Standardized video counts of Southeast U.S. Atlantic gray triggerfish (*Balistes capriscus*) from the Southeast Reef Fish Survey

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SEDAR41-DW03

Submitted: 31 June 2014

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Please cite this document as:

Purcell, K., N. Bacheler, L. Coggins. 2014. Standardized video counts of Southeast U.S. Atlantic gray triggerfish (*Balistes capriscus*) from the Southeast Reef Fish Survey. SEDAR41-DW03. SEDAR, North Charleston, SC. 16 pp.

Standardized video counts of Southeast U.S. Atlantic gray triggerfish (*Balistes capriscus*) from the Southeast Reef Fish Survey

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Abstract

Standardized video counts of gray triggerfish were generated from video cameras deployed by the Southeast Reef Fish Survey for 2011 – 2013. Samples between Cape Hatteras, North Carolina, and St. Lucie Inlet, Florida, were included in the analyses. The index is meant to describe population trends for gray triggerfish in the region. A zero-inflated negative binomial model was used to standardize video count data by a variety of predictor variables that could influence abundance and video counts.

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 from 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 survey 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.

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*, NOAA Ship

Nancy Foster, 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 fish traps with attached video cameras were deployed at each station sampled in our study (Figure 1). Chevron traps were constructed from plastic-coated, galvanized 2-mm diameter wire (mesh size = 3.4 cm2) 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 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. 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).

Relative abundance of reef fish on video was 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 was the MeanCount for that species in each video sample. Zero-inflated modeling approaches used below require count data instead of continuous data like MeanCount. Therefore, these analyses used a response variable called SumCount that 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. Therefore, SumCount values were only used from videos where 41 frames were read (~99% of all samples).

SERFS employs 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. Video readers also quantify microhabitat features (percent of bottom that is hardbottom, maximum substrate relief, substrate size, coverage of attached biota, predominant biotic type, and maximum biotic height), 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

Data Subsetting

Overall, 3985 survey videos were available covering a period of 4 years (2010-2013). We removed any data points in which the survey video was considered unreadable by an analyst, or if the video was located in water greater than 100 meters due to very limited samples in waters deeper than 100 m. Additionally, any survey video for which less than 41 video frames were read was removed from the full data set (*n* =73, ~1.8%). Standardizing the number of readable frames for any data point was essential due to our use of SumCount as a response variable (see above). We also removed video samples from the analysis in which any predictor variable were missing. Finally, due to the limited spatial and temporal extent of the survey during the 2010 sampling season, a decision was made by the panel of the Southeast Reef Fish Survey Video Index Development Workshop (video index workshop; Bacheler and Carmichael 2014) to exclude 2010 data due limitations in spatial overlap of the survey area and the core spatial occupancy of gray triggerfish.

Of the 3985 video samples considered for inclusion in the final data set, 1101 were removed based on the data subsetting guidelines described above, leaving 2884 samples in the gray triggerfish modeling analyses for 2011 – 2013 (Figure 2).

Standardization

Response Variable

For the video index of gray triggerfish, we modeled the SumCount (total number of gray triggerfish observed across 41 video frames). There a number of viable candidate response variables applicable for the estimation of abundance from video surveys, the relative merits of which were discussed at length in the video index workshop (Bacheler and Carmichael 2014). The panel accepted the rational for using MeanCount, or the average number of individuals observed during a video reading, and recommended the use of SumCount as a response variable for the zero-inflated modeling approach.

Explanatory Variables

We considered 9 explanatory variables in our model: year, depth, latitude, water temperature, turbidity, and current direction, all of which were recommended during the video index workshop (Bacheler and Carmichael 2014). The workshop panel also suggested including habitat variables, for which we included biotic density and substrate composition.

YEAR (*y*) – Year was include because standardized catch rates by year are the objective of this analysis. We modeled data from 2011-2013, and 2010 was excluded based on spatial and temporal incongruence with species core habitat. Annual summaries of data points considered are outlined in Table 2.

SEASON (t) – A temporal parameter based on the Julian day samples were collected (Figure 3). The season parameter is treated as factor and divided into octiles based on the recommendations of the video index workshop.

DEPTH (*d*) – Water depth, a key component effecting the distribution of gray triggerfish, was considered for all data points in waters shallower than 100 m (Figure 3). Data points were excluded from deeper waters generally due to limited samples and rare occurrence. Depth was treated as a factor with four levels and assigned based on quantiles. Annual depth distribution for survey data are outlined in Table 2.

LATITUDE (*lat*) – The latitude of video samples was a key spatial parameter in the model (Figure 3). Based on recommendations made by the video index workshop, latitude was included in the model and divided into 4 levels based on quantiles.

TEMPERATURE (*temp*) – The bottom water temperature was collected from each station and incorporated as a predictor variable. Bottom temperatures ranged from 12-29 degrees Celsius (Figure 3). For the model, temperature was treated as a factor with 4 levels based on quantiles.

TURBIDITY (*wc*) – Due to the effect of turbidity on both species distributions and on the ability of an analyst to process video survey samples, we included the categorical variable water clarity (*wc*) in the model. Turbidity information was recorded during video analysis based on the ability of an analyst to perceive the horizon and surrounding habitat and was scored at three levels.

