to that area. The primary sampling unit (site) is then randomly selected from a 0.1 by 0.1 mile grid that was overlaid onto the reef area in a given block. From these sites 50% are randomly selected for deployment of the vertical line gear and which is always deployed following camera deployment and retrieval. The NMFS efforts continue as a piggyback effort despite the new design. The main reasons are that the SEAMAP reef fish video survey is a 26 year time-series that will not be changed and there are no additional resources to dedicate completely to a vertical line survey. Data will still be contributed if needed.

METHODS

While the underlying research designs (i.e. random site selection) were initially state specific (i.e. 2010-2015) the vertical line gear, deployment methods and biological collections were standardized across laboratories with a few exceptions. The vertical line gear was composed of three main elements including a mainline, backbone, and gangions. The mainline was composed of 300 m of 2-mm, 181-kg-test, clear monofilament and contained on a spool. The detachable back bone is constructed using 6.7-m of 181-kg-test that has a 6/0 snap swivel at both ends that are secured with a crimped 2.2 mm double sleeve. The backbone is attached on one end to the mainline and at the terminal end to a 5–10 kg weight. Ten detachable gangions constructed of 45-kg-test, twisted monofilament line are attached to the backbone at preset 61 cm intervals using either Rosco swivel snaps or AK snaps (survey dependent). A subsurface buoy is attached to the swivel connecting the backbone and mainline to ensure vertical positioning of the hooks during deployment. A second surface buoy is attached once the weight has contacted the bottom which enables line to be paid off the reel while maintaining the deployment position of the gear over the intended site (i.e. prevents dragging). Each backbone used one size of circle hook on a single deployment and depending on vessel size either 2 or 3 reels are deployed at any given site. Circle hooks deployed were Mustad Series 39960D hooks of sizes 8/0, 11/0, and 15/0. Hook size to be fished on a reel was determined randomly at the start of each fishing day and then was rotated clockwise among reel positions on the starboard, aft, and port sides of the vessel at each subsequent station. In the cases where the vessel was too small to deploy three reels, one of the hook sizes would not be used at the site, however the rotation of hooks at each site cycled the hooks throughout the day (i.e. all hooks were not necessarily deployed at every site). Hooks were baited with Atlantic Mackerel *Scomber scombrus* that were cut to match the size of each hook. During deployment, the vertical line remained attached to the vessel; however, line was slowly paid out so that the gear was fished without dragging over the bottom. Gear was deployed on the bottom for 5 min and was then retrieved. In some cases the Louisiana survey encountered habitat that had significant vertical relief that presented entanglement issues such as toppled platforms. At those sites it was deemed to inefficient to fish the gear directly on the bottom due to snagging and so the captain identified a 'safe' fishing depth at which the gear could be deployed. Thus for these problematic sites the fishing depth is different from bottom depth but the verticality of these sites generally caused fish to be distributed up in the water column and associated with the structure. Catch was identified, weighed (kg), and measured (FL, mm). Otoliths and gonads were removed from a randomly selected subset of fish, ensuring spatiotemporal coverage.

INDEX DEVELOPMENT

Most of the state partners did not begin vertical line sampling programs until 2011 which resulted in spatio-temporal imbalances in the sites available for analysis and which are also confounded with habitats selected for sampling. Due to the spatio-temporal/habitat imbalances we did not include data that was collected in various surveys from 2005-2010 but could be included in future analyses if desired (e.g. with a weighted model). The most consistent sampling is associated with a piggyback survey conducted in conjunction with the SEAMAP reef fish video survey operated by NMFS Mississippi Laboratories. Vertical line deployments were conducted randomly at 50% of the video sites from 2010-present and use the SEAMAP vertical line protocols for those deployments. That survey is focused on high-relief natural reef sites primarily located on the shelf-edge break. Both Alabama and Louisiana began deploying vertical lines in 2011 and were primarily focused on artificial reefs. In 2011 NMFS Mississippi Laboratories conducted the Congressional Supplemental Sampling Program (CSSP) survey which included extensive deployment of vertical line gear on natural bottom throughout the northern Gulf of Mexico (Campbell et al. 2014). The CSSP survey represents the most extensive sampling conducted with the gear under a unified design, but unfortunately it was only conducted in 2011 and did not include artificial reef as part of the design. Because it did not include artificial reef we did not include the CSSP data in index development, however if runs are desired that include this data they are formatted and ready for analysis. Alabama, Florida and Mississippi received funding from NFWF to conduct vertical line sampling that uses the SEAMAP protocols however those collections were conducted using different survey designs and thus were also excluded from use in index development. Spatial maps (Figures 1-6) represent all possible data that could be used, but not all of the sites represented necessarily were used in the delta lognormal models. For example CSSP data in 2011 was not used but it an excellent representation of the spatial extent of red snapper catch in the northern GOM and thus we wanted to use that data as a contrast to the less extensive SEAMAP collections in other years.

Sites with blanks entered for hook status on five or more hooks were deleted from the analysis. Sites with blank hook status on five or less hooks were included in the analysis and those blank records were deleted, and thus catch-per-unit-effort (CPUE) was calculated based on the remaining hooks. When hook status was entered as ‘Missing’ those records were deleted and as before the CPUE calculated based on the remaining hooks (i.e. we assumed the hook did not effectively fish at the site). We calculated CPUE as fish/hook^{-1}/min^{-1} with the equation:

$$CPUE = \frac{(\#\ of\ red\ snapper\ caught/number\ of\ hooks\ fished)}{number\ of\ minutes\ fished}$$

The number of hooks fished was pooled over all bandit reels and thus all hook sizes that potentially fished at a site with the exception of missing or blank hook status records. Depending on vessel and survey the number of reels and hook sizes varied between 2-3 fished at each site and a binomial variable indicated whether or not a hook size was deployed. This variable was included in the models to account for unequal probability of deployment of a hook size at any one particular site. When habitat at a site was known it was categorized into natural bottom, artificial reef or petroleum platforms otherwise it was deemed unknown. Artificial reef is a general catch-all that could contain any variety and sizes of structure but all could be determined to be man-made. Artificial reefs could also contain toppled petroleum platforms and those were often a part of Louisiana’s artificial reef planning zones. No artificial reefs had vertical structure that encompassed the entire water column to the surface whereas petroleum platforms had vertical structure throughout the water column. While petroleum platforms were of various sizes and forms and included things as small as a group of standpipes to large size standing platforms, because there is not enough information on size we considered them all to be equivalent. Additionally petroleum platforms, by law, are tracked by the Bureau of Ocean Energy Management (BOEM) and are known features (i.e. navigation hazards) thus we can determine with reasonable certainty the number of this habitat available to sample.

Fisheries independent data frequently have high numbers of 'zero-counts' commonly referred to as 'zero-inflated' data distributions, they are common in ecological count data and are a special case of over dispersion that cannot be easily addressed using traditional transformation procedures (Hall 2000). Delta lognormal models have been frequently used to model trawl, longline catch rate data and will be explored here (Campbell et al. 2012). The GLIMMIX and MIXED procedure in SAS (v. 9.4) were used to develop the binomial and lognormal sub-models in the delta lognormal model (Lo et al. 1992). Best fitting models were determined by evaluating the conditional likelihood, over-dispersion parameter (Pearson chi-square/DF), and visual interpretation of the Q/Q plots. Preliminary evaluation of model fits demonstrated that the delta lognormal model fit the data best and thus all other model runs used that approach.

GOM-wide, east-GOM, and west-GOM models were run and independent variables tested in the model included year, strata, reef, depth, and hook. Variables that decreased AIC, improved over-dispersion and reduced CV's were retained in final models. East and west GOM is divided at the Mississippi River delta (89 west longitude). Year indicates survey year and is always included in the model. Strata are defined by region (i.e. state) and depth (10-20 m, 20-40 m, and 40-150m) zone (see the SEAMAP unified design information above). In 2016 sites were proportionally allocated by area occupied by five habitat types within region/depth zone whereas from 2010-2015 strata was assigned to a site according to depth and region after the fact (i.e. unified strata were not part of the original state based designs). Reef is a habitat variable indicating if the site was natural bottom, artificial reef, petroleum platform or unknown. Depth is the fishing depth at the site not necessarily the same as the site depth (e.g. Louisiana on toppled platforms). Hook (H8, H11, H15) are binary variables indicating whether a hook was used at a site (1) or not used at a site (0). In addition we provide two extra model runs for the Gulf-wide, east-GOM, and west-GOM models in which the habitat variable is used to filter and create habitat specific indices for artificial bottom (includes both artificial reefs and petroleum platforms) and for natural bottom. Reef was removed as a variable in these models (i.e. filtered on reef habitat) and unknown bottom types were excluded from these habitat specific models.

