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# Red snapper standardized catch rates from the Marine Recreational Fisheries Statistics Survey for the southeastern U.S. Atlantic Ocean, 1991-2009

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U.S. Atlantic Ocean recreational catches of red snapper, *Lutjanus campechanus*, occur most commonly in the private/rental boat and charterboat modes. The Marine Recreational Fisheries Statistics Survey (MRFSS) is a fishery-dependent survey where total catch including discards is reported in angler intercepts and effort is estimated from telephones surveys. Total catch rates (i.e., catch per unit effort, CPUE) can indicate changes in relative abundance. In 1991, MRFSS made several improvements to the survey including linking ancillary intercepts from the same fishing trip together and recording the total number of anglers in the party. Therefore, the data for this analysis was constrained to MRFSS intercepts from 1991-2009 in the private/rental boat and charterboat modes from North Carolina through the Florida Keys (Figure 1). I attempted to calculate two separate indices, north and south of Cape Canaveral, but data were not sufficient for convergence in the southern region. Therefore, I generated a single index that included region as a potential variable. This index was created with and without the B2 data.

There were 152,319 MRFSS intercepts in the charterboat and private/rental boat modes from nearshore (state) and offshore waters (federal), and 43 species including red snapper occurred on at least 0.5% of those intercepts. In this analysis, those additional intercepts from the same fishing trip that caught fish but were unavailable to the creel sampler were linked back to the main intercept for the party.

Over the 19 years from 1991 through 2009, there were 1,711 intercepts that caught red snapper in the study area (Table 1a and 1b, Figure 2a and 2b). However, there were trips that could have caught red snapper, but didn't. To identify that effort and include it in the catch rate standardization process, Stephens and MacCall (2004) logistic regressions (S&M) were employed. The rationale of S&M is to identify a homogeneous group of intercepts that are believed to reflect the abundance of the target species. The S&M method uses a logistic regression of presence or absence by species on each intercept to predict whether the target species (red snapper) could be caught on the trip. Following Stephens and MacCall's example, species that occurred on less than 1% of the total number of intercepts were omitted.

For the S&M method, the intercept data were rearranged to one record per intercept with binomial (presence or absence) information for each of the 43 species. The response variable in the logistic regression was the presence (1) or absence (0) of red snapper on each intercept and the predictor variables in the full model were the presence or absence

of the other 42 species. There were 30 species (Table 2, Figure 3) whose regression coefficients were significant at the $\alpha = 0.05$ level and those species were used in the final, reduced model.

Potential thresholds (estimated probability of catching red snapper) for choosing whether to include an intercept in the catch rate analysis ranged from 0.01 to 0.99 and the critical value was based on the minimum absolute difference between observed number of intercepts with red snapper and the predicted number of intercepts. The smallest absolute difference occurred with a threshold of 0.152 (Figure 4). There were 1,709 intercepts that exceeded the 0.152 threshold.

Once the MRFSS intercepts for calculating the catch rates were selected, the total number of red snapper caught was calculated for each selected intercept and annual catch rates were estimated with generalized linear models (GLM). I applied an approach based on Lo et al. (1992) by dividing the data into two datasets: 1) red snapper presence or absence data (1,709 intercepts) and fit to a GLM with a binomial distribution with a logit link and 2) the total catch of red snapper on positive intercepts (718 intercepts) were fit to a GLM with a gamma distribution with a log link. Potential explanatory variables were year (1991-2009), wave (two-month time period), mode (charterboat or private/rental boat), area (nearshore or offshore), region (North Carolina through Georgia; Nassau County through Flagler County, Florida: Volusia County through Dade County, Florida; and Monroe County, Florida), hours fished (0, 2, 4, 6, 8, 10, 12+ hr), and the number of anglers on the trip (1, 2, 3, 4, 5, 6, 8, 10, 12+). Potential variables were evaluated for inclusion in the GLM through a step-wise process. For each step-wise level, provided that the variable with the lowest Akaike Information Criterion (AIC) value was also significant at the $\alpha = 0.05$ level (from twice the change in log-likelihood), that variable was added to the model for use in the calculations in the next step (Table 3a, 3b, 3c and 3d).

With the B2 data, the GLM explained 41.43% of the deviance with region explaining 15.21%, year explaining 9.62% of the deviance (Table 3a), and wave, area, hours fished, mode and number of anglers explaining the rest. The model for the total number of red snapper caught per intercept on positive intercepts using a gamma distribution with a log link explained 10.8% of the deviance with most of the deviance explained by year (3.78%), wave (2.29%), number of anglers (1.58%) and the rest by the remaining variables (Table 3b). Without the B2 data, the GLM explained 42.86% of the deviance with number of anglers explaining 13.48%, mode explaining 12.18% of the deviance (Table 3c), and wave, region, area, hours fished and year explaining the rest. The model for the total number of red snapper caught per intercept on positive intercepts using a gamma distribution with a log link explained 26.36% of the deviance with most of the deviance explained by year (8.79%) and wave (6.12%) and the rest by the remaining variables (Table 3d). The annual mean catch per intercept values (Table 1a and 1b, Stephens and MacCall columns) were calculated with a Monte Carlo method based on the number of intercepts by two-month wave, area, mode, region, hours fished and number of anglers per year to determine the probability of a non-zero intercept multiplied by the mean number of red snapper caught per angler. Random variation was added to

each outcome by multiplying the standard error of the proportion positive by a random, normal deviate and by multiplying the standard error of the number per intercept by a different random, deviate. After the random deviates were added to the terms, the terms were back-transformed to their original scales and multiplied together. This process was repeated for each of the 1,709 intercepts and the index was the mean of the outcomes by year (Figure 5a and 5b).

The S&M standardization method appears to add noise to the relative abundance index data both with and with the B2 data (Figure 6a and 6b). However, a trend is more apparent in the standardized relative CPUE index than in the nominal index. When comparing the with and without B2 versions of the index, the B2 data adds noise and slight increase in the severity of the upward trend (Figure 7).

Literature Cited

Lo, N. C., L. D. Jacobson, and J. L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515-2526.

Stephens, A. and A. MacCall. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fisheries Research 70:299-310.

**Table 1a.** Nominal and standardized total catch rates of red snapper from charterboat and private/rental boat MRFSS modes from nearshore and offshore waters from North Carolina through the Florida Keys using intercepts selected with the Stephens and MacCall logistic regressions. The N is the number of intercepts included in the analysis where red snapper were caught. Run with B2 data.

| | Nominal | | | | Stephens and MacCall | | | |
|---|---|---|---|---|---|---|---|---|
| Year | N | Mean | CV | Scaled to Mean | N | Mean | CV | Scaled to Mean |
| 1991 | 44 | 5.98 | 0.51 | 1.01 | 9 | 0.68 | 0.35 | 0.32 |
| 1992 | 90 | 6.24 | 0.60 | 1.05 | 21 | 0.56 | 0.34 | 0.26 |
| 1993 | 45 | 4.93 | 0.49 | 0.83 | 16 | 1.82 | 0.90 | 0.84 |
| 1994 | 80 | 5.79 | 0.55 | 0.98 | 20 | 1.06 | 0.58 | 0.49 |
| 1995 | 59 | 6.32 | 0.37 | 1.07 | 21 | 1.39 | 0.51 | 0.64 |
| 1996 | 51 | 5.82 | 0.66 | 0.98 | 14 | 0.71 | 0.47 | 0.33 |
| 1997 | 40 | 5.60 | 0.75 | 0.95 | 5 | 0.11 | 0.08 | 0.05 |
| 1998 | 54 | 6.43 | 0.48 | 1.09 | 17 | 0.82 | 0.39 | 0.38 |
| 1999 | 95 | 6.40 | 0.41 | 1.08 | 46 | 2.40 | 0.97 | 1.10 |
| 2000 | 92 | 7.12 | 0.45 | 1.20 | 41 | 3.26 | 1.48 | 1.50 |
| 2001 | 117 | 5.16 | 0.43 | 0.87 | 61 | 1.53 | 0.66 | 0.70 |
| 2002 | 108 | 6.18 | 0.30 | 1.04 | 52 | 3.34 | 1.01 | 1.54 |
| 2003 | 143 | 5.48 | 0.38 | 0.93 | 67 | 2.52 | 0.96 | 1.16 |
| 2004 | 153 | 6.75 | 0.41 | 1.14 | 69 | 2.44 | 1.00 | 1.12 |
| 2005 | 104 | 5.47 | 0.41 | 0.92 | 42 | 2.48 | 1.01 | 1.14 |
| 2006 | 116 | 5.76 | 0.36 | 0.97 | 52 | 1.22 | 0.43 | 0.56 |
| 2007 | 94 | 5.59 | 0.34 | 0.94 | 44 | 2.56 | 0.86 | 1.18 |
| 2008 | 118 | 5.17 | 0.40 | 0.87 | 59 | 2.35 | 0.94 | 1.08 |
| 2009 | 106 | 6.08 | 0.35 | 1.03 | 62 | 2.46 | 0.87 | 1.13 |

**Table 1b.** Nominal and standardized total catch rates of red snapper from charterboat and private/rental boat MRFSS modes from nearshore and offshore waters from North Carolina through the Florida Keys using intercepts selected with the Stephens and MacCall logistic regressions. The N is the number of intercepts included in the analysis where red snapper were caught. Run without B2 data.