CURRENT DIRECTION (*cd*) – A categorical variable estimating current direction based on the video point of view. Current direction data was included to better account for variability in detection due to the current moving fish away or towards the camera. This variable was collected during video processing and scored as a 4-level categorical variable (Towards, Away, Sideways, Unknown).

BIOTIC DENSITY (*bd*) – An estimation of the percent cover of attached biota visible on each video. The estimation was made based on percentage cover and ranged from 0 – 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*) – An estimate of the amount of hardbottom in the video viewing area. This variable was treated as a categorical variable with 4 levels: none (0%), low (1-9%), moderate (10-39%) and high (>40%).

Zero-Inflated Model

The recommendation of the video index workshop was to apply a zero-inflated modeling approach to the development of fishery-independent video index for gray triggerfish in the South Atlantic. Zero-inflated models are valuable tools for modeling distributions that do not fit standard error distributions due to the 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). Due to the high proportion of zero counts found in our data set (Figure 4), we used a zero inflated mixed model approach which models the occurrence of zero values using two different processes, a binomial and a count processes (Zuur et al. 2009). The benefit and utility of this approach was discussed at length during the video index workshop (Bacheler and Carmichael 2014) and their use was the final recommendation of the panel.

Initially, we considered a null model (1) using both a zero-inflated Poisson (ZIP) and a zero-inflated negative binomial (ZINB) formulation.

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

We compared the variance structure of each model formulation using likelihood ratio tests (Zuur et al 2009) to determine the most appropriate model error structure for the development of a gray triggerfish video index. The results of the likelihood ratio test (Table 1) show clear support for the ZINB formulation. The 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). Finally, a comparison between the fitted and original data for the ZIP and ZINB model formulation shows the superiority of using the negative binomial error structure (Figure 5).

We used a step-wise backwards model selection procedure to systematically exclude unnecessary parameters from our model formulation. The final gray triggerfish ZINB model formulation (2), based on the results of AIC and likelihood ratio tests (Zuur et al. 2009), excluded substrate composition (*sc*) from the binomial component of the model and the year (*y*) and water clarity (*wc*) parameters from the negative binomial component of model (Table 2).

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

Diagnostics of the final model showed no clear patterns of association between Pearson's residuals and fitted values or the fitted values and original data (Figure 6). In addition an examination of model residuals for the spatio-temporal (Figure 7) and environmental parameters showed no clear patterns of association, indicating acceptable model choice (Zuur et al 2009). Finally, a comparison of predicted values against the original data distribution (Figure 9) visualizes how our model fits the original data.

All data manipulation and analysis was conducted using R version 3.0.2 (R Core Team 2014). Modeling was executed using the **zeroinfl** function in the **pscl** package (Jackman 2008), available from the Comprehensive R Archive Network (CRAN).

Results

Annual standardized index values for gray triggerfish including coefficient of variation estimates are presented in Table 4. The relative nominal video counts for gray triggerfish fell within the 2.5% and 97.5% confidence intervals of the standardized index and tracked closely to the relative nominal index for all years included in this analysis (Figure 10). Due to the short temporal extent of this index (3 years), limited inferences can be made about changes in gray triggerfish abundance.

Literature cited

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Table 1: Preliminary model error structure comparison

	df	Likelihood	df	χ^2	*p*-value
ZIP	58	-10207.13			
ZINB	59	-4266.24	1	11881.79	<0.001

Table 2: Annual total number of video samples included in the analysis

Year	Number of video samples	Depth range (m)	Latitude range	Date range
2011	624	15-93	27.22-34.54	139-298
2012	1059	15-98	27.22-35.01	115-284
2013	1201	15-92	27.33-35.01	114-277

Table 3: Model selection results for Zero-Inflated Negative Binomial model for gray triggerfish observed during SERFS video surveys, 2011-2013

	Removed Term						
Step	Binomial Model	Negative Binomial Model	*df*	AIC	χ^2	df	*p*-value
0	<none>	<none>	59	8747.94			
1	<none>	*sc*	57	8744.57	0.631	2	0.729
2	<none>	*sc*, *temp*	54	8740.86	2.28	3	0.514
3	<none>	*sc*, *temp*, *wc*	52	8735.58	1.71	2	0.423

Table 2: The relative nominal SumCount, number of stations sampled, proportion positive, standardized index, and CV for the SERFS gray triggerfish video index.

Year	Relative nominal (SumCount)	N	Proportion positive	Standardized index	CV
2011	0.97	624	0.24	0.95	0.11
2012	0.93	1059	0.26	0.97	0.10
2013	1.09	1201	0.27	1.06	0.09