Results

Evaluation of the model fit criteria such as the over dispersion scales, AIC and plots of residuals indicated that while the delta-lognormal model produces some under and over-fitting, the model fits were appropriate for the distribution. Spatial distribution of red snapper catch is confounded by the sampling designs themselves and the changes that have occurred through time with various states beginning programs (LA and AL in 2011, FL in 2014 and TX ion 2015) and with the initiation of the unified design in 2016 (Figures 1-6). Spatial distributions of red snapper catch in 2010, 2012-2015 show restricted spatial distributions whereas in contrast the CSSP data in 2011 and the unified SEAMAP design in 2016 show far more expansive spatial distributions. This is obviously an effect of the underlying research designs applied in those the various years rather than a population expansion or contraction especially considering the species under consideration. There are stations represented throughout the GOM on the shelf edge break in all years except 2014 and those are associated with the NMFS MS Labs piggy back survey. In 2014 there was no sampling conducted west of the Appelbaum Bank (close to the Flower Gardens NMS) due to vessel issues and Texas did not begin their program until 2015. General trends indicate higher catch rates and proportion positives in the west-GOM relative to the east with positive catch information becoming less frequent on the west Florida Shelf. Highest catch rates in the east are associated with the Alabama survey that has a high number of sites associated with the Hugh-Swingle artificial reef permitting area as well as with sites in the panhandle region of Florida to the west of Cape San Blas. Regardless of region highest proportion positives and highest catch rates are associated with artificial reefs and petroleum platforms. This discrepancy is particularly strong in the eastern data set and is largely an effect of high proportion positives and catch rates observed in Hugh-Swingle in Alabama (Figures 1-6).

The GOM-wide model showed improved model performance and significant effects for year, reef, and depth and non-significant effects on the other variables. Proportion positive ranged from 0.312 (2016) to 0.53 (2013). Index trends show an increase in proportion positive from 2011 through 2013 with a subsequent decrease beginning in 2014 (Table 2, Figure 7). While there is typically a doubling of proportion positive for artificial reefs the trends in proportion positive were generally similar and the combined index represented a moderate state between the two habitat specific models. Both the artificial and natural models show an increase in CPUE between 2011 and 2012 and a subsequent slow/flat decrease thereafter but lagged by a year with the natural bottom index (Table 2, Figure 8). As with the proportion positives the combined index moderates the influence of the two habitat specific indices. The combined index appears more closely resemble the artificial index which might be due to the generally high proportion positives and CPUE's observed in that habitat relative to natural bottom.

The east-GOM model showed significant effects for year and reef and non-significant effects on strata, depth and the binomial hook variables. Proportion positives ranged from 0.18 (2016) to 0.45 (2012). Index trends show an increase in proportion positive from 2011 through 2012 with subsequent decreases every thereafter (Table 3, Figure 9). Proportion positives were anywhere from 2-4 times higher for artificial reefs as compared to natural reefs. The trends in proportion positive showed a strong decreasing trend in the artificial reef data whereas the natural bottom data showed highly consistent trends (10-12% proportion positive). All three east-GOM indices show a declining trend in CPUE through time and as with the Gulf-wide models the combined index represented a moderate state between the two habitat specific models with 2011 data composed only of natural habitat data (Table 3, Figure 10).

The west-GOM model showed significant effects for year, reef and strata and non-significant effects on depth and the binomial hook variables. Proportion positives ranged from 0.39 (2011) to 0.73 (2014). Index trends show an increase in proportion positive from 2011 through 2014 with subsequent plateauing or slight decreases every year thereafter (Table 4, Figure 11). Proportion positives were typically ~2 times higher for artificial reefs as compared to natural reefs and the differences were not as strong in the west as they were in the east. Trends in CPUE show increasing catch rates for both the natural and artificial data through 2014 at which point the indices both show slightly decreasing trend (Table 4, Figure 12). The combined index mimics the artificial reef index strongly which is likely an artifact of the low sample sizes on natural reef in the western, natural habitat index combined with high proportion positives associated with artificial habitats.

Comparing the index trends to the SEAMAP reef fish video survey, shows that the regional models track the video index quite closely and the Gulf-wide index shows similar trends but with more variability (Figures 13, 14, 15). The natural habitat vertical line indices match exceptionally well to the reef fish video survey indices which is not surprising given that the video index is evaluating similar habitat and additionally many of sites sampled are the same (i.e. NMFS reef fish survey piggybacks vertical line drops). The GOM wide index would indicate a stable to slightly decreasing trend from 2011-2016 in all three indices (Figure 13), the east-GOM is showing a decreasing trend from 2011-2016 (Figure 14), and the west-GOM is showing an increasing trend from 2011-2016 with some evidence of recent stabilization.

Red snapper fork lengths show somewhat similar mean size (~460 mm) from 2011-2015, but in 2016 we see a significant decline in the size of fish captured (418 mm)(Figure 16). This might be the effect of inclusion of small fish entering the data set that are associated with the Mississippi and Texas surveys both of which showed the smallest sizes collected (401 and 384 mm respectively). The largest fish are captured from natural habitats (482 mm) followed by artificial (457 mm) and petroleum platforms (430 mm)(Figure 18). There is a strong effect on fork length associated with hook size with the smallest captured on the 8/0 hook (407 mm) followed by the 11/0 (452 mm) and the 15/0 hook (523 mm) respectively (Figure 17). Selectivity analysis has been performed on components of the data and indicate dome shaped selectivity for the 8/0 and 11/0 hooks and right skewed selectivity for the 15/0 hooks (Campbell et al. 2014). The selectivity analysis indicated that inverse Gaussian distributions fit the data best however the 15/0 data might be most appropriately fit to logistic distributions (i.e. full selection). Selectivity analysis is confounded by the habitat sampled and gear mainly due to the fact that larger fish are captured in the longline survey.

Literature Cited

Campbell, M.D., A.G. Pollack, W.B. Driggers, and E.R. Hoffmayer. 2014. Estimation of hook selectivity of red snapper (*Lutjanus campechanus*) and vermilion snapper (*Rhomboplites aurorubens*) from fishery independent surveys of natural reefs of the northern Gulf of Mexico. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science. 6(1):260-273.

Campbell, M.D., A.G. Pollack, C.T. Gledhill, T.S. Switzer, and D.A. DeVries. 2015. Comparison of relative abundance indices calculated from two methods of generating video count data. Fisheries Research. 170:125-133.

Gregalis, K.C., L.S. Schlenker, J.M. Drymon, J.F. Mareska, and S.P. Powers. 2012. Evaluating the performance of vertical longlines to survey reef fish populations in the northern Gulf of Mexico. Transactions of the American Fisheries Society, 141(6):1453-1464.

Karnauskas, M., J.F. Walter III, M.D. Campbell, A.G. Pollack. 2017. Mapping red snapper abundance in the northern Gulf of Mexico based on a comprehensive fishery-independent survey. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science. 9(1):50-67.

Moser Jr., J.G., A.G. Pollack, G.W. Ingram Jr., C.T. Gledhill, T.A. Henwood, and W.B. Driggers III. 2012. Developing a survey methodology for sampling red snapper, *Lutjanus campechanus*, at oil and gas platforms in the northern Gulf of Mexico. SEDAR31-DW26. SEDAR, North Charleston, SC. 25 pp.

Scott-Denton, E., P.F. Cryer, J.P. Gocke, M.R. Harrelson, D.L. Kinsella, J.R. Pulver, R.C. Smith, and J.A Williams. 2011. Descriptions of the U.S. Gulf of Mexico reef fish bottom longline and vertical line fisheries based on observer data. Marine Fisheries Review, 73:1-26.

Table 1. History of vertical line sampling by SEAMAP partners in the Gulf of Mexico. Sites sampled and number of drops (in parentheses) by year and partner. This table reflects SEAMAP, NFWF and other extramural funded projects

Years	AL SEAMAP	AL NFWF	FL	LA	NMFS Video	NMFS Oil Platform	NMFS CSSP	MS NFWF	TX
2005						67 (201)			
2006									
2007						76 (228)			
2008									
2009									
2010	91(273)				345 (345)				
2011	76(152)			61 (244)	116 (230)		1931 (5776)		
2012	81 (241)			98 (292)	156 (299)				
2013	43 (125)			263 (788)	130 (389)				
2014	42 (124)		130 (262)	100 (300)	108 (280)				
2015	77 (229)	95 (285)	120 (265)	109 (324)	82 (242)				33 (85)
2016	45 (136)	92 (276)	262 (526)	65 (193)	95 (211)			NA	47 (106)

Figure 1. Vertical sampling stations conducted in 2010, showing habitat type in color with red snapper CPUE modulated by bubble size.

