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

Sustainable Fisheries Branch*

May 2023

This document describes the SEDAR 86 update to the SEDAR 53 commercial logbook handline index for red grouper.

Commercial Fisheries Logbook Program (CFLP) overview

Landings and fishing effort of commercial vessels operating in the southeast U.S. Atlantic have been monitored by the NMFS Southeast Fisheries Science Center through the Coastal Fisheries Logbook Program (CFLP). The program collects information about each fishing trip from all vessels holding federal permits to fish in waters managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. Initiated in the Gulf in 1990, the CFLP began collecting logbooks from Atlantic commercial fishers in 1992, when 20% of Florida vessels were targeted. Beginning in 1993, sampling in Florida was increased to require reports from all vessels permitted in coastal fisheries, and since then has maintained the objective of a complete census of federally permitted vessels in the southeast U.S.

Catch per unit effort (CPUE) from the logbooks was used to develop an index of abundance for red grouper landed with vertical lines (manual handline and electric reel), the dominant gear for this red grouper stock (Tables 1 and 2). Thus, the size and age range of fish included in the index is the same as that of landings from this same fleet.

For each fishing trip, the CFLP database included a unique trip identifier, the landing date, fishing gear deployed, areas fished, number of days at sea, number of crew, gear-specific fishing effort, species caught, and weight of the landings. Fishing effort data available for vertical line gear (manual and electric) included number of lines fished, hours fished, and number of hooks per line.

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. Outliers in the data used as factors in the model or to calculate cpue. Values falling outside the 99.5 percentile of the data were excluded from the analyses. For trip-level data (crew, days at sea, hours fished, number of lines, and number of hooks per line) all snapper-grouper trips were evaluated. Positive red grouper trips were evaluated for outliers in red grouper cpue (Table 3).

2. Other data exclusions and assumptions (delayed reporting, multiple gears, area reported)

Data were restricted to include only those trips with landings and effort data reported within 45 days of the completion of the trip (some reporting delays were longer than one year). Reporting delays beyond 45 days likely resulted in less reliable effort data (landings data may be reliable even with lengthy reporting delays if trip ticket reports were referenced by the reporting fisher). Also excluded were records reporting

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multiple gears fished, which prevents designating catch and effort to specific gears. Therefore, only trips which reported one gear fished were included in these analyses. For records where more than one area was reported, the first area reported was used to determine the latitude associated with the trip.

3. Starting year

The CFLP began in 1992 with complete coverage beginning in 1993. 1993 was chosen as the starting year.

4.Terminal year - spawning closure, commercial closures due to gag quota

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 2). Removing trips from these months allows us to extend the headboat logbook index until the terminal year of the assessment (2017). In 2012 commercial red grouper closed due to gag meeting quotas temporarily in October(21-31), then re-opened on November 1st and closed for the remainder of the year on November 22nd, 2012. The terminal year was set to 2017 with the removal of all trips from January to April across all years. Additionally, quotas decreased from 343,200 lbs in 2017 to 61,000 lbs in 2018.

Evaluation of explanatory variables

YEAR – Year was necessarily included, as standardized catch rates by year are the desired. Years modeled were 1993-2017. The total number of red grouper trips by year is provided in table 1 and reported catch per year is provided in table 2.

SEASON – Season included two levels: summer (May - August) and fall (September-December). The density of trips by month with associated season factor is shown in Figure 3.

AREA – Areas reported in the logbook on a one degree grid (Figure 1). The majority of the positive trips and catch for commercial handline is in the Carolinas (Figures 4 and 5). The coast was divided into two areas split at 29 degrees Latitude near Cape Canaveral, FL (Figure 3).

DAYS AT SEA – Days at sea (sea days) were pooled into three levels: one day (one), two to four days (twotofour), and five or more days (fiveplus). Figure 3

CREW SIZE – Crew size (includes Captain) could influence the total effort during and could be a psuedo-factor for vessel size. The quartile split values (at 25, 50, and 75%) for red grouper crew size fall at 2, 2, and 3 crew per trip. Crew size factor was fixed at three levels: one (one), two (two), and three or more crew (threeplus). Figure 3 shows the density of trips associated with each crew size.

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 (CAR), Georgia-N.Florida (GNF), and S. Florida (SF) 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 MacCall (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 Taylor 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 5% or more of trips for CAR and GNF and 2% for SF. SF had too few species at a cutoff of 5% (6 species). However, the cutoff values had little influence on the trips selected because the species with the highest probabilities (positive and negative) were always included. Species with management closures were also omitted because the potential for erroneously removing trips likely to have caught red grouper during years of restrictions.

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 eliminated banded rudderfish, bluestripped grunt, and lesser amberjack; for the GNF sampling area, it eliminated greater amberjack, jolthead porgy, and knobbed porgy; for the SF sampling area, it eliminated gray snapper. Regression coefficients of included species for all areas are given in Appendix 1 and shown in figure 7. A trip was then included if its associated probability of catching red grouper was higher than a threshold probability (Figure 7). 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).

Standardization

CPUE was modeled using the delta-GLM approach (Lo, Jacobson, and Squire 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 eiiects, 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 standardized (quantile) residuals, suggested reasonable fits of the Bernoulli submodel (Figure 8).

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 9 and 10).

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 11). The increase in the error since 2010 may be due to the lower proportion of positive catches.

Table 1: Commercial logbook red grouper trips by gear.

	Diving	Handline	Other
1993	113	1488	33
1994	156	1922	36
1995	167	2343	68
1996	185	2746	44
1997	281	3110	54
1998	315	3292	143
1999	215	2864	93
2000	195	2587	87
2001	236	2564	74
2002	284	2610	110
2003	219	2341	115
2004	213	2205	77
2005	220	2120	69
2006	127	2143	59
2007	203	2560	70
2008	141	2456	29
2009	136	2004	11
2010	115	1246	15
2011	182	1263	32
2012	160	920	39
2013	214	807	16
2014	251	806	32
2015	246	589	29
2016	133	574	23
2017	152	584	26

Table 2: Commercial logbook red grouper landings by gear (Thousand pounds).

	Diving	Handline	Other
1993	2.66	87.41	2.45
1994	4.25	106.50	12.30
1995	5.64	180.98	20.50
1996	4.03	182.82	4.76
1997	8.43	244.68	1.89
1998	8.32	285.13	15.87
1999	7.19	326.13	14.37
2000	5.42	301.17	33.66
2001	5.79	260.02	18.61
2002	8.95	271.16	4.80
2003	5.79	259.11	5.37
2004	5.59	215.44	13.89
2005	5.50	184.77	2.52
2006	2.26	300.97	1.82
2007	5.59	530.35	1.88
2008	4.84	566.67	0.58
2009	3.53	360.13	0.18
2010	4.60	292.75	0.26
2011	5.41	205.80	0.44
2012	5.11	120.80	10.06
2013	10.33	90.03	9.06
2014	9.15	70.06	24.66
2015	9.13	55.36	19.64
2016	5.43	34.50	4.09
2017	7.57	29.75	11.19

Table 3: CFLP Handline cutoff values for outliers (records reporting more (upper),or less (lower) were excluded).

	manual	electric
lines fished (upper)	6	6
hooks per line (upper)	8	8
days at sea (upper)	10	12
crew (upper)	5	5
hours fished (lower)	4	4
hours fished (upper)	100	130
cpue (upper)	24	24

Table 4: Nominal and standardized CPUE for red grouper 1980-2017 with CVs for stardardized index of abundance.