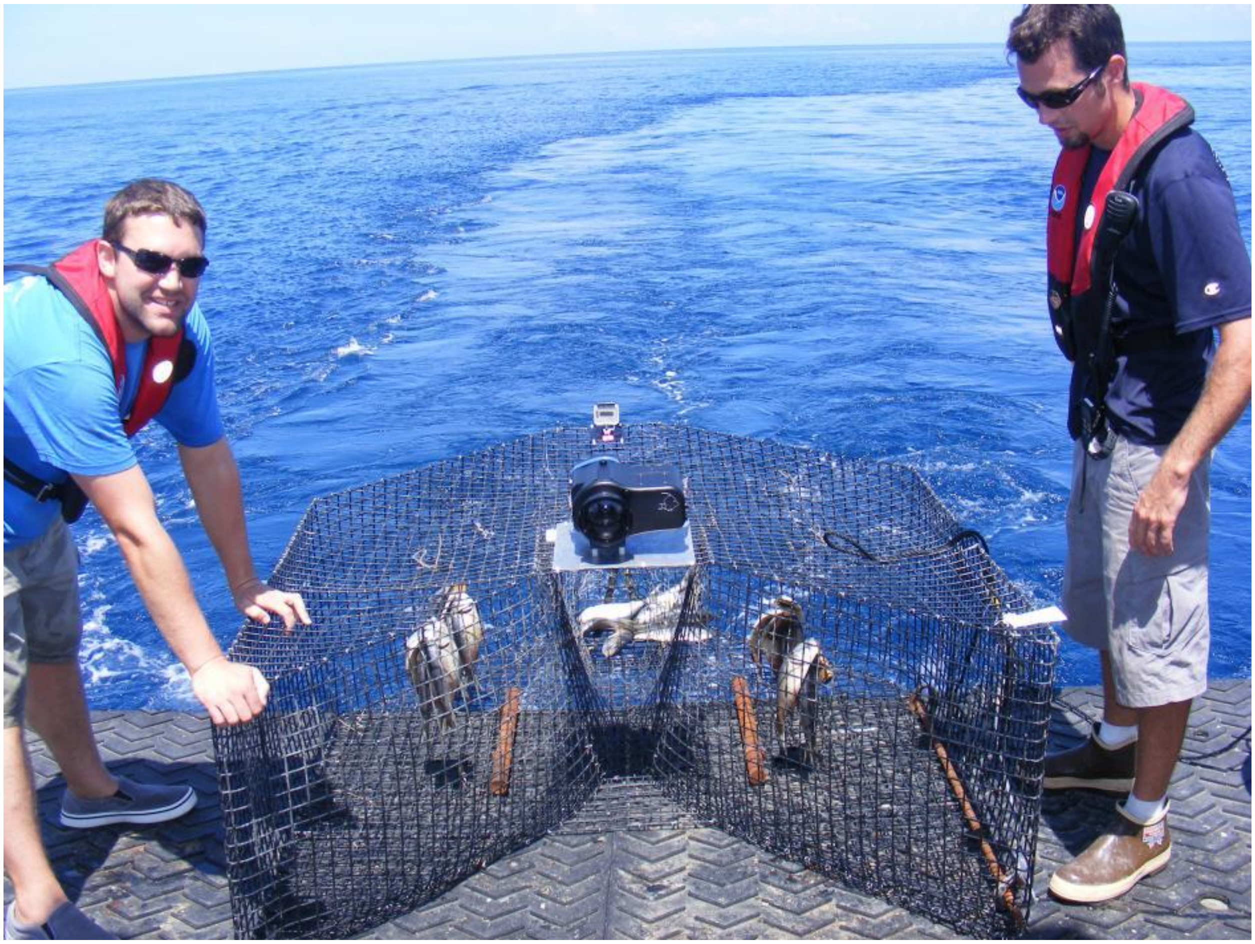

Figure 1: Chevron trap used by SERFS showing the attached underwater video cameras.