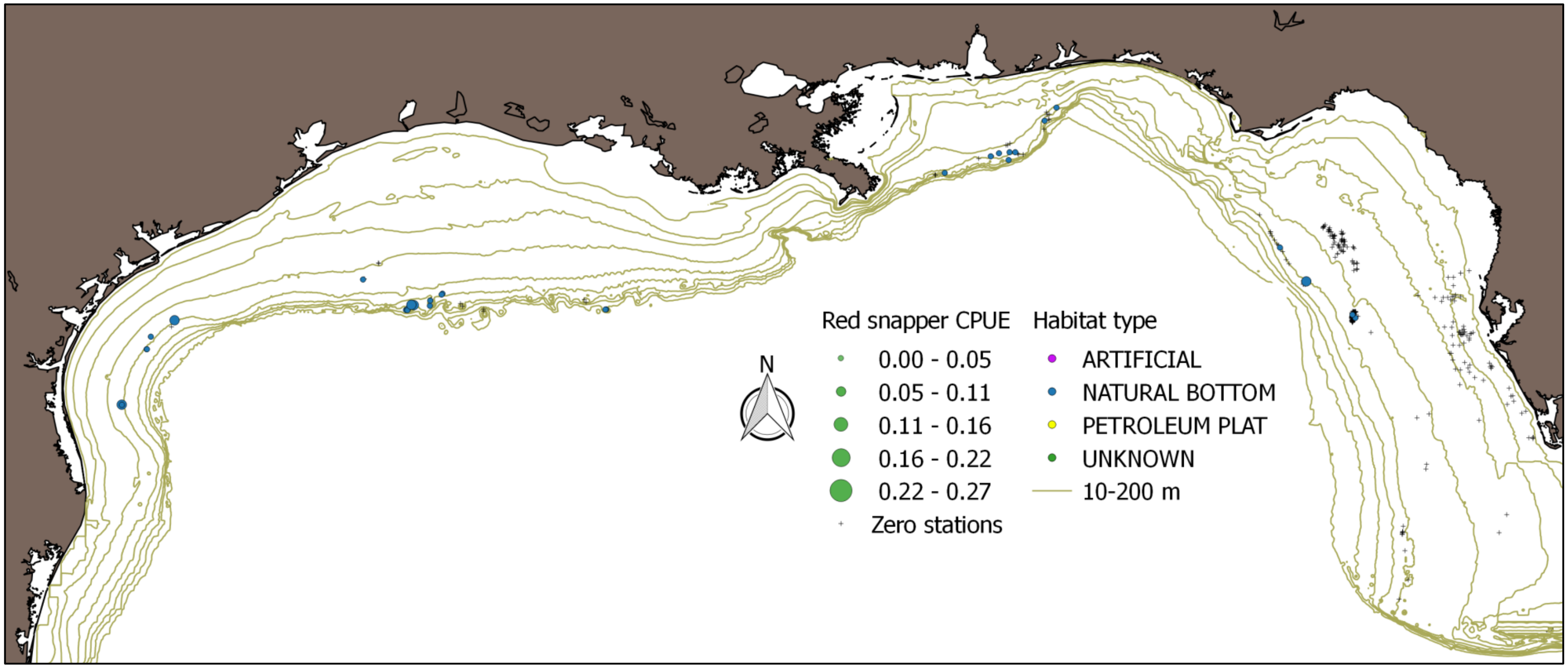

Figure 2. Vertical sampling stations conducted in 2011, showing habitat type in color with red snapper CPUE modulated by bubble size. Includes survey stations sampled during the Mississippi Labs CSSP survey to demonstrate that there are available data, however those data are currently not included in any of the models given that it was a single year of effort. Beginning of the Alabama and Louisiana state run surveys conducted as part of the SEAMAP program.

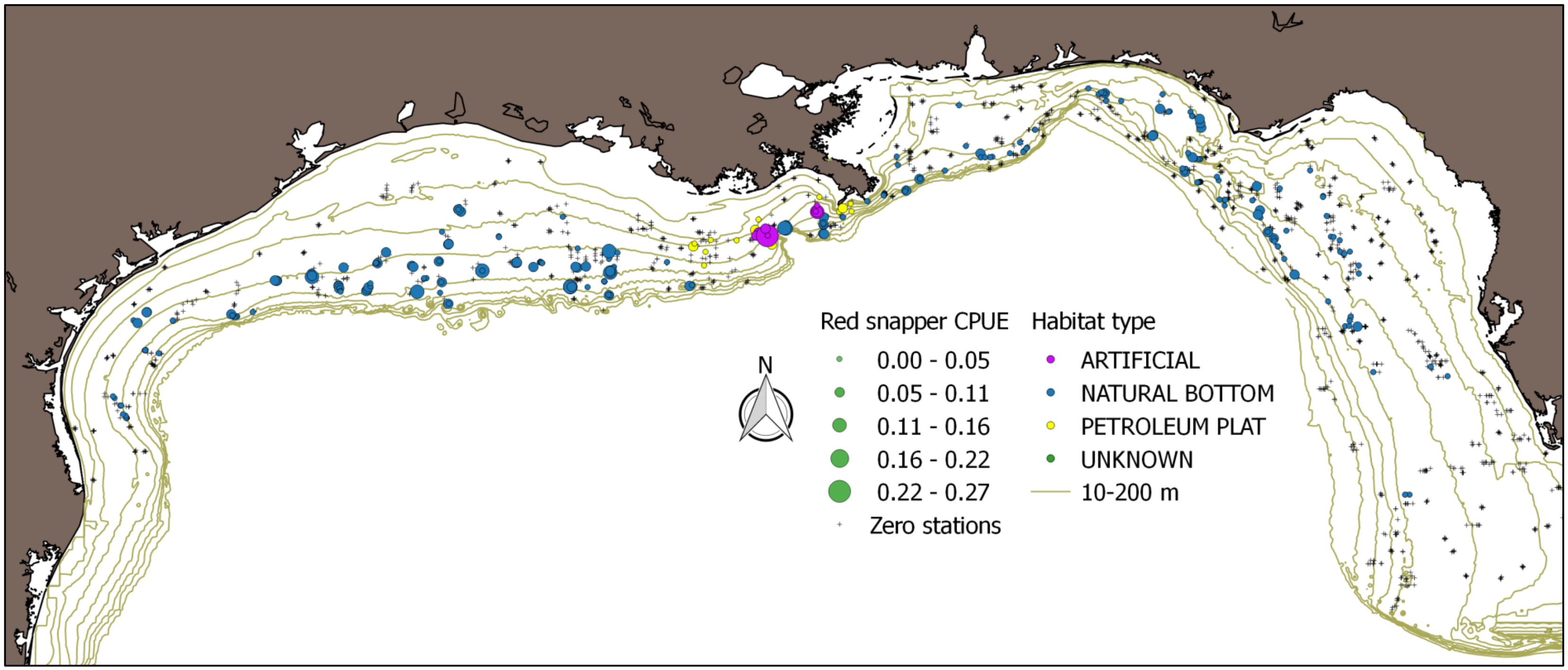

Figure 3. Vertical sampling stations conducted in 2012, showing habitat type in color with red snapper CPUE modulated by bubble size.

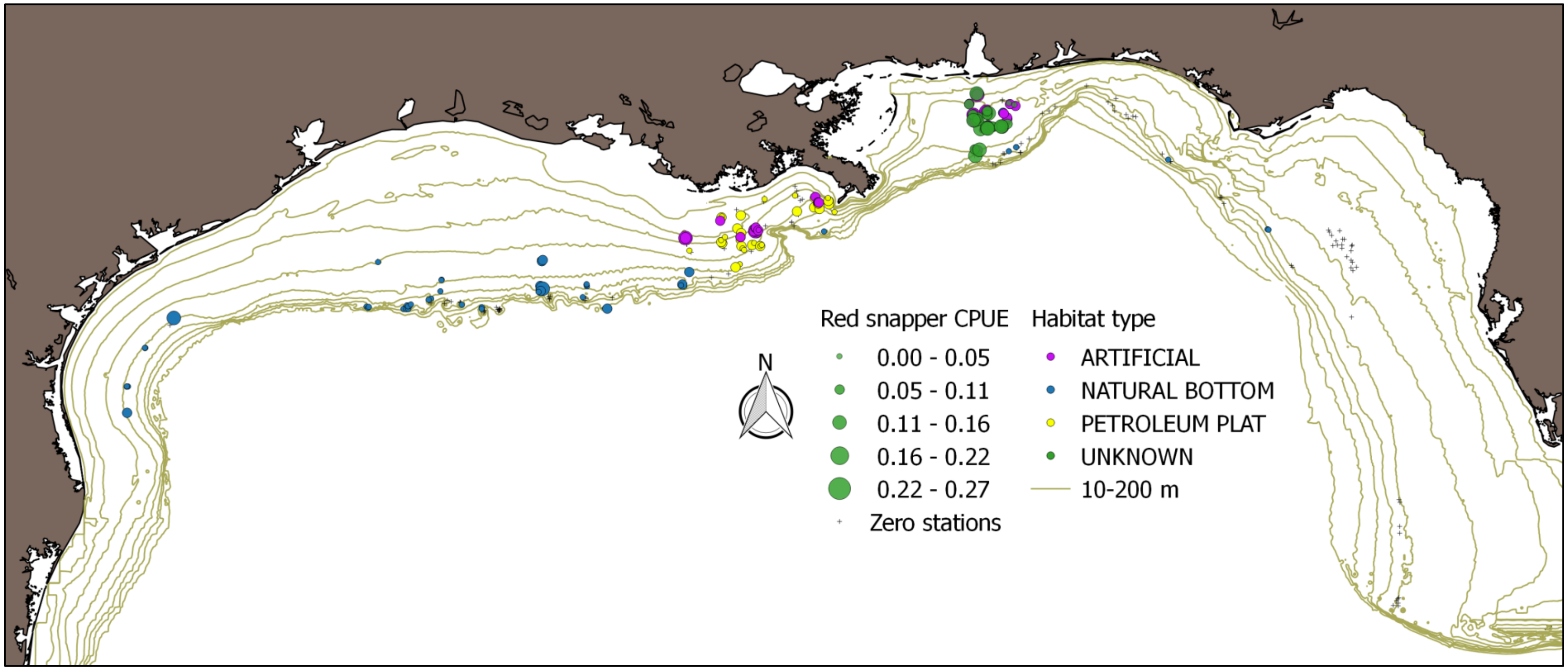

Figure 4. Vertical sampling stations conducted in 2013, showing habitat type in color with red snapper CPUE modulated by bubble size.

