# Standardized catch rates of small coastal sharks from the Commercial Shark Fishery Longline Observer Program, 1994-2005

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## Introduction

The shark bottom longline fishery is active in the Atlantic Ocean from about the Mid-Atlantic Bight to south Florida and throughout the Gulf of Mexico. Vessels in the fishery are typically fiberglass and average 50 feet in length. Longline characteristics vary regionally with gear normally consisting of about 5-15 miles of longline and 500-1500 hooks. Gear is set at sunset and allowed to soak overnight before hauling back in the morning. There are currently about 100 active vessels in this fishery out of about 250 vessels that possess directed shark fishing permits. These vessels make between 4000-9000 sets per year. The bottom longline gear targets large coastal sharks, but small coastal sharks, pelagic sharks, and dogfish species are also caught.

Observations of the Atlantic shark directed bottom longline fishery have been conducted since 1994 (Burgess and Morgan, 2003, and references therein). From 1994 through 2001, observer coverage was conducted on a voluntary basis. Beginning with the 2002 fishing season, observer coverage of the Atlantic shark directed bottom longline fishery became mandatory under authority of 50 CFR 635.7. Observer coverage from 1994 through the 1$^{st}$ trimester season of 2005 was coordinated by the Commercial Shark Fishery Observer Program (CSFOP), Florida Museum of Natural History, University of Florida, Gainesville, FL (Burgess and Morgan, 2003). Starting with the 2$^{nd}$ trimester season of 2005, responsibility for the fishery observer program was transferred to National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), Panama City Laboratory, Panama City, FL.

Nominal relative abundance series from these data were previously presented at the 1998 and 2002 (Cortés 2002) Stock Evaluation Workshops and a standardized series at the 2005 large coastal SEDAR (Cortes et al. 2005). However, data from this observer program have not been used in any small coastal stock assessment. The present study attempts to standardize catch rates for small coastal sharks using data collected by on-board observers from 1994-2005.

## Methods

A combined data set was developed based on observer programs from Burgess and Morgan (2003) and Smith et al. (2006). Because observations of the fishery have been conducted using two different non-overlapping sampling strategies (i.e. voluntary and mandatory), catch rates were modeled independently for two time series representing periods of 1994-2001 (voluntary) and 2002-2005 (mandatory). Catch rates were

standardized in a two-part generalized linear model analysis using the PROC GENMOD procedure in SAS (SAS Inst., Inc.). For the purposes of analysis, several categorical variables were constructed:

-"Year" = 1994-2001, 2002-2005

- "Area": location of set (Figure 1).
North Atlantic Ocean=North of 36°31' N
South Atlantic Ocean=South of 36°31' N to 24°32' N including the straights of Florida
Gulf of Mexico

- "Time of Day": the time of day the set started defined from the time the first hook was set in the water;
Day=0501-1800 hrs
Night=1801-0500 hrs

-"Season"
Winter=Jan-Mar
Spring=Apr-Jun
Summer=Jul-Sep
Fall=Oct-Dec

-"Depth": defined as the mean depth when the first hook was set and the last hook was retrieved.
1-100 ft
101-200 ft
201-300 ft
301-400 ft
401-500 ft
501-600 ft
601-700 ft

-"Hooktype": the hook that was used by the majority of the set
Large hook (type undefined)
Large C hook
Large J hook
Medium hook (type undefined)
Medium C hook
Medium J hook
Small hook (type undefined)
Small C hook
Small J hook
Undefined hook

-"Baitype": the bait that was used by the majority of the set
Clupeid/mullet
Teleost (general)
Shark

Skate/Ray
Tuna
Other (undefined or multiple bait types)

The proportion of sets that caught sharks (when at least one shark was caught) was modeled assuming a binomial distribution with a logit link function. Positive catches were modeled assuming a Poisson distribution with a log link. An offset of effort (number of hooks*soak time) was utilized in the Poisson model.

Initially, a null model was run with no factors entered into the model. Models were then fit in a stepwise forward manner adding one independent variable. Each factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor with the greatest reduction in deviance was then incorporated into the model providing the effect was significant at $p<0.05$ based on a Chi-Square test, and the deviance per degree of freedom was reduced by at least 1% from the less complex model. The process was continued until no factors met the criterion for incorporation into the final model. Regardless of its level of significance, year was kept in all final models. After selecting the set of fixed factors and interactions for each error distribution, all interactions that included the factor year were treated as random interactions (Ortiz and Arocha, 2004). This process converted the basic models from generalized linear models into generalized linear mixed models. The final model determination was evaluated using the Akaike Information Criteria (AIC), and Schwarz's Bayesian Criterion (BIC). Models with smaller AIC and BIC values are preferred to those with larger values. These models were fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute Inc.) and the MIXED procedure in SAS statistical computer software (PROC GLIMMIX). Relative indices of abundance were calculated as the product of the year effect least square means from the two independent models.

**Results and Discussion**

A total of 1360 longline sets from 1994-2005 contained essential data necessary to standardize catch rates. Locations of sets made can be found in Figure 1.

Atlantic sharpnose shark

For Atlantic sharpnose sharks, the proportion of positive sets was 54.6 % for the period 1994-2001 and 55.9 % for the period 2002-2005. The stepwise construction of the models is summarized in Table 1. The standardized abundance index is shown in Figure 2. To allow for visual comparison with the nominal values, both series were scaled to their respective means. The index statistics can be found in Table 2.

Blacknose sharks

The proportion of positive sets was 28.7 % for the period 1994-2001 and 37.7 % for 2002-2005 for blacknose shark. The stepwise construction of the models is summarized in Table 3. The standardized abundance index is shown in Figure 2 and the index statistics can be found in Table 4.

Bonnetheads

Due to small sample size and the lack of samples in some years, catch rate series were not constructed for bonnetheads.

Finetooth shark

Due to small sample size and the lack of samples in some years, catch rate series were not constructed for finetooth shark.

Small coastal aggregate

The proportion of positive sets was 66.8 % during 1994-2001 and 69.6 % during 2002-2005 for the small coastal aggregate. The stepwise construction of the models is summarized in Table 5. The standardized abundance index is shown in Figure 2 and index statistics can be found in Table 5.

**Acknowledgements**

We thank all the observers since inception of the programs for collecting data sometimes during somewhat arduous conditions. Marta Ribera provided assistance with mapping set locations.

**Literature cited**

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Table 1. Analysis of deviance of explanatory variables for the binomial and Poisson generalized linear and mixed model formulations of the proportion of positive and positive catches for Atlantic sharpnose sharks for (A) 1994-2001 and (B) 2002-2005. Final models selected are in bold.

