**Standardized catch rates of U.S. snowy grouper (Epinephelus niveatus) from commercial logbook handline data**

Sustainable Fisheries Branch, National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort, NC (contact: Rob Cheshire)

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# Standardized catch rates of U.S. snowy grouper (Epinephelus niveatus) from commercial logbook handline data

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

June 2013

## 1. Introduction

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 snowy grouper landed with vertical lines (manual handline and electric/hydraulic reel). Thus, the size and age range of fish included in the index is the same as that of landings from this same fleet. The time series used for construction of the index spanned 1993–2005. In 2006 a 275 gutted pound trip limit was implemented resulting in a dramatic increase in the number of trips that at or close to the trip limit (Figure 1), which would result in the inability for the index to track abundance. Three models were considered for input to the SEDAR 36 assessment of snowy grouper: 1) GLM of the positive snowy grouper trips (Pos), 2) GLM of the positive snowy grouper trips where snowy grouper represented 50% or more of the total catch in pounds (Pos50), 3) Stephens and MacCall delta-GLM approach using species associations to determine snowy grouper trips separately for the areas north and south of Cape Canaveral, FL (SM). The SM model considered all 73 species in the snapper-grouper management unit, but ultimately included those present in at least 1% of records.

## 2. Data and treatment

### 2.1 Available Data

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 (reported fields described in Appendix 1). Fishing effort data available for vertical line gear included number of lines fished, hours fished, and number of hooks per line. For this southeast U.S. Atlantic stock, areas used in analysis were those between 24 and 37 degrees latitude, inclusive of the boundaries (Figure 1).

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 multiple areas or gears fished, which prevents designating catch and effort to specific locations or gears. Therefore, only trips which reported one area and one gear fished were included in these analyses.

Clear outliers in the data, e.g. values falling outside the 99.5 percentile of the data, were also excluded from the analyses. These outliers were identified for manual handlines as records reporting more than 28 lines fished, 17 hooks per line fished, 13 days at sea, or 8 crew members, and they were identified for electric reels as records reporting more than 9 lines fished, 12 hooks per line fished, 12 days at sea, or 8 crew members. Records reporting more than 4483 or 3308 total pounds for manual handline and electric reels respectively were excluded.

## 3. Standardization

The response variable, CPUE, was calculated for each trip as,

CPUE = pounds of snowy grouper/hook-hours

where hook-hours is the product of number of lines fished, number of hooks per line, and total hours fished. Explanatory variables, all categorical, are described below. Estimates of variance for the all models were based on 1000 bootstrap runs where trips were chosen randomly with replacement by year with the sample size retained by year. All analyses were programmed in R, with much of the code adapted from Dick (2004).

### 3.1 Explanatory variables considered

YEAR — Year was necessarily included, as standardized catch rates by year are the desired outcome. Years modeled were 1993–2005. The total number of snowy grouper trips for each model by year is provided in Table 1.

MONTH/SEASON— Month was included as an explanatory factor for the Pos and SM models (Table 2). Due to the smaller sample size of the Pos50 data set, three month intervals were combined to create a SEASON variable (Table 3).

REGION — Four levels of spatial factors were considered for the Pos and SM models ; 1. NC, 2. SC, 3. GA and Northern FL (Ga-NFL) combined, and 4. South Florida. The Pos50 model was limited to two variables; 1. NC, SC, GA, and North Florida and 2. South Florida (Table 4). The nominal CPUE associated with each region is plotted in Figure 3.

CREW SIZE — Crew size (crew) was pooled into four levels for the Pos and SM models: one, two, three, and four or more (4plus). The Pos50 model was limited to two levels; one, and two or more (2plus). The number of trips per year by crew is shown in Table 5.

DAYS AT SEA — Days at sea were pooled into three levels: one or two days (1-2), three or four days (3-4), and five or more days (5plus) for all models. The number of trips per year by sea days is shown in Table 6.

3.2 Positive CPUE models (Pos and Pos50)
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 factors. The two distributions, each with their best set of explanatory variables, were compared using AIC. Lognormal outperformed gamma for both models and was therefore applied in the final GLM. Uncertainty was estimated from 1000 bootstrap runs sampling with replacement in proportion to the sample size by year.

3.3 Stephens and MacCall delta-GLM model (SM)
Bernoulli Submodel
One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching snowy grouper on a particular trip. First, stepwise AIC (Venables and Ripley 1997) with a backwards selection algorithm was used to eliminate factors that did not improve model fit. Both gamma and lognormal distributions retained all factors.

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 factors. The two distributions, each with their best set of explanatory variables, were compared using AIC. Lognormal outperformed gamma and was therefore applied in the final GLM.

Both the Bernoulli and positive CPUE submodels were fit together using code adapted for Dick (2004). Lognormal and gamma distributions compared using AIC. The lognormal distribution outperformed the gamma distribution. Uncertainty was estimated from 1000 bootstrap runs sampling with replacement in proportion to the sample size by year.

# 4. Results

Standard model diagnostics suggested reasonable fits of the lognormal model for the Pos (Figures 4, 5) and Pos50 (Figures 6,7) models. The Q:Q plot for the Pos50 model shows the predicted values are not fit particularly well at lower CPUE. The species associated both positively and negatively with snowy grouper seem appropriate, with blueline tilefish being the predominant positively associated species (Figure 8). However, other deep-water species which are not as common may not have met the cut-off criteria for inclusion. Standard model diagnostics suggested reasonable fits of the SM model (Figures 9, 10). The nominal CPUE, predicted standardized CPUE, and predicted error are given in Figure 11 and Table 7. The predicted standardized CPUE values are compared in Figure 12.

## 5. Discussion

The commercial logbook index (handline and longline combined) was not recommended for use in SEDAR 4. However, more recent assessments have used the commercial logbook indices as model input. The blueline tilefish assessment (SEDAR 32) included both the commercial handline and longline indices. The primary difference between the snowy grouper and blueline tilefish is targeting. Blueline tilefish are, for the most part, a bycatch of snowy grouper effort. Trends in population abundance can be masked in fishery dependent indices if fishermen can switch to other, more productive areas as the population is depleted. For this reason, indices of bycatch species in a fishery may be more likely to reflect population trends.

The ability to identify effort directed at snowy grouper, and other deep-water species, is problematic because of switching effort to other species during a trip. Discussion with fishermen revealed several reasons why this may occur. Snowy grouper predominantly are fished during the day and, where multi-day trips are more common like NC, fishermen are likely to switch to other species at night. Current and weather conditions may also change during a trip causing fishermen to move to other, usually shallower, habitat. As long as these patterns are consistent over time, they may not be a concern for the models using just positive trips (Pos and Pos50). However, the Stephens and MacCall method predicts trips that were in snowy grouper habitat based on species associations. Therefore, trips that fish multiple habitats limit the ability of the model to predict trips in snowy grouper habitat.

Fishermen from both NC and FL suggested juvenile “snowflake” snowy grouper were caught in the same habitat as the adults. However, only juveniles are caught on the shallower (<180 ft) portion of the shelf. This is particularly true in areas where there is more shelf habitat such as NC. The Pos50 model was an attempt to get an index of trips targeting the deep-water habitat where the catch is mostly snowy grouper. However, the trips meeting the criteria of 50% or more snowy grouper are higher in Florida (Table 4). This may be due to the larger number of multiple day trips where targeting may change during a trip as the distance to deep water increases in the northern part of the range. These longer trips may be a smaller percent snowy due to switching target species.

