Standardized video counts of Southeast U.S. Atlantic red porgy (*Pagrus pagrus*) from the Southeast Reef Fish Survey

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Standardized video counts of Southeast U.S. Atlantic red porgy (*Pagrus pagrus*) from the Southeast Reef Fish Survey

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Abstract

Standardized video counts of red porgy were generated from video cameras deployed by the Southeast Reef Fish Survey during 2011–2017. The analysis included samples taken between Cape Hatteras, North Carolina and St. Lucie Inlet, Florida. The index is meant to describe population trends of red porgy in the region using a variety of predictor variables that could influence abundance and video counts. We compared multiple model structures using AIC, and ultimately applied a zero-inflated negative binomial model to standardize the video count data. The 2015–2017 index values and uncertainty included a calibration factor to account for a change in camera type.

Background

The Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program has conducted most of the historical fishery-independent sampling in the U.S. South Atlantic (North Carolina to Florida). MARMAP has used a variety of gears over time, but chevron traps are one of the primary gears used to monitor reef fish species and have been deployed since the late 1980s. In 2009, MARMAP began receiving additional funding to monitor reef fish through the SEAMAP-SA program. In 2010, the SouthEast Fishery-Independent Survey (SEFIS) was initiated by NMFS to work collaboratively with MARMAP/SEAMAP-SA using identical methods to collect additional fishery-independent samples in the region. Together, these three programs are now called the Southeast Reef Fish Survey (SERFS). In 2010, video cameras were attached to some traps deployed by SERFS, and beginning in 2011 all traps included video cameras (Figure 1).

The SERFS currently samples between Cape Hatteras, North Carolina and St. Lucie Inlet, Florida. This survey targets hardbottom habitats between approximately 15 and 100 meters deep. SERFS began affixing high-definition video cameras to chevron traps on a limited basis in 2010 (Georgia and Florida only), but since 2011 has attached cameras to all chevron traps as part of their normal monitoring efforts. In 2015, the video cameras were changed from Canon to GoPro, to implement a wider field of view and thus observe more fish. A calibration study (detailed below) with both camera types used simultaneously was undertaken to account for differences in fish counts.

Hard-bottom sampling stations were selected for sampling in one of three ways. First, most sites were randomly selected from the SERFS sampling frame that consisted of approximately 3,000 sampling stations on or very near hard bottom habitat. Second, some stations in the sampling frame were sampled opportunistically even though they were not randomly selected for sampling in a given year. Third, new hard-bottom stations were added during the study period through the use of information from various sources including fishermen, charts, and historical surveys. These new locations were investigated using a vessel echosounder or drop cameras and sampled if hard bottom was detected. Only those new stations landing on hardbottom habitat were included in the analyses. All sampling for this study occurred during daylight hours between April and October on the R/V *Savannah*, R/V *Palmetto*, R/V *Sand Tiger*, or the NOAA Ship *Pisces* using identical methodologies as described below. Samples were intentionally spread out spatially on each cruise (see Figure 2 in Bacheler and Carmichael 2014).

Chevron traps were constructed from plastic-coated, galvanized 2-mm diameter wire (mesh size = 3.4 cm^2) and measured 1.7 m × 1.5 m × 0.6 m, with a total volume of 0.91 m^3. Trap mouth openings were shaped like a teardrop and measured approximately 18 cm wide and 45 cm high. Each trap was baited with 24 menhaden (*Brevoortia* spp.). Traps were typically deployed in groups of six, and each trap in a set was deployed at least 200 m (usually > 400 m) from all other traps to provide some measure of independence between traps. A soak time of 90 minutes was targeted for each trap deployed.

Canon Vixia HFS-200 high-definition video cameras in Gates underwater housings were attached to chevron traps in 2011–2014, facing outward over the mouth (Figure 1). In 2015, Canon cameras were replaced with GoPro Hero 4 cameras over the trap mouth. Fish were counted exclusively using cameras over the trap mouth. A second high-definition GoPro Hero video or Nikon Coolpix S210/S220 still camera was attached over the nose of most traps in an underwater housing, and was used to quantify microhabitat features in the opposite direction. Cameras were turned on and set to record before traps were deployed, and were turned off after trap retrieval. Trap-video samples were excluded from our analysis if videos were unreadable for any reason (e.g., too dark, camera out of focus, files corrupt) or the traps did not fish properly (e.g., bouncing or dragging due to waves or current, trap mouth was obstructed).

In advance of the switch to GoPro cameras exclusively in 2015, we conducted a calibration study in the summer of 2014 where Canon and GoPro cameras were attached to traps side-by-side and fish were counted at the same time. A total of 54 side-by-side comparisons were recorded. Thirty-seven samples observed either red porgy for both cameras and were used to develop a calibration.

Relative abundance of reef fish on video has been estimated using the *MeanCount* approach (Conn 2011; Schobernd et al. 2014). *MeanCount* was calculated as the mean number of individuals of each species over a number of video frames in the video sample. Video reading time was limited to an interval of 20 total minutes, commencing 10 minutes after the trap landed on the bottom to allow time for the trap to settle. One-second snapshots were read every 30 seconds for the 20-minute time interval, totaling 41 snapshots read for each video. The mean number of individuals for each target species in the 41 snapshots is the *MeanCount* for that species in each video sample. Zero-inflated modeling approaches described below require count data instead of continuous data like *MeanCount*. Therefore, these analyses used a response variable called *SumCount*, which was simply the sum of all individuals seen across all video frames. *SumCount* and *MeanCount* track exactly linearly with one another when the same numbers of video frames are used in their calculation (Bacheler and Carmichael 2014). Therefore, *SumCount* values were only used from videos where 41 frames were read (~93% of all samples).

SERFS employed video readers to count fish on videos. There was an extensive training period for each video reader, and all videos from new readers were re-read by fish video reading experts until they were very high quality. After that point, 10% or 15 videos (whichever was larger) were re-read annually by fish video reading experts as part of quality control. Video readers also quantified microhabitat features (biotic density and substrate composition), in order to standardize for habitat types sampled over time. Water clarity was also scored for each sample as poor, fair, or good. If bottom substrate could not be seen, then water clarity was considered poor, and if bottom habitat could be seen but the horizon was not visible, water clarity was considered fair. If the horizon could be seen in the distance, water clarity was considered to be good. Including water clarity in index models allowed for a standardization of fish counts based on variable water clarities over time and across the study area. A CTD cast was also taken for each simultaneously deployed group of traps, within 2 m of the bottom, and water temperature from these CTD casts was available for standardization models.

Data and Treatment

Overall, there were 10,107 survey videos with data available covering a period of 7 years (2011–2017). Although data were available from 2010, they were not considered here due to limitations in spatial overlap of the survey area and the spatial occupancy of red porgy, consistent with recommendations from the Southeast Reef Fish Survey Video Index Development Workshop (Bacheler and Carmichael 2014). For the years considered, several data filters were applied. We removed any data points in which the survey video was considered unreadable by an analyst (e.g., too dark, corrupt video file), or if the trapping event was flagged for any irregularity that could have affected catch rates (e.g., trap dragged or bounced). Additionally, any survey video for which fewer than 41 video frames were read was removed from the full data set. Standardizing the number or readable frames for any data point was essential due to our use of *SumCount* as a response variable (see above). We also identified any video sample in which corresponding predictor variable were missing and removed them from the final data set.

Of the 10,107 video samples considered for inclusion, 1,723 were removed based on the data subsetting guidelines described above, leaving 8384 sampling events for the analysis, of which 3275 were positive for red porgy (39.1%). The spatial distribution of the videos included in the analysis cover the area from NC to South Florida (Figures 2 - 4).

Standardization

Response Variable

We modeled the *SumCount* as the response variable. *SumCount* measures the total number of red porgy observed across all 41 video frames in a sampling event.

Explanatory Variables

We considered 9 explanatory variables: year, season, depth, latitude, water temperature, turbidity, current direction, biotic density, and substrate composition. Although all of these explanatory variables were considered, we included in the final formulation only those that improved model performance.

