Small Coastal Shark Data Workshop Document

Life history and population genetics of blacknose sharks, *Carcharhinus acronotus*, in the South Atlantic Bight and the northern Gulf of Mexico.

William B. Driggers III [1], G. Walter Ingram Jr. [1], Mark A. Grace [1], John K. Carlson [2], Glenn F. Ulrich [3], James A. Sulikowski [4] and Joseph M. Quattro [5].

1. National Marine Fisheries Service, Southeast Fisheries Science Center, Mississippi Laboratories, P.O. Drawer 1207, Pascagoula, MS 39567.

2. National Marine Fisheries Service, Southeast Fisheries Science Center, Panama City Laboratory, 3500 Delwood Beach Rd., Panama City, FL 32408

3. South Carolina Department of Natural Resources, Marine Resources Division, 217 Fort Johnson Rd. Charleston, SC 29422

4. University of New England, Marine Science Center, 11 Hills Beach Rd. Biddeford, ME 04005.

5. University of South Carolina, Department of Biological Sciences. Columbia, SC 29208

Introduction

Blacknose sharks, *Carcharhinus acronotus*, occur seasonally in coastal and offshore waters of the South Atlantic Bight (SAB) and the northern Gulf of Mexico (GOM) from Cape Hatteras, NC to Brownsville, TX and are frequently caught in commercial and recreational fisheries (Compagno, 1984, Carlson and Bethea, 2006, Smith et al., 2005). This species is managed as part of the small coastal shark complex which also includes finetooth (*Carcharhinus isodon*), Atlantic sharpnose (*Rhizoprionodon terraenovae*) and bonnethead (*Sphyrna tiburo*) sharks (NMFS, 1993). In the most recent small coastal shark stock assessment, conducted in 2002, it was determined that biomass levels of blacknose sharks were at or above that necessary to produce maximum sustainable yield, however, there was some uncertainty associated with this conclusion (Cortes, 2002).

Various aspects of the life history of blacknose sharks in both the SAB and GOM have been examined (Carlson, 1999; Driggers et al., 2004a, 2004 b; Middlemiss et al., in review, Schwartz, 1982, Sulikowski et al., 2007) and regional differences in the biology of this species have been identified (Driggers et al. 2004a, 2004b, Sulikowski et al., 2007). The purpose of this document is to summarize the results of several studies on the life history of blacknose sharks in the SAB and GOM, compare important life history parameters reported in these studies and examine the population structure this species within the territorial waters of the United States (US).

Methods

Length and weight data from blacknose sharks collected in the SAB and GOM by Driggers et al. (2004a) and Grace (unpublished data) were used to generate conversions among lengths for sexes combined and sex specific length-weight relationships using regression analyses. Stretch total length (STL) was measured from the tip of the snout to the posterior tip of the upper lobe of the caudal fin while fully extended along the axis of the body. Total length (TL) was measured from the tip of the snout to the posterior tip of the upper lobe of the caudal fin while in its natural position. Fork length (FL) was measured from the tip of the snout to the posterior notch of the caudal fin. Precaudal length was measured from the tip of the snout to the anterior edge of the precaudal pit on the upper caudal peduncle. All length measurements were taken on a straight line along the axis of the body to the nearest mm. Weight was measured to the nearest 0.1 kg.

To examine the life history and population structure of blacknose sharks in the SAB and GOM, data were compiled from a number of sources (Carlson et al., 1999; Carlson, unpublished data; Driggers and Quattro, unpublished data; Driggers et al., 2004a, 2004b; Kohler et al., 1998; Kohler, unpublished data; Middlemiss et al., in review; Sulikowski et al., 2007; Ulrich et al., in press). Sex specific length and age data used by Driggers et al. (2004 a) and Middlemiss et al. (in review) were fitted to the von Bertalanffy growth function (VBGF) to generate sex specific and region specific growth models. Additionally, data from both sexes were merged to generate both region specific and a general growth model for blacknose sharks in the territorial waters of the US. Potential differences in the resulting models were tested to determine if area or sex specific differences in blacknose shark growth dynamics exist using the likelihood ratio test (Cerrato, 1990).

Maturity ogives were fitted to size, age and binomial maturity data from Driggers et al. (2004b) and Carlson (unpublished data), using least squares nonlinear regression, for each region and combined regions using the algorithm $Y = 1/(1+e^{-(a+bx)})$ for each sex and both sexes combined. Ages for the length and maturity data provided by Carlson (unpublished data) were back transformed based on the size at capture for each specimen and the VBGF parameters presented by Middlemiss et al. (in review). When back transformed ages were less than zero, age was considered zero for analyses. Initial parameter estimates for size ogives were a = -100 and b = 0.1 and for age ogives were a = 0.1 and b = 0.1. Size and age at which 50% of the population was mature was calculated from model parameter estimates as $-a/b$ (Mollet et al., 2000). To examine the effects of area and sex on potential differences in size and age at 50% maturity ogives were compared used χ^2-tests of likelihood ratios.

Information concerning the fecundity of female blacknose sharks in the SAB and GOM is from Driggers et al. (2004b) and Sulikowski et al. (2007). Data from both studies were combined to determine mean fecundity when treating blacknose sharks from the SAB and GOM as a single stock using a t-test (Zar, 1999). To determine if the ratio of female to male blacknose sharks caught during NMFS Mississippi Laboratory (MS Labs) fishery independent longline surveys was different than the expected ratio of 1:1 a chi-square test with Yates' correction was used (Zar, 1999). These surveys were conducted throughout the range of blacknose sharks in US waters from 1996 to 2006. To supplement these data information on blacknose sharks caught during South Carolina Department of Natural Resources (SCDNR) inshore longline surveys conducted off the coast of South Carolina were included in analyses.

The population structure of blacknose sharks from the SAB and GOM was examined by direct sequencing of the mitochondrial DNA (mtDNA) control region. Fin clips were collected from specimens off the coast of South Carolina and throughout the GOM. Genomic DNA was extracted from the fin clips using a Qiagen Dneasy Tissue Kit following the manufacturer's instructions. The mtDNA control region was then amplified using polymerase chain reaction (PCR) from samples that yielded sufficient DNA using the following primers (Stoner et al., 2003):

Forward primer: 5' TTG GCT CCC AAA GCC AAR ATT CTG 3'

Reverse primer: 5' CCC TCG TTT TWG GGG TTT TTC GAG 3'

Initial denaturation lasted for 3 minutes at 94°C followed by 40 cycles (denaturation: 94°C for 1 minute; annealing: 58°C for 1 minute; extension: 72°C for 2 minutes) and final extension at 72°C for 7 minutes. Following a purification process the PCR product was then directly cycle sequenced using flourescently labeled BigDye terminators (Perkin Elmer Biosystems) according to the following protocol: 25 cycles of denaturation: 96°C for 30 seconds; annealing: 50°C for 15 seconds; extension: 60°C for 4 minutes. After purifying the sequencing reaction samples were run out on an ABI Prism 377XL automated sequencer (Perkin Elmer). Sequences were aligned by eye using the computer program Sequencher. Data were analyzed using the program Arlequin. Analysis of molecular variance (AMOVA) (Excoffier et al., 1992) was used for data analysis and genetic variation was partitioned into within and between basins to detect potential population differences. An exact test was also performed to determine if population differentiation existed between the two basins.

