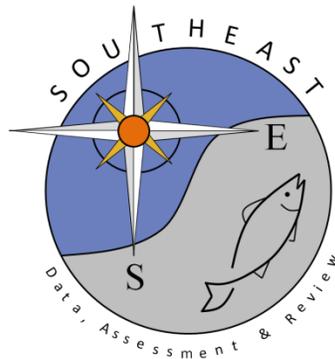


Standardized catch rates of red grouper (*Epinephelus morio*) from the Southeast U.S. from headboat logbook data

Sustainable Fisheries Branch – NMFS (contact: Rob Cheshire)

SEDAR53-WP02

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Standardized catch rates of red grouper (*Epinephelus morio*) in the southeast U.S. from headboat logbook data

*Sustainable Fisheries Branch**

August 2016

This document describes the the development of the SEDAR 53 headboat index for red grouper.

General EDA - Headboat effort

The effort patterns for the carolinas (CAR) and Georgia-North Florida (GNF) are fairly constant over time with most trips either being half- or full-day. The majority of trips in South Florida (SF) are half-day trips. The dip in the number of trips from the mid-1990s until the late 2000s in SF is attributed more to reporting than changes in effort (Figure 1). The positive red grouper trips are shown in figure 2.

Data Exclusions

1. Outlier removal

Extreme values occur more frequently in self-reported data because there are limited methods for validating data. Recent SEDAR stock assessments have removed values at the extreme upper tail of distribution for cpue and associated fields for self-reported fishery-dependent data. We excluded trips with the largest 0.5% values for catch in number (> 26) and cpue (> 0.167) for trips that caught red grouper. The number of anglers on a trip can also influence cpue when calculated as fish/angler-hour. Trips with the largest 0.5% values for reported anglers (> 108) were removed. Figure 3 shows the excluded cpue of excluded trips based on outlier definitions by region. Removing a small percentage of the trips with extreme values for variables used to calculate CPUE is an unbiased method to correct for potential errors in self-reported data.

2. Cutoff for number of trips per vessel and number of anglers

Logbooks submitted by vessels that participated infrequently in the fishery are likely to be less accurate and may add noise to the data. Even if a vessel fished infrequently for one year, the number of trips should be greater than 30. We removed vessels that had fewer than 30 trips in the logbook database. It is rare for a headboat to fish with few anglers. There is anecdotal information that headboats would sometimes fish with just the crew and that logbooks for these trips were submitted. Experienced crew are likely to be more efficient at catching fish than paying customers. Captains may also limit distance to reduce fuel costs for trips with few paying customers. Trips with 6 or fewer anglers were excluded.

3. Starting year

For SEDAR 19 the starting year for the headboat index was 1978. The headboat program increased it's range to south Florida by 1978 but the reporting appears to be in the burn-in phase, especially for full-day trips, until 1980. The number of trips reported may not be important if the subsample is unbiased. However, it takes time for vessel captains and crew to develop consistent and accurate reporting skills. This may be

*National Marine Fisheries Service, Southeast Fisheries Science Center, 101 Pivers Island Rd, Beaufort, NC 28516

especially true for south Florida due to higher species diversity. The total number of reported trips in SF increases dramatically from 1978 - 1980 (Figure 1). The number of reported positive red grouper half-day trips in south Florida increases from 34 in 1978 to 601 in 1979 and then plateaus. The number of positive red grouper full-day trips are 47, 56, and 170 for 1978 - 1980 after which the value ranges from 200-250 for several years (Figure 2). The starting year for the headboat index was set to 1980 since south Florida contributes significantly to the positive red grouper trips.

4. Terminal year - spawning closure exclusion

The shallow-water grouper closure (Jan-Apr) took effect in 2010. Comparisons of the median cpue by region for all months and May-Dec shows little difference in median cpue across regions (Figure 4). Removing trips from these months allows us to extend the headboat logbook index until the terminal year of the assessment (2015). The peaks in the number of positive red grouper trips are similar between the seasonal closure and open months prior to the 2010 seasonal closure by region (Figure 5). 2015 was chosen as the terminal year with the removal of all trips from January to April across all years.

5. Trip types

For SEDAR 19, the relatively few multi-day trips were combined with full-day trips and the 3/4-day trips were combined with the half-day trips. Figure 6 shows the noisy positive red grouper median cpue associated with these trip types for the Carolinas (CAR) and Georgia-North Florida (GNF) while South Florida(SF) is fairly stable. It is difficult to determine the number of hours spent fishing on multi-day trips which can add noise to the cpue. Combining trip types with either small sample size or high uncertainty with the more reliable half and full-day trips increases the noise in cpue (Figure 7). There are relatively few positive red grouper trips across all areas for 3/4-, and multi-day trips. Multi-day and 3/4-day trips were removed from all areas. There were relatively few half-day positive red grouper trips in CAR and GNF. The half-day trips in these areas are likely fishing at shallower depths and may be associated with ontogenetic inshore-offshore movements for red grouper. Half-day trips were excluded for CAR and GNF. Half-day trips were retained for south Florida, assuming half-day trips can fish the same areas as a full-day trip due to the narrow shelf. Trip type was retained to calculate the CPUE unit of fish/angler-hour (where hour is defined by trip type), but was dropped as an explanatory variable. This has the added benefit of not using trip type both as a factor, and to calculate the response variable.

Nominal catch rates

Nominal catch rates of positive red grouper trips by year and region from the data as filtered for input into the Stephens and MacCall analysis are shown in figure 8.

Evaluation of explanatory variables

YEAR - Year was necessarily included, as standardized catch rates by year are the desired outcome. Years modeled were 1980-2015.

AREA - The areas modeled for the SEDAR 19 headboat logbook index were not changed for SEDAR 53. The three areas include the Carolinas (CAR), Georgia and North Florida (to Cape Canveral, FL), South Florida (South of Cape Canveral, FL). These areas were defined due to shelf characteristics and associated fishing behavior as well as species compositions.

SEASON - Month was used as the within-year factor for SEDAR 19. For SEDAR 53, a third of the months were dropped due to the spawning closure. The patterns in the remaining positive red grouper trips by month and region show few trips in the Carolinas for Nov and Dec. However, Nov and Dec have the most positive red grouper trips for South Florida (Figure 9). The seasonal pattern in cpue across months seems consistent

across areas with slightly higher values for Sep. - Dec. compared to May-Aug.(Figures 10 and 11). Season was chosen as the explanatory variable.

VESSEL SIZE (vsize) - For SEDAR 19, a factor was developed for the number of anglers using the quartiles of the number of anglers across all trips as breaks for the factors. Given the large range of vessel sizes, a trip with 20 anglers could be either almost full or almost empty. Here we develop a factor for vessel size and crowding separately using the number of anglers. The proxy for vessel size is the maximum anglers reported over all trips for a vessel (Figure 12). This was then divided into four factors based on visual inspection of the density plots into: 1. less than 30 maximum anglers (a.lt30), 2. 30-59 maximum anglers (b.30-59), 3. 60-89 maximum anglers (c.60-89), and 4. 90 or more maximum anglers (d.ge90),(Figure 13).

PERCENT FULL (pctfact) The number of anglers reported for a trip was divided by the maximum number of anglers for a vessel to obtain an estimate of crowding. This was then divided into 4 equally spaced factors; 1. less than 25% full (a.lt25), 25-49% full (b.25-49), 50-74% full (c.50-74), and 75% or more full(d.ge75). The density of percent full by area and the density of cpue associated with each factor are shown in figure 14.

Analytical decisions

1. Subsetting trips - Use Stephens and MacCall (2004) method
2. Species included in Stephens and MacCall approach: limit to snapper-grouper complex and remove species with full-year closures, ID issue, or large shifts in desirability over the index period
3. Apply Stephens and MacCall to Carolinas, Georgia-N.Florida, and S. Florida with Cape Canaveral, FL separating North and South Florida

Subsetting trips

Effective effort was based on those trips from areas where red grouper were available to be caught. Without fine-scale geographic information on fishing location, trips to be included in the analysis must be inferred, which was done here using the method of (Stephens and A. 2004). 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. The method was applied separately for the three regions considered due to species composition shifts. A zoogeographic boundary is apparent near Cape Canaveral (Shertzer, Williams, and J. 2009) which is the break between GNF and SF areas. Another break between the CAR and GNF areas was included to limit the influence of species at the edge of their range (e.g. scup in the North or yellowtail snapper to the South). To avoid undue influence of rare species on regression estimates, species included in each analysis were limited to those occurring in 4% or more of trips. A range of 1% to 5% was considered with 1% including too many species and 5% too few, especially in SF. However, the cutoff had little influence on the trips selected because the species with the highest probabilities (positive and negative) were always included. We limited the species to the snapper-grouper species that were on the headboat logbook forms across all years included in the index. The species listed on logbook forms for the entire period differed by region (Table 1). Species with management closures were also omitted because the potential for erroneously removing trips likely to have caught red grouper during years of restrictions (Table 2). Gray triggerfish is a species that was less desirable during the early part of the survey and therefore may not be good indicator of red grouper habitat. Figure 15, from a headboat data quality study, shows the trend in reporting where trip reports could be matched to port samplers measurements for gray triggerfish. The increase in gray triggerfish in the early 1990s is associated the increase in desirability of gray triggerfish described by headboat Captains. This study was limited mostly to full-day trips and ends in 2013. The same analysis showed consistent reporting for red grouper over time with the peaks in fish missed, as determined by fish lengths taken by port samplers, to fish reported (Figure 16).

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 each trip to presence/absence of other species. For the CAR area, stepwise AIC did not eliminate any species; for the GNF sampling area, it eliminated white grunt; for the SF sampling area, it eliminated bluestripped grunt. Regression coefficients of included species for all areas are given in Appendix 1 and shown in figure 17. A trip was then included if its associated probability of catching red grouper was higher than a threshold probability (Figure 17). The threshold was designed to be that which resulted in the same number of predicted and observed positive trips, as suggested by Stephens and MacCall (2004). After applying the Stephens and MacCall method, and the constraints described above, the resulting subsetted data set contained 4,663 trips in CAR, of which 31% were positive; 3,462 trips in the GNF area, of which 24% were positive; and 12,181 trips from SF, of which 25% were positive. Retention of positive and zero red grouper trips across factors are shown in Figures 18 - 20. The nominal catch rate after the subsetting for SEDAR 19 and SEDAR 53 are fairly similar (Figure 21)

Standardization

CPUE was modeled using the delta-GLM approach (Lo, L., and J. 1992; Dick 2004; Maunder and Punt 2004). This approach combines two separate generalized linear models (GLMs), one to describe presence/absence of the focal species, and one to describe catch rates of successful trips (trips that caught the focal species). Estimates of variance were based on 1000 bootstrap runs where trips were chosen randomly with replacement (Efron and Tibshirani 1993). All analyses were programmed in R, with much of the code adapted from Dick (2004).

Bernoulli submodel

The Bernoulli component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching red snapper on any given trip. Initially, all explanatory variables were included in the model as main effects, and then stepwise AIC (Venables and Ripley 1997) with a backwards selection algorithm was used to eliminate those variables that did not improve model fit. In this case, the stepwise AIC procedure did not remove any explanatory variables. Diagnostics, based on Pearson residuals, suggested reasonable fits of the Bernoulli submodel (Figure 22).

Positive CPUE submodel

Two parametric distributions were considered for modeling positive values of CPUE, lognormal and gamma. For both distributions, all explanatory variables were initially included as main effects, and then stepwise AIC (Venables and Ripley 1997) with a backwards selection algorithm was used to eliminate those variables that did not improve model fit. For both lognormal and gamma distributions, the best model fit included all explanatory variables. The two distributions, each with their best set of explanatory variables (all of them), were compared using AIC. Lognormal outperformed gamma, and was therefore applied in the final delta-GLM. Diagnostics suggested reasonable fits of the lognormal submodel (Figures 23 and 24).

Results

The standardized index was similar to the nominal index with the exception of a few years associated with peaks in the catch rate (Figure 25). For 1983 the standardized index was lower than the nominal and the 2005 peak in catch rate was increased in the standardization. There may be concern that management measures, such as the red snapper closure that started in 2009, may influence catchability for red grouper. However, the large decrease in catch rate occurs just prior to 2009, Assessment methods that account for changes in catchability could be implemented over time periods where effort may have been influenced by management measures.

Table 1: Species listed on headboat logbook forms in 1980 for North and South Carolina (CAR) and Georgia - Florida (GFL) which are in the snapper-grouper complex.

CAR	GFL
Gag	Almaco.jack
Greater.amberjack	Blackfin.snapper
Knobbed.porgy	Blue.runner
Red.Grouper	Blueline.Tilefish
Red.Hind	Bluestriped.grunt
Red.porgy	Cubera.snapper
Red.snapper	Gag
Rock.Hind	Gray.snapper
Scamp	Gray.triggerfish
Scup	Graysby
Silk.snapper	Greater.amberjack
Snowy.Grouper	Jolthead.por gy
Tomtate	Knobbed.porgy
Vermilion.snapper	Lane.snapper
Warsaw.Grouper	Mutton.snapper
White.grunt	Queen.triggerfish
Whitebone.porgy	Red.Grouper
Yellowfin.Grouper	Red.Hind
	Red.porgy
	Red.snapper
	Rock.Hind
	Sand.tilefish
	Scamp
	Silk.snapper
	Tomtate
	Vermilion.snapper
	White.grunt
	Whitebone.porgy
	Yellowfin.Grouper
	Yellowmouth.Grouper

Table 2: Species removed from the Stephens and MacCall method for defining red grouper trips due to seasonal or complete closures or ad-hoc evidence of shifts in desirability.

Species.removed
Red.porgy
Gray.triggerfish
Red.snapper
Vermilion.snapper
Mutton.snapper
Snowy.Grouper
Gag
Black.sea.bass
Blueline.tilefish

Table 3: Nominal and standardized CPUE for red grouper 1980-2015 with CVs for standardized index of abundance.

Year	N	Nominal.CPUE	Relative.nominal	Standardized.CPUE	CV
1980	273	0.00	0.97	0.98	0.13
1981	349	0.00	0.61	0.54	0.13
1982	283	0.00	0.58	0.66	0.18
1983	370	0.01	1.61	1.16	0.12
1984	368	0.00	0.86	0.78	0.14
1985	497	0.00	0.87	0.86	0.10
1986	706	0.00	1.07	0.90	0.08
1987	756	0.00	0.71	0.53	0.09
1988	614	0.00	0.70	0.80	0.10
1989	460	0.00	0.76	0.70	0.10
1990	685	0.00	0.38	0.42	0.11
1991	548	0.00	0.47	0.57	0.11
1992	742	0.00	0.71	0.73	0.09
1993	649	0.00	0.85	0.93	0.08
1994	643	0.00	1.06	0.97	0.09
1995	645	0.00	0.79	0.91	0.08
1996	664	0.01	1.98	1.35	0.07
1997	930	0.01	1.23	1.32	0.06
1998	828	0.01	1.78	1.81	0.06
1999	590	0.01	1.61	1.64	0.07
2000	598	0.01	1.39	1.15	0.07
2001	521	0.00	1.22	1.12	0.09
2002	371	0.00	0.58	0.68	0.12
2003	351	0.00	0.90	1.11	0.11
2004	588	0.01	1.87	1.73	0.07
2005	489	0.01	2.48	3.20	0.07
2006	432	0.01	1.69	2.11	0.08
2007	372	0.01	1.53	1.81	0.09
2008	501	0.00	0.45	0.51	0.12
2009	610	0.00	0.34	0.41	0.12
2010	554	0.00	0.73	0.64	0.09
2011	482	0.00	0.73	0.74	0.09
2012	650	0.00	0.45	0.51	0.10
2013	621	0.00	0.97	0.79	0.08
2014	713	0.00	0.64	0.59	0.09
2015	847	0.00	0.40	0.36	0.10