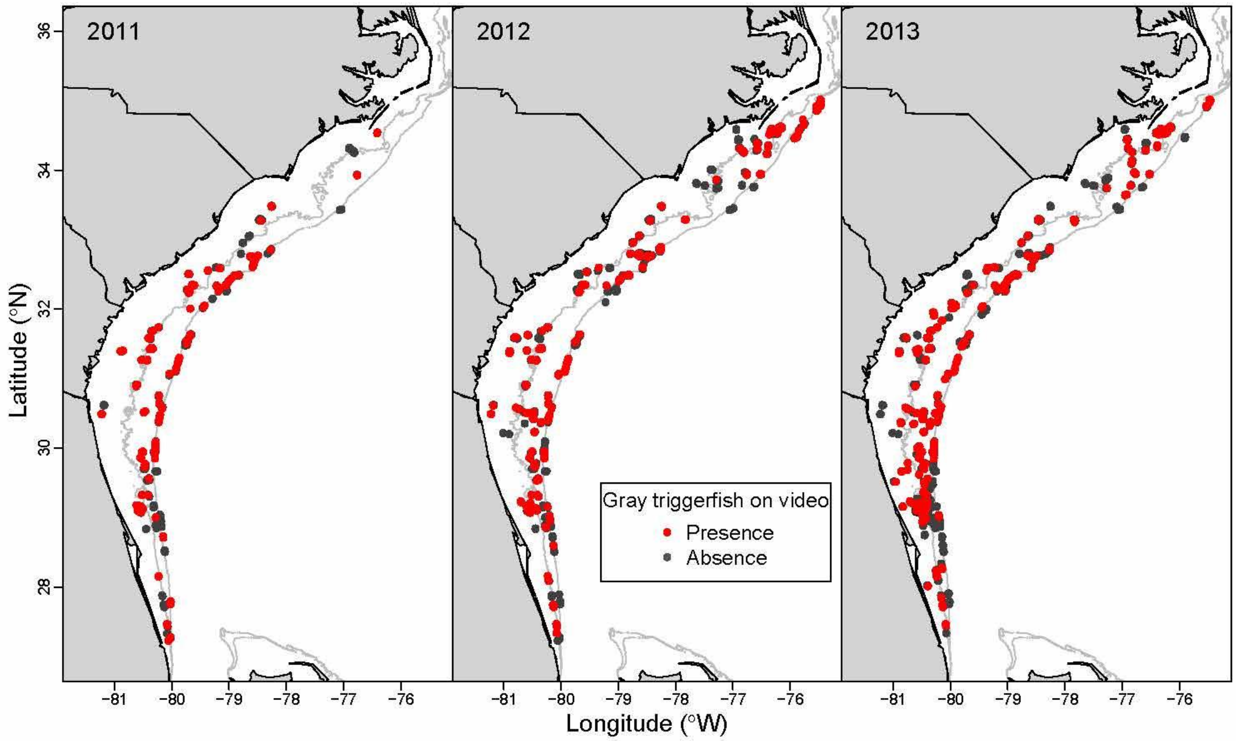

Figure 2: Annual spatial distribution of underwater video samples collected by SERFS in 2011 – 2013. Dark gray points indicate no gray triggerfish were seen on video and red points indicate gray triggerfish were seen on video. Note that red points were overlaid on top of gray points, and points may overlap.

