Construction of a headboat index for south Atlantic and Gulf black grouper

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Background

The headboat fishery is sampled separately from other recreational fisheries, and includes an area ranging from North Carolina to the Florida keys on the Atlantic coast and from the dry Tortugas to southeast Texas on the Gulf coast (Figure 1). The headboat fishery comprises large, for-hire vessels that charge a fee per angler and typically accommodate 6–60 passengers. With simple hook & line gear, passengers on these vessels frequently target hard bottom reefs, sampling many members of the snapper-grouper complex. Headboat records were examined in detail, and catch-per-unit-effort (CPUE) standardization was employed in an effort to generate a fishery dependent index.

Black grouper are primarily caught off of the coast of southern Florida (Table 1). All analyses were thus restricted to headboat sampling strata 11, 12, 17, and 21.

Possible confounding factors

Prior to analysis, data were examined in an effort to identify possible factors that might confound inferences about relative abundance.

For recreational fisheries in the south Atlantic, the relevant regulatory history proceeds as follows:

December 12, 1986 – State of Florida institutes a 5 grouper aggregate bag limit
January 1, 1992 – Federal regulations stipulate a 5 grouper aggregate bag limit; black grouper 20 inch size limit.
February 2, 1999 – Federal regulations dictate that no more than 2 members of the 5 grouper bag limit may be black or gag grouper; black grouper 24 inch TL size limit.

BAG LIMIT CHANGES

In SEDAR-19-DW-03, I investigated the aggregate bag limit by calculating the percentage of headboat trips where anglers caught 5 or more grouper, and contrasted this percentage before and after regulations were implemented. It was assumed that anglers would continue fishing until the boat's limit was reached (i.e., 5 groupers * number of anglers). Included in the list of grouper species were black grouper, gag, speckled hind, snowy grouper, golden tilefish, red grouper, scamp, blueline tilefish, Warsaw grouper, yellowfin grouper, and yellowmouth grouper. The number of trips meeting or exceeding the bag limit was less than 1%.

To examine the black and gag limitations that began on February 2, 1999, I used the same approach. In no year was the proportion of trips meeting the bag limit greater than 0.003, nor did there appear to be an effect of regulations on this proportion (Fig. 2). Accordingly, I assumed that bag limits had negligible effects of headboat CPUE for black grouper.

SIZE LIMITS

The lead analyst suggested keeping the index time series intact in the face of increasing minimum size limits because decreases in CPUE associated with such changes can be accounted for with different selectivity curves. However, headboat length compositions should be examined prior to using headboat indices for simpler models (e.g., surplus production, stock reduction, etc.). In particular, if smaller fish are commonly retained prior to implementation of a size limit, one would expect CPUE to decrease after the size limit is employed. If this is the case, analysts should consider either not using or splitting the headboat index into multiple time series for analysis with simpler models.

Subsetting

Effective effort was based on those trips from areas where black grouper were available to be caught. Without fine-scale geographic information on fishing location, trips to be included in the analysis must be inferred. To do so, the method of Stephens and MacCall (2004) was applied. The method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. To avoid numerical computation errors, we limited the number of species in each analysis to those occurring in 5% or more of trips (Table 2). A backwards stepwise AIC procedure (Venables and Ripley 1997) was then used to perform further selection among possible species as predictor variables, where the most general model included all listed species as main effects. In this procedure, a generalized linear model with Bernoulli response was used to relate presence/absence of red grouper in headboat trips to presence/absence of other species. This approach eliminated lane snapper and gray triggerfish from the list of predictor variables. Species specific regression coefficients are presented in Figure 3.

A trip was then included if its associated probability of catching black grouper was higher than a threshold probability (Figure 4). The threshold was defined to be that which results in the same number of predicted and observed positive trips, as suggested by Stephens and MacCall (2004). After applying Stephens and MacCall (2004) and the constraints described above, the resulting subsetted data set contained 11,057 trips (4.6% of trips), of which ~20% were positive.

Explanatory variables

TRIP TYPE – Trips were originally grouped according to whether they were half day, three quarters, full day, or multi-day trips. It was assumed that half day trips fished for 5 hours, three quarters day trips fished for 7 hours, full day trips fished for 9 hours, and multi-day trips fished for 12 hours/day. Consistent with previous south Atlantic SEDARs (e.g. SEDAR 2008), multi-day trips were combined with full day trips and three quarters day trips were combined with half day trips as factor variables in the standardization process, while the original number of hours was retained for effort determinations. Nominal CPUE appeared to be higher for full and multi-day trips (0.0027 fish per angler-hour; SE 0.0002) than for half and three-quarters day trips

(0.0017 fish per angler hour; SE 0.0001), suggesting trip type influences CPUE and thus should be included in the standardization process.

NUMBER OF ANGLERS

Based on subsetted data, most trips had fewer than 50 passengers (mean 25.5, median 23). Nominal CPUE appeared to decrease as a function of the number of anglers (Figure 5). As effort was summarized by angler-hours, the number of anglers was not independent of CPUE and thus I was reluctant to include it as a possible predictor variable in standardization. However, if headboat captain's behavior changes (e.g., fishing locations) as a function of the number of anglers (e.g., revenue to buy fuel, etc.), it may be an important variable to consider. As a compromise, I considered 4 discrete categories for the number of anglers as factors in the standardization process, corresponding to quartiles of the distribution of number of anglers. In particular, the following levels were considered: (1) 14 or fewer anglers, (2) 15-23 anglers, (3) 24-33 anglers, and (4) 34-133 anglers.

VESSEL

After subsetting data, there were 116 unique vessels that undertook trips likely to have caught red grouper. These ranged from 16 vessels that undertook only one trip to one vessel that contributed 1,604 trips. There was a large range of values among vessels for nominal CPUE and percent of positive trips (Figure 6), part of which is due to the large number of low sample sizes.

YEAR

Following data subsetting, the number of records ranged from 47 in 1978 to 649 in 1993. Nominal CPUE and the percent of positive observations largely mirrored each other, showing minima in the late 1970s, throughout the 1990s, and again in the terminal year (2008). Relative maxima occurred in the early to mid 1980s and again around 2005 (Figure 7). Note that sampling did not start in the Gulf of Mexico (including area 21) until 1986.

MONTH

The number of subset trips, nominal CPUE, and percent of trips catching black grouper varied considerably by month (Figure 8). All three were lower in the summer months than winter months.

Standardization

Prior to analysis, all vessels with fewer than 10 trips likely to have caught black grouper (that is, fewer than 10 subsetted trip) were eliminated to reduce dimensionality and better standardize effort. This reduced the total trips considered from 11,057 to 10,869, and reduced the number of unique vessels from 116 to 62. For the trips remaining, I modeled CPUE using the delta-glm approach (cf., Lo et al. 1992; Dick 2004; Maunder and Punt 2004). In particular, I compared fits of lognormal, gamma, and inverse-Gaussian models for positive CPUE, and examined which combination of predictor variables best explained CPUE patterns (both for positive CPUE and 0/1 CPUE). All analyses were performed in the R programming language, with code adapted from Dick (2004).

POSITIVE CPUE SUBMODEL

As with analysis of red grouper CPUE (SEDAR-19-DW-03), generalized linear model (GLM) fits to positive CPUE data indicated extreme underprediction of high CPUE values using standard model choices (e.g., lognormal, gamma). Also like the red grouper analysis, an analysis with $CPUE^{-1.0}$ eliminated this problem to a large degree. With $CPUE^{-1.0}$ as the dependent variable, a gamma model performed much better than a lognormal (ΔAIC=233) or inverse Gaussian (ΔAIC=3723) model, and was selected for all subsequent analysis.

To determine predictor variables important for predicting positive CPUE, I started by fitting a model with all main effects. I then compared reduced models by removing each predictor successively to see if there were variables that could be removed without degrading the explanatory power of the model. All variables proved to be important predictors of either positive CPUE, 0/1 CPUE, or both (Table 3) and were thus retained in analysis. All predictor variables were modeled as fixed effects (and as factors rather than continuous variables). Standard model diagnostics (Figures 9-12) appeared reasonable, and were conducted with randomized quantile residuals (Dunn and Smyth 1996).

BERNOULLI SUBMODEL

The other component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching black grouper on a particular trip. The same approach was taken as for the positive GLM. There did not appear to be any recognizable patterns in randomized quantile residuals for this submodel (Figures 13-15).

Extracting effects and interpreting the index

Population marginal means (Searle et al. 1980) were used to extract predictions for the year factor. A bias correction was also employed to account for the transformation of the response variable from ($CPUE^{-1.0}$) to CPUE space as follows: (a) a large number of prediction in ($CPUE^{-1.0}$) space were generated for year *y* with a gamma error structure and a dispersion parameter obtained from the GLM, (b) these predictions were back-transformed into (CPUE) space, and (c) the mean value of the back transformed predictions was taken to be the index value for year *y*. These machinations correctly account for computation of the expected value of the prediction in CPUE space, where simple back-transformations of the mean trend in ($CPUE^{-1.0}$) space would not. Jackknife estimates of variance were computed using the ‘leave one out’ estimator (Dick 2004) and also included this bias correction.