| | Nominal | | | | Stephens and MacCall | | | |
|---|---|---|---|---|---|---|---|---|
| Year | N | Mean | CV | Scaled to Mean | N | Mean | CV | Scaled to Mean |
| 1991 | 44 | 5.59 | 1.22 | 1.32 | 9 | 0.27 | 92.91 | 0.42 |
| 1992 | 90 | 5.61 | 0.69 | 1.32 | 14 | 0.14 | 61.12 | 0.85 |
| 1993 | 45 | 4.33 | 0.91 | 1.02 | 13 | 0.37 | 57.14 | 0.42 |
| 1994 | 80 | 5.38 | 1.00 | 1.26 | 18 | 0.47 | 58.43 | 0.75 |
| 1995 | 59 | 4.63 | 0.93 | 1.09 | 14 | 0.47 | 57.10 | 0.56 |
| 1996 | 51 | 5.33 | 1.13 | 1.26 | 10 | 0.26 | 47.78 | 0.48 |
| 1997 | 40 | 4.65 | 1.35 | 1.09 | 4 | 0.05 | 85.89 | 0.38 |
| 1998 | 54 | 4.78 | 1.04 | 1.12 | 13 | 0.26 | 59.95 | 0.51 |
| 1999 | 95 | 3.82 | 0.66 | 0.90 | 31 | 0.63 | 43.55 | 0.90 |
| 2000 | 92 | 3.59 | 0.76 | 0.84 | 32 | 0.85 | 47.73 | 0.87 |
| 2001 | 117 | 3.64 | 0.72 | 0.86 | 47 | 0.57 | 58.16 | 1.10 |
| 2002 | 108 | 3.64 | 0.82 | 0.86 | 44 | 1.11 | 45.72 | 1.02 |
| 2003 | 143 | 3.75 | 0.64 | 0.88 | 44 | 0.57 | 55.58 | 1.35 |
| 2004 | 153 | 4.70 | 0.57 | 1.11 | 52 | 0.89 | 50.44 | 1.44 |
| 2005 | 104 | 3.74 | 0.59 | 0.88 | 26 | 0.53 | 47.34 | 0.98 |
| 2006 | 116 | 4.13 | 0.53 | 0.97 | 34 | 0.31 | 43.88 | 1.09 |
| 2007 | 94 | 3.50 | 0.56 | 0.82 | 26 | 0.54 | 42.75 | 0.89 |
| 2008 | 118 | 3.75 | 0.47 | 0.88 | 43 | 0.95 | 53.38 | 1.11 |
| 2009 | 106 | 4.62 | 0.98 | 1.09 | 42 | 0.67 | 46.46 | 1.00 |

**Table 2.** Species names and codes with significant regression coefficients ($\alpha = 0.05$) to predict whether red snapper were caught on MRFSS intercepts for charterboat and private/rental boat MRFSS modes from nearshore and offshore waters.

| NODC Code | Scientific Name | Common Name | Coefficient | Error |
|---|---|---|---|---|
| | | Intercept | -4.6741 | 0.0487 |
| 8835020102 | Morone saxatilis | BASS, STRIPED | -5.1450 | 1.0029 |
| 8839010101 | Thunnus thynnus | TUNA, BLUEFIN | -3.5865 | 1.0016 |
| 8857030301 | Mycteroperca microlepis | GROUPER, GAG | -3.5060 | 0.4499 |
| 88260201 | Prionotus | SEAROBINS, NORTH AMERICAN | -2.6777 | 1.0110 |
| 8710010201 | Scomberomorus cavalla | MACKEREL, KING | -2.3956 | 0.7212 |
| 8850030402 | Tautoga onitis | TAUTOG | -2.3028 | 0.7089 |
| 8835440102 | Thunnus albacares | TUNA, YELLOWFIN | -2.1059 | 0.5803 |
| 8850030403 | Seriola dumerili | AMBERJACK, GREATER | -1.9187 | 0.4178 |
| 8835430101 | Scomberomorus maculatus | MACKEREL, SPANISH | -1.7977 | 0.4365 |
| 8835440702 | Rhomboplites aurorubens | SNAPPER, VERMILION | -1.5932 | 0.3578 |
| 8835250101 | Centropristis striata | BASS, BLACK SEA | -1.2779 | 0.1633 |
| 88500304 | Thunnus | TUNA | -1.1144 | 0.4713 |
| 8850060101 | Lutjanus griseus | SNAPPER, GRAY | -1.1022 | 0.2749 |
| 8850030502 | Caranx crysos | RUNNER, BLUE | -1.0664 | 0.1735 |
| 88570303 | Paralichthys | FLOUNDER | -0.9601 | 0.3397 |
| 8835400102 | Cynoscion nebulosus | SEATROUT, SPOTTED | -0.9369 | 0.1160 |
| 8835280306 | Ocyurus chrysurus | SNAPPER, YELLOWTAIL | -0.7484 | 0.1810 |
| 8835290101 | Squalus acanthias | DOGFISH, SPINY | -0.7286 | 0.0926 |
| 8835360103 | Haemulon plumieri | GRUNT, WHITE | -0.6074 | 0.1684 |
| 8835360401 | Coryphaena hippurus | DOLPHIN | -0.3131 | 0.1361 |
| 8850030501 | Epinephelus morio | GROUPER, RED | -0.2895 | 0.0800 |
| 8850030102 | Rachycentron canadum | COBIA | -0.2317 | 0.1131 |
| 8835020408 | Istiophorus platypterus | SAILFISH | 0.5484 | 0.1144 |
| 8835360102 | Lutjanus analis | SNAPPER, MUTTON | 0.5812 | 0.1069 |
| 8835260101 | Euthynnus alletteratus | TUNNY, LITTLE | 0.7704 | 0.1230 |
| 8860020201 | Stenotomus chrysops | SCUP | 1.1691 | 0.0818 |
| 8835280801 | Micropogonias undulatus | CROAKER, ATLANTIC | 1.2259 | 0.0954 |
| 8835020301 | Pomatomus saltatrix | BLUEFISH | 1.7117 | 0.0665 |
| 8835360501 | Balistes capriscus | TRIGGERFISH, GRAY | 2.0746 | 0.0802 |
| 8835020501 | Paralichthys dentatus | FLOUNDER, SUMMER | 2.1837 | 0.0769 |

**Table 3a.** Stepwise selection of variables to include in estimating the proportion of positive MRFSS intercepts for red snapper (shaded lines) with a GLM (binomial distribution and logit link) selected with Stephens and MacCall logistic regression based on lowest AIC values. The fields include the variables, the degrees of freedom for that variable (df), the deviance of the model with those variables, the mean deviance (deviance/df), the change in mean deviance ( Δ mean dev), percent reduction in mean deviance (% mean dev), cumulative reduction in mean deviance, log likelihood, the change in log likelihood from previous run, minus two times the change in log-likelihood, chi-square value, the Chi-square degrees of freedom, the probability of the null hypothesis (Prob Ho), and the Akaike Information Criterion (AIC). Run with B2 data.