YEAR (*y*) – Year was included because standardized catch rates by year are the objective of this analysis. We modeled data from 2011–2017. Annual summaries of data points considered are outlined in Table 1.

SEASON (t) – Season is a temporal parameter based on the Julian day of sampling (Figure 7). The season parameter is treated as a factor with days distributed among quartiles.

DEPTH (*d*) – Water depth was treated as a factor with four levels based on quartiles (Figure 7). Annual depth distribution for survey data are outlined in Table 1.

LATITUDE (*lat*)– The latitude of video samples (Figure 7) was divided into 8 levels based on octiles.

TEMPERATURE (*temp*) – The bottom water temperature was collected from each station and incorporated as a predictor variable. Bottom temperatures ranged from 12.4 to 29.3 degrees Celsius (Figure 7). For the model, temperature was treated as a factor with 8 levels based on octiles.

TURBIDITY (*wc*) – Turbidity can affect both species distributions and the ability of an analyst to identify species in video survey samples. Turbidity information is recorded during video analysis based on the ability of an analyst to perceive the horizon and surrounding habitat, and it was scored at 3 levels.

CURRENT DIRECTION (*cd*) – This categorical variable describes current direction based on the video point of view. Current direction was included to better account for variability in detection due to the current moving fish away or towards the camera. This variable is assigned one of 3 levels during video processing.

BIOTIC DENSITY (*bd*) – Biotic density is an estimate of the percent cover of attached biota visible during any video. The estimation is made based on percentage cover and ranged from 0 to 98%. For our analysis *bd* was treated as a categorical variable with 4 levels: none (0%), low (1–9%), moderate (10–39%) and high (>40%).

SUBSTRATE COMPOSITION (*sc*) – Substrate composition is an estimate of the proportion of the visible substrate that is hardbottom and is assigned during video processing. This variable was treated as a categorical variable with 4 levels: none, low, moderate, and high.

Zero-Inflated Model

The recommendation of the video index workshop (Bacheler and Carmichael 2014) was to apply a zero-inflated modeling approach to the development of fishery-independent video indices. Zero-inflated models are valuable tools for modeling distributions that do not fit standard error distributions due to excessive number of zeroes. These data distributions are often referred to as "zero-inflated" and are a common condition of count based ecological data. Zero inflation is considered a special case of over-dispersion that is not readily addressed using traditional transformation procedures (Hall 2000, Zeileis et al. 2008). Due to the high proportion of zero counts found in our data set (Figure 8), we used a zero-inflated mixed model approach that accounts for the high occurrence of zero values, as well as the positive counts. The model does so by combining binomial and count processes (Zuur et al. 2009, Zeileis et al. 2008).

The modeling approached used here was similar to that used in SEDAR41 for gray triggerfish and red snapper. As in SEDAR 41, we initially considered a full null model (1) using both a zero-inflated Poisson (ZIP) and a zero-inflated negative binomial (ZINB) formulation,

$$SumCount = y + wc + cd + sc + bd + d + t + lat + temp \mid y + wc + cd + sc + bd + d + t + lat + temp \quad (1)$$

In this formulation, variables to the left of the "|" apply to the count sub-model, and variables to the right apply to the binomial sub-model. We compared the variance structure of each model formulation using AIC and likelihood ratio tests (Zuur et al 2009) to determine the most appropriate model error structure for the development of a red porgy video index. The results of these tests (Table 2) show clear support for the ZINB formulation. These results concur with our expectations based on the over dispersion within the video survey data and with the recommendations of the video index development panel (Bacheler and Carmichael 2014). A comparison between the fitted and original data for the ZIP and ZINB model formulations is shown in Figure 9. The rootogram (Kleiber and Zeileis 2017) in the lower panels of Figure 9 extends the Tukey (1977) rootogram to regression models. These plots are useful as diagnostics specific to overdispersion and/or excess zeros in count data models.

We used a step-wise backwards model selection procedure to systematically exclude unnecessary parameters from our model formulation. The final red porgy ZINB model formulation, based on the results of AIC and likelihood ratio tests (Zuur et al. 2009), excluded *temp* from the negative binomial component of the model and the binomial component of the model. The data were fit well using the preferred model (Figure 10).

All data manipulation and analysis was conducted using R version 3.5.0 (R Core Team 2018). Modeling was executed using the **zeroinfl** function in the **countreg** package (Zeileis and Kleiber 2017), available from the Comprehensive R Archive Network (CRAN).

Calibration of gear

Because camera gear changed in 2015 from Canon to GoPro, index values in 2015–2017 were adjusted to make them comparable to values prior. Red porgy were observed in videos from 24 traps during the calibration study. *MeanCounts* from Canon cameras were regressed on *MeanCounts* from GoPro cameras to estimate a slope parameter β of 0.58(SE=0.03) (Figure 11). for all data. The calibration factor was used to adjust the 2015, 2016, and 2017 index values, to make them comparable to data from earlier years.

Uncertainty

Uncertainty in the index was computed using a bootstrap procedure with n=1000 replicates. In each replicate, a data set of the original size was created by drawing observations (rows) at random with replacement. This was done by year, to maintain the same annual sample size as in the original data. The model (Equation 1) was fitted to each data set, and uncertainty (CVs) was computed. All of the 1000 fits converged.

Uncertainty in the 2015–2017 calibration factor was included in the bootstrap procedure by drawing a random value from a normal distribution with a mean of 0.50 and a standard deviation of 0.02 (estimates from the regression using trimmed data). These values, one for each bootstrap replicate, were used to scale the 2015–2017 index estimates. Thus this method accounts for the adjustment in the 2015–2017 estimates, as well as as the corresponding CVs.

Results and discussion

Annual standardized index values for red porgy including CVs are presented in Table 3. The relative nominal index fell within the 2.5% and 97.5% confidence intervals of the standardized index and tracked closely with the standardized index (Figure 12).

During 2011-2017, red porgy were observed in about 35-48% of video samples.

Literature cited

Bacheler, N. M., and J. Carmichael. 2014. Southeast Reef Fish Survey Video Index Development Workshop, Final Report. NMFS-SEFSC and SAFMC. SEDAR41-RD23.

Conn, P. B. 2011. An Evaluation and Power Analysis of Fishery Independent Reef Fish Sampling in the Gulf of Mexico and U. S. South Atlantic. NOAA Tech. Memorandum NMFS-SEFSC-610.

Hall, D. B. 2000. Zero-Inflated Poisson binomial regression with random effects: a case study. Biometrics, 56: 1030-1039.

Kleiber C. and A. Zeileis. 2017. “Visualizing Count Data Regressions Using Rootograms.” The American Statistician, 70(3), 296–303. doi: 10.1080/00031305.2017.1173590.

R Core Team. 2018. R: A Language and Environmenet for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. URL: http://www.R-project.org/.

Schobernd, Z. H., N. M. Bacheler, and P. B. Conn. 2014. Examining the Utility of Alternative Video Monitoring Metrics for Indexing Reef Fish Abundance. CJFAS. 71:464-471.

Tukey J.W. 1977. Exploratory Data Analysis. Addison-Wesley Publishing Company, Phillipines.

Zeileis A. and C. Kleiber. 2017. countreg: Count Data Regression. R package version 0.2-0/r34, URL http://R-Forge.R-project.org/projects/countreg/.

Zeileis A., C. Kleiber, and S. Jackman. 2008. “Regression Models for Count Data in R.” Journal of Statistical Software, 27(8), 1–25. doi: 10.18637/jss.v027.i08.

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 video samples included in the analysis

Year	Number of video samples	Depth range (m)	Latitude range	Date range (Julian date)
2011	586	15-93	27.23-34.54	140-299
2012	1076	15-106	27.23-35.02	115-284
2013	1221	15-100	27.33-35.02	115-278
2014	1381	15-110	27.23-35.02	114-295
2015	1394	16-110	27.26-35.02	112-296
2016	1393	17-115	27.23-35.01	125-300
2017	1333	15-100	27.23-35.02	117-273

Table 2: Preliminary model error structure comparison

	df	Likelihood	AIC	χ^2	df	*p*-value
ZIP	74	-86977	174102			
ZINB	75	-17563	35276	138828	1	<0.001

Table 3: The relative nominal *SumCount*, number of stations sampled, proportion positive, standardized index, and CV for the SERFS red porgy video index. The 2015-2017 values shown here reflect the calibration.