(A) 1994-2001

| **Proportion positive- Binomial error distribution** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 819 | 1129.707 | 1.379 | | | | |
| AREA | 818 | 1049.474 | 1.283 | 6.989 | 6.99 | 80.23 | <.0001 |
| YEAR | 812 | 1050.668 | 1.294 | 6.195 | | 79.04 | <.0001 |
| BAITTYPE | 814 | 1079.128 | 1.326 | 3.890 | | 50.58 | <.0001 |
| HOOKTYPE | 818 | 1097.746 | 1.342 | 2.710 | | 31.96 | <.0001 |
| TIMEOFDAY | 818 | 1097.746 | 1.342 | 2.710 | | 31.96 | <.0001 |
| SEASON | 816 | 1116.063 | 1.368 | 0.845 | | 13.64 | 0.0034 |
| DEPTH | 815 | 1119.528 | 1.374 | 0.415 | | 10.18 | 0.0375 |
| | | | | | | | |
| AREA+ | | | | | | | |
| YEAR | 811 | 980.449 | 1.209 | 12.356 | 5.37 | 69.03 | <.0001 |
| BAITTYPE | 813 | 983.758 | 1.210 | 12.277 | | 65.72 | <.0001 |
| HOOKTYPE | 813 | 1014.748 | 1.248 | 9.513 | | 34.73 | <.0001 |
| TIMEOFDAY | 817 | 1036.435 | 1.269 | 8.032 | | 13.04 | 0.0003 |
| | | | | | | | |
| AREA+YEAR+ | | | | | | | |
| BAITTYPE | 806 | 918.503 | 1.140 | 17.384 | 5.03 | 61.95 | <.0001 |
| HOOKTYPE | 806 | 931.171 | 1.155 | 16.245 | | 49.28 | <.0001 |
| TIMEOFDAY | 810 | 969.250 | 1.197 | 13.250 | | 11.20 | 0.0008 |
| | | | | | | | |
| AREA+YEAR+BAITTYPE | | | | | | | |
| HOOKTYPE | 801 | 893.148 | 1.115 | 19.163 | 1.78 | 25.36 | 0.0001 |
| TIMEOFDAY | 805 | 916.458 | 1.138 | 17.466 | | 2.04 | 0.1527 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| **YEAR+AREA+BAITTYPE+HOOKTYPE** | **3592.4** | **3597.0** | **3590.4** | | | | |
| YEAR+AREA+BAITTYPE+ HOOKTYPE YEAR*AREA | 4321.4 | 4322.8 | 4317.4 | | | | |
| YEAR+AREA+BAITTYPE+ HOOKTYPE YEAR*BAITTYPE | 4278.9 | 4282.2 | 4274.9 | | | | |
| YEAR+AREA+BAITTYPE+ HOOKTYPE YEAR*HOOKTYPE | | Convergence criteria not met. | | | | | |
| **Positive catches- Poisson error distribution** | | | | | | | |
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 447 | 41720.463 | 93.334 | | | | |
| BAITTYPE | 442 | 27975.959 | 63.294 | 32.186 | 32.19 | 13744.50 | <.0001 |
| HOOKTYPE | 446 | 33082.056 | 74.175 | 20.528 | | 8638.41 | <.0001 |
| TIMEOFDAY | 446 | 33082.056 | 74.175 | 20.528 | | 8638.41 | <.0001 |
| DEPTH | 443 | 37949.086 | 85.664 | 8.218 | | 3771.38 | <.0001 |
| YEAR | 440 | 38390.775 | 87.252 | 6.517 | | 3329.69 | <.0001 |
| AREA | 446 | 40100.044 | 89.910 | 3.668 | | 1620.42 | <.0001 |
| SEASON | 444 | 41543.059 | 93.565 | -0.248 | | 177.40 | <.0001 |
| | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| BAITTYPE+ | | | | | | | |
| DEPTH | 438 | 23432.121 | 53.498 | 42.681 | 10.50 | 4543.84 | <.0001 |
| AREA | 441 | 24488.436 | 55.529 | 40.505 | | 3487.52 | <.0001 |
| TIMEOFDAY | 441 | 24497.836 | 55.551 | 40.482 | | 3478.12 | <.0001 |
| YEAR | 435 | 24592.949 | 56.536 | 39.427 | | 3383.01 | <.0001 |
| HOOKTYPE | 437 | 25239.007 | 57.755 | 38.120 | | 2736.95 | <.0001 |
| | | | | | | | |
| BAITTYPE+DEPTH+ | | | | | | | |
| TIMEOFDAY | 437 | 21043.604 | 48.155 | 48.406 | 5.72 | 2388.52 | <.0001 |
| YEAR | 431 | 21006.128 | 48.738 | 47.781 | | 2425.99 | <.0001 |
| AREA | 437 | 22338.139 | 51.117 | 45.232 | | 1093.98 | <.0001 |
| HOOKTYPE | 433 | 22173.706 | 51.209 | 45.133 | | 1258.41 | <.0001 |
| | | | | | | | |
| BAITTYPE+DEPTH+TIMEOFDAY | | | | | | | |
| YEAR | 430 | 17983.917 | 41.823 | 55.190 | 6.78 | 3059.69 | <.0001 |
| HOOKTYPE | 432 | 20035.784 | 46.379 | 50.309 | | 1007.82 | <.0001 |
| AREA | 436 | 20434.201 | 46.867 | 49.785 | | 609.40 | <.0001 |
| | | | | | | | |
| BAITTYPE+DEPTH+TIMEOFDAY+YEAR | | | | | | | |
| HOOKTYPE | 425 | 16494.250 | 38.810 | 58.418 | 3.23 | 1489.67 | <.0001 |
| AREA | 429 | 17190.065 | 40.070 | 57.068 | | 793.85 | <.0001 |
| | | | | | | | |
| BAITTYPE+DEPTH+TIMEOFDAY+YEAR+ HOOKTYPE+ | | | | | | | |
| AREA | 424 | 15691.205 | 37.008 | 60.349 | 1.93 | 803.05 | <.0001 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+BAITTYPE+DEPTH+ TIMEOFDAY+HOOKTYPE+AREA | 1913.2 | 1917.2 | 1911.2 | | | | |
| YEAR+BAITTYPE+DEPTH+TIMEOFDAY+ HOOKTYPE+AREA YEAR*BAITTYPE | 1885.6 | 1888.8 | 1881.6 | | | | |
| YEAR+BAITTYPE+DEPTH+TIMEOFDAY+ HOOKTYPE+AREA YEAR*DEPTH | 1900.1 | 1902.6 | 1896.1 | | | | |
| **YEAR+BAITTYPE+DEPTH+TIMEOFDAY+ HOOKTYPE+AREA YEAR*TIMEOFDAY** | **1877.9** | **1879.4** | **1873.9** | | | | |
| YEAR+BAITTYPE+DEPTH+TIMEOFDAY+ HOOKTYPE+AREA YEAR*HOOKTYPE | 1901.7 | 1904.1 | 1897.7 | | | | |
| YEAR+BAITTYPE+DEPTH+TIMEOFDAY+ HOOKTYPE+AREA YEAR*AREA | 1913.2 | 1913.9 | 1911.2 | | | | |

(B) 2002-2005

| **Proportion positive-Binomial error distribution** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 539 | 740.996 | 1.375 | | | | |
| DEPTH | 533 | 687.686 | 1.290 | 6.150 | 6.15 | 53.31 | <.0001 |
| BAITTYPE | 534 | 714.067 | 1.337 | 2.732 | | 26.93 | <.0001 |
| HOOKTYPE | 530 | 719.516 | 1.358 | 1.250 | | 21.48 | 0.0107 |
| SEASON | 536 | 733.827 | 1.369 | 0.413 | | 7.17 | 0.0667 |
| YEAR | 536 | 736.478 | 1.374 | 0.053 | | 4.52 | 0.2107 |
| TIMEOFDAY | 538 | 740.383 | 1.376 | -0.103 | | 0.61 | 0.4336 |
| AREA | 538 | 740.867 | 1.377 | -0.168 | | 0.13 | 0.7195 |
| | | | | | | | |
| DEPTH | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| BAITTYPE | 528 | 652.948 | 1.237 | 10.047 | 3.90 | 34.74 | <.0001 |
| HOOKTYPE | 524 | 664.966 | 1.269 | 7.692 | | 22.72 | 0.0069 |
| | | | | | | | |
| DEPTH+BAITTYPE+ | | | | | | | |
| HOOKTYPE | 519 | 627.179 | 1.208 | 12.098 | 2.05 | 25.77 | 0.0022 |
| | | | | | | | |
| YEAR+DEPTH+ BAITTYPE+HOOKTYPE | 516 | 620.243 | 1.202 | 12.565 | 0.47 | 24.49 | 0.0036 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| **YEAR+DEPTH+ BAITTYPE+HOOKTYPE** | **2424.4** | **2428.700** | **2422.400** | | | | |
| YEAR+DEPTH+BAITTYPE+ HOOKTYPE YEAR*DEPTH | 2443.5 | 2445.900 | 2439.500 | | | | |
| YEAR+DEPTH+BAITTYPE+ HOOKTYPE YEAR*BAIT | | Convergence criteria not met. | | | | | |
| YEAR+DEPTH+BAITTYPE+ HOOKTYPE YEAR*HOOK | | Convergence criteria not met. | | | | | |
| **Positive catches-Poisson error distribution** | | | | | | | |
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 301 | 17726.525 | 58.892 | | | | |
| SEASON | 298 | 15280.954 | 51.278 | 12.928 | 12.93 | 2445.57 | <.0001 |
| HOOKTYPE | 292 | 16133.715 | 55.252 | 6.180 | | 1592.81 | <.0001 |
| BAITTYPE | 296 | 16998.715 | 57.428 | 2.486 | | 727.81 | <.0001 |
| YEAR | 298 | 17226.785 | 57.808 | 1.841 | | 499.74 | <.0001 |
| DEPTH | 296 | 17259.467 | 58.309 | 0.990 | | 467.06 | <.0001 |
| AREA | 300 | 17621.829 | 58.739 | 0.259 | | 104.70 | <.0001 |
| TIMEOFDAY | 300 | 17725.383 | 59.085 | -0.327 | | 1.14 | 0.2853 |
| | | | | | | | |
| SEASON | | | | | | | |
| BAITTYPE | 293 | 14538.427 | 49.619 | 15.746 | 2.82 | 742.53 | <.0001 |
| HOOKTYPE | 289 | 14488.596 | 50.134 | 14.872 | | 792.36 | <.0001 |
| YEAR | 295 | 15233.056 | 51.637 | 12.319 | | 47.90 | <.0001 |
| | | | | | | | |
| SEASON+BAITTYPE+ | | | | | | | |
| HOOKTYPE | 284 | 13742.583 | 48.389 | 17.834 | 2.09 | 795.84 | <.0001 |
| YEAR | 290 | 14455.582 | 49.847 | 15.359 | | 82.84 | <.0001 |
| | | | | | | | |
| SEASON+BAITTYPE+ HOOKTYPE+ | | | | | | | |
| YEAR | 281 | 13568.017 | 48.285 | 18.011 | 0.18 | 174.57 | <.0001 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+SEASON+ BAITTYPE+HOOKTYPE | 1517.5 | 1521.2 | 1515.5 | | | | |
| YEAR+SEASON+ BAITTYPE+HOOKTYPE YEAR*SEASON | 1517.5 | 1517.9 | 1515.5 | | | | |
| YEAR+SEASON+ BAITTYPE+HOOKTYPE YEAR*BAIT | 1499.8 | 1501.4 | 1495.8 | | | | |
| **YEAR+SEASON+ BAITTYPE+HOOKTYPE YEAR*HOOK** | **1496.4** | **1498.9** | **1492.4** | | | | |

Table 2. The relative standardized index of abundance and coefficients of variation for Atlantic sharpnose shark.

| YEAR | ABSOLUTE INDEX | CV |
|---|---|---|
| 1994 | 0.0001 | 38.140 |
| 1995 | 0.0031 | 3.124 |
| 1996 | 0.0018 | 4.041 |
| 1997 | 0.0032 | 3.032 |
| 1998 | 0.0056 | 1.901 |
| 1999 | 0.0231 | 0.972 |
| 2000 | 0.0128 | 1.688 |
| 2001 | 0.0090 | 1.803 |
| 2002 | 0.0014 | 0.509 |
| 2003 | 0.0014 | 0.406 |
| 2004 | 0.0023 | 0.423 |
| 2005 | 0.0028 | 0.438 |

Table 3. Analysis of deviance of explanatory variables for the binomial and Poisson generalized linear and mixed model formulations of the proportion of positive and positive catches for blacknose sharks for 1994-2001 (A) and 2002-2005 (B). Final models selected are in bold.