There was limited information available on the movements of blacknose sharks in the SAB and GOM. Published accounts of blacknose shark seasonality in the SAB and GOM were compared in an effort to determine the migratory behavior of this species and determine if movement between the SAB and GOM occurs. Additionally, both published and unpublished tag return data were compared to the proposed migratory pattern of blacknose sharks. When measured lengths and dates at tagging and recapture were available these data were compared with the growth models presented herein.

Results

Conversions for various length relationships and length-weight relationships are listed in Table 1.

South Atlantic Bight

Size at capture and direct age estimate data were available for 117 females and 109 males collected off the coast of South Carolina. Direct age estimates were based on visual analyses of vertebral centra. The FL of specimens ranged from 644 to 1101 mm and 633 to 1063 mm for females and males, respectively. The maximum age observed for females was 12.5 years and for males was 10.5 years. VBGF parameter estimates for females, males and combined sexes are summarized in Table 2. Females had a higher L_∞, lower k and lower t_o than males (Fig. 1) and there was a significant difference in the VBGF parameter estimates between the sexes (likelihood ratio = 27.31, $p < 0.01$). Comparisons of time at liberty based on tag recapture data and predicted time at liberty based on back transforming age at tagging and recapture from the various region specific von Bertalanffy growth function (VBGF) parameter estimates for blacknose sharks in the SAB are presented in Table 3.

Off the coast of South Carolina female blacknose sharks reach 50% maturity at a FL of 909.80 mm (n = 122) and an age of 4.5 years (n = 115) (Figs. 2 and 3; Tables 4 and 5). The largest immature female was 953 mm FL and the smallest mature female was 910 mm FL; both individuals had an age of 4.5 years. Males reached 50% maturity at a FL of 890.64 mm (n = 108) and an age of 4.3 years (n = 104) (Figs. 2 and 3; Tables 4 and 5). The largest immature male was 926 mm FL and was 4.5 years old. The smallest mature male was 875 mm FL and was 3.5 years old. The predicted proportions of mature sharks by sex, size and age class are listed in Table 6. There was a significant difference in the size at maturity ogives between females and males ($\chi^2 = 6.97$, $p = 0.01$) but not between the age at maturity ogives ($\chi^2 = 0.75$, $p = 0.39$).

Pregnant female blacknose sharks (n = 26) carried a mean of 3.53 (S.D. = 0.70) pups with litter size ranging from 1 to 5. Based on the concurrent presence of gravid females without vitellogenic ovarian follicles and non-gravid adult females with preovulatory follicles during the late spring Driggers et al. (2004b) concluded that female blacknose sharks reproduce biennially in the SAB; a conclusion in agreement with the findings of Castro (1993)(Figure 4). Conversely, Driggers et al. (2004b) determined that male blacknose sharks are capable of reproducing annually. The ratio of female to male embryos was 1:1.1, which was not different from the expected ratio of 1:1 ($p = 0.92$). There was a significant relationship between the length of a pregnant female and the number of pups carried (ANOVA, $p = 0.02$).

The ratio of females (n= 38) to males (n = 33) caught during NMFS MS Labs longline surveys did not differ from the expected ratio of 1:1 ($\chi^2 = 0.35$, $p = 0.64$). Similarly, the ratio of females (n = 270) to males (n = 236) was not different from the expected ratio of 1:1 for blacknose sharks caught in the coastal waters of South Carolina during surveys conducted by the South Carolina Department of Natural Resources ($\chi^2 = 2.15$, $p > 0.05$). The size distributions of blacknose sharks caught in the SAB between 9 and approximately 180 m during NMFS MS Labs longline surveys and between 1 and 18 m during SCDNR longline surveys are presented in Figures 5 and 6.

Northern Gulf of Mexico

Ages were assigned to 76 female, 72 males and two blacknose sharks of unknown sex captured in the GOM by analyzing x-radiographs of vertebral centra (Middlemiss et al., in review). The length of females ranged from 331 to1053 mm FL while the length of males ranged from 315 to 1001 mm FL. The maximum observed age was 11.5 years for females and 9.5 years for males. VBGF parameter estimates for females, males and combined sexes are summarized in Table 2. Females had a higher L_∞, lower k and lower t_o than males (Fig. 7) and there was a significant difference in the VBGF parameter estimates between the sexes (likelihood ratio = 18.67, $p < 0.01$). Comparisons of time at liberty based on tag recapture data and predicted time at liberty based on back transforming age at tagging and recapture from the various region specific von Bertalanffy growth function (VBGF) parameter estimates for blacknose sharks in the GOM are presented in Table 7.

In the GOM female blacknose sharks reach 50% maturity at a length of 848.68 mm FL and an age of 6.63 years (n = 57) while males reach 50% maturity at a length of 848.07 mm FL and an age of 5.40 years (n = 118) (Fig. 8 and 9; Tables 4 and 5). The smallest mature female was 8.69 years old and 949 mm FL and the largest immature female was 4.77 years old and 751 mm FL. The smallest mature male was 4.98 years old and 828 mm FL while the largest immature male was 5.15 years old and 837 mm FL. The predicted proportions of mature sharks by sex, size and age class are listed in Table 8. There was no significant difference between female and male maturity ogives for size ($\chi^2 = 0.00$, $p = 0.99$) or age ($\chi^2 = 0.08$, $p = 0.77$).

Pregnant female blacknose sharks (n = 30) carried a mean of 3.13 (S.D. = 1.07) pups per litter with litter sizes ranging from 1 to 5 (Sulikowski et al., 2007). After examining reproductive tissues from blacknose sharks collected in the GOM, Sulikowski et al. (2007) determined that female and male blacknose sharks reproduce annually. This conclusion was further supported by the absence of non-gravid mature females and the presence of vitellogenic follicles and pups in all adult females captured during May (Figure 10). There was no significant difference between the size of the mother and the number of pups carried (ANOVA, $p > 0.05$). The ratio of female (n= 582) to males (n = 671) caught during NMFS MS Labs longline surveys was 1:1.15 and was different than the expected ratio of 1:1 ($\chi^2 = 6.32$, $p = 0.01$). The size distribution of blacknose sharks caught in the GOM between 9 and 366 m during NMFS MS Labs longline surveys are presented in Figure 11.