Year	Relative nominal (*SumCount*)	N	Proportion positive	Standardized index	CV
2011	1.346	586	0.480	1.411	0.09
2012	1.017	1076	0.392	1.165	0.08
2013	0.850	1221	0.359	0.814	0.08
2014	1.146	1381	0.440	1.041	0.07
2015	0.914	1394	0.385	0.981	0.08
2016	0.827	1393	0.371	0.763	0.08
2017	0.900	1333	0.355	0.824	0.08

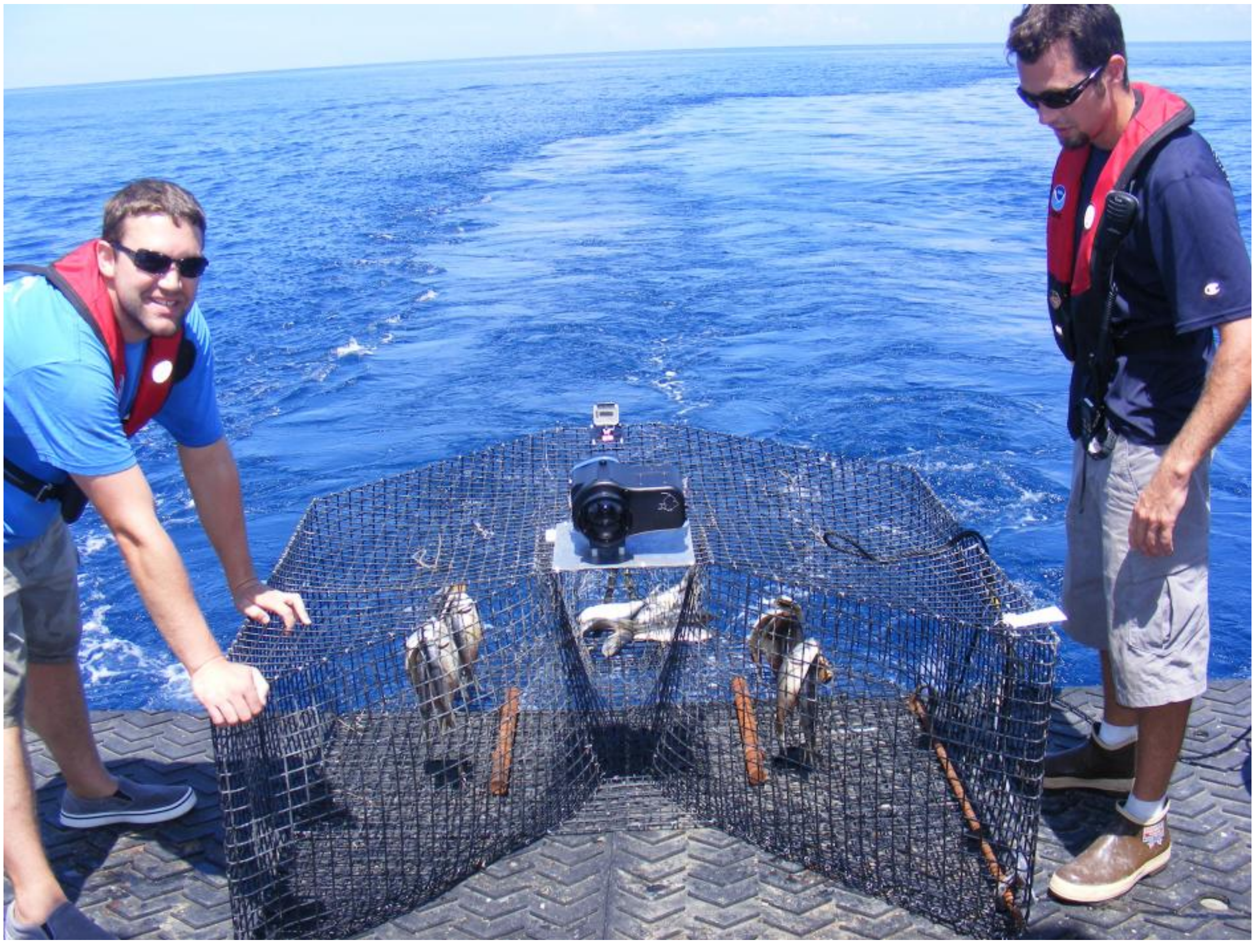

Figure 1: Chevron trap used by SERFS showing the Canon camera over the mouth and GoPro on the trap nose.

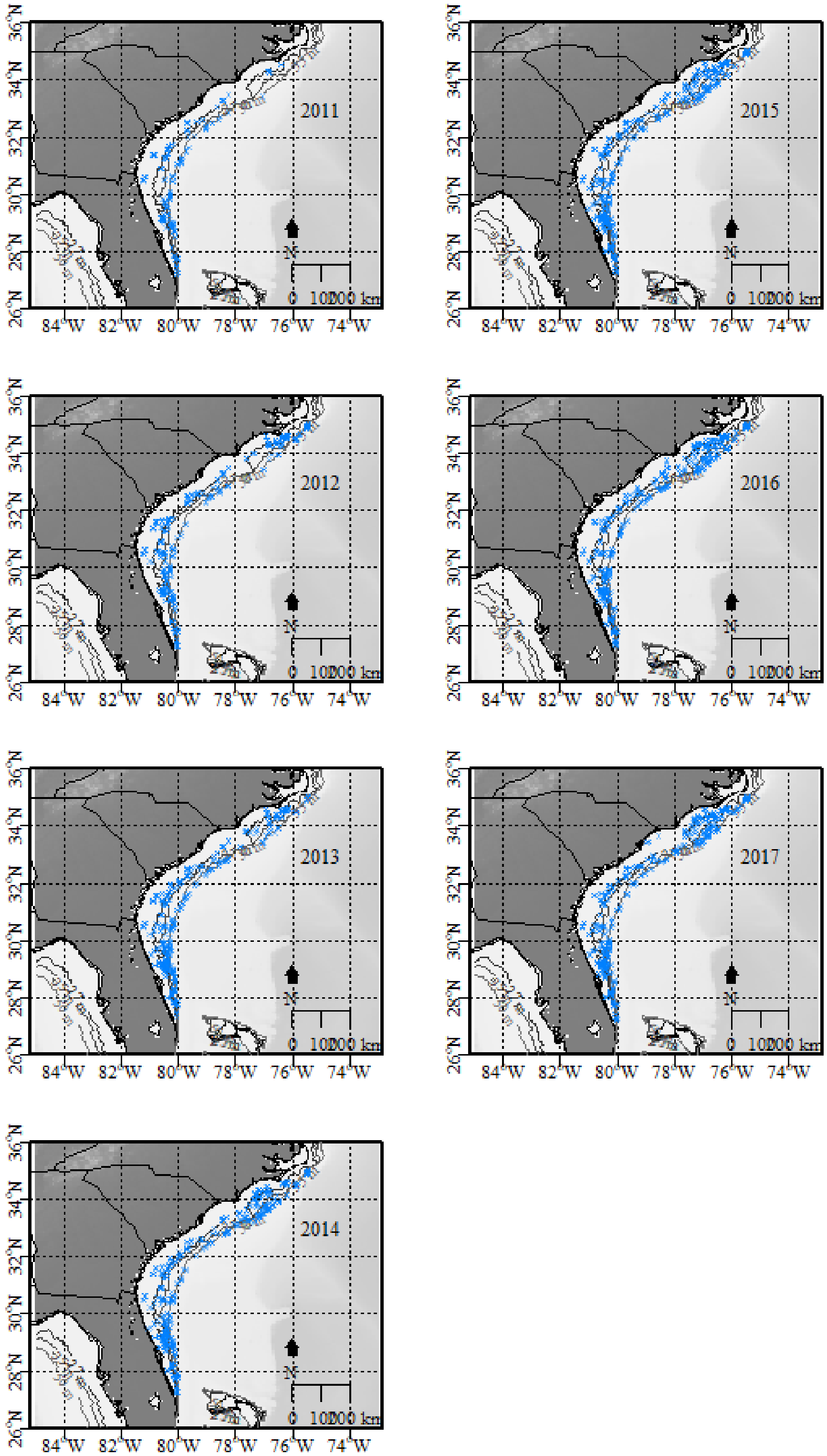

Figure 2: Annual spatial distribution of underwater video samples collected by SERFS in 2011 – 2017 where no red porgy were seen on video. Bottom contours are drawn at the breaks for the depth factor (27, 35, and 50 meters).