| Variables | | df | Deviance | Mean dev | Δ mean dev | % expl | Cum % | log like | Δ log like | Chi sq | df | Prob Ho | AIC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Null | Deviance | 1708 | 2325.38 | 1.3615 | | | | -1162.69 | | | 1 | | 2327.38 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1690 | 2240.2717 | 1.3256 | 0.0359 | 2.64% | | -1120.1358 | -42.5542 | 85.1084 | 18 | 1.07818E-10 | 123.1084 |
| Wave | Deviance | 1703 | 2308.0066 | 1.3553 | 0.0062 | 0.46% | | -1154.0033 | -8.6867 | 17.3734 | 5 | 0.003843464 | 29.3734 |
| Area | Deviance | 1707 | 2265.639 | 1.3273 | 0.0342 | 2.51% | | -1132.8195 | -29.8705 | 59.741 | 1 | 1.08199E-14 | 63.741 |
| Mode_fx | Deviance | 1707 | 2302.9182 | 1.3491 | 0.0124 | 0.91% | 0.91% | -1151.4591 | -11.2309 | 22.4618 | 1 | 2.14365E-06 | 26.4618 |
| Region | Deviance | 1704 | 2242.634 | 1.3161 | 0.0454 | 3.33% | | -1121.317 | -41.373 | 82.746 | 4 | 4.56062E-17 | 92.746 |
| Hr fished | Deviance | 1702 | 2287.3875 | 1.3439 | 0.0176 | 1.29% | | -1143.6937 | -18.9963 | 37.9926 | 6 | 1.12711E-06 | 51.9926 |
| Num anglers | Deviance | 1700 | 2254.9369 | 1.3264 | 0.0351 | 2.58% | | -1127.4684 | -35.2216 | 70.4432 | 8 | 4.01065E-12 | 88.4432 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1689 | 2203.4793 | 1.3046 | 0.0569 | 4.18% | | -1101.7397 | -60.9503 | 121.9006 | 19 | 4.88929E-17 | 161.9006 |
| Wave | Deviance | 1702 | 2277.9383 | 1.3384 | 0.0231 | 1.70% | 2.61% | -1138.9691 | -23.7209 | 47.4418 | 6 | 1.5274E-08 | 61.4418 |
| Area | Deviance | 1706 | 2249.5434 | 1.3186 | 0.0429 | 3.15% | | -1124.7717 | -37.9183 | 75.8366 | 2 | 3.40637E-17 | 81.8366 |
| Region | Deviance | 1703 | 2135.3081 | 1.2439 | 0.1176 | 8.64% | | -1067.654 | -95.036 | 190.072 | 5 | 3.7707E-39 | 202.072 |
| Hr fished | Deviance | 1701 | 2272.2517 | 1.3358 | 0.0257 | 1.89% | | -1136.1259 | -26.5641 | 53.1282 | 7 | 3.49723E-09 | 69.1282 |
| Num anglers | Deviance | 1699 | 2254.9184 | 1.3272 | 0.0343 | 2.52% | | -1127.4592 | -35.2308 | 70.4616 | 9 | 1.23615E-11 | 90.4616 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1684 | 2182.2369 | 1.2959 | 0.0656 | 4.82% | | -1091.1185 | -71.5715 | 143.143 | 24 | 6.15315E-19 | 193.143 |
| Area | Deviance | 1701 | 2219.9517 | 1.3051 | 0.0564 | 4.14% | | -1109.9759 | -52.7141 | 105.4282 | 7 | 8.1374E-20 | 121.4282 |
| Region | Deviance | 1698 | 2114.6812 | 1.2454 | 0.1161 | 8.53% | | -1057.3406 | -105.3494 | 210.6988 | 10 | 9.42538E-40 | 232.6988 |
| Hr fished | Deviance | 1696 | 2245.6704 | 1.3241 | 0.0374 | 2.75% | 5.35% | -1122.8352 | -39.8548 | 79.7096 | 12 | 4.68859E-12 | 105.7096 |
| Num anglers | Deviance | 1694 | 2222.855 | 1.3122 | 0.0493 | 3.62% | | -1111.4275 | -51.2625 | 102.525 | 14 | 1.55344E-15 | 132.525 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1678 | 2152.6549 | 1.2829 | 0.0786 | 5.77% | | -1076.3275 | -86.3625 | 172.725 | 30 | 5.45853E-22 | 234.725 |
| Area | Deviance | 1695 | 2197.7274 | 1.2966 | 0.0649 | 4.77% | 10.12% | -1098.8637 | -63.8263 | 127.6526 | 13 | 6.12812E-21 | 155.6526 |
| Region | Deviance | 1692 | 2082.4429 | 1.2308 | 0.1307 | 9.60% | | -1041.2215 | -121.4685 | 242.937 | 16 | 1.44966E-42 | 276.937 |
| Num anglers | Deviance | 1688 | 2189.8333 | 1.2973 | 0.0642 | 4.72% | | -1094.9167 | -67.7733 | 135.5466 | 20 | 3.52358E-19 | 177.5466 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1677 | 2107.9642 | 1.257 | 0.1045 | 7.68% | | -1053.9821 | -108.7079 | 217.4158 | 31 | 7.0989E-30 | 281.4158 |
| Region | Deviance | 1691 | 2036.2277 | 1.2042 | 0.1573 | 11.55% | | -1018.1138 | -144.5762 | 289.1524 | 17 | 1.94022E-51 | 325.1524 |
| Num anglers | Deviance | 1687 | 2148.1139 | 1.2733 | 0.0882 | 6.48% | 16.60% | -1074.057 | -88.633 | 177.266 | 21 | 1.00831E-26 | 221.266 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1669 | 2053.6915 | 1.2305 | 0.131 | 9.62% | 26.22% | -1026.8457 | -135.8443 | 271.6886 | 39 | 1.21614E-36 | 351.6886 |
| Region | Deviance | 1683 | 1994.8495 | 1.1853 | 0.1762 | 12.94% | | -997.4247 | -165.2653 | 330.5306 | 25 | 4.26749E-55 | 382.5306 |
| | | | | | | | | | | | | | |
| Region | Deviance | 1665 | 1921.9953 | 1.1544 | 0.2071 | 15.21% | 41.43% | -960.9976 | -201.6924 | 403.3848 | 43 | 4.50683E-60 | 491.3848 |

**Table 3b.** Stepwise selection of variables to include in estimating the total catch of red snapper on positive MRFSS intercepts for red snapper (shaded lines) with a GLM (gamma distribution and log link) selected with Stephens and MacCall logistic regression based on lowest AIC values. The fields include the variables, the degrees of freedom for that variable (df), the deviance of the model with those variables, the mean deviance (deviance/df), the change in mean deviance ( Δ mean dev), percent reduction in mean deviance (% mean dev), cumulative reduction in mean deviance, log likelihood, the change in log likelihood from previous run, minus two times the change in log-likelihood, chi-square value, the Chi-square degrees of freedom, the probability of the null hypothesis (Prob Ho), and the Akaike Information Criterion (AIC). Run with B2 data.

| Variables | | df | Deviance | Mean dev | Δ mean de | % expl | Cum % | log like | Δ log like | Chi sq | df | Prob Ho | AIC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Null | Deviance | 712 | 986.6681 | 1.3858 | | | | -2021.41 | | | 1 | | 4044.819 |
| | | | | | | | | | | | | | |
| Year | Deviance | 694 | 942.342 | 1.3578 | 0.028 | 2.02% | | -2002.16 | -19.2457 | 38.4914 | 18 | 0.003333 | 76.4914 |
| Wave | Deviance | 707 | 961.4326 | 1.3599 | 0.0259 | 1.87% | | -2010.55 | -10.8604 | 21.7208 | 5 | 0.000592 | 33.7208 |
| Area | Deviance | 711 | 986.6129 | 1.3876 | -0.0018 | -0.13% | | -2021.39 | -0.0234 | 0.0468 | 1 | 0.828728 | 4.0468 |
| Mode_fx | Deviance | 711 | 986.6515 | 1.3877 | -0.0019 | -0.14% | | -2021.4 | -0.0071 | 0.0142 | 1 | 0.905146 | 4.0142 |
| Region | Deviance | 709 | 975.6148 | 1.376 | 0.0098 | 0.71% | 0.71% | -2016.68 | -4.7262 | 9.4524 | 3 | 0.023843 | 17.4524 |
| Hr fished | Deviance | 706 | 979.2738 | 1.3871 | -0.0013 | -0.09% | | -2018.25 | -3.1564 | 6.3128 | 6 | 0.389077 | 20.3128 |
| Num angle | Deviance | 704 | 982.1591 | 1.3951 | -0.0093 | -0.67% | | -2019.49 | -1.9222 | 3.8444 | 8 | 0.870882 | 21.8444 |
| | | | | | | | | | | | | | |
| Year | Deviance | 691 | 928.5934 | 1.3438 | 0.042 | 3.03% | | -1996.03 | -25.3786 | 50.7572 | 21 | 0.000286 | 94.7572 |
| Wave | Deviance | 704 | 956.7779 | 1.3591 | 0.0267 | 1.93% | | -2008.52 | -12.8912 | 25.7824 | 8 | 0.001144 | 43.7824 |
| Area | Deviance | 708 | 975.6131 | 1.378 | 0.0078 | 0.56% | | -2016.68 | -4.7269 | 9.4538 | 4 | 0.050705 | 19.4538 |
| Mode_fx | Deviance | 708 | 975.116 | 1.3773 | 0.0085 | 0.61% | 1.32% | -2016.47 | -4.9406 | 9.8812 | 4 | 0.042477 | 19.8812 |
| Hr fished | Deviance | 703 | 964.3657 | 1.3718 | 0.014 | 1.01% | | -2011.82 | -9.5852 | 19.1704 | 9 | 0.023782 | 39.1704 |
| Num angle | Deviance | 701 | 971.2333 | 1.3855 | 0.0003 | 0.02% | | -2014.8 | -6.6128 | 13.2256 | 11 | 0.278836 | 37.2256 |
| | | | | | | | | | | | | | |
| Year | Deviance | 690 | 927.3592 | 1.344 | 0.0418 | 3.02% | | -1995.48 | -25.9331 | 51.8662 | 22 | 0.000326 | 97.8662 |
| Wave | Deviance | 703 | 956.7277 | 1.3609 | 0.0249 | 1.80% | | -2008.5 | -12.9131 | 25.8262 | 9 | 0.002181 | 45.8262 |
| Area | Deviance | 707 | 975.1156 | 1.3792 | 0.0066 | 0.48% | | -2016.47 | -4.9408 | 9.8816 | 5 | 0.07866 | 21.8816 |
| Hr fished | Deviance | 702 | 963.2506 | 1.3722 | 0.0136 | 0.98% | 2.30% | -2011.34 | -10.0696 | 20.1392 | 10 | 0.027963 | 42.1392 |
| Num angle | Deviance | 700 | 970.9512 | 1.3871 | -0.0013 | -0.09% | | -2014.67 | -6.7345 | 13.469 | 12 | 0.335892 | 39.469 |
| | | | | | | | | | | | | | |
| Year | Deviance | 684 | 915.0345 | 1.3378 | 0.048 | 3.46% | | -1989.9 | -31.5065 | 63.013 | 28 | 0.000166 | 121.013 |
| Wave | Deviance | 697 | 942.7408 | 1.3526 | 0.0332 | 2.40% | | -2002.34 | -19.069 | 38.138 | 15 | 0.000861 | 70.138 |
| Area | Deviance | 701 | 963.2318 | 1.3741 | 0.0117 | 0.84% | 3.15% | -2011.33 | -10.0777 | 20.1554 | 11 | 0.043254 | 44.1554 |
| Num angle | Deviance | 694 | 960.1129 | 1.3834 | 0.0024 | 0.17% | | -2009.97 | -11.4352 | 22.8704 | 18 | 0.19562 | 60.8704 |
| | | | | | | | | | | | | | |
| Year | Deviance | 683 | 914.7474 | 1.3393 | 0.0465 | 3.36% | | -1989.77 | -31.6371 | 63.2742 | 29 | 0.000238 | 123.2742 |
| Wave | Deviance | 696 | 942.4537 | 1.3541 | 0.0317 | 2.29% | 5.43% | -2002.21 | -19.1962 | 38.3924 | 16 | 0.00133 | 72.3924 |
| Num angle | Deviance | 693 | 960.0386 | 1.3853 | 0.0005 | 0.04% | | -2009.94 | -11.4676 | 22.9352 | 19 | 0.240208 | 62.9352 |
| | | | | | | | | | | | | | |
| Year | Deviance | 678 | 897.9003 | 1.3243 | 0.0615 | 4.44% | | -1982.04 | -39.3669 | 78.7338 | 34 | 2.09E-05 | 148.7338 |
| Num angl | Deviance | 688 | 938.3838 | 1.3639 | 0.0219 | 1.58% | 7.01% | -2000.41 | -21.0031 | 42.0062 | 24 | 0.012884 | 92.0062 |
| | | | | | | | | | | | | | |
| Year | Deviance | 670 | 893.3843 | 1.3334 | 0.0524 | 3.78% | 10.80% | -1979.95 | -41.4608 | 82.9216 | 42 | 0.00017 | 168.9216 |