Areas Combined

Von Bertalanffy growth function parameter estimates for female, male and sexes combined are presented in Table 2. As was observed when treating the SAB and GOM data separately, females had a higher L_∞, lower k and lower t_o than males (Fig 12) and there was a significant difference in the VBGF parameter estimates between the sexes (likelihood ratio = 391.65, $p < 0.01$). Additionally, there were significant differences in VBGF parameter estimates when comparing SAB and GOM females (likelihood ratio = 240.48, $p < 0.01$) and SAB and GOM males (likelihood ratio = 178.21, $p < 0.01$). Comparisons of time at liberty based on tag recapture data and predicted time at liberty based on back transforming age at tagging and recapture from the various region specific von Bertalanffy growth function (VBGF) parameter estimates for blacknose sharks in the SAB and GOM combined are presented in Tables 3 and 7.

The size and age at 50% maturity for blacknose sharks in the SAB and GOM combined were 909.82 mm FL and 4.51 years for females, 881.11 mm FL and 4.55 years for males, and 896 mm FL and 4.54 years for the sexes combined (Figs 13 and 14; Tables 4 and 5). The predicted proportions of mature sharks by sex, size and age class are listed in Table 9. There was a significant difference in the size at maturity ogives for females and males ($\chi^2 = 7.07$, $p = 0.01$) but not in the age at maturity ogives ($\chi^2 = 0.90$, $p = 0.34$).

There was no significant difference in the number of pups per litter between the SAB and GOM (t-value = 1.41, $p = 0.16$). The mean number of pups per litter was 3.29 (S.D. = 0.96). There was no significant relationship between the length of a female and the number of pups carried ($p = 0.77$). The ratio of females to males in the combined area was not different from the expected ratio of 1:1 ($\chi^2 = 1.31$, $p = 0.24$). The size distributions of blacknose sharks caught in the SAB and GOM during NMFS MS Labs longline surveys are presented in Figure 15.

Population structure

Eighty-six SAB and 79 GOM samples were successfully sequenced (~1000 bps). Eight haplotypes were found based on mtDNA control region polymorphisms (Table 10). Haplotype 1 was the most common haplotype in both basins. Haplotype 2 occurred in both the SAB and GOM. Haplotypes 5 and 6 were found only in SAB samples while haplotypes 3,4,7, and 8 were found only in the GOM. The AMOVA results indicated that 1.42% of the total genetic variation was partitioned between the SAB and GOM ($p = 0.08$). The exact test of sample differentiation indicated that there was a significant difference in haplotype frequencies between the SAB and GOM ($p < 0.01$).

Tag-recapture data suggests that blacknose sharks do not move between the SAB and GOM. Eleven blacknose sharks have been tagged and recaptured after more than six months at liberty in the SAB. Times at liberty ranged from one to ten years. In the GOM, five blacknose sharks have been tagged and recaptured that were at liberty for over one year. Times at liberty ranged from approximately 3.8 years to 8.7 years and all were recaptured in the GOM.

Analyses of fishery independent data indicates that blacknose sharks undergo predictable seasonal migrations in the SAB and GOM. Off the east coast of central Florida, Dodrill (1977) found that blacknose shark were abundant from September until May and completely absent from this area from July until late August. A fishery independent survey, conducted by the SCDNR, indicates that in the late spring, blacknose sharks are present in the coastal waters of South Carolina. Blacknose sharks continue to move north during the early summer and are abundant off North Carolina from July through September (Schwartz, 1984). Blacknose sharks leave North Carolina waters in late September and begin to move south (Schwartz, 1984). At that time blacknose shark catches are highest off South Carolina (Ulrich et al., in press; G. Ulrich, unpublished data). By late November, blacknose sharks are no longer in South Carolina waters; however, abundance increases off the central east coast of Florida (Dodrill, 1977). During the cooler months some blacknose sharks in the northern portions of their range may also migrate offshore, rather than southward, (Driggers, unpublished data; C. Jensen, personal communication).

The migratory pattern of blacknose sharks in the GOM shows a similar trend. Springer (1939) found that blacknose sharks were present year round off the southwest coast of Florida. Clark and von Schmidt (1965) reported that blacknose sharks were caught off the Gulf coast of central Florida from March through November, with the highest catch per unit effort in May. Blacknose sharks move into the waters off the Florida panhandle during the same time, but are absent from November through February (Carlson et al., 1999). Together these data indicate that blacknose sharks migrate from southern waters during March into more northern portions of their range and return to the southern portions of their range during November and December. The capture of 16 blacknose sharks during March of 2003 approximately 110 km due south of Pascagoula, MS suggests that blacknose in the central GOM could migrate offshore rather than alongshore as appears to be the case in the eastern GOM.

The suggested migratory patterns of blacknose sharks in the SAB and GOM suggests that a mechanism exists that could limit gene flow between the areas. In both the SAB and GOM blacknose sharks are at the northern most extent of their range during June and July; a time that coincides with mating (Driggers et al., 2004b, Sulikowski et al., 2007). Given the year round presence of blacknose sharks off the coast of southern Florida it is possible that three genetic populations exist. An analysis of blacknose shark distribution in the GOM during August and September suggests the potential for further limitation of gene flow resulting from their disjunct distribution (Figure 16). Furthermore, very limited tag recapture information (n = 1) supports the possibility that blacknose sharks do not move between the eastern and western GOM.