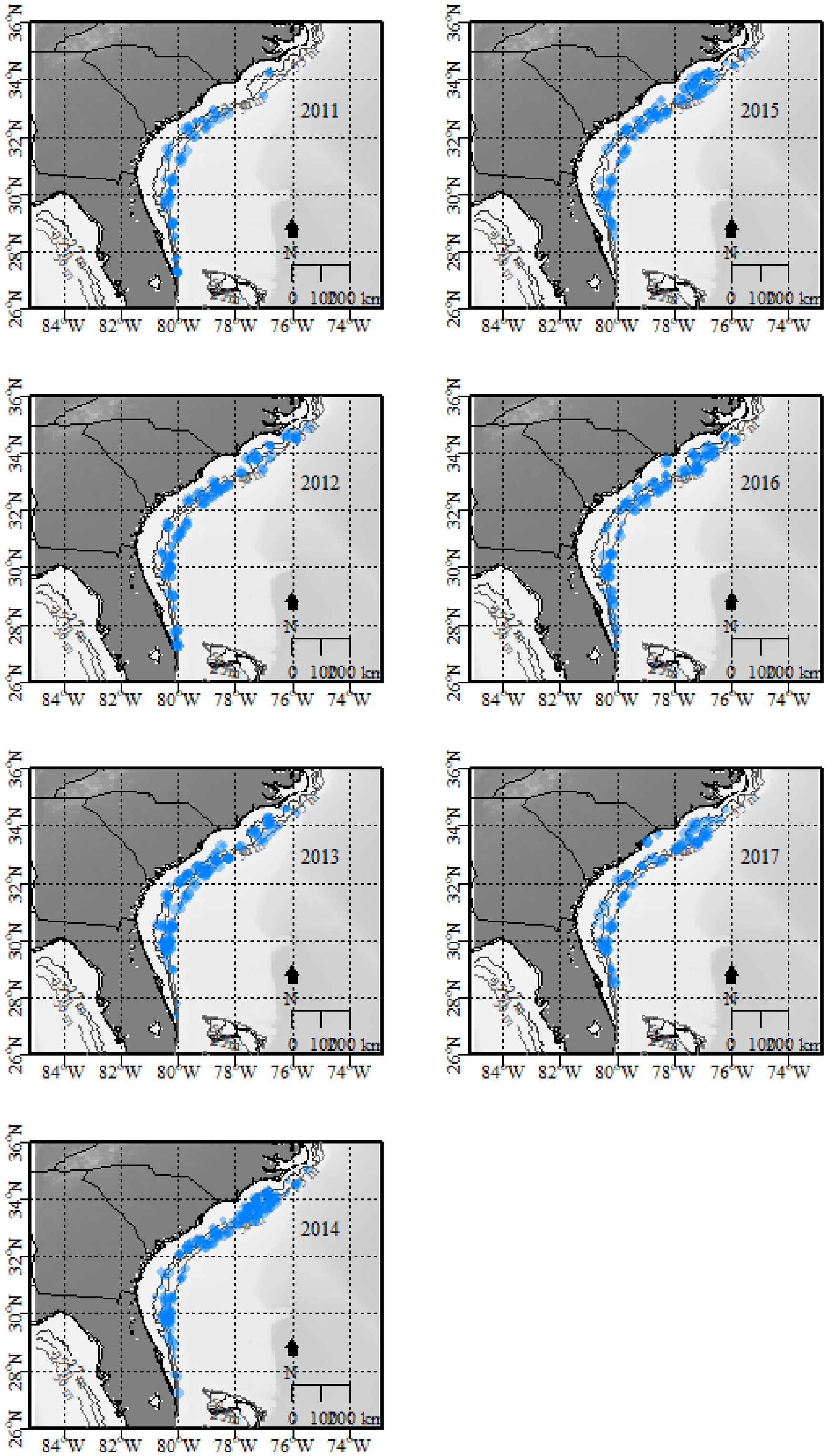

Figure 3: Annual spatial distribution of underwater video samples collected by SERFS in 2011 – where the sum of red porgy in the video frames counted was from 1 to 5. This represents approximately 25% of the positive videos for red porgy. Bottom contours are drawn at the breaks for the depth factor (27, 35, and 50 meters).

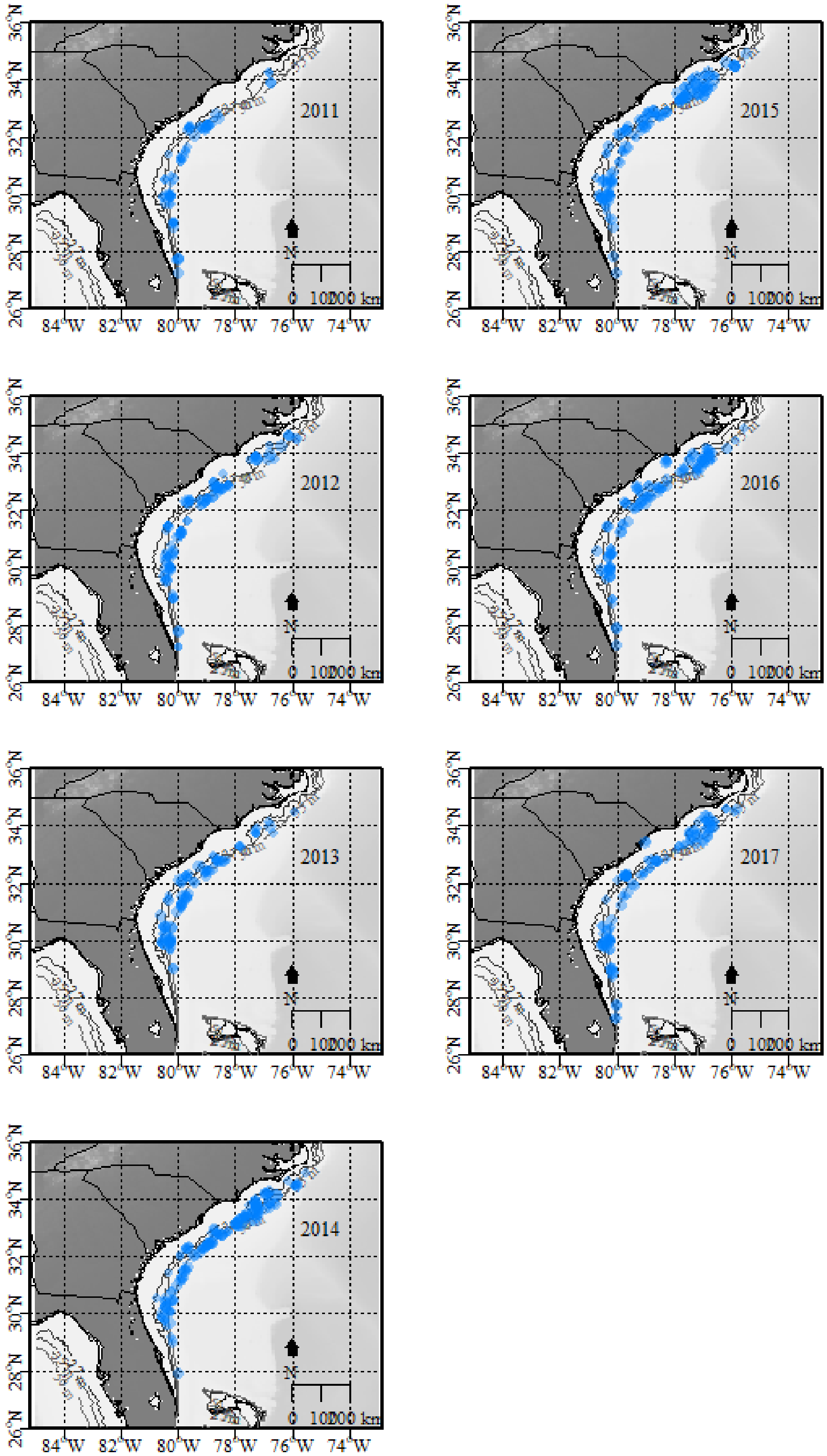

Figure 4: Annual spatial distribution of underwater video samples collected by SERFS in 2011 – 2017 where the sum of red porgy in the video frames counted was from 6 to 15. This represents approximately 25% of the positive videos for red porgy of positive trips. Bottom contours are drawn at the breaks for the depth factor (27, 35, and 50 meters).