Results

Index values are presented in Table 4, and depicted visually in Figure 16.

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Tables

Table 1. Number of headboat trips reporting catch of black grouper, 1978-2008 by sampling strata. Areas 11, 12, 17, and 21 are all in south Florida and make up 91.5% of all reported positive trips.

Strata	# Pos Trips	Percent
3	3	0.02
4	6	0.05
5	4	0.03
6	2	0.02
7	11	0.08
8	103	0.79
11	1042	7.94
12	7538	57.46
13	18	0.14
17	944	7.20
18	37	0.28
21	2482	18.92
22	125	0.95
23	365	2.78
24	149	1.14
25	166	1.27
26	97	0.74
27	26	0.20

Table 2. Species (common name) included in logistic regressions for Stevens and MacCall (2004) method. Species were included if they appeared in the catch records of 5% or more of headboat trips in southern Florida.

- Bigeye
- Blue runner
- Black sea bass
- Bluestriped grunt
- Gag
- Gray snapper
- Gray triggerfish
- Great barracuda
- Jolthead porgy
- King mackerel
- Knobbed porgy
- Lane snapper
- Little tunny
- Littlehead porgy
- Mutton snapper
- Red grouper
- Tomtate
- Vermilion snapper
- Yellowtail snapper
- White grunt

Table 3. Results of AIC model selection to determine the appropriate level of predictor variables in model structure for delta-GLM standardization. The effect of removing a variable from model structure is shown in terms of ΔAIC, the difference in AIC score from the highest ranked model. This is done both for a) the positive CPUE GLM, and b) the 0/1 GLM.

	GLM type	
Model structure	Positive CPUE GLM	0/1 GLM
full	0.7	0.0
-month	67.9	10.4
-vessel	1025.1	707.8
-type	37.6	119.5
-anglers	0.0	676.4

Table 4. Standardized and nominal CPUE indices for black grouper from the headboat data. A CV was calculated using the leave-one-out jackknife estimator implemented by Dick (2004).

Year	Delta-GLM	CV	Nominal
1978	0.97	0.71	0.26
1979	1.66	0.42	0.60
1980	1.47	0.33	0.87
1981	1.32	0.32	0.83
1982	1.55	0.30	1.61
1983	1.76	0.32	2.72
1984	1.05	0.31	1.16
1985	1.28	0.30	1.17
1986	0.85	0.32	0.62
1987	1.35	0.31	1.52
1988	0.48	0.34	0.53
1989	0.78	0.32	0.92
1990	0.57	0.35	0.45
1991	0.68	0.35	0.52
1992	0.83	0.30	0.58
1993	0.55	0.30	0.55
1994	0.78	0.29	0.83
1995	0.97	0.30	1.55
1996	0.82	0.28	0.84
1997	0.53	0.31	0.68
1998	0.63	0.32	0.88
1999	0.44	0.35	0.69
2000	0.39	0.37	0.49
2001	0.41	0.30	0.75
2002	0.59	0.33	1.01
2003	0.52	0.33	1.64
2004	1.00	0.35	2.08
2005	2.97	0.31	2.24
2006	1.26	0.31	0.97
2007	1.90	0.31	1.00
2008	0.64	0.36	0.43

Figures

Figure 1. Spatial sampling strata from the headboat survey off the southeast U.S. Spatial strata 11, 12, 17, and 21 were considered as likely to have caught black grouper and were included in CPUE standardization.

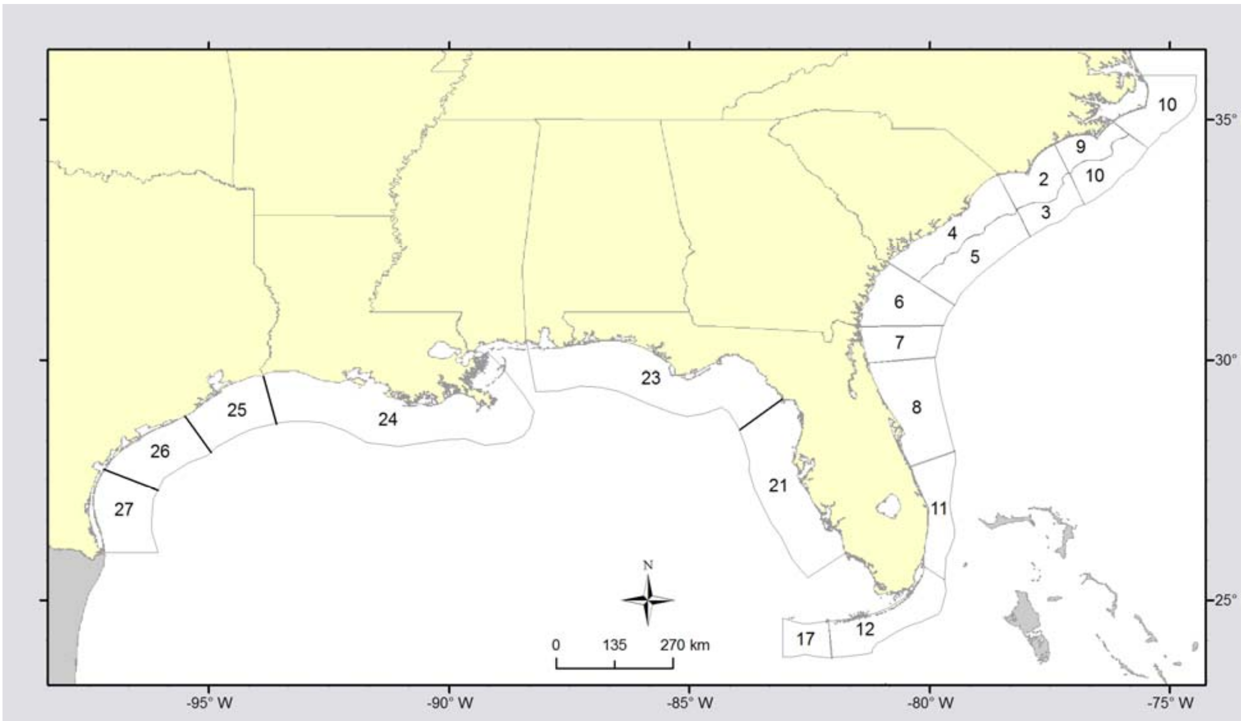


Figure 2. Proportion of headboat trips in southern Florida resulting in two or more black or gag groupers per angler as a function of year.