(A) 1994-2001

| **Proportion positive- Binomial error distribution** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 819 | 984.286 | 1.202 | | | | |
| DEPTH | 815 | 913.934 | 1.121 | 6.692 | 6.692 | 70.35 | <.0001 |
| BAITTYPE | 814 | 927.707 | 1.140 | 5.169 | | 56.58 | <.0001 |
| AREA | 818 | 944.305 | 1.154 | 3.945 | | 39.98 | <.0001 |
| YEAR | 812 | 944.580 | 1.163 | 3.207 | | 39.71 | <.0001 |
| HOOKTYPE | 814 | 964.644 | 1.185 | 1.394 | | 19.64 | 0.0015 |
| SEASON | 816 | 973.101 | 1.193 | 0.773 | | 11.18 | 0.011 |
| TIMEOFDAY | 818 | 979.770 | 1.198 | 0.337 | | 4.52 | 0.0336 |
| | | | | | | | |
| DEPTH+ | | | | | | | |
| AREA | 814 | 843.783 | 1.037 | 13.748 | 7.056 | 70.15 | <.0001 |
| BAITTYPE | 810 | 866.254 | 1.069 | 11.014 | | 47.68 | <.0001 |
| YEAR | 808 | 889.561 | 1.101 | 8.393 | | 24.37 | 0.001 |
| HOOKTYPE | 810 | 903.033 | 1.115 | 7.236 | | 10.90 | 0.0534 |
| | | | | | | | |
| DEPTH+AREA+ | | | | | | | |
| BAITTYPE | 809 | 808.375 | 0.999 | 16.857 | 3.109 | 35.41 | <.0001 |
| YEAR | 807 | 817.658 | 1.013 | 15.694 | | 26.13 | 0.0005 |
| | | | | | | | |
| YEAR+DEPTH+AREA+BAIT | 802 | 784.297 | 0.978 | 18.629 | 1.772 | 33.36 | <.0001 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+DEPTH+AREA+BAIT | 3946.3 | 3951.0 | 3944.3 | | | | |
| **YEAR+DEPTH+ AREA+BAIT YEAR*DEPTH** | **3942.2** | **3945.1** | **3938.2** | | | | |
| YEAR+DEPTH+ AREA+BAIT YEAR*AREA | 3994.1 | 3995.6 | 3990.1 | | | | |
| YEAR+DEPTH+ AREA+BAIT YEAR*BAIT | 3943.1 | 3946.4 | 3939.1 | | | | |
| **Positive catches-Poisson error distribution** | | | | | | | |
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 235 | 3448.7746 | 14.676 | | | | |
| TIMEOFDAY | 234 | 2465.986 | 10.538 | 28.191 | 28.191 | 982.79 | <.0001 |
| HOOKTYPE | 231 | 2446.643 | 10.592 | 27.829 | | 1002.13 | <.0001 |
| AREA | 234 | 2659.397 | 11.365 | 22.559 | | 789.38 | <.0001 |
| BAITTYPE | 230 | 3217.938 | 13.991 | 4.665 | | 230.84 | <.0001 |
| DEPTH | 231 | 3309.983 | 14.329 | 2.362 | | 138.79 | <.0001 |
| YEAR | 228 | 3285.996 | 14.412 | 1.795 | | 162.78 | <.0001 |
| SEASON | 233 | 3437.369 | 14.753 | -0.525 | | 11.41 | 0.0033 |
| | | | | | | | |
| TIMEOFDAY+ | | | | | | | |
| HOOKTYPE | 230 | 2038.9873 | 8.865 | 39.593 | 11.401 | 427.00 | <.0001 |
| AREA | 233 | 2177.9631 | 9.347 | 36.306 | | 288.02 | <.0001 |
| DEPTH | 230 | 2369.3967 | 10.302 | 29.804 | | 96.59 | <.0001 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| YEAR | 227 | 2404.7649 | 10.594 | 27.815 | | 61.22 | <.0001 |
| BAITTYPE | 229 | 2436.5876 | 10.640 | 27.498 | | 29.40 | <.0001 |
| | | | | | | | |
| TIMEOFDAY+HOOKTYPE+ | | | | | | | |
| AREA | 229 | 1956.1548 | 8.542 | 41.794 | 2.201 | 82.83 | <.0001 |
| DEPTH | 226 | 1941.1032 | 8.589 | 41.475 | | 97.88 | <.0001 |
| YEAR | 223 | 1876.4271 | 8.414 | 42.664 | | 162.56 | <.0001 |
| BAITTYPE | 225 | 1992.2041 | 8.854 | 39.667 | | 46.78 | <.0001 |
| | | | | | | | |
| TIMEOFDAY+HOOKTYPE+AREA | | | | | | | |
| YEAR | 222 | 1846.8541 | 8.319 | 43.313 | 1.520 | 109.30 | <.0001 |
| BAITTYPE | 224 | 1910.9668 | 8.531 | 41.869 | | 45.19 | <.0001 |
| DEPTH | 225 | 1922.3282 | 8.544 | 41.783 | | 33.83 | <.0001 |
| | | | | | | | |
| YEAR+TIMEOFDAY+HOOKTYPE+AREA | 222 | 1846.8541 | 8.319 | 43.313 | 1.520 | 29.57 | <.0001 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+TIMEOFDAY+ HOOKTYPE+AREA | 890.6 | 894.0 | 888.6 | | | | |
| **YEAR+TIMEOFDAY+ HOOKTYPE+AREA YEAR*TIME** | **885.4** | **886.9** | **881.4** | | | | |
| YEAR+TIMEOFDAY+ HOOKTYPE+AREA YEAR*HOOK | 890.6 | 891.7 | 888.6 | | | | |
| YEAR+TIMEOFDAY+ HOOKTYPE+AREA YEAR*AREA | 890.6 | 891.3 | 888.6 | | | | |

(B) 2002-2005

| **Proportion positive- Binomial error distribution** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 539 | 716.003 | 1.328 | | | | |
| AREA | 538 | 589.2121 | 1.095 | 17.555 | 17.555 | 126.79 | <.0001 |
| BAITTYPE | 534 | 647.779 | 1.213 | 8.681 | | 68.220 | <.0001 |
| DEPTH | 533 | 663.215 | 1.244 | 6.330 | | Negative of Hessian not positive definite. | |
| SEASON | 536 | 695.867 | 1.298 | 2.268 | | 20.140 | 0.0002 |
| YEAR | 536 | 706.807 | 1.319 | 0.732 | | 9.200 | 0.0268 |
| HOOKTYPE | 530 | 699.560 | 1.320 | 0.637 | | 16.440 | 0.0582 |
| TIMEOFDAY | 538 | 712.998 | 1.325 | 0.235 | | 3.010 | 0.0830 |
| | | | | | | | |
| AREA+ | | | | | | | |
| BAITTYPE | 533 | 556.4334 | 1.044 | 21.411 | 3.856 | 32.78 | <.0001 |
| YEAR | 535 | 580.4017 | 1.085 | 18.333 | | 8.81 | 0.0319 |
| SEASON | 535 | 583.3579 | 1.090 | 17.917 | | 5.85 | 0.1189 |
| | | | | | | | |
| AREA+BAITTYPE | | | | | | | |
| YEAR | 530 | 549.9655 | 1.038 | 21.885 | 0.474 | 30.44 | <.0001 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| **YEAR+AREA+BAITTYPE** | **2543.4** | **2547.7** | **2541.4** | | | | |
| YEAR+AREA+BAITTYPE YEAR*AREA | 2566.1 | 2566.3 | 2562.1 | | | | |
| YEAR+AREA+BAITTYPE YEAR*BAITTYPE | 2579.0 | 2581.0 | 2575.0 | | | | |

| **Positive catches- Poisson error distribution** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 203 | 3463.9670 | 17.064 | | | | |
| BAITTYPE | 198 | 2828.912 | 14.287 | 16.271 | 16.271 | 635.06 | <.0001 |
| YEAR | 200 | 3189.166 | 15.946 | 6.552 | | 274.8 | <.0001 |
| AREA | 202 | 3229.881 | 15.990 | 6.296 | | 234.09 | <.0001 |
| DEPTH | 199 | 3231.315 | 16.238 | 4.841 | | 232.65 | <.0001 |
| TIMEOFDAY | 202 | 3387.260 | 16.769 | 1.730 | | 76.71 | <.0001 |
| HOOKTYPE | 194 | 3286.373 | 16.940 | 0.726 | | 177.59 | <.0001 |
| SEASON | 200 | 3396.052 | 16.980 | 0.490 | | 67.92 | <.0001 |
| | | | | | | | |
| BAITTYPE+ | | | | | | | |
| AREA | 197 | 2639.3708 | 13.398 | 21.484 | 5.213 | 189.54 | <.0001 |
| DEPTH | 194 | 2678.4576 | 13.806 | 19.089 | | 150.45 | <.0001 |
| YEAR | 195 | 2760.4238 | 14.156 | 17.041 | | 68.49 | <.0001 |
| TIMEOFDAY | 197 | 2814.544 | 14.287 | 16.273 | | 14.37 | 0.0002 |
| | | | | | | | |
| BAITTYPE+AREA+ | | | | | | | |
| DEPTH | 193 | 2478.7351 | 12.843 | 24.735 | 3.250 | 160.64 | <.0001 |
| YEAR | 194 | 2533.5654 | 13.060 | 23.466 | | 105.81 | <.0001 |
| TIMEOFDAY | 196 | 2607.0142 | 13.301 | 22.051 | | 32.36 | <.0001 |
| | | | | | | | |
| BAITTYPE+AREA+DEPTH | | | | | | | |
| YEAR | 190 | 2360.4 | 12.423 | 27.196 | 2.462 | 118.34 | <.0001 |
| TIMEOFDAY | 192.0 | 2447.7 | 12.748 | 25.291 | | 31.06 | <.0001 |
| | | | | | | | |
| BAITTYPE+AREA+ DEPTH+YEAR | | | | | | | |
| TIMEOFDAY | 189.0 | 2284.9 | 12.089 | 29.153 | 1.957 | 75.53 | <.0001 |
| | | | | | | | |
| YEAR+BAITTYPE+ AREA+DEPTH+TIMEOFDAY | | | | | | | |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+BAITTYPE+AREA+ DEPTH+TIMEOFDAY | 791.8 | 795.0 | 789.8 | | | | |
| YEAR+BAITTYPE+AREA+ DEPTH+TIMEOFDAY YEAR*BAIT | 791.8 | 792.5 | 789.8 | | | | |
| **YEAR+BAITTYPE+AREA+ DEPTH+TIMEOFDAY YEAR*AREA** | **788.2** | **788.4** | **784.2** | | | | |
| YEAR+BAITTYPE+AREA+ DEPTH+TIMEOFDAY YEAR*DEPTH | 791.2 | 792.8 | 787.2 | | | | |
| YEAR+BAITTYPE+AREA+ DEPTH+TIMEOFDAY YEAR*TIME | 792.1 | 792.2 | 788.1 | | | | |