The positive trip model (Pos) seems to be the most likely candidate if the commercial logbook index is included as model input for the snowy grouper assessment. This was also the modeling approach used in SEDAR32 for blueline tilefish indices developed from commercial logbook data. Since juveniles occur in both deep and shallower habitat the index will represent the entire population even if constrained to just deep-water species. The nominal index by region raises some concerns about how the criteria of filtering deep-water trips increased the proportion of trips from FL for the Pos50 model (Figure 3). Only about 15-30% of the positive snowy grouper trips met the criteria to be included in the Pos50 anlaysis. The Stephens and MacCall method may not be able to clearly identify snowy grouper habitat by species associations due to the inability to separate the shallow juvenile habitat from the deepwater habitat. The relative rarity of other deep-water species may also impede the SM method from defining snowy grouper trips.

## Literature cited

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Shertzer, K.W., E.H. Williams, and J.C. Taylor. 2009. Spatial structure and temporal patterns in a large marine ecosystem: Exploited reef fishes of the southeast United States. Fish. Res.
100:126–133.

Venables, W. N. and B. D. Ripley. 1997. Modern Applied Statistics with S-Plus, 2nd Edition. Springer-Verlag, New York.

Table 1. Number of snowy grouper trips by year for each model type. The positive (SM Pos) and zero (SM-0) snowy grouper trips are reported for the Stephens and MacCall method. The percent of trips that caught snowy grouper and were excluded based on species association are reported as 'SM Pos dropped'

| Year | Pos | Pos50 | SM | SM-0 | SM-Pos | SM Pos dropped |
|---|---|---|---|---|---|---|
| 1993 | 602 | 100 | 530 | 204 | 326 | 46% |
| 1994 | 982 | 175 | 942 | 357 | 585 | 40% |
| 1995 | 1204 | 195 | 1049 | 378 | 671 | 44% |
| 1996 | 1145 | 193 | 1021 | 351 | 670 | 41% |
| 1997 | 1632 | 339 | 1325 | 397 | 928 | 43% |
| 1998 | 1120 | 248 | 922 | 317 | 605 | 46% |
| 1999 | 1245 | 344 | 998 | 324 | 674 | 46% |
| 2000 | 1115 | 310 | 1019 | 373 | 646 | 42% |
| 2001 | 1226 | 310 | 1200 | 491 | 709 | 42% |
| 2002 | 1117 | 317 | 1064 | 431 | 633 | 43% |
| 2003 | 952 | 246 | 886 | 349 | 537 | 44% |
| 2004 | 777 | 227 | 755 | 321 | 434 | 44% |
| 2005 | 717 | 245 | 765 | 379 | 386 | 46% |

Table 2. Number of snowy grouper trips by year and month for the 'Pos' and 'SM' models.

| Year<br>Pos | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | 11 | 3 | 44 | 82 | 102 | 114 | 137 | 75 | 7 | 3 | 2 | 22 |
| 1994 | 53 | 70 | 82 | 124 | 114 | 114 | 64 | 89 | 84 | 78 | 57 | 53 |
| 1995 | 67 | 82 | 122 | 101 | 144 | 128 | 166 | 114 | 88 | 68 | 63 | 61 |
| 1996 | 73 | 139 | 65 | 79 | 108 | 121 | 76 | 152 | 65 | 81 | 88 | 98 |
| 1997 | 114 | 113 | 157 | 125 | 185 | 174 | 160 | 170 | 145 | 119 | 71 | 99 |
| 1998 | 102 | 79 | 78 | 94 | 162 | 165 | 102 | 73 | 75 | 78 | 71 | 41 |
| 1999 | 97 | 103 | 109 | 87 | 152 | 138 | 138 | 111 | 79 | 80 | 65 | 86 |
| 2000 | 80 | 121 | 98 | 105 | 109 | 104 | 112 | 102 | 91 | 83 | 72 | 38 |
| 2001 | 109 | 114 | 105 | 99 | 147 | 126 | 86 | 112 | 99 | 64 | 64 | 101 |
| 2002 | 109 | 80 | 77 | 99 | 102 | 103 | 99 | 104 | 89 | 120 | 83 | 52 |
| 2003 | 53 | 85 | 75 | 86 | 111 | 103 | 67 | 121 | 77 | 92 | 45 | 37 |
| 2004 | 39 | 63 | 71 | 88 | 77 | 81 | 85 | 81 | 31 | 64 | 46 | 51 |
| 2005 | 63 | 68 | 90 | 84 | 95 | 66 | 72 | 48 | 47 | 33 | 24 | 27 |
| SM | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1993 | 13 | 1 | 43 | 85 | 91 | 71 | 109 | 70 | 5 | 3 | 8 | 31 |
| 1994 | 62 | 60 | 86 | 104 | 109 | 112 | 64 | 77 | 77 | 69 | 61 | 61 |
| 1995 | 80 | 75 | 109 | 97 | 104 | 95 | 106 | 101 | 82 | 67 | 75 | 58 |
| 1996 | 67 | 121 | 61 | 71 | 92 | 100 | 77 | 152 | 58 | 71 | 77 | 74 |
| 1997 | 85 | 90 | 128 | 79 | 151 | 142 | 121 | 165 | 133 | 93 | 55 | 83 |
| 1998 | 87 | 81 | 80 | 76 | 131 | 124 | 75 | 54 | 48 | 57 | 65 | 44 |
| 1999 | 83 | 82 | 74 | 82 | 114 | 104 | 104 | 94 | 68 | 65 | 55 | 73 |
| 2000 | 64 | 70 | 103 | 105 | 95 | 92 | 101 | 87 | 93 | 84 | 80 | 45 |
| 2001 | 86 | 94 | 109 | 92 | 137 | 139 | 78 | 113 | 121 | 66 | 63 | 102 |
| 2002 | 90 | 71 | 92 | 99 | 91 | 98 | 86 | 95 | 86 | 104 | 95 | 57 |
| 2003 | 49 | 63 | 79 | 63 | 98 | 93 | 71 | 99 | 86 | 88 | 50 | 47 |
| 2004 | 53 | 56 | 80 | 80 | 77 | 72 | 70 | 69 | 31 | 67 | 50 | 50 |
| 2005 | 55 | 62 | 80 | 67 | 102 | 83 | 68 | 55 | 68 | 52 | 37 | 36 |

Table 3. Number of snowy grouper trips by year and month for the 'Pos50' analysis.

| Year | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec |
|---|---|---|---|---|
| 1993 | 9 | 52 | 35 | 4 |
| 1994 | 41 | 73 | 29 | 32 |
| 1995 | 51 | 56 | 67 | 21 |
| 1996 | 44 | 51 | 55 | 43 |
| 1997 | 66 | 140 | 78 | 55 |
| 1998 | 59 | 94 | 53 | 42 |
| 1999 | 101 | 98 | 79 | 66 |
| 2000 | 102 | 94 | 65 | 49 |
| 2001 | 90 | 84 | 68 | 68 |
| 2002 | 106 | 98 | 50 | 63 |
| 2003 | 52 | 86 | 61 | 47 |
| 2004 | 51 | 70 | 61 | 45 |
| 2005 | 81 | 88 | 47 | 29 |

Table 4. Number of snowy grouper trips by region and year for each model type.