**Table 3c.** Stepwise selection of variables to include in estimating the proportion of positive MRFSS intercepts for red snapper (shaded lines) with a GLM (binomial distribution and logit link) selected with Stephens and MacCall logistic regression based on lowest AIC values. The fields include the variables, the degrees of freedom for that variable (df), the deviance of the model with those variables, the mean deviance (deviance/df), the change in mean deviance ( Δ mean dev), percent reduction in mean deviance (% mean dev), cumulative reduction in mean deviance, log likelihood, the change in log likelihood from previous run, minus two times the change in log-likelihood, chi-square value, the Chi-square degrees of freedom, the probability of the null hypothesis (Prob Ho), and the Akaike Information Criterion (AIC). Run without B2 data.

| Variables | | df | Deviance | Mean dev | Δ mean dev | % expl | Cum % | log like | Δ log like | Chi sq | df | Prob Ho | AIC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Null | Deviance | 1708 | 2093.496 | 1.2257 | | | | -1046.75 | | | 1 | | 2095.496 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1690 | 2043.035 | 1.2089 | 0.0168 | 1.37% | | -1021.52 | -25.2304 | 50.4608 | 18 | 6.43E-05 | 88.4608 |
| Wave | Deviance | 1703 | 2077.984 | 1.2202 | 0.0055 | 0.45% | 0.45% | -1038.99 | -7.7562 | 15.5124 | 5 | 0.008383 | 27.5124 |
| Area | Deviance | 1707 | 2054.673 | 1.2037 | 0.022 | 1.79% | | -1027.34 | -19.4116 | 38.8232 | 1 | 4.64E-10 | 42.8232 |
| Mode_fx | Deviance | 1707 | 2035.448 | 1.1924 | 0.0333 | 2.72% | | -1017.72 | -29.0239 | 58.0478 | 1 | 2.56E-14 | 62.0478 |
| Region | Deviance | 1704 | 2056.747 | 1.207 | 0.0187 | 1.53% | | -1028.37 | -18.3743 | 36.7486 | 4 | 2.03E-07 | 46.7486 |
| Hr fished | Deviance | 1702 | 2063.209 | 1.2122 | 0.0135 | 1.10% | | -1031.6 | -15.1437 | 30.2874 | 6 | 3.47E-05 | 44.2874 |
| Num anglers | Deviance | 1700 | 1999.995 | 1.1765 | 0.0492 | 4.01% | | -999.997 | -46.7507 | 93.5014 | 8 | 9.03E-17 | 111.5014 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1685 | 2030.092 | 1.2048 | 0.0209 | 1.71% | | -1015.05 | -31.7018 | 63.4036 | 23 | 1.21E-05 | 111.4036 |
| Area | Deviance | 1702 | 2034.073 | 1.1951 | 0.0306 | 2.50% | | -1017.04 | -29.7115 | 59.423 | 6 | 5.9E-11 | 73.423 |
| Mode_fx | Deviance | 1702 | 2007.801 | 1.1797 | 0.046 | 3.75% | | -1003.9 | -42.8473 | 85.6946 | 6 | 2.37E-16 | 99.6946 |
| Region | Deviance | 1699 | 2041.617 | 1.2017 | 0.024 | 1.96% | 2.41% | -1020.81 | -25.9395 | 51.879 | 9 | 4.76E-08 | 71.879 |
| Hr fished | Deviance | 1697 | 2044.796 | 1.2049 | 0.0208 | 1.70% | | -1022.4 | -24.3501 | 48.7002 | 11 | 1.07E-06 | 72.7002 |
| Num anglers | Deviance | 1695 | 1965.358 | 1.1595 | 0.0662 | 5.40% | | -982.679 | -64.0691 | 128.1382 | 13 | 4.91E-21 | 156.1382 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1681 | 1998.87 | 1.1891 | 0.0366 | 2.99% | | -999.435 | -47.313 | 94.626 | 27 | 1.93E-09 | 150.626 |
| Area | Deviance | 1698 | 1999.318 | 1.1775 | 0.0482 | 3.93% | 6.34% | -999.659 | -47.0891 | 94.1782 | 10 | 7.92E-16 | 116.1782 |
| Mode_fx | Deviance | 1698 | 1895.801 | 1.1165 | 0.1092 | 8.91% | | -947.9 | -98.8476 | 197.6952 | 10 | 4.88E-37 | 219.6952 |
| Hr fished | Deviance | 1693 | 2004.323 | 1.1839 | 0.0418 | 3.41% | | -1002.16 | -44.5865 | 89.173 | 15 | 1.41E-12 | 121.173 |
| Num anglers | Deviance | 1691 | 1899.108 | 1.1231 | 0.1026 | 8.37% | | -949.554 | -97.194 | 194.388 | 17 | 3.83E-32 | 230.388 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1680 | 1958.561 | 1.1658 | 0.0599 | 4.89% | | -979.281 | -67.4675 | 134.935 | 28 | 5.95E-16 | 192.935 |
| Mode_fx | Deviance | 1697 | 1861.829 | 1.0971 | 0.1286 | 10.49% | | -930.914 | -115.834 | 231.6676 | 11 | 1.9E-43 | 255.6676 |
| Hr fished | Deviance | 1692 | 1971.57 | 1.1652 | 0.0605 | 4.94% | 11.28% | -985.785 | -60.9632 | 121.9264 | 16 | 2.34E-18 | 155.9264 |
| Num anglers | Deviance | 1690 | 1866.555 | 1.1045 | 0.1212 | 9.89% | | -933.277 | -113.471 | 226.9412 | 18 | 3.85E-38 | 264.9412 |
| | | | | | | | | | | | | | |
| Year | Deviance | 1674 | 1930.24 | 1.1531 | 0.0726 | 5.92% | 17.20% | -965.12 | -81.6282 | 163.2564 | 34 | 8.15E-19 | 233.2564 |
| Mode_fx | Deviance | 1691 | 1847.574 | 1.0926 | 0.1331 | 10.86% | | -923.787 | -122.961 | 245.922 | 17 | 1.42E-42 | 281.922 |
| Num anglers | Deviance | 1684 | 1849.677 | 1.0984 | 0.1273 | 10.39% | | -924.839 | -121.91 | 243.819 | 24 | 2.76E-38 | 293.819 |
| | | | | | | | | | | | | | |
| Mode_fx | Deviance | 1673 | 1800.805 | 1.0764 | 0.1493 | 12.18% | 29.38% | -900.403 | -146.345 | 292.6906 | 35 | 1.95E-42 | 364.6906 |
| Num anglers | Deviance | 1666 | 1809.479 | 1.0861 | 0.1396 | 11.39% | | -904.739 | -142.009 | 284.0172 | 42 | 1.13E-37 | 370.0172 |
| | | | | | | | | | | | | | |
| Num anglers | Deviance | 1665 | 1765.791 | 1.0605 | 0.1652 | 13.48% | 42.86% | -882.895 | -163.853 | 327.7052 | 43 | 1.77E-45 | 415.7052 |