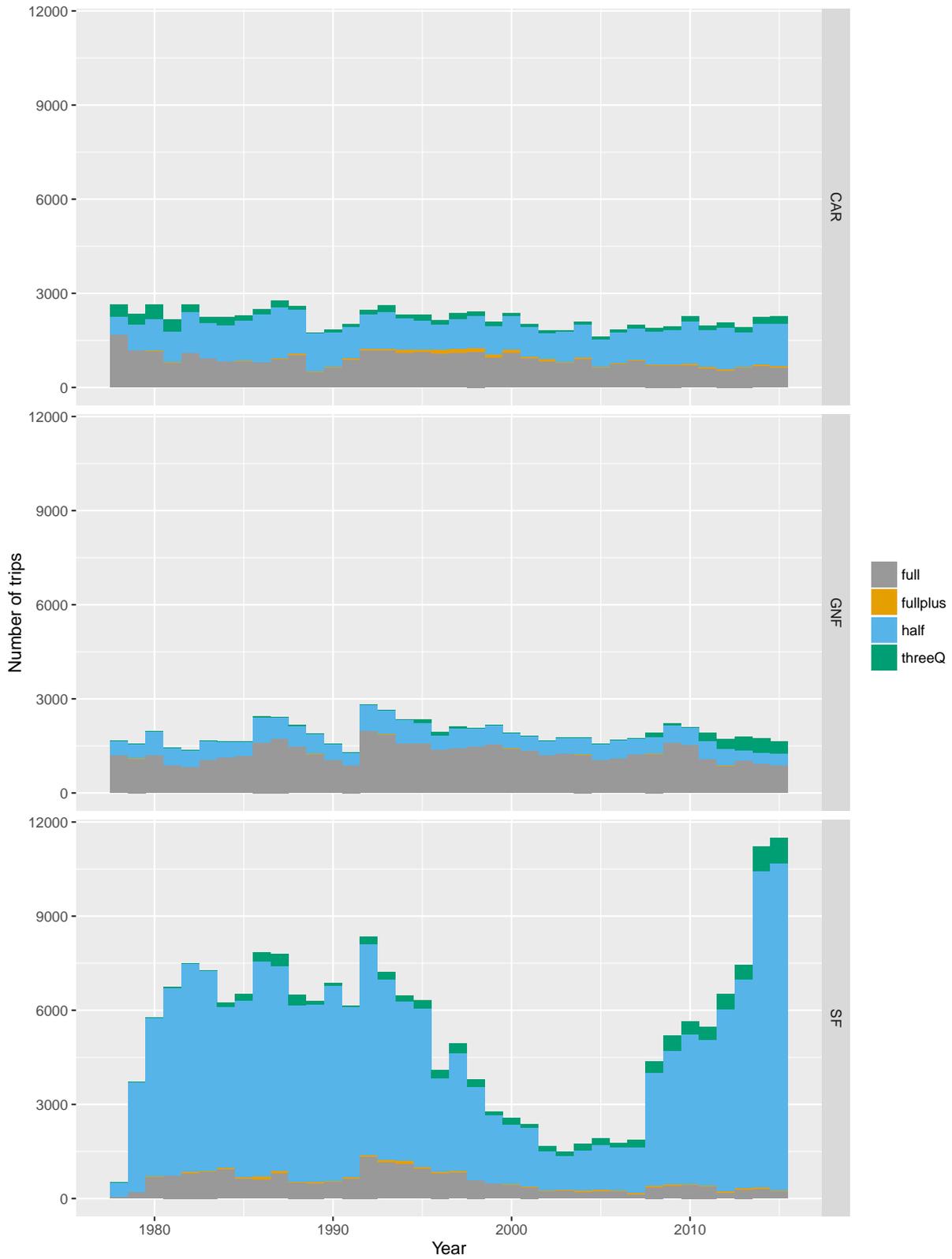


Figure 1: Number of headboat trips that submitted logbooks 1978-2015 for half-day trips (half), full-day trips (full), three-quarter day trips (threeQ), and multiple-day trips ranging from 1.5 to 7 days (fullplus) by region (CAR-carolininas, GNF - Georgia to Cape Canaveral, FL, SF - South florida).

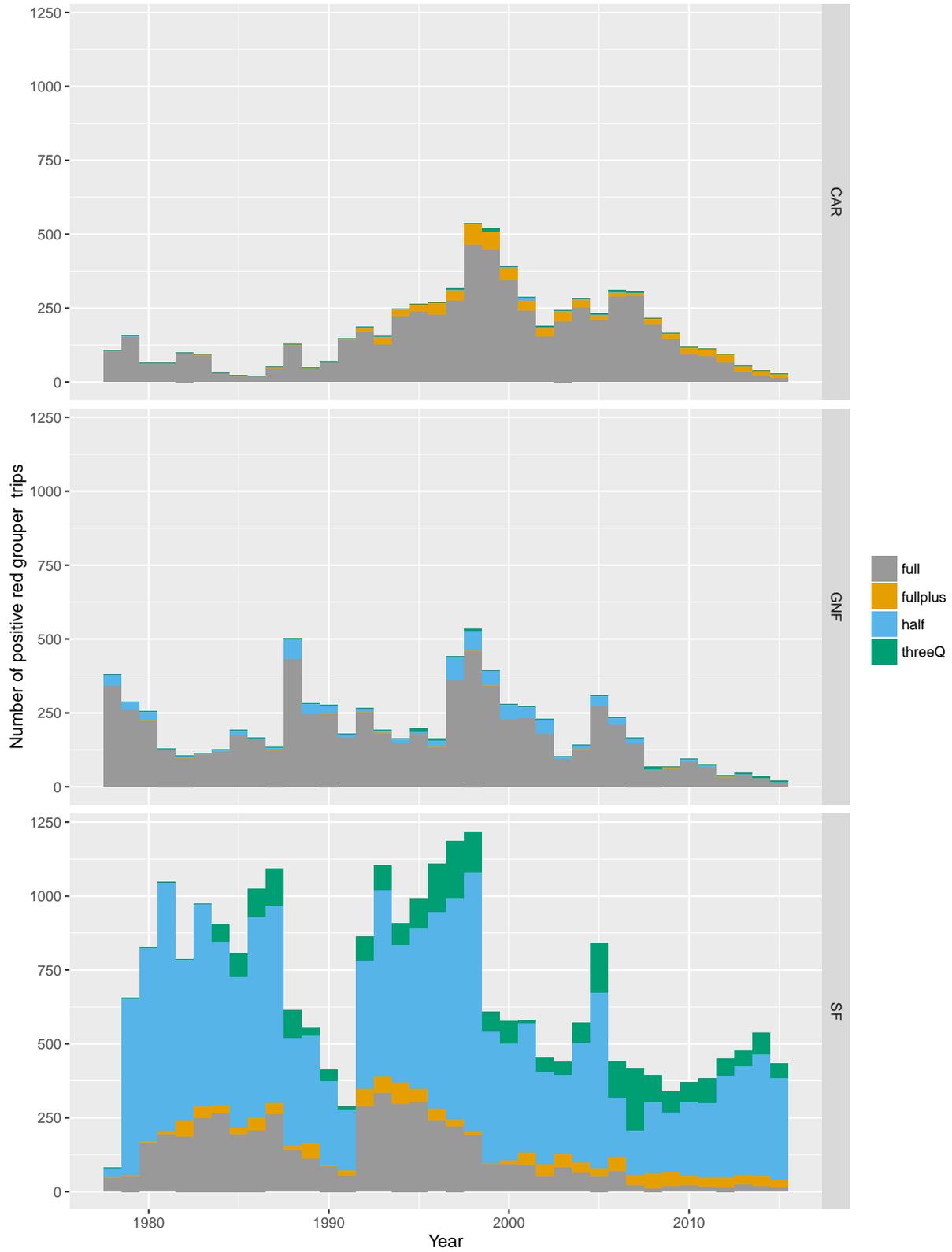


Figure 2: Number of positive red grouper headboat trips that submitted logbooks 1978-2015 for half-day trips (half), full-day trips (full), three-quarter day trips (threeQ), and multiple-day trips ranging from 1.5 to 7 days by region (CARr-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida).

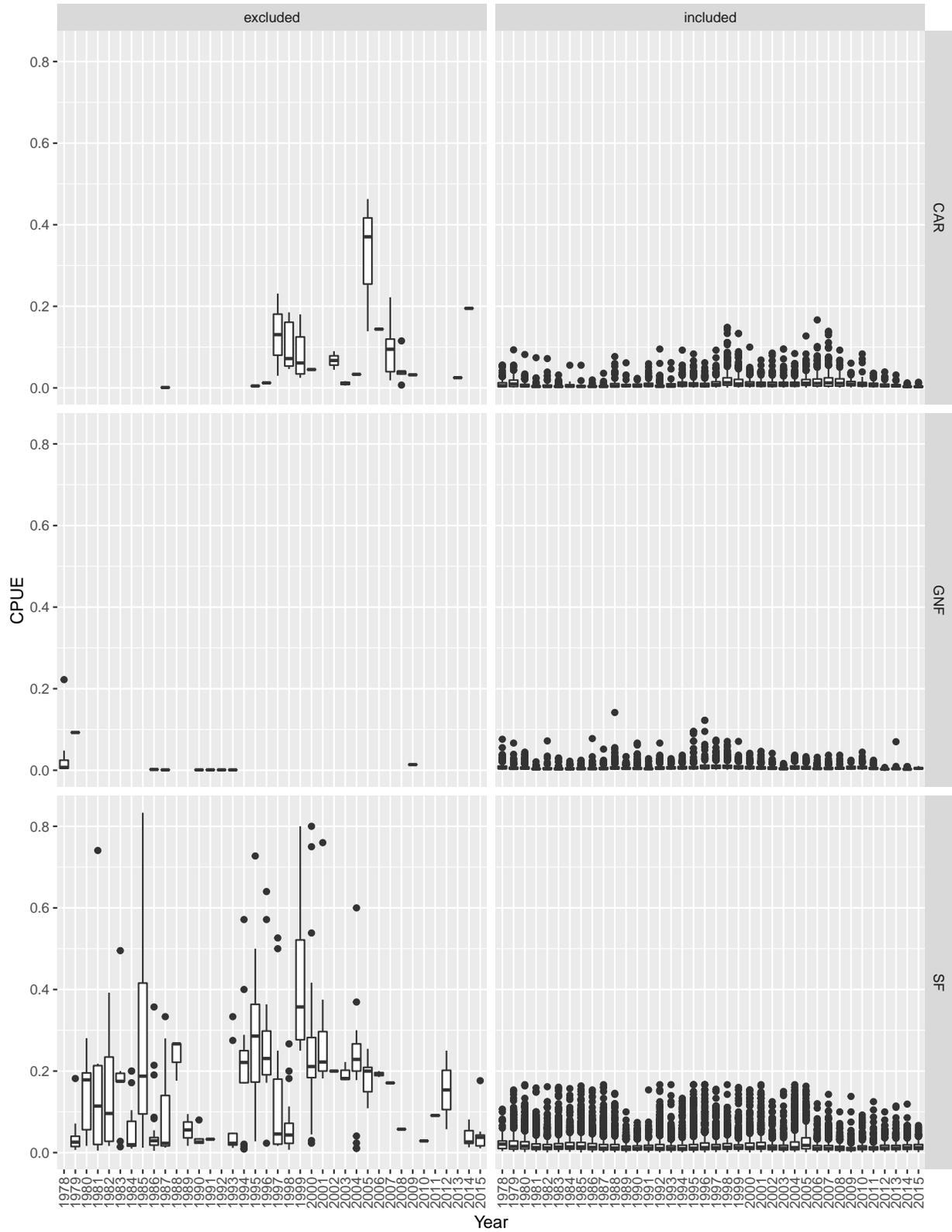


Figure 3: Records determined as outliers (excluded) based on removal of values above the 99.5th percentile for anglers, number of fish caught, and cpue.

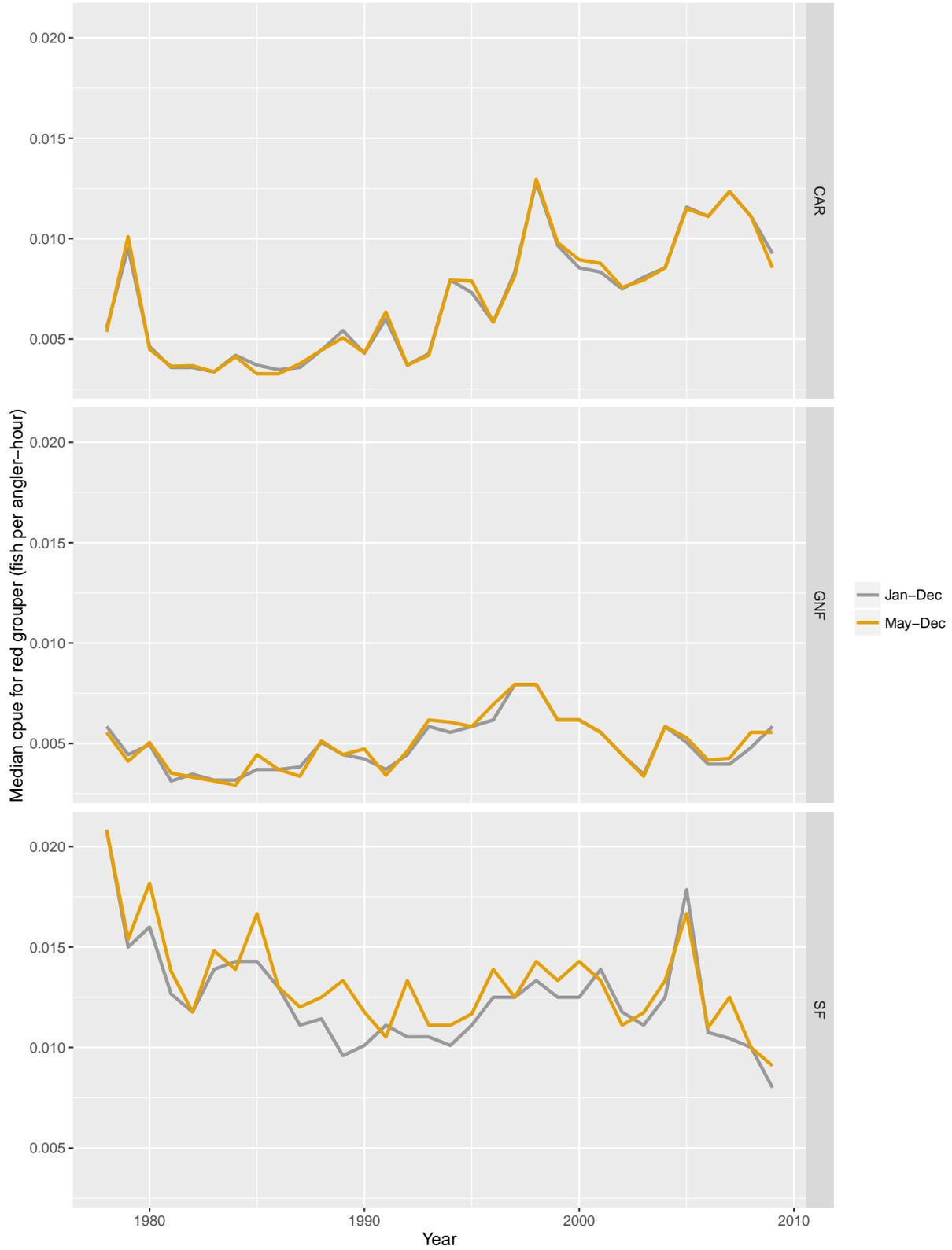


Figure 4: Median nominal red grouper catch rates by region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida) for all months and just May-Dec.