| | Pos | | | | Pos50 | | SM | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | NC | SC | GA-NFL | SFL | NC-NFL | SFL | NC | SC | GA-NFL | SFL |
| 1993 | 152 | 132 | 114 | 204 | 34 | 66 | 131 | 113 | 125 | 161 |
| 1994 | 239 | 178 | 187 | 377 | 49 | 126 | 228 | 155 | 280 | 279 |
| 1995 | 267 | 265 | 246 | 426 | 56 | 139 | 227 | 244 | 312 | 266 |
| 1996 | 271 | 201 | 236 | 436 | 63 | 130 | 249 | 143 | 272 | 357 |
| 1997 | 347 | 236 | 351 | 697 | 120 | 219 | 321 | 167 | 280 | 557 |
| 1998 | 288 | 197 | 194 | 441 | 94 | 154 | 244 | 148 | 196 | 334 |
| 1999 | 368 | 176 | 178 | 523 | 129 | 215 | 294 | 129 | 151 | 424 |
| 2000 | 291 | 132 | 132 | 560 | 81 | 229 | 251 | 145 | 191 | 432 |
| 2001 | 338 | 192 | 135 | 561 | 77 | 233 | 314 | 229 | 233 | 424 |
| 2002 | 311 | 132 | 133 | 541 | 67 | 250 | 315 | 158 | 199 | 392 |
| 2003 | 187 | 174 | 114 | 477 | 62 | 184 | 198 | 157 | 139 | 392 |
| 2004 | 160 | 138 | 88 | 391 | 57 | 170 | 173 | 160 | 134 | 288 |
| 2005 | 178 | 111 | 89 | 339 | 69 | 176 | 200 | 153 | 122 | 290 |

Table 5. Number of snowy grouper trips by crew size and year for each model.

| | Pos | | | | Pos50 | | SM | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4plus | 1 | 2plus | 1 | 2 | 3 | 4plus |
| 1993 | 132 | 207 | 149 | 114 | 34 | 66 | 122 | 178 | 132 | 98 |
| 1994 | 272 | 302 | 233 | 175 | 85 | 90 | 204 | 263 | 267 | 208 |
| 1995 | 305 | 384 | 307 | 208 | 87 | 108 | 191 | 331 | 304 | 223 |
| 1996 | 298 | 412 | 247 | 188 | 84 | 109 | 249 | 341 | 235 | 196 |
| 1997 | 486 | 530 | 387 | 229 | 153 | 186 | 387 | 438 | 314 | 186 |
| 1998 | 311 | 372 | 288 | 149 | 121 | 127 | 255 | 285 | 248 | 134 |
| 1999 | 329 | 496 | 296 | 124 | 137 | 207 | 266 | 375 | 239 | 118 |
| 2000 | 345 | 407 | 260 | 103 | 122 | 188 | 261 | 341 | 256 | 161 |
| 2001 | 362 | 441 | 293 | 130 | 156 | 154 | 293 | 373 | 351 | 183 |
| 2002 | 341 | 410 | 267 | 99 | 146 | 171 | 266 | 332 | 307 | 159 |
| 2003 | 311 | 372 | 172 | 97 | 114 | 132 | 268 | 313 | 198 | 107 |
| 2004 | 240 | 323 | 148 | 66 | 92 | 135 | 209 | 248 | 189 | 109 |
| 2005 | 188 | 310 | 156 | 63 | 97 | 148 | 204 | 264 | 201 | 96 |

Table 6. Number of snowy grouper trips by days at sea and year for each model type.

| | Pos | | | Pos50 | | | SM | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2-3 | 4plus | 1 | 2-3 | 4plus | 1 | 2-3 | 4plus |
| 1993 | 184 | 147 | 271 | 64 | 25 | 11 | 172 | 136 | 222 |
| 1994 | 368 | 202 | 412 | 131 | 35 | 9 | 312 | 197 | 433 |
| 1995 | 385 | 293 | 526 | 150 | 32 | 13 | 272 | 279 | 498 |
| 1996 | 433 | 286 | 426 | 121 | 52 | 20 | 374 | 237 | 410 |
| 1997 | 685 | 399 | 548 | 227 | 81 | 31 | 584 | 330 | 411 |
| 1998 | 432 | 278 | 410 | 168 | 58 | 22 | 342 | 250 | 330 |
| 1999 | 595 | 336 | 314 | 254 | 69 | 21 | 461 | 259 | 278 |
| 2000 | 593 | 274 | 248 | 238 | 60 | 12 | 488 | 246 | 285 |
| 2001 | 581 | 282 | 363 | 236 | 57 | 17 | 480 | 284 | 436 |
| 2002 | 537 | 284 | 296 | 244 | 68 | 5 | 420 | 297 | 347 |
| 2003 | 460 | 213 | 279 | 186 | 42 | 18 | 411 | 195 | 280 |
| 2004 | 395 | 159 | 223 | 179 | 37 | 11 | 324 | 149 | 282 |
| 2005 | 373 | 141 | 203 | 204 | 33 | 8 | 334 | 165 | 266 |

Table 7. Nominal and standardized CPUE with associated CV from all model runs.

| Year | N | Relative Nominal CPUE | Standardized CPUE | CV |
|---|---|---|---|---|
| | | **Pos** | | |
| 1993 | 602 | 0.67 | 0.77 | 0.07 |
| 1994 | 982 | 0.62 | 0.66 | 0.06 |
| 1995 | 1204 | 0.76 | 0.70 | 0.05 |
| 1996 | 1145 | 0.71 | 0.82 | 0.05 |
| 1997 | 1632 | 0.80 | 0.96 | 0.05 |
| 1998 | 1120 | 0.93 | 1.04 | 0.05 |
| 1999 | 1245 | 1.59 | 1.40 | 0.06 |
| 2000 | 1115 | 1.32 | 1.05 | 0.06 |
| 2001 | 1226 | 0.98 | 0.94 | 0.05 |
| 2002 | 1117 | 1.07 | 0.93 | 0.05 |
| 2003 | 952 | 1.02 | 1.16 | 0.05 |
| 2004 | 777 | 1.14 | 1.34 | 0.06 |
| 2005 | 717 | 1.39 | 1.24 | 0.07 |
| | | **Pos50** | | |
| 1993 | 100 | 0.80 | 0.70 | 0.11 |
| 1994 | 175 | 0.78 | 0.72 | 0.09 |
| 1995 | 195 | 0.96 | 0.92 | 0.09 |
| 1996 | 193 | 0.95 | 0.94 | 0.09 |
| 1997 | 339 | 0.81 | 0.64 | 0.07 |
| 1998 | 248 | 0.98 | 0.89 | 0.08 |
| 1999 | 344 | 1.58 | 1.50 | 0.07 |
| 2000 | 310 | 1.25 | 1.10 | 0.07 |
| 2001 | 310 | 0.94 | 0.88 | 0.06 |
| 2002 | 317 | 0.98 | 0.99 | 0.07 |
| 2003 | 246 | 0.85 | 0.96 | 0.07 |
| 2004 | 227 | 1.01 | 1.43 | 0.07 |
| 2005 | 245 | 1.11 | 1.33 | 0.07 |
| | | **SM** | | |
| 1993 | 530 | 0.96 | 0.87 | 0.12 |
| 1994 | 942 | 0.66 | 0.64 | 0.08 |
| 1995 | 1049 | 0.68 | 0.86 | 0.07 |
| 1996 | 1021 | 0.76 | 1.05 | 0.07 |
| 1997 | 1325 | 1.07 | 1.20 | 0.06 |
| 1998 | 922 | 1.00 | 0.92 | 0.08 |
| 1999 | 998 | 1.36 | 1.32 | 0.08 |
| 2000 | 1019 | 1.06 | 0.85 | 0.07 |
| 2001 | 1200 | 1.07 | 1.04 | 0.07 |
| 2002 | 1064 | 0.95 | 0.96 | 0.07 |
| 2003 | 886 | 0.97 | 1.05 | 0.08 |
| 2004 | 755 | 1.21 | 1.29 | 0.08 |
| 2005 | 765 | 1.22 | 0.95 | 0.10 |

Figures

Figure 1. Commercial handline snowy grouper trips per year (right axis), associated trip limits which dropped from 2500 to 275 gutted pounds in 2006 (right axis), and the proportion of the trips at or above 90% of the trip limit (left axis).