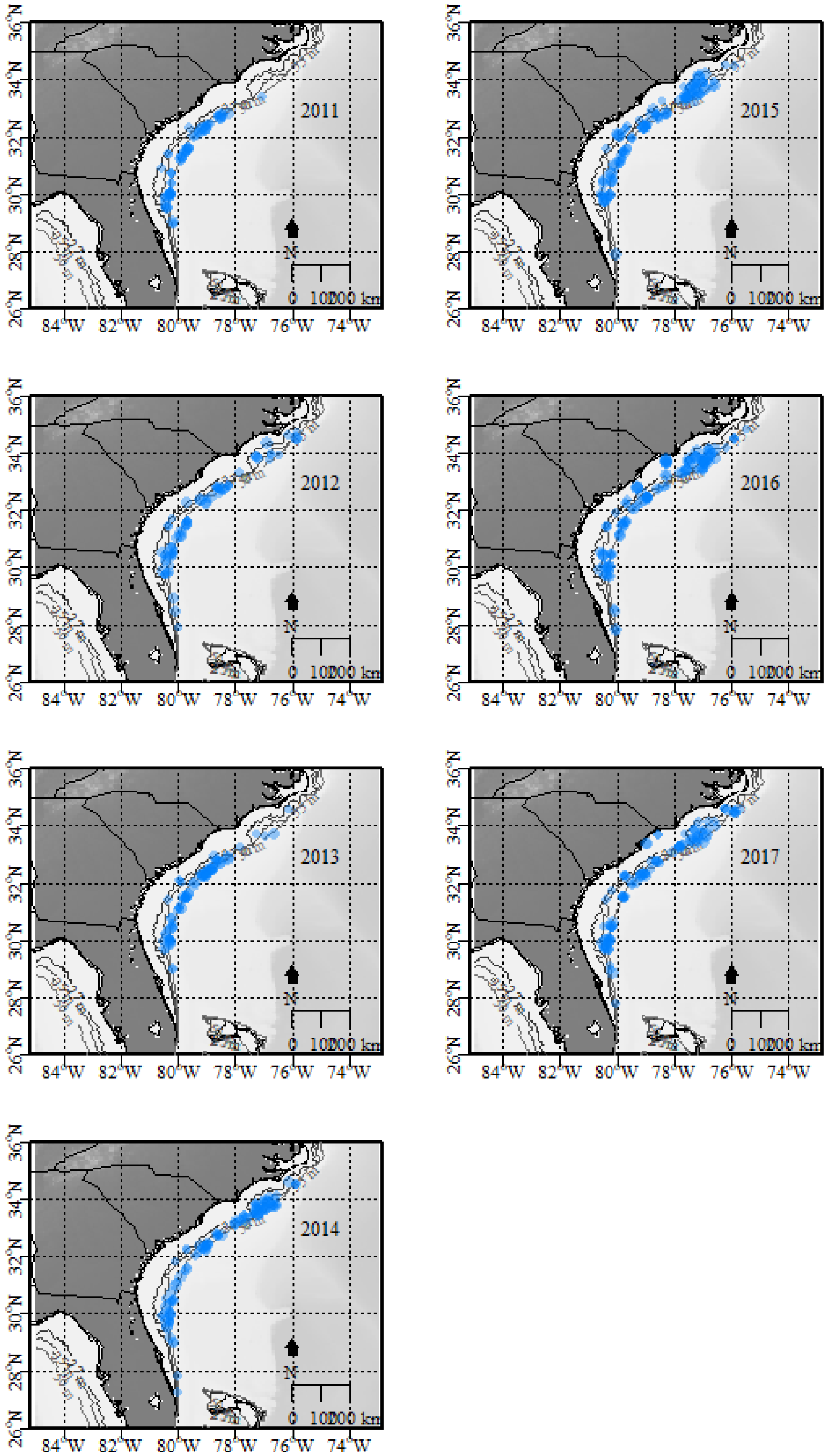

Figure 5: Annual spatial distribution of underwater video samples collected by SERFS in 2011 – 2017 where the sum of red porgy in the video frames counted was from 16 to 44. This represents approximately 25% of the positive videos for red porgy of positive trips. Bottom contours are drawn at the breaks for the depth factor (27, 35, and 50 meters).