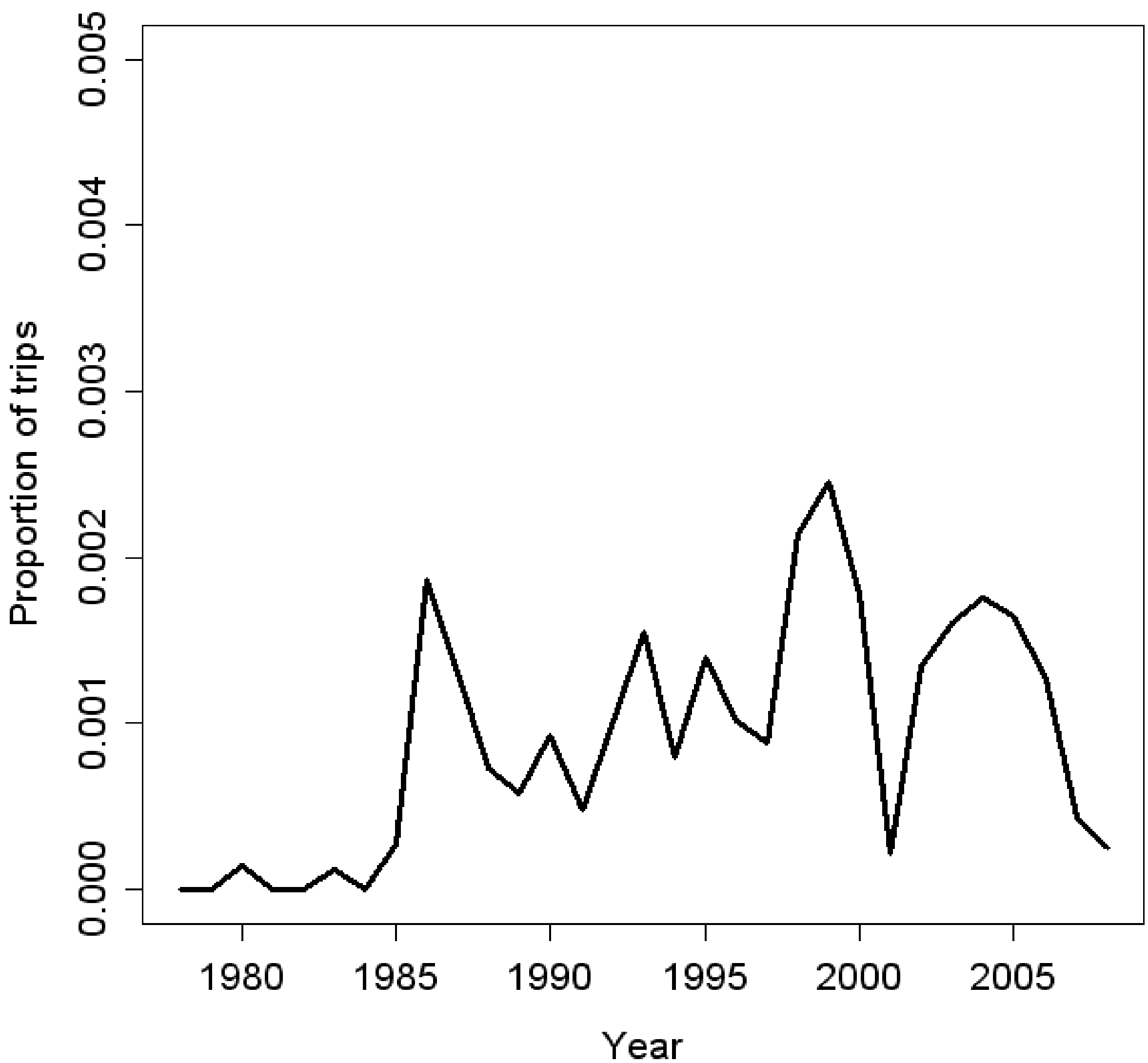


Figure 3. Estimates of species-specific regression coefficients from Stephens and MacCall method applied to headboat data, as used to estimate each trip's probability of catching the focal species.

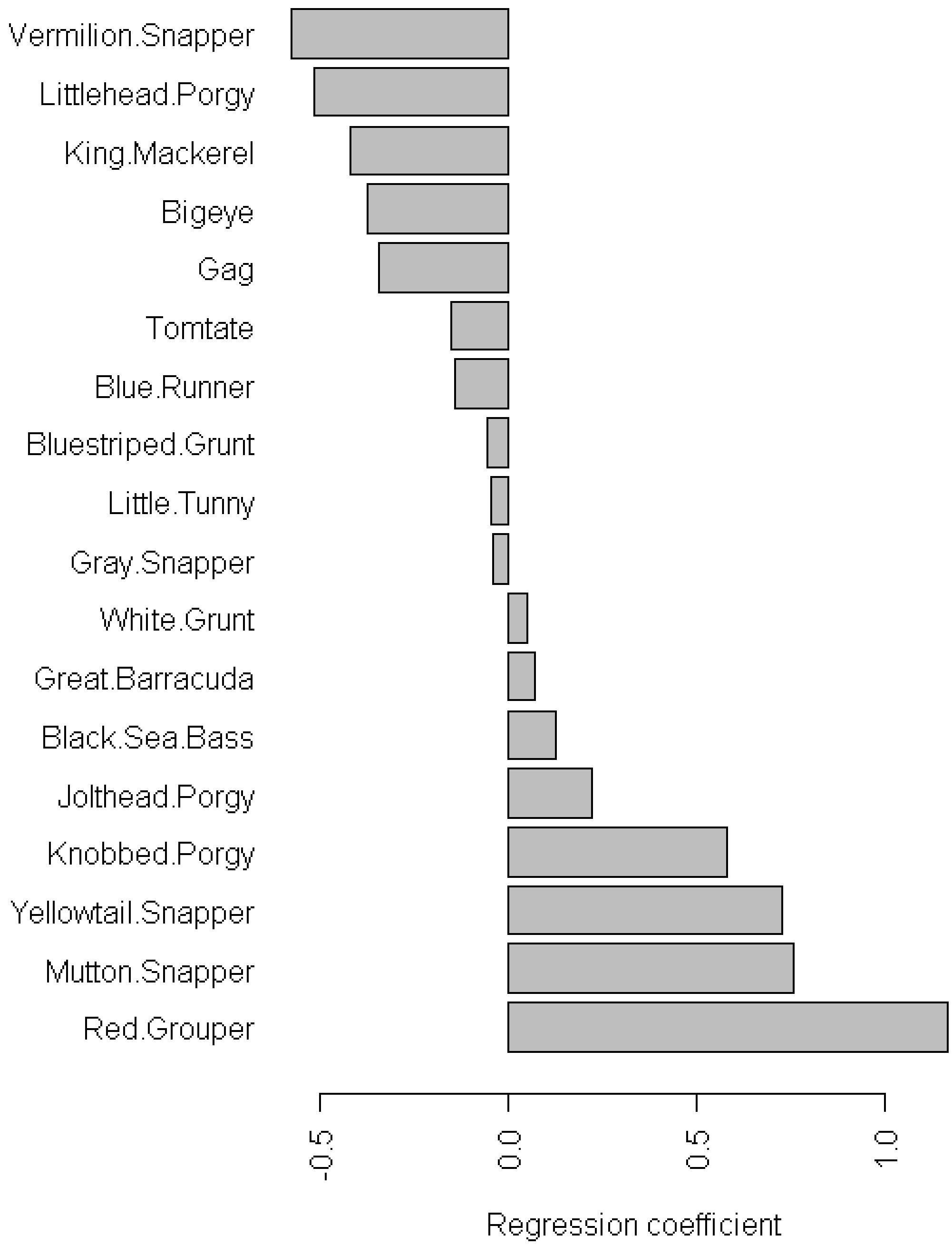


Figure 4. Absolute difference between observed and predicted number of positive trips from Stephens and MacCall method applied to headboat data southern Florida. Left and right panels differ only in the range of probabilities shown.

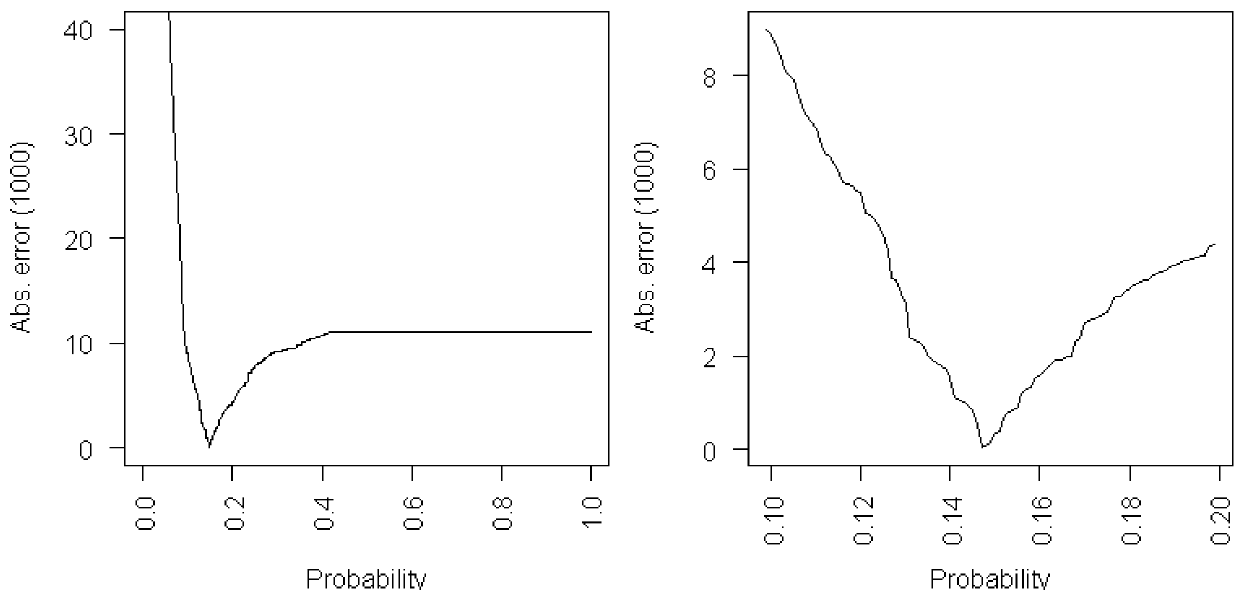
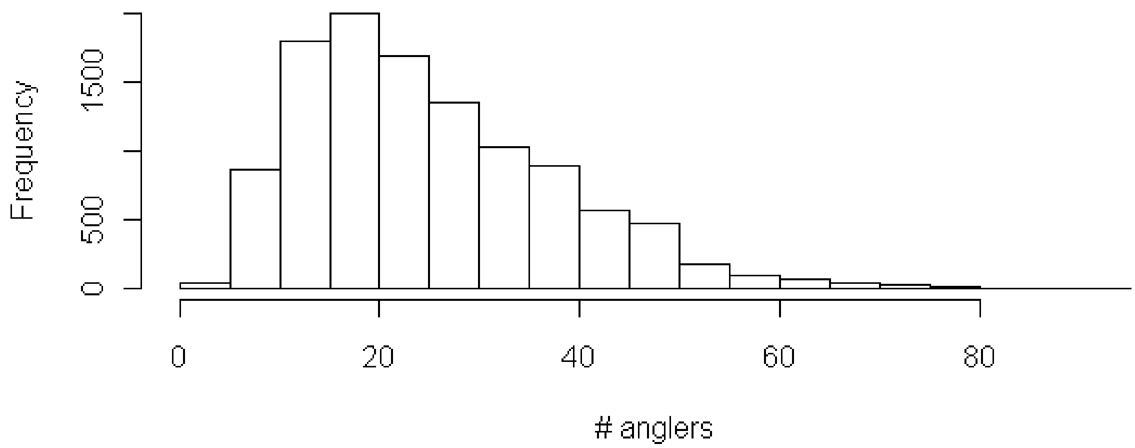