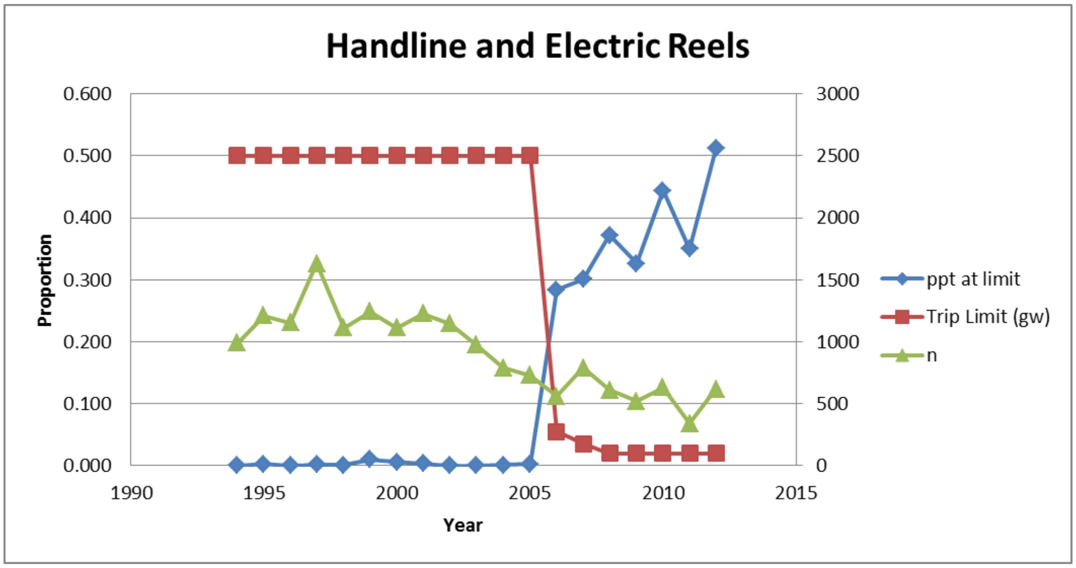


Figure 2. Commercial handline trips (left panel) and positive snowy grouper commercial handline trips (right panel). The green symbols represent the areas that combined signify fifty percent of the total trips, the red and green circles combined represent seventy-five percent of the total trips, the red, green, and yellow symbols combined represent ninety-nine percent of the total trips, and the gray symbols represent one percent of the trips. The area between 24 and 37 degrees latitude were included in this analysis (solid horizontal red lines).

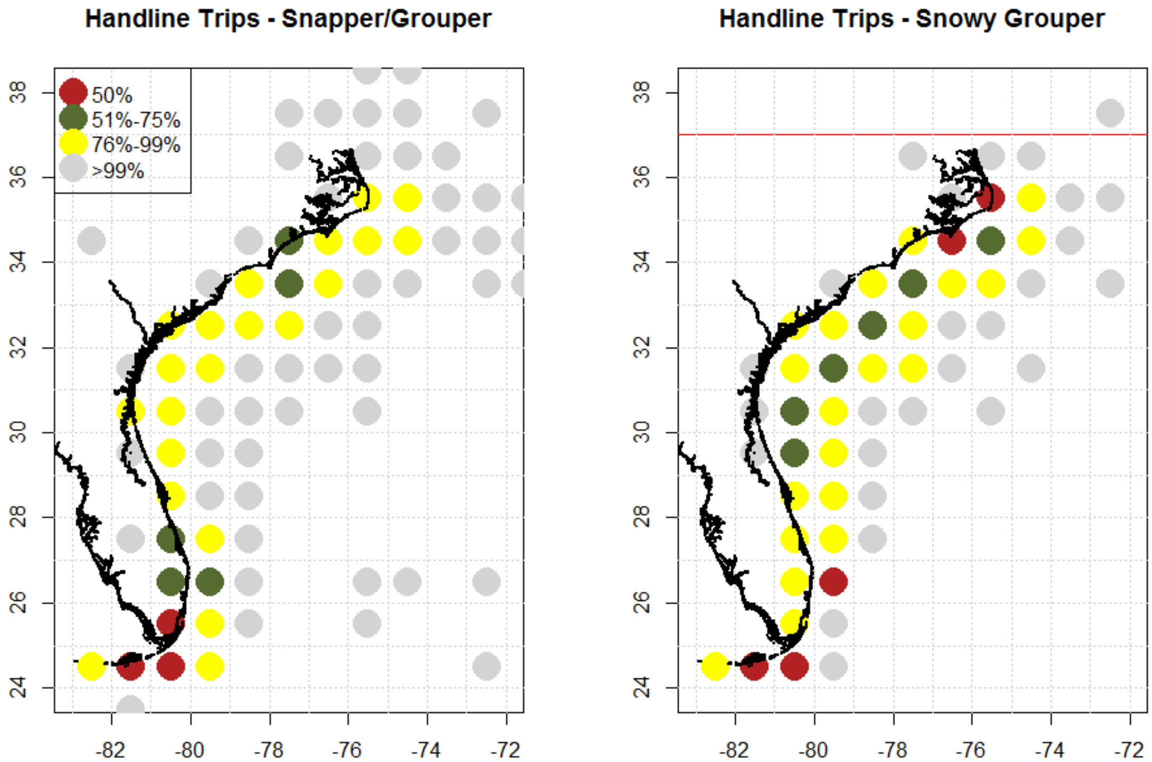
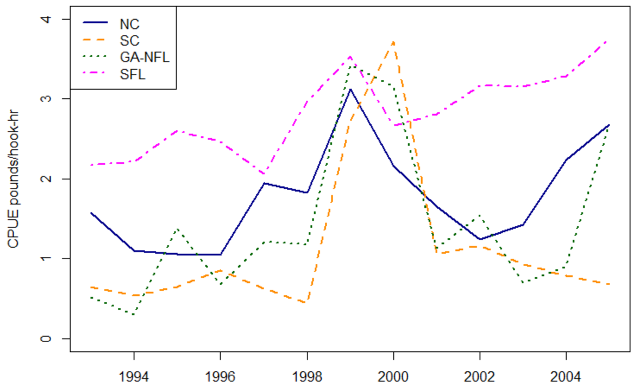
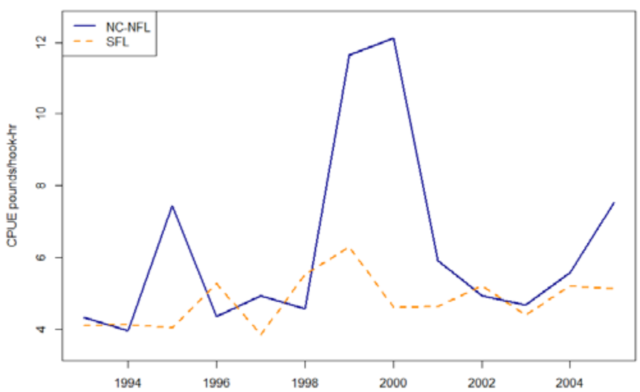


Figure 3. Snowy grouper nominal CPUE by region for Pos (A), Pos50 (B), and SM (C) models. Florida was split at Cape Canaveral.

