Standardized video counts of Southeast U.S. Atlantic red snapper (*Lutajanus campechanus*) from the Southeast Reef Fish Survey

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Standardized video counts of Southeast U.S. Atlantic red snapper (*Lutjanus campechanus*) from the Southeast Reef Fish Survey

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Abstract

Standardized video counts of red snapper were generated from video cameras deployed by the Southeast Reef Fish Survey for 2010 – 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 red snapper 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, and a camera calibration study was used to calibrate counts of red snapper between the two cameras used during monitoring.

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. All four years of data are included here, as recommended by Bacheler and Carmichael (2014; SEDAR41-RD23).

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 m3. 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.

GoPro Hero (2010) or Canon Vixia HFS-200 high-definition video cameras in Gates underwater housings (2011 – 2013) 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 are 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 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 are re-read by fish video reading experts until they are very high quality. After that point, 10% or 15 videos (whichever is larger) are re-read annually by fish video reading experts. Video readers also quantify microhabitat features (i.e., 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.

Camera calibration

GoPro cameras were used for fish counts in 2010, while Canon cameras were used in 2011 – 2013. To calibrate fish count between these two cameras, side-by-side Canon-GoPro videos were taken during the summer of 2013 and read for red snapper. Additionally, a lab experiment was conducted to quantify differences in field of view between the two cameras. Results indicated the Canon cameras saw 51% of the field of video of GoPro cameras, but the quality of GoPro videos was perhaps slightly lower than that of Canon videos. A total of 15 calibration videos were read that included red snapper. Based on a regression analysis applied to the calibration video results, there were 53% (1 minus the regression slope parameter) fewer red snapper seen on Canon cameras compared to GoPro cameras, which is almost exactly what one would predict based on the reduction of field of view on Canon cameras compared to GoPro cameras (see Figures 7-9 in Bacheler and Carmichael 2014). Therefore, it was recommended that the 2010 relative abundance data point be reduced by 53% to account for differences in viewing areas among the cameras.

Data and Treatment

Data subsetting

Overall, there were 3987 survey videos with red snapper present during the examined 4 year sampling period (2010-2013). We removed any data points in which the survey video was considered unreadable by an analyst, or if the survey point 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. 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 variables were missing and removed them from the final data set.

Of the total 3987 video samples considered for inclusion in our modeling analysis, 885 were removed based on the data subsetting approach described above, leaving 3102 samples in the red snapper analyses for 2010 – 2013 (Figure 2).

Standardization

Response Variable

For the video index of red snapper we modeled the SumCount, or total number of red snapper observed across 41 video frames. There were 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 during the video index development 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 suitable for a zero-inflated modeling approach. The use of SumCount requires that an equal number of video frames (n = 41) be considered for each data point considered in the model estimation.

Explanatory Variables

We considered 9 explanatory variables in our model analysis: year, depth, latitude, water temperature, turbidity, and current direction, all of which were recommended during the video index development 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 2010-2013, noting that data from 2010 was spatially limited due to reduced video deployment during this initial year. Due to the high spatial overlap between the sampled region and the spatial occupancy of red snapper, data from 2010 were included in this analysis. This decision was supported by recommendations from the video index development panel (Bacheler Carmicheal 2014). Annual summaries of data points considered are outlined in Table 2.

SEASON (*t*) – A temporal parameter based on the Julian day the sample was collected (Figure 3). The season parameter is treated as an octile factor based on the recommendations of the video index development workshop.

DEPTH (*d*) – Water depth is a key component affecting the distribution of red snapper, so we considered all data points in waters shallower than 100m. Data points were excluded from deeper waters generally due to limited samples and rare occurrence (Figure 3). Annual depth distribution for survey data are outlined in Table 2.

LATITUDE (*lat*) – The latitudes of video samples were included as a spatial parameter in the model (Figure 3). Based on recommendations made by the video index development workshop, latitude was treated as a factor in the model and divided into 8 levels based on octiles.

TEMPERATURE (*temp*) – bottom water temperature was collected from each station and incorporated as a predictor variable. Bottom water temperature ranged from 12 – 29 degrees Celsius (Figure 3). For the standardization, 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 water clarity (*wc*) in our standardization 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 3 levels (0 – Horizon visible, 1 – Habitat but not horizon visible, 2 – Habitat not visible).

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) and was incorporated into the model as such.

BIOTIC DENSITY (*bd*) – An estimation of the percent cover of attached biota visible during any video. The estimation is 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 red snapper in the South Atlantic. Zero-inflated models are valuable tools for modeling distributions that do not fit standard error distribution 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). 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, a null model (1) was considered employing 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 a likelihood ratio test (Zuur et al. 2009) to determine the most appropriate model formulation for the development of a video index for red snapper. The likelihood ratio test (Table 1) showed strong support for application of a ZINB formulation that, in addition to a comparison of model fits for both the ZIP and ZINP formulations (Figure 5), resulted in decision to use a ZINB approach. The results concurred with expectations based on the level of zero-inflation and over dispersion within the original red snapper data and with the recommendations of the video index development panel (Bacheler and Carmichael 2014).