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Conversion	Sex	Equation	r^2	n	Source
FL →STL	combined	STL = 45.2829 + (1.18784 * FL)	0.99	230	Driggers et al. (2004a)
FL → TL	combined	TL = 97.7298 + (1.07623 * FL)	0.91	1008	Grace (unpublished data)
FL →PCL	combined	PCL = -15.4285 + (0.927212 * FL)	0.99	228	Driggers et al. (2004a)
STL →WT	combined	WT = e (-1.86401 + 0.00348703 * STL))	0.96	223	Driggers (unpublished data)
TL →WT	combined	WT = e (-1.6493 + (0.00336578 * TL))	0.88	875	Grace (unpublished data)
FL →WT	combined	WT = e (-1.53642 + (0.0038724 * FL))	0.92	895	Grace (unpublished data)
PCL →WT	combined	WT = e (-1.65385 + 0.00449338 * PCL))	0.96	220	Driggers (unpublished data)
STL →WT	female	WT = e (-1.89212 + 0.00350761 * STL))	0.96	122	Driggers (unpublished data)
TL →WT	female	WT = e (-1.63653 + (0.0033694 * TL))	0.89	419	Grace (unpublished data)
FL →WT	female	WT = e (-1.57009 + 0.00390995 * FL))	0.94	429	Grace (unpublished data)
PCL →WT	female	WT = e (-1.69861 + 0.00454707 * PCL))	0.96	116	Driggers (unpublished data)
STL →WT	male	WT = e (-1.82352 + 0.00345566 * STL))	0.95	100	Driggers (unpublished data)
TL →WT	male	WT = e (-1.55543 + (0.00325485 * TL))	0.84	456	Grace (unpublished data)
FL →WT	male	WT = e (-1.40531 +(0.00372243 *FL))	0.85	466	Grace (unpublished data)
PCL →WT	male	WT = e (-1.58232 + 0.00440527 * PCL))	0.94	103	Driggers (unpublished data)

Table 1. Morphometric relationships for blacknose sharks in the South Atlantic Bight and the northern Gulf of Mexico. STL = stretch total length (mm), TL = total length (mm), FL = fork length (mm), PCL = precaudal length (mm) and WT = weight (kg).

	Female	S.E.	95% C.I.	Male	S.E.	95% C.I.	Combined	S.E.	95% C.I.
Northern Gulf of Mexico									
L_∞ (FL mm)	1363.24	213.58	937.58 to 1788.89	1053.55	93.01	867.99 to 1239.10	1174.81	99.31	978.55 to 1371.07
K	0.10	0.03	0.04 to 0.170	0.22	0.06	0.09 to 0.35	0.15	0.03	0.09 to 0.22
t_o (years)	-3.23	0.54	-4.31 to -2.16	-2.04	0.49	-3.02 to -1.07	-2.59	0.37	-3.32 to -1.87
Max. observed age (years)	11.5	▪	▪	9.5	▪	▪	11.5	▪	▪
Max. observed FL (mm)	1053	▪	▪	1001	▪	▪	1053	▪	▪
Theoretical longevity (years)	34.7	▪	▪	15.7	▪	▪	23.1	▪	▪
N	76	▪	▪	72	▪	▪	150	▪	▪
South Atlantic Bight									
L_∞ (FL mm)	1135.50	26.46	1083.00 to 1187.85	1058.60	21.99	1014.97 to 1102.17	1106.00	19.32	1068.42 to 1144.56
K	0.18	0.02	0.14 to 0.23	0.21	0.03	0.16 to 0.26	0.19	0.02	0.15 to 0.22
t_o (years)	-4.07	0.48	-5.02 to -3.12	-3.90	0.49	-4.88 to -2.93	-4.17	0.38	-4.92 to -3.43
Max. observed age (years)	12.5	▪	▪	10.5	▪	▪	12.5	▪	▪
Max. observed FL (mm)	1101	▪	▪	1063	▪	▪	1101	▪	▪
Theoretical longevity (years)	19.0	▪	▪	16.4	▪	▪	18.2	▪	▪
N	117	▪	▪	109	▪	▪	226	▪	▪
Areas Combined									
L_∞ (FL mm)	1042.57	24.30	994.63 to 1090.51	979.27	19.80	940.19 to 1018.34	1012.32	16.21	980.44 to 1044.20
K	0.30	0.03	0.24 to 0.36	0.36	0.04	0.28 to 0.43	0.32	0.02	0.27 to 0.37
t_o (years)	-1.71	0.19	-2.08 to -1.34	-1.62	0.22	-2.05 to -1.18	-1.70	0.15	-1.99 to -1.41
N	193	▪	▪	181	▪	▪	376	▪	▪
Theoretical longevity (years)	11.6	▪	▪	9.6	▪	▪	10.8	▪	▪

Table 2. Comparison of von Bertalanffy growth function parameter estimates for blacknose sharks in the South Atlantic Bight (Driggers et al., 2004a), the northern Gulf of Mexico (Middlemiss et al., in review) and combined areas.

Date tagged	10/24/1997	6/12/2002	6/6/1990	4/4/1985	6/23/2006	6/12/2002	6/12/2002	8/28/1997	8/14/2002	6/23/2006
FL at tagging (mm)	915	962	500	965	1071	962	1034	843	827	945
Date recaptured	6/16/2006	8/1/2005	12/4/1993	5/1/1986	7/3/2006	8/1/2005	6/25/2003	7/10/2001	9/19/2002	9/27/2006
FL at recapture (mm)	983	1101	1005	1182	1160	1005	1078	1006	1023	965
Sex	M	M	M	M	M	M	F	F	F	U
Time at liberty (years)	8.65	3.14	3.50	1.07	0.03	3.14	1.04	3.87	0.10	0.26
Age at tagging [1]	6.42	8.31	-0.05	8.46	$FL > L_{\infty}$	8.31	▪	▪	▪	▪
Age at recapture [1]	9.48	$FL > L_{\infty}$	11.12	$FL > L_{\infty}$	$FL > L_{\infty}$	11.12	▪	▪	▪	▪
Difference [1]	3.06	XXX	11.16	XXX	XXX	2.80	▪	▪	▪	▪
Age at tagging [2]	▪	▪	▪	▪	▪	▪	9.35	3.47	3.17	▪
Age at recapture [2]	▪	▪	▪	▪	▪	▪	12.50	7.99	8.77	▪
Difference [2]	▪	▪	▪	▪	▪	▪	3.16	4.53	5.60	▪
Age at tagging [3]	5.07	6.56	-1.00	6.67	14.00	6.56	10.21	3.39	3.08	5.97
Age at recapture [3]	7.39	24.25	8.43	$FL > L_{\infty}$	$FL > L_{\infty}$	8.43	15.18	8.48	9.46	6.67
Difference [3]	2.32	17.69	9.43	XXX	XXX	1.87	4.97	5.09	6.38	0.70
Age at tagging [4]	6.17	9.92	0.43	10.47	$FL > L_{\infty}$	9.92	▪	▪	▪	▪
Age at recapture [4]	$FL > L_{\infty}$	$FL > L_{\infty}$	$FL > L_{\infty}$	$FL > L_{\infty}$	$FL > L_{\infty}$	$FL > L_{\infty}$	▪	▪	▪	▪
Difference [4]	XXX	XXX	XXX	XXX	XXX	XXX	▪	▪	▪	▪
Age at tagging [5]	▪	▪	▪	▪	▪	▪	14.46	3.86	3.60	▪
Age at recapture [5]	▪	▪	▪	▪	▪	▪	$FL > L_{\infty}$	9.57	11.68	▪
Difference [5]	▪	▪	▪	▪	▪	▪	XXX	5.71	8.08	
Age at tagging [6]	5.64	7.71	0.44	7.90	$FL > L_{\infty}$	7.71	$FL > L_{\infty}$	3.91	3.62	6.80
Age at recapture [6]	9.40	$FL > L_{\infty}$	13.75	$FL > L_{\infty}$	$FL > L_{\infty}$	13.75	$FL > L_{\infty}$	14.21	$FL > L_{\infty}$	7.90
Difference [6]	3.76	XXX	13.32	XXX	XXX	6.04	XXX	10.31	XXX	1.11
Source	SCDNR	NAPP	NAPP	NAPP	NAPP	SCDNR	NAPP	NAPP	SCDNR	SCDNR