A



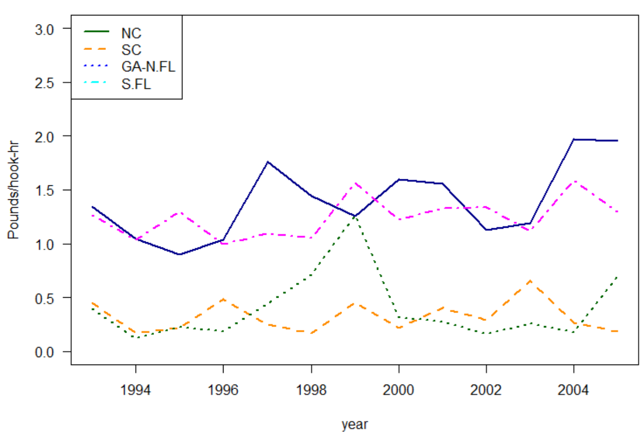
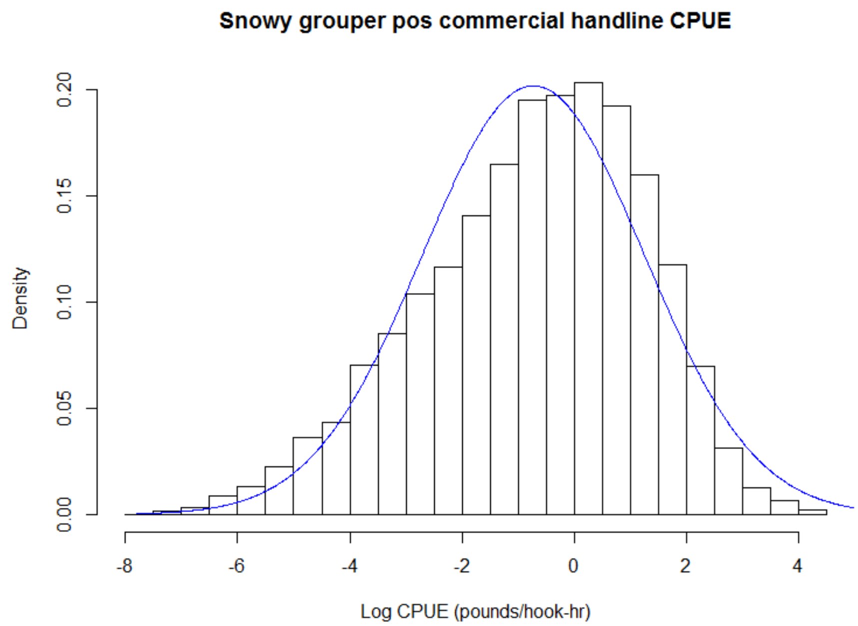



Figure 4. Diagnostics of lognormal model fits to positive CPUE data for the Pos model. Top panel shows the histogram of empirical log CPUE, with the normal distribution (empirical mean and variance) overlaid. Bottom panel shows the quantile-quantile plot of residuals from the fitted model.



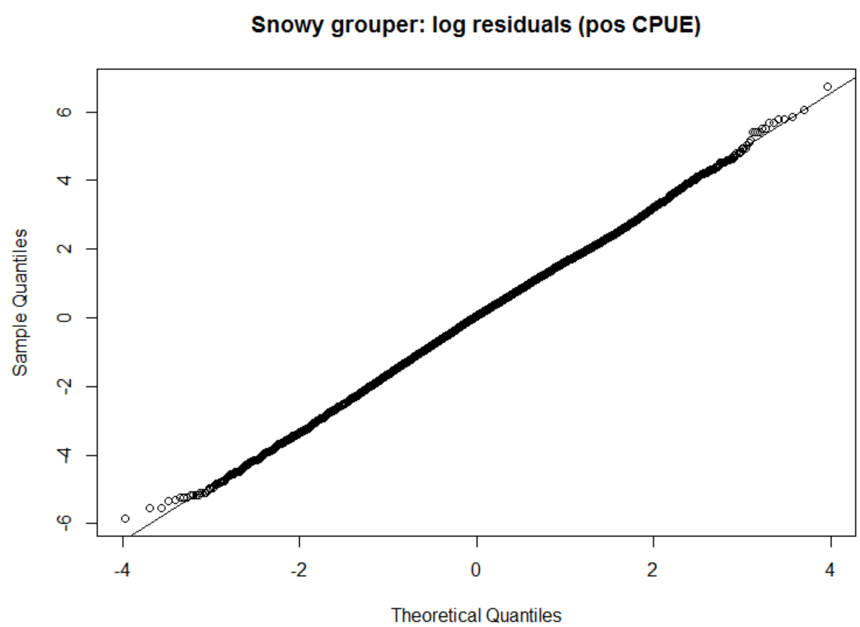



Figure 5. Diagnostics of lognormal model fits to positive CPUE data for the Pos model. Box-and-whisker plots give first, second (median), and third quartiles, as well as limbs that extend approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are raw.

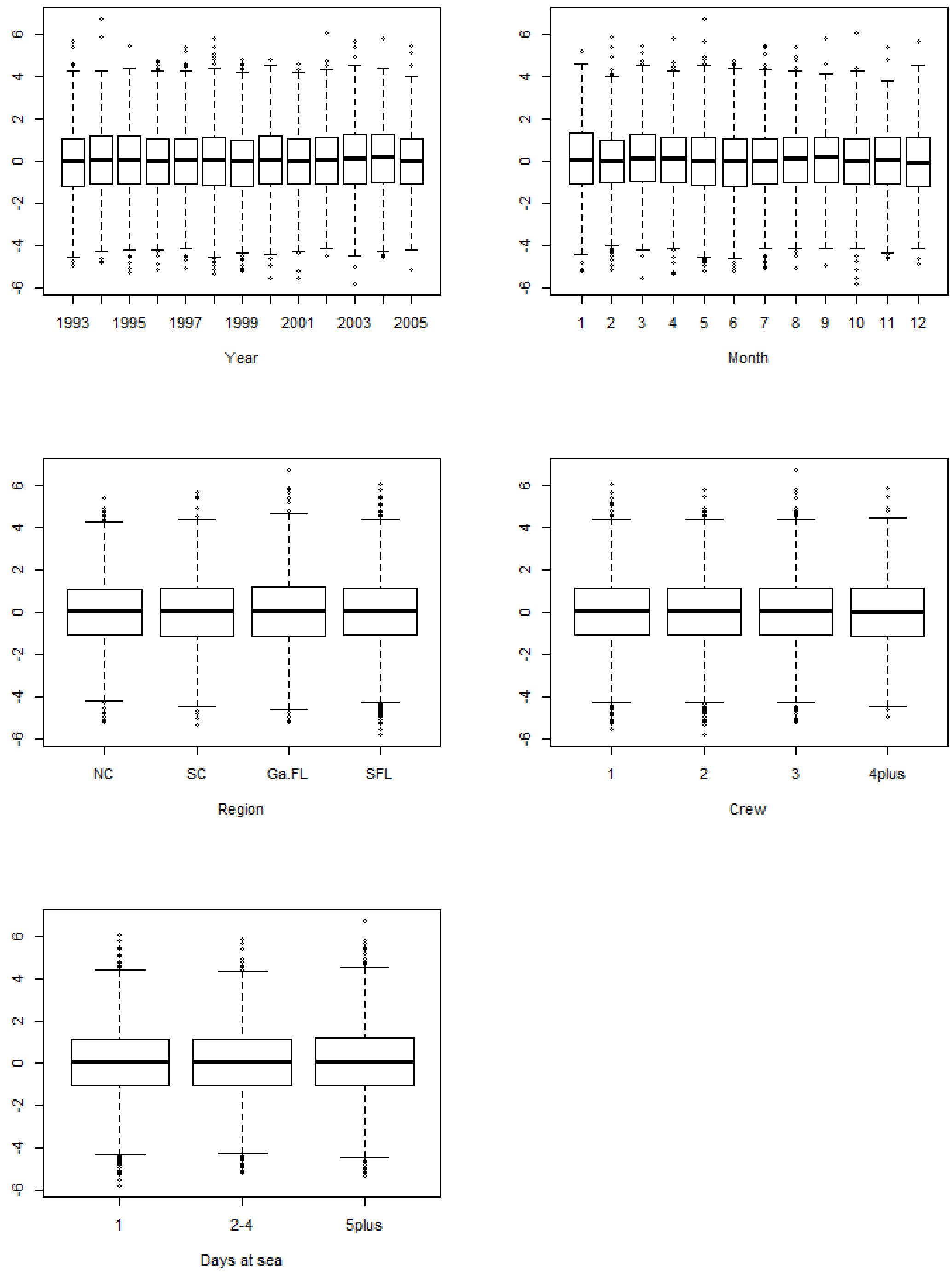
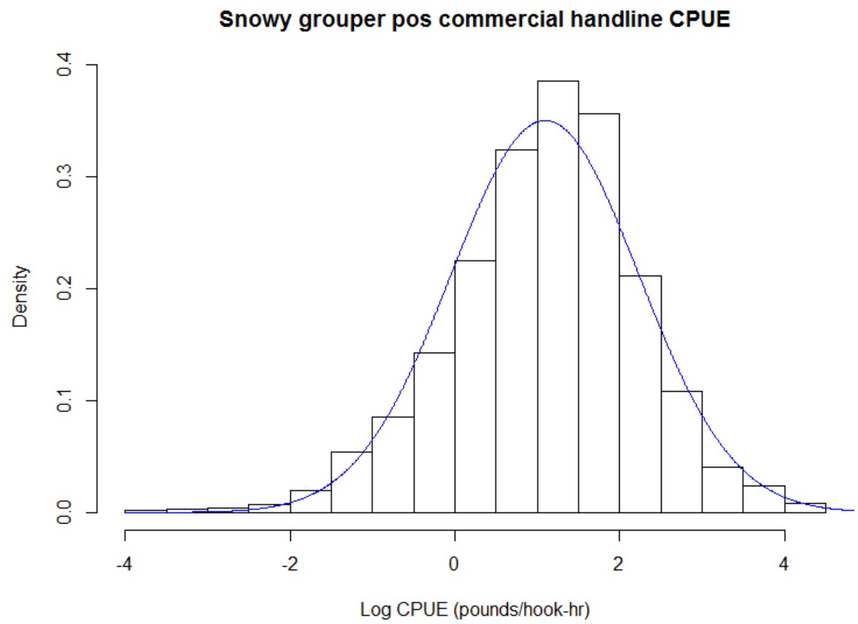