A backwards step-wise model selection procedure was used to exclude unnecessary model parameters from the null model (1) formulation. The optimum red snapper model formulation (2) was determined using a combination of AIC and likelihood ratio tests (Zuur et al. 2009) and excluded water clarity (*wc*) and temperature (*temp*) from the binomial component of the model and excluded both water clarity (*wc*) and season (*t*) from the negative binomial component of the model (Table 3).

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

Model diagnostics showed no discernable pattern of association between Pearson's residuals and fitted values or the fitted values and the original data (Figure 6). An examination of model residuals for the spatio-temporal (Figure 7) and environmental model parameters (Figure 8) showed no clear patterns of association, indicating correspondence to underlying model assumptions (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 red snapper including coefficient of variation estimates are presented in Table 4. The relative nominal video counts for red snapper differed considerably in comparison to the standardized index with only the 2011 relative nominal value falling within the 2.5% and 97.5% confidence intervals of the standardized index (Figure 10). The nominal value for 2010 (2.30) was considerably higher than the standardized index value for 2010 (1.42), which was expected due to the integration of a camera calibration to the standardized index. Additionally, the standardization index procedure increased estimates of abundance for both the 2012 and 2013 survey years with the relative nominal value falling below and outside of the index confidence intervals. Due to the short temporal extent of this index (4 years), limited inferences can be discerned concerning patterns of red snapper abundance, however the index does indicate an increase in relative video counts since the 2011 survey year and relative stability for the 2012-2013 survey years.

Literature cited

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Table 1: Preliminary model formulation comparison

	df	Likelihood	df	χ^2	*p*-value
ZIP	70	-8513			
ZINB	71	-3753	1	9521.5	<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
2010	218	16-64	28.71-31.74	209-300
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 red snapper observed during SERFS video surveys, 2010-2013

	Removed Term						
Step	**Binomial Process**	**Count Process**	***df***	**AIC**	**χ2**	***df***	***p-value***
null	<none>	<none>	71	7647.17			
1	*temp*	<none>	68	7643.01	1.84	3	0.606
2	*temp, wc*	<none>	66	7641.71	2.69	2	0.259
3	*temp, wc*	*wc*	64	7640.60	2.89	2	0.235
4	*temp, wc*	*wc, t*	57	7638.46	11.85	7	0.105

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

Year	Relative nominal SumCount	N	Proportion positive	Standardized index	CV
2010	2.30	218	0.267	1.42	0.17
2011	0.42	624	0.155	0.57	0.17
2012	0.59	1059	0.206	1.00	0.15
2013	0.66	1201	0.233	0.96	0.11