Figure 5. Number of anglers per trip and nominal CPUE for headboat trips likely to have caught black grouper (i.e., from trips selected by application of the Stephens-MacCall method).



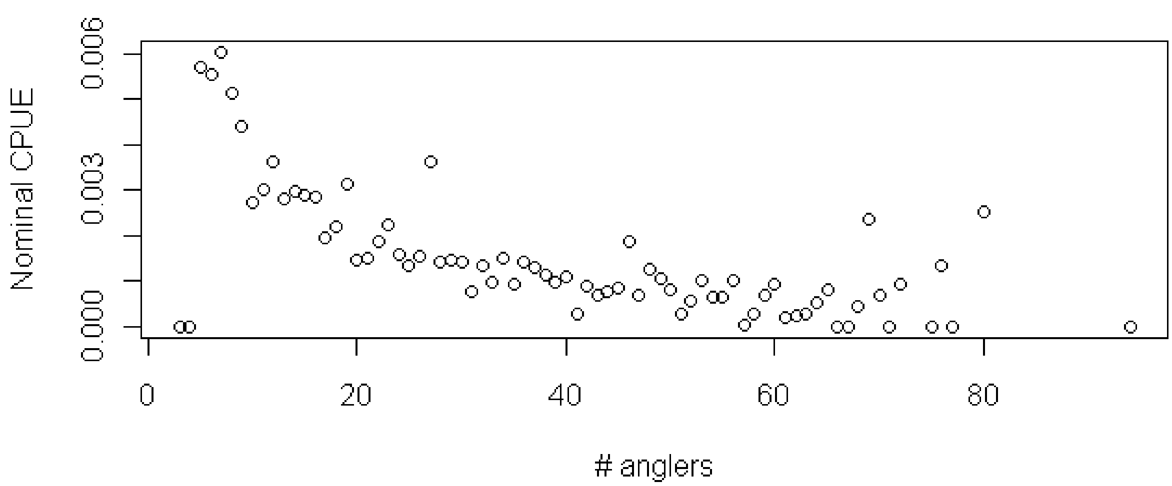
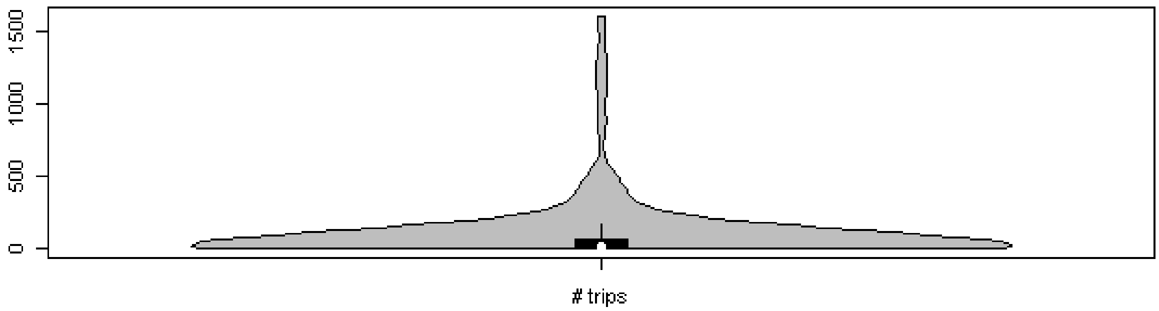
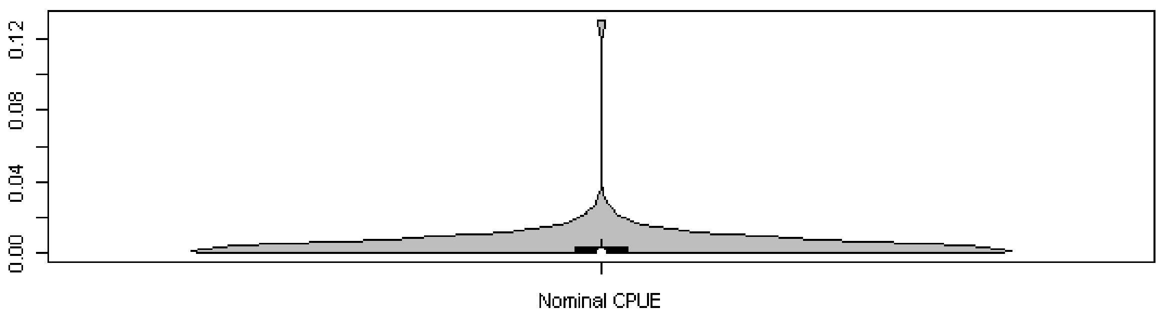


Figure 6. Violin plots giving the distribution of sample sizes (# trips), nominal CPUE, and % of positive observations for different vessels. The violin plot combines a traditional box-whisker plot with a kernel density estimate (essentially a smoothed histogram). Results are only summarized for trips selected as being likely to have caught black grouper using the method of Stephens and MacCall (2004).





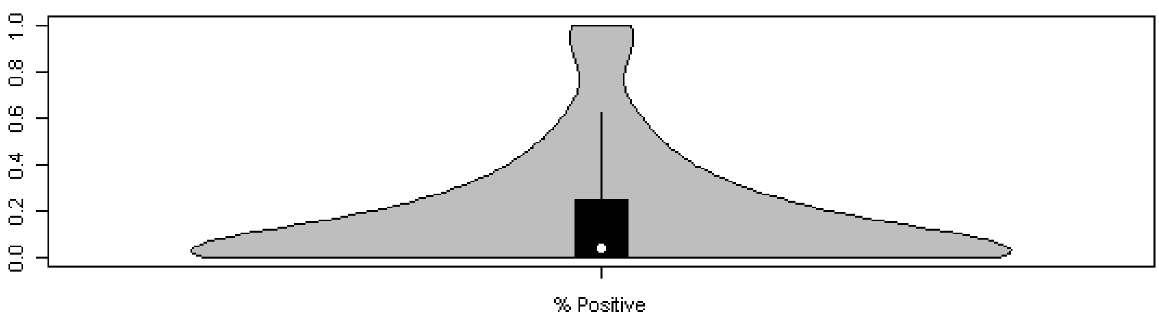


Figure 7. Sample sizes, nominal CPUE, and % of positive observations by year for trips selected by the method of Stephens and MacCall (2004).