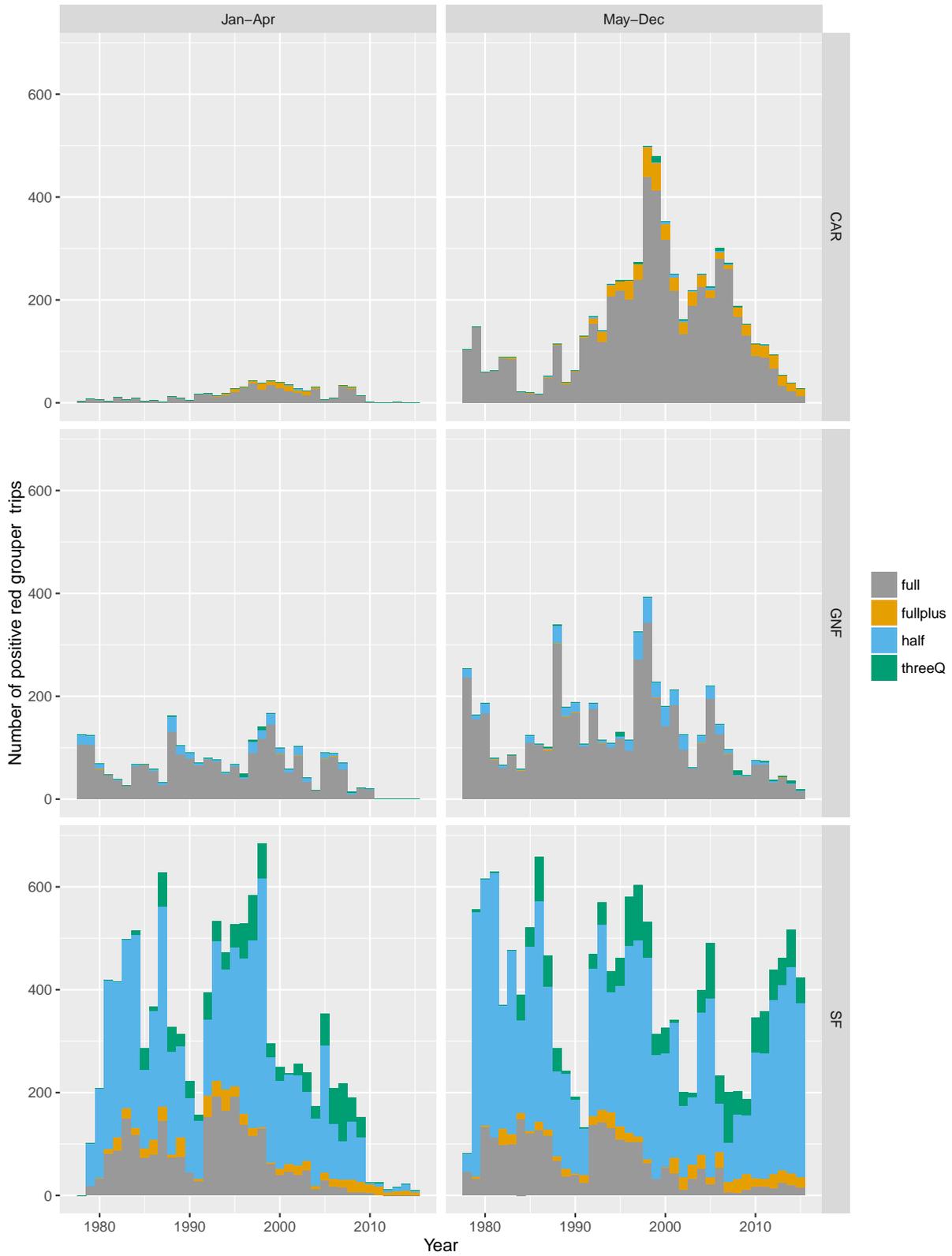


Figure 5: Positive red grouper trips by region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida) and season. January to April is the shallow-water grouper spawning closure season that began in 2010.

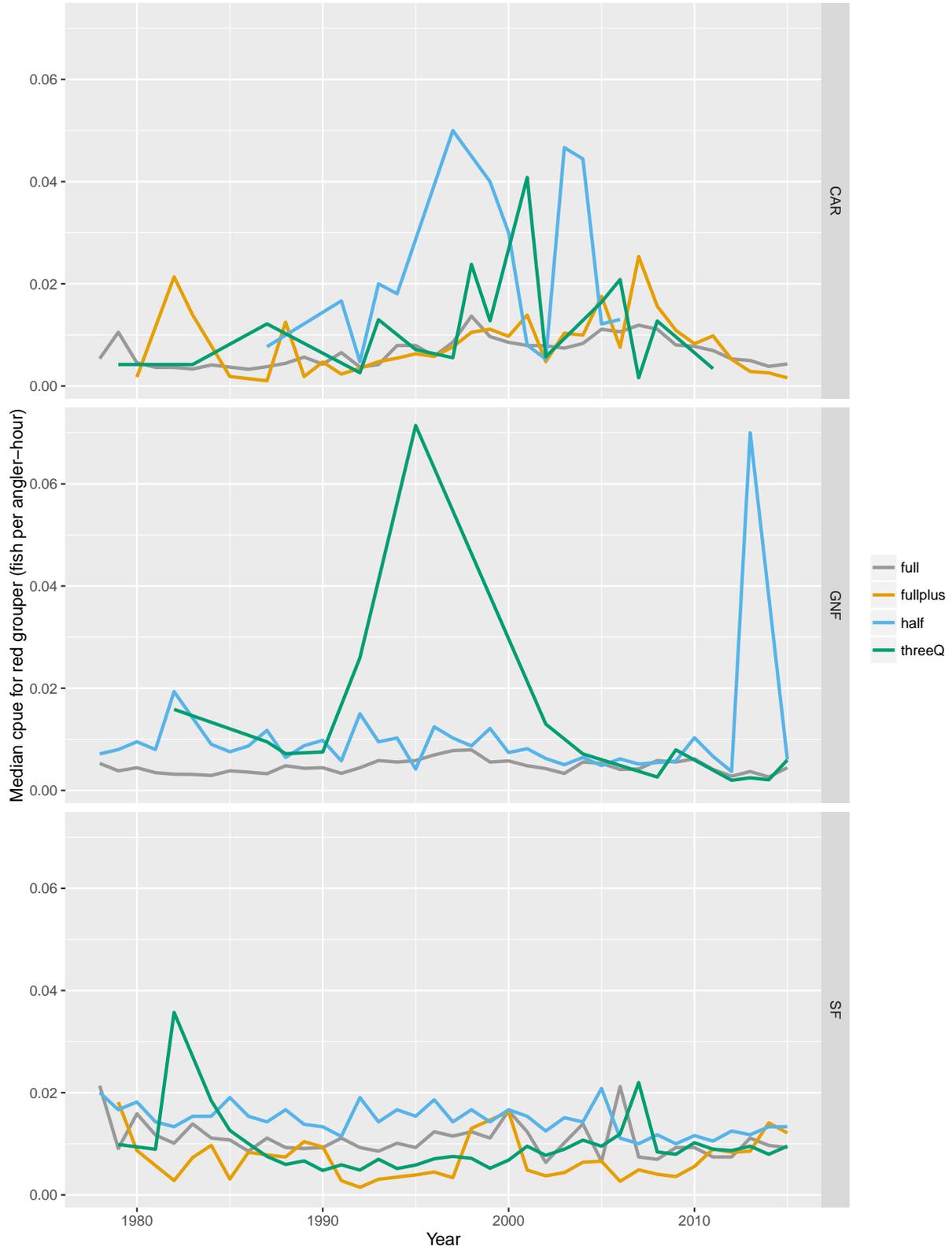


Figure 6: Red grouper cpue by region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida) for May - Dec.

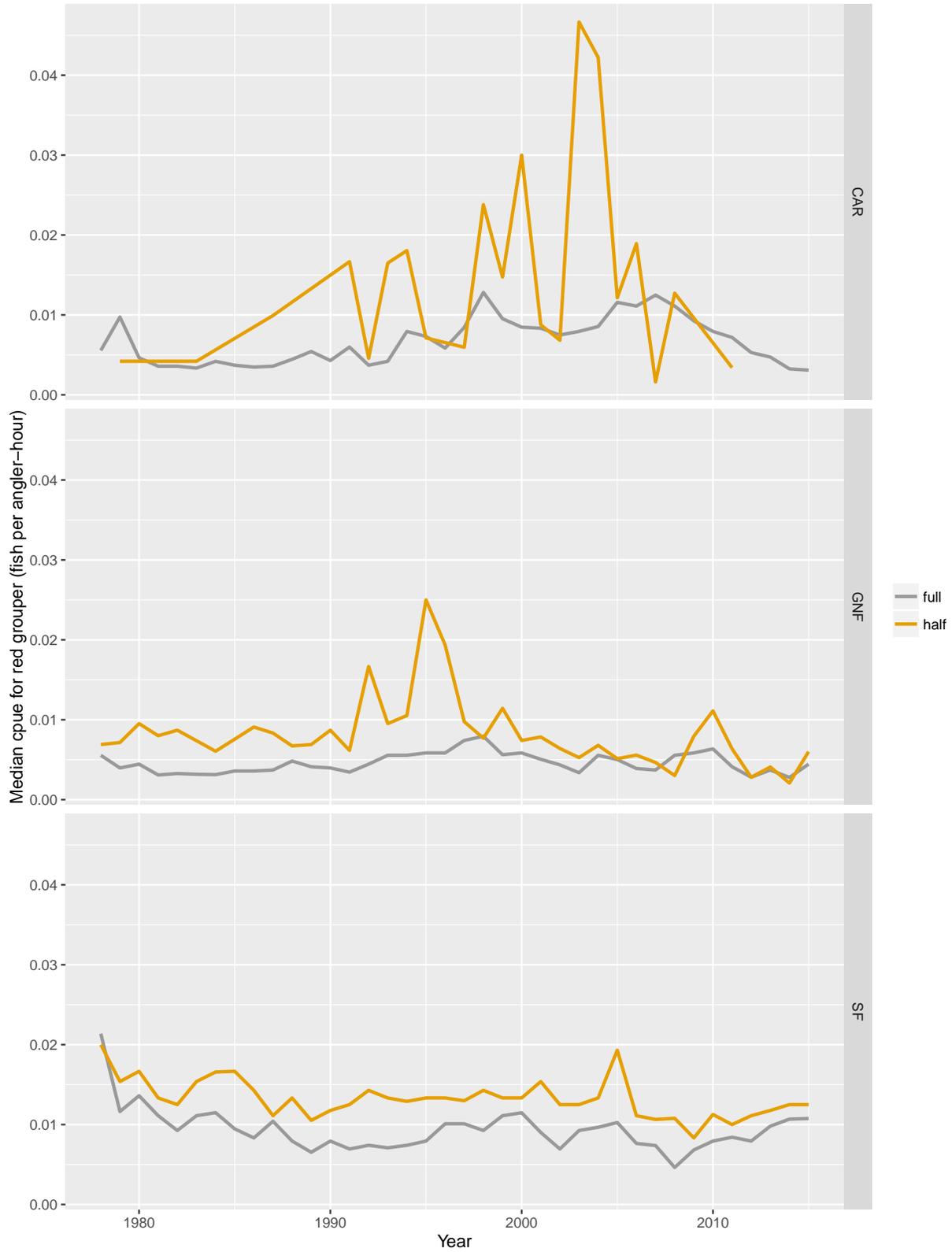


Figure 7: Red grouper cpue by region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida) for May - Dec. Trips are aggregated into full- (includes multi-day trips) and half- (includes 3/4-day) trips. January to April is the shallow-water grouper spawning closure season that began in 2010.

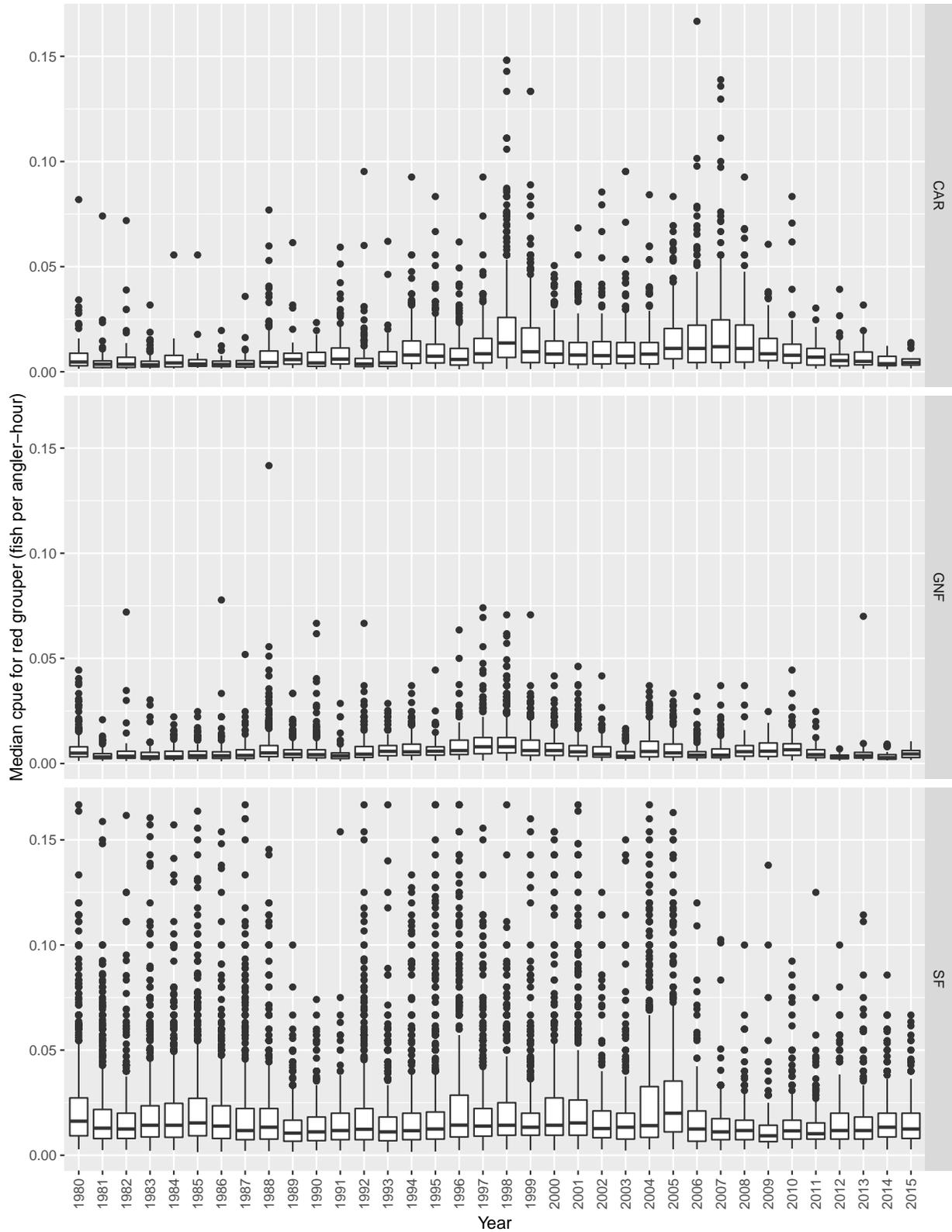


Figure 8: Red grouper cpue by region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida) and season. Multi-day and 3/4-day trips are removed for all regions. Half-day trips are removed for CAR and GNF. Half-day trips and full-day trips are aggregated for SF. Years are limited to 1980-2015.

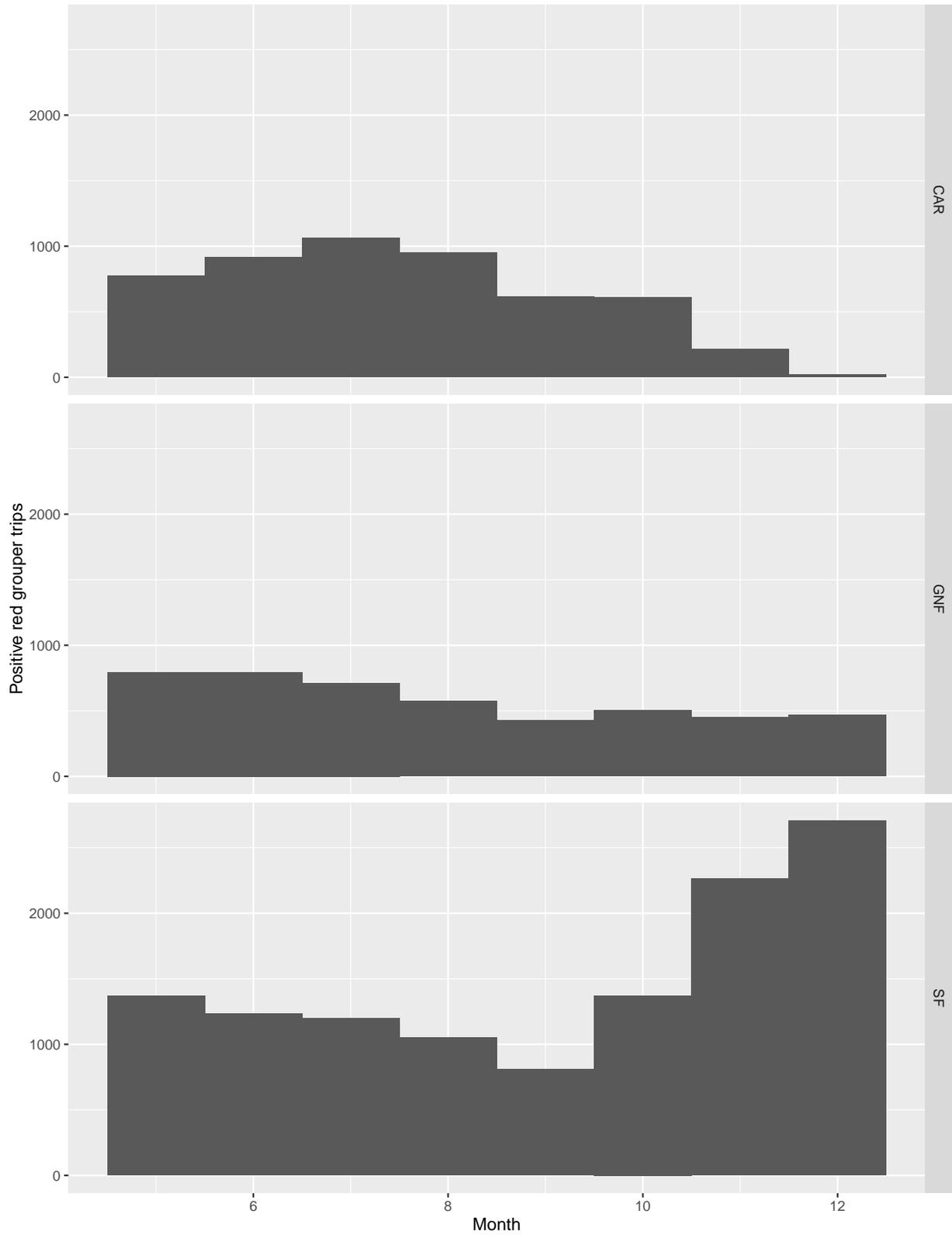


Figure 9: Positive red grouper trips by month and region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida).