Table 4. The relative standardized index of abundance and coefficients of variation for blacknose shark.

| YEAR | ABSOLUTE INDEX | CV |
|---|---|---|
| 1994 | 0.0075 | 8.134 |
| 1995 | 0.0094 | 5.508 |
| 1996 | 0.0110 | 4.984 |
| 1997 | 0.0025 | 16.537 |
| 1998 | 0.0094 | 5.717 |
| 1999 | 0.0162 | 5.070 |
| 2000 | 0.0162 | 5.929 |
| 2001 | 0.0079 | 11.394 |
| 2002 | 0.0008 | 4.245 |
| 2003 | 0.0004 | 6.953 |
| 2004 | 0.0004 | 6.527 |
| 2005 | 0.0012 | 3.542 |

Table 5. Analysis of deviance of explanatory variables for the binomial and Poisson generalized linear and mixed model formulations of the proportion of positive and positive catches for the small coastal aggregate for 1994-2001 (A) and 2002-2005 (B). Final models selected are in bold.

(A) 1994-2001

| **Proportion positive- Binomial error distribution** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 819 | 1042.025 | 1.272 | | | | |
| BAITTYPE | 814 | 985.568 | 1.211 | 4.837 | 4.837 | 56.46 | <.0001 |
| YEAR | 812 | 992.529 | 1.222 | 3.929 | | 49.50 | <.0001 |
| DEPTH | 815 | 999.397 | 1.226 | 3.620 | | 42.63 | <.0001 |
| HOOKTYPE | 814 | 1011.153 | 1.242 | 2.367 | | 30.87 | <.0001 |
| TIMEOFDAY | 818 | 1024.806 | 1.253 | 1.532 | | 17.22 | <.0001 |
| AREA | 818 | 1036.041 | 1.267 | 0.453 | | 5.98 | 0.0144 |
| SEASON | 816 | 1039.213 | 1.274 | -0.097 | | 2.81 | 0.4215 |
| | | | | | | | |
| BAITTYPE+ | | | | | | | |
| YEAR | 807 | 939.865 | 1.165 | 8.463 | 3.626 | 45.70 | <.0001 |
| DEPTH | 810 | 946.656 | 1.169 | 8.143 | | 38.91 | <.0001 |
| HOOKTYPE | 809 | 967.968 | 1.196 | 5.959 | | 17.60 | 0.0035 |
| TIMEOFDAY | 813 | 979.483 | 1.205 | 5.308 | | 6.08 | 0.0136 |
| | | | | | | | |
| BAITTYPE+YEAR | | | | | | | |
| DEPTH | 803 | 894.119 | 1.113 | 12.484 | 4.022 | 45.75 | <.0001 |
| HOOKTYPE | 802 | 917.600 | 1.144 | 10.074 | | 22.26 | 0.0005 |
| | | | | | | | |
| BAITTYPE+YEAR+DEPTH | | | | | | | |
| HOOKTYPE | 798 | 878.849 | 1.101 | 13.440 | 0.956 | 15.27 | 0.0093 |
| | | | | | | | |
| YEAR+BAITTYPE+DEPTH | 803 | 894.119 | 1.113 | 12 | 4.022 | 45.75 | <.0001 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| **YEAR+BAITTYPE+DEPTH** | **3795.7** | **3800.4** | **3793.7** | | | | |
| YEAR+BAITTYPE+DEPTH YEAR*BAIT | 3797.5 | 3800.8 | 3793.5 | | | | |
| YEAR+BAITTYPE+DEPTH YEAR*DEPTH | 3807.2 | 3810.1 | 3803.2 | | | | |
| | | | | | | | |
| **Positive catches- Poisson error distribution** | | | | | | | |
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 547 | 47551.735 | 86.932 | | | | |
| BAITTYPE | 542 | 33073.589 | 61.021 | 29.806 | 29.806 | 14478.10 | <.0001 |
| TIMEOFDAY | 546 | 36227.332 | 66.350 | 23.675 | | 11324.40 | <.0001 |
| HOOKTYPE | 542 | 37849.559 | 69.833 | 19.669 | | 9702.18 | <.0001 |
| AREA | 546 | 42860.221 | 78.499 | 9.701 | | 4691.51 | <.0001 |
| YEAR | 540 | 43561.394 | 80.669 | 7.204 | | 3990.34 | <.0001 |
| DEPTH | 543 | 44610.079 | 82.155 | 5.495 | | 2941.66 | <.0001 |
| SEASON | 544 | 47112.752 | 86.604 | 0.377 | | 438.98 | <.0001 |
| | | | | | | | |
| BAITTYPE+ | | | | | | | |
| AREA | 541 | 26905.043 | 49.732 | 42.792 | 12.986 | 6168.55 | <.0001 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TIMEOFDAY | 541 | 27688.625 | 51.180 | 41.126 | | 5384.96 | <.0001 |
| HOOKTYPE | 537 | 29294.648 | 54.552 | 37.247 | | 3778.94 | <.0001 |
| YEAR | 535 | 29261.259 | 54.694 | 37.084 | | 3812.33 | <.0001 |
| DEPTH | 538 | 29758.018 | 55.312 | 36.373 | | 3315.57 | <.0001 |
| | | | | | | | |
| BAITTYPE+AREA | | | | | | | |
| TIMEOFDAY | 540 | 24169.026 | 44.757 | 48.514 | 5.722 | 2736.02 | <.0001 |
| YEAR | 534 | 24194.858 | 45.309 | 47.880 | | 2710.19 | <.0001 |
| HOOKTYPE | 536 | 24698.925 | 46.080 | 46.993 | | 2206.12 | <.0001 |
| DEPTH | 537 | 24774.462 | 46.135 | 46.930 | | 2130.58 | <.0001 |
| | | | | | | | |
| BAITTYPE+AREA+TIME | | | | | | | |
| YEAR | 533 | 20832.052 | 39.085 | 55.040 | 6.526 | 3336.97 | <.0001 |
| DEPTH | 536 | 22369.676 | 41.734 | 51.992 | | 1799.35 | <.0001 |
| HOOKTYPE | 535 | 22396.189 | 41.862 | 51.845 | | 1772.84 | <.0001 |
| | | | | | | | |
| BAITTYPE+AREA+TIME+YEAR | | | | | | | |
| HOOKTYPE | 528 | 18366.245 | 34.785 | 59.986 | 4.946 | 2465.81 | <.0001 |
| DEPTH | 529 | 19466.538 | 36.799 | 57.669 | | 1365.51 | <.0001 |
| | | | | | | | |
| YEAR+BAITTYPE+AREA+ TIME+DEPTH+HOOKTYPE | 524.0 | 17333.081 | 33.078 | 61.949 | 1.963 | 2133.46 | <.0001 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+BAITTYPE+AREA+ TIME+DEPTH+HOOKTYPE | 2317.1 | 2321.4 | 2315.1 | | | | |
| YEAR+BAITTYPE+AREA+ TIME+DEPTH+HOOKTYPE YEAR*BAIT | 2276.8 | 2280.0 | 2272.8 | | | | |
| YEAR+BAITTYPE+AREA+ TIME+DEPTH+HOOKTYPE YEAR*AREA | 2317.1 | 2317.9 | 2315.1 | | | | |
| **YEAR+BAITTYPE+AREA+ TIME+DEPTH+HOOKTYPE YEAR*TIME** | **2272.7** | **2274.2** | **2268.7** | | | | |
| YEAR+BAITTYPE+AREA+ TIME+DEPTH+HOOKTYPE YEAR*DEPTH | 2299.1 | 2301.7 | 2295.1 | | | | |
| YEAR+BAITTYPE+AREA+ TIME+DEPTH+HOOKTYPE YEAR*HOOK | 2306.1 | 2308.6 | 2302.1 | | | | |