**Table 3d.** Stepwise selection of variables to include in estimating the total catch of red snapper on positive MRFSS intercepts for red snapper (shaded lines) with a GLM (gamma distribution and log link) selected with Stephens and MacCall logistic regression based on lowest AIC values. The fields include the variables, the degrees of freedom for that variable (df), the deviance of the model with those variables, the mean deviance (deviance/df), the change in mean deviance ( Δ mean dev), percent reduction in mean deviance (% mean dev), cumulative reduction in mean deviance, log likelihood, the change in log likelihood from previous run, minus two times the change in log-likelihood, chi-square value, the Chi-square degrees of freedom, the probability of the null hypothesis (Prob Ho), and the Akaike Information Criterion (AIC). Run without B2 data.

| Variables | | df | Deviance | Mean dev | Δ mean dev | % expl | Cum % | log like | Δ log like | Chi sq | df | Prob Ho | AIC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Null | Deviance | 448 | 553.5123 | 1.2355 | | | | -1207.05 | | | 1 | | 2416.1 |
| | | | | | | | | | | | | | |
| Year | Deviance | 430 | 528.4716 | 1.229 | 0.0065 | 0.53% | | -1195.00 | -12.0525 | 24.105 | 18 | 0.151618 | 62.105 |
| Wave | Deviance | 443 | 525.6135 | 1.1865 | 0.049 | 3.97% | | -1193.59 | -13.4604 | 26.9208 | 5 | 5.91E-05 | 38.9208 |
| Area | Deviance | 447 | 553.0826 | 1.2373 | -0.0018 | -0.15% | | -1206.85 | -0.2027 | 0.4054 | 1 | 0.524314 | 4.4054 |
| Mode_fx | Deviance | 447 | 543.7569 | 1.2165 | 0.019 | 1.54% | 1.54% | -1202.41 | -4.6364 | 9.2728 | 1 | 0.002326 | 13.2728 |
| Region | Deviance | 445 | 534.3588 | 1.2008 | 0.0347 | 2.81% | | -1197.88 | -9.1738 | 18.3476 | 3 | 0.000373 | 26.3476 |
| Hr fished | Deviance | 442 | 546.7558 | 1.237 | -0.0015 | -0.12% | | -1203.85 | -3.2033 | 6.4066 | 6 | 0.379215 | 20.4066 |
| Num angle | Deviance | 440 | 540.0119 | 1.2273 | 0.0082 | 0.66% | | -1200.61 | -6.436 | 12.872 | 8 | 0.11633 | 30.872 |
| | | | | | | | | | | | | | |
| Year | Deviance | 429 | 523.41 | 1.2201 | 0.0154 | 1.25% | | -1192.50 | -14.5506 | 29.1012 | 19 | 0.06441 | 69.1012 |
| Wave | Deviance | 442 | 517.1162 | 1.1699 | 0.0656 | 5.31% | | -1189.36 | -17.6871 | 35.3742 | 6 | 3.65E-06 | 49.3742 |
| Area | Deviance | 446 | 543.2686 | 1.2181 | 0.0174 | 1.41% | 2.95% | -1202.18 | -4.8704 | 9.7408 | 2 | 0.00767 | 15.7408 |
| Region | Deviance | 444 | 530.7517 | 1.1954 | 0.0401 | 3.25% | | -1196.12 | -10.9342 | 21.8684 | 4 | 0.000213 | 31.8684 |
| Hr fished | Deviance | 441 | 538.3397 | 1.2207 | 0.0148 | 1.20% | | -1199.81 | -7.2431 | 14.4862 | 7 | 0.043179 | 30.4862 |
| Num angle | Deviance | 439 | 533.5455 | 1.2154 | 0.0201 | 1.63% | | -1197.48 | -9.5698 | 19.1396 | 9 | 0.024032 | 39.1396 |
| | | | | | | | | | | | | | |
| Year | Deviance | 428 | 522.1381 | 1.2199 | 0.0156 | 1.26% | | -1191.87 | -15.1817 | 30.3634 | 20 | 0.064175 | 72.3634 |
| Wave | Deviance | 441 | 516.3755 | 1.1709 | 0.0646 | 5.23% | | -1188.99 | -18.0585 | 36.117 | 7 | 6.89E-06 | 52.117 |
| Region | Deviance | 443 | 530.5894 | 1.1977 | 0.0378 | 3.06% | 6.01% | -1196.04 | -11.0137 | 22.0274 | 5 | 0.000517 | 34.0274 |
| Hr fished | Deviance | 440 | 537.9538 | 1.2226 | 0.0129 | 1.04% | | -1199.62 | -7.4298 | 14.8596 | 8 | 0.061934 | 32.8596 |
| Num angle | Deviance | 438 | 532.7979 | 1.2164 | 0.0191 | 1.55% | | -1197.12 | -9.9342 | 19.8684 | 10 | 0.030522 | 41.8684 |
| | | | | | | | | | | | | | |
| Year | Deviance | 425 | 501.3557 | 1.1797 | 0.0558 | 4.52% | | -1181.36 | -25.6939 | 51.3878 | 23 | 0.000604 | 99.3878 |
| Wave | Deviance | 438 | 511.5793 | 1.168 | 0.0675 | 5.46% | | -1186.58 | -20.4748 | 40.9496 | 10 | 1.15E-05 | 62.9496 |
| Hr fished | Deviance | 437 | 525.2619 | 1.202 | 0.0335 | 2.71% | 8.72% | -1193.42 | -13.6341 | 27.2682 | 11 | 0.004185 | 51.2682 |
| Num angle | Deviance | 435 | 520.4823 | 1.1965 | 0.039 | 3.16% | | -1191.04 | -16.0054 | 32.0108 | 13 | 0.002393 | 60.0108 |
| | | | | | | | | | | | | | |
| Year | Deviance | 419 | 490.5067 | 1.1707 | 0.0648 | 5.24% | | -1175.71 | -31.3378 | 62.6756 | 29 | 0.000284 | 122.6756 |
| Wave | Deviance | 432 | 502.2632 | 1.1626 | 0.0729 | 5.90% | | -1181.82 | -25.2268 | 50.4536 | 16 | 1.94E-05 | 84.4536 |
| Num angle | Deviance | 429 | 515.5362 | 1.2017 | 0.0338 | 2.74% | 11.45% | -1188.57 | -18.4799 | 36.9598 | 19 | 0.008027 | 76.9598 |
| | | | | | | | | | | | | | |
| Year | Deviance | 411 | 479.8799 | 1.1676 | 0.0679 | 5.50% | | -1170.07 | -36.9757 | 73.9514 | 37 | 0.000293 | 149.9514 |
| Wave | Deviance | 424 | 491.7847 | 1.1599 | 0.0756 | 6.12% | 17.57% | -1176.38 | -30.6671 | 61.3342 | 24 | 4.13E-05 | 111.3342 |
| | | | | | | | | | | | | | |
| Year | Deviance | 406 | 457.5277 | 1.1269 | 0.1086 | 8.79% | 26.36% | -1157.84 | -49.2104 | 98.4208 | 42 | 2E-06 | 184.4208 |

