Standardized catch rates of scamp and yellowmouth grouper (*Mycteroperca phenax* and *Myteroperca interstitialis*) in the southeast U.S. from commercial logbook data

Sustainable Fisheries Branch

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*Sustainable Fisheries Branch**

March 2020

This document describes the the development of the SEDAR 68 commercial logbook handline index for scamp and yellowmouth grouper. A consensus decision was made at the stock identification workshop to combine these species (SEDAR 68 Stock ID report).

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), defined as whole weight per hook hour, from the logbooks was used to develop an index of abundance for scamp and yellowmouth grouper landed with vertical lines (manual handline and electric reel), the dominant gear for this scamp and yellowmouth grouper stock. 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. 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 scamp and yellowmouth grouper trips were evaluated for outliers in scamp and yellowmouth grouper cpue (Table 1).

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). Also excluded were records reporting multiple gears fished, which prevents designating catch and effort to specific gears. Therefore, only

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

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 1). Removing trips from these months allows us to extend the commercial logbook index until the terminal year of the assessment (2018). In 2012 commercial scamp and yellowmouth 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 2018 with the removal of all trips from January to April across all years. To ensure consistency among years, the days associated with the gag closures in October (10 days) and November (8 days) were filtered as well as the entire month of December.

Evaluation of explanatory variables

YEAR – Year was necessarily included, as standardized catch rates by year are the desired outcome. Years modeled were 1993-2018.

SEASON – Season included two levels: summer (May - August) and fall (September-November). 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 2). The majority of the positive trips and catch for commercial handline is in the Carolinas (Figures 4 and 5). Initially, a regional split at Cape Canaveral was considered but due to the limited samples in the SF region the coast was divided into two areas split at 32 degrees Latitude near Savannah, GA (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 a trip and could be a psuedo-factor for vessel size. The quartile split values (at 25, 50, and 75%) for scamp and yellowmouth grouper crew size fall at 1, 2, and 3 plus crew per trip. 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 scamp and yellowmouth 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, 2% or more for GNF and 1% for SF. The regions GNF and SF had too few species at a cutoff of 5%. 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 scamp and yellowmouth grouper during years of restrictions (red porgy, red snapper, vermilion snapper, mutton snapper, snowy grouper, gag, black sea bass, blueline tilefish and yellowtail snapper). With these nine species being removed due to management regulations this subsetting method, more particularly the species to include in Stephens and MacCall, may need to be revisited prior to an operational assessment.

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 scamp and yellowmouth grouper in each trip to presence/absence of other species. For the CAR area, stepwise AIC eliminated black grouper, white grunt and bluestriped grunt; for the GNF sampling area, it eliminated blue runner; for the SF sampling area, it eliminated French grunt, blue runner, Crevalle jack, white grunt, black grouper, bluestriped grunt, hogfish and 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 scamp and yellowmouth 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). Retention of positive and zero scamp and yellowmouth grouper trips across factors are shown in Figures 8 - 10. A large number of positive trips were retained while a large proportion of zero trips were dropped. The proportion of scamp and yellowmouth grouper relative to the other associated species for each of these regions is much different north and south of Cape Canaveral. This difference can bee seen in the disproportionate removal of zero trips for the SF region. The nominal catch rate before and after the subsetting are fairly similar (Figure 11)

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 scamp and yellowmouth grouper 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 standardized (quantile) residuals, suggested reasonable fits of the Bernoulli submodel (Figure 12).

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 distributions, the best model fit included all explanatory variables. The two distributions were compared using AIC. Gamma outperformed lognormal, and was therefore applied in the final delta-GLM. Diagnostics suggested a reasonable fit (Figures 13 and 14).

Results

The standardized index was similar to the nominal index (Figure 15).

Table 1: 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	128
cpue (upper)	3	3

Table 2: Nominal and standardized CPUE for scamp and yellowmouth grouper 1993-2017 with CVs for stardardized index of abundance.

Year	N	Nominal.CPUE	Relative.nominal	Standardized.CPUE	Proportion.Positive	CV
1993	935	0.42	0.87	0.91	0.74	0.05
1994	906	0.37	0.78	0.77	0.76	0.05
1995	1078	0.42	0.87	0.90	0.74	0.05
1996	1031	0.43	0.91	0.98	0.77	0.05
1997	1168	0.42	0.88	0.89	0.72	0.05
1998	1121	0.50	1.04	1.10	0.68	0.05
1999	990	0.62	1.30	1.30	0.71	0.05
2000	1040	0.52	1.09	1.16	0.77	0.04
2001	1053	0.49	1.04	1.07	0.80	0.04
2002	1147	0.51	1.07	1.05	0.74	0.05
2003	965	0.63	1.33	1.39	0.78	0.04
2004	861	0.50	1.06	0.99	0.73	0.05
2005	957	0.54	1.13	1.14	0.74	0.05
2006	897	0.60	1.27	1.41	0.79	0.05
2007	1170	0.56	1.17	1.24	0.78	0.04
2008	1129	0.48	1.00	1.00	0.79	0.04
2009	1053	0.42	0.88	0.83	0.74	0.05
2010	916	0.48	1.00	0.88	0.77	0.05
2011	937	0.40	0.85	0.78	0.73	0.05
2012	829	0.52	1.09	1.06	0.76	0.05
2013	790	0.47	0.98	0.95	0.78	0.05
2014	644	0.49	1.03	1.14	0.78	0.05
2015	698	0.44	0.92	0.84	0.74	0.06
2016	634	0.40	0.84	0.74	0.69	0.07
2017	648	0.41	0.87	0.81	0.69	0.06
2018	657	0.35	0.74	0.67	0.66	0.07

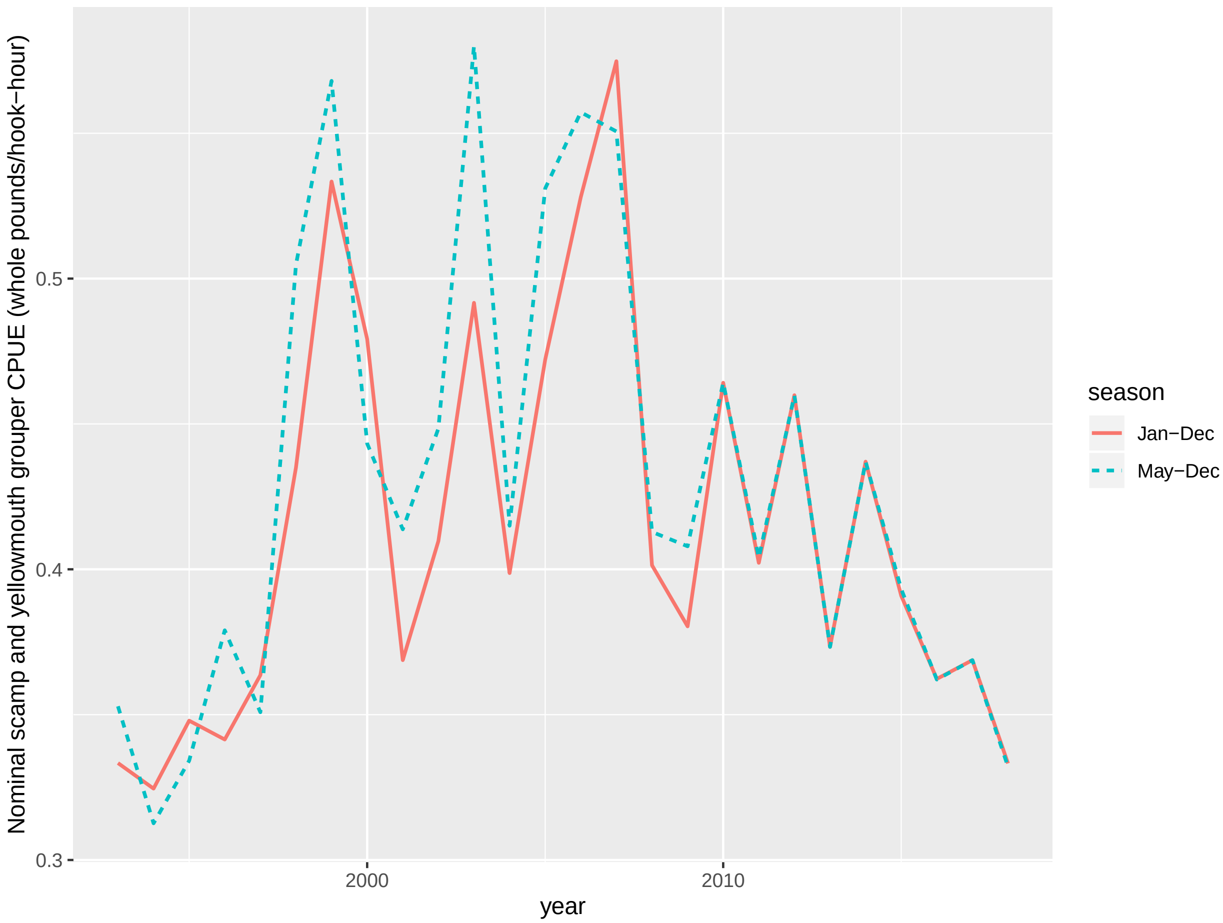

Figure 1: Nominal CPUE for positve scamp and yellowmouth grouper trips with and without the Jan-Apr spawning closure beginning in 2010).