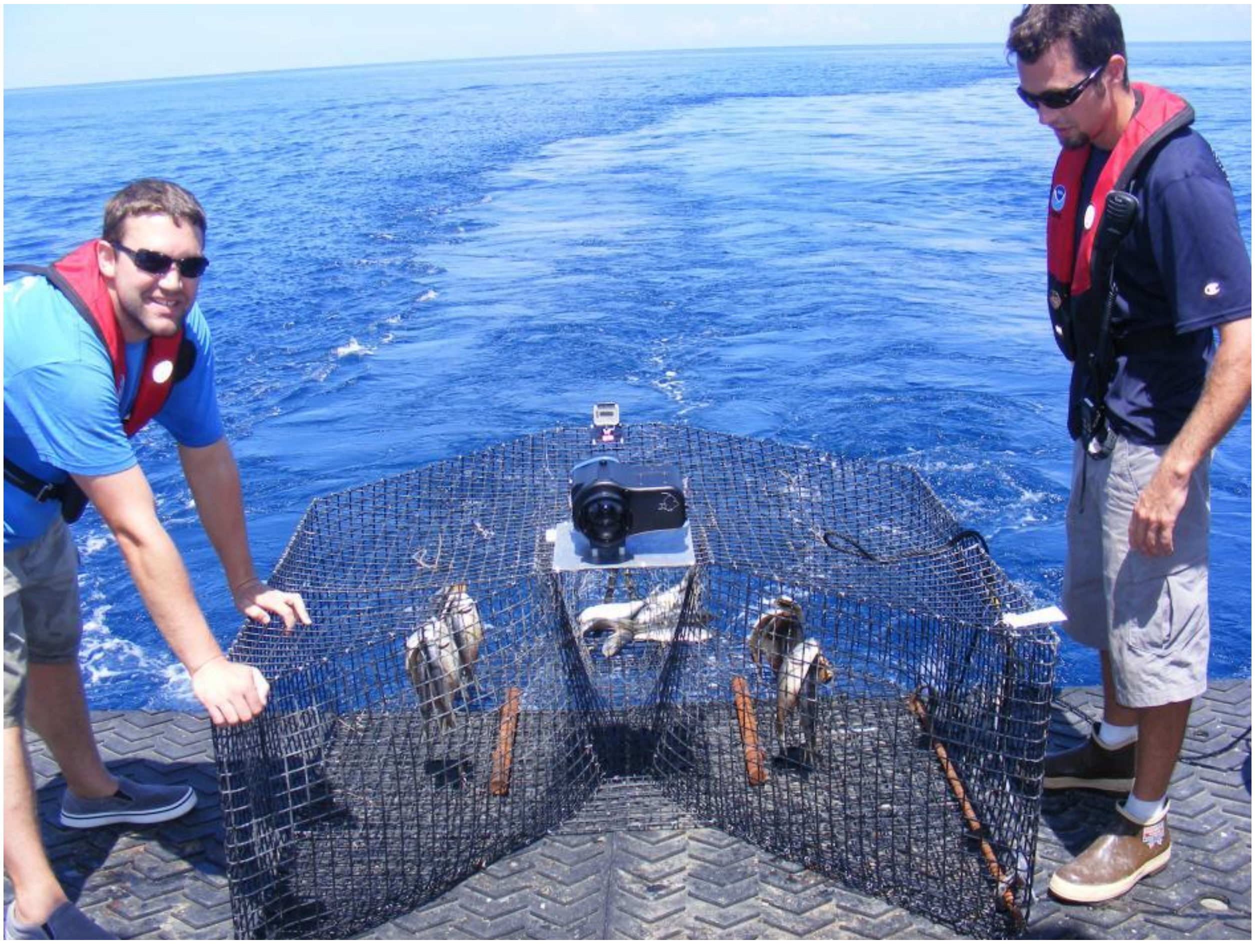

Figure 1: Chevron trap used by SERFS showing the attached underwater video cameras.

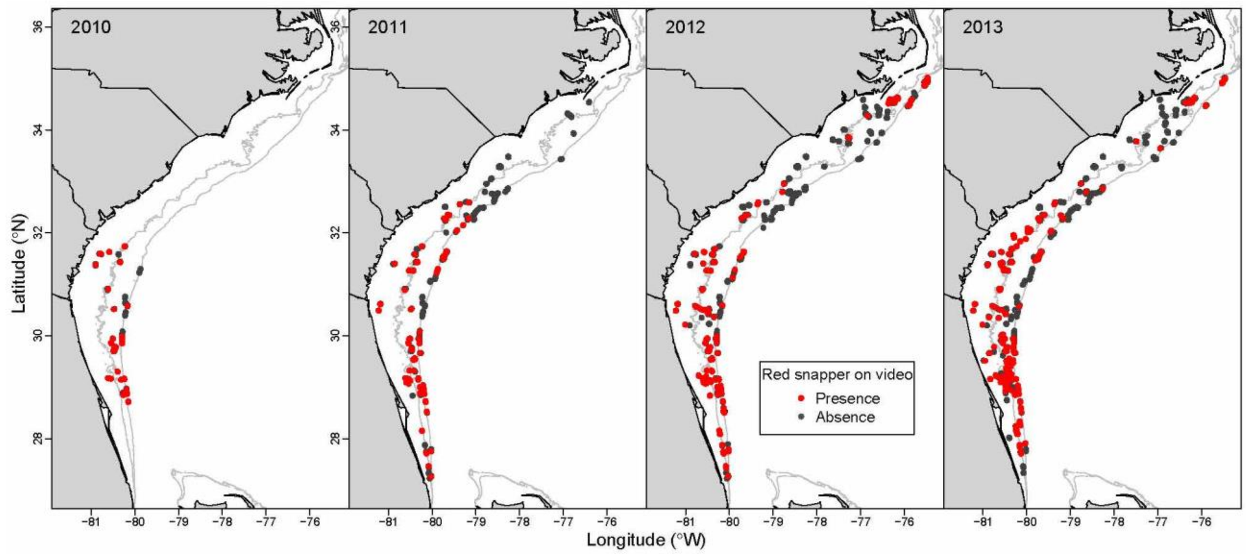

Figure 2: Annual spatial distribution of underwater video samples collected by SERFS in 2010 – 2013. Dark gray points indicate no red snapper were seen on video and red points indicate red snapper were seen on video. Note that red points were overlaid on top of gray points, and points may overlap.