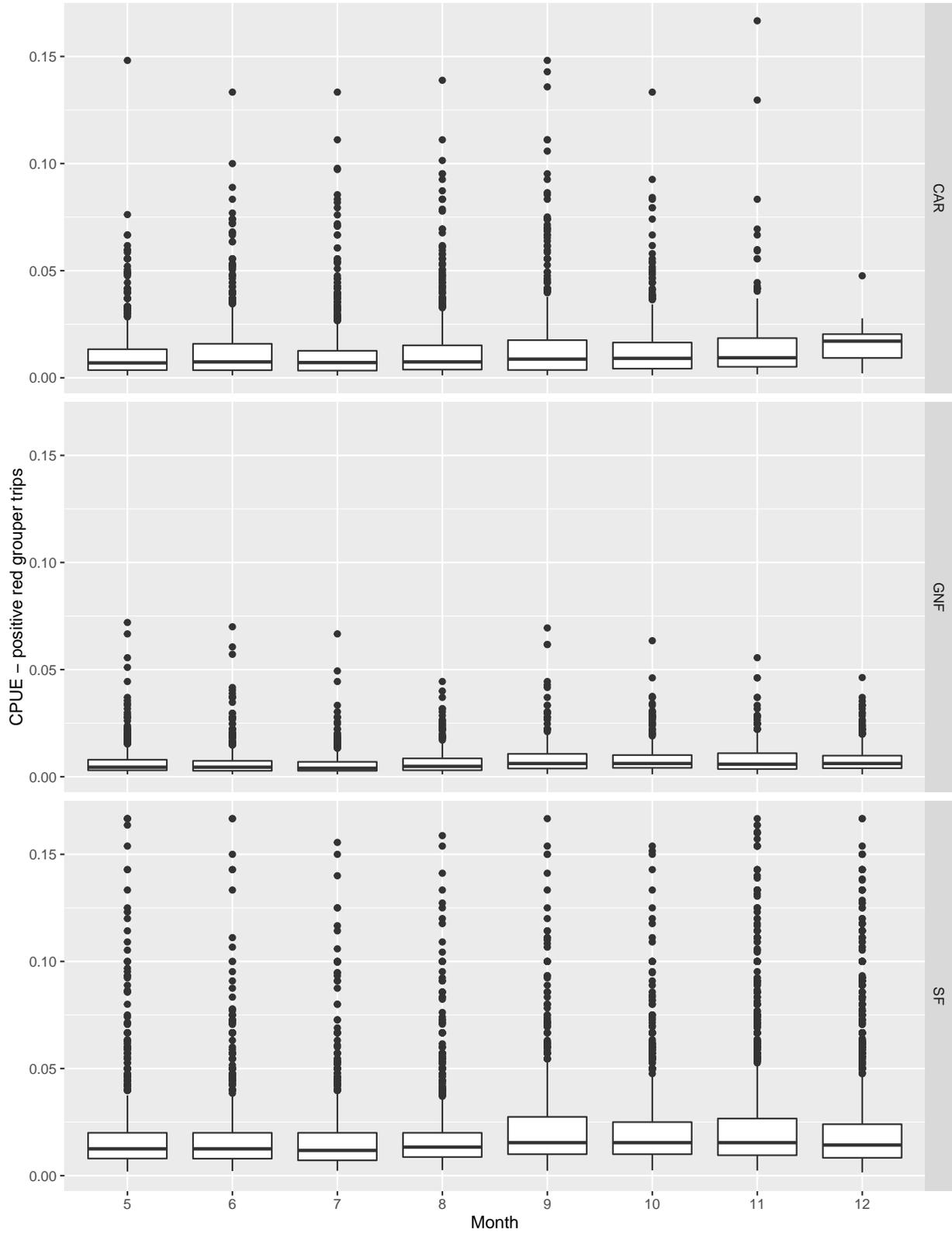


Figure 10: Red grouper cpue for positive trips by month and region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida).

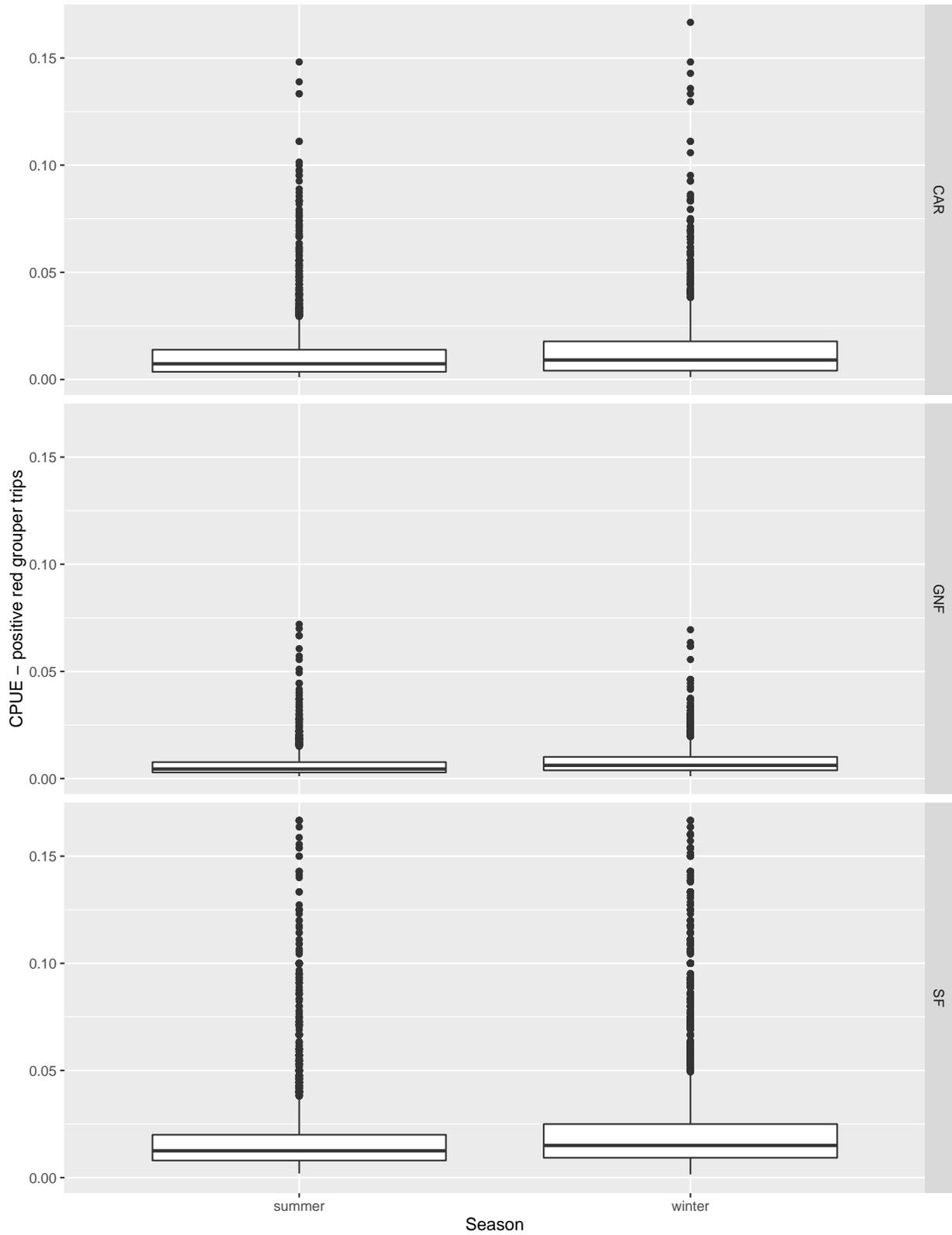


Figure 11: Red grouper cpue for positive trips by season and region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida).

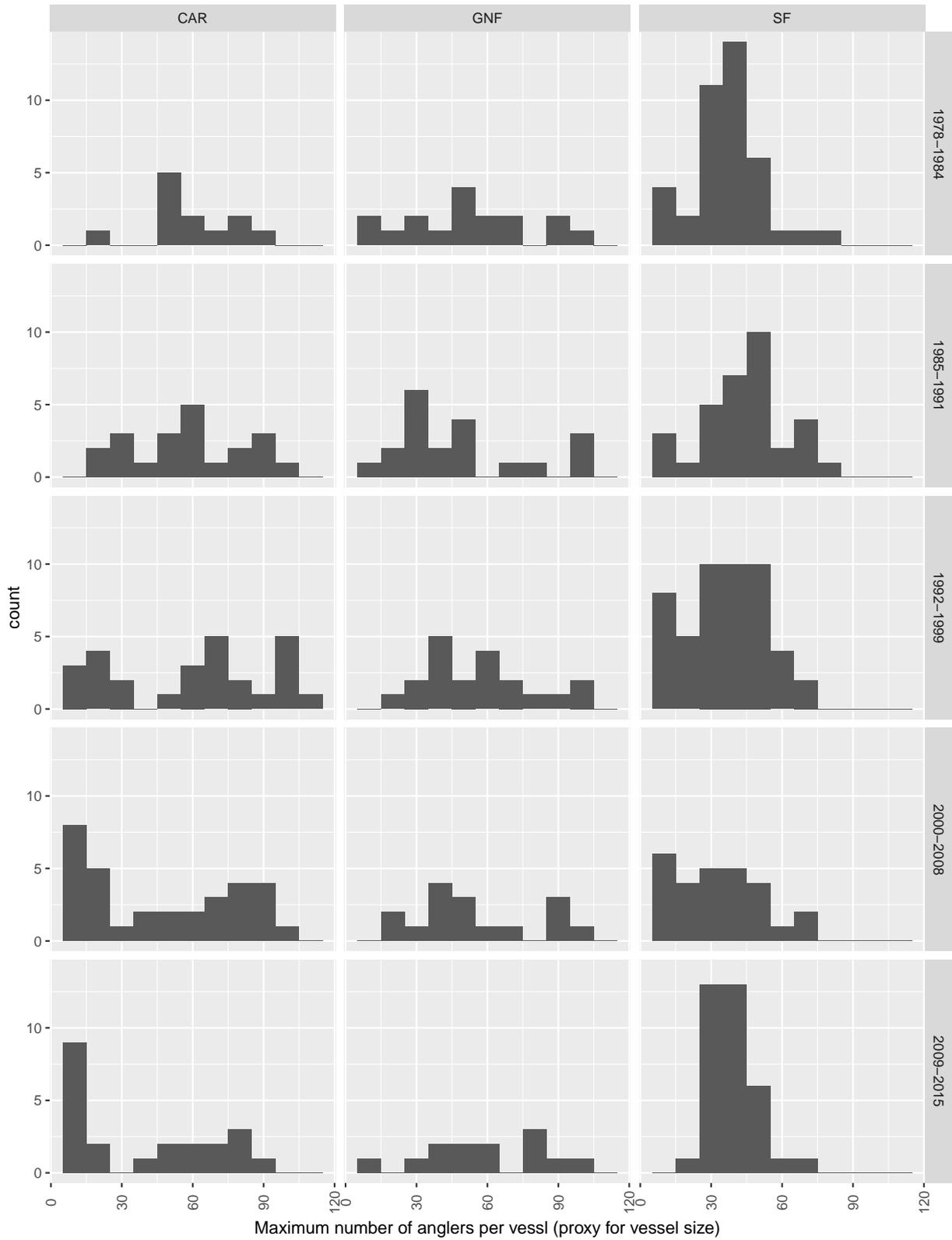


Figure 12: Maximum number of anglers as a proxy for vessel size (single value for each vessel) by region (CAR-carolinas, GNF - Georgia to Cape Canaveral, FL, SF - South florida).

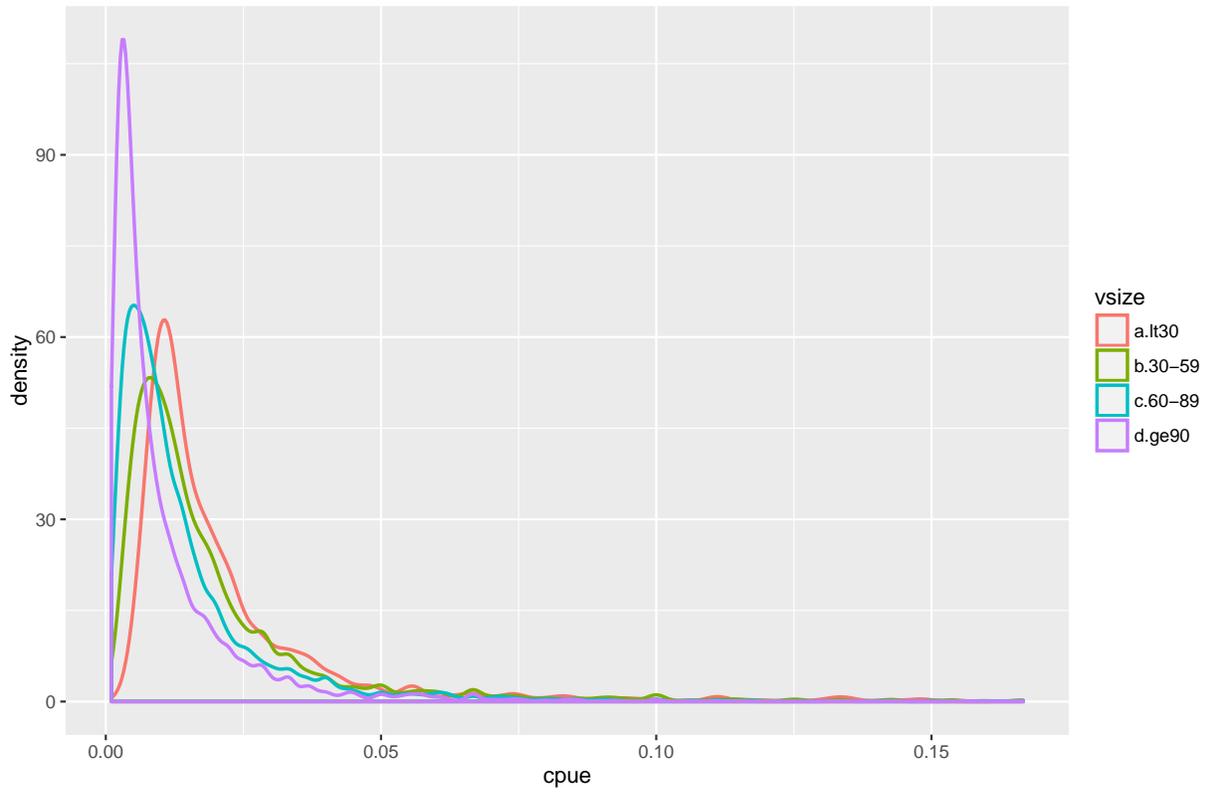
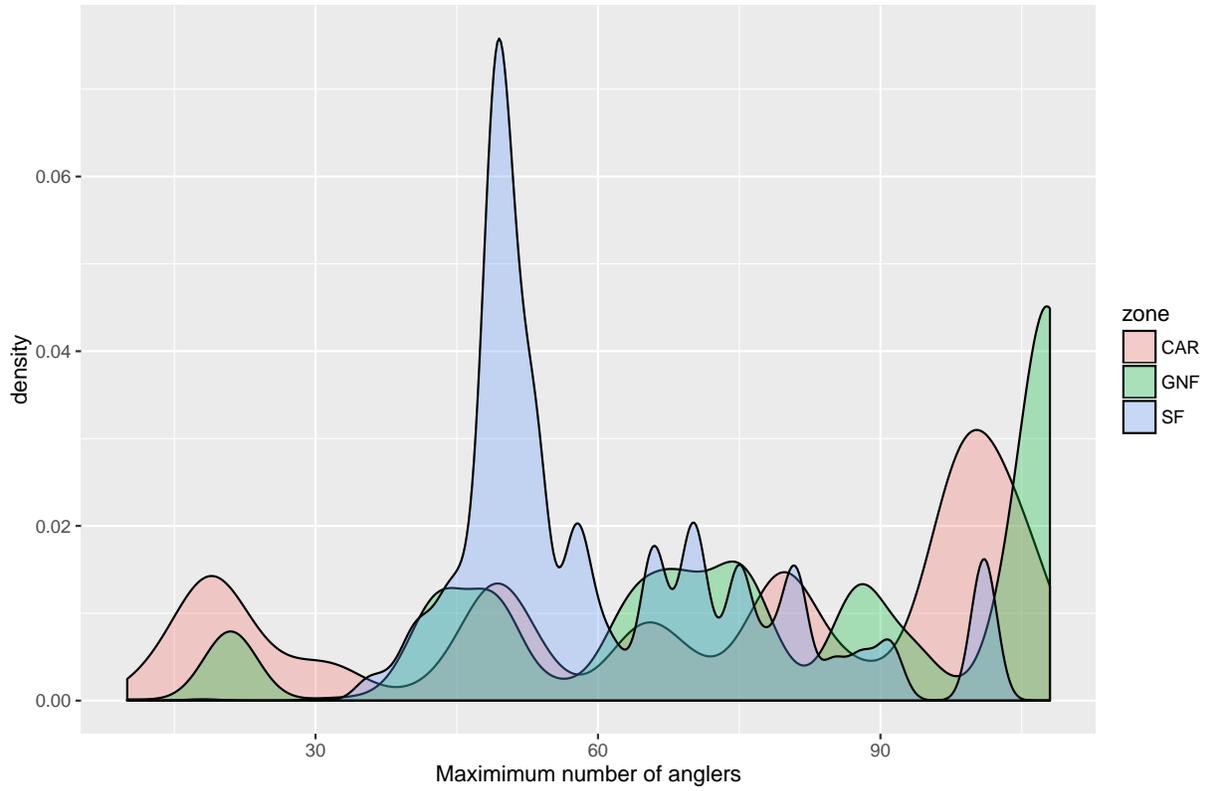