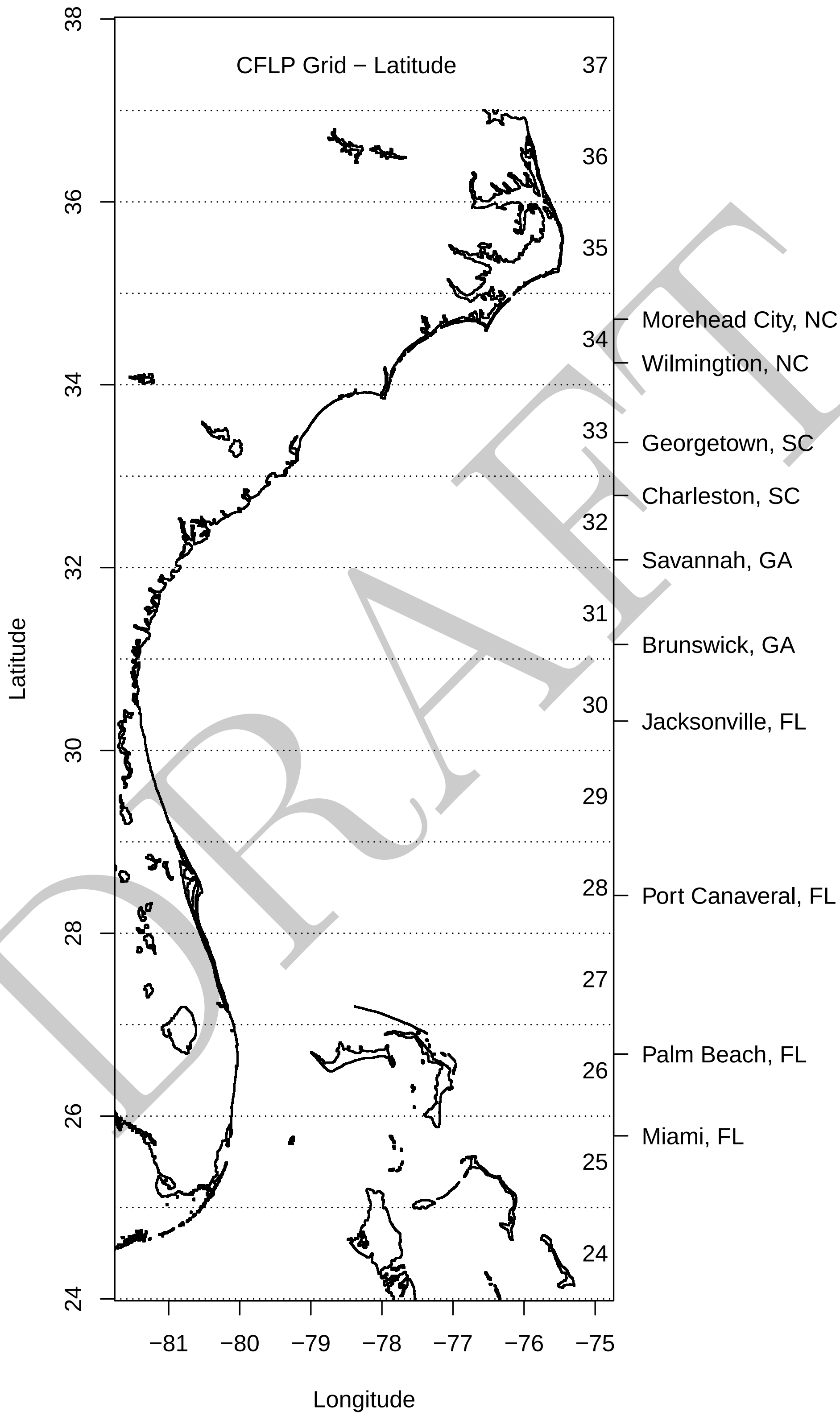

Figure 2: CFLP Latitude Stratification (midpoint of each latitudinal grid is labeled with the floor for the bin).

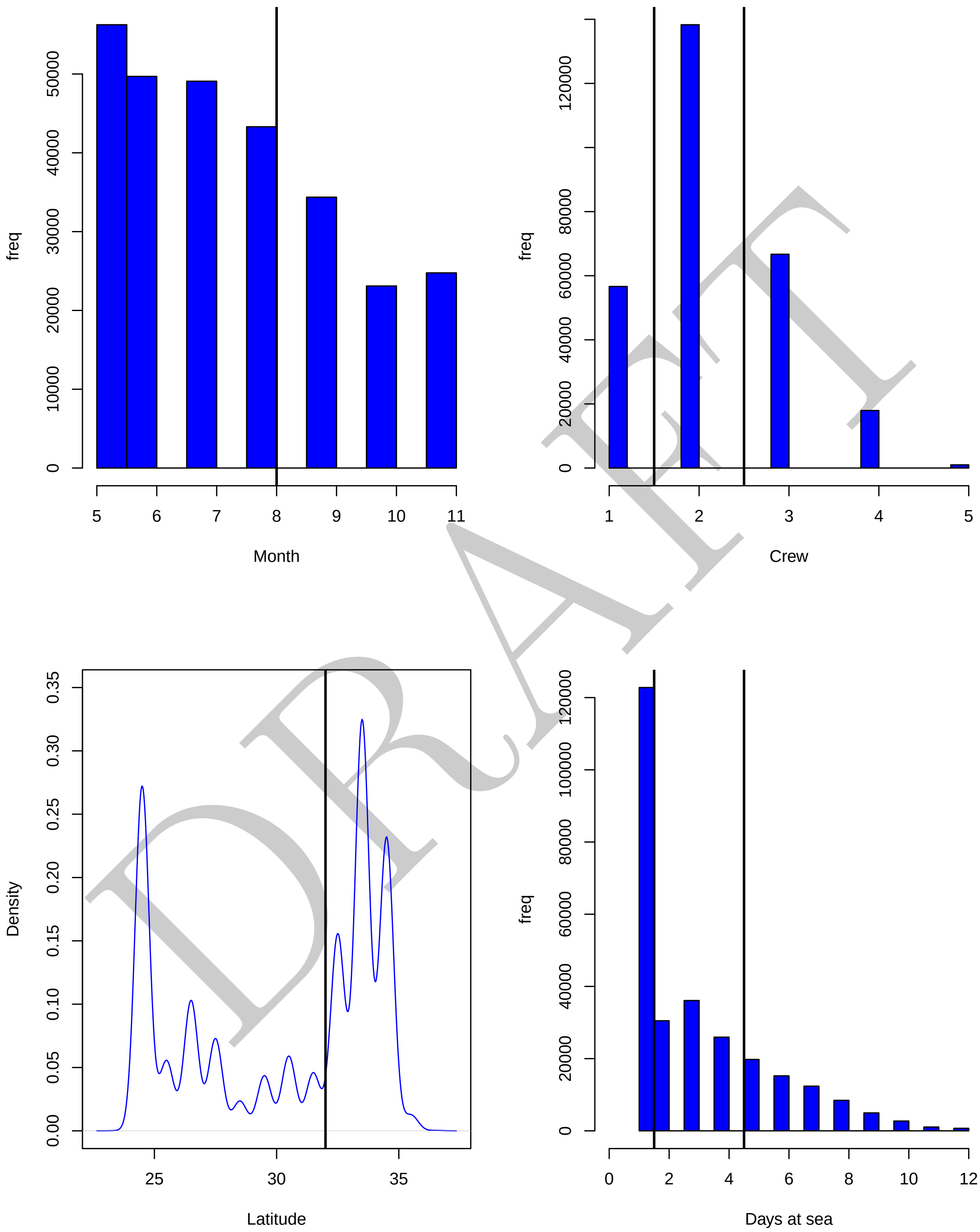

Figure 3: Scamp and yellowmouth grouper handline explanatory variable factorization. Vertical lines represent breaks for factors.