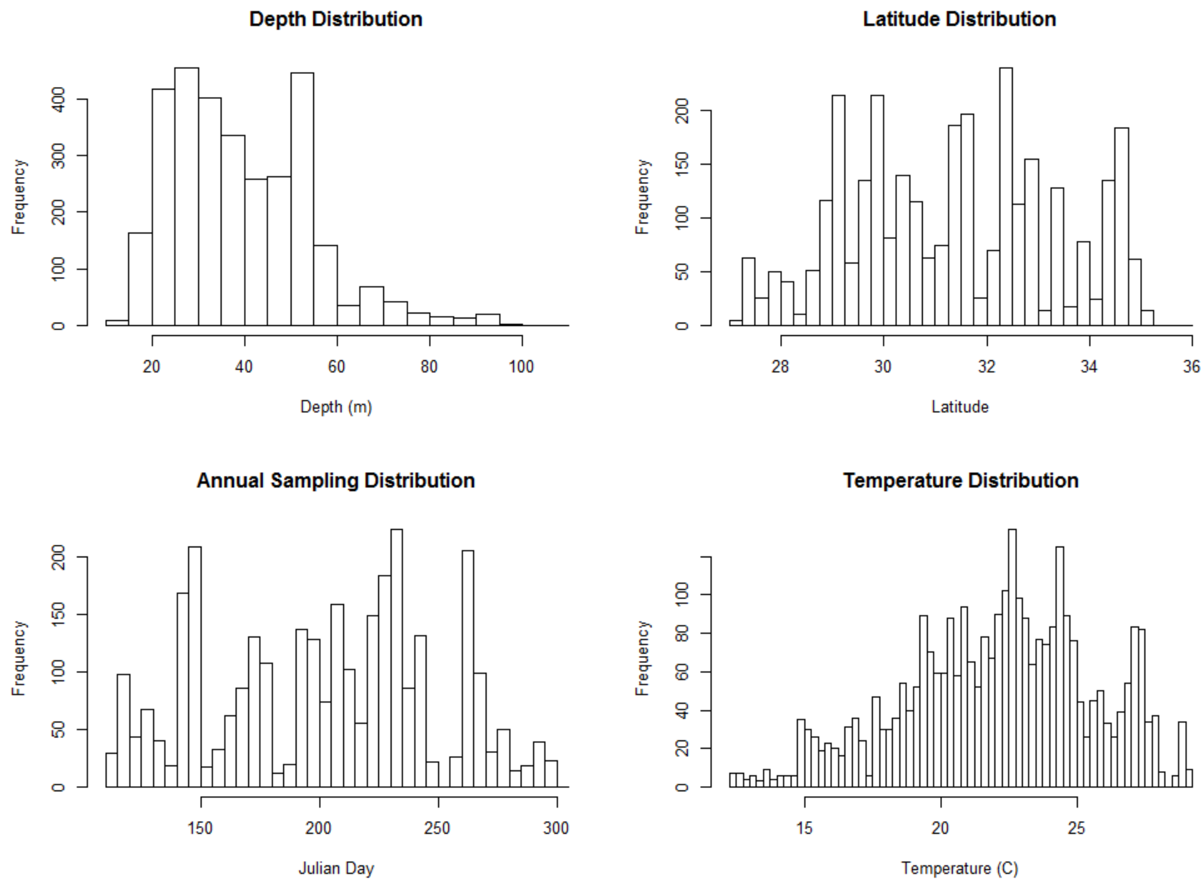

Figure 3: Sample distribution for the original data continuous variables.

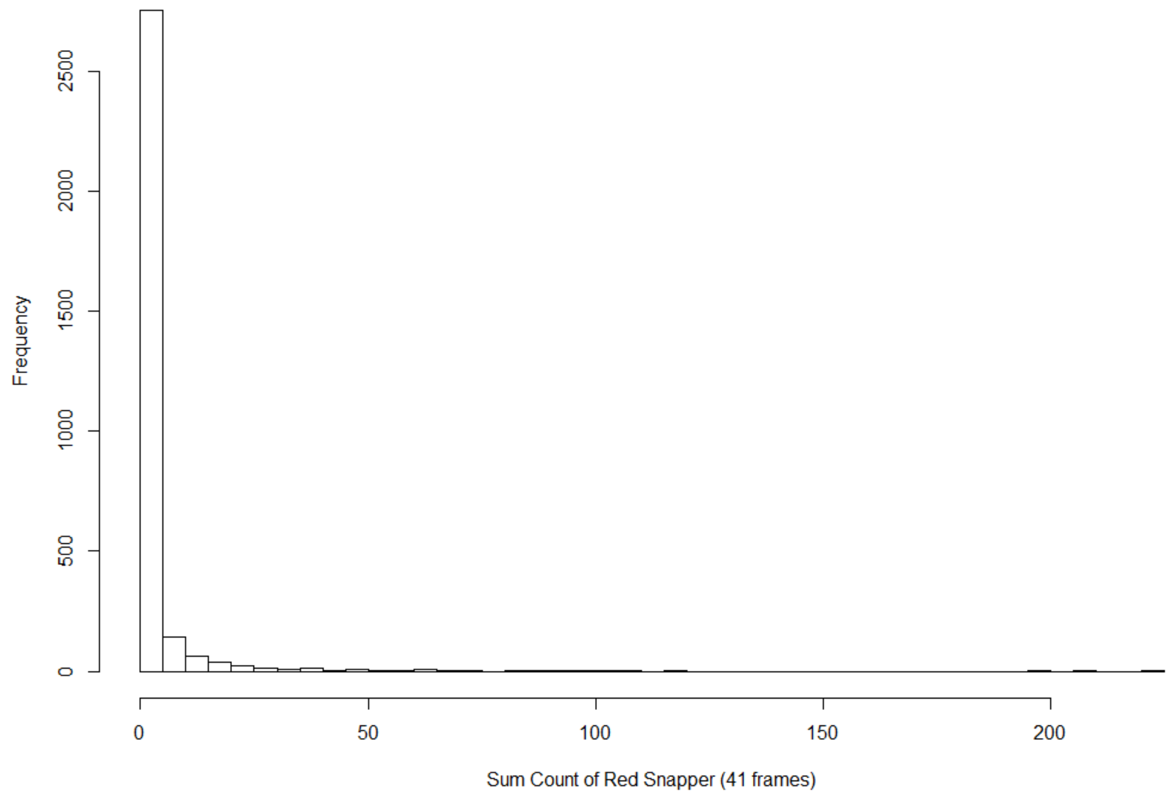

Figure 4: SumCount distribution for red snapper video observations in the South Atlantic.