Year	N	Nominal.CPUE	Relative.nominal	Standardized.CPUE	CV
1993	1220	0.29	0.29	0.35	0.07
1994	1485	0.35	0.34	0.28	0.08
1995	1599	0.50	0.49	0.53	0.06
1996	1737	0.43	0.43	0.62	0.05
1997	1887	0.61	0.60	0.67	0.05
1998	1781	0.97	0.96	1.09	0.05
1999	1480	1.14	1.12	1.36	0.04
2000	1464	1.07	1.06	1.06	0.05
2001	1557	1.05	1.04	0.91	0.06
2002	1691	1.17	1.16	0.90	0.06
2003	1504	1.13	1.12	1.02	0.06
2004	1302	1.05	1.03	0.90	0.06
2005	1204	1.03	1.02	0.96	0.06
2006	1202	1.52	1.50	1.43	0.06
2007	1549	2.45	2.42	2.31	0.05
2008	1456	2.24	2.21	2.69	0.05
2009	1206	1.36	1.34	1.58	0.05
2010	1166	1.70	1.68	1.79	0.06
2011	1063	1.48	1.46	1.38	0.07
2012	843	0.94	0.93	0.94	0.07
2013	847	0.74	0.73	0.69	0.08
2014	711	0.67	0.66	0.59	0.09
2015	743	0.52	0.51	0.39	0.10
2016	828	0.48	0.47	0.30	0.10
2017	721	0.45	0.44	0.26	0.11

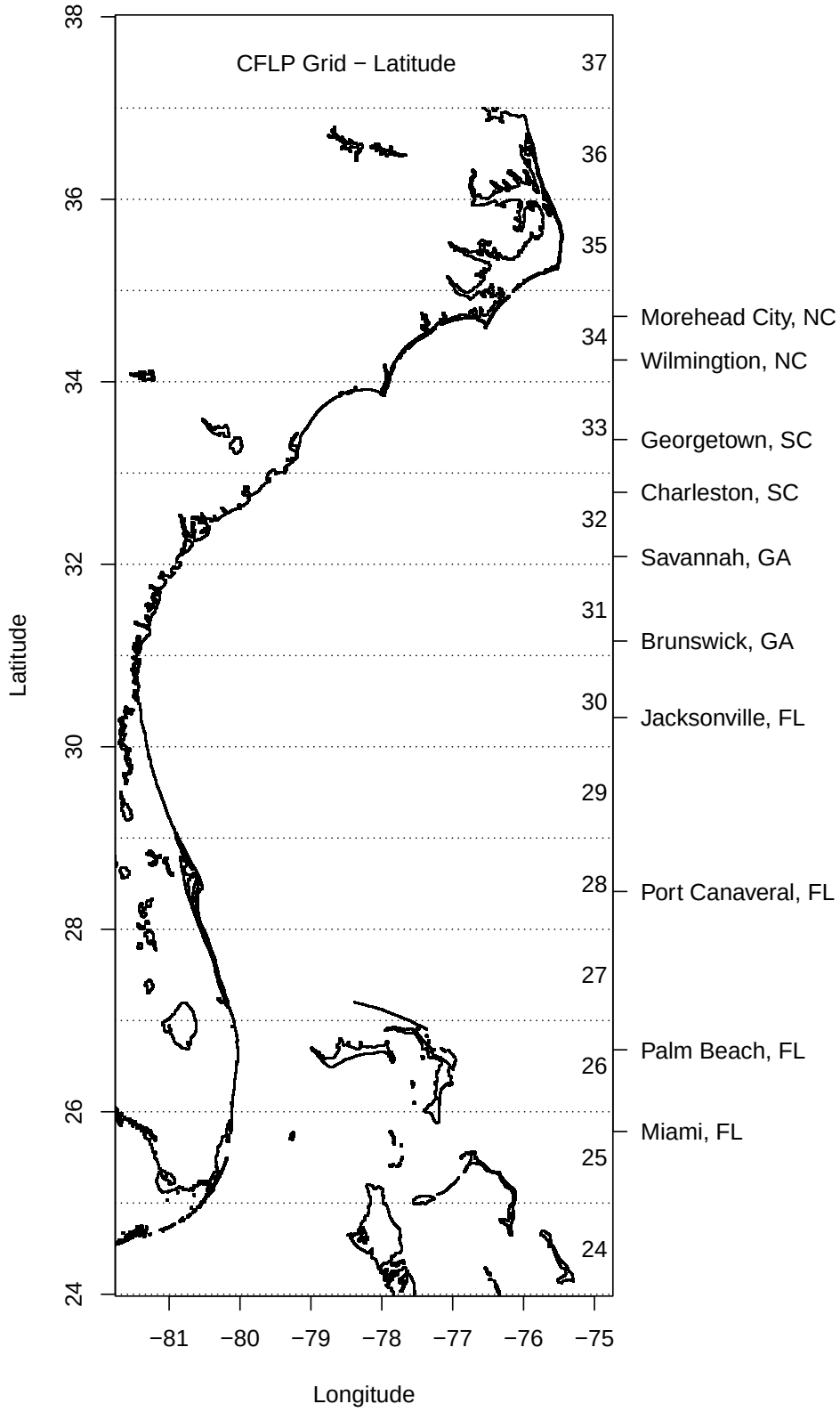

Figure 1: CFLP Latitude Stratification (midpoint of each latitudinal grid is labeled with the floor for the bin).

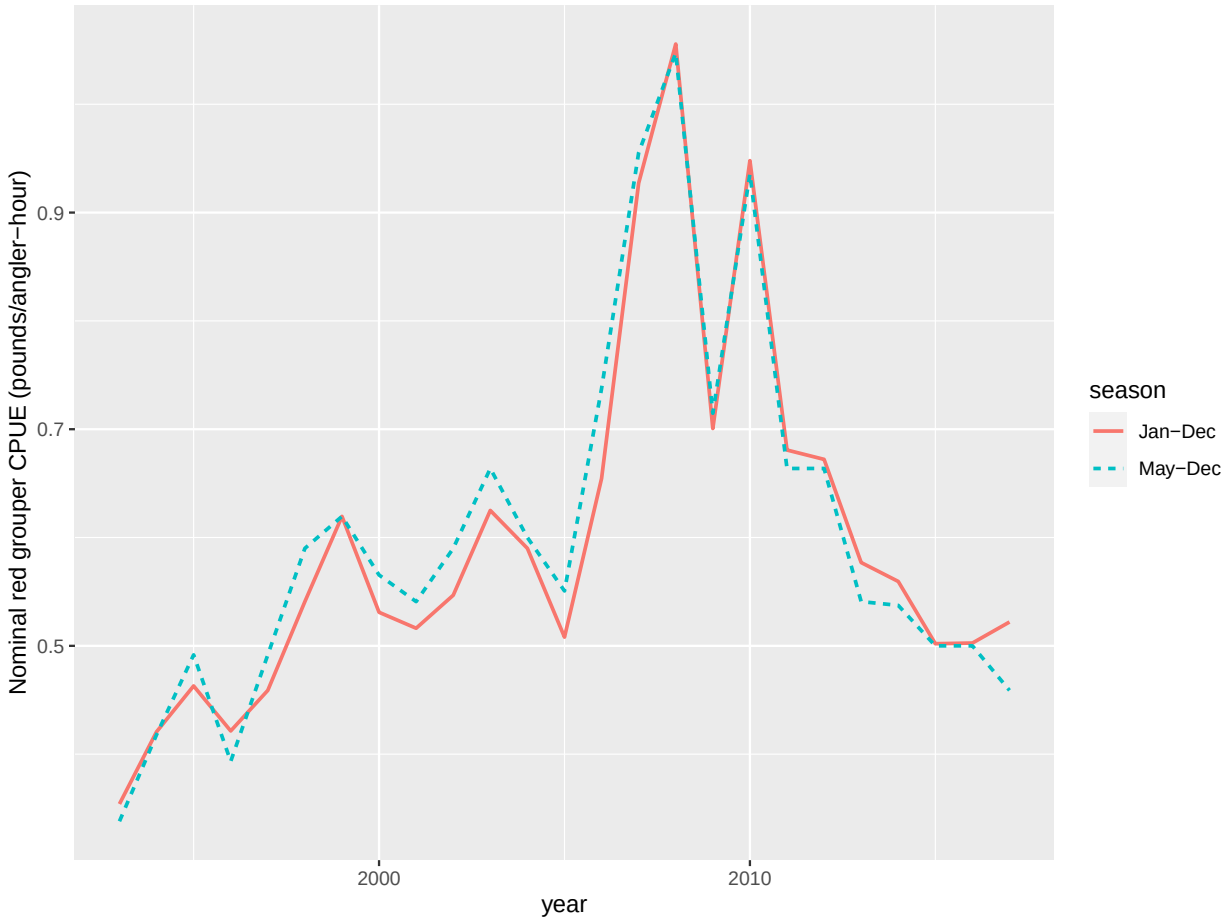

Figure 2: Nominal CPUE for positve red grouper trips with and without the Jan-Apr spawning closure beginning in 2010).