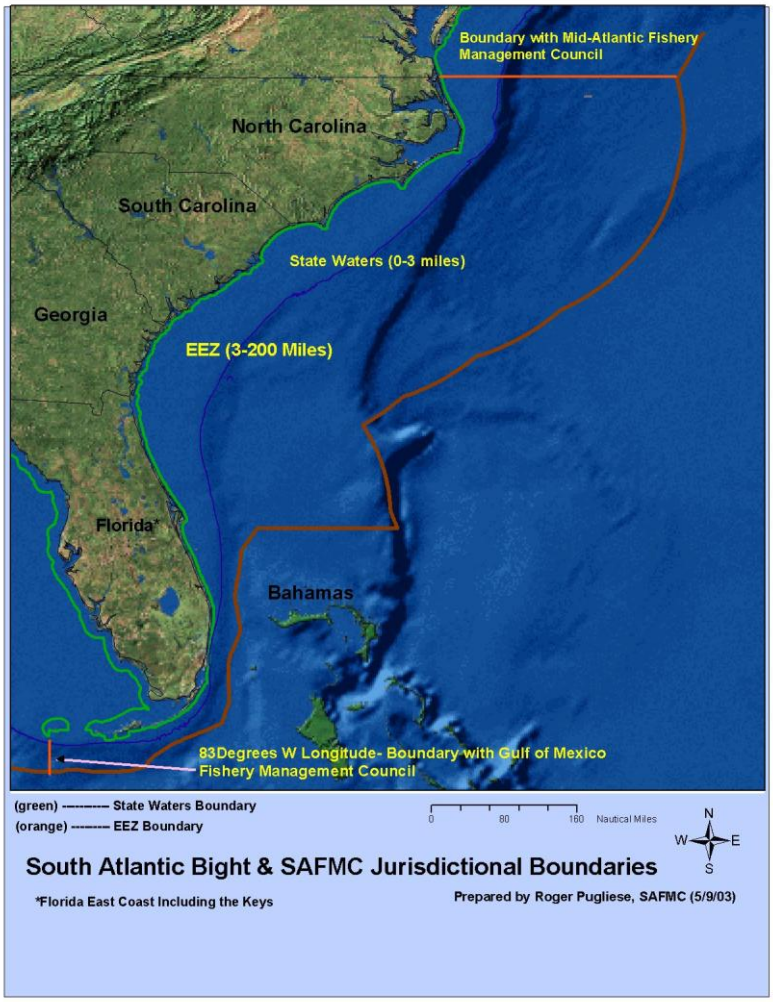


**Figure 1.** A map of the study area: North Carolina through the Florida Keys.

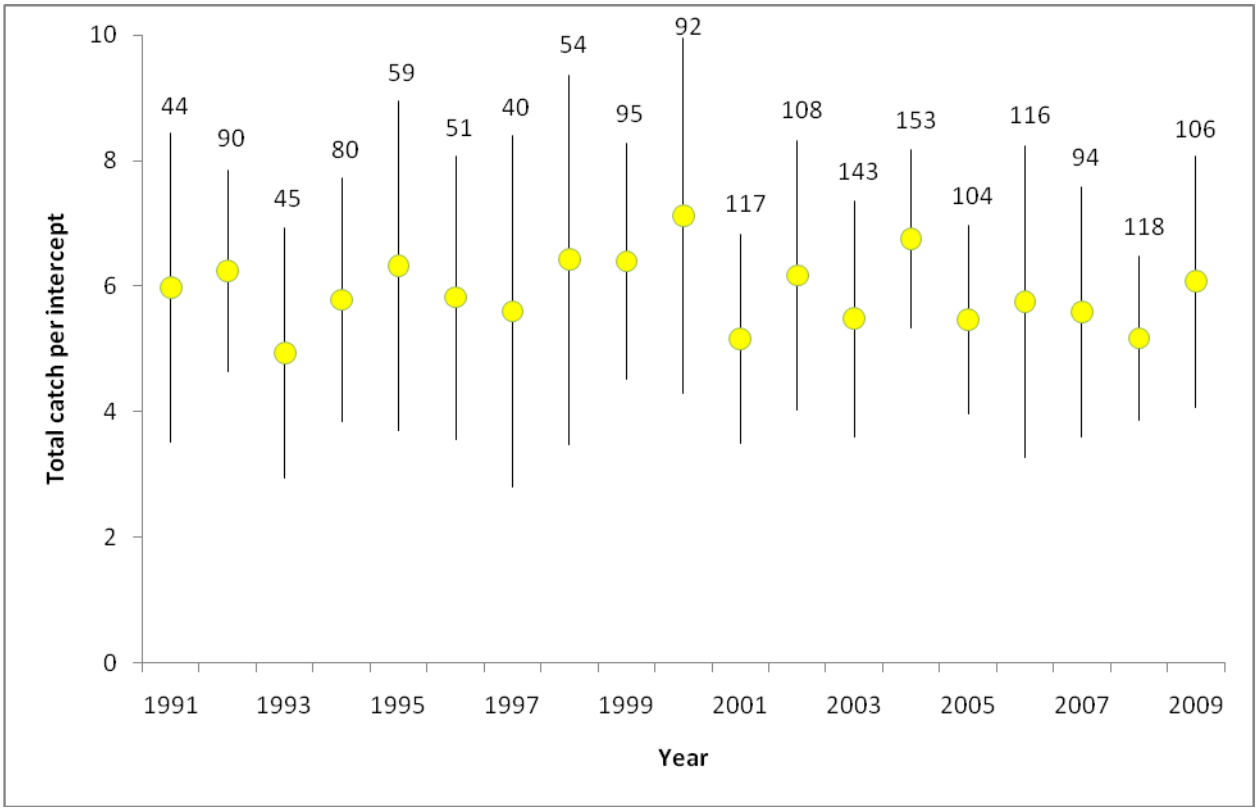


**Figure 2a**. Nominal catch rate of red snapper by year from North Carolina to southern Florida with B2. The vertical lines are the 95% confidence interval and the circle is the mean. The numbers above the figures are the number of intercepts in the private/rental and charterboat modes per year.

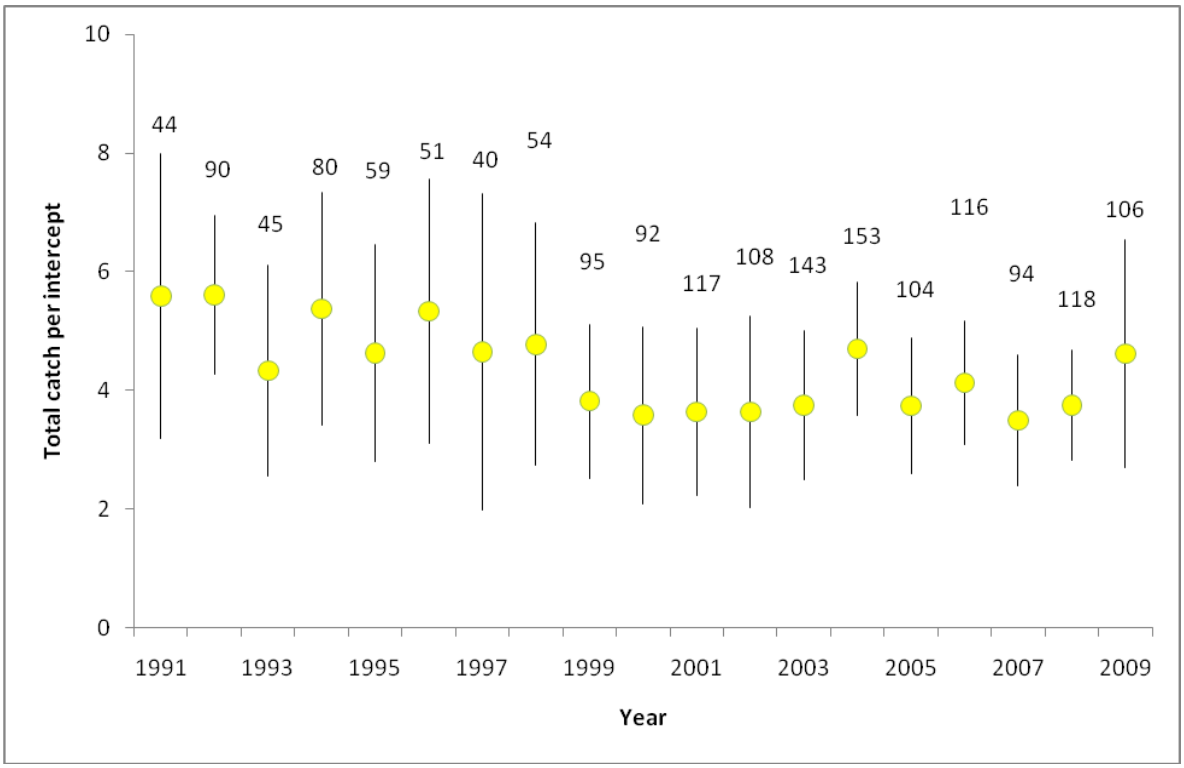


**Figure 2b**. Nominal catch rate of red snapper by year from North Carolina to southern Florida without B2. The vertical lines are the 95% confidence interval and the circle is the mean. The numbers above the figures are the number of intercepts in the private/rental and charterboat modes per year.

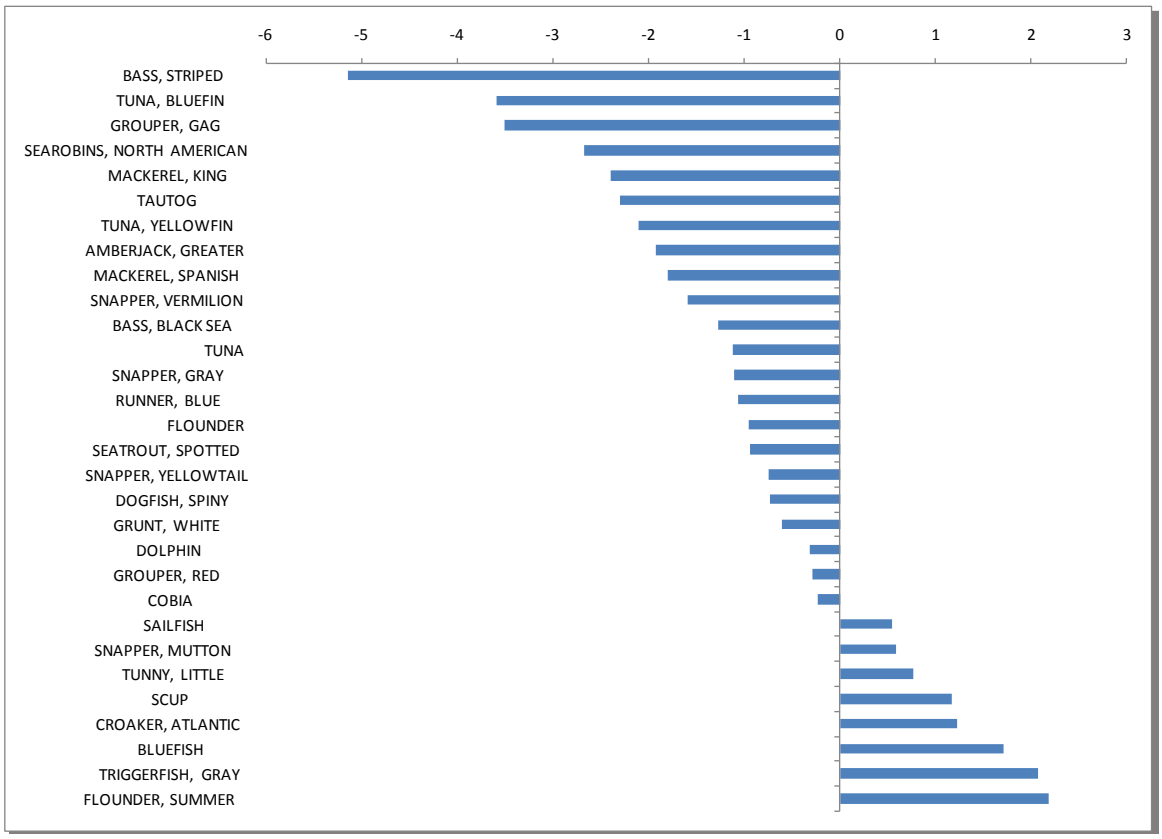


**Figure 3.** Species with significant logistic regression coefficients at the $\alpha = 0.05$ level for determining whether a MRFSS intercept should be selected for calculating annual total catch rates using the Stephens and MacCall method.