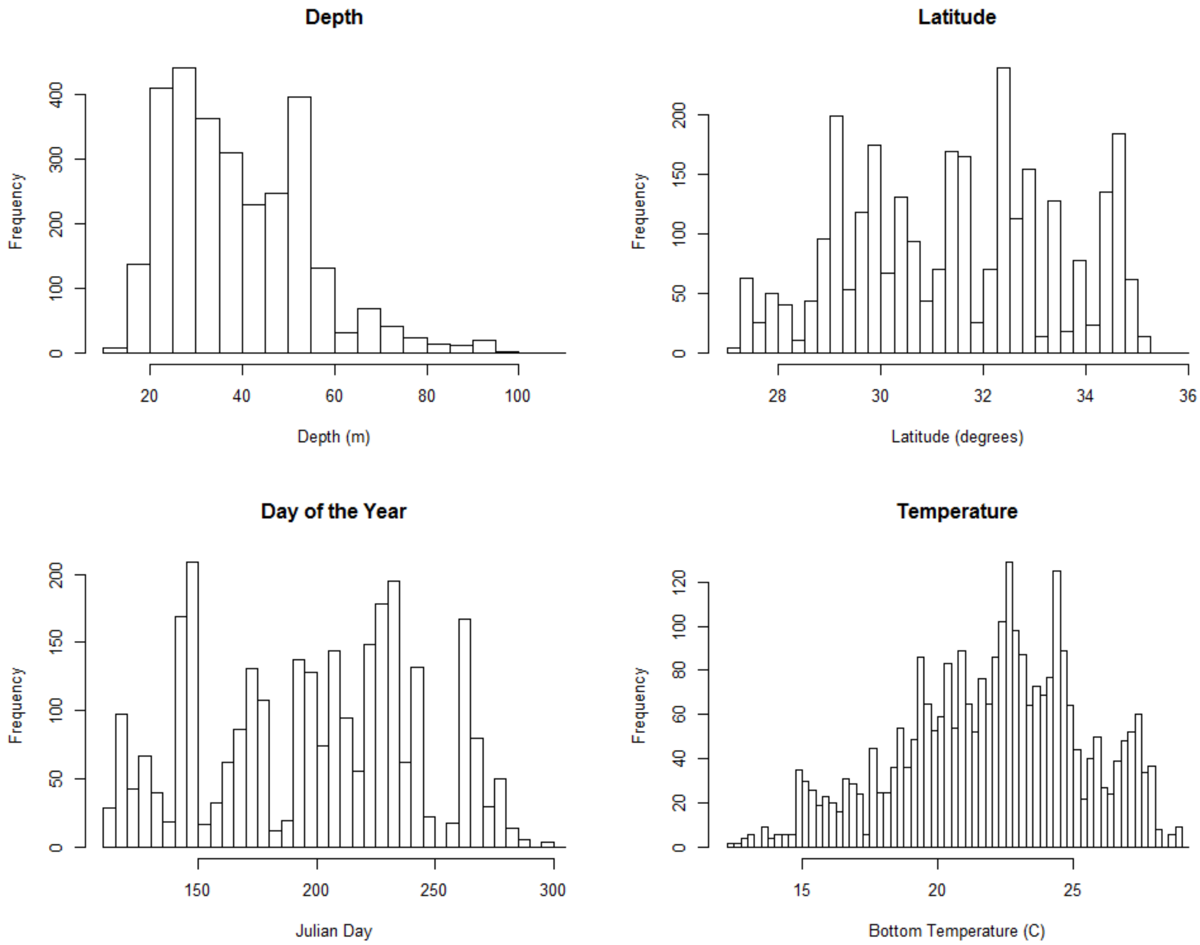

Figure 3: Sample distribution for original data continuous variables

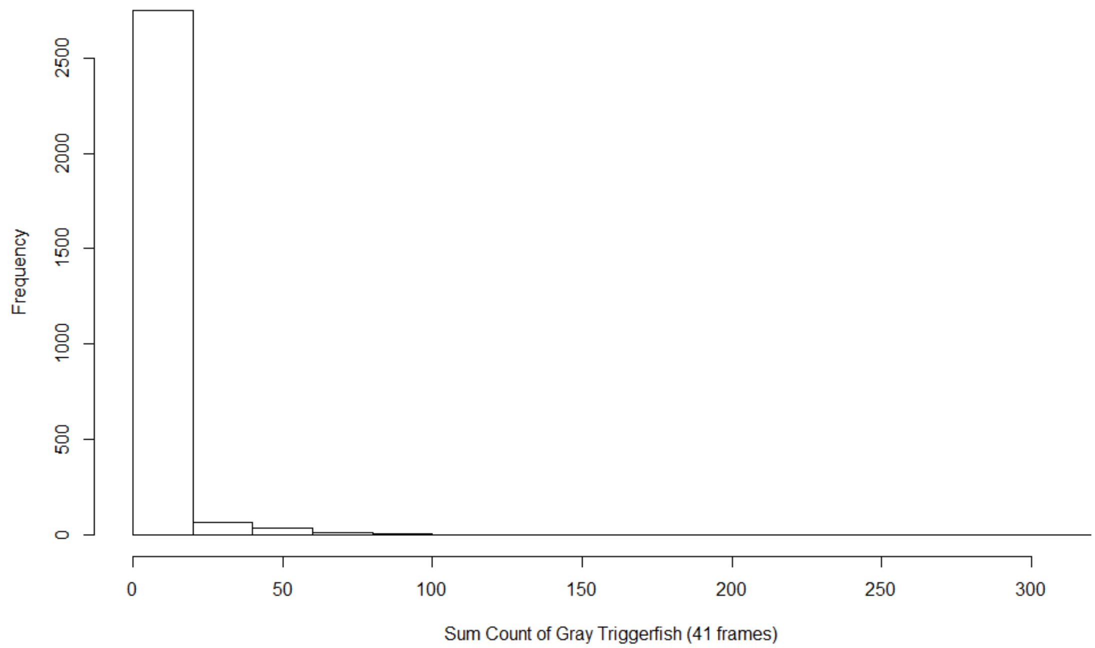

Figure 4: SumCount distribution for gray triggerfish video observations in the South Atlantic.

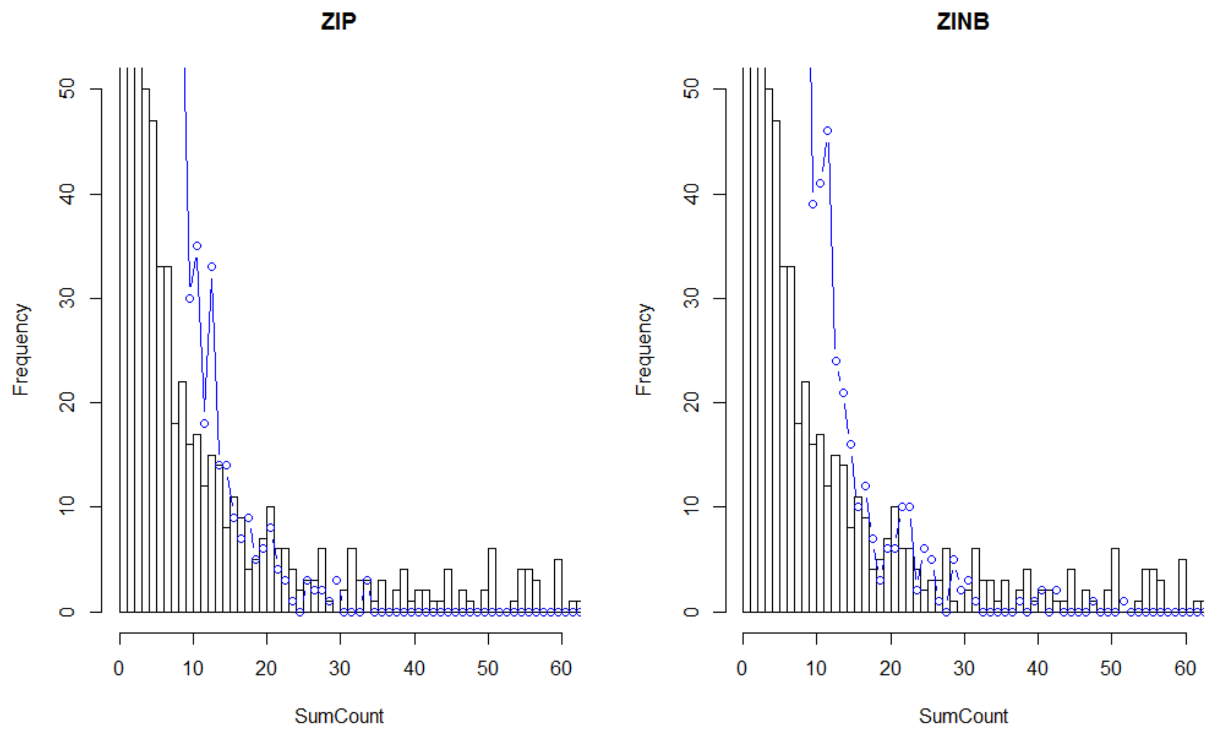

Figure 3: Model formulation comparison, with ZIP (left) and ZINB (right) fitted values plotted against the original data distribution