Figure 13: Density of maximum number of anglers across areas and cpue associated the factors for maximum anglers as a proxy for vessel size.

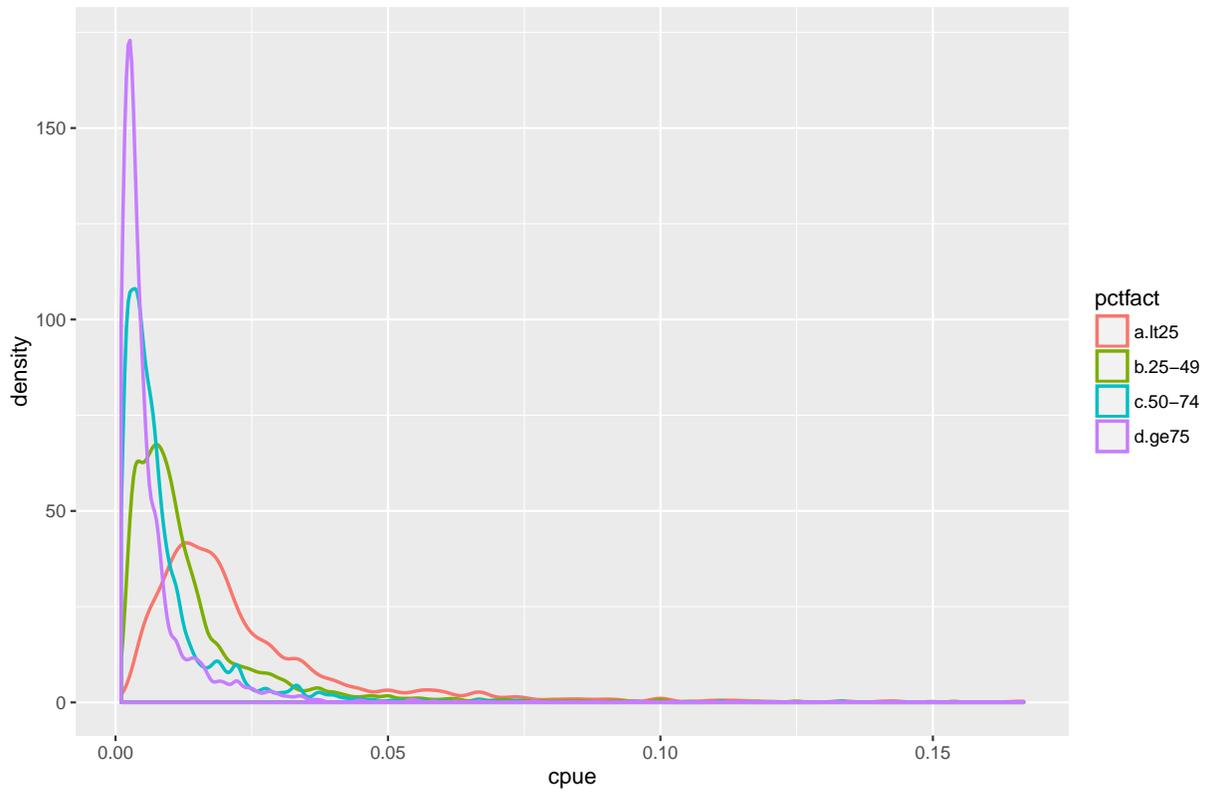
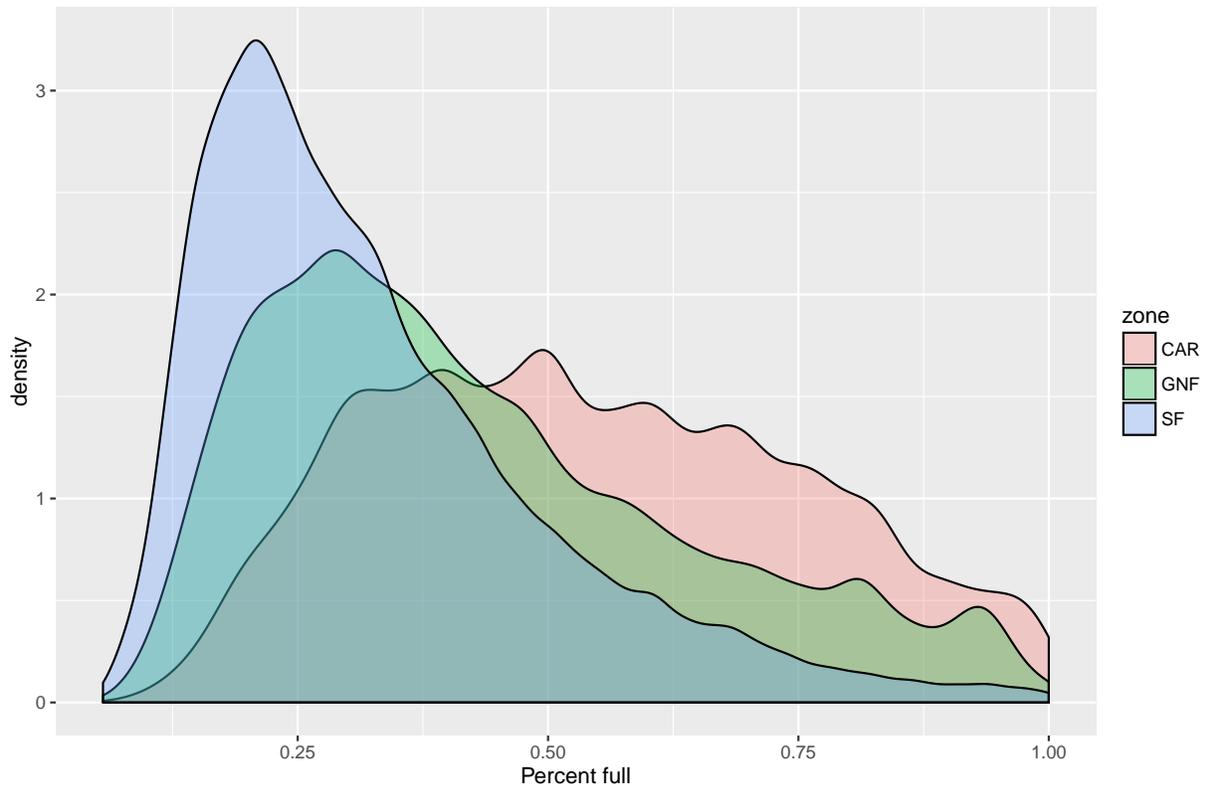


Figure 14: Density of percent full across areas and cpue associated the factors for percent full.

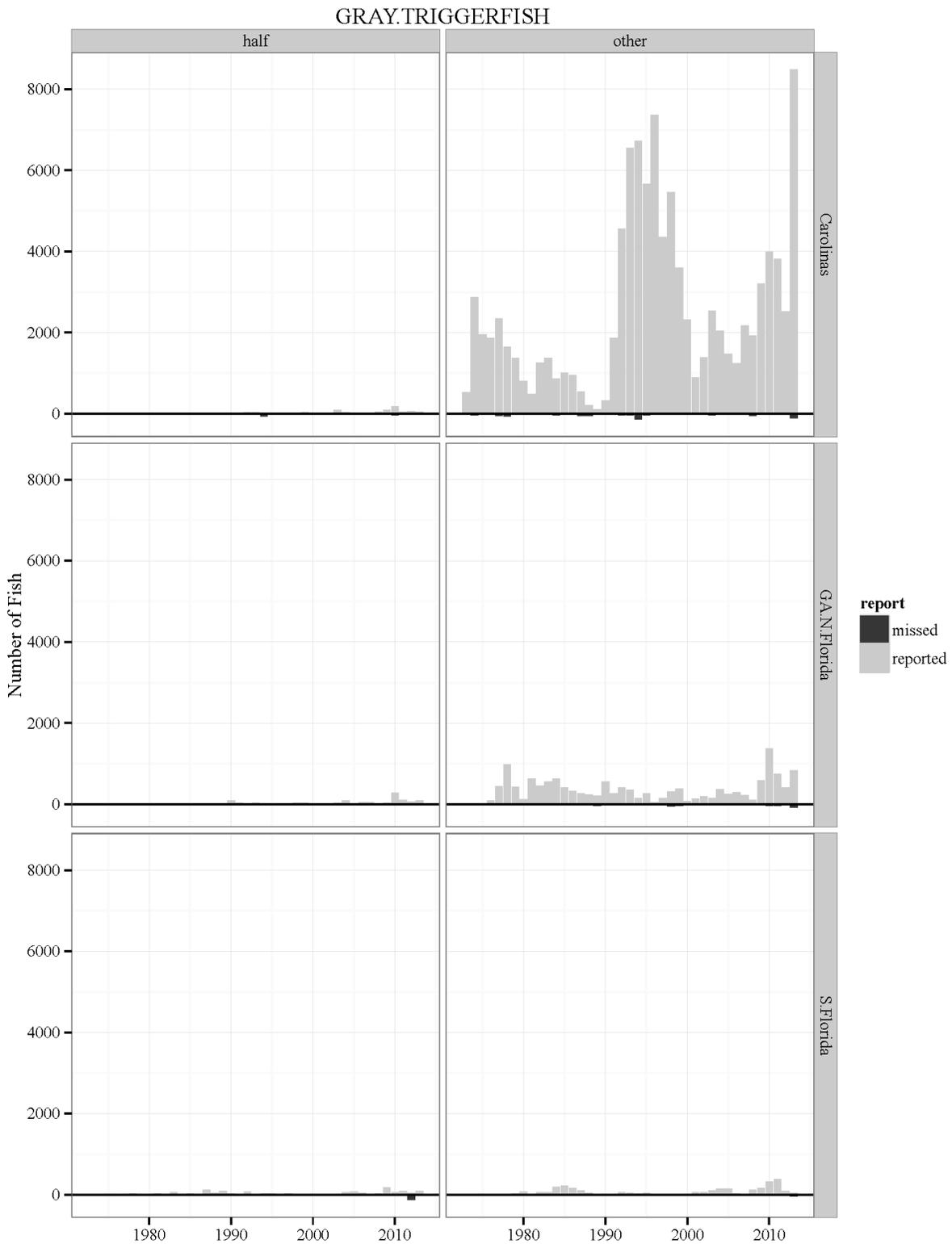


Figure 15: Comparison of the number of fish measured by a port sampler for a trips that could be matched to the number of fish reported for gray triggerfish. A general field for triggerfish was on the logbook form for in all areas from the beginning of the survey however headboat captains reported that they were mostly discarded during the early part of the survey because of angler preference. Gray Triggerfish was added to the for for the Carolinas in 1984.

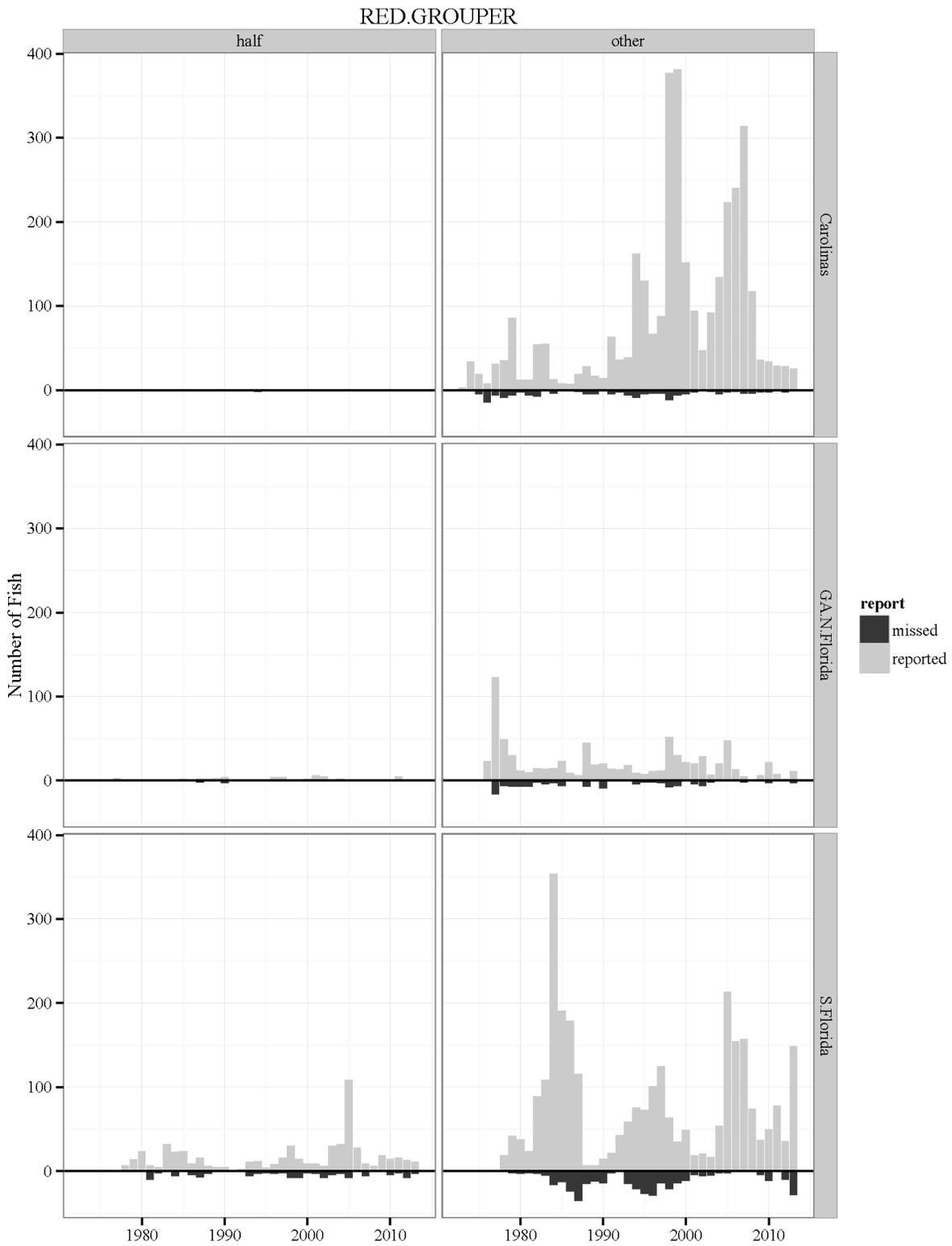


Figure 16: Comparison of the number of fish measured by a port sampler for a trips that could be matched to the number of fish reported for red grouper. Red grouper was on the logbook form for in all areas from the beginning of the survey and reporting is consistent over time.