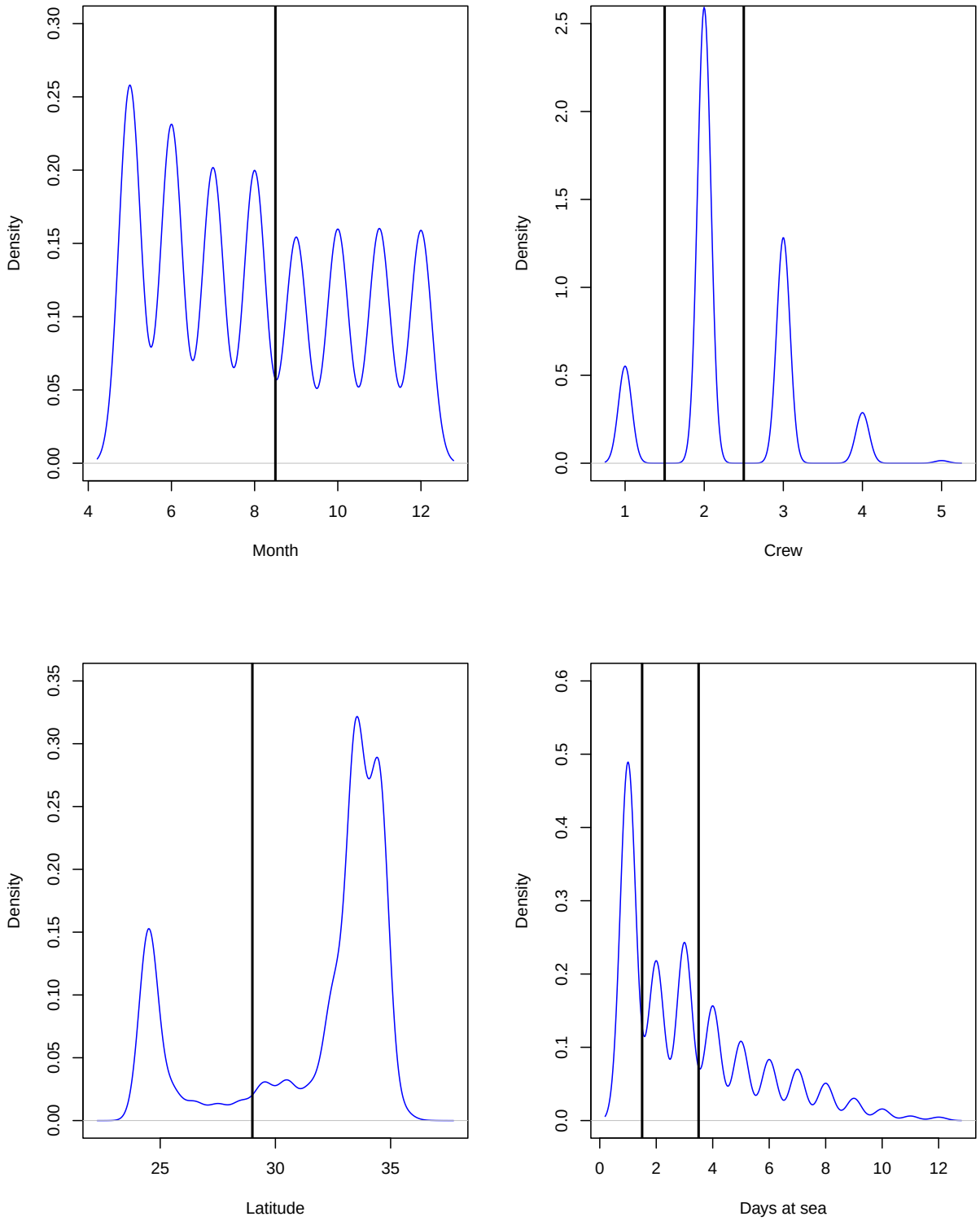

Figure 3: Red grouper handline explanatory variable factorization. Vertical lines represent breaks for factors.

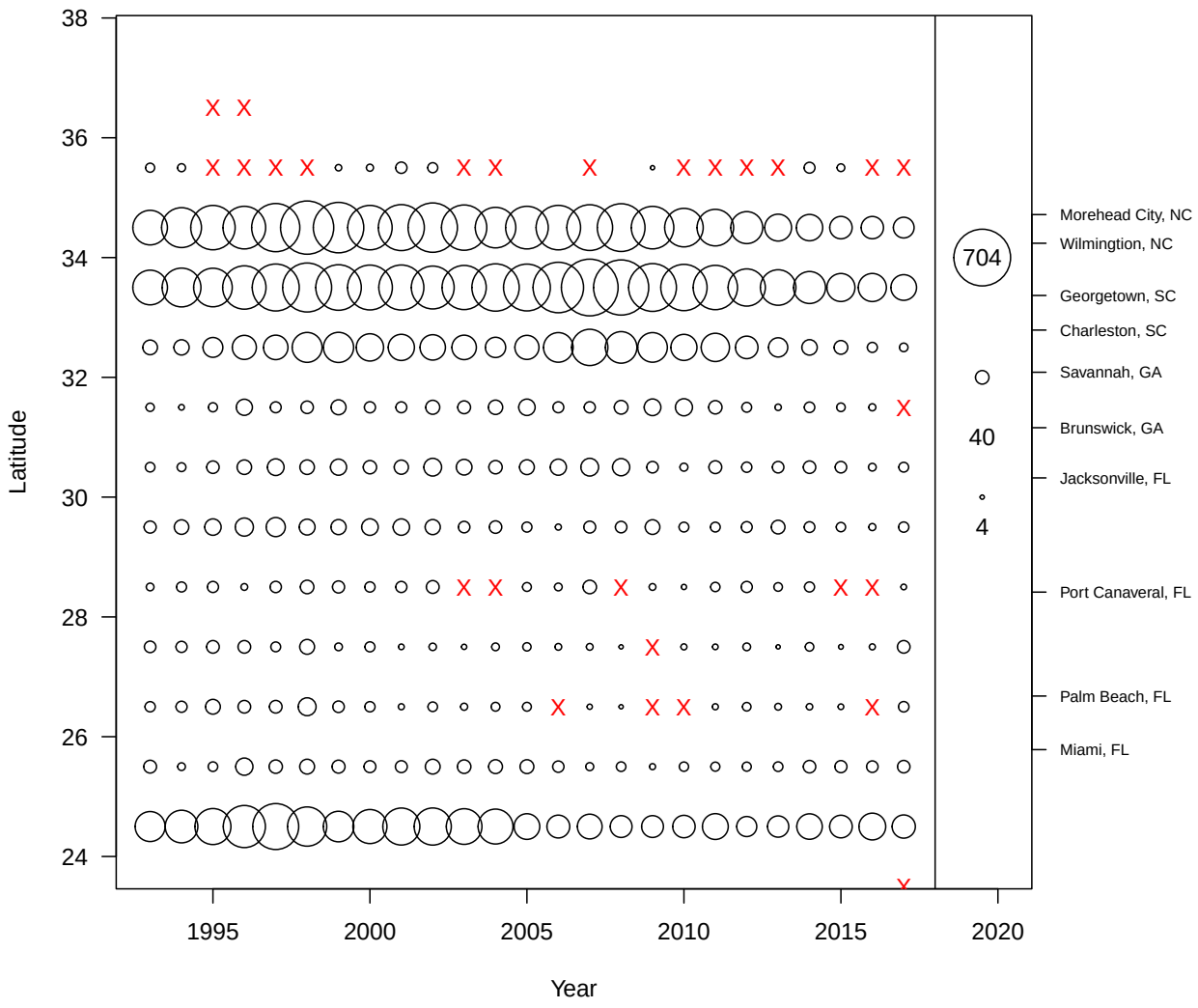

Figure 4: Red grouper handline trips by year and latitude. Symbol size relative to number of trips, 'X' signifies confidential data and represents a small percentage of the total trips.