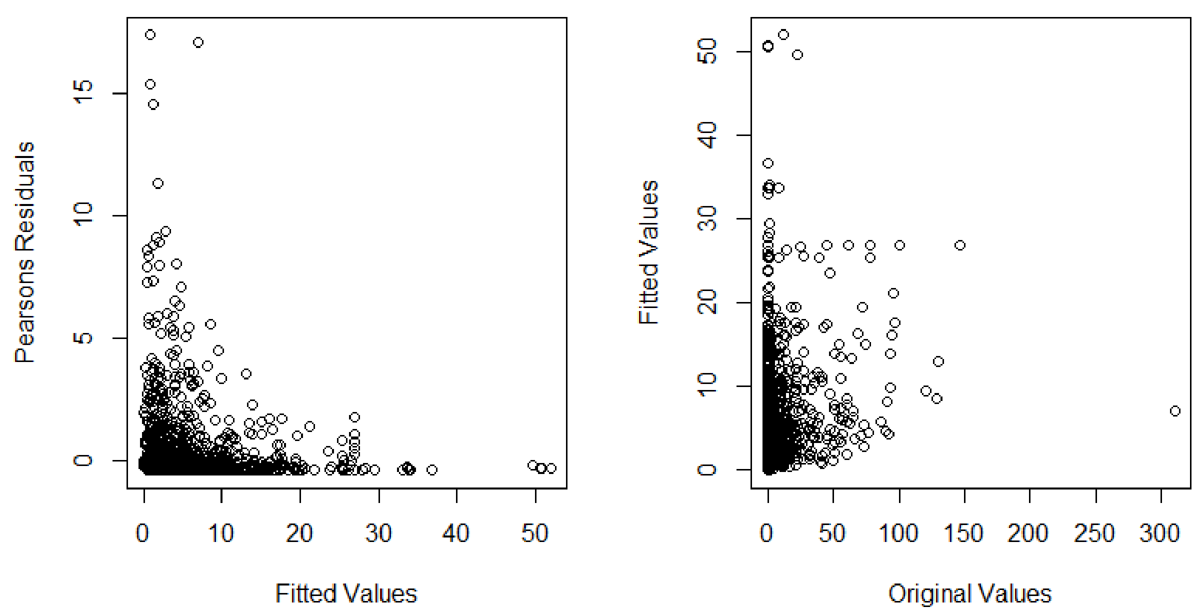

Figure 4: Model diagnostic plot showing fitted model values against Pearson's residuals (left) and fitted values plotted against original data values (right)