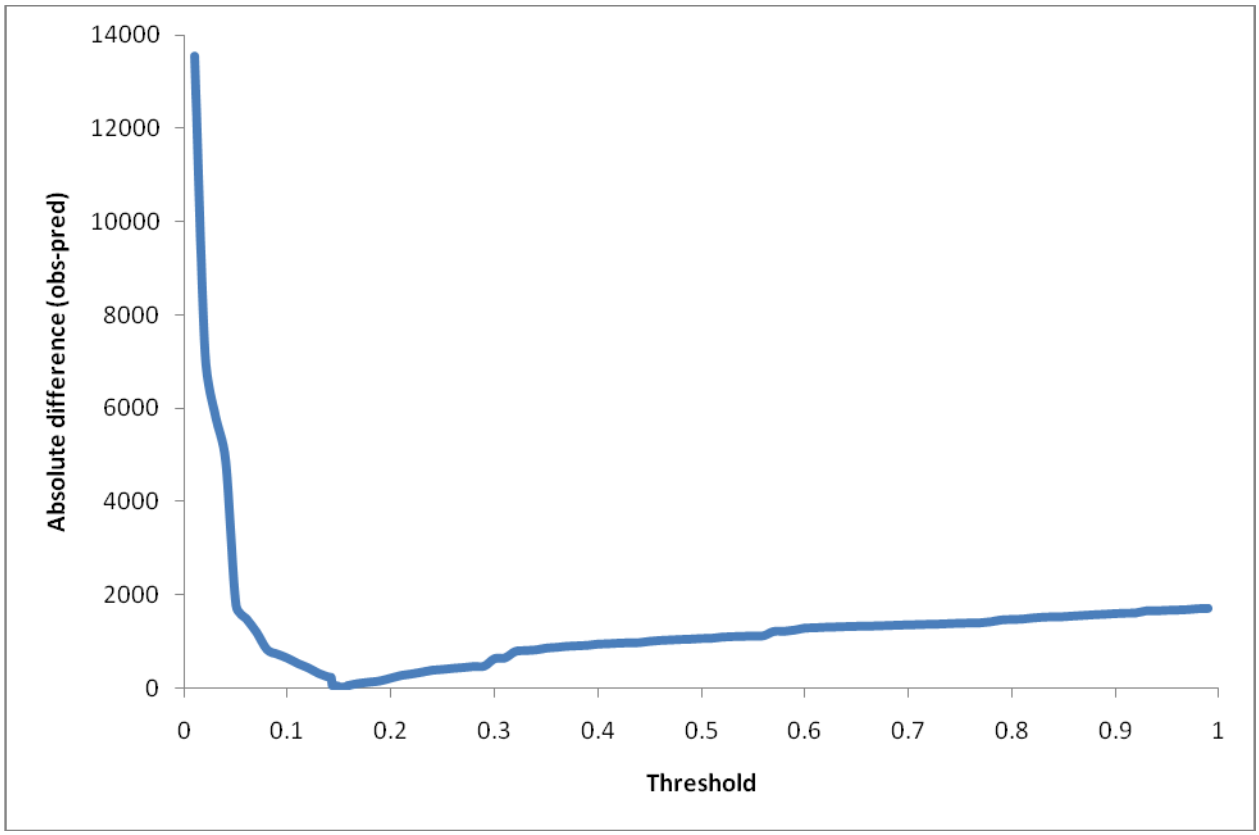


**Figure 4.** Absolute difference between the numbers of observed and predicted intercepts with red snapper from the logistic regression over a range of threshold values.

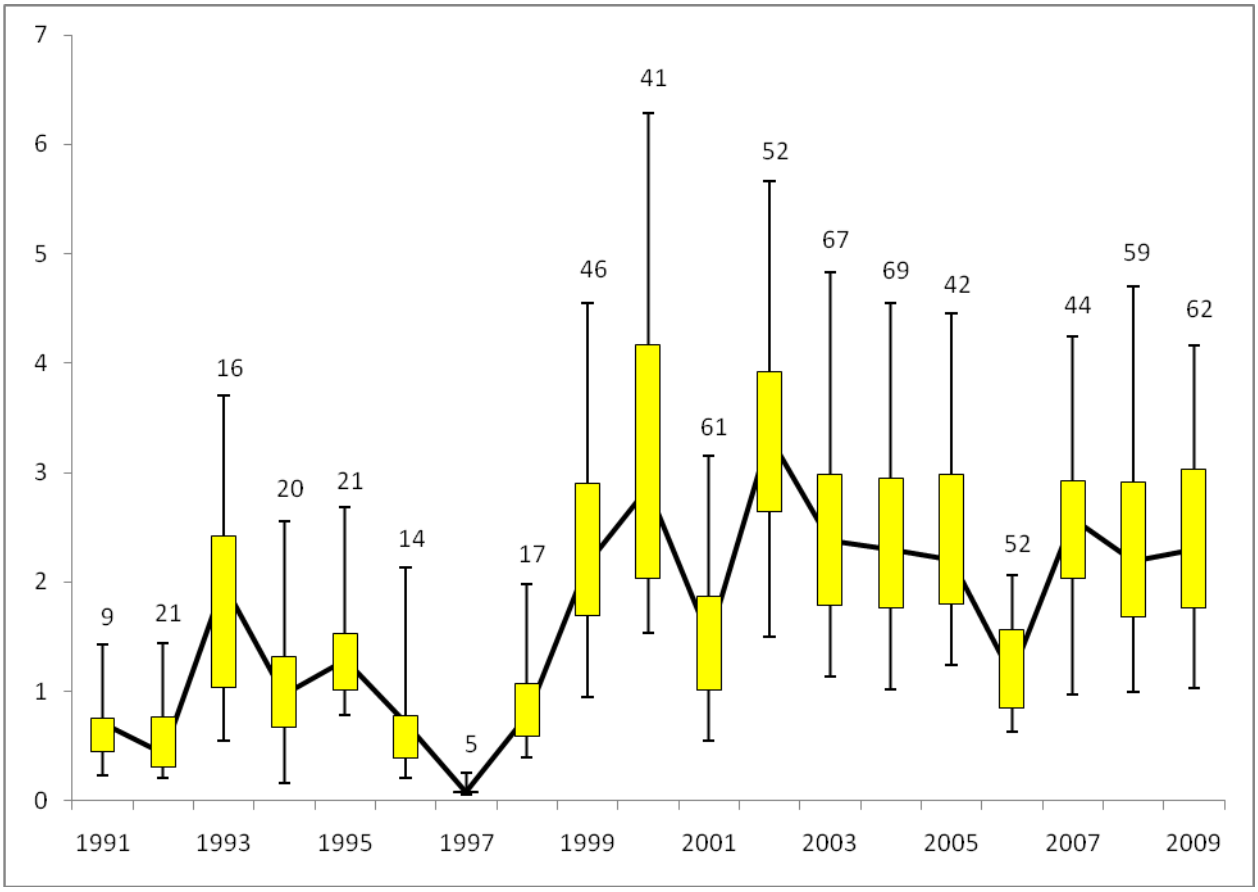


**Figure 5a.** Standardized annual total catch of red snapper per angler hour per intercept with intercepts selected by Stephens and MacCall's logistic regression with the B2 data. The vertical lines are the 95% confidence interval, the box is the inter-quartile range, the horizontal line is the median of the outcomes and the number above the lines are the number of intercepts that caught red snapper for each year.