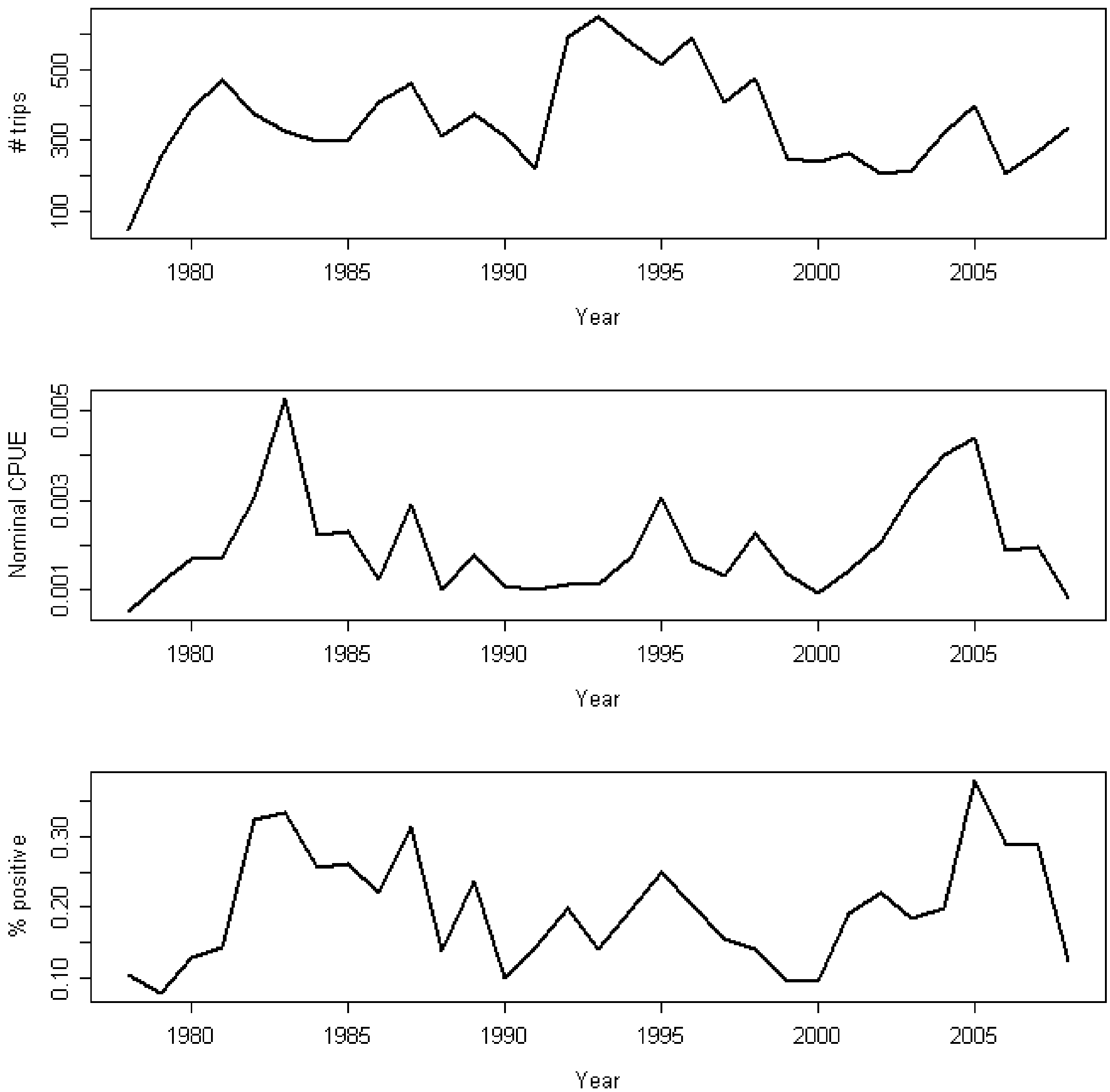


Figure 8. Sample sizes, nominal CPUE, and % of positive observations by month for trips selected by the method of Stephens and MacCall (2004).

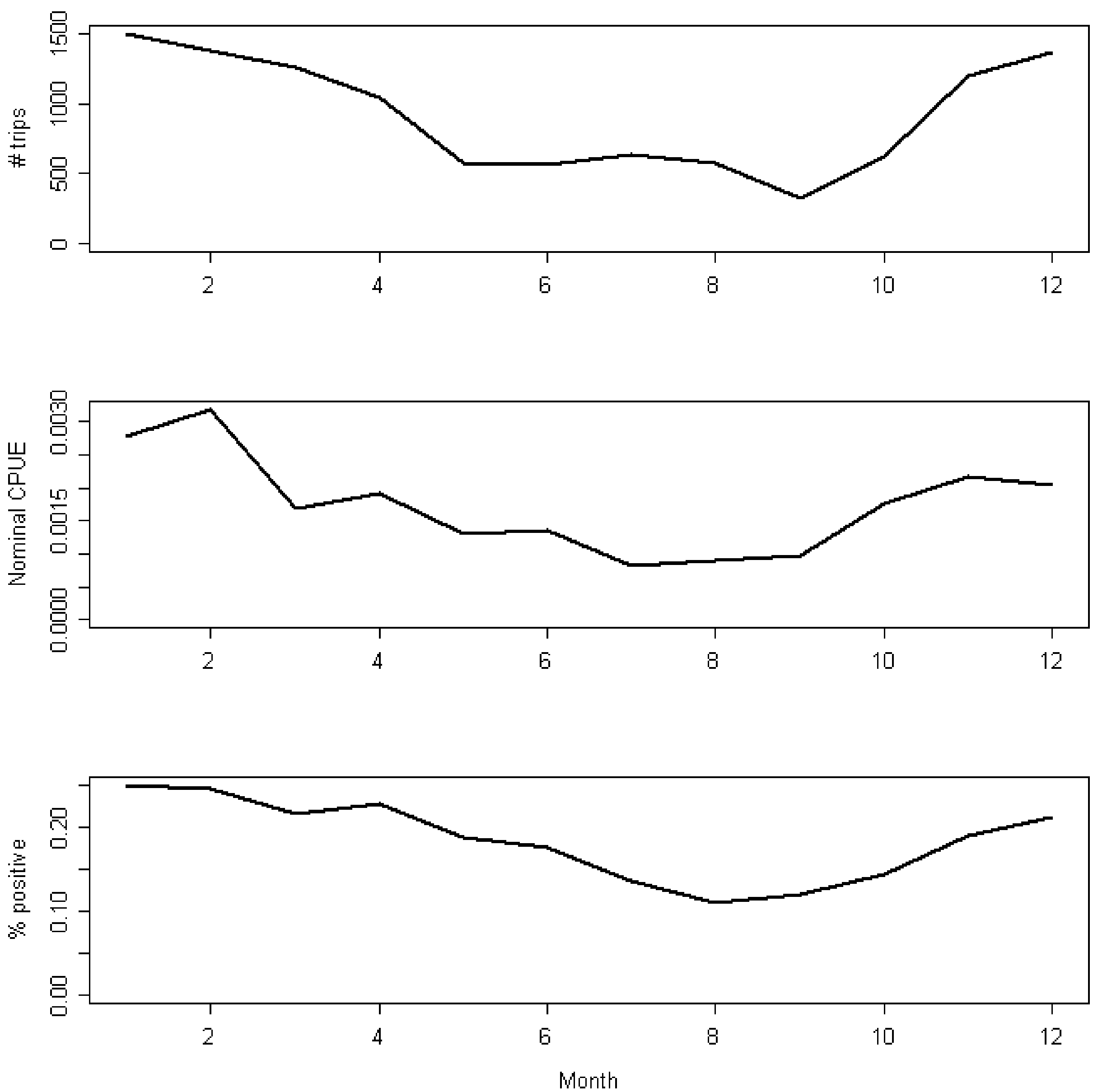


Figure 9. Standard diagnostics for the gamma GLM for positive black grouper headboat CPUE data. There is slight overprediction at higher levels of the dependent variables, but residual variance appears to be constant across the range of fitted values and divergence from gamma quantiles appears minimal.