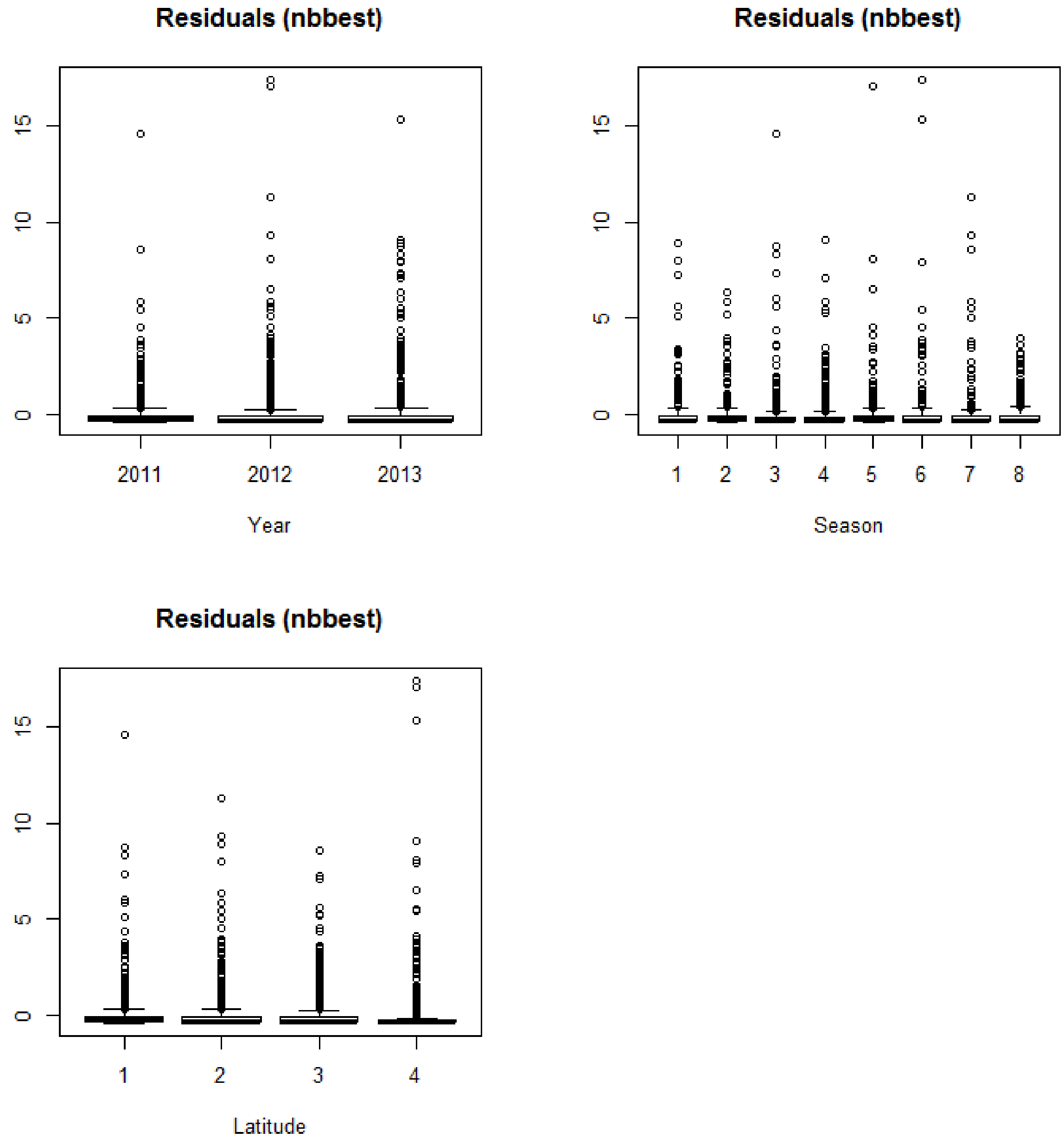

Figure 5: Model diagnostic plot showing Pearson's residuals from the final model plotted against both temporal and spatial model variables

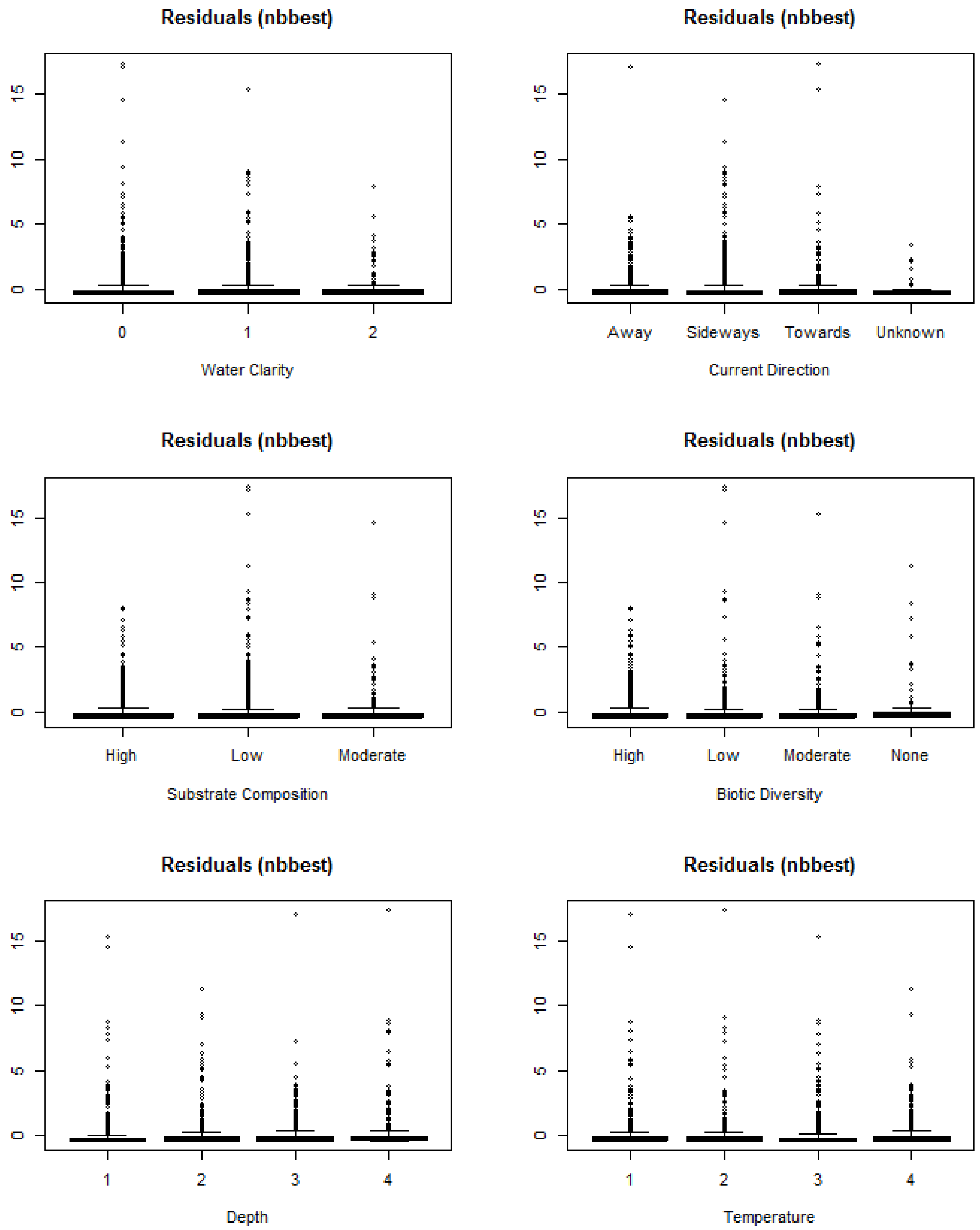

Figure 6: Model diagnostic plots showing Pearson's residuals for the final model plotted against environmental model parameters.