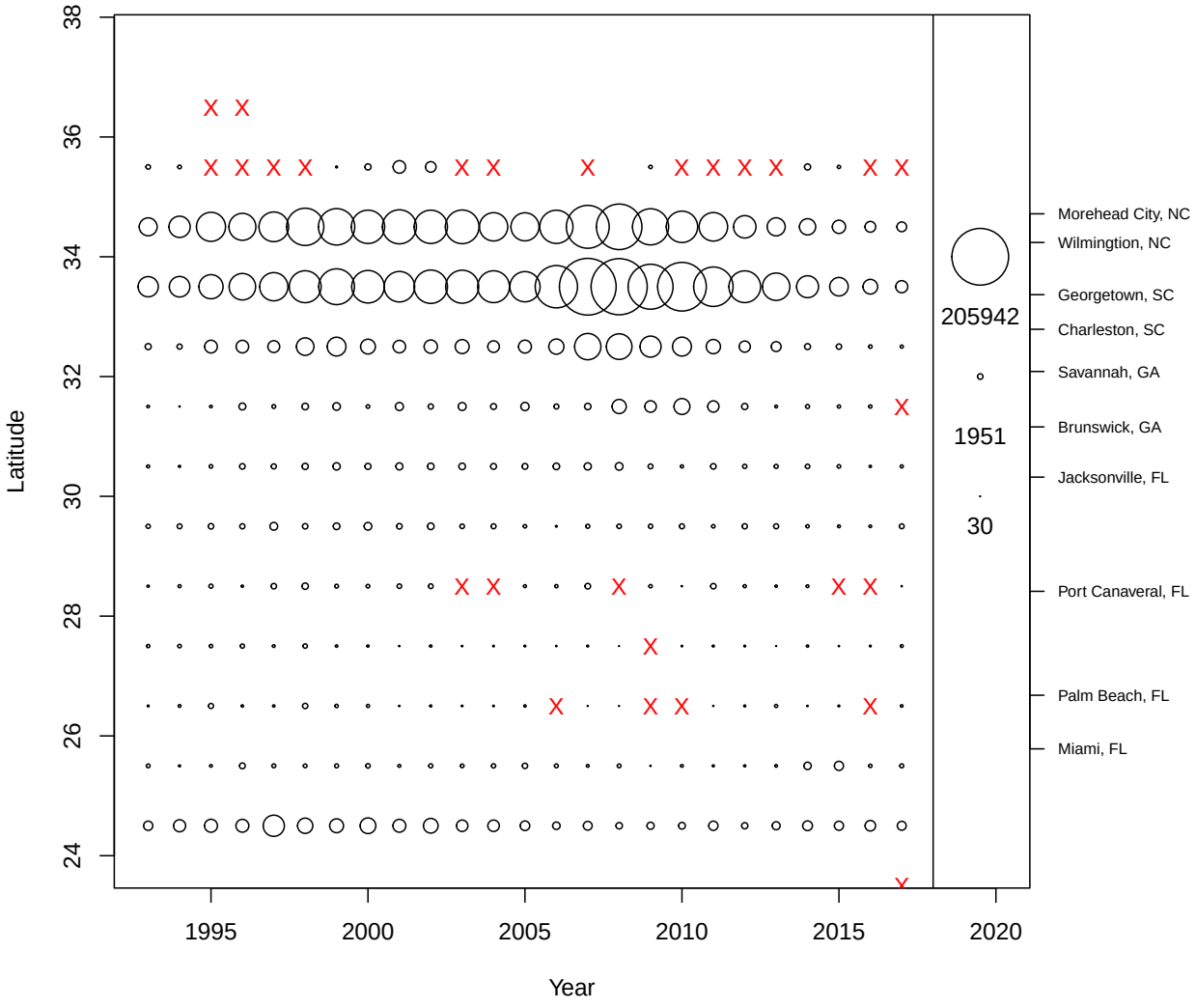

Figure 5: Red grouper handline catch (whole pounds) by year and latitude. Symbol size relative to catch, 'X' signifies confidential data and represents a small percentage of the total catch.

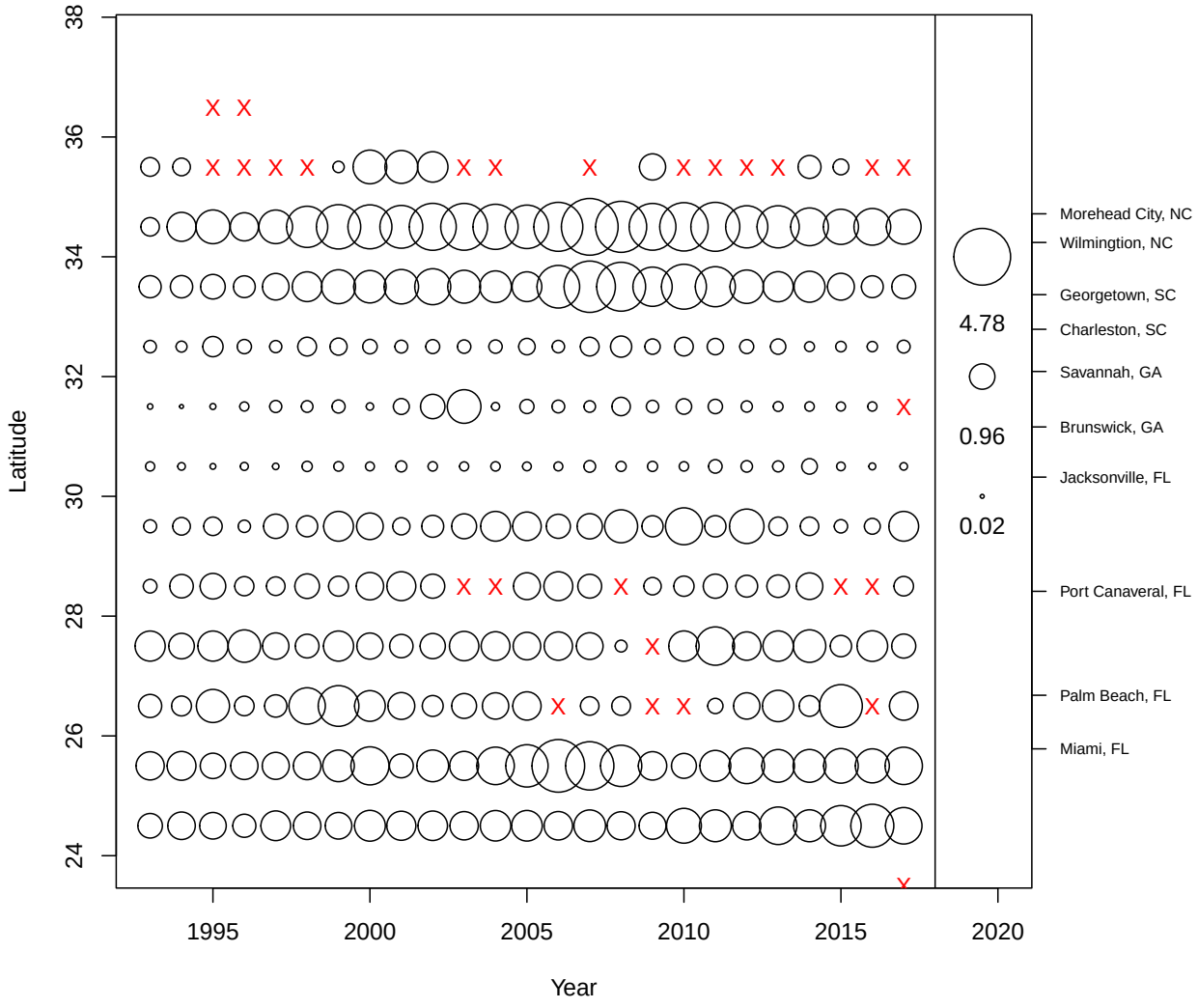

Figure 6: Red snapper handline mean cpue (whole pounds/hook-hour) by year and latitude. Symbol size relative to cpue, 'X' signifies confidential data and represents a small percentage of the total records.