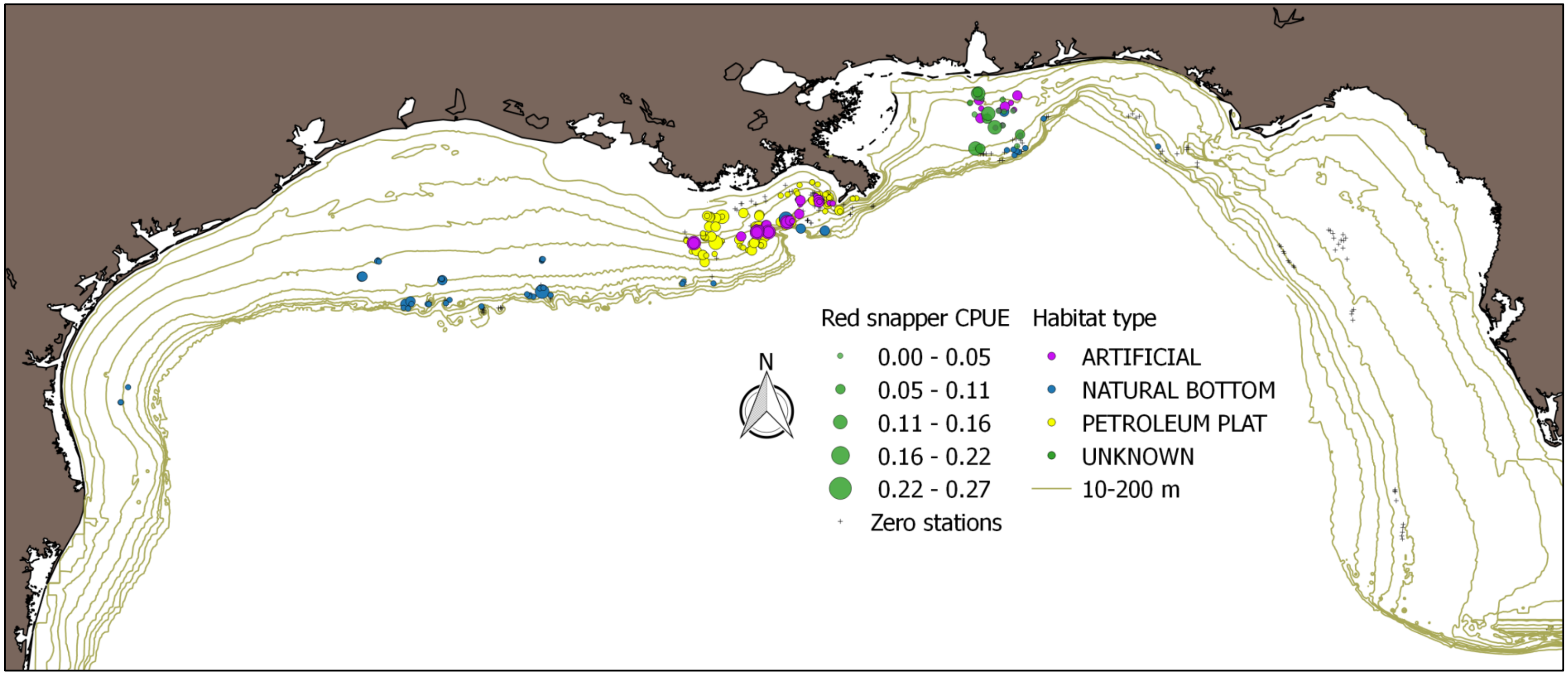

Figure 5. Vertical sampling stations conducted in 2014, showing habitat type in color with red snapper CPUE modulated by bubble size. Beginning of the Florida state run survey conducted as part of the SEAMAP program.

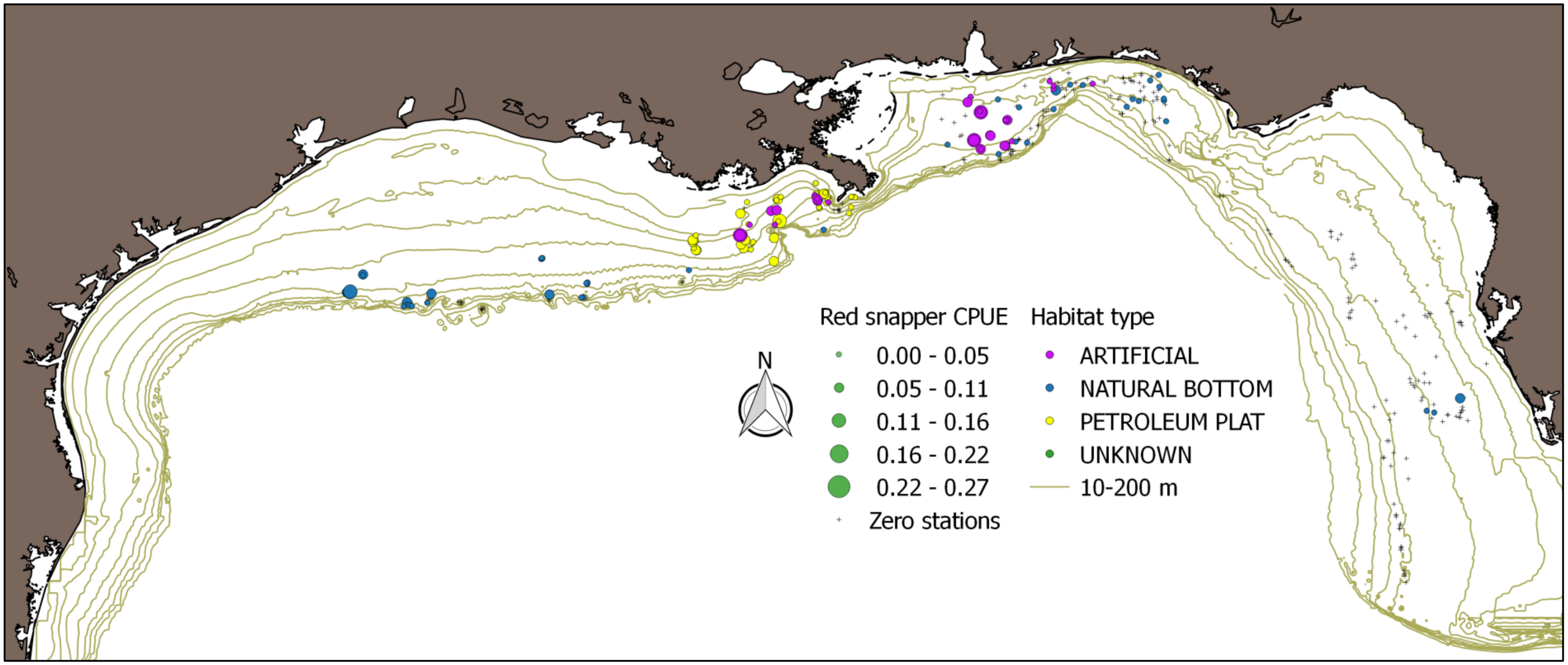

Figure 6. Vertical sampling stations conducted in 2015, showing habitat type in color with red snapper CPUE modulated by bubble size. Beginning of the Texas state run survey conducted as part of the SEAMAP program.

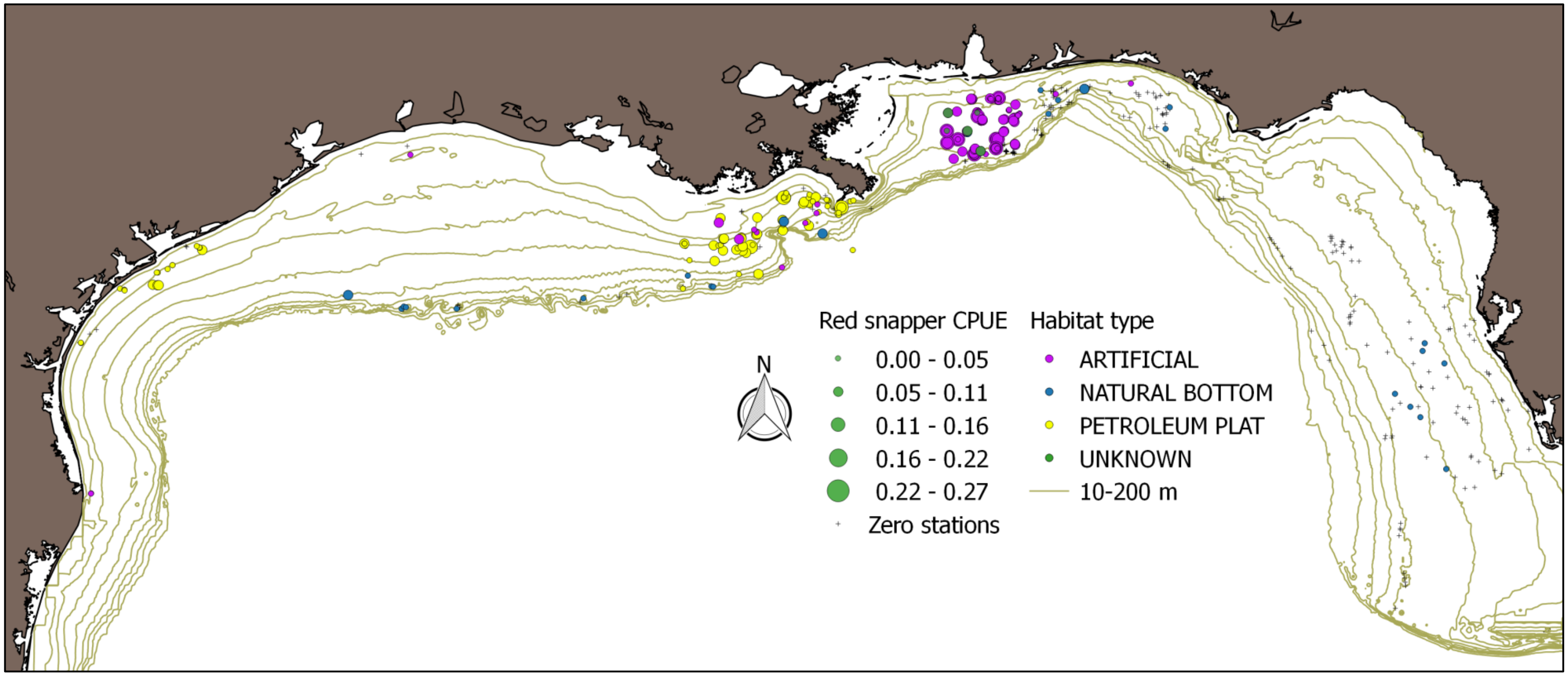

Figure 6. Vertical sampling stations conducted in 2016, showing habitat type in color with red snapper CPUE modulated by bubble size. Beginning of the consolidated SEAMAP sampling design to achieve a balanced spatial design and sampling.