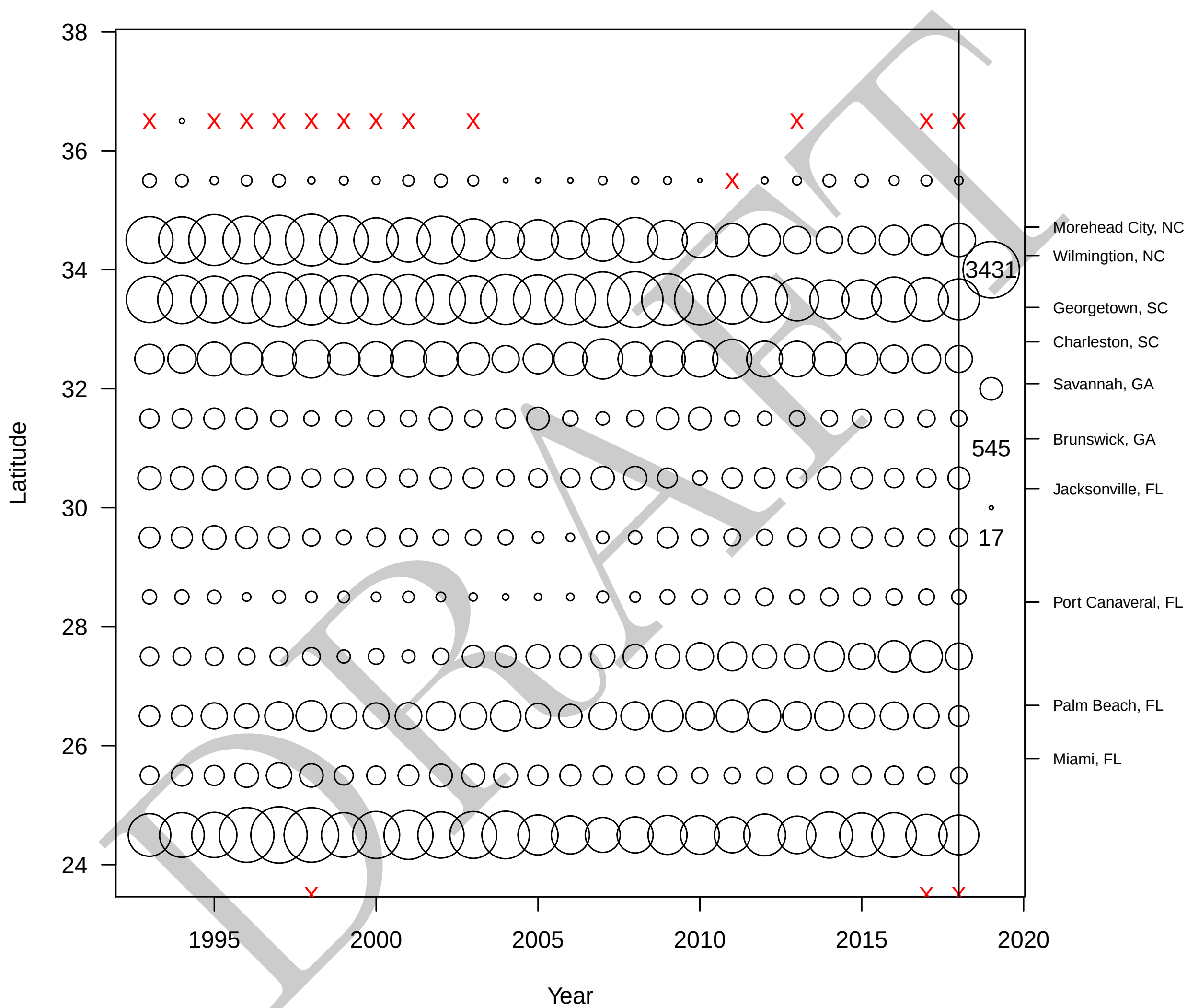

Figure 4: Scamp and yellowmouth grouper handline trips by year and latitude. Symbol size relative to number of trips, 'X' signifies confidential data and represents a small percentage of the total trips.

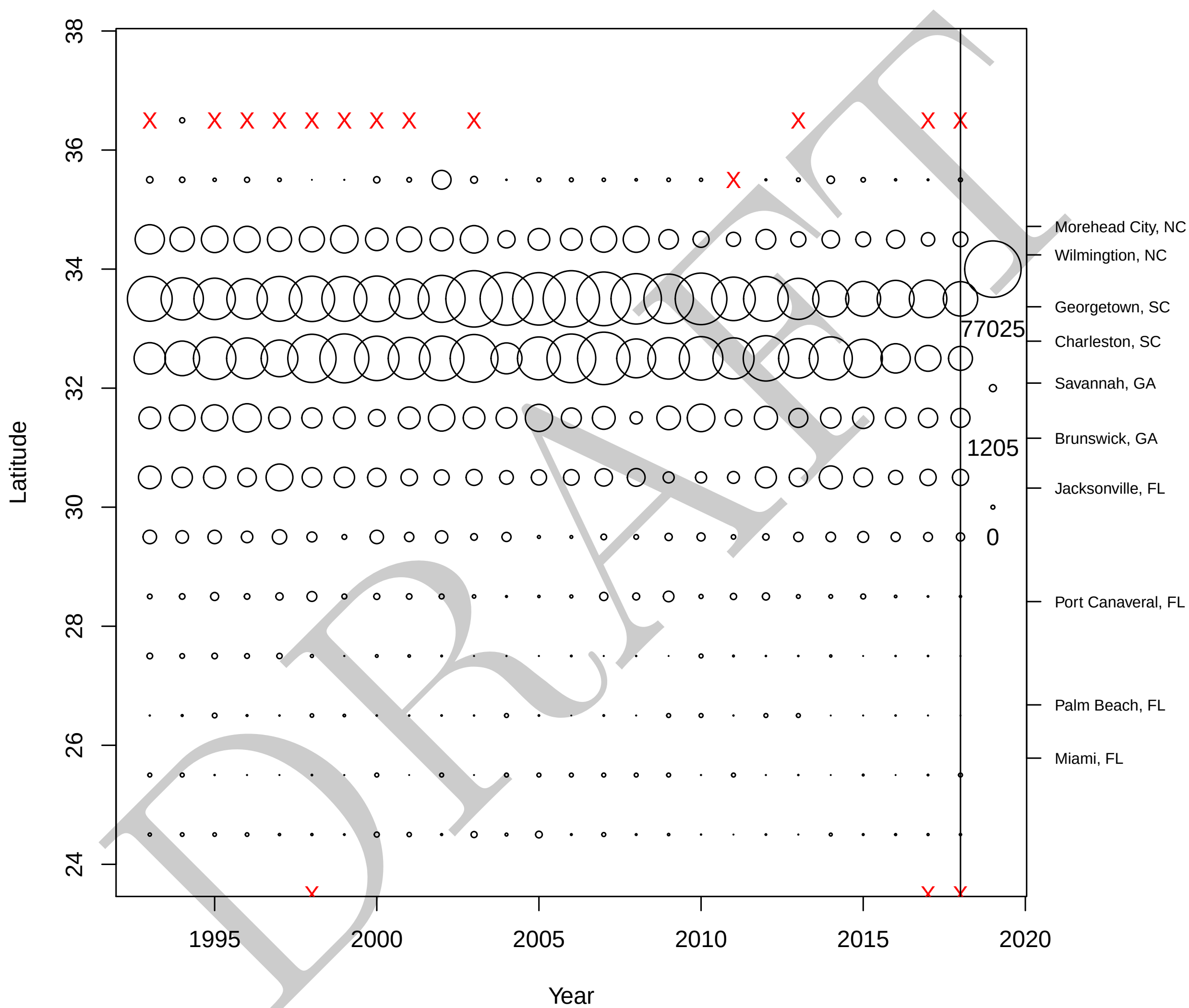

Figure 5: Scamp and yellowmouth grouper handline catch (whole pounds) by year and latitude. Symbol size relative to catch, 'X' signifies confidential data and represents a small percentage of the total catch.