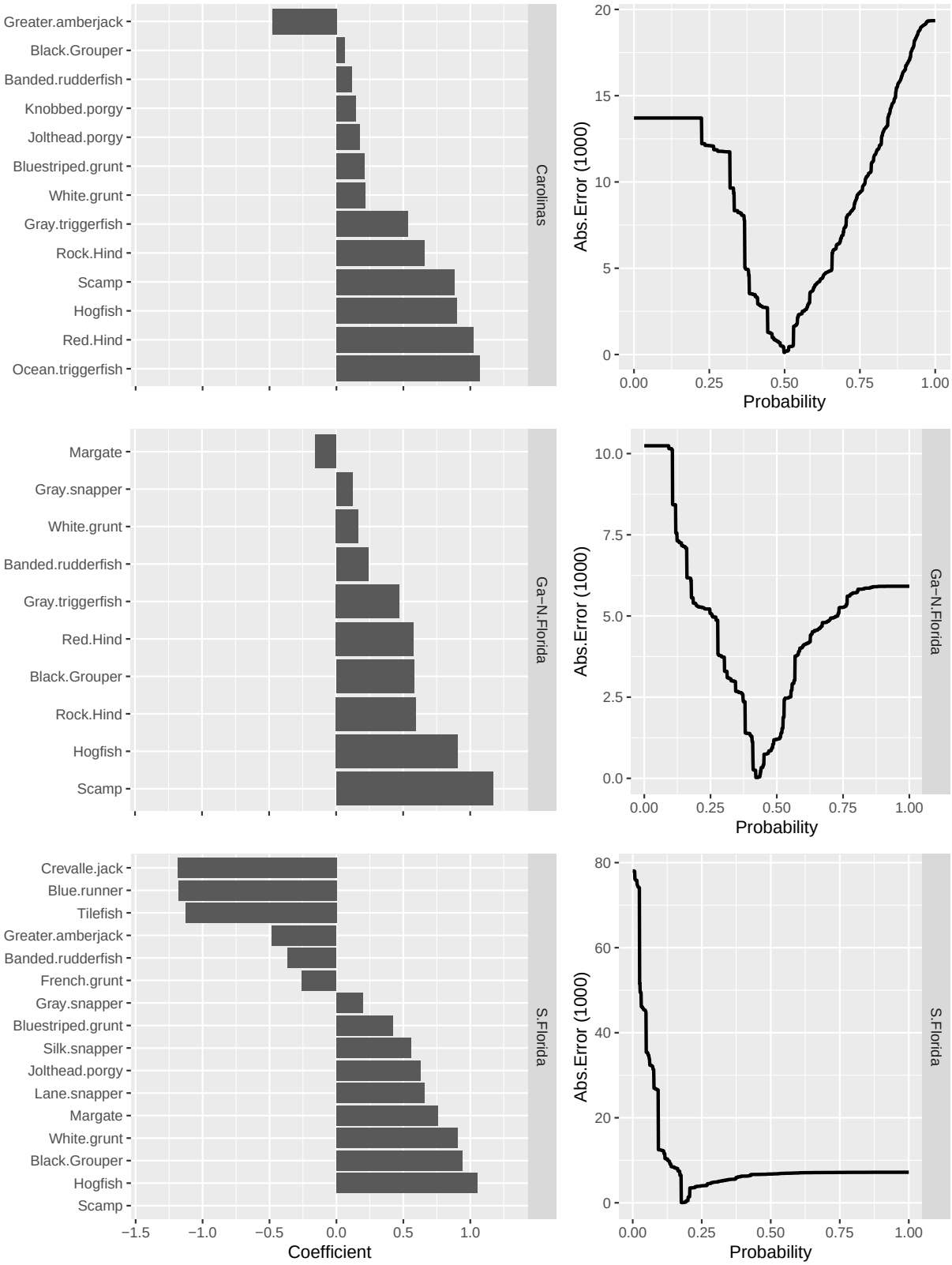

Figure 7: Estimates of species-specific regression coefficients used to predict each trip's probability of catching the focal species on the left panel. The right panel shows the absolute difference between observed and predicted number of positive trips across a range of probability cutoff values.

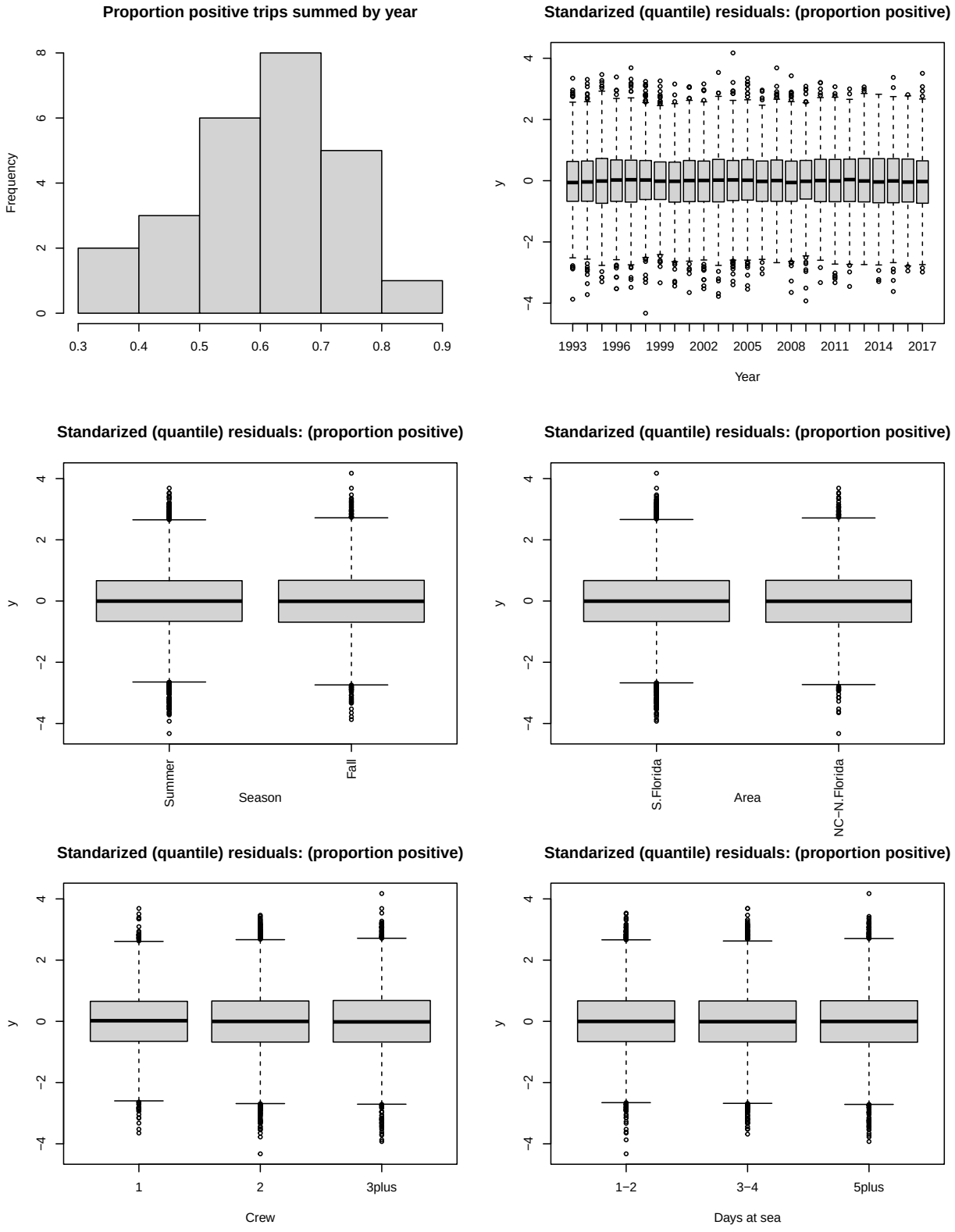

Figure 8: Diagnostics of Bernoulli submodel fits to positive versus zero CPUE data. Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are standardized (quantile) residuals.