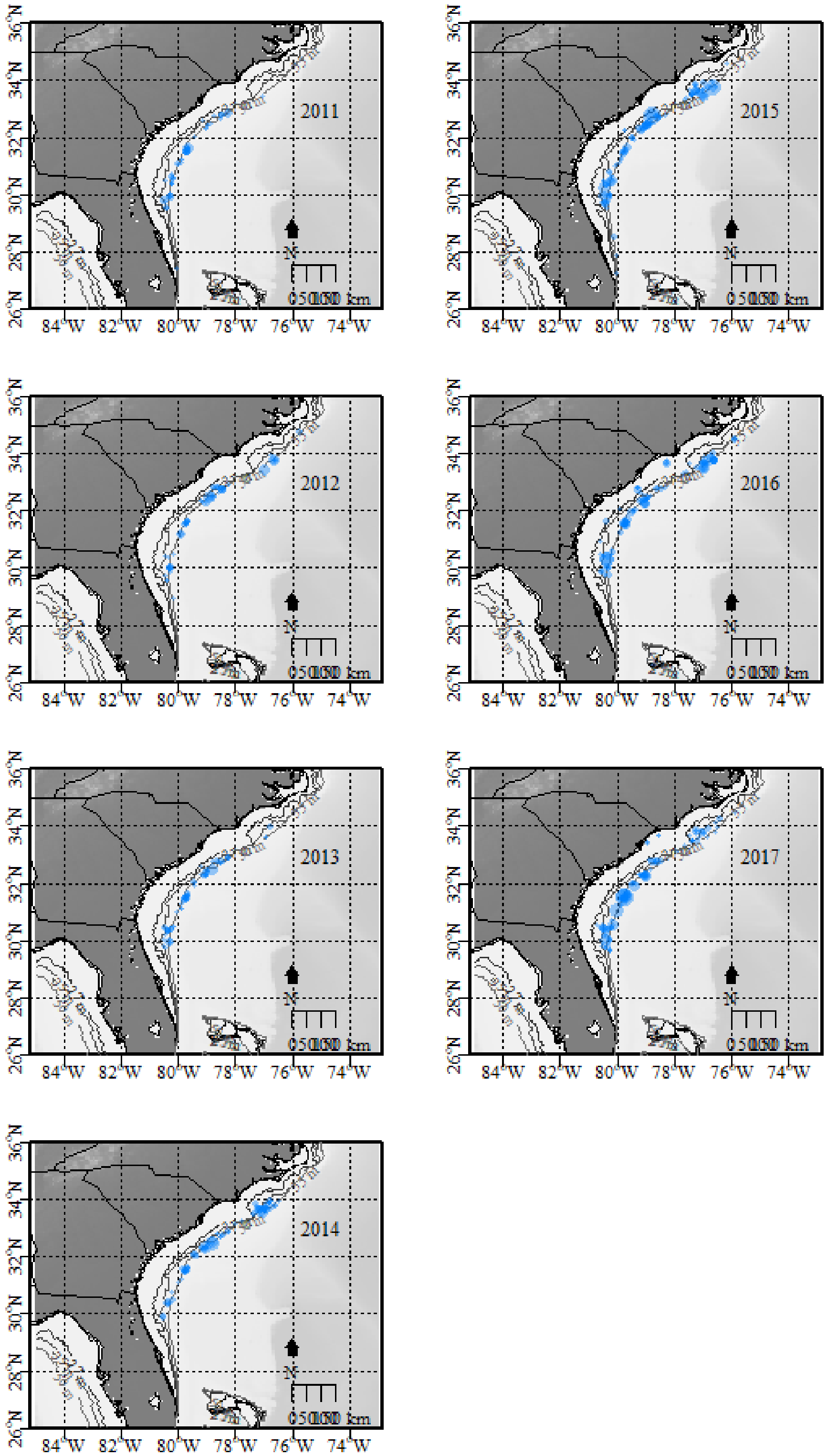

Figure 6: Annual spatial distribution of underwater video samples collected by SERFS in 2011 – 2017 where the sum of red porgy in the video frames counted was 45 or more. This represents approximately 25% of the positive videos for red porgy of positive trips. Bottom contours are drawn at the breaks for the depth factor (27, 35, and 50 meters).

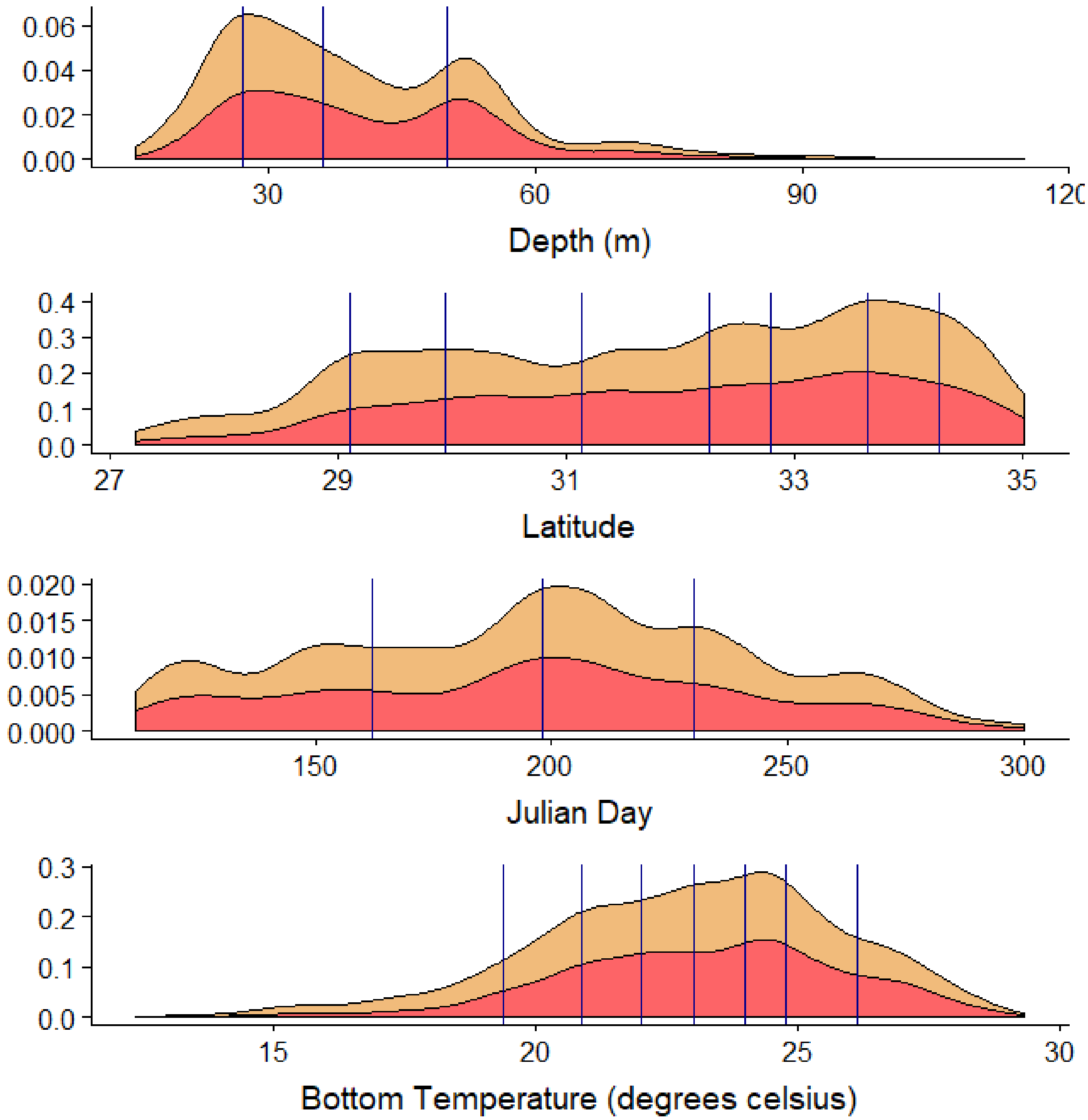

Figure 7: Sample distribution of data collected as continuous variables for positive (red) and zero (orange) counts. Vertical lines represent break points for factor definitions.

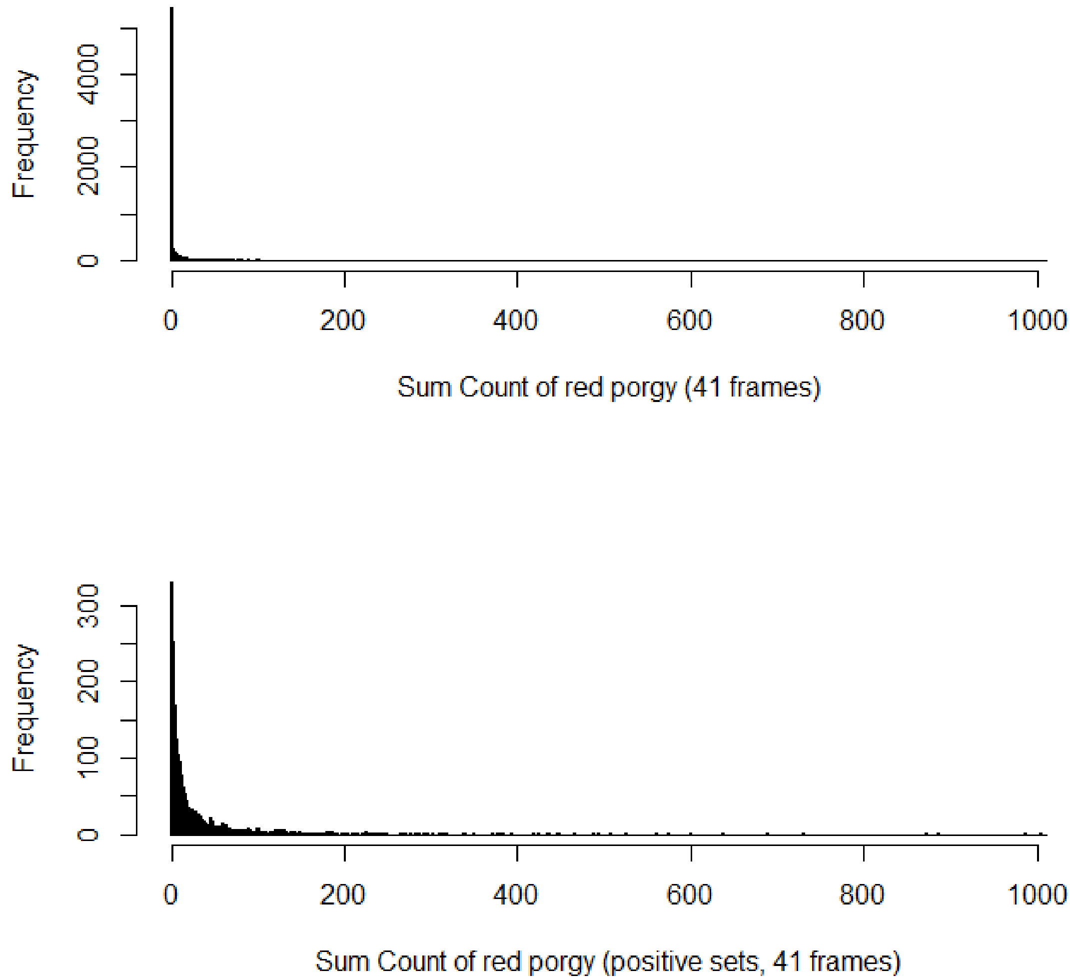

Figure 8: Top panel: *SumCount* distribution of Red porgy video observations in the South Atlantic. Bottom panel: *SumCount* distribution of Red porgy video observations, excluding zeros.