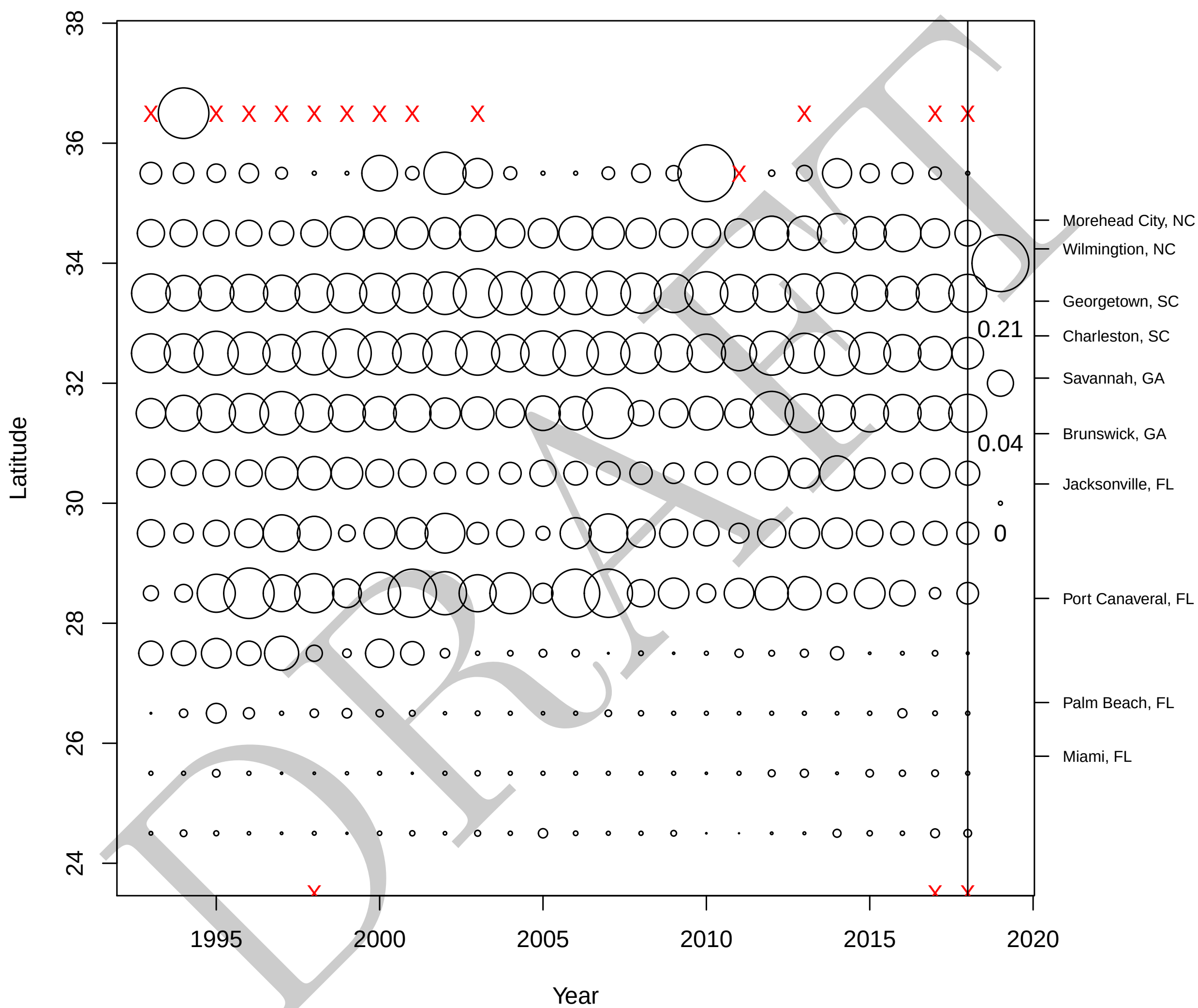

Figure 6: Scamp and yellowmouth grouper handline mean cpue (whole pounds/hook-hour) by year and latitude. Symbol size relative to cpue, 'X' signifies confidential data and represents a small percentage of the total records.

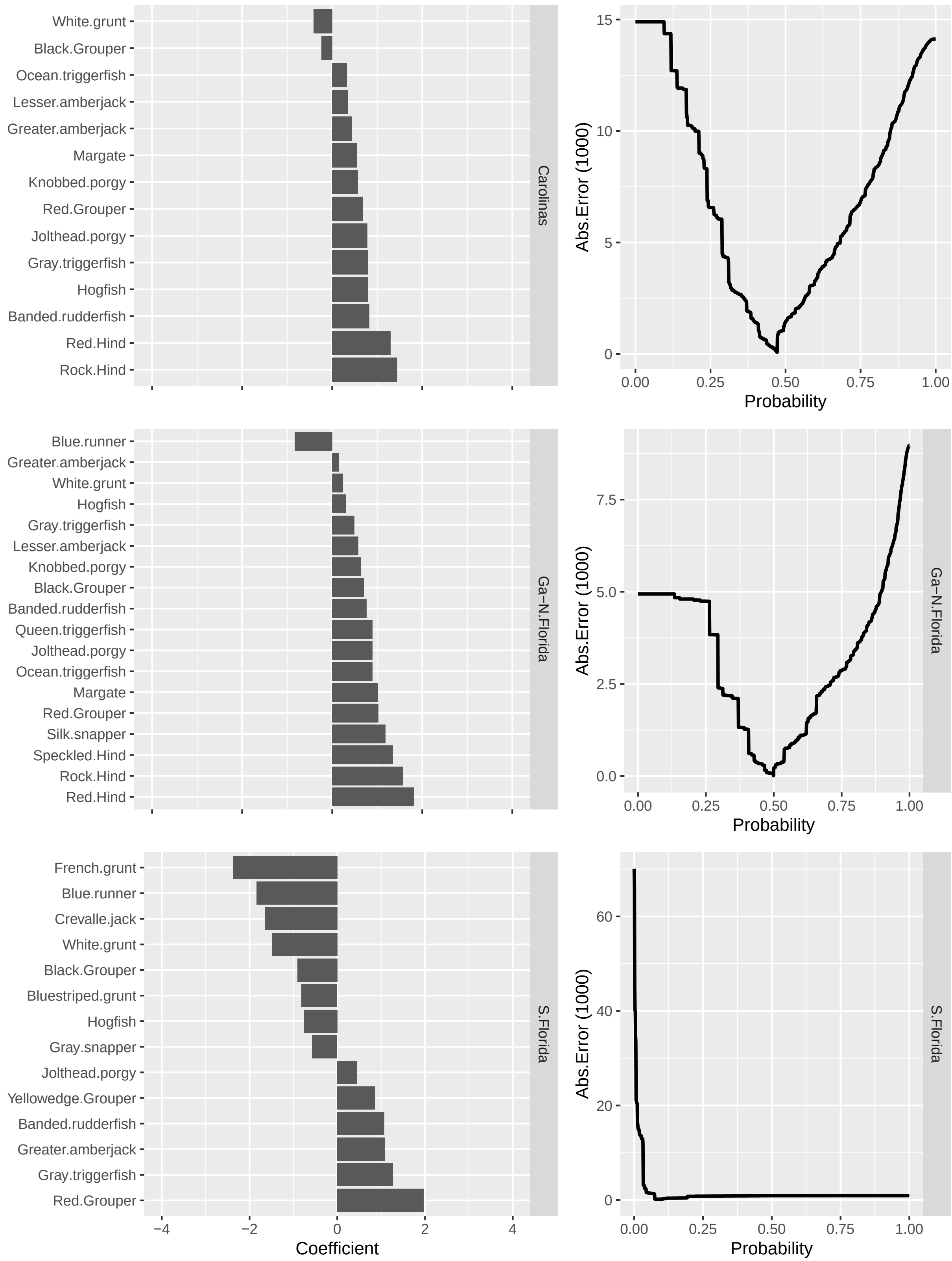

Figure 7: Estimates of species-specific regression coefficients used to predict each trip's probability of catching the focal species on the left panel. The right panel shows the absolute difference between observed and predicted number of positive trips across a range of probability cutoff values.

Figure 8: Positive and zero scamp and yellowmouth grouper trips retained after subsetting using Stephens and MacCall approach by year.