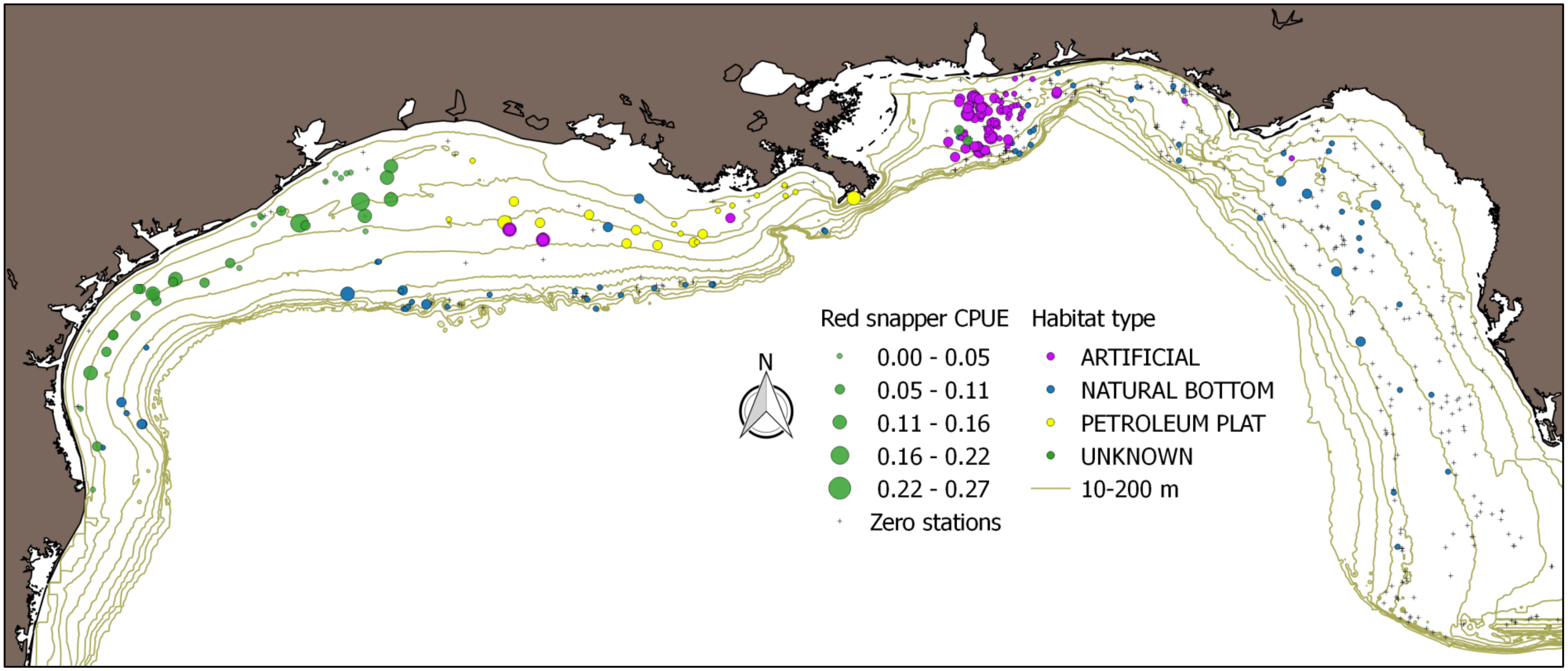

Table 2. Gulf of Mexico red snapper vertical line relative abundance delta lognormal model output by reef type and year.

	Sample size			Lo Index			Standard Error (SI)		
Year	*Artificial*	*Natural*	*ComboReef*	*Artificial*	*Natural*	*ComboReef*	*Artificial*	*Natural*	*ComboReef*
2011	59	118	223	0.0318	0.0067	0.0382	0.0060	0.0016	0.0053
2012	122	176	335	0.0523	0.0094	0.0316	0.0050	0.0014	0.0030
2013	268	150	436	0.0290	0.0095	0.0236	0.0021	0.0014	0.0019
2014	142	238	380	0.0366	0.0086	0.0202	0.0031	0.0013	0.0021
2015	217	203	421	0.0391	0.0039	0.0203	0.0029	0.0008	0.0020
2016	108	359	512	0.0289	0.0066	0.0155	0.0037	0.0008	0.0017

	Proportion Positive			Standardized Index			CV (SI)		
Year	*Artificial*	*Natural*	*ComboReef*	*Artificial*	*Natural*	*ComboReef*	*Artificial*	*Natural*	*ComboReef*
2011	0.424	0.195	0.395	0.875	0.899	1.534	0.188	0.240	0.140
2012	0.697	0.301	0.501	1.442	1.261	1.269	0.095	0.148	0.094
2013	0.590	0.360	0.528	0.800	1.279	0.949	0.074	0.142	0.082
2014	0.725	0.210	0.403	1.009	1.147	0.812	0.086	0.149	0.105
2015	0.682	0.133	0.418	1.079	0.530	0.815	0.073	0.206	0.100
2016	0.500	0.203	0.316	0.796	0.884	0.622	0.127	0.126	0.108

Figure 7. Gulf of Mexico vertical line delta lognormal model proportion positive by habitat and year.

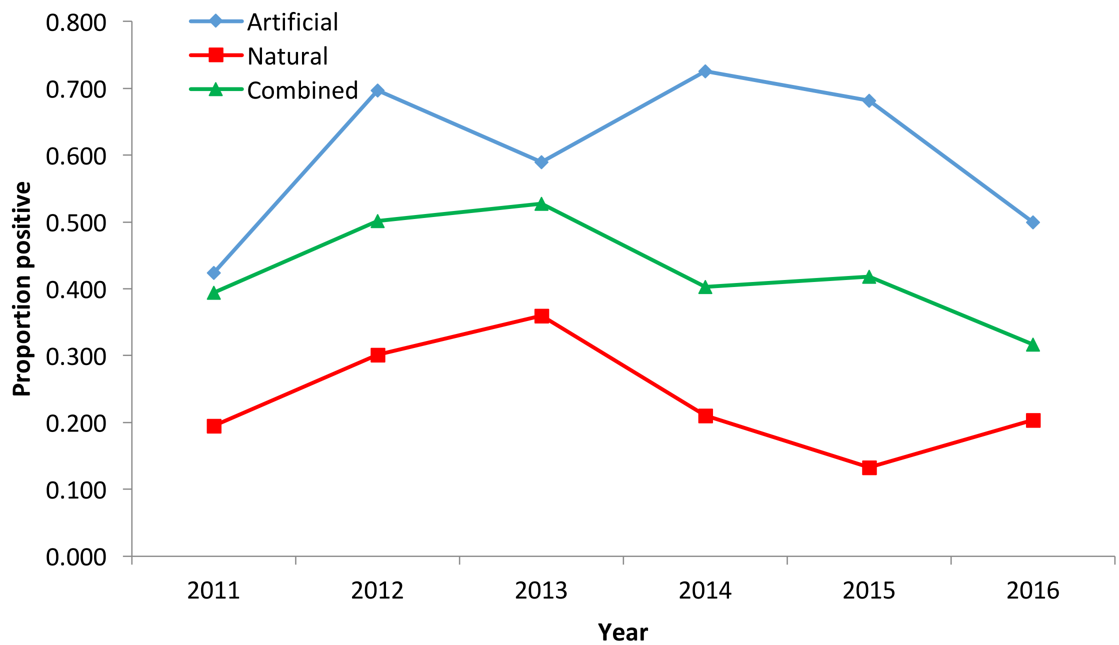

Figure 8. Gulf of Mexico vertical line delta lognormal model relative index of abundance by habitat and year.