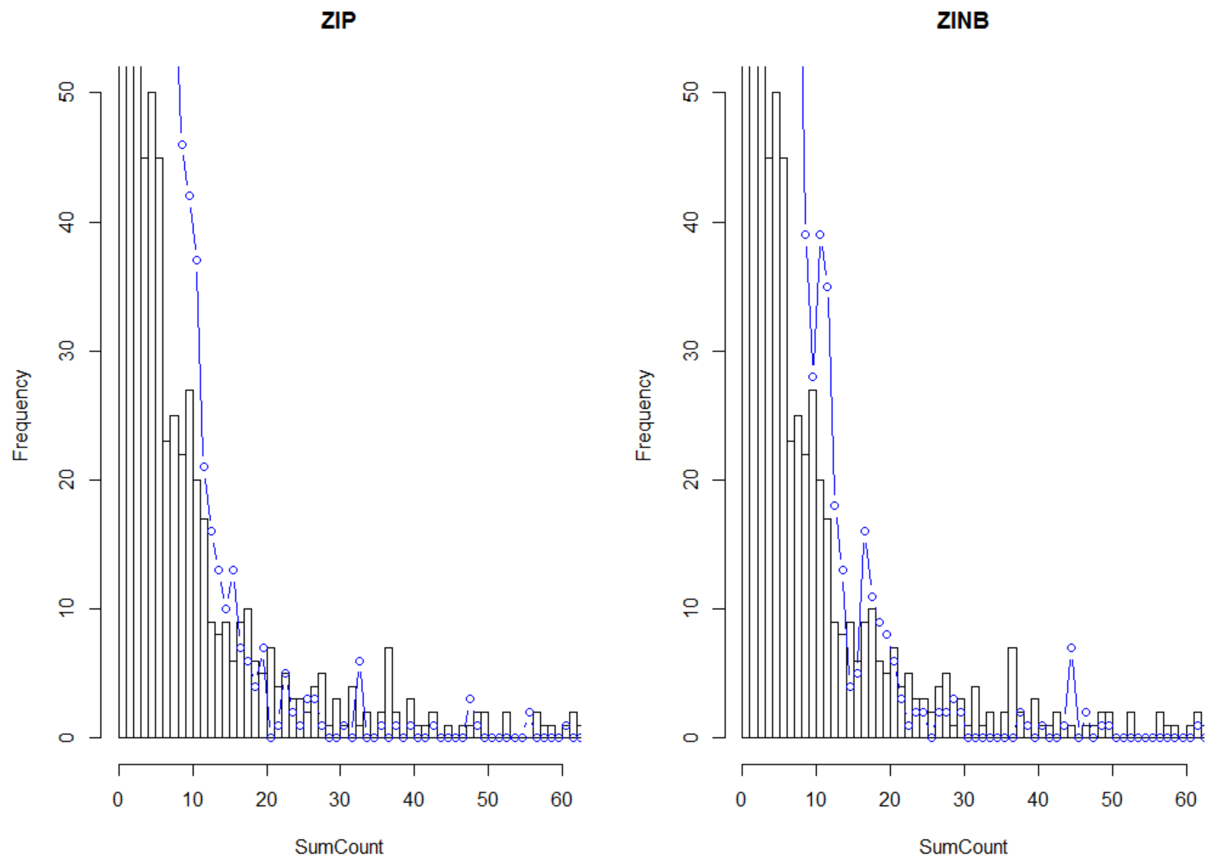

Figure 3: Model formulation comparison, with ZIP (left) and ZINB (right) fitted values plotted against the original data distribution