Figure 6. Diagnostics of lognormal model fits to positive CPUE data for the Pos50 model. Top panel shows the histogram of empirical log CPUE, with the normal distribution (empirical mean and variance) overlaid. Bottom panel shows the quantile-quantile plot of residuals from the fitted model.



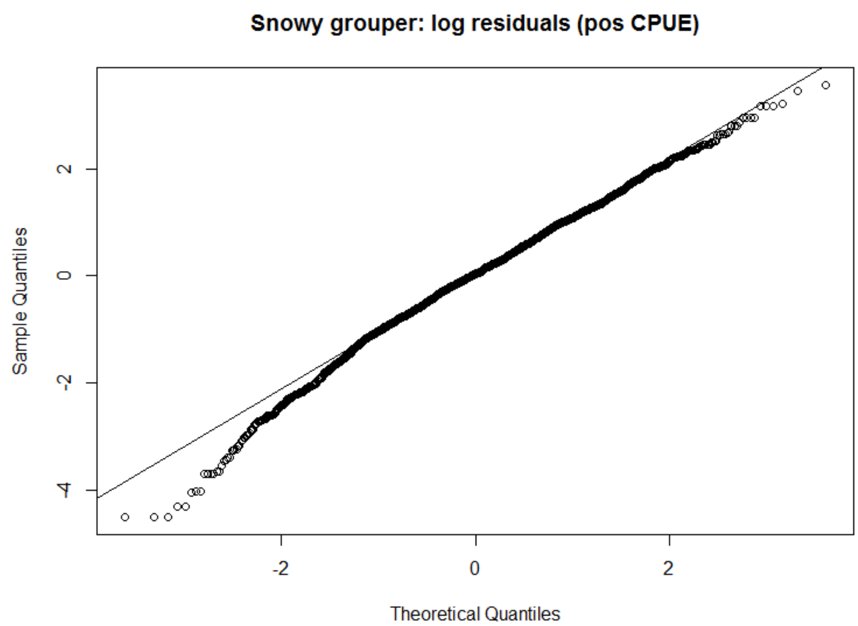



Figure 7. Diagnostics of lognormal model fits to positive CPUE data for the Pos50 model. Box-and-whisker plots give first, second (median), and third quartiles, as well as limbs that extend approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are raw.

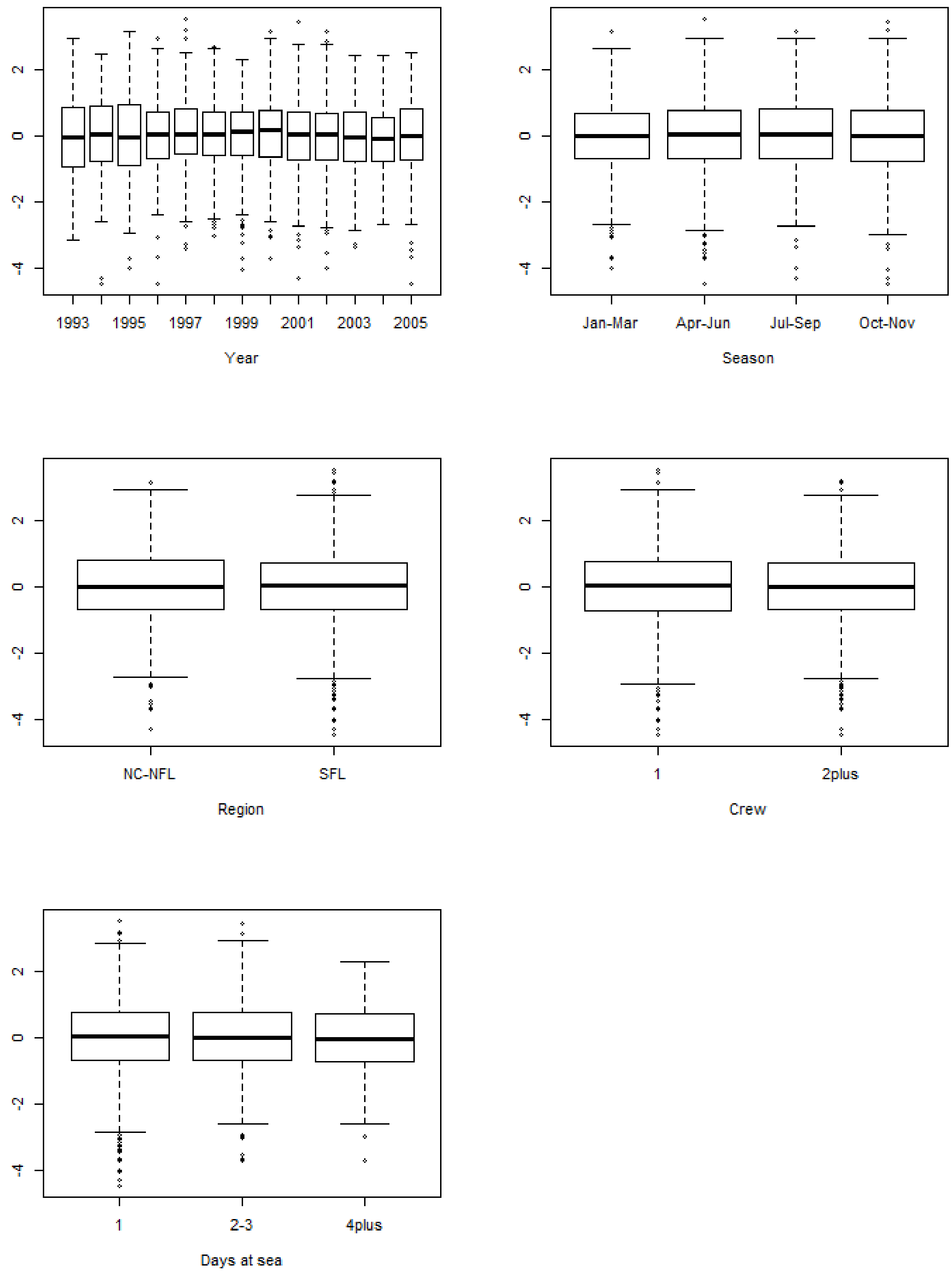
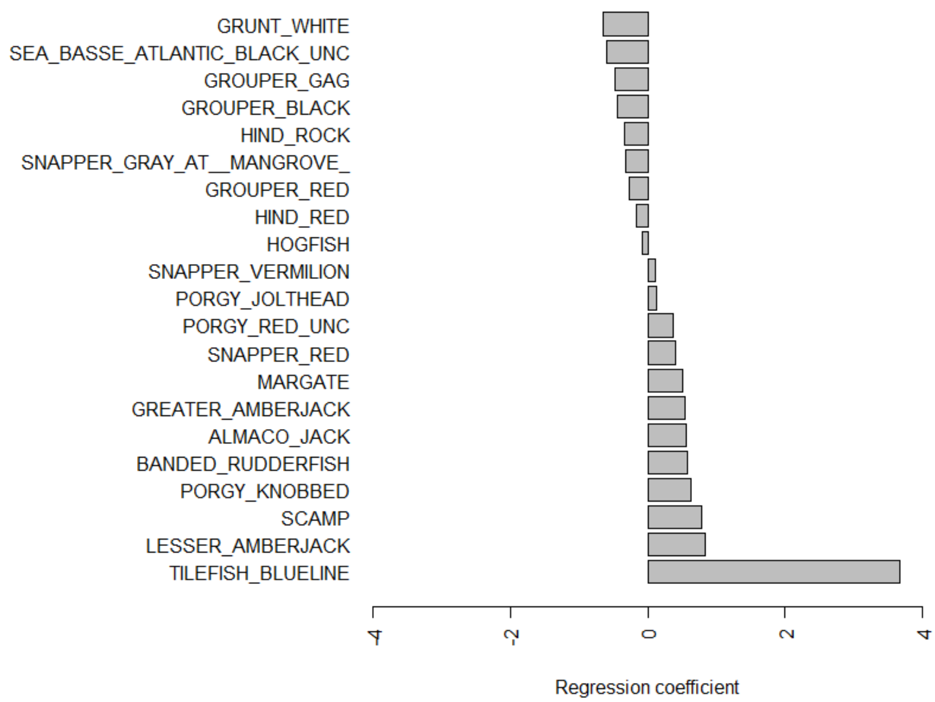