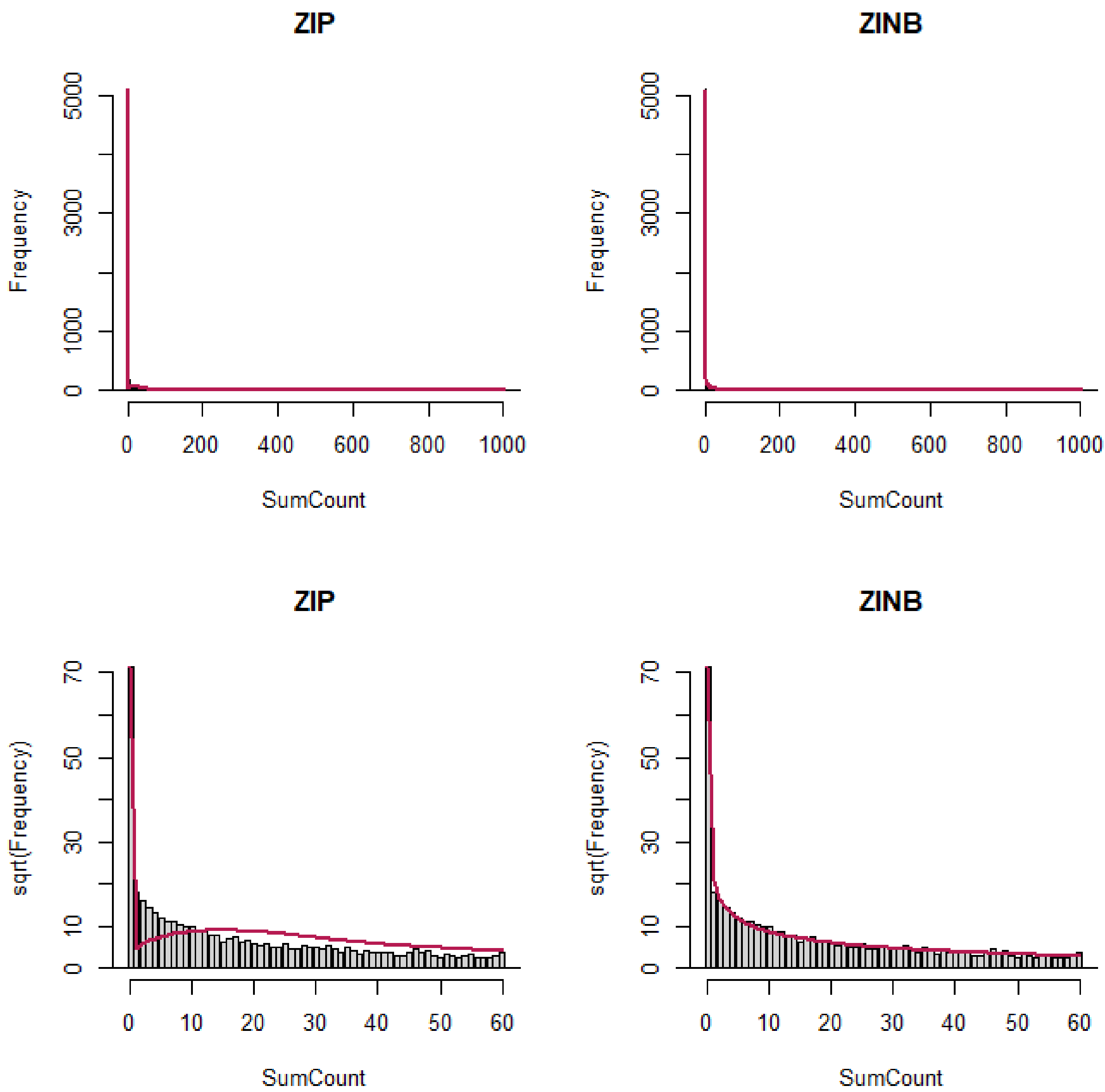

Figure 9: Model formulation comparison, with ZIP (left) and ZINB (right) fitted values plotted against the original data distribution with all covariates included. The lower panels are square root transformed and truncated at 100 fish for inspection of goodness of fit over the range of values for the bulk of the data.

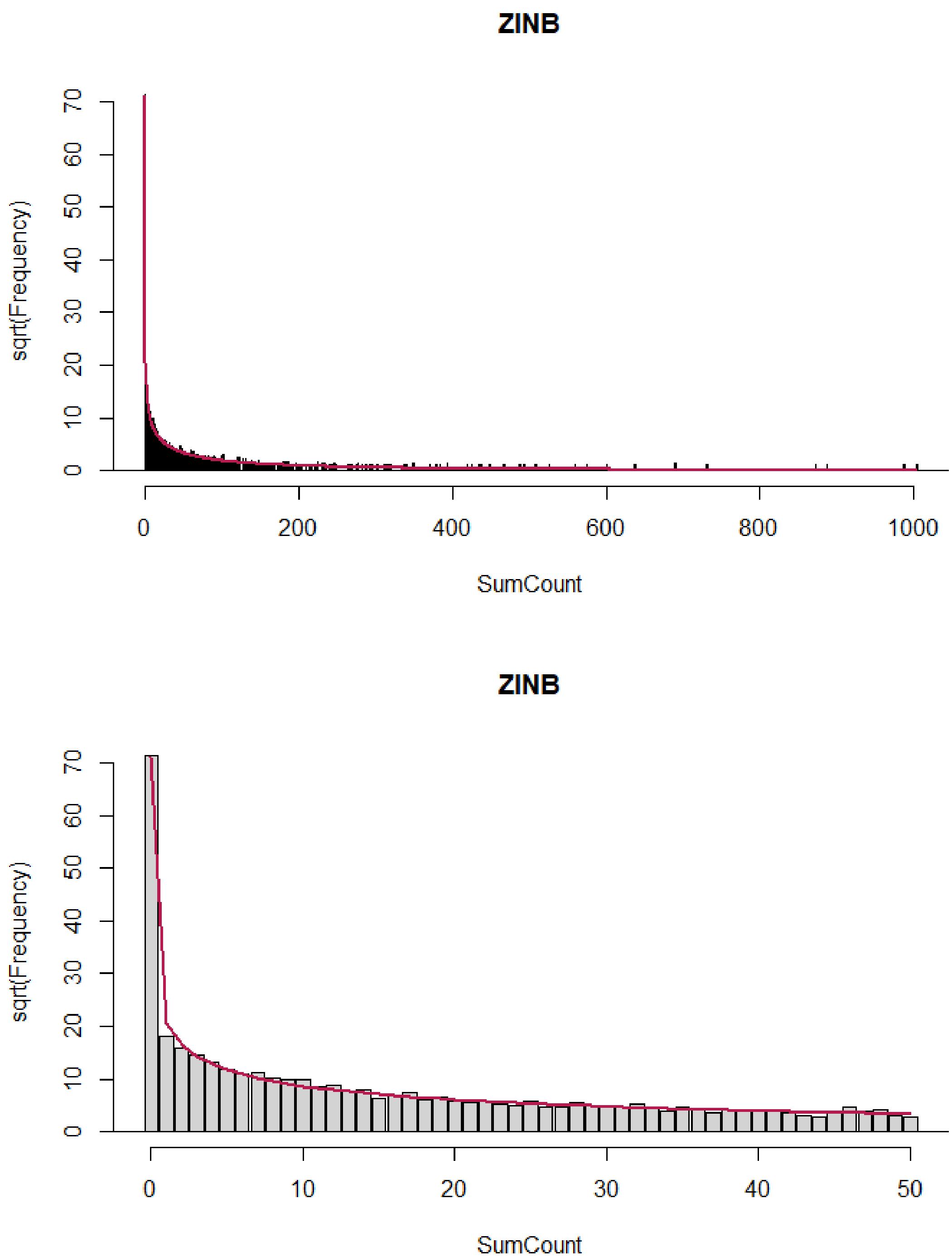

Figure 10: Model diagnostic plots of fitted model values (red line) against the original data distribution for the preferred model. Limited x-axis distribution view (lower).