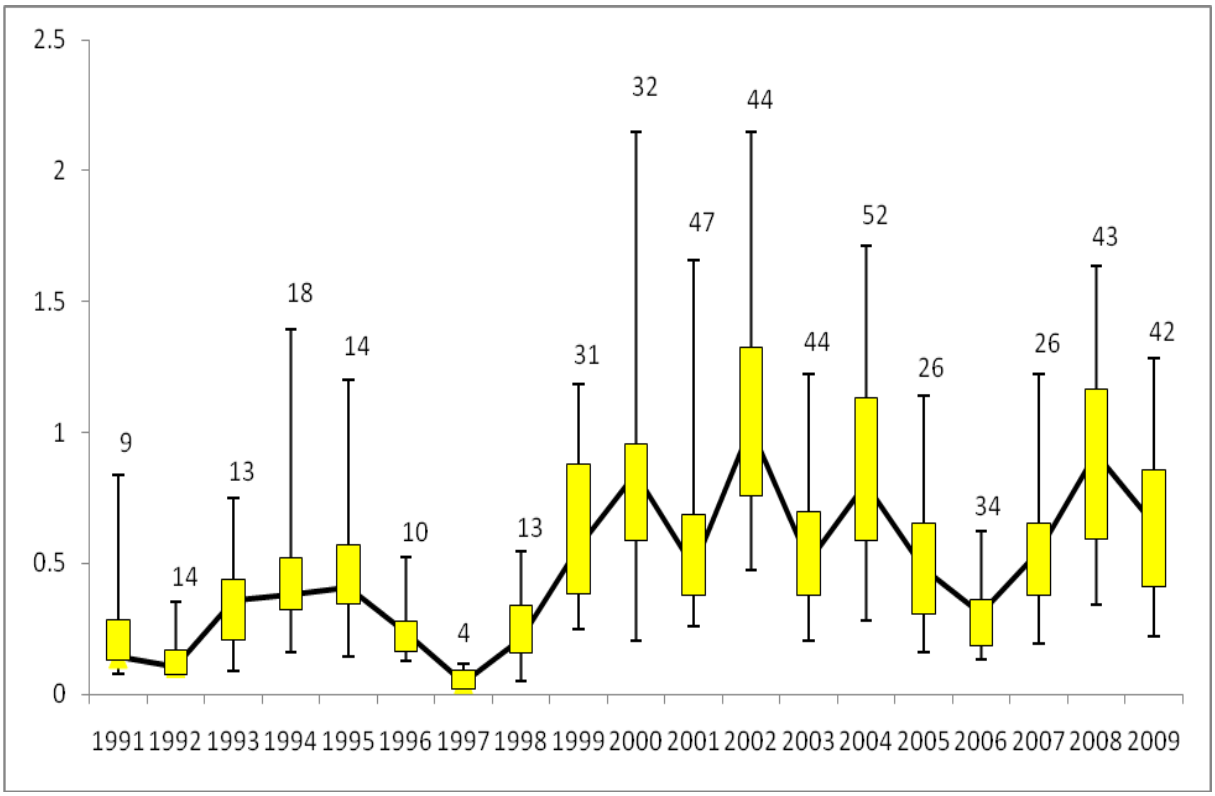


**Figure 5b.** Standardized annual total catch of red snapper per angler hour per intercept with intercepts selected by Stephens and MacCall's logistic regression without the B2 data. The vertical lines are the 95% confidence interval, the box is the inter-quartile range, the horizontal line is the median of the outcomes and the number above the lines are the number of intercepts that caught red snapper for each year.

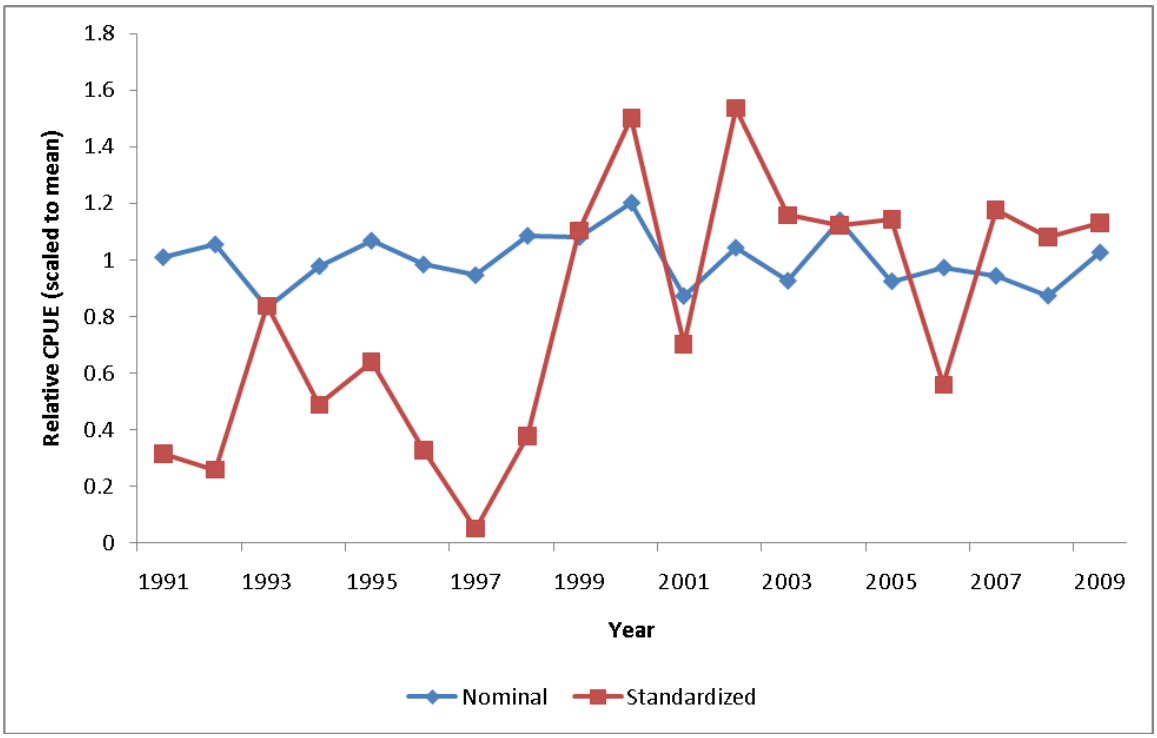


**Figure 6a**. Comparison of the nominal catch rates to the standardized catch rates calculated with intercepts selected by the Stephens and MacCall regression with the B2 data.

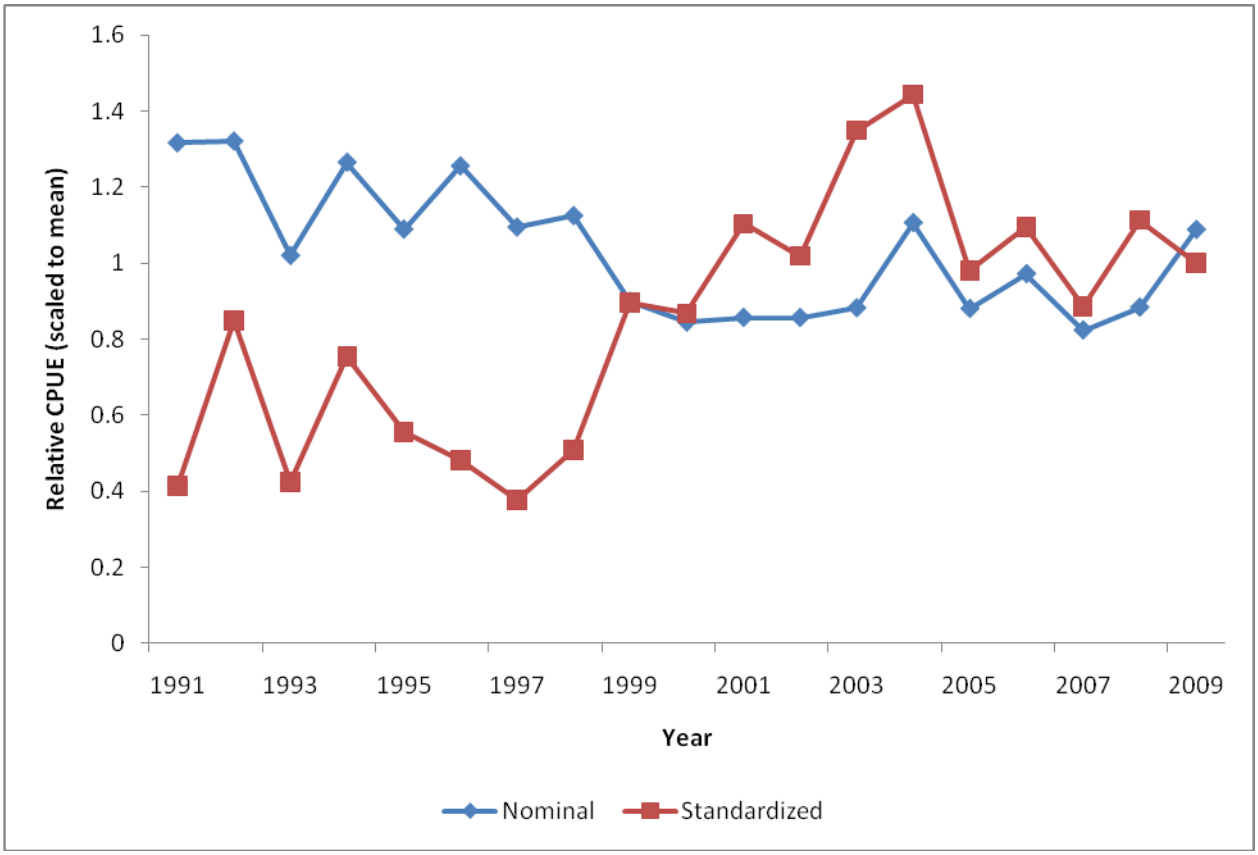


**Figure 6b**. Comparison of the nominal catch rates to the standardized catch rates calculated with intercepts selected by the Stephens and MacCall regression without the B2 data.


**Figure 7**. Comparison of the standardized catch rates calculated with intercepts selected by the Stephens and MacCall regression with and without the B2 data.