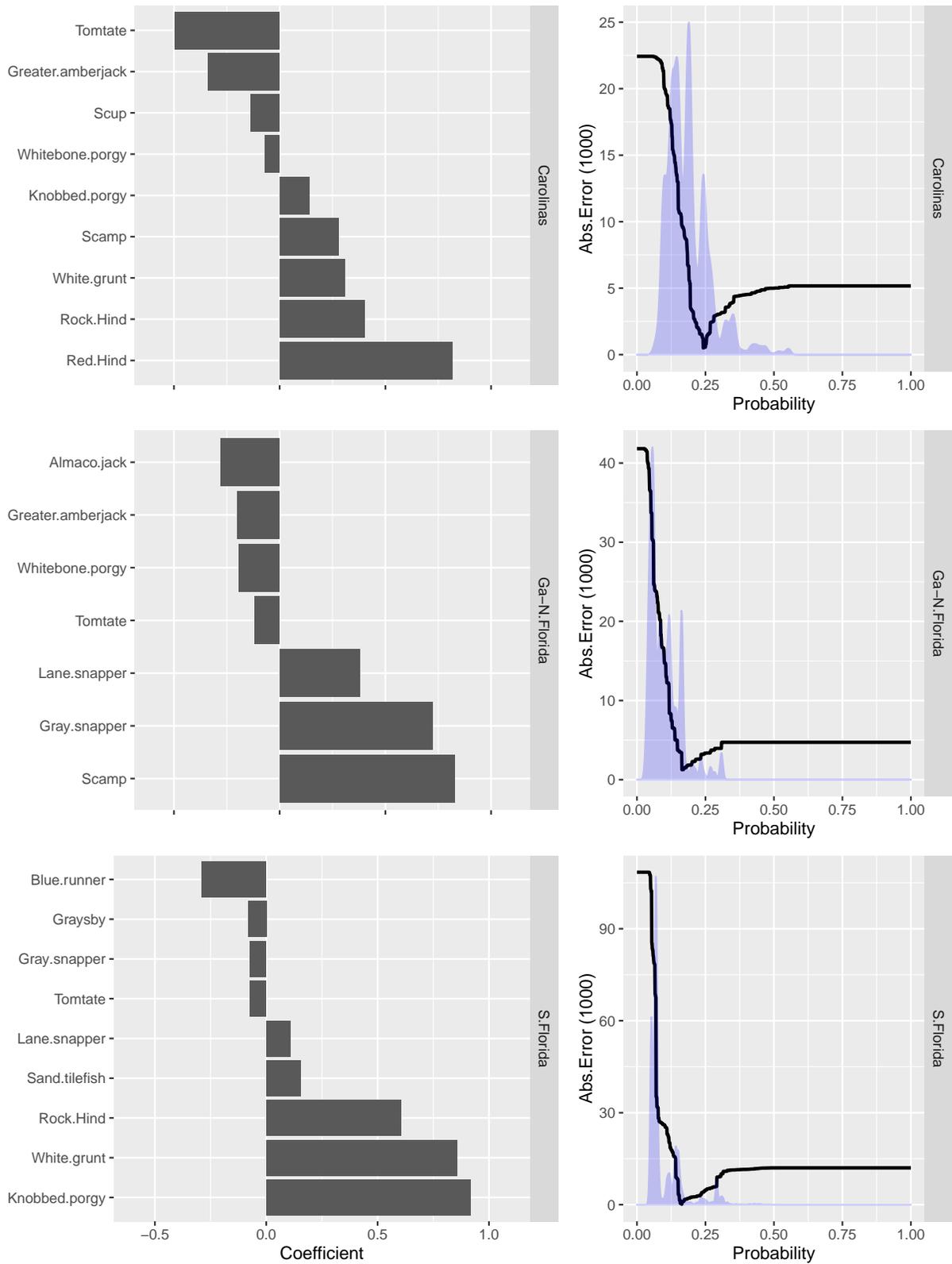


Figure 17: Estimates of species-specific regression coefficients used to predict each trip’s probability of catching the focal species on the left panel. The right panel shows the absolute difference between observed and predicted number of positive trips across a range of probability cutoff values. .

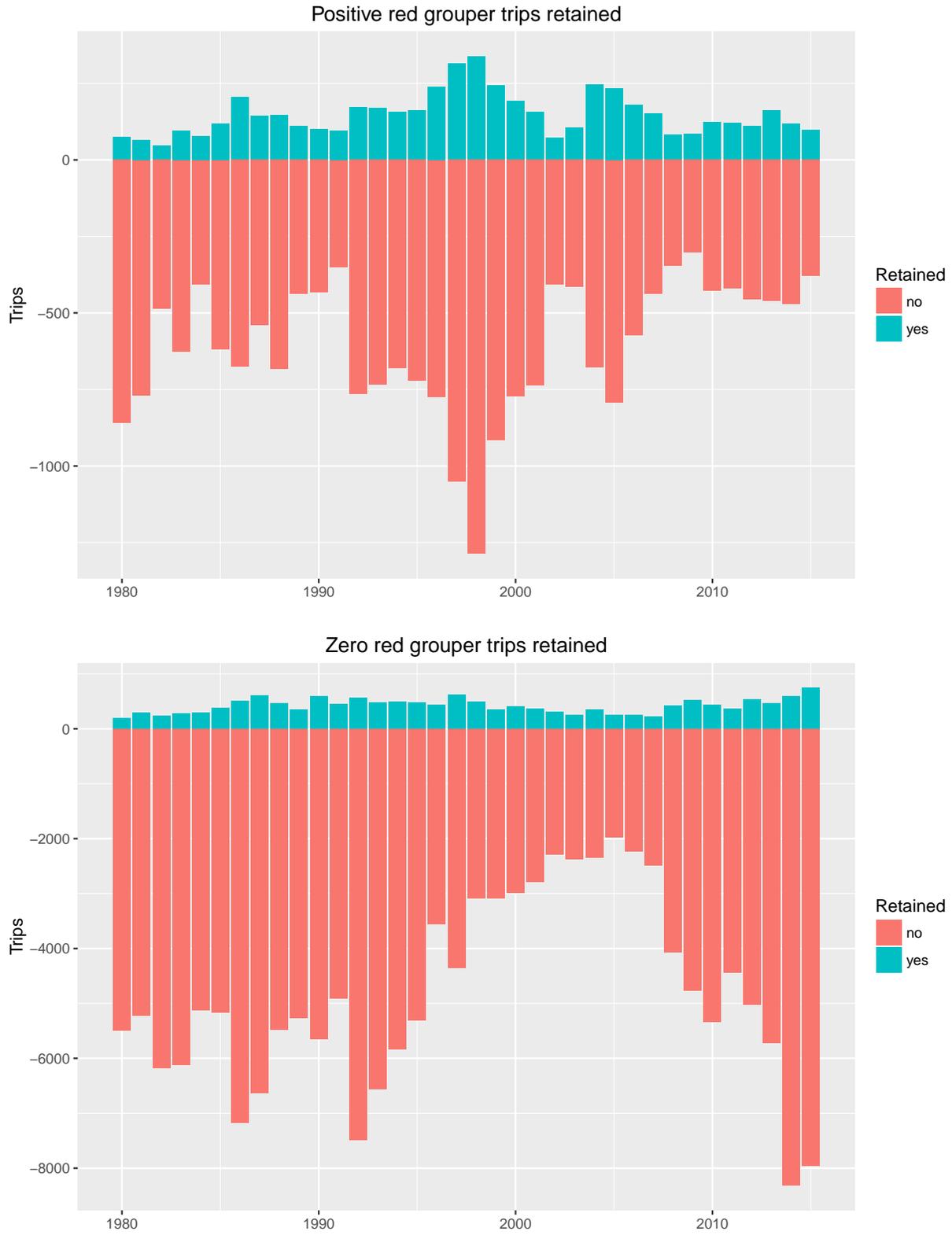


Figure 18: Positive and zero red grouper trips retained after subsetting using Stephens and MacCall approach by year.

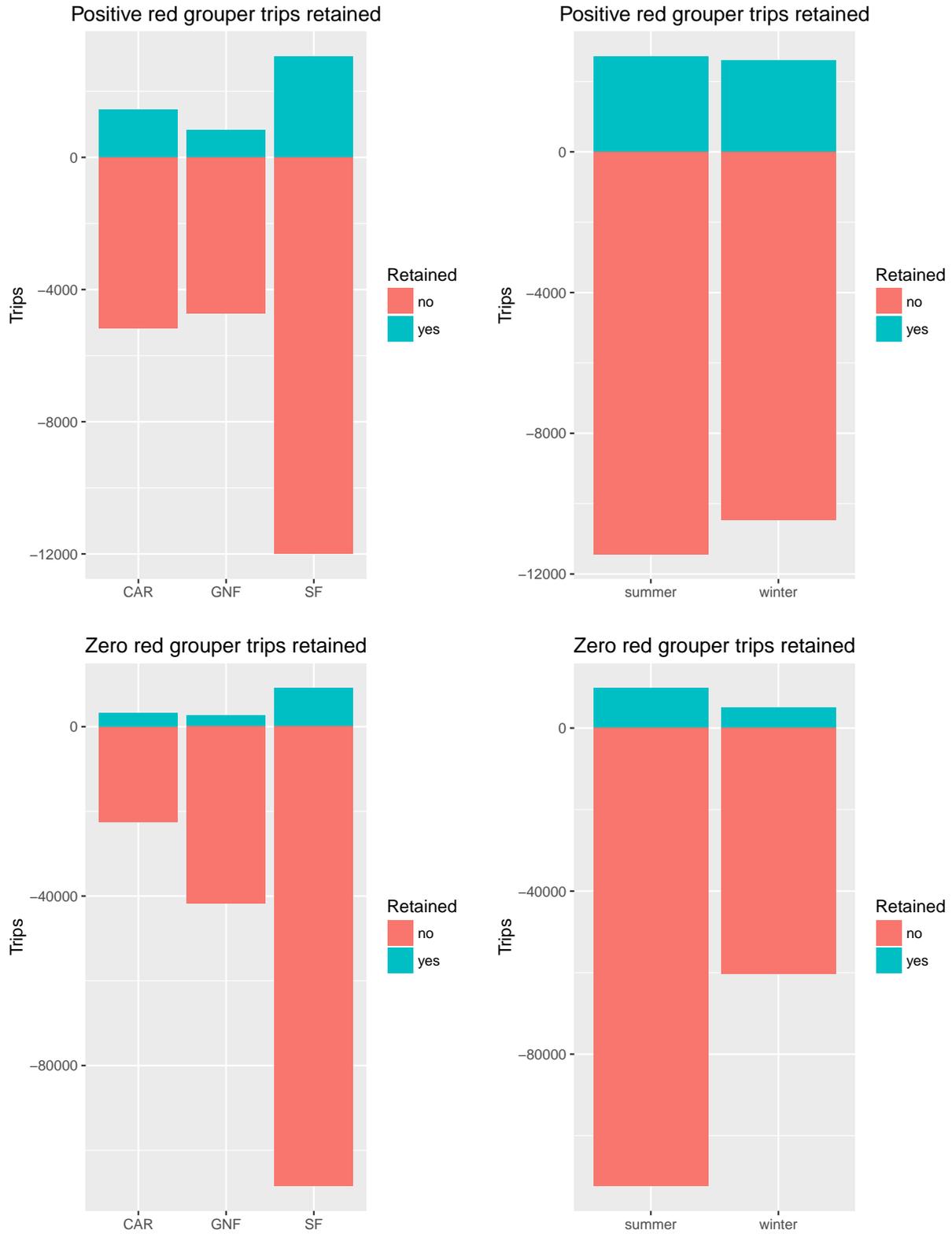


Figure 19: Positive and zero red grouper trips retained after subsetting using Stephens and MacCall approach by area and season.

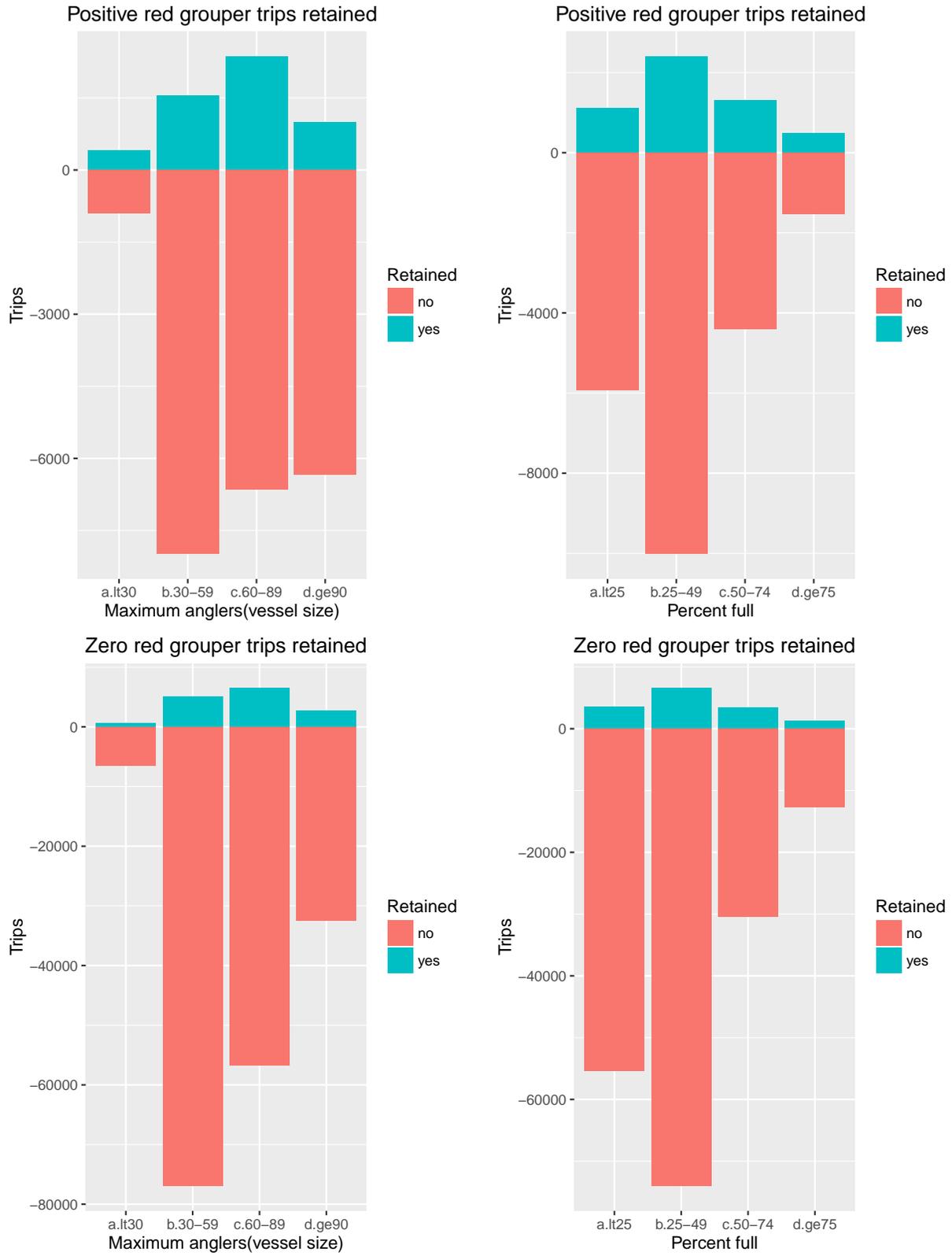


Figure 20: Positive and zero red grouper trips retained after subsetting using Stephens and MacCall approach by factors for maximum anglers and percent full.