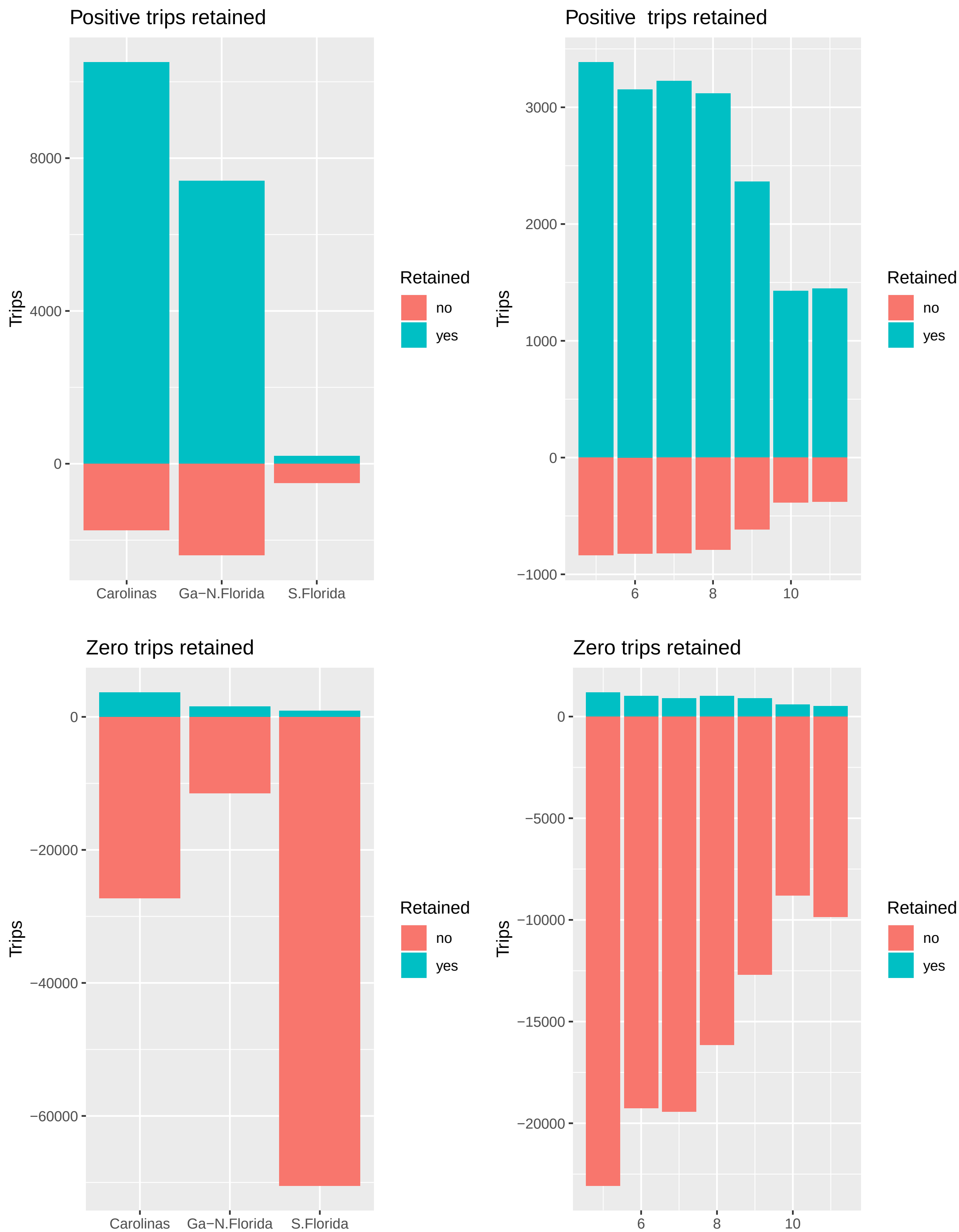

Figure 9: Positive and zero scamp and yellowmouth grouper trips retained after subsetting using Stephens and MacCall approach by area and month (season).

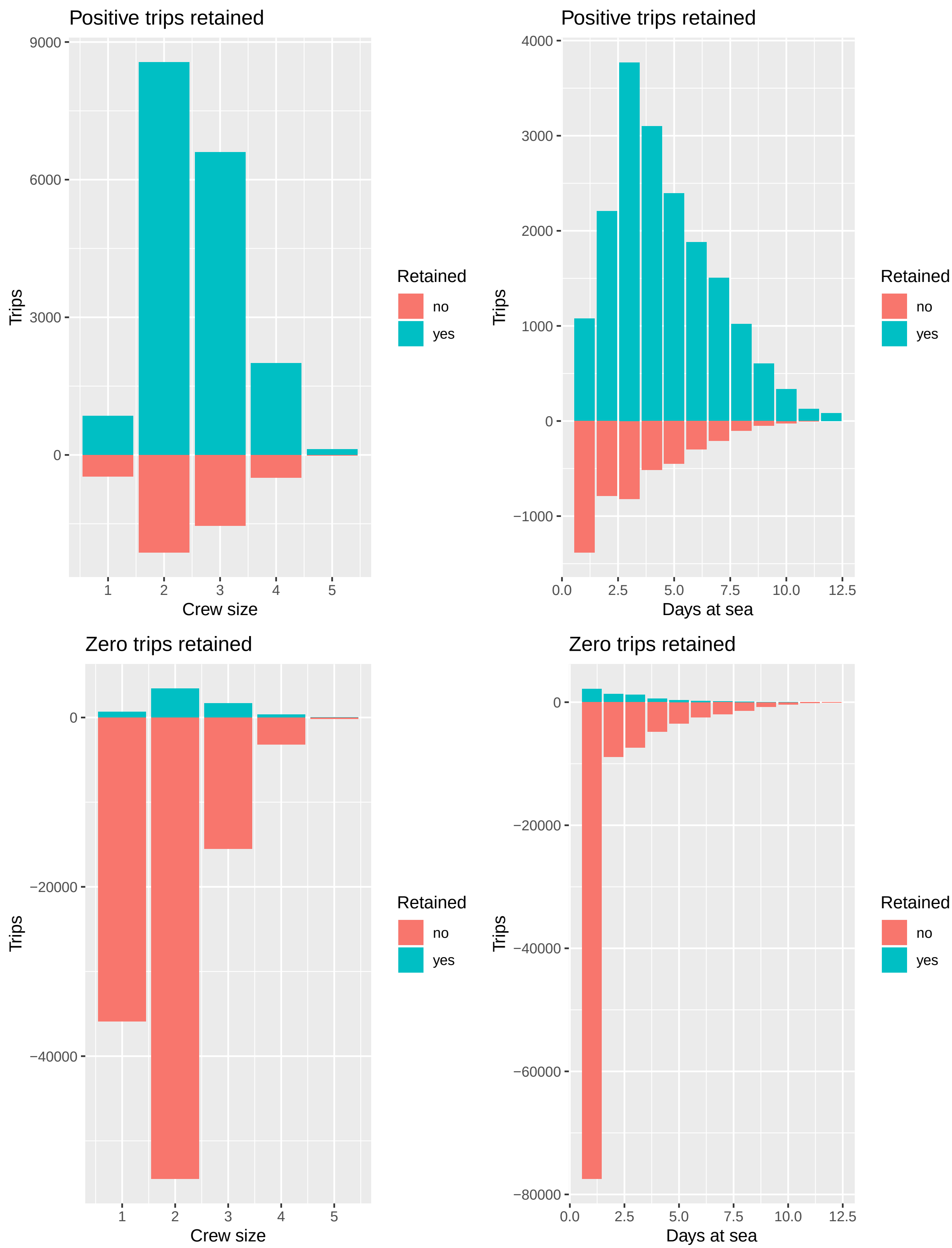

Figure 10: Positive and zero scamp and yellowmouth grouper trips retained after subsetting using Stephens and MacCall approach by factors for crew size and days at sea.

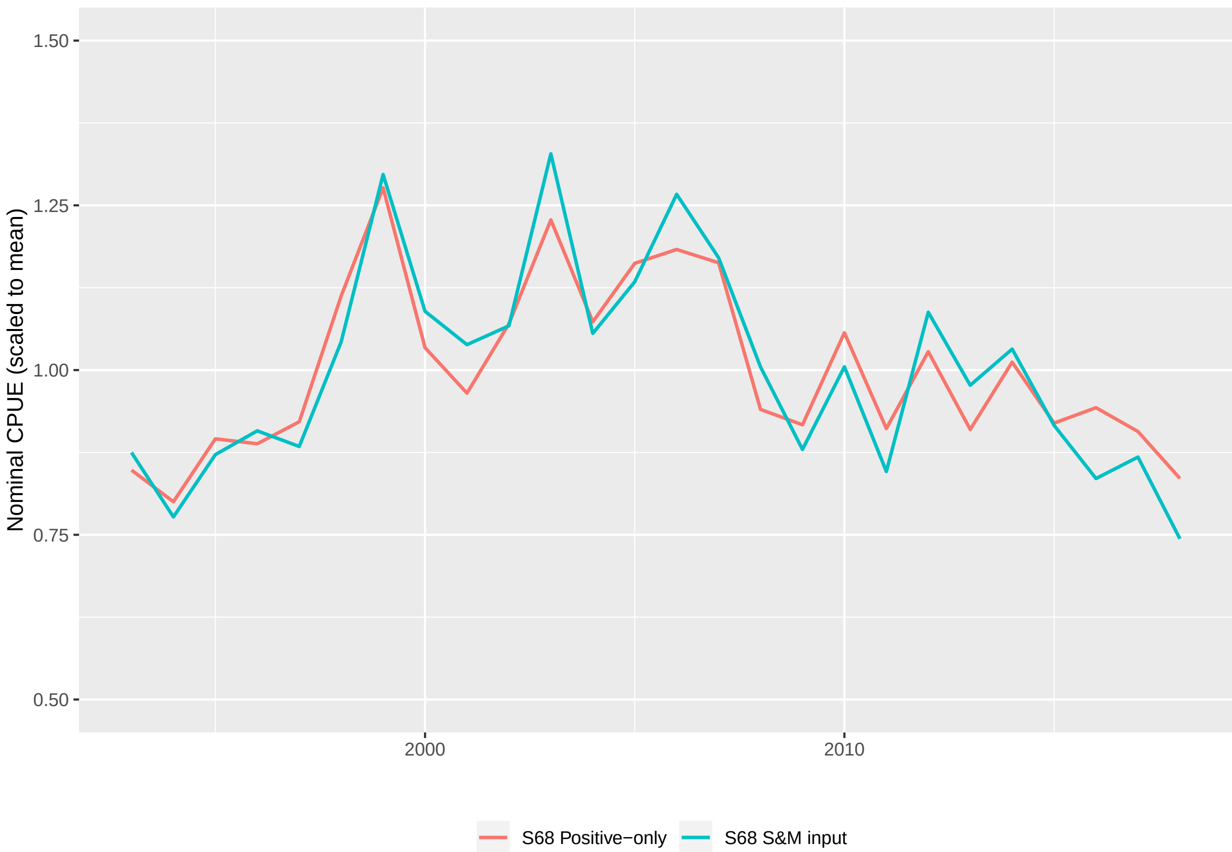

Figure 11: Nominal scamp and yellowmouth grouper cpue for raw data and subsetted trips.