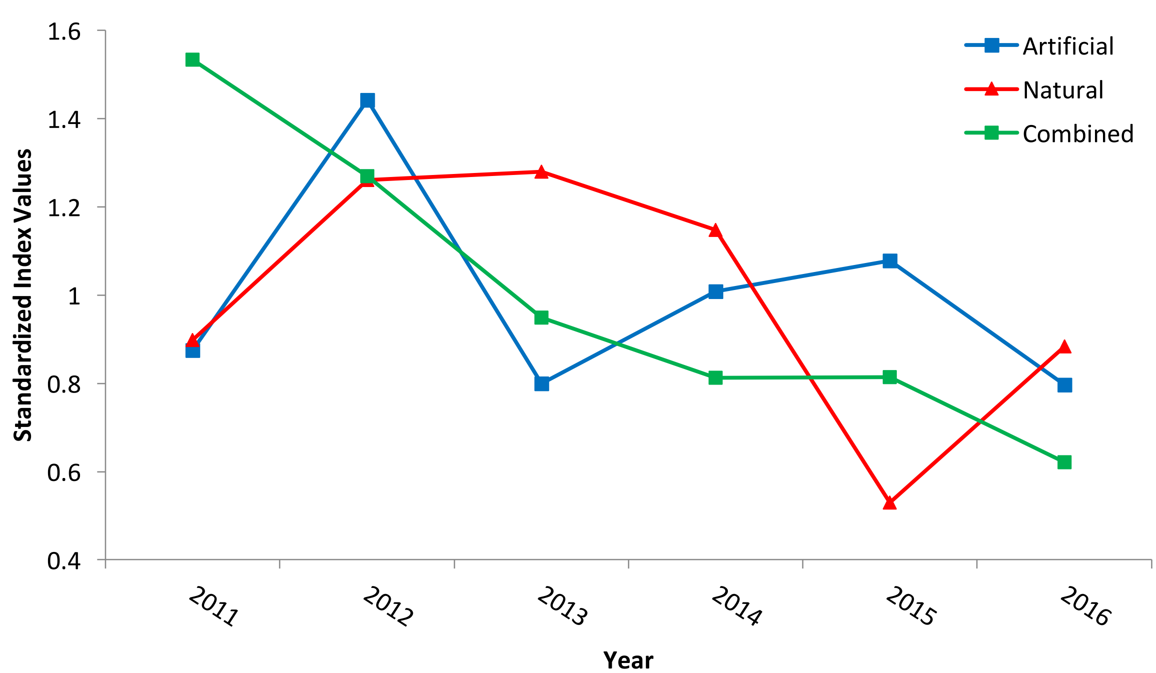

Table 3. East Gulf of Mexico red snapper vertical line relative abundance delta lognormal model output by reef type and year.

	Sample size			Lo Index			Standard Error (SI)		
Year	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*
2011	46	105	151	0.2165	0.0060	0.0409	0.0353	0.0022	0.0075
2012	30	77	144	0.0817	0.0026	0.0264	0.0156	0.0015	0.0043
2013	16	75	109	0.0273	0.0023	0.0133	0.0089	0.0012	0.0029
2014	44	191	235	0.0306	0.0032	0.0108	0.0080	0.0011	0.0023
2015	80	179	260	0.0382	0.0016	0.0125	0.0068	0.0007	0.0022
2016	72	288	360	0.0185	0.0034	0.0092	0.0049	0.0009	0.0017

	Proportion Positive			Standardized Index			CV (SI)		
Year	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*
2011	0.870	0.190	0.397	3.147	1.885	2.173	0.163	0.365	0.183
2012	0.900	0.104	0.451	1.188	0.809	1.401	0.190	0.585	0.164
2013	0.750	0.120	0.358	0.397	0.715	0.705	0.327	0.550	0.217
2014	0.545	0.120	0.200	0.444	1.021	0.571	0.262	0.348	0.211
2015	0.613	0.084	0.250	0.555	0.493	0.663	0.179	0.433	0.180
2016	0.389	0.128	0.181	0.269	1.078	0.487	0.263	0.276	0.183

Figure 9. East Gulf of Mexico vertical line delta lognormal model proportion positive by habitat and year.

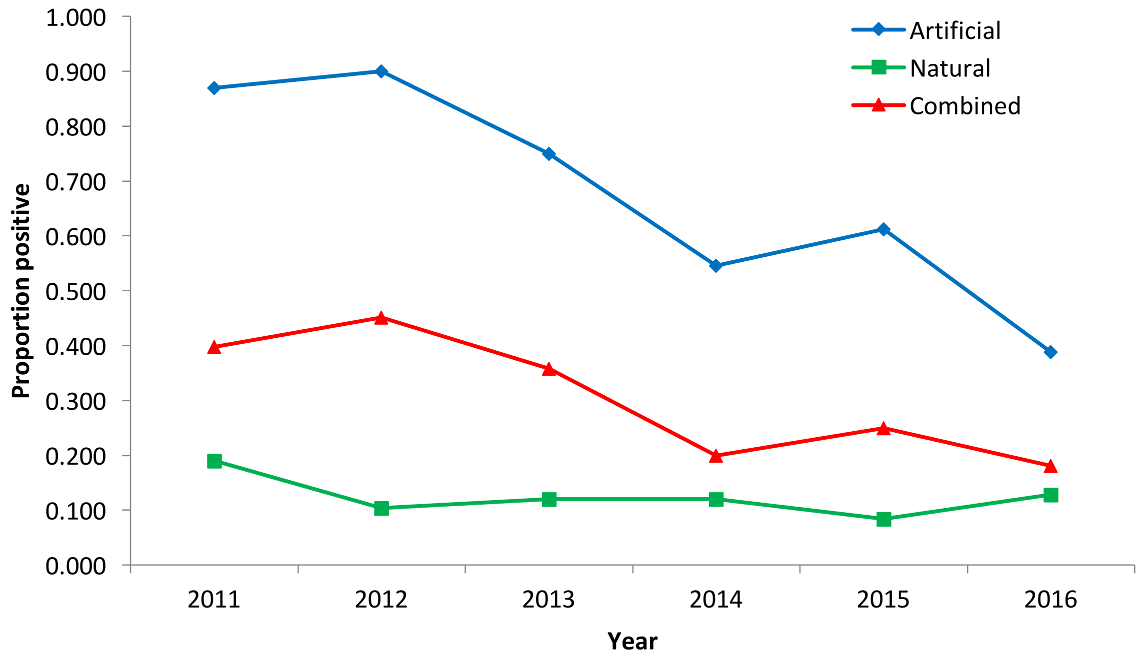

Figure 10. East Gulf of Mexico vertical line delta lognormal model relative index of abundance by habitat and year.

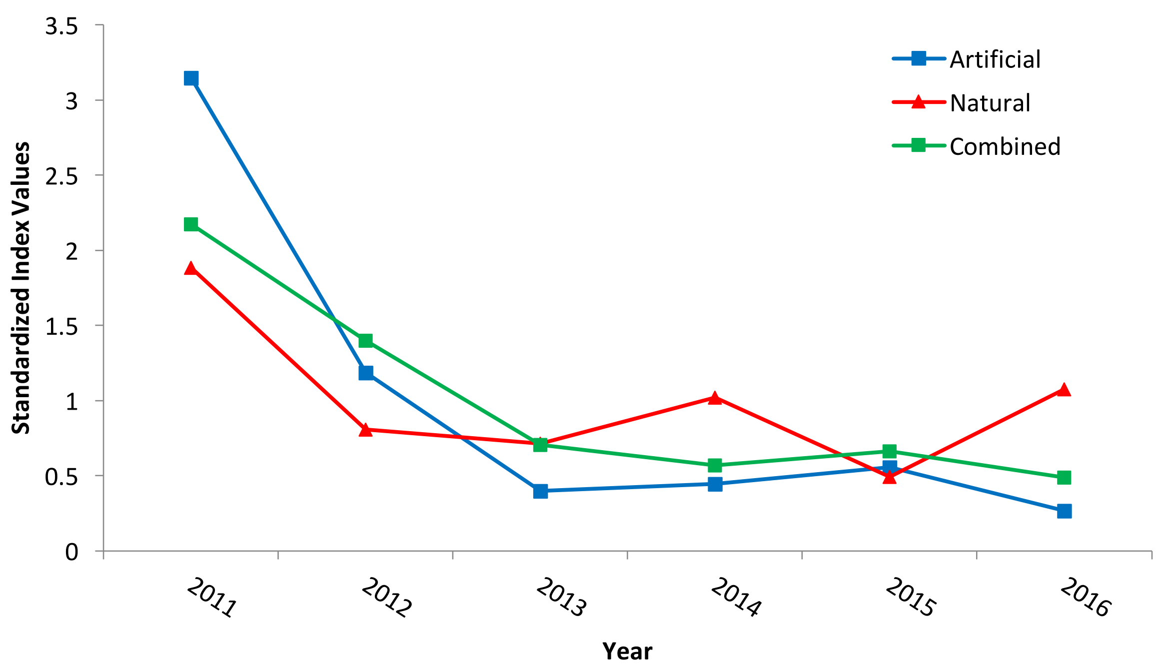

Table 4. West Gulf of Mexico red snapper vertical line relative abundance delta lognormal model output by reef type and year.

	Sample size			Lo Index			Standard Error (SI)		
Year	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*
2011	59	13	72	0.032	0.005	0.023	0.005	0.005	0.003
2012	92	99	191	0.043	0.019	0.032	0.004	0.004	0.002
2013	252	75	327	0.028	0.020	0.026	0.002	0.004	0.001
2014	98	47	145	0.039	0.030	0.036	0.003	0.008	0.003
2015	137	24	161	0.038	0.019	0.035	0.003	0.008	0.002
2016	36	71	152	0.050	0.020	0.037	0.007	0.005	0.003

	Proportion Positive			Standardized Index			CV (SI)		
Year	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*	*Artificial*	*Natural*	*Combined*
2011	0.424	0.231	0.389	0.827	0.271	0.739	0.156	0.897	0.145
2012	0.630	0.455	0.539	1.128	1.004	1.010	0.100	0.220	0.074
2013	0.579	0.600	0.584	0.742	1.072	0.819	0.065	0.207	0.055
2014	0.806	0.574	0.731	1.006	1.579	1.144	0.086	0.267	0.071
2015	0.723	0.500	0.689	0.997	1.009	1.116	0.077	0.411	0.071
2016	0.722	0.507	0.638	1.301	1.065	1.172	0.145	0.240	0.089

Figure 11. West Gulf of Mexico vertical line delta lognormal model proportion positive by habitat and year.