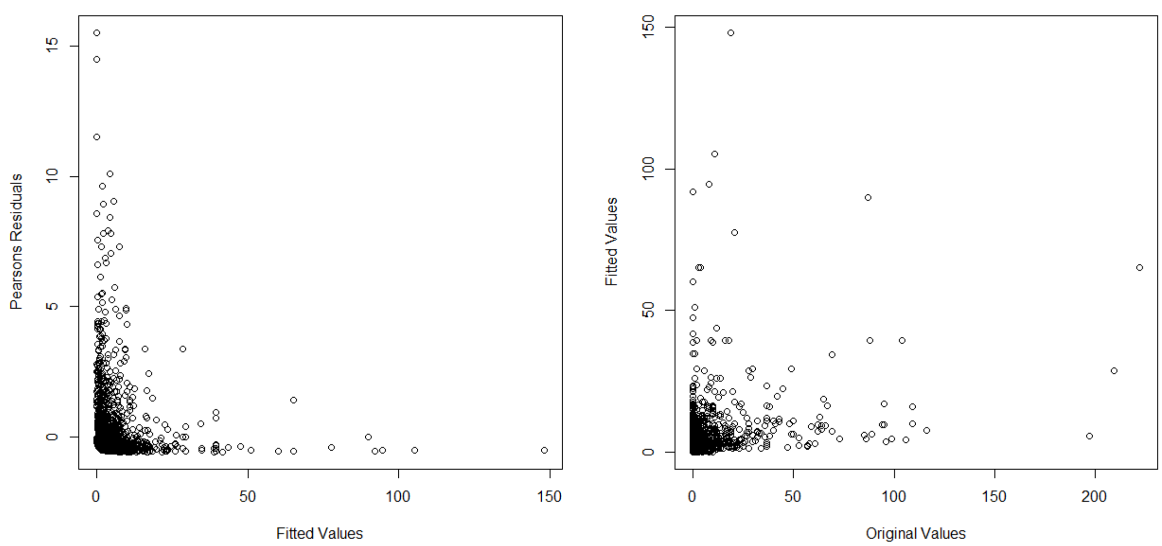

Figure 4: Model diagnostic plots showing fitted model values against Pearson's residuals (left) and fitted values plotted against original data values (right)

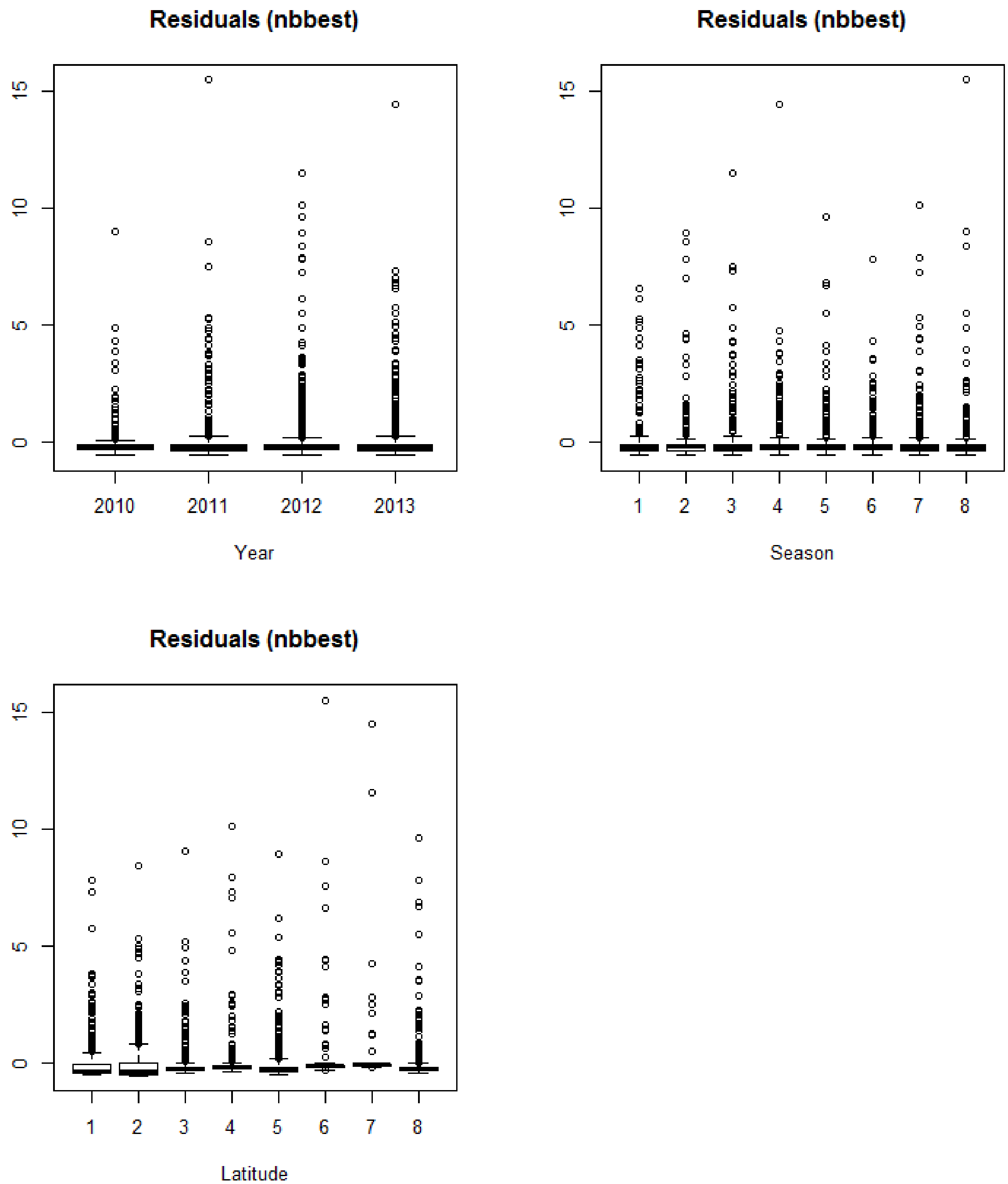

Figure 5: Model diagnostic plots showing Pearson's residuals from the final model plotted against both the temporal and spatial model variables