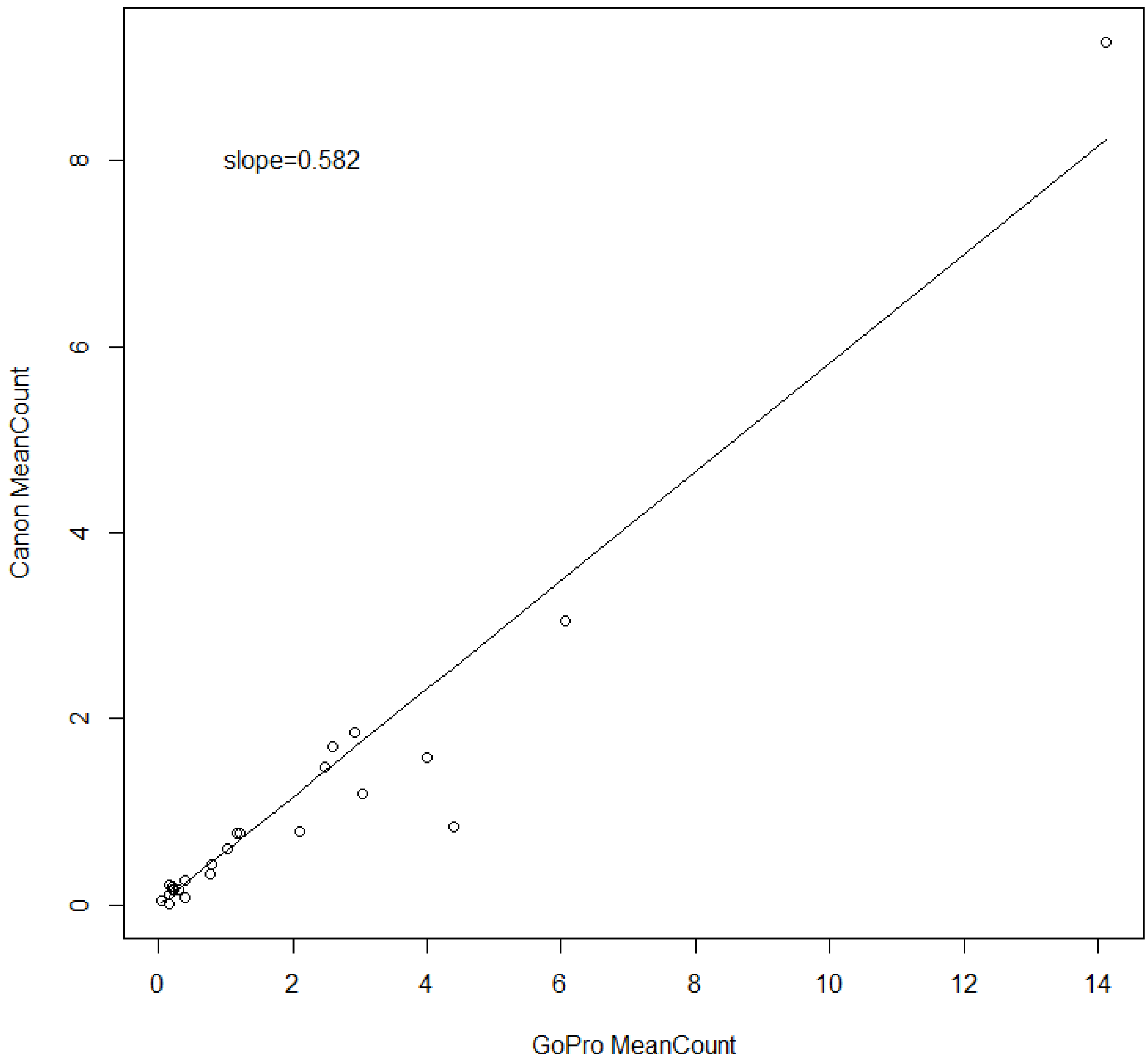

Figure 11: Linear regression (intercept=0) using all red porgy data in the calibration study.

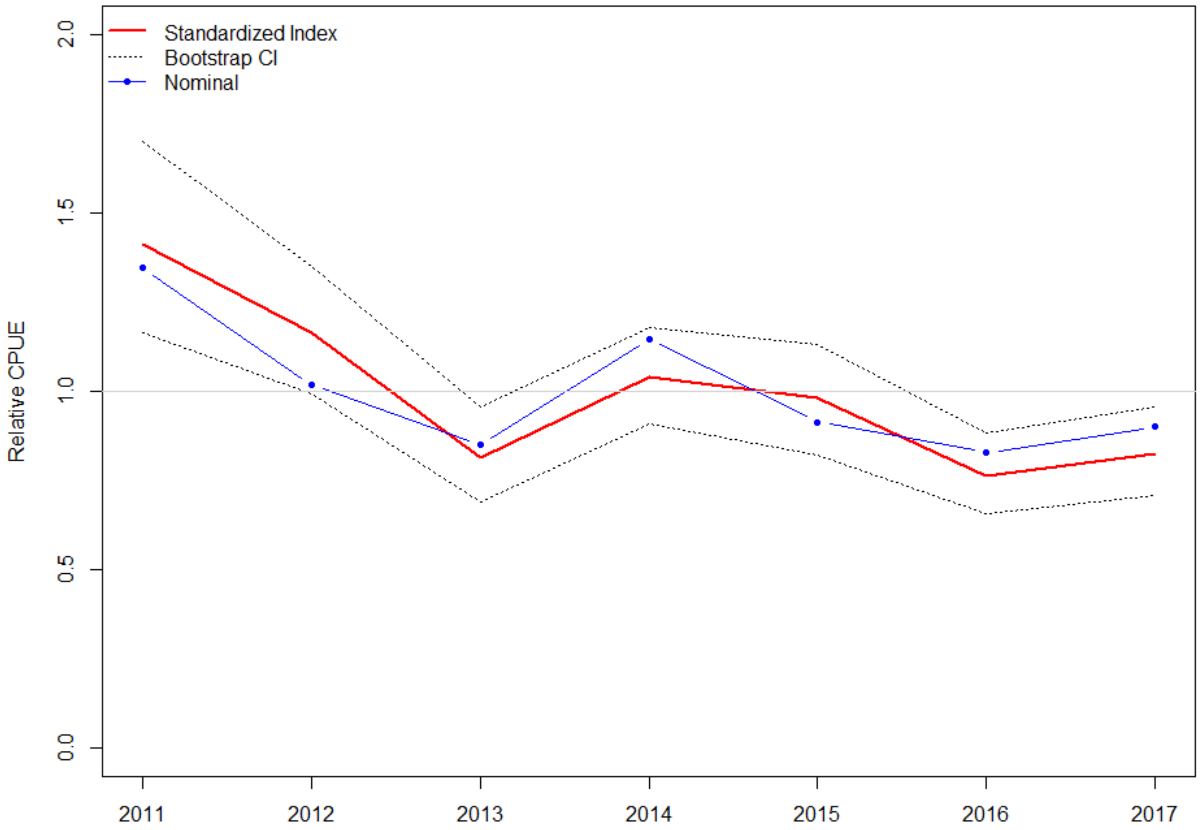

Figure 12: Relative standardized index (solid line) with 2.5% and 97.5% confidence intervals (dashed lines) and the relative nominal index (blue) for red porgy in the SERFS video survey.