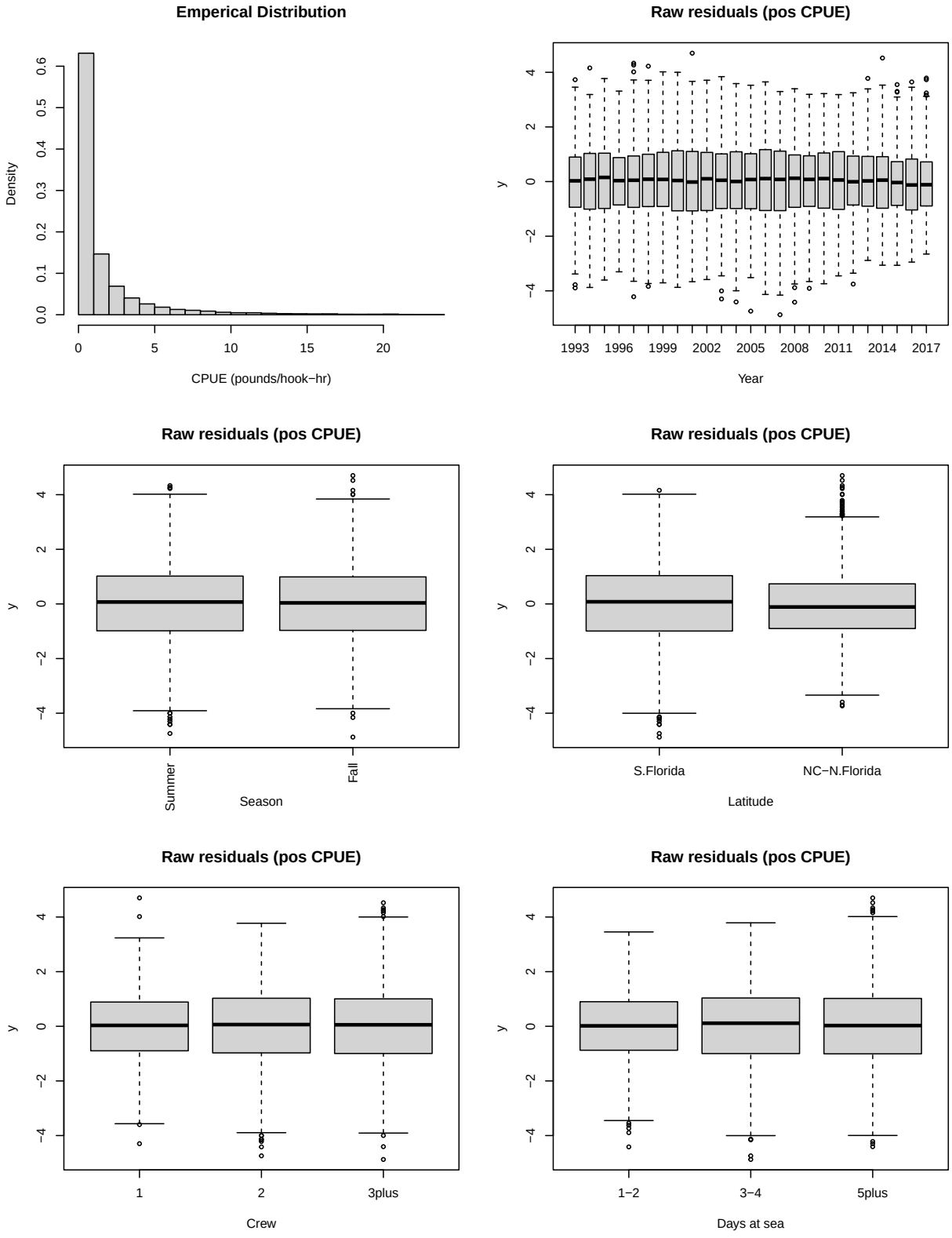

Figure 9: Diagnostics of lognormal submodel fits to positive CPUE data. Top left panel shows the distribution of positive cpue. Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are raw.