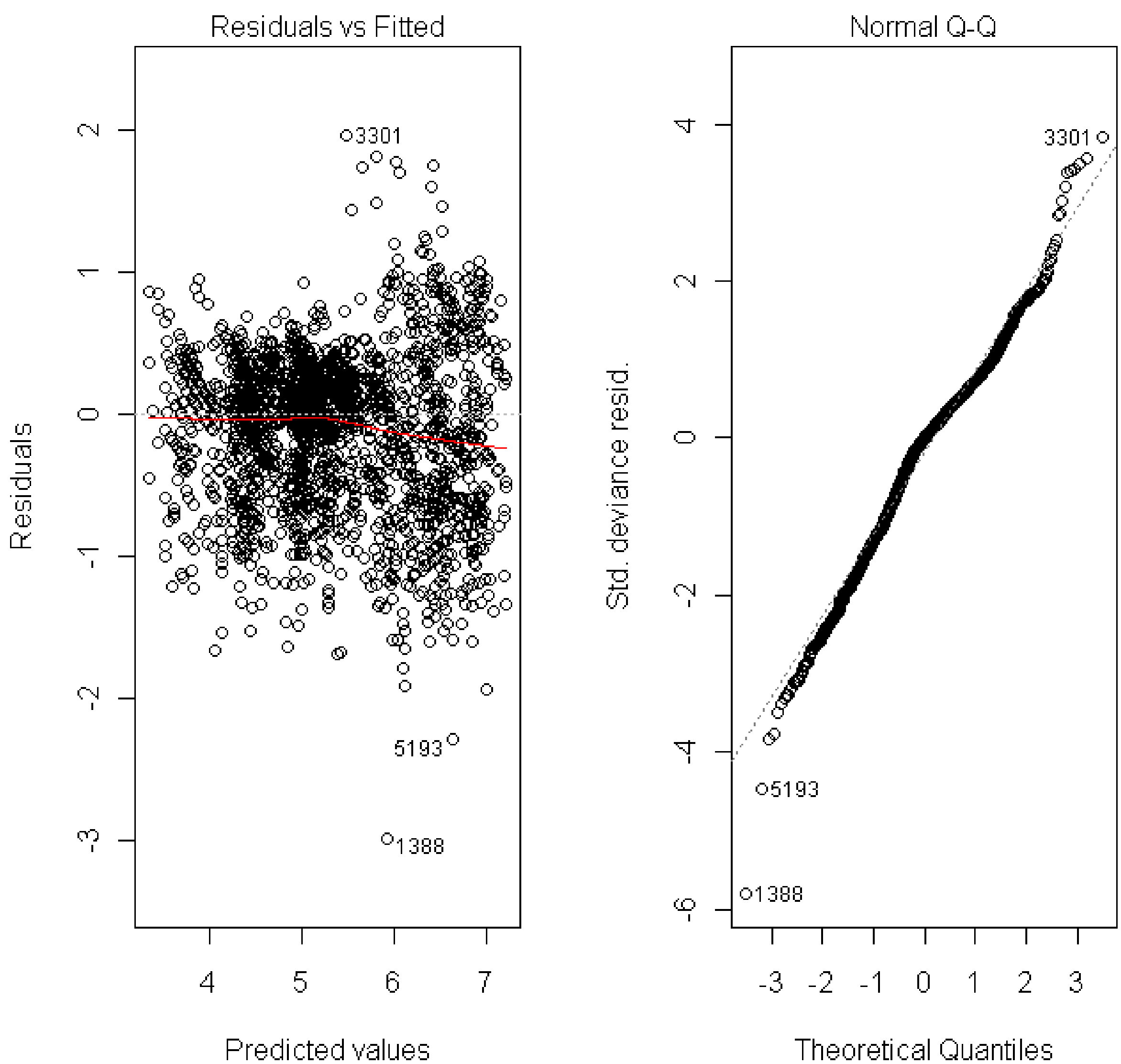


Figure 10. A plot of randomized quantile residuals by predictor variable in the selected model for positive red grouper CPUE from the headboat survey. Box-and-whisker plots give median values instead of mean values.

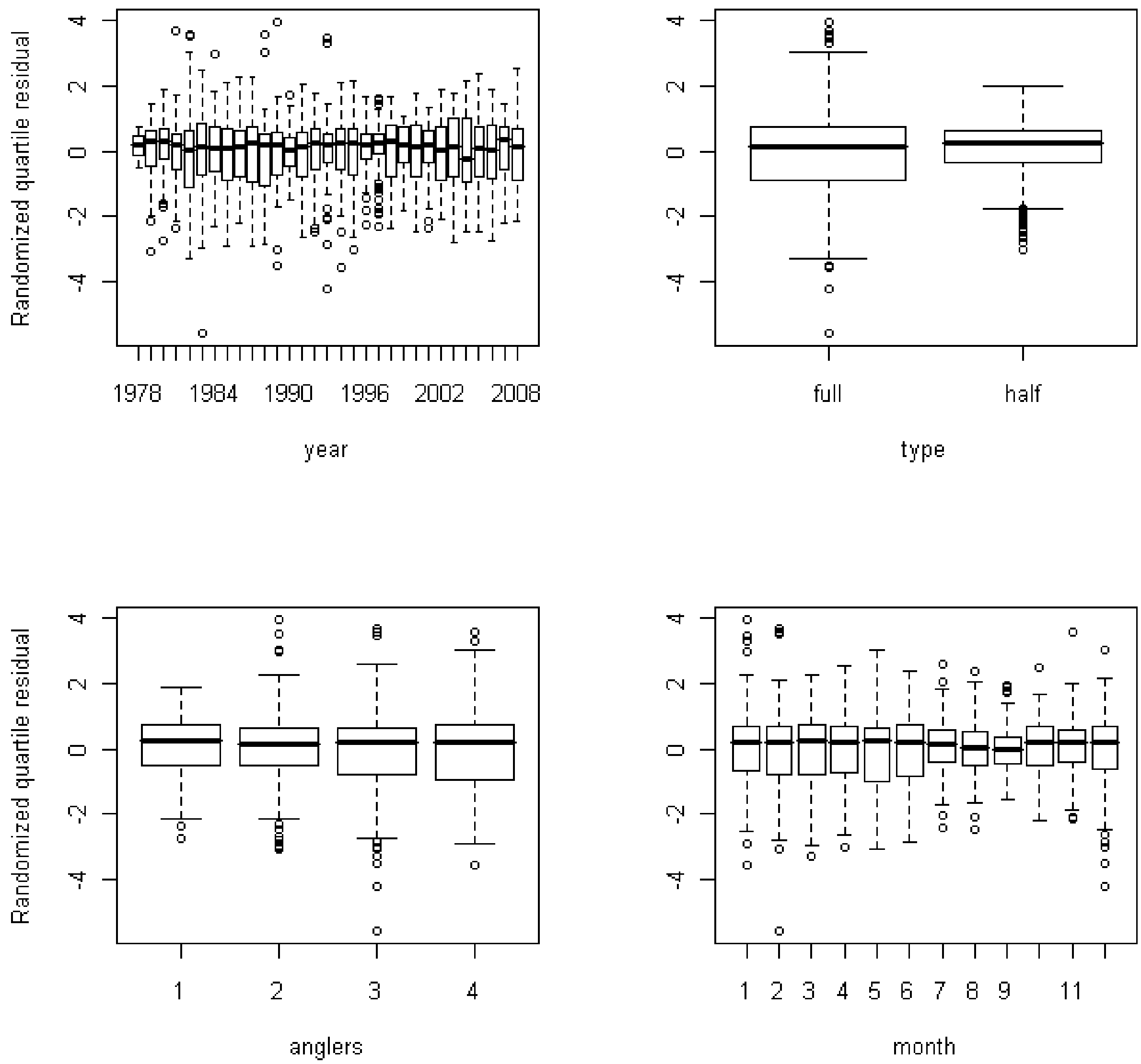


Figure 11. A plot of randomized quartile residuals by vessel in the selected model for positive black grouper CPUE from the headboat survey.