(B) 2002-2005

| **Proportion positive- Binomial error distribution** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 539 | 663.087 | 1.230 | | | | |
| DEPTH | 533 | 589.606 | 1.106 | 10.081 | 10.081 | 73.48 | <.0001 |
| BAITTYPE | 534 | 627.264 | 1.175 | 4.517 | | 35.82 | <.0001 |
| AREA | 538 | 636.386 | 1.183 | 3.848 | | 26.70 | <.0001 |
| SEASON | 536 | 647.079 | 1.207 | 1.868 | | 16.01 | 0.0011 |
| HOOKTYPE | 530 | 644.871 | 1.217 | 1.096 | | 18.22 | 0.0327 |
| YEAR | 536 | 653.2981 | 1.219 | 0.925 | | 9.79 | 0.0204 |
| TIMEOFDAY | 538 | 663.043 | 1.232 | -0.179 | | 0.04 | 0.8323 |
| | | | | | | | |
| DEPTH | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| BAITTYPE | 528 | 544.9557 | 1.032 | 16.103 | 6.022 | 44.65 | <.0001 |
| AREA | 532 | 570.5405 | 1.072 | 12.825 | | 19.07 | <.0001 |
| YEAR | 530 | 581.5268 | 1.097 | 10.811 | | 8.08 | 0.0444 |
| HOOKTYPE | 524 | 575.5248 | 1.098 | 10.721 | | 14.08 | 0.1195 |
| SEASON | 530 | 584.693 | 1.103 | 10.325 | | 4.91 | 0.1783 |
| | | | | | | | |
| DEPTH+BAITTYPE+ | | | | | | | |
| YEAR | 525.0 | 527.4 | 1.005 | 18.344 | 2.241 | 17.57 | 0.0005 |
| AREA | 527 | 533.7 | 1.013 | 17.681 | | 11.26 | 0.0008 |
| | | | | | | | |
| DEPTH+BAITTYPE+YEAR | | | | | | | |
| AREA | 524.0 | 517.2 | 0.987 | 19.767 | 1.423 | 10.18 | 0.0014 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+DEPTH+BAITTYPE+AREA | 2634.7 | 2639.0 | 2633 | | | | |
| YEAR+DEPTH+BAITTYPE+ AREA YEAR*DEPTH | | | Convergence criteria not met. | | | | |
| YEAR+DEPTH+BAITTYPE+ AREA YEAR*BAIT | | | Convergence criteria not met. | | | | |
| YEAR+DEPTH+BAITTYPE+ AREA YEAR*AREA | | | Convergence criteria not met. | | | | |
| | | | | | | | |
| **Positive catches-Poisson error distribution** | | | | | | | |
| **FACTOR** | **DF** | **DEVIANCE** | **DEVIANCE/DF** | **%DIFF** | **DELTA%** | **CHISQUARE** | **PR>CHI** |
| NULL | 375 | 19673.7306 | 52.463 | | | | |
| SEASON | 372 | 17477.709 | 46.983 | 10.446 | 10.446 | 2196.02 | <.0001 |
| BAITTYPE | 370 | 18511.780 | 50.032 | 4.635 | | 1161.95 | <.0001 |
| HOOKTYPE | 366 | 18425.933 | 50.344 | 4.039 | | 1247.8 | <.0001 |
| YEAR | 372 | 18935.950 | 50.903 | 2.974 | | 737.78 | <.0001 |
| AREA | 374 | 19389.052 | 51.842 | 1.183 | | 284.68 | <.0001 |
| DEPTH | 370 | 19342.390 | 52.277 | 0.356 | | 331.34 | <.0001 |
| TIMEOFDAY | 374 | 19647.923 | 52.535 | -0.136 | | 25.81 | <.0001 |
| | | | | | | | |
| SEASON | | | | | | | |
| BAITTYPE | 367 | 16546.2943 | 45.085 | 14.063 | 3.617 | 931.41 | <.0001 |
| HOOKTYPE | 363 | 16691.9512 | 45.983 | 12.351 | | 785.76 | <.0001 |
| YEAR | 369 | 17385.4402 | 47.115 | 10.194 | | 92.27 | <.0001 |
| AREA | 371 | 17426.238 | 46.971 | 10.469 | | 51.47 | <.0001 |
| | | | | | | | |
| SEASON+BAITTYPE | | | | | | | |
| HOOKTYPE | 358 | 15829.2375 | 44.216 | 15.721 | 1.657 | 717.06 | <.0001 |
| AREA | 366 | 16505.1661 | 45.096 | 14.043 | | 41.13 | <.0001 |
| YEAR | 364 | 16416.5533 | 45.100 | 14.034 | | 129.74 | <.0001 |
| | | | | | | | |
| SEASON+BAITTYPE+HOOKTYPE | | | | | | | |
| YEAR | 355 | 15632.2 | 44.034 | 16.066 | 0.346 | 197 | <.0001 |
| AREA | 357 | 15818.8 | 44.310 | 15.540 | | 10.4 | 0.0013 |
| | | | | | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** | | | | |
| YEAR+SEASON+BAITTYPE+HOOKTYPE | 1849.5 | 1853.4 | 1847.5 | | | | |
| YEAR+SEASON+BAITTYPE+HOOKTYPE | 1850.4 | 1851.2 | 1846.4 | | | | |

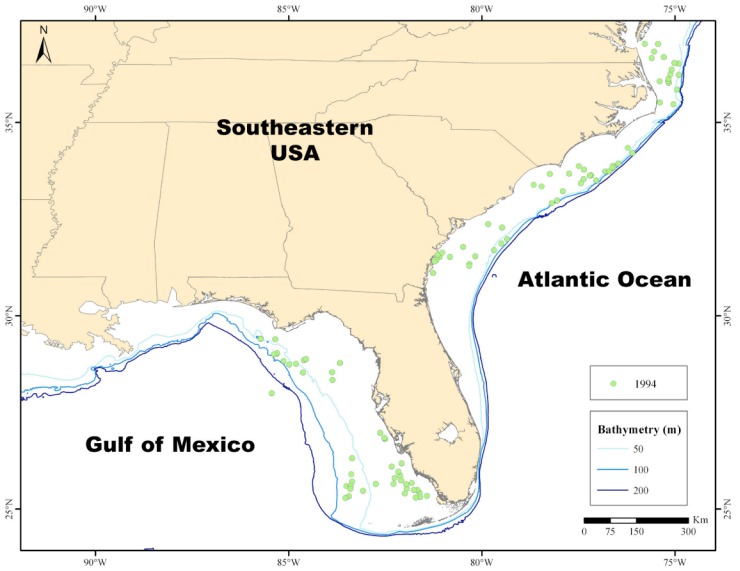
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| YEAR*SEASON | | | | | | | |
| YEAR+SEASON+BAITTYPE+HOOKTYPE YEAR*BAIT | 1817.2 | 1819.0 | 1813.2 | | | | |
| YEAR+SEASON+BAITTYPE+HOOKTYPE YEAR*HOOK | 1831.5 | 1834.0 | 1827.5 | | | | |

Table 4. The relative standardized index of abundance and coefficients of variation for the small coastal aggregate shark.

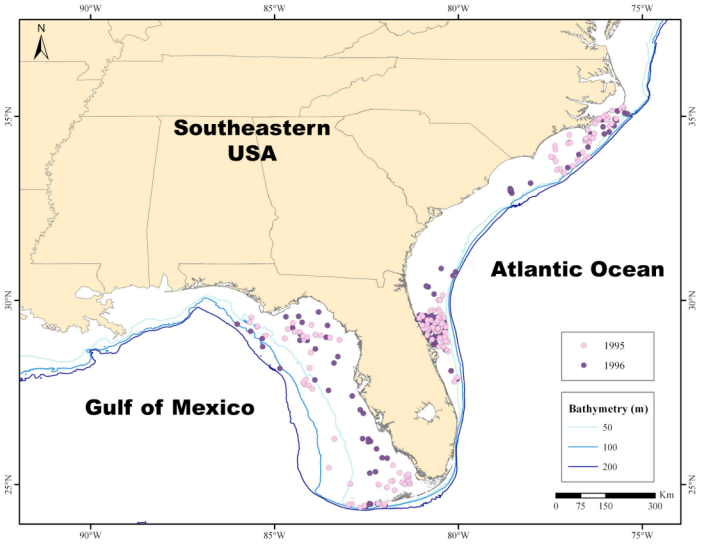
| YEAR | ABSOLUTE INDEX | CV |
|---|---|---|
| 1994 | 0.0004 | 11.142 |
| 1995 | 0.0042 | 1.797 |
| 1996 | 0.0025 | 2.412 |
| 1997 | 0.0035 | 2.171 |
| 1998 | 0.0064 | 1.292 |
| 1999 | 0.0208 | 0.890 |
| 2000 | 0.0138 | 1.241 |
| 2001 | 0.0091 | 1.420 |
| 2002 | 0.0015 | 2.922 |
| 2003 | 0.0021 | 2.344 |
| 2004 | 0.0029 | 2.083 |
| 2005 | 0.0034 | 1.346 |

Figure 1. Distribution of longline sets from the bottom longline observer program by year.