Figure 8. Species association for the for the SM model north (A) and south (B) of Cape Canaveral, FL.

A



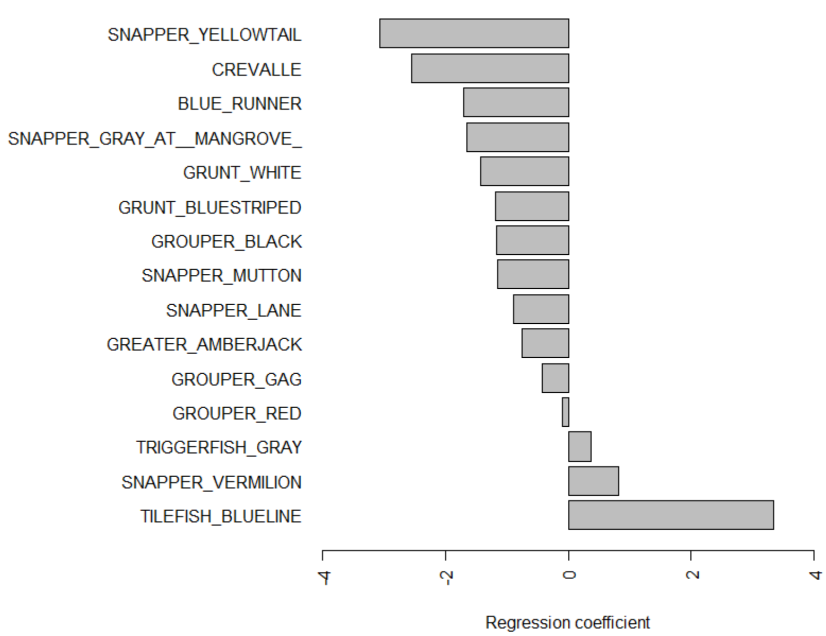
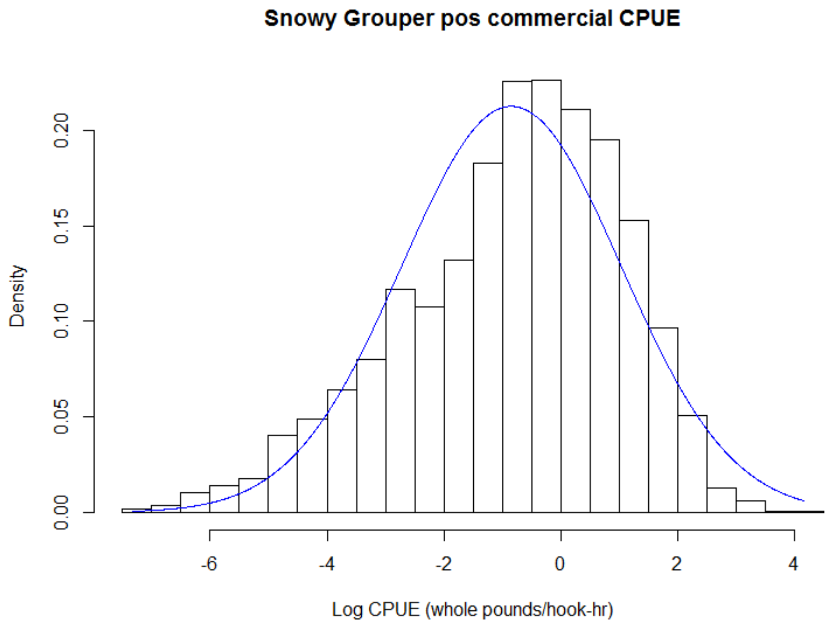



Figure 9. Diagnostics of lognormal model fits to positive CPUE data for the SM model. Top panel shows the histogram of empirical log CPUE, with the normal distribution (empirical mean and variance) overlaid. Bottom panel shows the quantile-quantile plot of residuals from the fitted model.



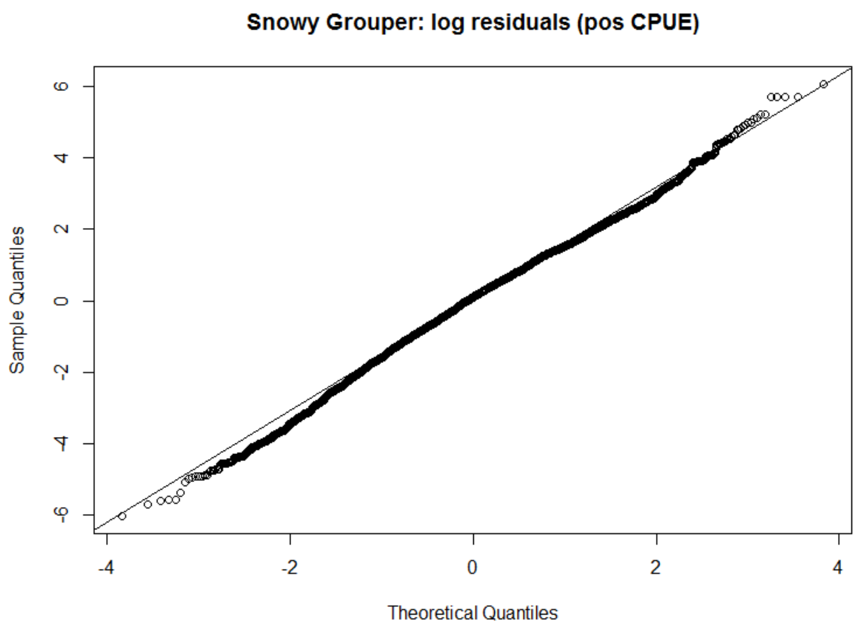



Figure 10. Diagnostics of lognormal model fits to positive CPUE data. Box-and-whisker plots give first, second (median), and third quartiles, as well as limbs that extend approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are raw.