Table 3. Legend on following page.

Table 3 (Cont.). Comparison of time at liberty based on tag recapture data and predicted time at liberty based on back transforming age at tagging and recapture from von Bertalanffy growth function (VBGF) parameter estimates for blacknose sharks in the South Atlantic Bight (SAB). Superscript numbers indicate which growth model (Driggers et al., (2004a) or Driggers et al. (2004a) and Middlemiss et al. (in review) combined) was used in the back transformation: 1 = SAB male specific VBGF, 2 = SAB female specific VBGF, 3 = SAB combined sexes VBGF, 4 = SAB and northern Gulf of Mexico (GOM) combined male specific VBGF, 5 = SAB and GOM female specific VBGF, 6 = SAB and GOM combined sexes VBGF. All ages are reported in years. XXX indicates that the length at tagging and/or recapture could not be back transformed and as a result the time difference could not be calculated. Data provided by South Carolina Department of Natural Resources (SCDNR) and National Marine Fisheries Service Apex Predators Program (NAPP)

South Atlantic Bight

	Parameter	Estimate	S.E.	95% lower C.I.	95% upper C.I.	n	Fork length (mm)
Female	*a*	-117.83	0.79	-119.40	-116.27	122	906.40
	b	0.13	0.00	0.13	0.13		
Male	*a*	-114.80	0.72	-116.23	-113.36	108	889.91
	b	0.13	0.00	0.13	0.13		
Sexes combined	*a*	-111.13	0.48	-112.08	-110.18	230	903.49
	b	0.12	0.00	0.12	0.12		

Northern Gulf of Mexico

	Parameter	Estimate	S.E.	95% lower C.I.	95% upper C.I.	n	Fork length (mm)
Female	*a*	-93.29	0.16	-93.60	-92.97	57	848.68
	b	0.11	0.00	0.11	0.11		
Male	*a*	-119.25	5.71	-130.55	-107.95	118	848.02
	b	0.14	0.00	0.13	0.15		
Sexes combined	*a*	-143.42	10.69	-164.52	-122.32	175	848.07
	b	0.17	0.01	0.16	0.18		

Areas combined

	Parameter	Estimate	S.E.	95% lower C.I.	95% upper C.I.	n	Fork length (mm)
Female	*a*	-109.10	0.62	-110.32	-107.87	179	909.82
	b	0.12	0.00	0.12	0.12		
Male	*a*	-115.77	0.62	-116.98	-114.55	226	881.11
	b	0.13	0.00	0.13	0.13		
Sexes combined	*a*	-111.09	0.38	-111.85	-110.34	405	896.68
	b	0.12	0.00	0.12	0.12		

Table 4. Size at 50% maturity for blacknose sharks in the South Atlantic Bight, northern Gulf of Mexico and areas combined.

South Atlantic Bight

	Parameter	Estimate	S.E.	95% lower C.I.	95% upper C.I.	n	Age (years)
Female	*a*	-36.13	161.53	-356.15	283.90	115	4.45
	b	8.12	35.91	-63.02	79.26		
Male	*a*	-13.42	2.28	-17.95	-8.90	104	4.26
	b	3.15	0.54	2.09	4.22		
Sexes combined	*a*	-15.85	3.16	-22.07	-9.63	219	4.37
	b	3.63	0.71	2.23	5.02		

Northern Gulf of Mexico

	Parameter	Estimate	S.E.	95% lower C.I.	95% upper C.I.	n	Age (years)
Female	*a*	-101.43	0.04	-101.51	-101.35	57	6.63
	b	15.31	0.00	15.31	15.31		
Male	*a*	-13.28	2.65	-18.54	-8.03	118	5.40
	b	2.46	0.51	1.46	3.46		
Sexes combined	*a*	-15.35	2.57	-20.43	-10.28	175	5.45
	b	2.82	0.50	1.84	3.80		

Areas combined

	Parameter	Estimate	S.E.	95% lower C.I.	95% upper C.I.	n	Age (years)
Female	*a*	-13.79	3.52	-20.74	-6.85	172	4.51
	b	3.06	0.79	1.51	4.61		
Male	*a*	-10.88	1.25	-13.34	-8.41	222	4.55
	b	2.39	0.27	1.86	2.92		
Sexes combined	*a*	-11.59	1.20	-13.96	-9.22	394	4.54
	b	2.56	0.27	2.03	3.08		

Table 5. Age at 50% maturity for blacknose sharks in the South Atlantic Bight, northern Gulf of Mexico and areas combined.

South Atlantic Bight

	Proportion mature				Proportion mature		
FL (mm)	Female	Male	Combined	Age (years)	Female	Male	Combined
350	0.00	0.00	0.00	0	0.00	0.00	0.00
400	0.00	0.00	0.00	0.5	0.00	0.00	0.00
450	0.00	0.00	0.00	1.5	0.00	0.00	0.00
500	0.00	0.00	0.00	2.5	0.00	0.00	0.00
550	0.00	0.00	0.00	3.5	0.00	0.08	0.04
600	0.00	0.00	0.00	4.5	0.60	0.68	0.62
650	0.00	0.00	0.00	5.5	1.00	0.98	0.98
700	0.00	0.00	0.00	6.5	1.00	1.00	1.00
750	0.00	0.00	0.00	7.5	1.00	1.00	1.00
800	0.00	0.00	0.00	8.5	1.00	1.00	1.00
850	0.00	0.01	0.00	9.5	1.00	1.00	1.00
900	0.22	0.77	0.43	10.5	1.00	1.00	1.00
950	0.99	1.00	1.00	11.5	1.00	1.00	1.00
1000	1.00	1.00	1.00	12.5	1.00	1.00	1.00
1050	1.00	1.00	1.00				
1100	1.00	1.00	1.00				
1150	1.00	1.00	1.00				

Table 6. Predicted proportion of mature blacknose sharks by sex, size and age in the South Atlantic Bight.