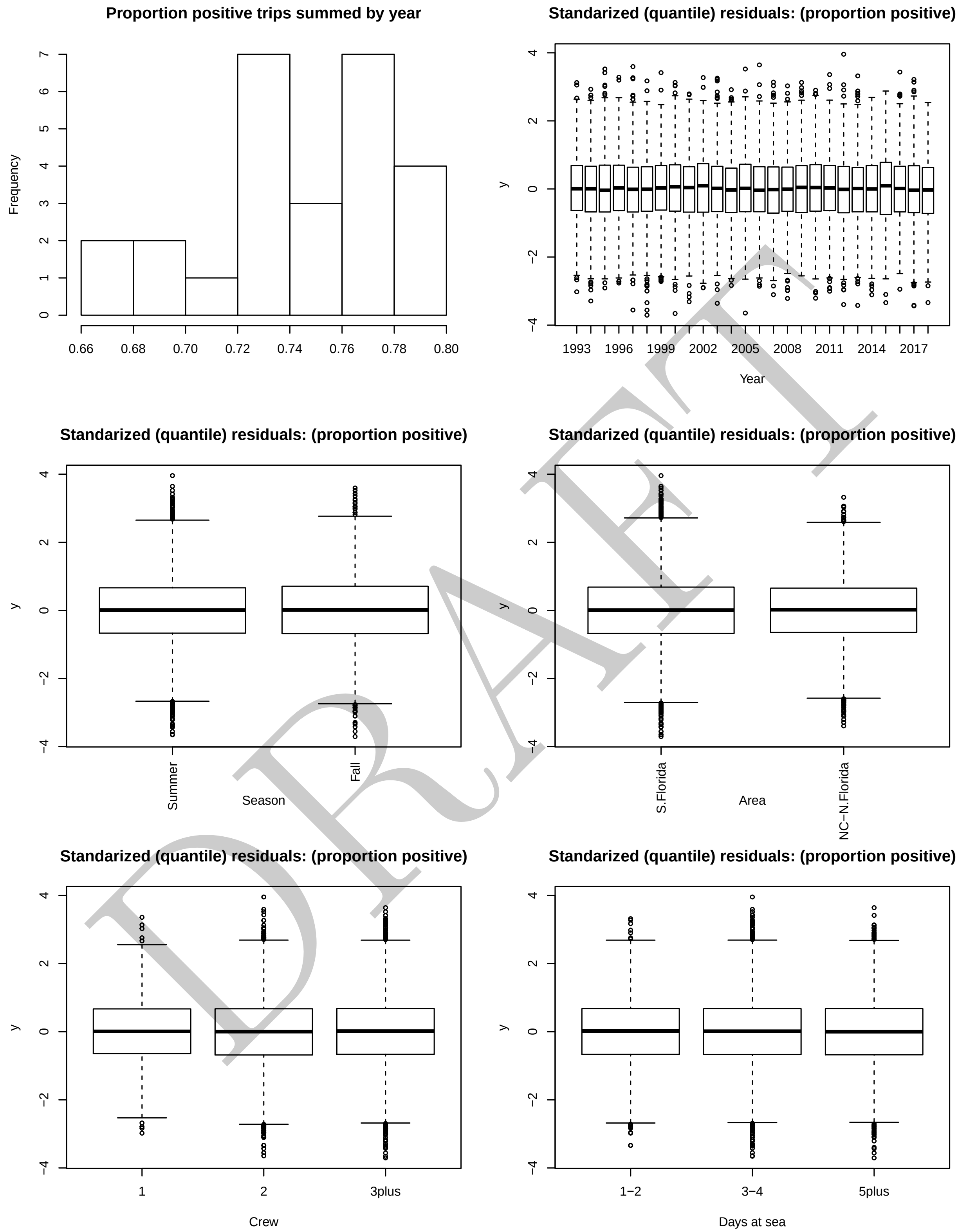

Figure 12: Diagnostics of Bernoulli submodel fits to positive versus zero CPUE data. Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are standardized (quantile) residuals.

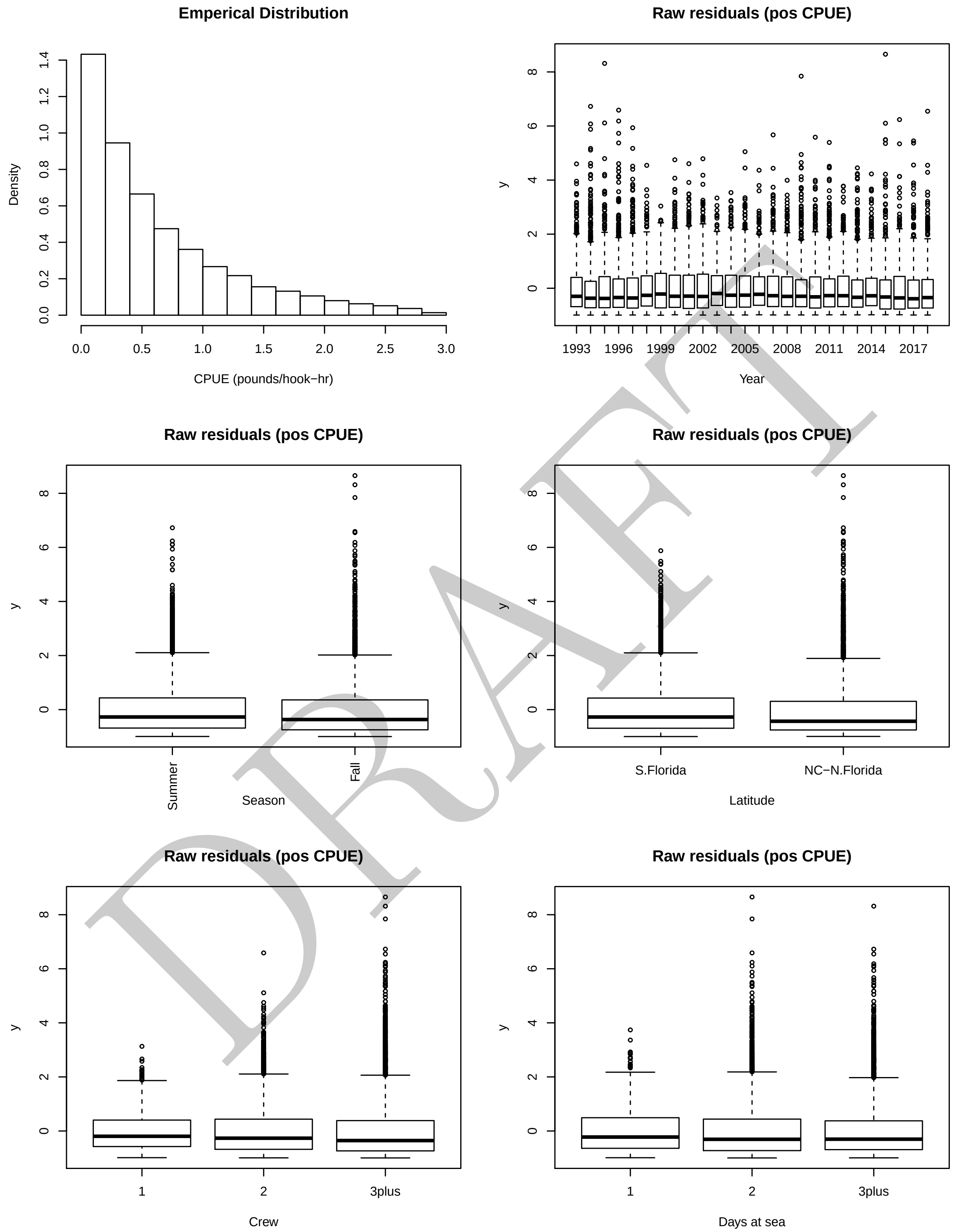

Figure 13: Diagnostics of lognormal submodel fits to positive CPUE data. Top left panel shows the distribution of positive cpue. Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are raw.