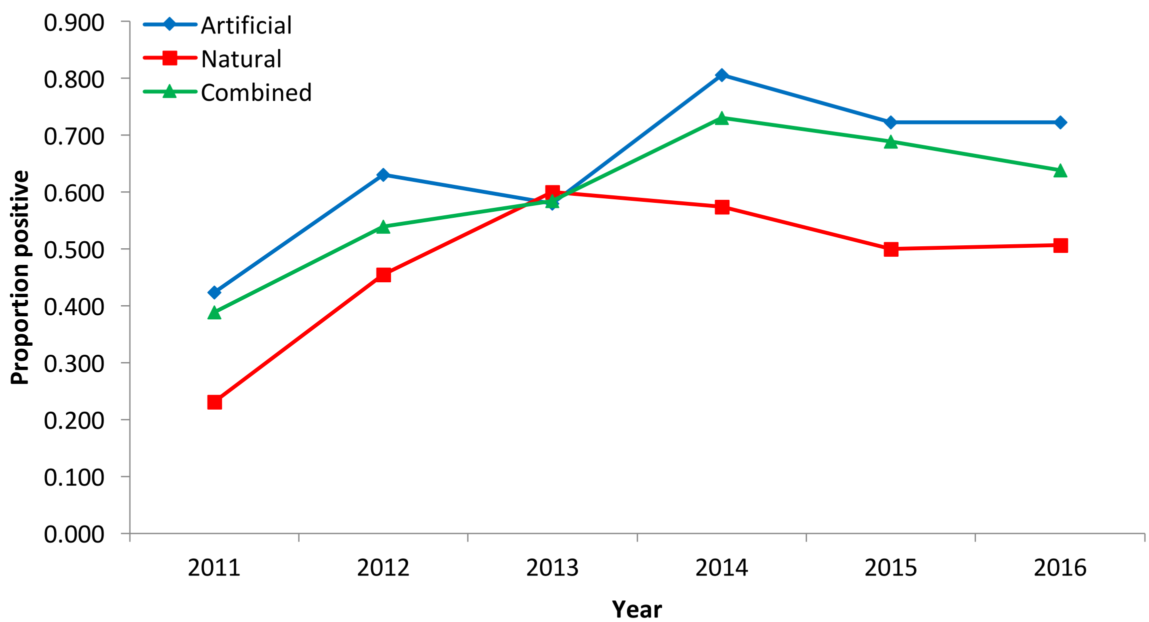

Figure 12. West Gulf of Mexico vertical line delta lognormal model relative index of abundance by habitat and year.

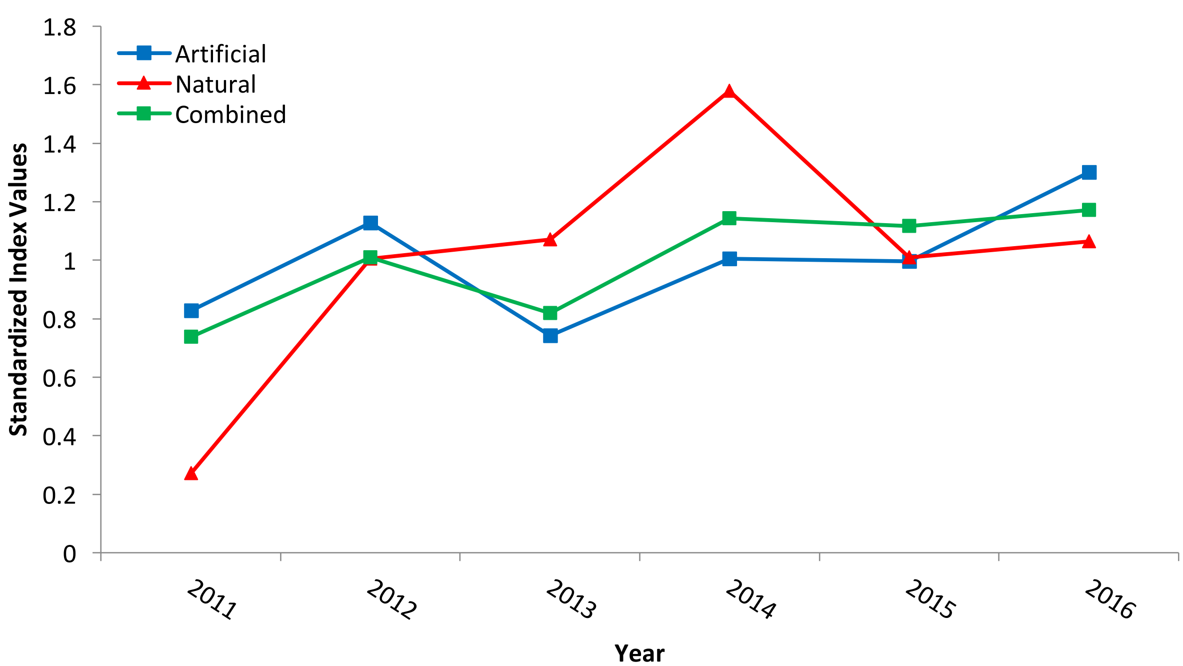

Figure 13. Gulf of Mexico vertical line relative indices of abundance compared to the SEAMAP reef fish video survey of the Gulf of Mexico. The video survey has been conducted since 1992 and targets the natural bottom, high-relief reefs.

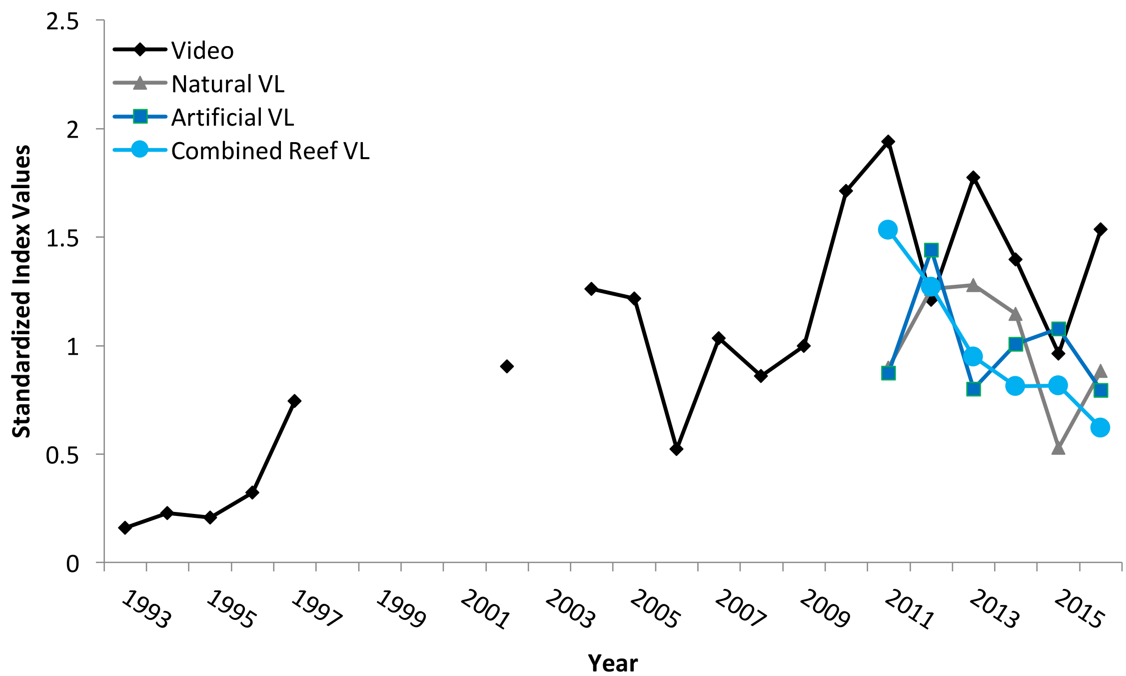

Figure 14. East Gulf of Mexico vertical line relative indices of abundance compared to the SEAMAP reef fish video survey of the east Gulf of Mexico. The video survey has been conducted since 1992 and targets the natural bottom, high-relief reefs.