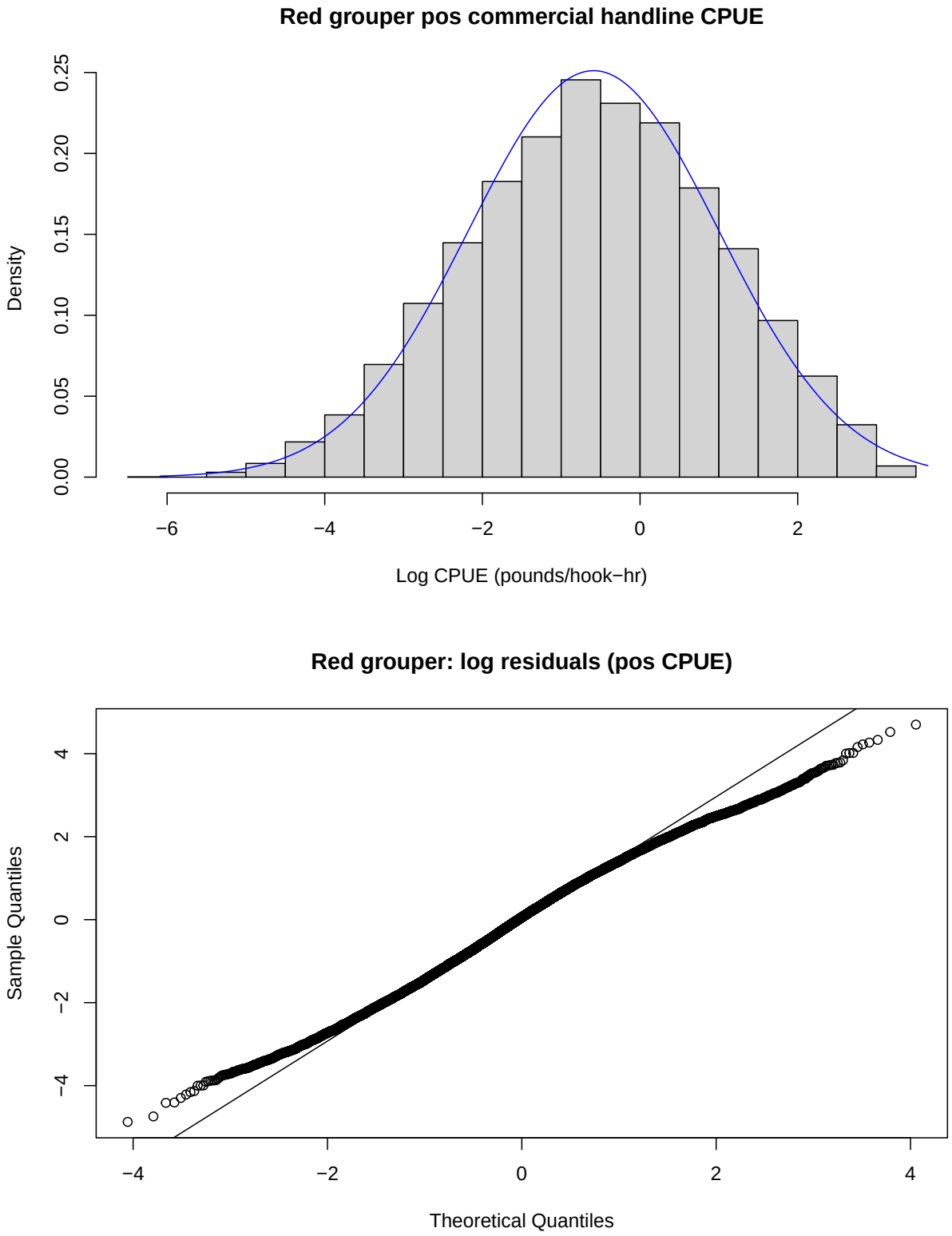

Figure 10: Histogram of empirical log CPUE, with the normal distribution (empirical mean and variance) overlaid. Quantile-quantile plot of residuals from the fitted lognormal submodel to the positive cpue cata.

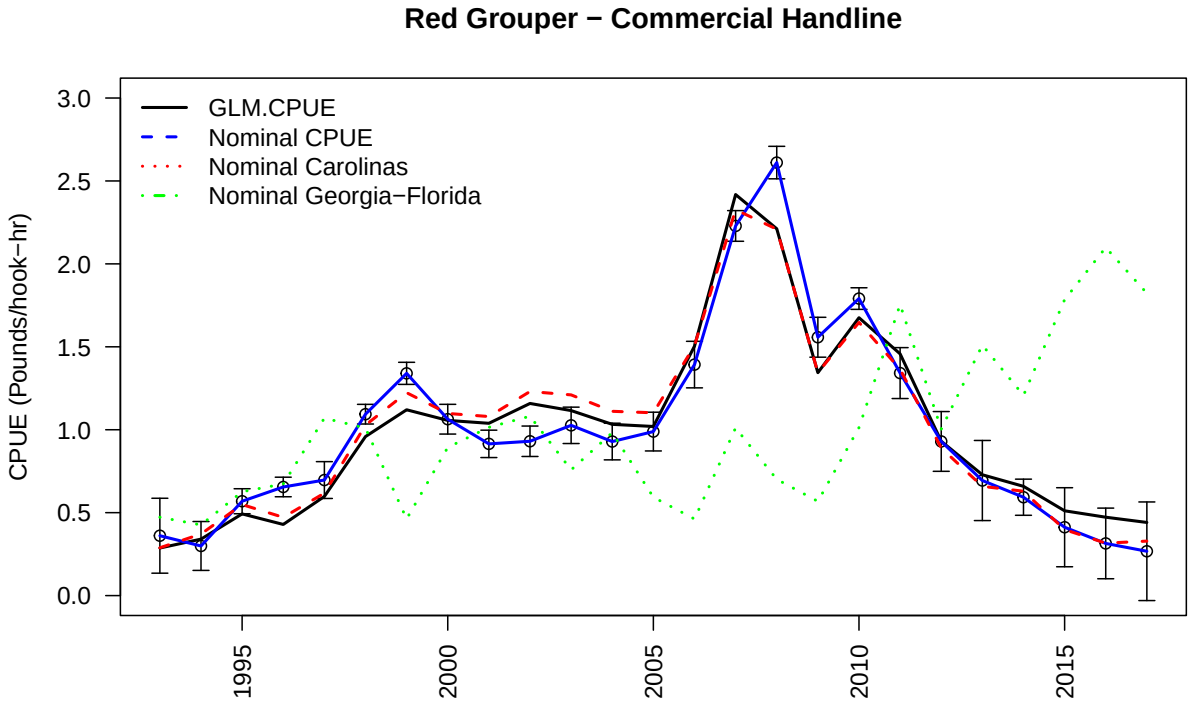

Figure 11: Standardized commercial handline red grouper catch rate (solid) with 95% confidence intervals and nominal catch rate (dashed).

Appendix

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

```
##
## Call:  glm(formula = Red.Grouper ~ Banded.rudderfish + Black.Grouper +
##     Bluestriped.grunt + Gray.triggerfish + Greater.amberjack +
##     Hogfish + Jolthead.porgy + Knobbed.porgy + Ocean.triggerfish +
##     Red.Hind + Rock.Hind + Scamp + White.grunt, family = "binomial",
##     data = n.mat.cut.df)
##
## Coefficients:
##       (Intercept)  Banded.rudderfish      Black.Grouper  Bluestriped.grunt
##          -0.75999            0.11456            0.06388            0.20848
##  Gray.triggerfish  Greater.amberjack            Hogfish     Jolthead.porgy
##           0.53167           -0.47926            0.90112            0.17149
##     Knobbed.porgy  Ocean.triggerfish           Red.Hind          Rock.Hind
##           0.14686            1.06878            1.02260            0.65922
##            Scamp        White.grunt
##           0.87935            0.21674
##
## Degrees of Freedom: 33054 Total (i.e. Null);  33041 Residual
## Null Deviance:       44860
## Residual Deviance: 37660     AIC: 37690
```

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 ~ Banded.rudderfish + Black.Grouper +
##     Gray.snapper + Gray.triggerfish + Hogfish + Margate + Red.Hind +
##     Rock.Hind + Scamp + White.grunt, family = "binomial", data = m.mat.cut.df)
##
## Coefficients:
##       (Intercept)  Banded.rudderfish      Black.Grouper       Gray.snapper
##           -2.1263             0.2383             0.5801             0.1219
##  Gray.triggerfish            Hogfish            Margate           Red.Hind
##            0.4712             0.9070            -0.1559             0.5784
##         Rock.Hind              Scamp        White.grunt
##            0.5960             1.1692             0.1671
##
## Degrees of Freedom: 16155 Total (i.e. Null);  16145 Residual
## Null Deviance:       21220
## Residual Deviance: 18370     AIC: 18390
```

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

```
##
## Call:  glm(formula = Red.Grouper ~ Banded.rudderfish + Black.Grouper +
##     Blue.runner + Bluestriped.grunt + Crevalle.jack + French.grunt +
##     Gray.snapper + Greater.amberjack + Hogfish + Jolthead.porgy +
##     Lane.snapper + Margate + Scamp + Silk.snapper + Tilefish +
##     White.grunt, family = "binomial", data = s.mat.cut.df)
##
## Coefficients:
```

```
##       (Intercept)  Banded.rudderfish      Black.Grouper        Blue.runner
##           -2.4866            -0.3636             0.9407            -1.1808
## Bluestriped.grunt      Crevalle.jack       French.grunt       Gray.snapper
##            0.4219            -1.1870            -0.2576             0.1980
## Greater.amberjack            Hogfish     Jolthead.porgy       Lane.snapper
##           -0.4815             1.0553             0.6266             0.6588
##           Margate              Scamp       Silk.snapper           Tilefish
##            0.7587             1.9686             0.5549            -1.1264
##       White.grunt
##            0.9051
##
## Degrees of Freedom: 85246 Total (i.e. Null);  85230 Residual
## Null Deviance:       49290
## Residual Deviance: 43370     AIC: 43400
```

Results of lognormal glm to determine factors.