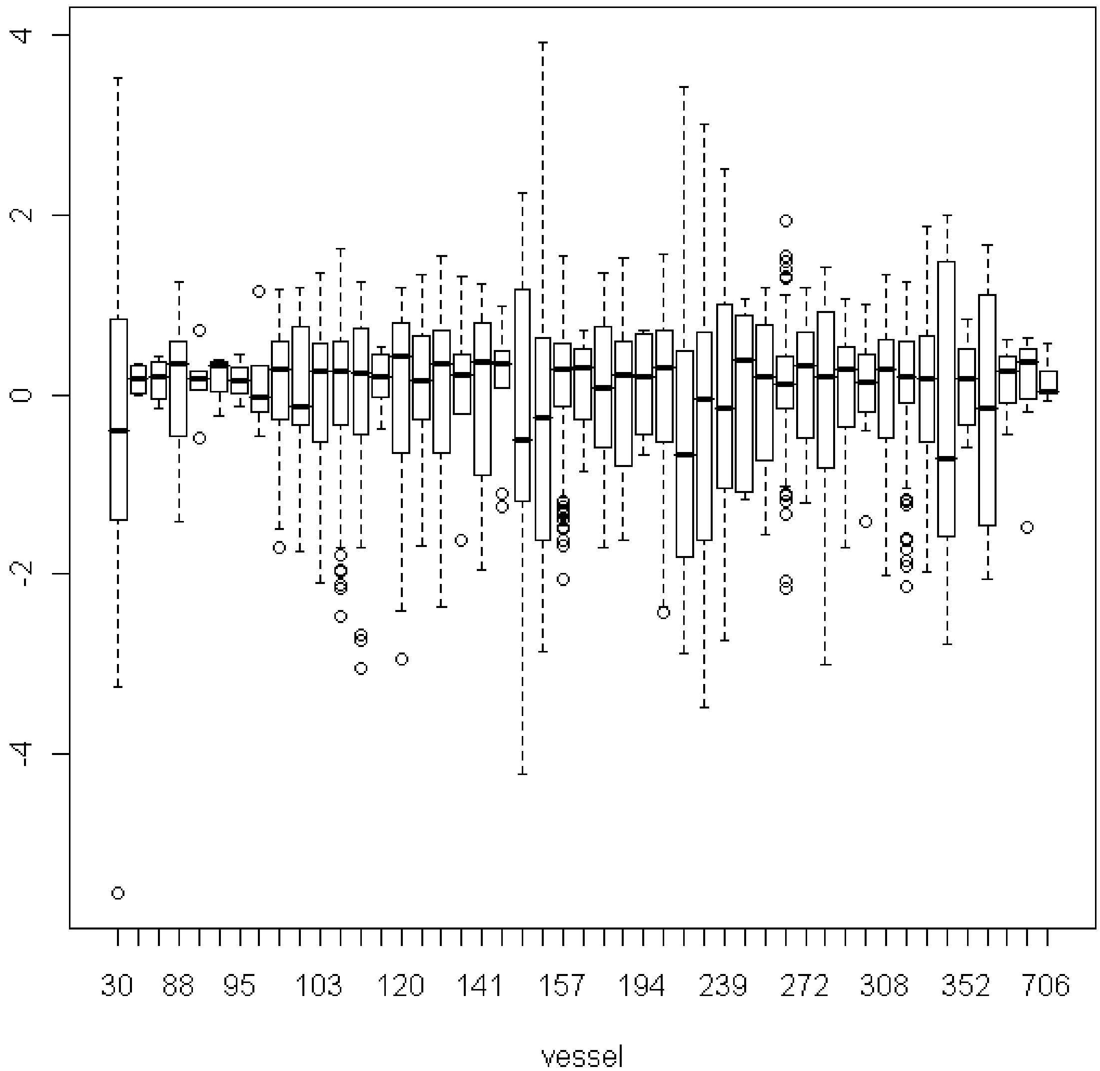


Figure 12. Observed (histogram) versus predicted (kernel density estimate; dark line) CPUE for the headboat survey for positive trips from the selected gamma GLM model. The GLM model was fit to 1/CPUE so this fit is also supplied for reference.

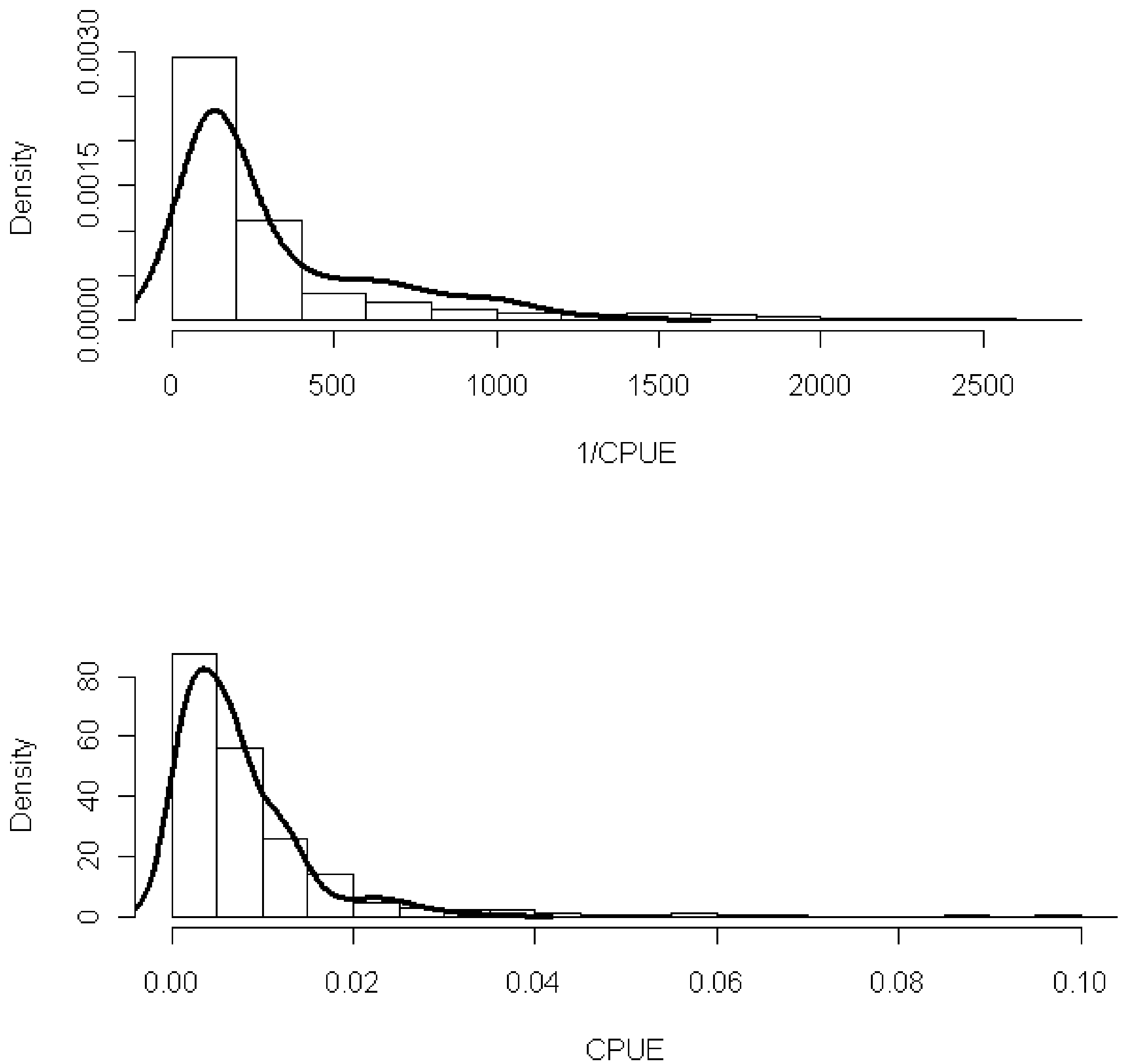


Figure 13. Standard diagnostics for the logistic regression model for black grouper headboat 0/1 CPUE data. Randomized quantile residuals appear to have zero mean across predicted values.

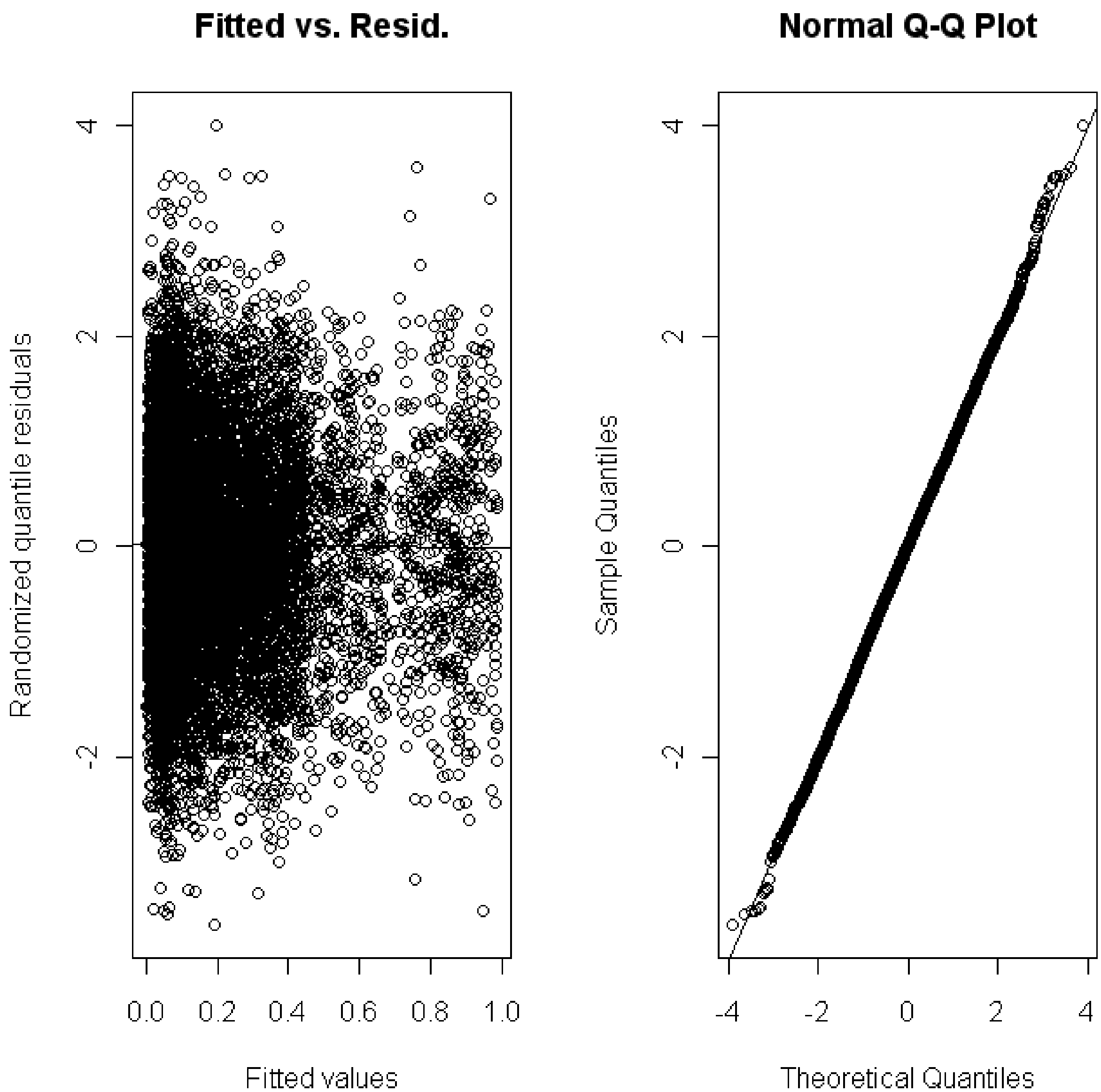


Figure 14. A plot of randomized quantile residuals by predictor variable in the selected model for 0/1 black grouper CPUE from the headboat survey. Box-and-whisker plots give median values instead of mean values.