Figure 21: Nominal red grouper cpue for subsetting trips for SEDAR 19, SEDAR 53, and all positive trips.

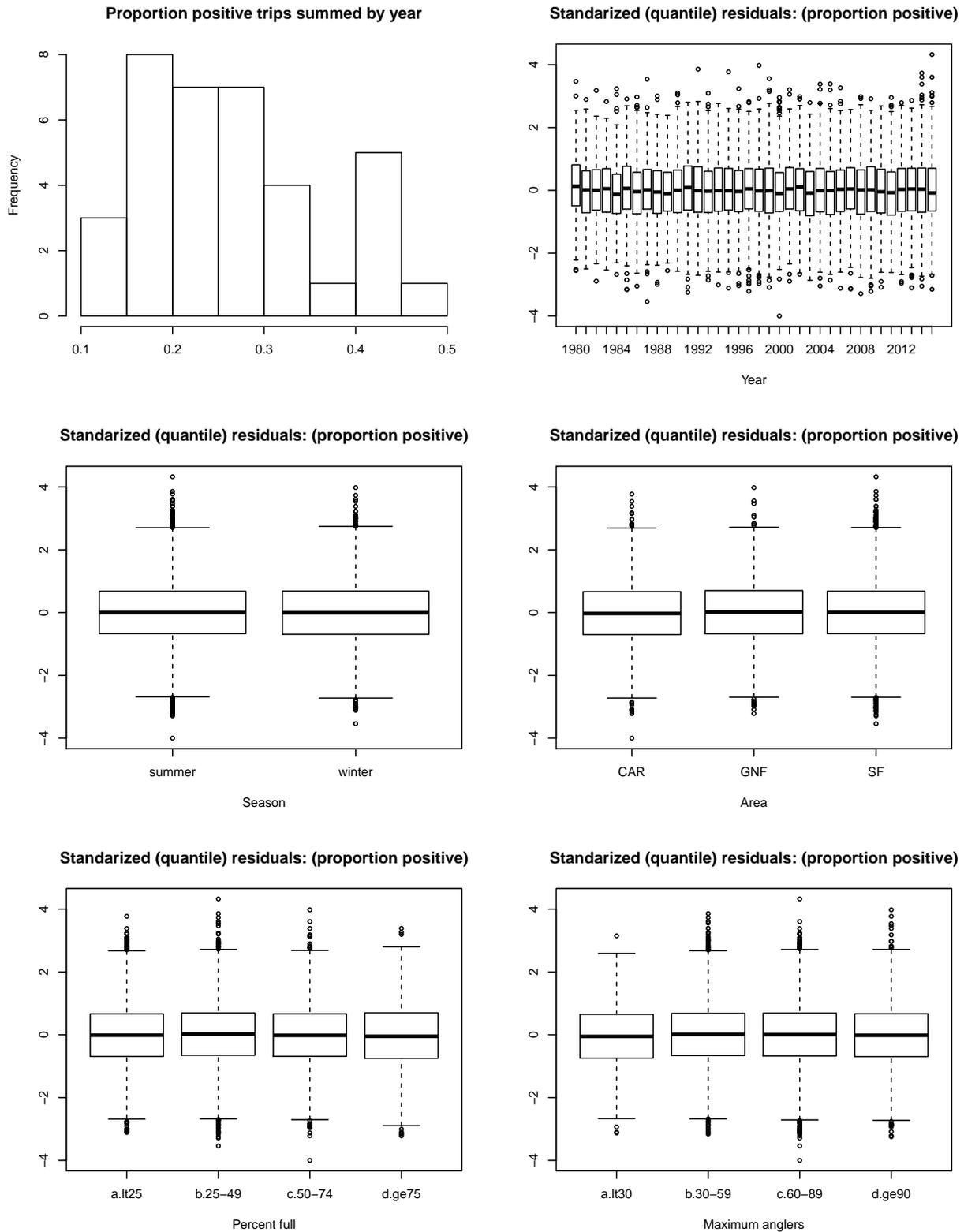


Figure 22: Diagnostics of Bernoulli submodel fits to positive versus zero CPUE data. Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are standardized (quantile) residuals.

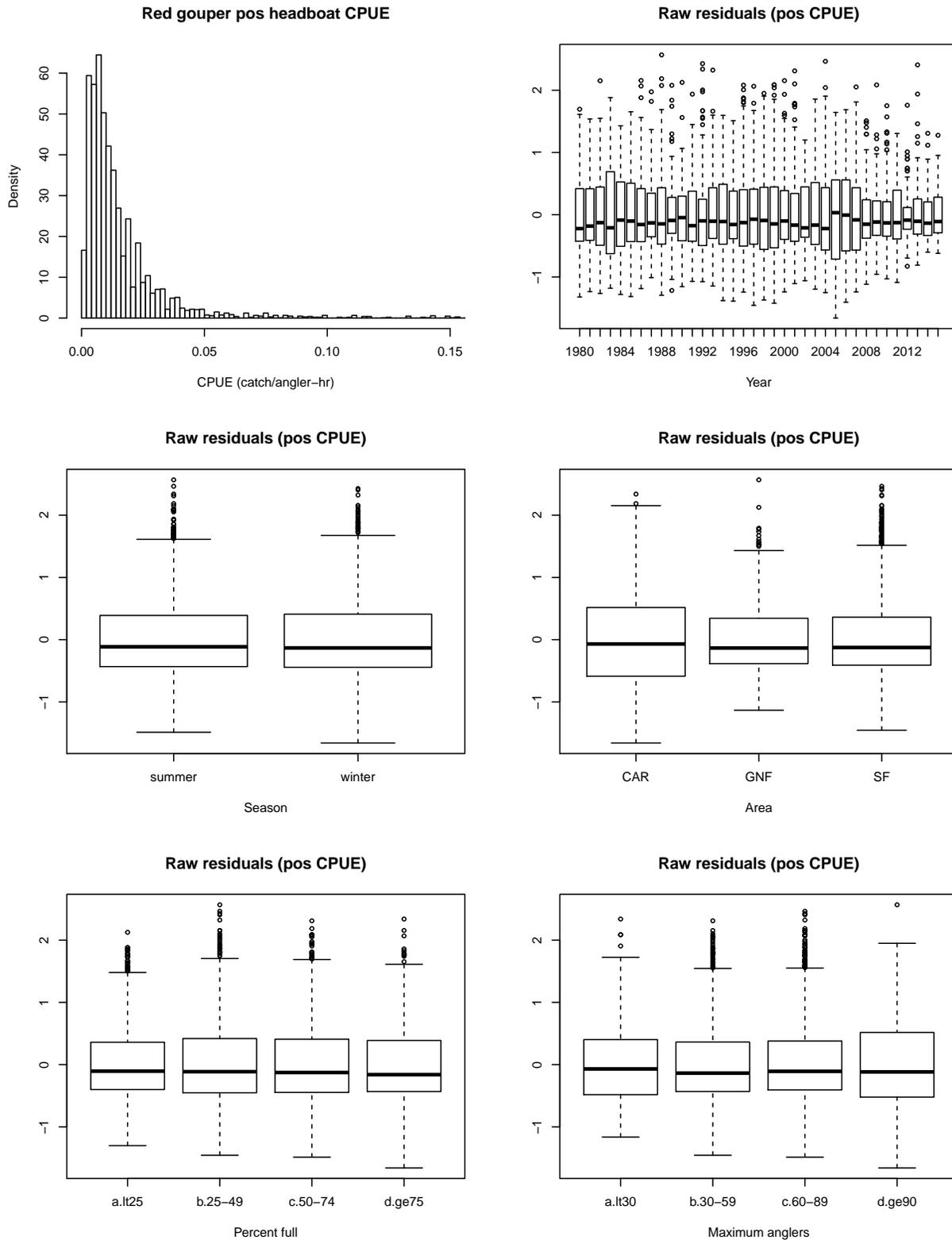


Figure 23: Diagnostics of lognormal submodel fits to positive CPUE data. Top left panel shows the distribution of positive cpue. Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are raw.

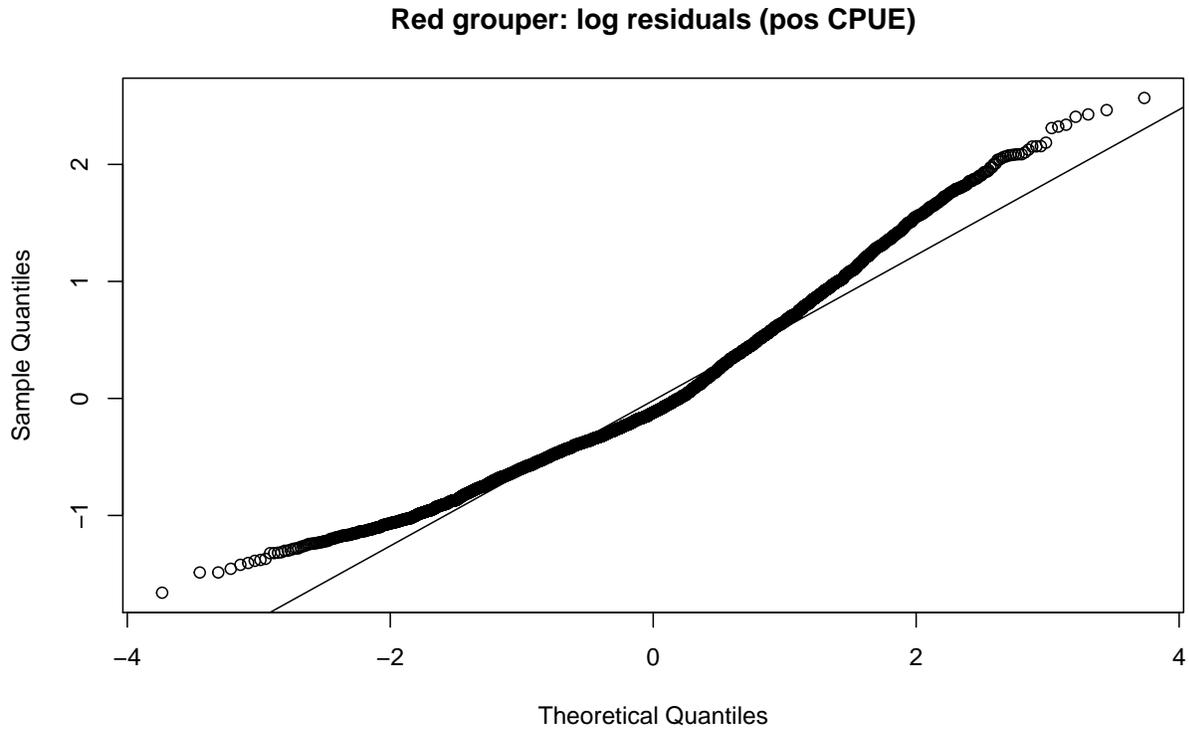
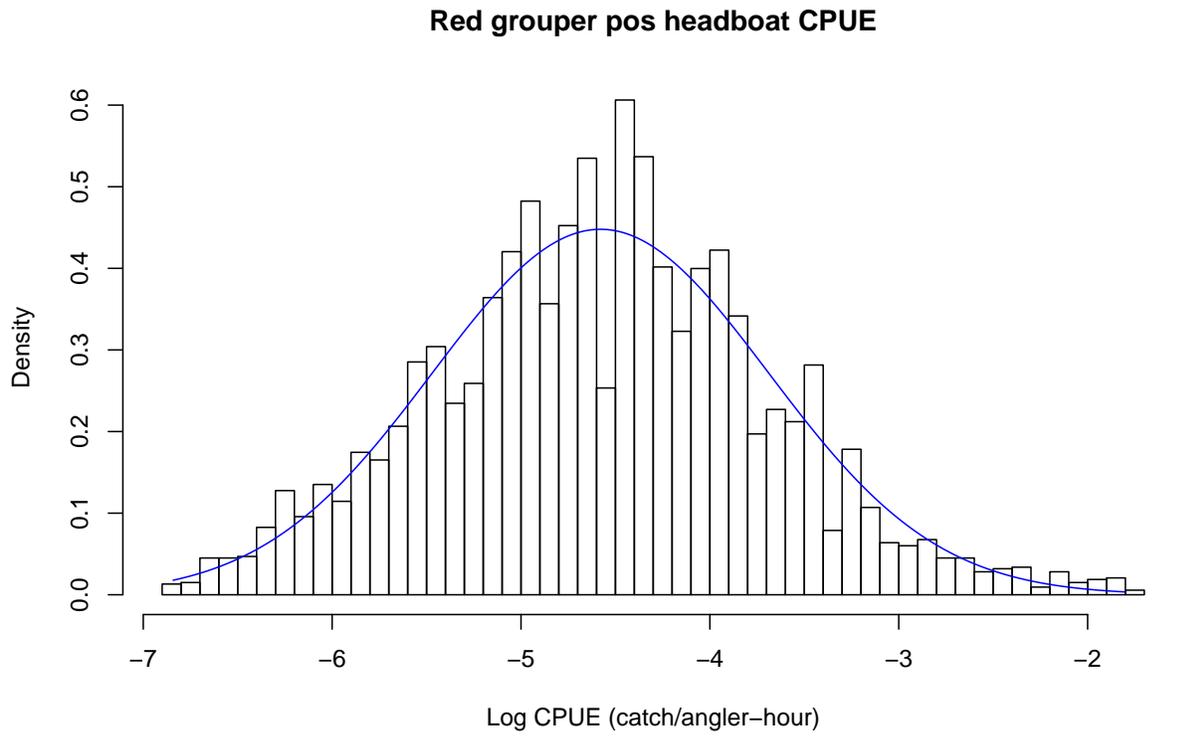


Figure 24: Histogram of empirical log CPUE, with the normal distribution (empirical mean and variance) overlaid. Quantile-quantile plot of residuals from the fitted lognormal submodel to the positive cpue cata.

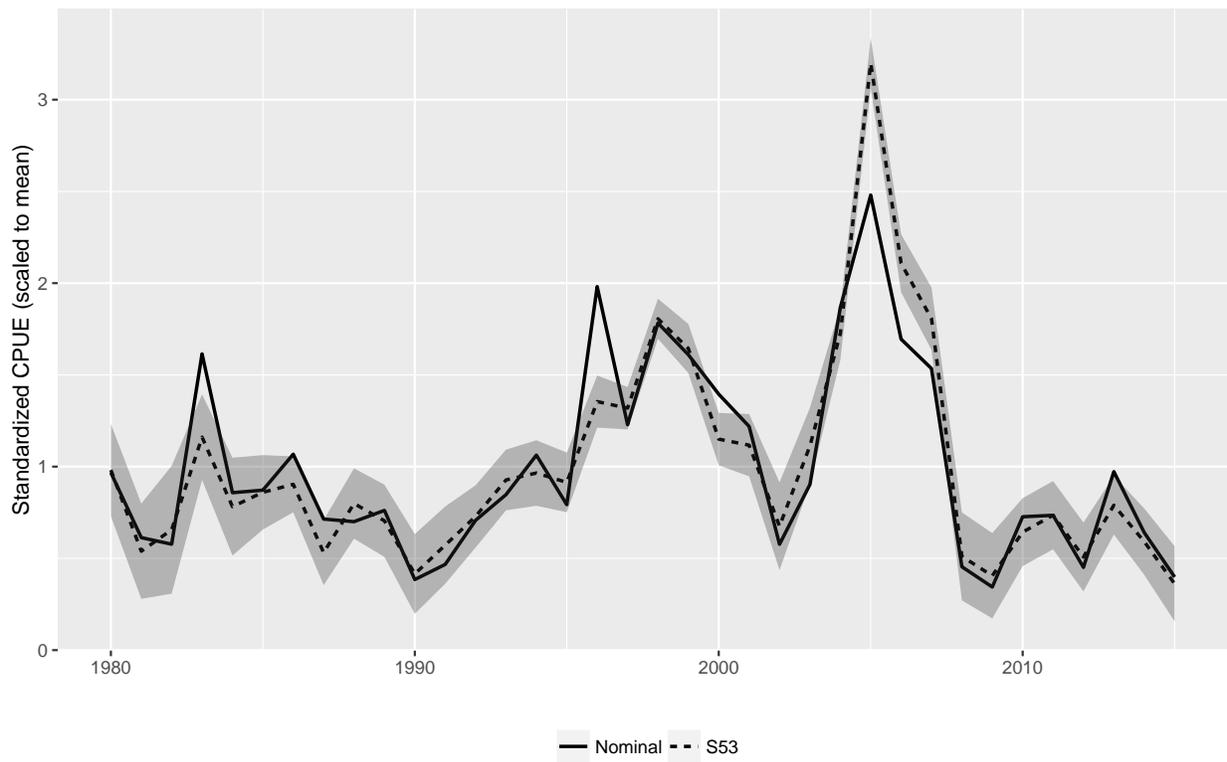


Figure 25: Standardized (dashed) with 95% confidence interval (shaded) and nominal index (solid) red grouper catch rate from headboat logbooks.