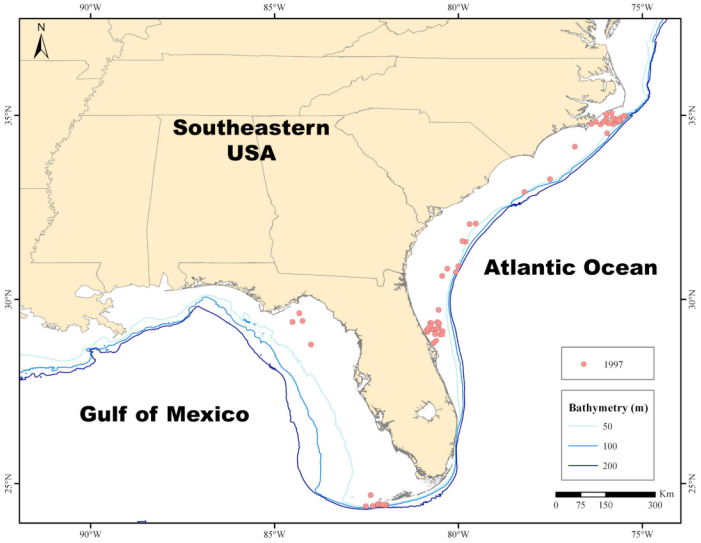
1994



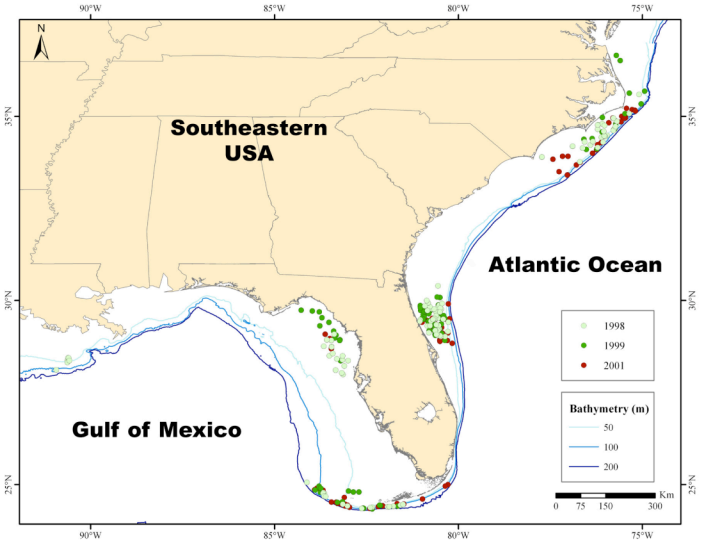

1995 and 1996



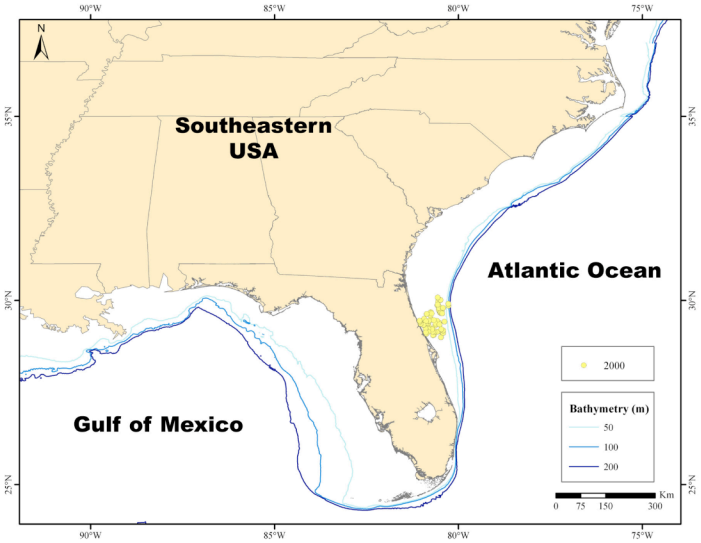
1997



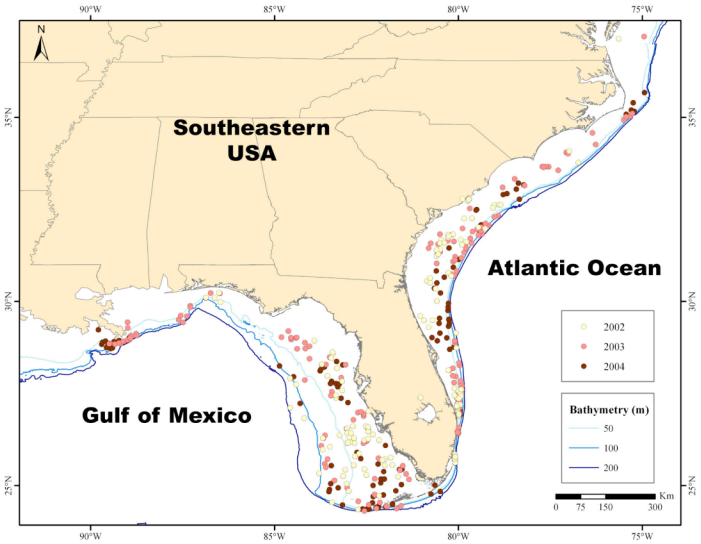

1998, 1999, and 2001



2000




2002, 2003, and 2004



2005

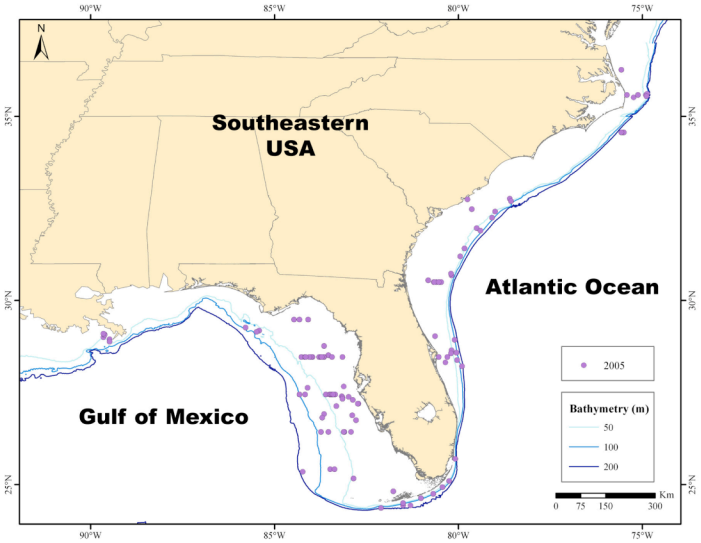
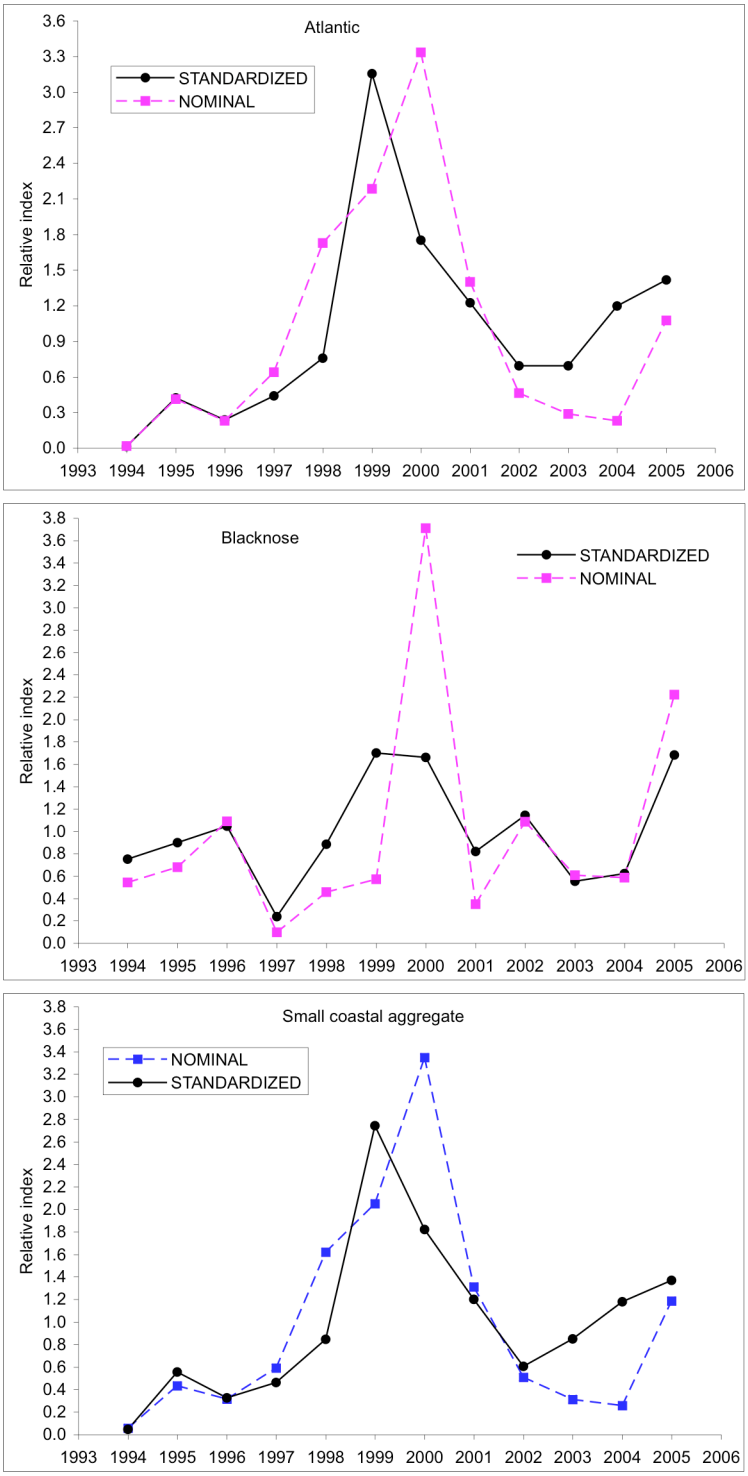

90°W
85°W
80°W
75°W
N
35°N
30°N
25°N
Southeastern
USA
Atlantic Ocean
Gulf of Mexico
2005
Bathymetry (m)
50
100
200
0 75 150 300
Km

Figure 2. Nominal and standardized indices of abundance for small coastal sharks. Each index has been divided by its mean.