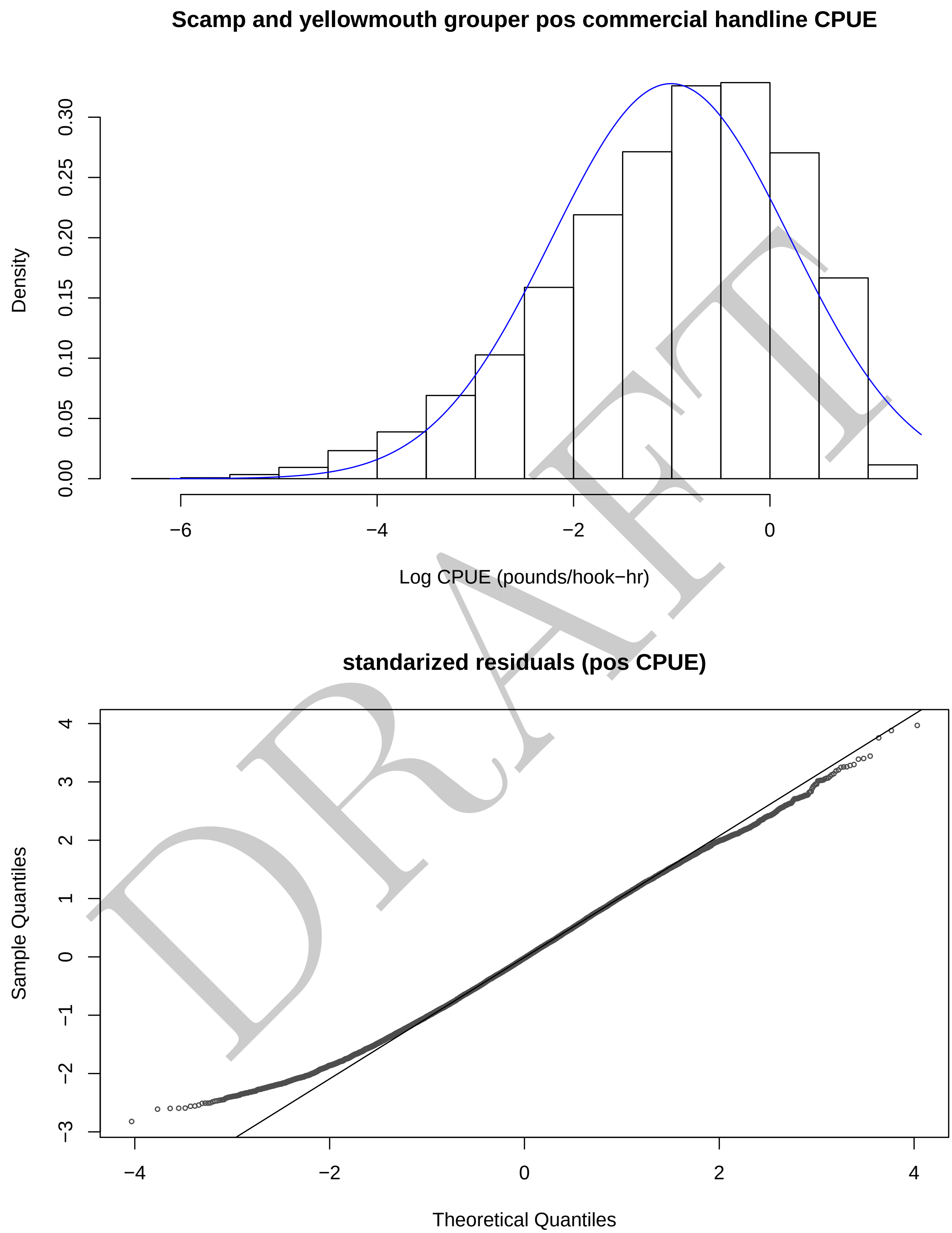

Figure 14: Histogram of empirical log CPUE, with the normal distribution overlaid. Quantile-quantile plot of residuals from the fitted gamma submodel to the positive cpue catch.

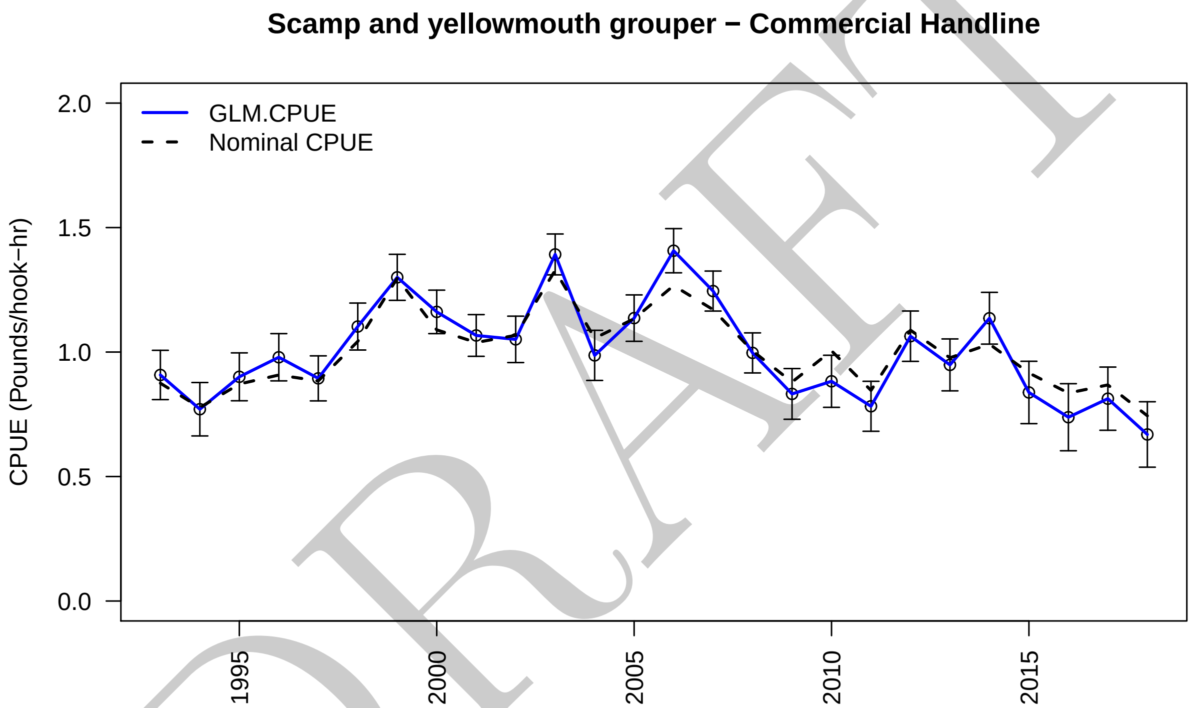

Figure 15: Standardized commercial handline scamp and yellowmouth grouper catch rate (solid) with 95% confidence intervals and nominal catch rate (dashed).

Appendix

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

```
##
## Call:  glm(formula = Scamp ~ Banded.rudderfish + Black.Grouper + Gray.triggerfish +
##     Greater.amberjack + Hogfish + Jolthead.porgy + Knobbed.porgy +
##     Lesser.amberjack + Margate + Ocean.triggerfish + Red.Grouper +
##     Red.Hind + Rock.Hind + White.grunt, family = "binomial",
##     data = n.mat.cut.df)
##
## Coefficients:
##       (Intercept)  Banded.rudderfish      Black.Grouper
##           -1.5904             0.8242            -0.2398
##  Gray.triggerfish  Greater.amberjack            Hogfish
##            0.7907             0.4318             0.7939
##    Jolthead.porgy      Knobbed.porgy   Lesser.amberjack
##            0.7844             0.5712             0.3528
##           Margate  Ocean.triggerfish        Red.Grouper
##            0.5488             0.3278             0.6893
##          Red.Hind          Rock.Hind        White.grunt
##            1.2941             1.4474            -0.4177
##
## Degrees of Freedom: 29024 Total (i.e. Null);  29010 Residual
## Null Deviance:      40220
## Residual Deviance: 30440     AIC: 30470
```