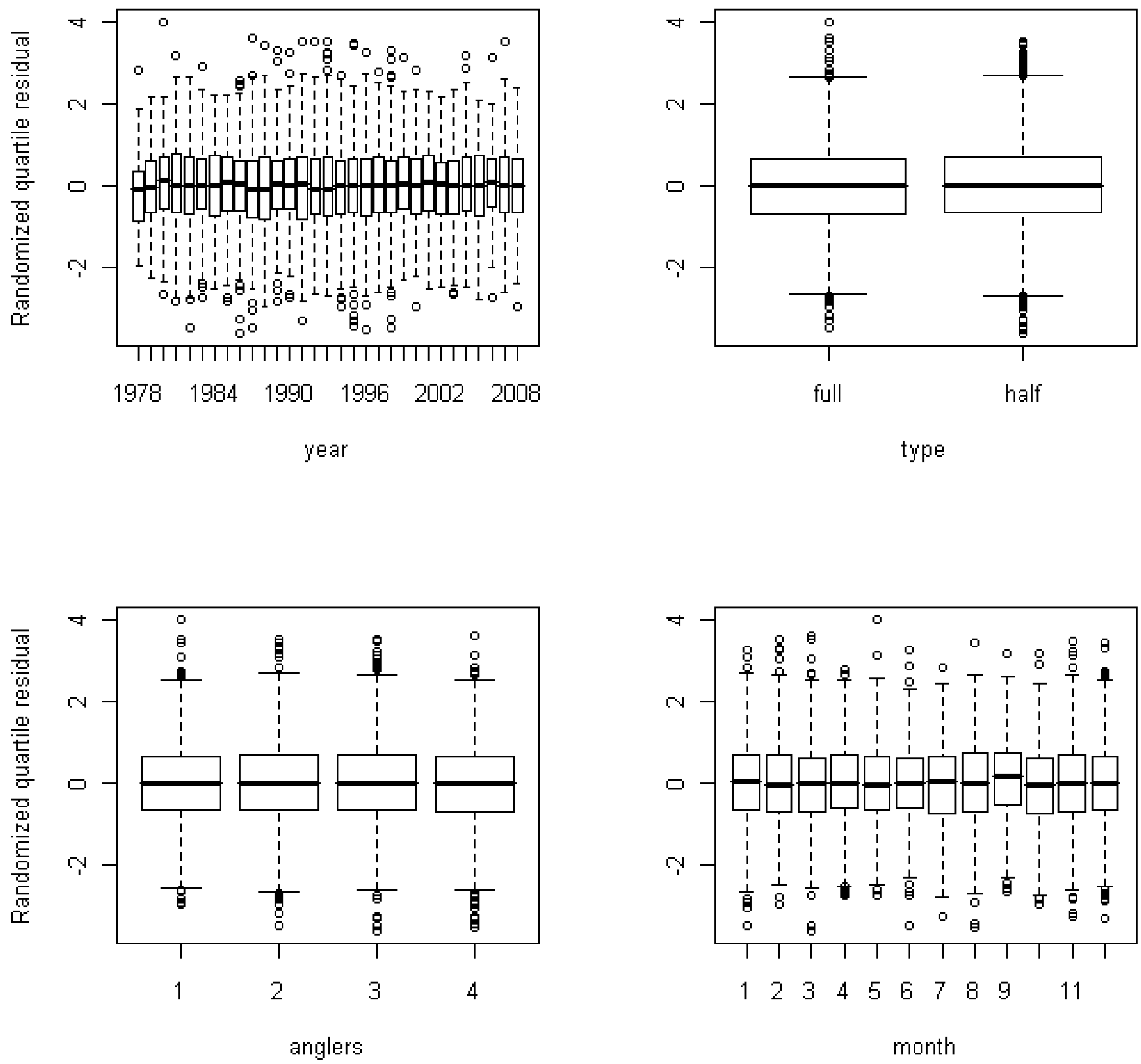


Figure 15. A plot of randomized quantile residuals by vessel for the black grouper 0/1 CPUE model from the headboat survey.

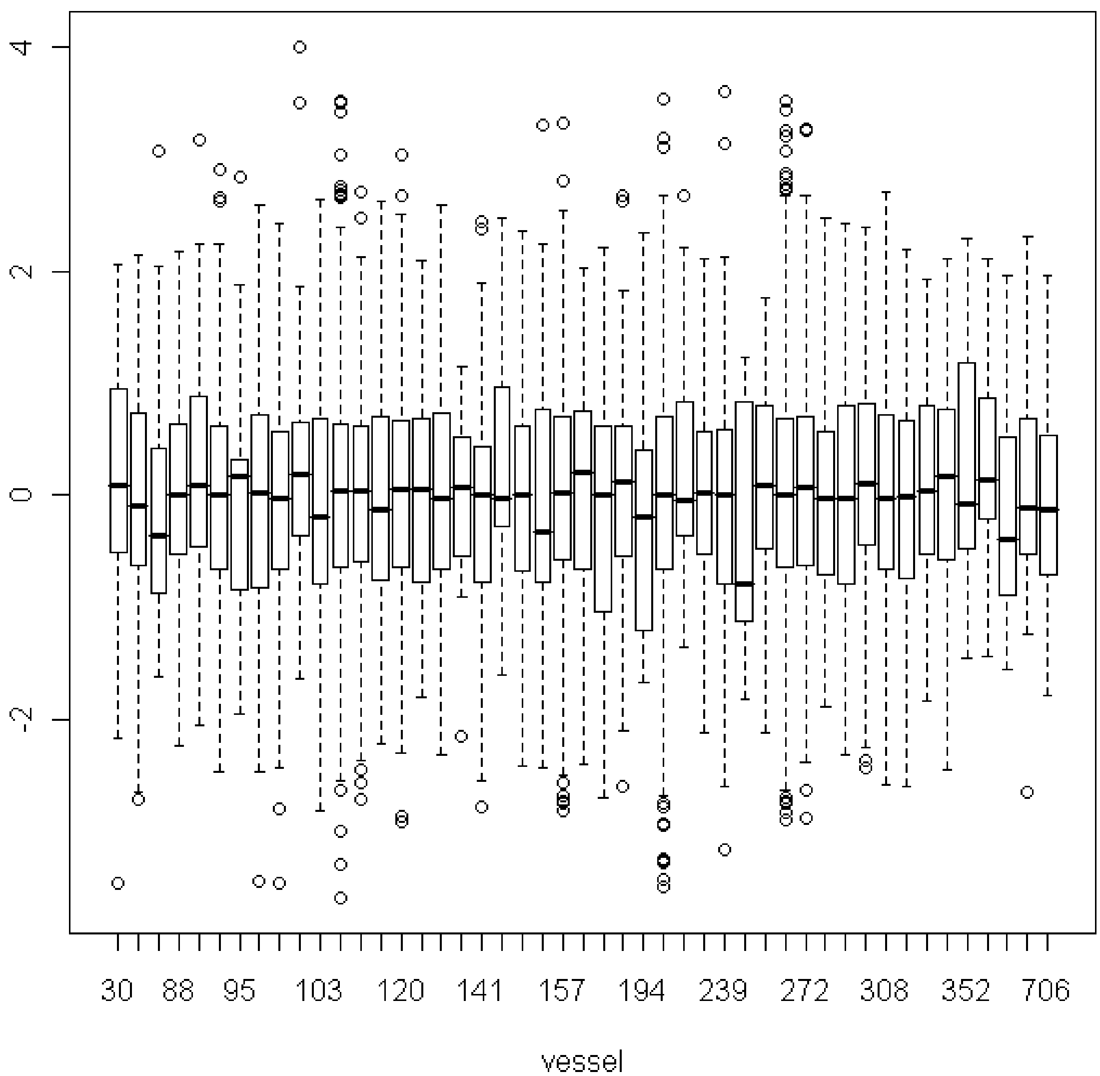


Figure 16. The standardized delta-GLM index for black grouper. Black circles and error bars (+/- 1 SE) represent values from the standardized index. Also presented for reference is nominal CPUE for those trips selected by the method of Stephens and MacCall (2004; red dashed line).