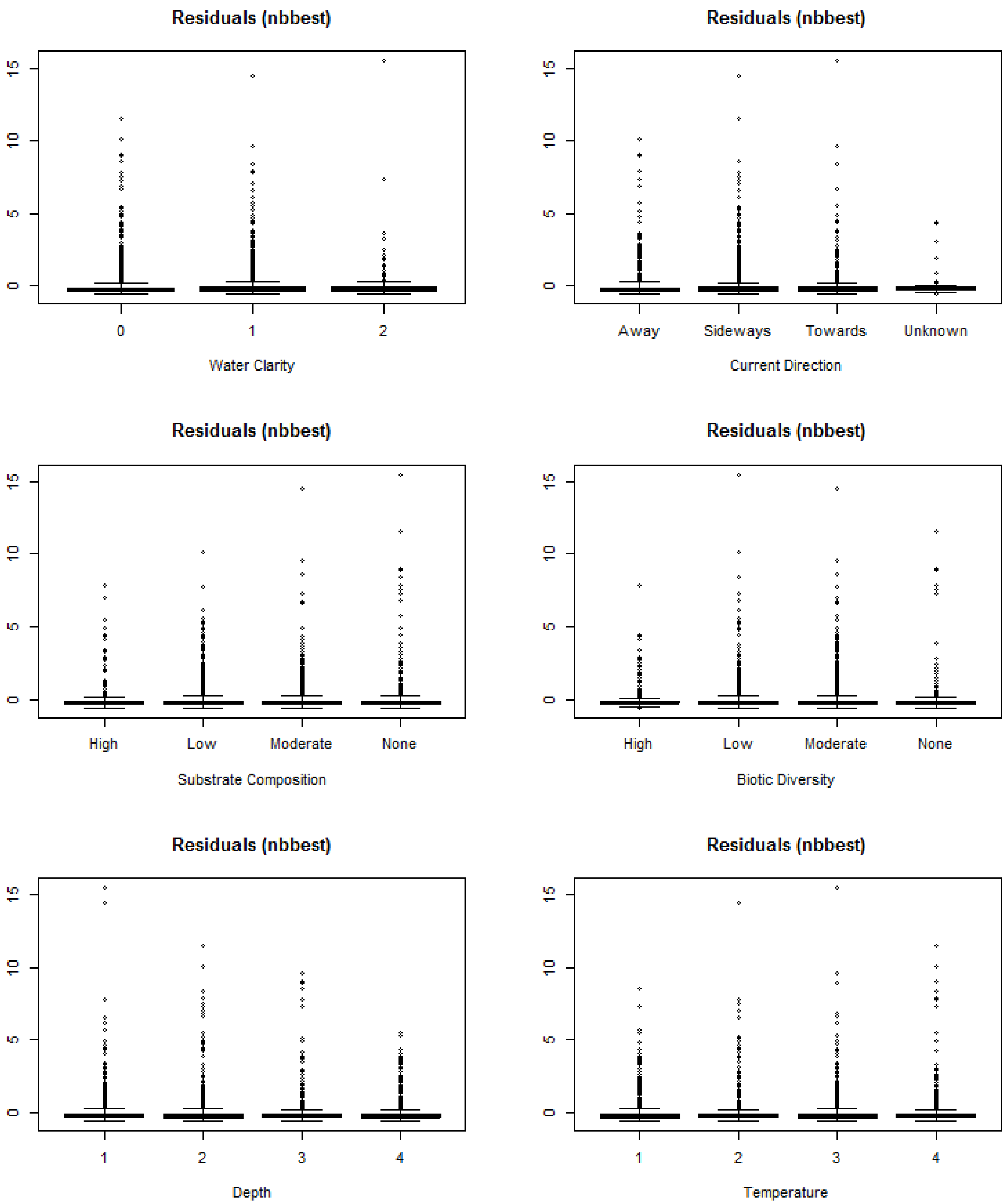

Figure 6: Model diagnostic plots showing Pearson's residuals for the final model plotted against environmental model parameters