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

```
##
## Call:  glm(formula = Scamp ~ Banded.rudderfish + Black.Grouper + Blue.runner +
##     Gray.triggerfish + Greater.amberjack + Hogfish + Jolthead.porgy +
##     Knobbed.porgy + Lesser.amberjack + Margate + Ocean.triggerfish +
##     Queen.triggerfish + Red.Grouper + Red.Hind + Rock.Hind +
##     Silk.snapper + Speckled.Hind + White.grunt, family = "binomial",
##     data = m.mat.cut.df)
##
## Coefficients:
##       (Intercept)  Banded.rudderfish      Black.Grouper
##           -1.0284             0.7663             0.7001
##       Blue.runner   Gray.triggerfish  Greater.amberjack
##           -0.8335             0.4960             0.1568
##           Hogfish     Jolthead.porgy      Knobbed.porgy
##            0.3021             0.8925             0.6398
##  Lesser.amberjack            Margate  Ocean.triggerfish
##            0.5833             1.0219             0.8959
## Queen.triggerfish        Red.Grouper           Red.Hind
##            0.8924             1.0261             1.8174
##         Rock.Hind       Silk.snapper      Speckled.Hind
##            1.5782             1.1801             1.3498
##       White.grunt
##            0.2400
##
## Degrees of Freedom: 13911 Total (i.e. Null);  13893 Residual
```

```
## Null Deviance:       18100
## Residual Deviance: 13280     AIC: 13320
```

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

```
##
## Call:  glm(formula = Scamp ~ Banded.rudderfish + Black.Grouper + Blue.runner +
##     Bluestriped.grunt + Crevalle.jack + French.grunt + Gray.snapper +
##     Gray.triggerfish + Greater.amberjack + Hogfish + Jolthead.porgy +
##     Red.Grouper + White.grunt + Yellowedge.Grouper, family = "binomial",
##     data = s.mat.cut.df)
##
## Coefficients:
##        (Intercept)   Banded.rudderfish       Black.Grouper
##            -4.4875              1.0695             -0.9065
##        Blue.runner   Bluestriped.grunt       Crevalle.jack
##            -1.8412             -0.8154             -1.6428
##       French.grunt        Gray.snapper    Gray.triggerfish
##            -2.3696             -0.5721              1.2671
##  Greater.amberjack             Hogfish      Jolthead.porgy
##             1.0864             -0.7588              0.4527
##        Red.Grouper         White.grunt  Yellowedge.Grouper
##             1.9722             -1.4908              0.8584
##
## Degrees of Freedom: 70998 Total (i.e. Null);  70984 Residual
## Null Deviance:       9833
## Residual Deviance: 8179  AIC: 8209
```

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
##   1.1661204   -0.0619162    0.0009514   -0.0036295    0.0154992
##    year1998     year1999     year2000     year2001     year2002
##   0.1531279    0.2927887    0.0916720    0.0385133    0.1173394
##    year2003     year2004     year2005     year2006     year2007
##   0.2184047    0.0945977    0.1556053    0.1741270    0.1140543
##    year2008     year2009     year2010     year2011     year2012
##  -0.0050826   -0.0361928    0.0228379   -0.0576152    0.0618897
##    year2013     year2014     year2015     year2016     year2017
##  -0.0207736    0.0086925   -0.0121212   -0.0259422   -0.0139122
##    year2018      season2         lat2        crew2        crew3
##  -0.0753960   -0.1865460   -0.2022091   -0.1947171   -0.3616201
##       away2        away3
##  -0.2456250   -0.2217431
##
## Degrees of Freedom: 18125 Total (i.e. Null);  18094 Residual
## Null Deviance:       6922
## Residual Deviance: 6225  AIC: 32130
```

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
##    0.253248    -0.121287    -0.009984     0.010847     0.045990
##    year1998     year1999     year2000     year2001     year2002
##    0.276655     0.421598     0.165700     0.065152     0.199626
##    year2003     year2004     year2005     year2006     year2007
##    0.306987     0.137179     0.268430     0.273139     0.198261
##    year2008     year2009     year2010     year2011     year2012
##   -0.009740    -0.031387     0.036314    -0.084752     0.129658
##    year2013     year2014     year2015     year2016     year2017
##    0.006658     0.060748     0.025009    -0.004482     0.035123
##    year2018      season2         lat2        crew2        crew3
##   -0.097434    -0.306176    -0.362044    -0.251900    -0.516376
##       away2        away3
##   -0.353143    -0.319525
##
## Degrees of Freedom: 18125 Total (i.e. Null);  18094 Residual
## Null Deviance:       20470
## Residual Deviance: 18720     AIC: 18590
```

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
##    -0.80792      0.13069      0.17482      0.29733      0.05290
##    year1998     year1999     year2000     year2001     year2002
##    -0.18940     -0.10881      0.30337      0.45453      0.07783
##    year2003     year2004     year2005     year2006     year2007
##     0.30158     -0.05781     -0.04370      0.30090      0.33717
##    year2008     year2009     year2010     year2011     year2012
##     0.34279     -0.04535      0.07785     -0.12760      0.17017
##    year2013     year2014     year2015     year2016     year2017
##     0.28421      0.44596      0.07687     -0.10021     -0.09330
##    year2018      season2         lat2        crew2        crew3
##    -0.21360     -0.30389     -0.78444      0.26245      0.57149
##       away2        away3
##     1.62218      2.92492
##
## Degrees of Freedom: 24253 Total (i.e. Null);  24222 Residual
## Null Deviance:       27420
## Residual Deviance: 22780     AIC: 22850
```

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 0.4283220        NA
## 1994 0.3634127        NA
## 1995 0.4248164        NA
## 1996 0.4618922        NA
## 1997 0.4218841        NA
## 1998 0.5201051        NA
## 1999 0.6133368        NA
## 2000 0.5478470        NA
## 2001 0.5031721        NA
## 2002 0.4957683        NA
## 2003 0.6567433        NA
## 2004 0.4654260        NA
## 2005 0.5360605        NA
## 2006 0.6637629        NA
## 2007 0.5873062        NA
## 2008 0.4701352        NA
## 2009 0.3924032        NA
## 2010 0.4163304        NA
## 2011 0.3689907        NA
## 2012 0.5017986        NA
## 2013 0.4474069        NA
## 2014 0.5358222        NA
## 2015 0.3951736        NA
## 2016 0.3482470        NA
## 2017 0.3833846        NA
## 2018 0.3155767        NA
##
## $pos.effects
## $pos.effects[[1]]
##         1         2
## 0.8994029 0.5978934
##
## $pos.effects[[2]]
##         1         2
## 0.9281861 0.5793526
##
## $pos.effects[[3]]
##         1         2         3
## 1.0661992 0.7355460 0.5028273
##
## $pos.effects[[4]]
##         1         2         3
## 0.9836422 0.5935019 0.6754727
##
##
## $bin.effects
## $bin.effects[[1]]
```

```
##         1         2
## 0.6688811 0.5985038
##
## $bin.effects[[2]]
##         1         2
## 0.7197860 0.5396574
##
## $bin.effects[[3]]
##         1         2         3
## 0.5678787 0.6307997 0.6994530
##
## $bin.effects[[4]]
##         1         2         3
## 0.2759740 0.6587355 0.8765764
##
##
## $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  22846.576106
## AIC.lognormal 19875.562331
## sigma.mle         1.144729
```

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 0.3472514        NA
## 1994 0.3230789        NA
## 1995 0.3668285        NA
## 1996 0.3903290        NA
## 1997 0.3710769        NA
## 1998 0.4233735        NA
## 1999 0.5065607        NA
## 2000 0.4565918        NA
## 2001 0.4324446        NA
## 2002 0.4367743        NA
## 2003 0.5255789        NA
## 2004 0.3892432        NA
## 2005 0.4463698        NA
## 2006 0.5079757        NA
## 2007 0.4768052        NA
## 2008 0.3879479        NA
## 2009 0.3305203        NA
## 2010 0.3709675        NA
## 2011 0.3028995        NA
## 2012 0.4211133        NA
## 2013 0.3870443        NA
## 2014 0.4294731        NA
## 2015 0.3666628        NA
## 2016 0.3320031        NA
## 2017 0.3464066        NA
## 2018 0.2881585        NA
##
## $pos.effects
## $pos.effects[[1]]
##         1         2
## 0.7265316 0.5349137
##
## $pos.effects[[2]]
##         1         2
## 0.7471126 0.5201782
##
## $pos.effects[[3]]
##         1         2         3
## 0.8053572 0.6260222 0.4805395
##
## $pos.effects[[4]]
##         1         2         3
## 0.7800955 0.5479988 0.5667350
##
##
## $bin.effects
## $bin.effects[[1]]
##         1         2
## 0.6688811 0.5985038
##
## $bin.effects[[2]]
##         1         2
## 0.7197860 0.5396574
##
```

```
## $bin.effects[[3]]
##         1         2         3
## 0.5678787 0.6307997 0.6994530
##
## $bin.effects[[4]]
##         1         2         3
## 0.2759740 0.6587355 0.8765764
##
##
## $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 22846.576106
## AIC.gamma    18397.456012
## shape.mle        1.105085
```

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