Date tagged	8/20/2001	8/11/2002	8/9/2002
FL at tagging (mm)	480	960	450
Date recaptured	5/25/2006	6/29/2006	8/27/2002
FL at recapture (mm)	910	1020	460
Sex	F	F	F
Time at liberty (years)	4.76	3.88	0.05
Age at tagging [1]	1.11	8.95	0.78
Age at recapture [1]	7.78	10.56	0.89
Difference [1]	6.67	1.61	0.11
Age at tagging [2]	0.91	8.74	0.63
Age at recapture [2]	7.34	10.92	0.72
Difference [2]	6.43	2.18	0.09
Age at tagging [3]	0.37	6.83	0.19
Age at recapture [3]	5.23	11.20	0.25
Difference [3]	4.87	4.37	0.06
Age at tagging [4]	0.32	7.59	0.14
Age at recapture [4]	5.49	FL > L_∞	0.20
Difference [4]	5.17	XXX	0.06

Table 7. Comparison of time at liberty based on tag recapture data and predicted time at liberty based on back transforming age at tagging and recapture from von Bertalanffy growth function (VBGF) parameter estimates for blacknose sharks in the northern Gulf of Mexico (GOM). Superscript numbers indicate which growth model (Middlemiss et al. (in review) or Driggers et al. (2004a) and Middlemiss et al. (in review) combined) was used in the back transformation: 1 = GOM female specific VBGF, 2 = GOM sexes combined VBGF, 3 = South Atlantic Bight (SAB) and GOM female specific VBGF and 4 = SAB and GOM sexes combined VBGF. All ages are reported in years. Data provided by National Marine Fisheries Service Panama City Laboratory.

Northern Gulf of Mexico

	Proportion mature				Proportion mature		
FL (mm)	Female	Male	Combined	Age (years)	Female	Male	Combined
350	0.00	0.00	0.00	0	0.00	0.00	0.00
400	0.00	0.00	0.00	0.5	0.00	0.00	0.00
450	0.00	0.00	0.00	1.5	0.00	0.00	0.00
500	0.00	0.00	0.00	2.5	0.00	0.00	0.00
550	0.00	0.00	0.00	3.5	0.00	0.01	0.00
600	0.00	0.00	0.00	4.5	0.00	0.10	0.06
650	0.00	0.00	0.00	5.5	0.00	0.56	0.54
700	0.00	0.00	0.00	6.5	0.13	0.94	0.95
750	0.00	0.00	0.00	7.5	1.00	0.99	1.00
800	0.00	0.00	0.00	8.5	1.00	1.00	1.00
850	0.54	0.57	0.58	9.5	1.00	1.00	1.00
900	1.00	1.00	1.00	10.5	1.00	1.00	1.00
950	1.00	1.00	1.00	11.5	1.00	1.00	1.00
1000	1.00	1.00	1.00	12.5	1.00	1.00	1.00
1050	1.00	1.00	1.00				
1100	1.00	1.00	1.00				
1150	1.00	1.00	1.00				

Table 8. Predicted proportion of mature blacknose sharks by sex, size and age in the northern Gulf of Mexico.

Areas Combined

	Proportion mature				Proportion mature		
FL (mm)	Female	Male	Combined	Age (years)	Female	Male	Combined
350	0.00	0.00	0.00	0	0.00	0.00	0.00
400	0.00	0.00	0.00	0.5	0.00	0.00	0.00
450	0.00	0.00	0.00	1.5	0.00	0.00	0.00
500	0.00	0.00	0.00	2.5	0.00	0.01	0.01
550	0.00	0.00	0.00	3.5	0.04	0.07	0.07
600	0.00	0.00	0.00	4.5	0.50	0.47	0.48
650	0.00	0.00	0.00	5.5	0.95	0.91	0.92
700	0.00	0.00	0.00	6.5	1.00	0.99	0.99
750	0.00	0.00	0.00	7.5	1.00	1.00	1.00
800	0.00	0.00	0.00	8.5	1.00	1.00	1.00
850	0.00	0.02	0.00	9.5	1.00	1.00	1.00
900	0.24	0.92	0.60	10.5	1.00	1.00	1.00
950	0.99	1.00	1.00	11.5	1.00	1.00	1.00
1000	1.00	1.00	1.00	12.5	1.00	1.00	1.00
1050	1.00	1.00	1.00				
1100	1.00	1.00	1.00				
1150	1.00	1.00	1.00				

Table 9. Predicted proportion of mature blacknose sharks by sex, size and age in the South Atlantic Bight and northern Gulf of Mexico when both regions are treated as one area.

Haplotype									Atlantic	Gulf
1	G	G	G	T	T	T	A	G	77	65
2	·	·	·	·	·	·	·	A	4	3
3	·	·	A	·	·	·	·	·	0	4
4	·	A	·	·	·	·	·	·	0	4
5	·	·	·	A	·	·	·	·	1	0
6	·	·	·	·	C	·	·	·	4	0
7	·	·	·	·	·	G	C	·	0	1
8	·	·	·	·	C	·	·	A	0	2
					Total Sequences				86	79

Table 10. Haplotype frequencies and distribution between the South Atlantic Bight and the northern Gulf of Mexico based on mtDNA sequence data.

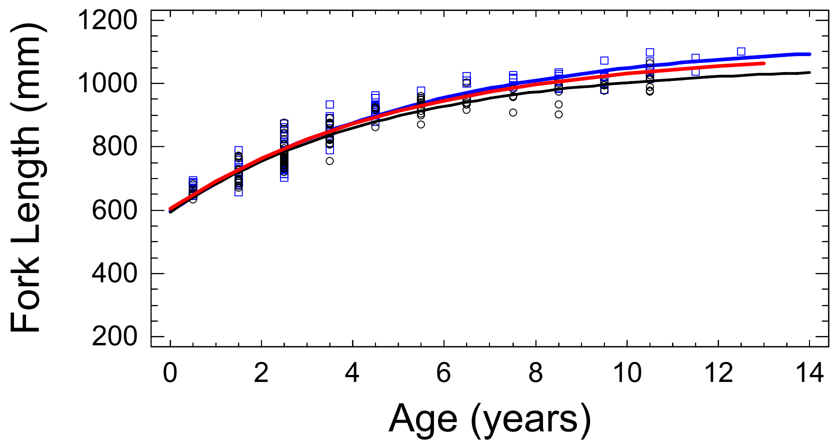

Figure 1. Von Bertalanffy growth models for blacknose sharks in the South Atlantic Bight based on size at capture and visual analyses of vertebral centra (Driggers et al., 2004a). Blue line and squares = female, black line and circles = male and red line with = sexes combined.