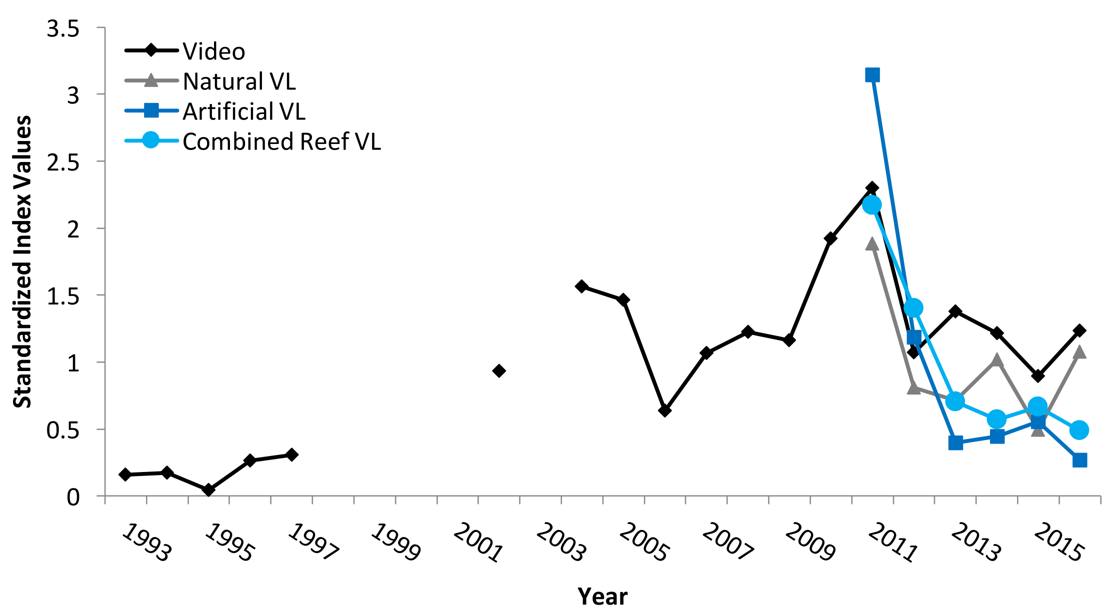

Figure 15. West Gulf of Mexico vertical line relative indices of abundance compared to the SEAMAP reef fish video survey of the east Gulf of Mexico. The video survey has been conducted since 1992 and targets the natural bottom, high-relief reefs.

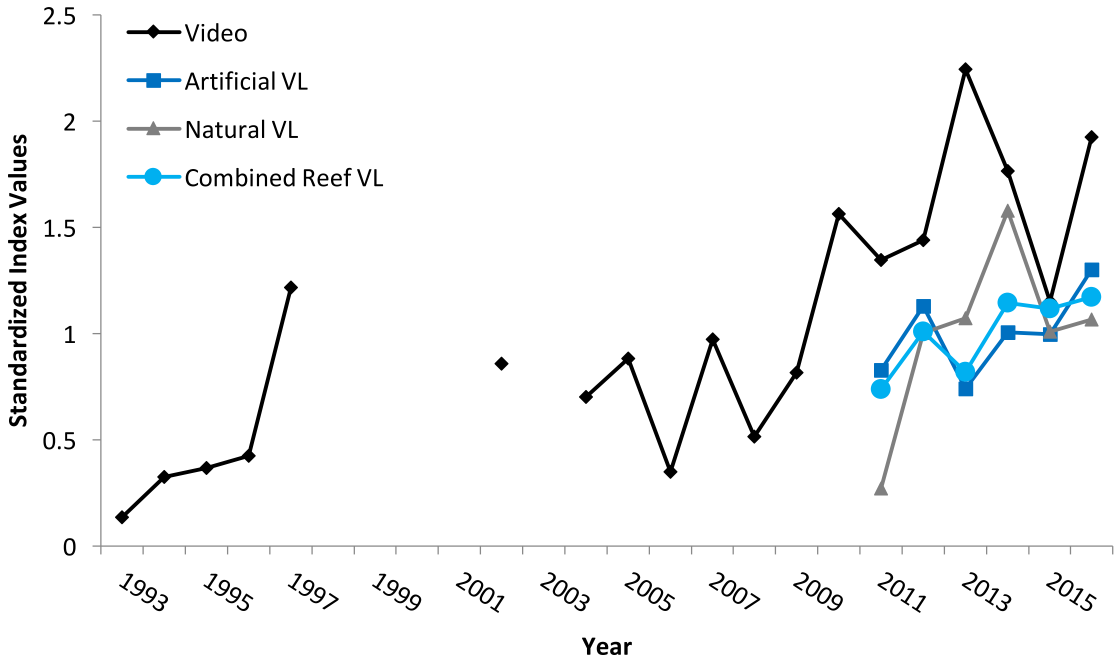

Table 5. Red snapper fork length descriptive statistics by vertical line survey by year, hook size, reef type and survey.

Year	MEAN	STD	MAX	MIN	N
2011	472.46	114.54	782	154	1953
2012	474.34	114.00	861	244	1376
2013	455.69	107.23	859	222	1769
2014	469.10	126.47	850	194	1617
2015	462.86	128.09	838	195	1840
2016	418.44	116.96	851	218	1849
Pooled	455.03	119.17	861	154	10404

Hook Size	MEAN	STD	MAX	MIN	N
8	407.25	100.81	816	154	3885
11	452.59	110.20	838	196	4295
15	523.29	123.19	861	219	2833

Reef Type	MEAN	STD	MAX	MIN	N
ARTIFICIAL	457.73	124.27	861	188	3951
NATURAL BOTTOM	482.97	116.29	836	154	2921
PETROLEUM PLAT	430.26	97.67	825	194	2552
UNKNOWN	437.20	130.42	826	218	1646

Source	MEAN	STD	MAX	MIN	N
AL	476.08	135.11	861	222	2602
FL	421.67	126.94	836	231	902
LA	450.24	92.21	825	194	3141
ML	485.43	99.54	741	249	672
MS	401.19	99.48	760	188	581
TX	384.66	112.88	757	195	440

Figure 16. Length frequency distribution of red snapper fork lengths measured in the SEAMAP vertical line survey of the Gulf of Mexico from 2011-2016 (pooled data).

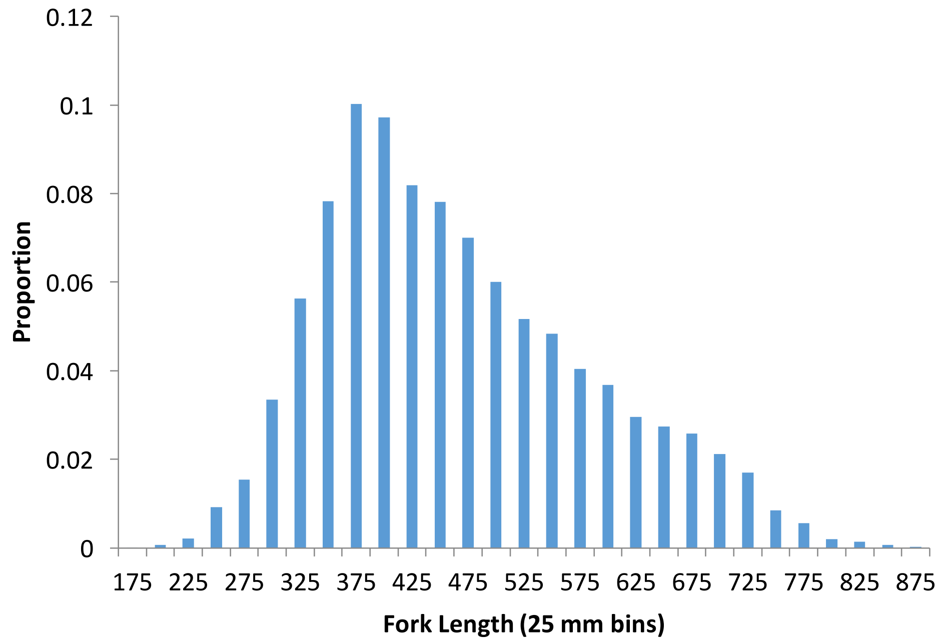

Figure 17. Length frequency distribution of red snapper fork lengths by hook size (8, 11 and 15: Mustad series 39960D) measured in the SEAMAP vertical line survey of the Gulf of Mexico from 2011-2016.

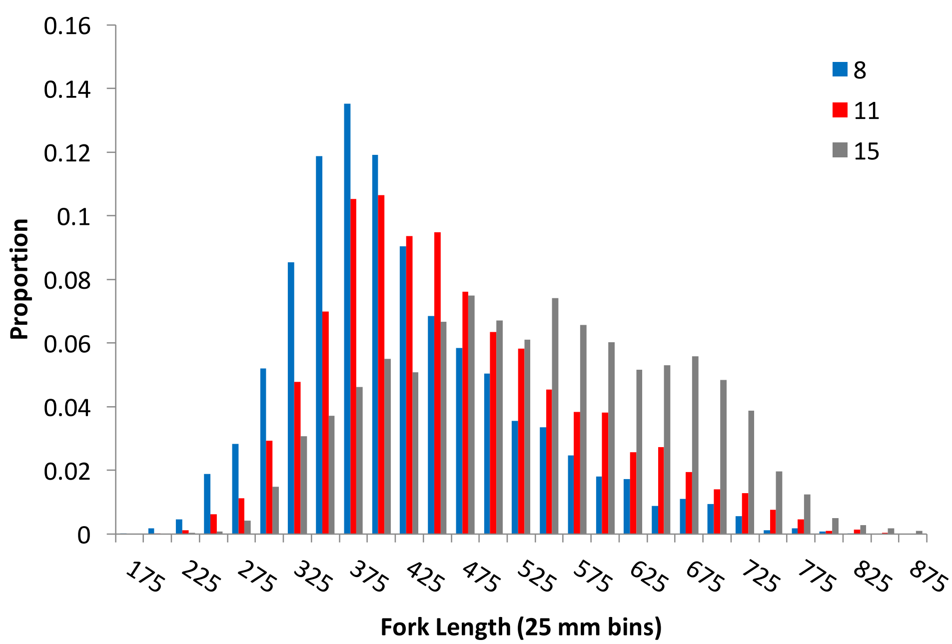

Figure 18. Length frequency distribution of red snapper fork lengths by habitat type and measured in the SEAMAP vertical line survey of the Gulf of Mexico from 2011-2016.