# ADDENDUM TO SEDAR 13-DW-12
# (Standardized catch rates of small coastal sharks from the Commercial Shark Fishery Longline Observer Program, 1994-2005)

## Introduction

Based on discussion at the 2007 Shark SEDAR 13, the present addendum to document **SEDAR 13-DW-12** revises standardized catch rates for Atlantic sharpnose and blacknose shark and provides a new catch rate series for Atlantic sharpnose shark for the Atlantic Ocean and Gulf of Mexico stock. All analysis followed standardization procedures previously outlined in **SEDAR 13-DW-12** except:

1. The original analysis in **SEDAR 13-DW-12** assumed a Poisson distribution when modeling the positive catch rates. After discussion with stock assessment analysts, CPUE is now expressed as the natural logarithm of the number of sharks caught per $10^{-5}$ hook hours, i.e.:

CPUE=log [(sharks kept+sharks released)/(number of hooks*soak time/100000)]

2. In **SEDAR 13-DW-12**, catch rates were modeled independently for two time series representing periods of 1994-2001 (voluntary) and 2002-2005 (mandatory) because observations of the fishery had been conducted using two different non-overlapping sampling strategies. However, a closer examination of the data revealed that some vessels (n=6) have been sampled throughout both designs, which will allow for combining the series and utilizing a new factor "program" (i.e. voluntary and mandatory) which will be used to test for any changes in CPUE related to observer program design. Moreover, examination of the data when the series is split by stock would preclude modeling Atlantic sharpnose shark as a separate time series because of low sample in some years in particular areas.

3. High CV's were also noted in the index in **SEDAR 13-DW-12** may have also been caused by few observations in some cells in particular "baittype" (which was highly skewed towards the "other" category). To increase observations per cell, category factors were refined. For example, baittype "shark" and "skate/ray" have been combined to a single category "elasmobranch".

New and revised estimates are listed below:

Table 1. Analysis of mixed model formulations of the proportion of positive and positive catches for Atlantic sharpnose shark. Final models selected are in bold.

A. Areas combined

| **Proportion positive-Binomial error distribution** | | | |
|---|---|---|---|
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| **YEAR+HOOK+DEPTH+BAIT+AREA** | **6157.8** | **6163.0** | **6155.8** |
| YEAR+HOOK+DEPTH+BAIT+AREA YEAR*HOOK | 6214.2 | 6218.1 | 6210.0 |
| YEAR+HOOK+DEPTH+BAIT+AREA YEAR*DEPTH | 6201.7 | 6205.8 | 6197.7 |
| YEAR+HOOK+DEPTH+BAIT+AREA YEAR*BAIT | 6201.9 | 6206.0 | 6197.9 |

| | | | |
|---|---|---|---|
| YEAR+HOOK+DEPTH+BAIT+AREA YEAR*AREA | 6256.0 | 6258.0 | 6252.0 |
| **Positive catches-Lognormal error distribution** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| YEAR+BAIT+TIME+SEASON+HOOK+AREA | 2738.2 | 2742.8 | 2736.2 |
| YEAR+BAIT+TIME+SEASON+HOOK+AREA YEAR*BAIT | 2710.3 | 2714.2 | 2706.3 |
| **YEAR+BAIT+TIME+SEASON+HOOK+AREA YEAR*TIME** | **2700.1** | **2702.5** | **2696.1** |
| YEAR+BAIT+TIME+SEASON+HOOK+AREA YEAR*SEASON | 2731.0 | 2733.9 | 2727.0 |
| YEAR+BAIT+TIME+SEASON+HOOK+AREA YEAR*HOOK | 2725.8 | 2725.8 | 2721.0 |
| YEAR+BAIT+TIME+SEASON+HOOK+AREA YEAR*AREA | 2739.8 | 2742.0 | 2735.8 |

B. Atlantic Ocean

| | | | |
|---|---|---|---|
| **Proportion positive-Binomial error distribution** | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| YEAR+BAIT+HOOK | **3683.1** | **3687.7** | **3681.1** |
| YEAR+BAIT+HOOK YEAR*BAIT | 3766.4 | 3768.4 | 3764.4 |
| YEAR+BAIT+HOOK YEAR*HOOK | 3767.8 | 3771.6 | 3763.8 |
| **Positive catches-Lognormal error distribution** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| YEAR+BAIT+TIME+HOOK+DEPTH | 1829 | 1833.2 | 1827 |
| YEAR+BAIT+TIME+HOOK+DEPTH YEAR*BAIT | 1818.3 | 1822.1 | 1814.3 |
| **YEAR+BAIT+TIME+HOOK+DEPTH YEAR*TIME** | **1805.6** | **1807.9** | **1801.6** |
| YEAR+BAIT+TIME+HOOK+DEPTH YEAR*HOOK | 1829.0 | 1832.0 | 1825.0 |
| YEAR+BAIT+TIME+HOOK+DEPTH YEAR*DEPTH | 1827.0 | 1830.0 | 1823.0 |

C. Gulf of Mexico

| | | | |
|---|---|---|---|
| **Proportion positive-Binomial error distribution** | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| **YEAR+DEPTH+BAIT** | **2683.5** | **2687.7** | **2681.5** |
| YEAR+DEPTH+BAIT YEAR*DEPTH | 2659.6 | 2663.0 | 2655.6 |
| YEAR+DEPTH+BAIT YEAR*BAIT | 2684.8 | 2687.9 | 2680.8 |
| **Positive catches-Lognormal error distribution** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| YEAR+DEPTH+HOOK+BAIT | 770.3 | 773.6 | 768.3 |
| YEAR+DEPTH+HOOK+BAIT YEAR*DEPTH | 769.6 | 772.9 | 765.6 |
| YEAR+DEPTH+HOOK+BAIT YEAR*HOOK | 771.5 | 774.3 | 767.5 |
| **YEAR+DEPTH+HOOK+BAIT YEAR*BAIT** | **765.8** | **768.4** | **761.8** |

Table 2. Analysis of mixed model formulations of the proportion of positive and positive catches for blacknose shark. Final models selected are in bold.

| | | | |
|---|---|---|---|
| **Proportion positive-Binomial error distribution** | | | |
| **MIXED MODEL** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| **YEAR+DEPTH+AREA+BAIT** | **6571.5** | **6576.7** | **6569.6** |

| | | | |
|---|---|---|---|
| YEAR+DEPTH+AREA+BAIT YEAR*DEPTH | 6601.8 | 6605.8 | 6597.8 |
| YEAR+DEPTH+AREA+BAIT YEAR*AREA | 6809.7 | 6811.9 | 6805.7 |
| YEAR+DEPTH+AREA+BAIT YEAR*BAIT | 6602.6 | 6606.6 | 6598.6 |
| **Positive catches-Lognormal error distribution** | **AIC** | **BIC** | **(-2) LOGLIKELIHOOD** |
| YEAR+TIME+HOOKTYPE | 1462.9 | 1466.9 | 1460.9 |
| YEAR+TIME+HOOKTYPE YEAR*TIME | 1464.8 | 1467.1 | 1460.8 |
| **YEAR+TIME+HOOKTYPE YEAR*HOOK** | **1454.2** | **1457.9** | **1450.2** |

Table 3. The standardized index of abundance, coefficients of variation (CV), lower (LCI) and upper (UCI) 95% confidence intervals and number of sets observed (N) for Atlantic sharpnose shark by area.

A. Atlantic sharpnose shark, area combined.

| YEAR | INDEX | CV | LCI | UCI | N |
|---|---|---|---|---|---|
| 1994 | 10.534 | 0.654 | 0.004 | 0.042 | 102 |
| 1995 | 118.473 | 0.561 | 0.050 | 0.407 | 162 |
| 1996 | 107.619 | 0.558 | 0.046 | 0.368 | 126 |
| 1997 | 157.065 | 0.563 | 0.066 | 0.541 | 80 |
| 1998 | 245.823 | 0.543 | 0.107 | 0.819 | 110 |
| 1999 | 760.861 | 0.547 | 0.330 | 2.553 | 99 |
| 2000 | 828.940 | 0.567 | 0.348 | 2.872 | 64 |
| 2001 | 292.945 | 0.551 | 0.126 | 0.990 | 77 |
| 2002 | 272.197 | 0.548 | 0.118 | 0.916 | 132 |
| 2003 | 167.911 | 0.547 | 0.073 | 0.564 | 171 |
| 2004 | 133.011 | 0.558 | 0.057 | 0.455 | 120 |
| 2005 | 148.218 | 0.558 | 0.063 | 0.507 | 128 |

B. Atlantic sharpnose shark, Atlantic Ocean.

| YEAR | INDEX | CV | LCI | UCI | N |
|---|---|---|---|---|---|
| 1994 | 36.151 | 0.620 | 0.012 | 0.116 | 55 |
| 1995 | 203.128 | 0.552 | 0.074 | 0.583 | 109 |
| 1996 | 146.506 | 0.550 | 0.054 | 0.419 | 86 |
| 1997 | 177.954 | 0.571 | 0.063 | 0.527 | 54 |
| 1998 | 400.443 | 0.549 | 0.147 | 1.144 | 72 |
| 1999 | 674.209 | 0.582 | 0.234 | 2.032 | 68 |
| 2000 | 977.488 | 0.569 | 0.347 | 2.882 | 64 |
| 2001 | 498.290 | 0.567 | 0.177 | 1.465 | 54 |
| 2002 | 395.279 | 0.573 | 0.139 | 1.174 | 68 |
| 2003 | 98.901 | 0.594 | 0.034 | 0.304 | 91 |
| 2004 | 75.067 | 0.653 | 0.023 | 0.253 | 51 |
| 2005 | 216.165 | 0.597 | 0.073 | 0.667 | 53 |