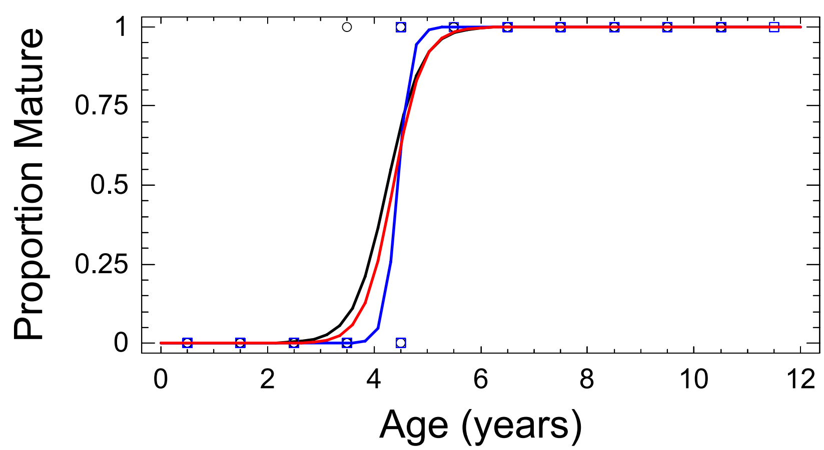

Figure 2. Age at 50% maturity for female, male and sexes combined for blacknose sharks in the South Atlantic Bight. Blue line and squares = female, black line and circles = male and red line = sexes combined.

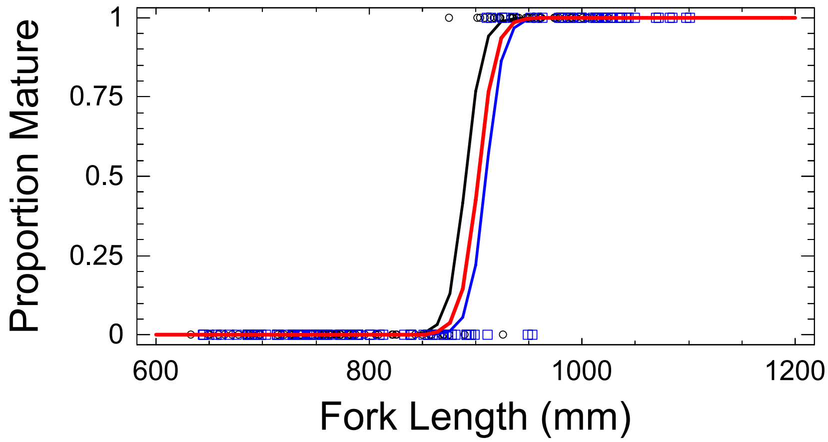

Figure 3. Size at 50% maturity for female, male and sexes combined for blacknose sharks in the South Atlantic Bight. Blue line and squares = female, black line and circles = male and red line = sexes combined.

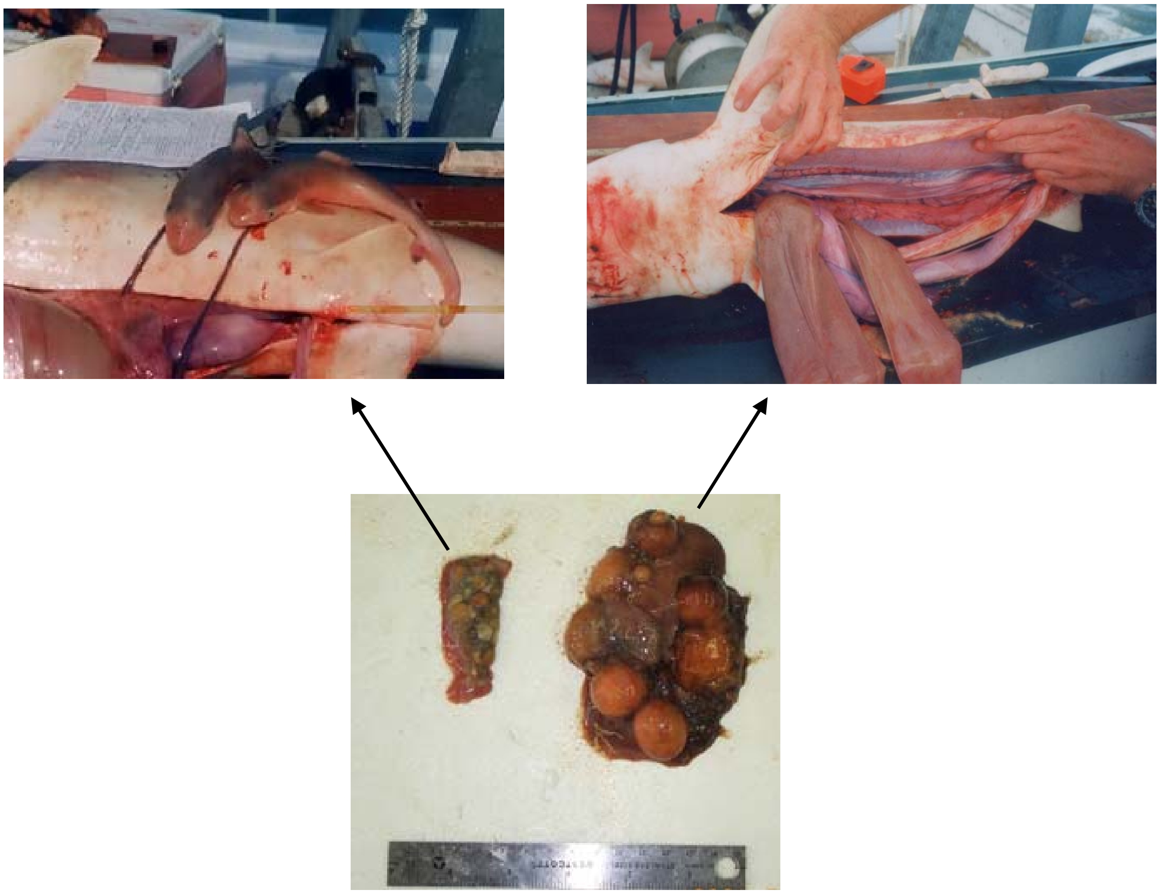

Figure 4. The reproductive systems of two female blacknose sharks caught in the South Atlantic Bight, off the coast of Charleston, SC during May of 1999. The picture in the upper left shows near term embryos removed from the left uteri. The picture on the upper right shows the reproductive tract of a mature female who was not carrying embryos. The picture on the bottom shows the condition of the ovary for each specimen. The presence of near term embryos and lack of vitellogenic activity for the specimen on the left and the preovulatory ovarian follicles and recrudescence of the uteri and oviducal glands for the specimen on the right indicates a biennial reproductive cycle.