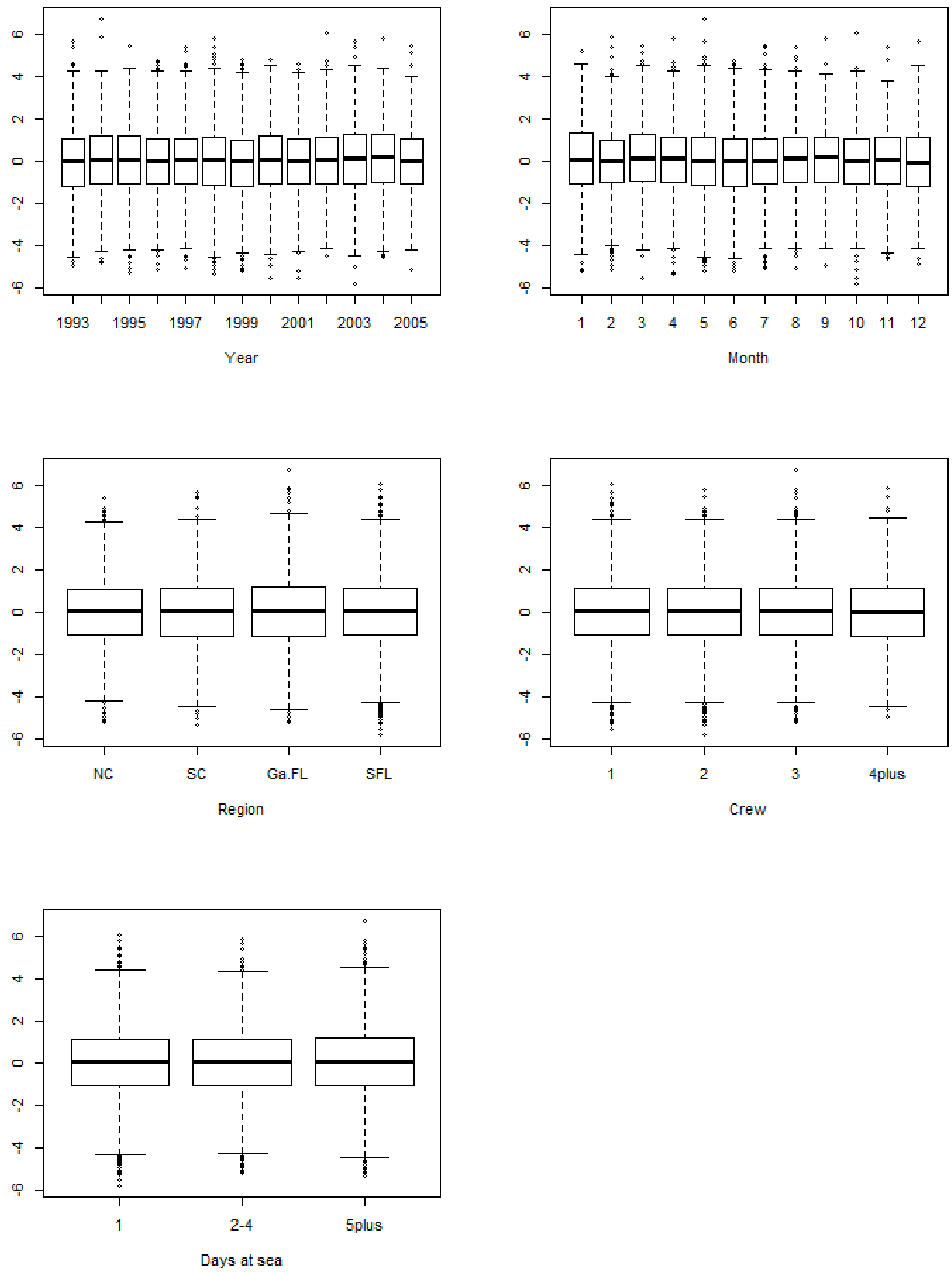
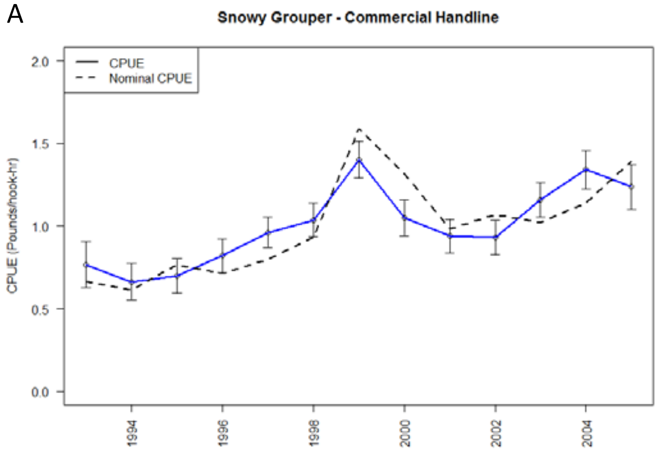
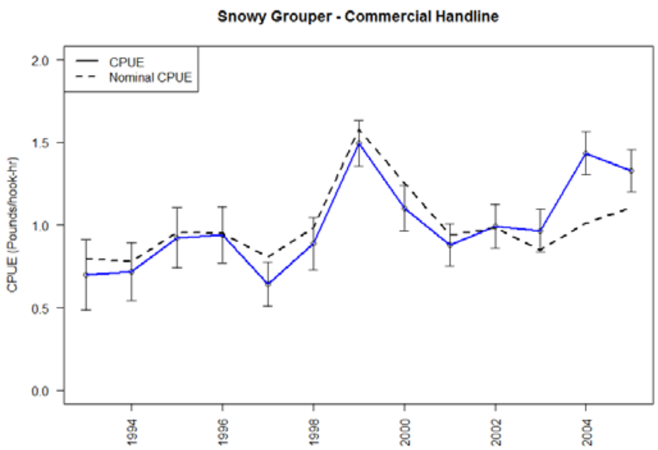


Figure 11. Snowy grouper standardized CPUE and nominal cpue for the Pos (A), Pos50 (B), and SM(C) models.

A



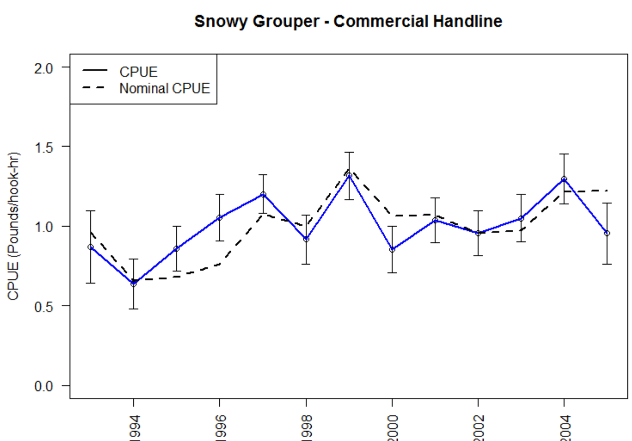



Figure 12. Standardized CPUE of all models compared.