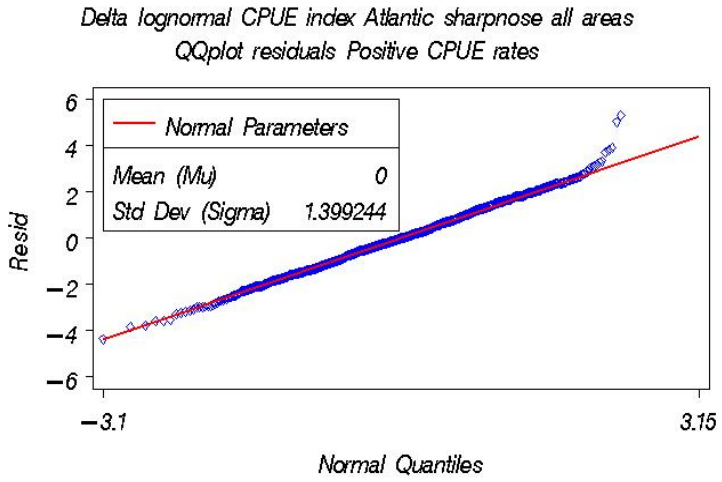
C. Atlantic sharpnose shark, Gulf of Mexico

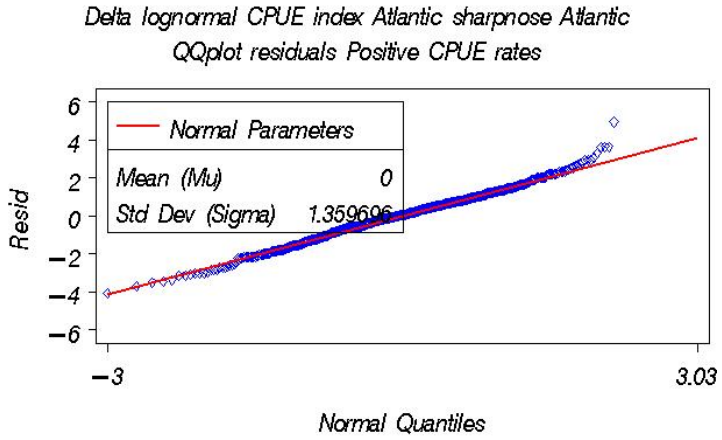
| YEAR | INDEX | CV | LCI | UCI | N |
|---|---|---|---|---|---|
| 1994 | 0.036 | 4.355 | 0.000 | 0.004 | 47 |
| 1995 | 1.533 | 0.909 | 0.001 | 0.023 | 53 |
| 1996 | 6.081 | 0.828 | 0.005 | 0.082 | 40 |
| 1997 | 167.410 | 0.575 | 0.184 | 1.555 | 26 |
| 1998 | 82.080 | 0.617 | 0.084 | 0.816 | 38 |
| 1999 | 102.412 | 0.526 | 0.122 | 0.878 | 31 |
| 2000 | | | | | |
| 2001 | 41.426 | 0.677 | 0.039 | 0.452 | 23 |
| 2002 | 92.860 | 0.498 | 0.116 | 0.760 | 64 |
| 2003 | 108.793 | 0.460 | 0.145 | 0.834 | 80 |
| 2004 | 170.670 | 0.463 | 0.226 | 1.316 | 69 |
| 2005 | 313.232 | 0.453 | 0.421 | 2.375 | 75 |

Table 4. The standardized index of abundance, coefficients of variation (CV), lower (LCI) and upper (UCI) 95% confidence intervals and number of sets observed (N) for blacknose shark.

| YEAR | INDEX | CV | LCI | UCI | N |
|---|---|---|---|---|---|
| 1994 | 17.126 | 0.615 | 0.042 | 0.407 | 102 |
| 1995 | 41.156 | 0.450 | 0.133 | 0.744 | 162 |
| 1996 | 35.776 | 0.459 | 0.114 | 0.657 | 126 |
| 1997 | 13.373 | 0.600 | 0.034 | 0.311 | 80 |
| 1998 | 37.706 | 0.465 | 0.119 | 0.700 | 110 |
| 1999 | 44.055 | 0.582 | 0.114 | 0.994 | 99 |
| 2000 | 130.194 | 0.522 | 0.373 | 2.663 | 64 |
| 2001 | 14.477 | 0.649 | 0.034 | 0.363 | 77 |
| 2002 | 67.202 | 0.368 | 0.252 | 1.049 | 132 |
| 2003 | 34.630 | 0.407 | 0.121 | 0.581 | 171 |
| 2004 | 28.780 | 0.501 | 0.085 | 0.568 | 120 |
| 2005 | 130.604 | 0.468 | 0.411 | 2.435 | 128 |

Figure 1. Quantile-quantile plots assessing the fits of the delta model for Atlantic sharpnose shark.



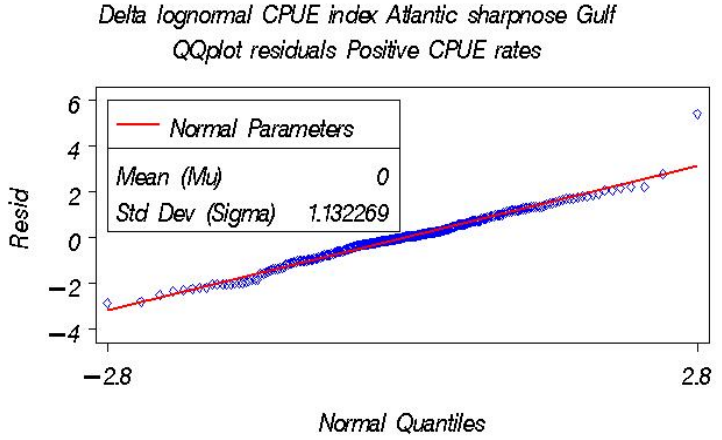



Figure 2. Quantile-quantile plots assessing the fits of the delta model for blacknose shark.

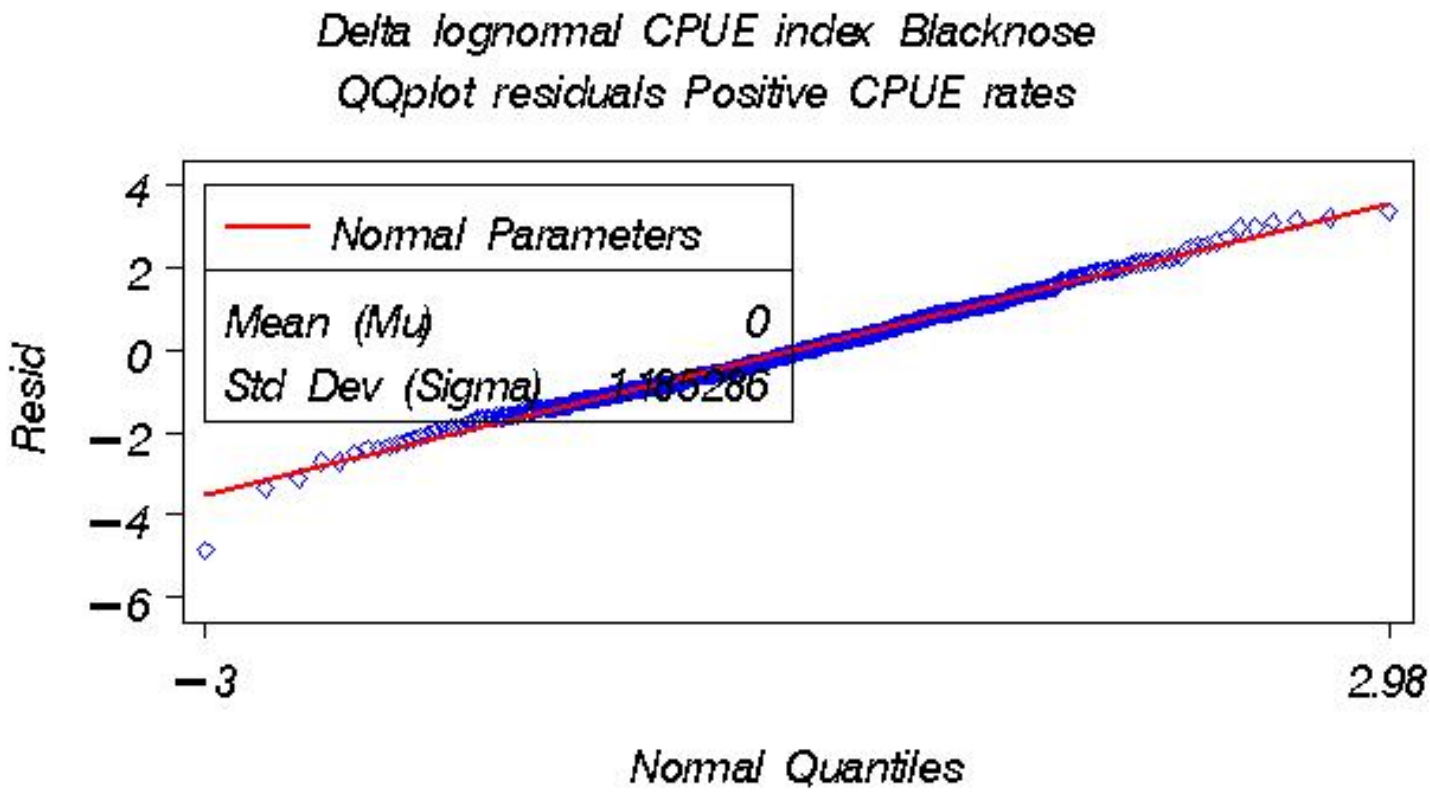


Figure 3. Standardized relative index (STDCPUE= index/maximum index) of abundance for Atlantic sharpnose and blacknose shark based on the final delta model. Nominal relative index (obscpue) are provided for comparison.