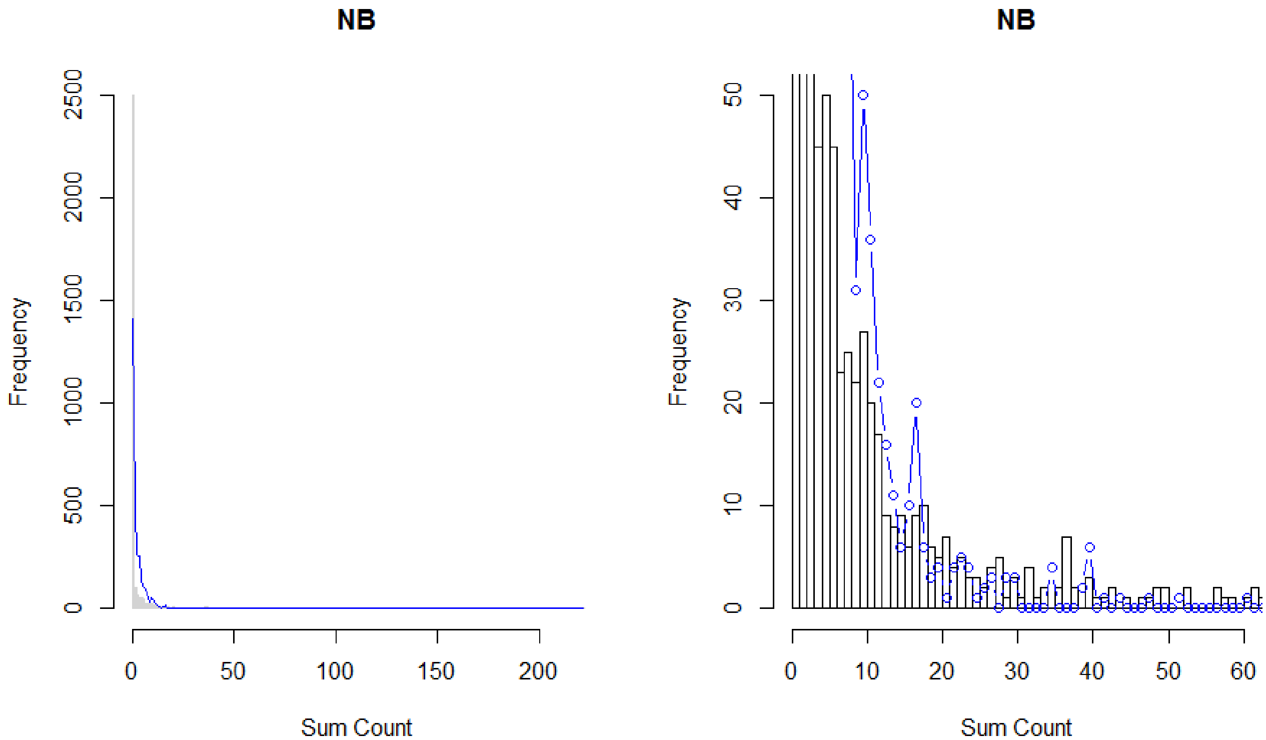

Figure 7: Model diagnostic plots of fitted model values (blue line) against the original data distribution. Full distribution view (left) and limited x-axis view (right)

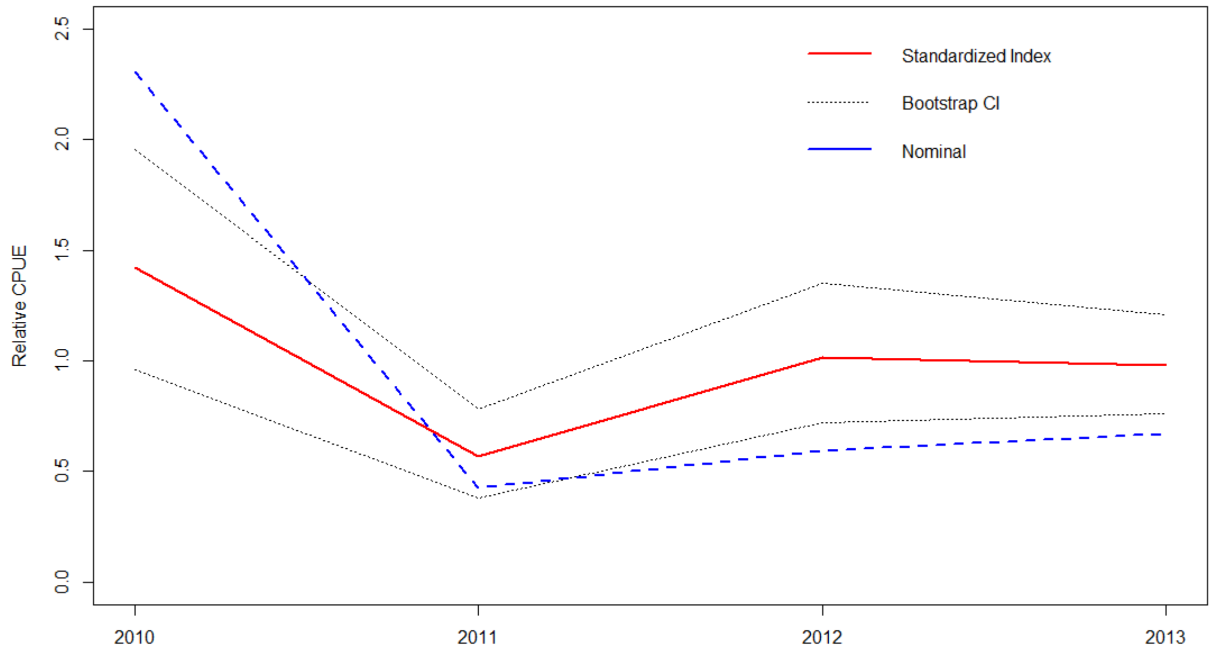

Figure 8: Relative standardized index (solid line) with 2.5% and 97.5% confidence intervals (dashed lines) and the relative nominal index (blue) for red snapper CPUE in the SERFS video survey