```
##
## Call:  glm(formula = cpue ~ year + season + lat + crew + away, family = gaussian(link = "identity"),
##     data = pos.dat)
##
## Coefficients:
## (Intercept)     year1994     year1995     year1996     year1997     year1998
##      3.0190       0.1037       0.2832       0.1751       0.3556       0.7063
##    year1999     year2000     year2001     year2002     year2003     year2004
##      0.8749       0.8435       0.8727       1.1042       0.9103       0.8610
##    year2005     year2006     year2007     year2008     year2009     year2010
##      0.8303       1.3024       2.2625       2.1170       1.1902       1.7807
##    year2011     year2012     year2013     year2014     year2015     year2016
##      1.5202       0.7262       0.6908       0.4804       0.3745       0.4606
##    year2017      season2         lat2        crew2        crew3        away2
##      0.3606      -0.4829      -1.2185       0.2170      -0.6503      -1.6654
##       away3
##     -2.7492
##
## Degrees of Freedom: 20026 Total (i.e. Null);  19996 Residual
## Null Deviance:       173800
## Residual Deviance: 139700    AIC: 95810
```

Results of gamma glm to determine factors.

```
##
## Call:  glm(formula = cpue ~ year + season + lat + crew + away, family = Gamma(link = "log"),
##     data = pos.dat)
##
## Coefficients:
## (Intercept)     year1994     year1995     year1996     year1997     year1998
##     0.68060      0.02497      0.18144      0.03813      0.19755      0.52902
##    year1999     year2000     year2001     year2002     year2003     year2004
##     0.65529      0.58722      0.58417      0.61916      0.67895      0.56612
##    year2005     year2006     year2007     year2008     year2009     year2010
##     0.53735      0.80693      1.24297      1.25763      0.80579      1.08254
##    year2011     year2012     year2013     year2014     year2015     year2016
##     0.93148      0.62373      0.54959      0.41404      0.30321      0.38996
##    year2017      season2         lat2        crew2        crew3        away2
##     0.27887     -0.20502     -0.18245      0.06714     -0.54899     -0.50275
```

```
##       away3
##    -1.34713
##
## Degrees of Freedom: 20026 Total (i.e. Null);  19996 Residual
## Null Deviance:       44290
## Residual Deviance: 32820     AIC: 48330
```

Results of binomial glm to determine factors.

```
##
## Call:  glm(formula = cpue ~ year + season + lat + crew + away, family = "binomial",
##     data = bin.dat)
##
## Coefficients:
## (Intercept)     year1994     year1995     year1996     year1997     year1998
##    -0.88089     -0.21027      0.32301      0.73873      0.80091      1.17911
##    year1999     year2000     year2001     year2002     year2003     year2004
##     1.38649      1.08345      0.83108      0.69325      0.88580      0.96300
##    year2005     year2006     year2007     year2008     year2009     year2010
##     1.04643      1.39986      1.59991      1.61912      1.21728      0.95303
##    year2011     year2012     year2013     year2014     year2015     year2016
##     0.86642      0.50110      0.18794      0.17878     -0.26311     -0.49731
##    year2017      season2         lat2        crew2        crew3        away2
##    -0.68148     -0.05859     -1.32339      0.55318      0.29300      0.84783
##       away3
##     0.80724
##
## Degrees of Freedom: 32245 Total (i.e. Null);  32215 Residual
## Null Deviance:       42790
## Residual Deviance: 35880     AIC: 35940
```

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 + season + lat + crew + away"
##
## $positive.formula
## [1] "Formula for gaussian GLM: log(cpue) ~ year + season + lat + crew + away"
##
## $deltaGLM.index
##          index jackknife
## 1993 0.2683123        NA
## 1994 0.2167244        NA
## 1995 0.4085244        NA
## 1996 0.4767802        NA
## 1997 0.5136426        NA
## 1998 0.8402764        NA
## 1999 1.0450773        NA
## 2000 0.8167495        NA
## 2001 0.7001262        NA
## 2002 0.6958142        NA
## 2003 0.7871450        NA
## 2004 0.6911452        NA
```

```
## 2005 0.7386074        NA
## 2006 1.1017646        NA
## 2007 1.7727772        NA
## 2008 2.0714562        NA
## 2009 1.2131708        NA
## 2010 1.3742223        NA
## 2011 1.0609478        NA
## 2012 0.7200526        NA
## 2013 0.5268732        NA
## 2014 0.4509722        NA
## 2015 0.3036214        NA
## 2016 0.2342685        NA
## 2017 0.1977110        NA
##
## $pos.effects
## $pos.effects[[1]]
##        1        2
## 1.519412 1.266514
##
## $pos.effects[[2]]
##        1        2
## 1.694653 1.135546
##
## $pos.effects[[3]]
##         1         2         3
## 1.6255250 1.7743293 0.9255511
##
## $pos.effects[[4]]
##         1         2         3
## 3.0283652 1.5015446 0.5870591
##
##
## $bin.effects
## $bin.effects[[1]]
##         1         2
## 0.4908175 0.4761869
##
## $bin.effects[[2]]
##         1         2
## 0.6446636 0.3256947
##
## $bin.effects[[3]]
##         1         2         3
## 0.4138459 0.5510927 0.4862321
##
## $bin.effects[[4]]
##         1         2         3
## 0.3503003 0.5572748 0.5472392
##
##
## $data.filter
## [1] "Data filter threshold set at 2 positive observations."
##
## $levels.deleted.by.filter
```

```
## $levels.deleted.by.filter$year
## [1] NA
##
## $levels.deleted.by.filter$season
## [1] NA
##
## $levels.deleted.by.filter$lat
## [1] NA
##
## $levels.deleted.by.filter$crew
## [1] NA
##
## $levels.deleted.by.filter$away
## [1] NA
##
##
## $aic
##                        [,1]
## AIC.binomial  35944.622332
## AIC.lognormal 45612.040709
## sigma.mle         1.360069
```

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 + season + lat + crew + away"
##
## $positive.formula
## [1] "Formula for Gamma GLM: cpue ~ year + season + lat + crew + away"
##
## $deltaGLM.index
##          index jackknife
## 1993 0.2419057        NA
## 1994 0.2141201        NA
## 1995 0.3566370        NA
## 1996 0.3886417        NA
## 1997 0.4699708        NA
## 1998 0.7724924        NA
## 1999 0.9458106        NA
## 2000 0.7878261        NA
## 2001 0.7018999        NA
## 2002 0.6790512        NA
## 2003 0.7917858        NA
## 2004 0.7325023        NA
## 2005 0.7379599        NA
## 2006 1.1057204        NA
## 2007 1.8225487        NA
## 2008 1.8599645        NA
## 2009 1.0339772        NA
## 2010 1.2222595        NA
## 2011 1.0100939        NA
## 2012 0.6154961        NA
```

```
## 2013 0.4740693        NA
## 2014 0.4115700        NA
## 2015 0.2721659        NA
## 2016 0.2488134        NA
## 2017 0.1924943        NA
##
## $pos.effects
## $pos.effects[[1]]
##        1        2
## 1.444227 1.176508
##
## $pos.effects[[2]]
##        1        2
## 1.428018 1.189861
##
## $pos.effects[[3]]
##         1         2         3
## 1.5306283 1.6369285 0.8839865
##
## $pos.effects[[4]]
##         1         2         3
## 2.4149734 1.4607385 0.6278563
##
##
## $bin.effects
## $bin.effects[[1]]
##         1         2
## 0.4908175 0.4761869
##
## $bin.effects[[2]]
##         1         2
## 0.6446636 0.3256947
##
## $bin.effects[[3]]
##         1         2         3
## 0.4138459 0.5510927 0.4862321
##
## $bin.effects[[4]]
##         1         2         3
## 0.3503003 0.5572748 0.5472392
##
##
## $data.filter
## [1] "Data filter threshold set at 2 positive observations."
##
## $levels.deleted.by.filter
## $levels.deleted.by.filter$year
## [1] NA
##
## $levels.deleted.by.filter$season
## [1] NA
##
## $levels.deleted.by.filter$lat
## [1] NA
```

```
##
## $levels.deleted.by.filter$crew
## [1] NA
##
## $levels.deleted.by.filter$away
## [1] NA
##
##
## $aic
##                       [,1]
## AIC.binomial 3.594462e+04
## AIC.gamma    4.788989e+04
## shape.mle    7.329498e-01
```

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