Appendix

Results of generalized linear model with Bernoulli response to select species associations with red grouper for the Carolinas.

```
##
## Call: glm(formula = Red.Grouper ~ Tomtate + White.grunt + Whitebone.porgy +
##   Greater.amberjack + Scamp + Rock.Hind + Knobbed.porgy + Scup +
##   Red.Hind, family = "binomial", data = n.sp.mat.trim)
##
## Coefficients:
##   (Intercept)          Tomtate      White.grunt
##   -1.73287         -0.49506         0.30901
##   Whitebone.porgy  Greater.amberjack      Scamp
##   -0.06817         -0.33868         0.27789
##   Rock.Hind      Knobbed.porgy      Scup
##   0.40206         0.14110         -0.13535
##   Red.Hind
##   0.81628
##
## Degrees of Freedom: 27599 Total (i.e. Null);  27590 Residual
## Null Deviance:      26610
## Residual Deviance: 25620      AIC: 25640
```

Results of generalized linear model with Bernoulli response to select species associations with red grouper for the Georgia-N.Florida.

```
##
## Call: glm(formula = Red.Grouper ~ Tomtate + Whitebone.porgy + Greater.amberjack +
##   Scamp + Gray.snapper + Lane.snapper + Almaco.jack, family = "binomial",
##   data = m.sp.mat.trim)
##
## Coefficients:
##   (Intercept)          Tomtate      Whitebone.porgy
##   -2.7388         -0.1186         -0.1921
##   Greater.amberjack      Scamp      Gray.snapper
##   -0.1999         0.8282         0.7239
##   Lane.snapper      Almaco.jack
##   0.3792         -0.2776
##
## Degrees of Freedom: 46537 Total (i.e. Null);  46530 Residual
## Null Deviance:      30560
## Residual Deviance: 29090      AIC: 29100
```

Results of generalized linear model with Bernoulli response to select species associations with red grouper for the S. Florida.

```
##
## Call: glm(formula = Red.Grouper ~ Tomtate + White.grunt + Rock.Hind +
##   Knobbed.porgy + Gray.snapper + Sand.tilefish + Blue.runner +
##   Graysby + Lane.snapper, family = "binomial", data = s.sp.mat.trim)
##
## Coefficients:
```

```
## (Intercept) Tomtate White.grunt Rock.Hind Knobbed.porgy
## -2.59037 -0.07224 0.85705 0.60330 0.91546
## Gray.snapper Sand.tilefish Blue.runner Graysby Lane.snapper
## -0.07246 0.15578 -0.28902 -0.08228 0.10951
##
## Degrees of Freedom: 120451 Total (i.e. Null); 120442 Residual
## Null Deviance: 78150
## Residual Deviance: 73420 AIC: 73440
```

Results of lognormal glm to determine factors.

```
##
## Call: glm(formula = log(cpue) ~ year + zone + season + vsize + pctfact,
## family = gaussian(link = "identity"), data = dat.pos)
##
## Coefficients:
## (Intercept) year1981 year1982 year1983
## -3.22134 -0.08664 0.07016 0.28705
## year1984 year1985 year1986 year1987
## 0.08719 0.03304 -0.07839 -0.18340
## year1988 year1989 year1990 year1991
## -0.02817 -0.14428 -0.16613 -0.05183
## year1992 year1993 year1994 year1995
## -0.09111 0.07030 0.19509 0.06595
## year1996 year1997 year1998 year1999
## 0.14103 0.13402 0.26785 0.18353
## year2000 year2001 year2002 year2003
## 0.06834 0.07407 0.02801 0.08013
## year2004 year2005 year2006 year2007
## 0.21970 0.64918 0.40468 0.26066
## year2008 year2009 year2010 year2011
## -0.06704 -0.14532 -0.09881 -0.08411
## year2012 year2013 year2014 year2015
## -0.12461 -0.07089 -0.01776 -0.06605
## zoneGNF zoneSF seasonwinter vsizeb.30-59
## -0.52073 0.22555 0.09661 -0.66027
## vsizec.60-89 vsized.ge90 pctfactb.25-49 pctfactc.50-74
## -1.09922 -1.23752 -0.53483 -1.06379
## pctfactd.ge75
## -1.37786
##
## Degrees of Freedom: 5327 Total (i.e. Null); 5283 Residual
## Null Deviance: 4228
## Residual Deviance: 2231 AIC: 10570
```

Results of gamma glm to determine factors.

```
##
## Call: glm(formula = cpue ~ year + zone + season + vsize + pctfact,
## family = Gamma(link = "log"), data = dat.pos)
##
## Coefficients:
## (Intercept) year1981 year1982 year1983
```

```

##      -2.979264      -0.218141      0.095666      0.390902
##      year1984      year1985      year1986      year1987
##      0.060409      0.008350      -0.081370      -0.280581
##      year1988      year1989      year1990      year1991
##      0.025484      -0.219358      -0.235461      -0.132254
##      year1992      year1993      year1994      year1995
##      -0.057889      0.030489      0.153864      -0.024938
##      year1996      year1997      year1998      year1999
##      0.158440      0.083422      0.254929      0.150983
##      year2000      year2001      year2002      year2003
##      0.003798      0.069518      -0.091175      0.033730
##      year2004      year2005      year2006      year2007
##      0.305224      0.629490      0.371297      0.259131
##      year2008      year2009      year2010      year2011
##      -0.177917      -0.282294      -0.225438      -0.236408
##      year2012      year2013      year2014      year2015
##      -0.302468      -0.192367      -0.181854      -0.254669
##      zoneGNF      zoneSF      seasonwinter      vsizeb.30-59
##      -0.694674      0.135974      0.130634      -0.542513
##      vsizec.60-89      vsized.ge90      pctfactb.25-49      pctfactc.50-74
##      -1.019588      -1.154153      -0.515645      -1.049624
##      pctfactd.ge75
##      -1.353076
##
## Degrees of Freedom: 5327 Total (i.e. Null); 5283 Residual
## Null Deviance: 4409
## Residual Deviance: 2530 AIC: -37130

```

Results of binomial glm to determine factors.

```

##
## Call: glm(formula = cpue ~ year + zone + season + vsize + pctfact,
##          family = "binomial", data = dat.bin)
##
## Coefficients:
##      (Intercept)      year1981      year1982      year1983
##      -0.936438      -0.677902      -0.628936      -0.168320
##      year1984      year1985      year1986      year1987
##      -0.428403      -0.231082      -0.005908      -0.575999
##      year1988      year1989      year1990      year1991
##      -0.247613      -0.260205      -0.896558      -0.647188
##      year1992      year1993      year1994      year1995
##      -0.286623      -0.178991      -0.293859      -0.192664
##      year1996      year1997      year1998      year1999
##      0.274477      0.243238      0.543904      0.526611
##      year2000      year2001      year2002      year2003
##      0.133406      0.081161      -0.540197      0.066425
##      year2004      year2005      year2006      year2007
##      0.548388      0.910794      0.576236      0.556779
##      year2008      year2009      year2010      year2011
##      -0.767398      -0.948945      -0.440749      -0.284296
##      year2012      year2013      year2014      year2015
##      -0.705319      -0.205714      -0.648527      -1.174000
##      zoneGNF      zoneSF      seasonwinter      vsizeb.30-59

```

```
##      -0.317946      0.013108      0.719356      -0.435943
##  vsizec.60-89    vsized.ge90  pctfactb.25-49  pctfactc.50-74
##      -0.355915      -0.260925      0.160178      0.210345
##  pctfactd.ge75
##      0.185387
##
## Degrees of Freedom: 20299 Total (i.e. Null); 20255 Residual
## Null Deviance:      23370
## Residual Deviance: 21960      AIC: 22050
```

Results of lognormal delta glm to compare models.

```
## $error.distribution
## [1] "Lognormal distribution assumed for positive observations."
##
## $binomial.formula
## [1] "Formula for binomial GLM: cpue ~ year + zone + vsize + pctfact + season"
##
## $positive.formula
## [1] "Formula for gaussian GLM: log(cpue) ~ year + zone + vsize + pctfact + season"
##
## $deltaGLM.index
##      index jackknife
## 1980 0.003258237      NA
## 1981 0.001789508      NA
## 1982 0.002178090      NA
## 1983 0.003853750      NA
## 1984 0.002596269      NA
## 1985 0.002855163      NA
## 1986 0.003000289      NA
## 1987 0.001763663      NA
## 1988 0.002653007      NA
## 1989 0.002340208      NA
## 1990 0.001378344      NA
## 1991 0.001899715      NA
## 1992 0.002419865      NA
## 1993 0.003078813      NA
## 1994 0.003204295      NA
## 1995 0.003035065      NA
## 1996 0.004497124      NA
## 1997 0.004378290      NA
## 1998 0.005996028      NA
## 1999 0.005457420      NA
## 2000 0.003817969      NA
## 2001 0.003708346      NA
## 2002 0.002241840      NA
## 2003 0.003693996      NA
## 2004 0.005728589      NA
## 2005 0.010620055      NA
## 2006 0.007000929      NA
## 2007 0.005996355      NA
## 2008 0.001695602      NA
## 2009 0.001346111      NA
## 2010 0.002135080      NA
```

```

## 2011 0.002441111      NA
## 2012 0.001684682      NA
## 2013 0.002621754      NA
## 2014 0.001963411      NA
## 2015 0.001199244      NA
##
## $pos.effects
## $pos.effects[[1]]
##      CAR      GNF      SF
## 0.012217805 0.007258471 0.015309101
##
## $pos.effects[[2]]
##      a.lt30      b.30-59      c.60-89      d.ge90
## 0.02342389 0.01210336 0.00780322 0.00679535
##
## $pos.effects[[3]]
##      a.lt25      b.25-49      c.50-74      d.ge75
## 0.023303924 0.013650754 0.008043246 0.005875349
##
## $pos.effects[[4]]
##      summer      winter
## 0.01055079 0.01162092
##
##
## $bin.effects
## $bin.effects[[1]]
##      CAR      GNF      SF
## 0.2901409 0.2292333 0.2928480
##
## $bin.effects[[2]]
##      a.lt30      b.30-59      c.60-89      d.ge90
## 0.3245112 0.2370250 0.2518006 0.2701145
##
## $bin.effects[[3]]
##      a.lt25      b.25-49      c.50-74      d.ge75
## 0.2431862 0.2738629 0.2839513 0.2789043
##
## $bin.effects[[4]]
##      summer      winter
## 0.2048927 0.3460077
##
##
## $data.filter
## [1] "Data filter threshold set at 2 positive observations."
##
## $levels.deleted.by.filter
## $levels.deleted.by.filter$year
## [1] NA
##
## $levels.deleted.by.filter$zone
## [1] NA
##
## $levels.deleted.by.filter$vsize
## [1] NA

```

```
##
## $levels.deleted.by.filter$pctfact
## [1] NA
##
## $levels.deleted.by.filter$season
## [1] NA
##
##
## $aic
##
##           [,1]
## AIC.binomial  2.205023e+04
## AIC.lognormal -3.822374e+04
## sigma.mle     6.470514e-01
```

Results of gamma delta glm to compare models.

```
## $error.distribution
## [1] "Gamma distribution assumed for positive observations."
##
## $binomial.formula
## [1] "Formula for binomial GLM: cpue ~ year + zone + vsize + pctfact + season"
##
## $positive.formula
## [1] "Formula for Gamma GLM: cpue ~ year + zone + vsize + pctfact + season"
##
## $deltaGLM.index
##           index jackknife
## 1980 0.011011341      NA
## 1981 0.008853250      NA
## 1982 0.012116785      NA
## 1983 0.016278212      NA
## 1984 0.011697028      NA
## 1985 0.011103674      NA
## 1986 0.010150828      NA
## 1987 0.008317357      NA
## 1988 0.011295559      NA
## 1989 0.008842481      NA
## 1990 0.008701230      NA
## 1991 0.009647240      NA
## 1992 0.010392006      NA
## 1993 0.011352239      NA
## 1994 0.012842887      NA
## 1995 0.010740136      NA
## 1996 0.012901787      NA
## 1997 0.011969336      NA
## 1998 0.014208710      NA
## 1999 0.012805941      NA
## 2000 0.011053245      NA
## 2001 0.011804059      NA
## 2002 0.010051788      NA
## 2003 0.011389089      NA
## 2004 0.014941614      NA
## 2005 0.020664462      NA
## 2006 0.015962190      NA
```

```

## 2007 0.014268535      NA
## 2008 0.009216627      NA
## 2009 0.008303123      NA
## 2010 0.008788882      NA
## 2011 0.008692999      NA
## 2012 0.008137293      NA
## 2013 0.009084405      NA
## 2014 0.009180405      NA
## 2015 0.008535693      NA
##
## $pos.effects
## $pos.effects[[1]]
##      CAR      GNF      SF
## 0.013225131 0.006602475 0.015151394
##
## $pos.effects[[2]]
##      a.lt30      b.30-59      c.60-89      d.ge90
## 0.021648771 0.012584124 0.007809655 0.006826389
##
## $pos.effects[[3]]
##      a.lt25      b.25-49      c.50-74      d.ge75
## 0.022770629 0.013596688 0.007971303 0.005884934
##
## $pos.effects[[4]]
##      summer      winter
## 0.01028378 0.01171890
##
##
## $bin.effects
## $bin.effects[[1]]
## CAR GNF SF
## 1 1 1
##
## $bin.effects[[2]]
## a.lt30 b.30-59 c.60-89 d.ge90
## 1 1 1 1
##
## $bin.effects[[3]]
## a.lt25 b.25-49 c.50-74 d.ge75
## 1 1 1 1
##
## $bin.effects[[4]]
## summer winter
## 1 1
##
##
## $data.filter
## [1] "Data filter threshold set at 2 positive observations."
##
## $levels.deleted.by.filter
## $levels.deleted.by.filter$year
## [1] NA
##
## $levels.deleted.by.filter$zone

```

```
## [1] NA
##
## $levels.deleted.by.filter$vsize
## [1] NA
##
## $levels.deleted.by.filter$pctfact
## [1] NA
##
## $levels.deleted.by.filter$season
## [1] NA
##
##
## $aic
##                                [,1]
## AIC.binomial          90.000000
## AIC.gamma            -37147.901513
## shape.mle              2.258177
```

References

- Dick, E.J. 2004. "Beyond Lognormal Versus Gamma: Discrimination Among Error Distributions for Generalized Linear Models." *Fisheries Research* 70: 351–66.
- Efron, B., and R. Tibshirani. 1993. *An Introduction to the Bootstrap*. London: Chapman; Hall.
- Lo, N., Jacobson L., and Squire J. 1992. "Indices of Relative Abundance from Fish Spotter Data Based on Delta-Lognormal Models." *Canadian Journal of Fisheries and Aquatic Sciences* 49: 2515–26.
- Maunder, M., and A. Punt. 2004. "Standardizing Catch and Effort Data: A Review of Recent Approaches." *Fisheries Research* 70: 141–59.
- Shertzer, E., K., E. Williams, and Taylor J. 2009. "Spatial Structure and Temporal Patterns in a Large Marine Ecosystem: Exploited Reef Fishes of the Southeast United States." *Fisheries Research* 100: 126–33.
- Stephens, A., and MacCall A. 2004. "A Multispecies Approach to Subsetting Logbook Data for Purposes of Estimating CPUE." *Fisheries Research* 70: 299–310.
- Venables, W. N., and B. D. Ripley. 1997. *Modern Applied Statistics with S-Plus, 2nd Edition*. New York, New York: Springer-Verlag.