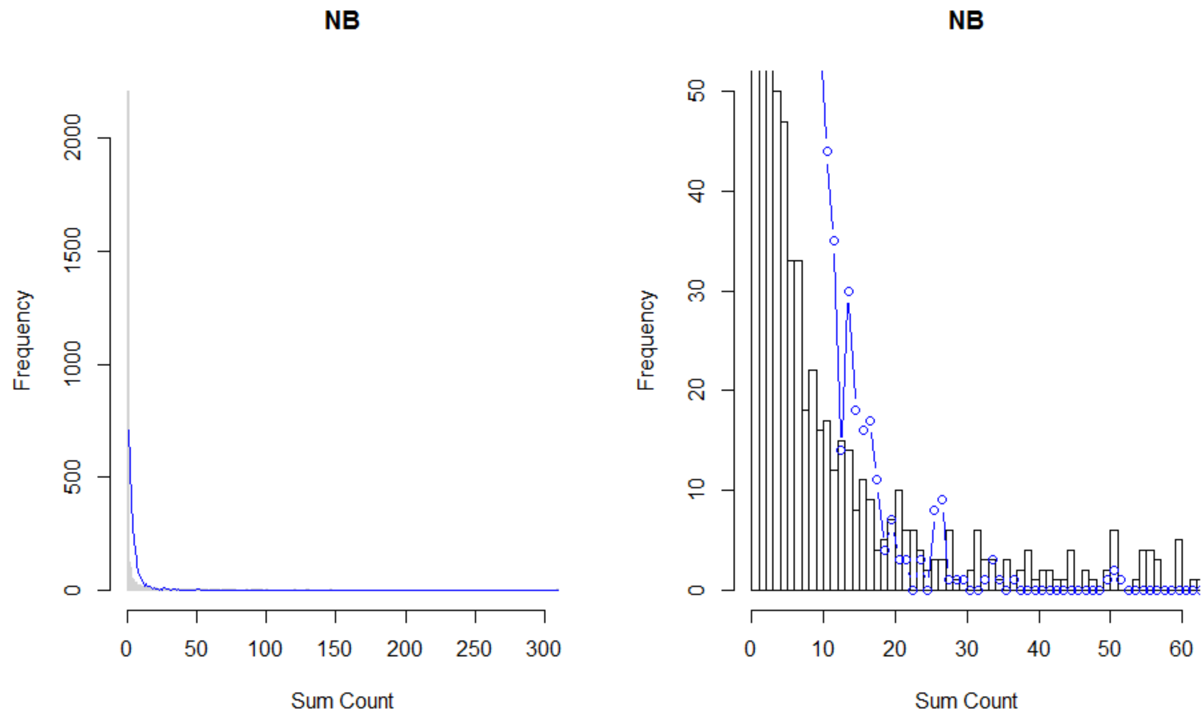

Figure 7: Model diagnostic plots of fitted model values (blue line) against the original data distribution. Full distribution view (left) limited x-axis view (right).

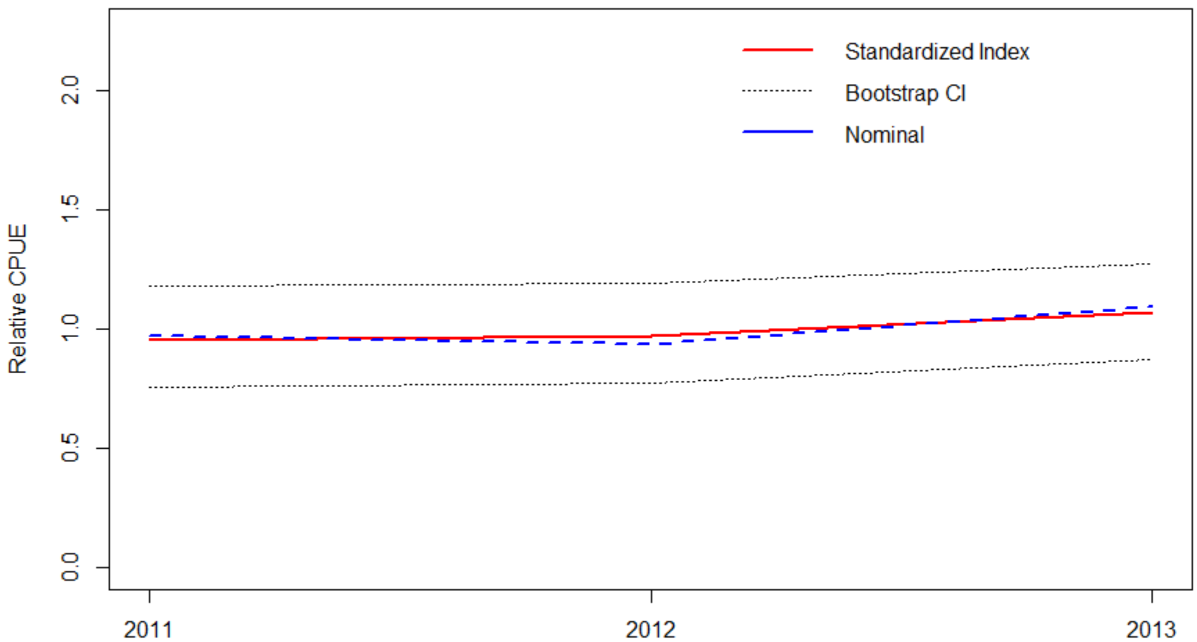

Figure 8: Relative standardized index (solid line) with 2.5% and 97.5% confidence intervals (dashed lines) and the relative nominal index (blue) for gray triggerfish video counts (CPUE) in the SERFS video survey