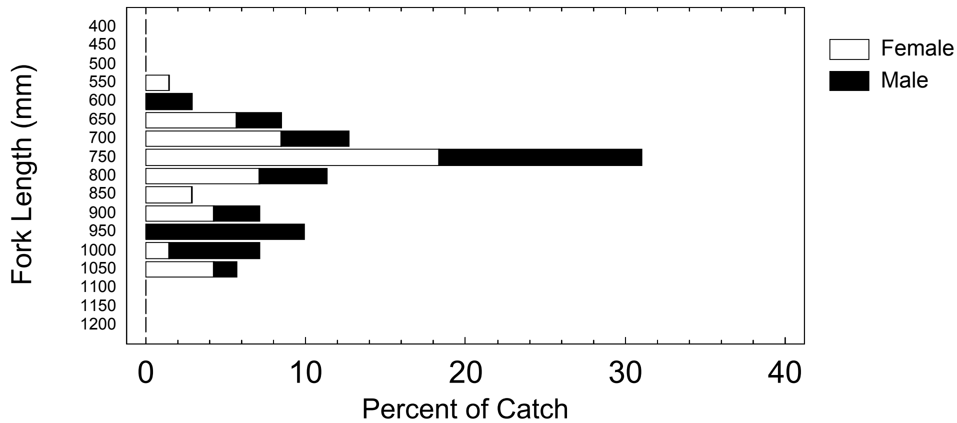

Figure 5. Length frequency distribution of blacknose sharks caught in the South Atlantic Bight during August and September between 9 and approximately 180 m during NMFS MS Labs bottom longline surveys, 1995-2006 (n = 71).

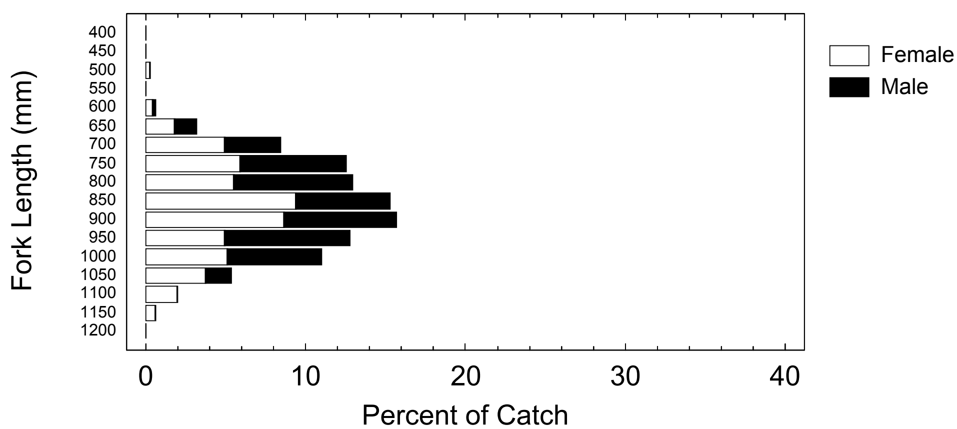

Figure 6. Length frequency distribution of blacknose sharks off the coast of South Carolina in the South Atlantic Bight during August and September off the coast of South Carolina between 1 and 18 m during South Carolina Department of Natural Resources longline surveys, 1992-2006 (n = 512).

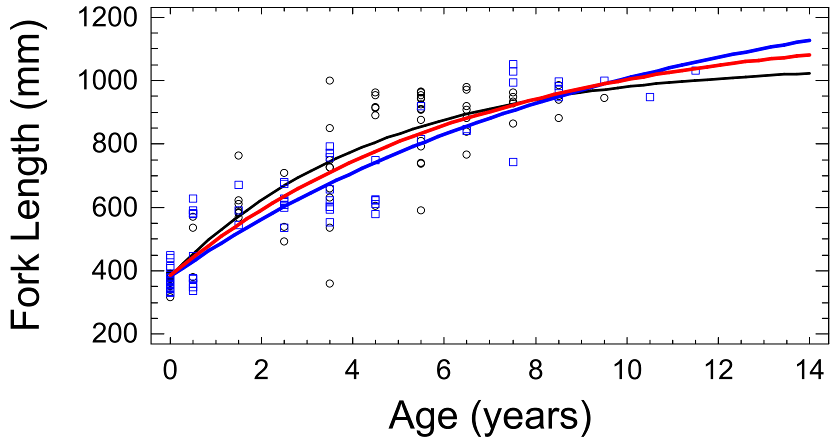

Figure 7. Von Bertalanffy growth models for blacknose sharks in the northern Gulf of Mexico based on size at capture and x-radiography analyses of vertebral centra (Middlemiss et al. in review). Blue line and squares = female, black line and circles = male and red line = sexes combined.

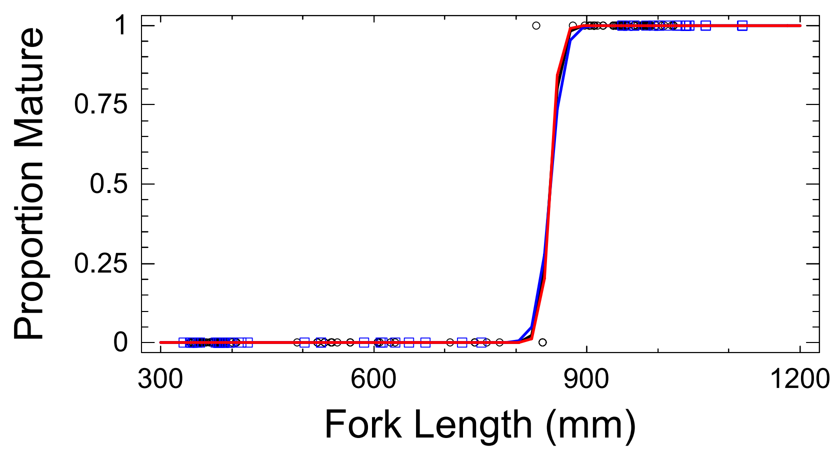

Figure 8. Size at 50% maturity for female, male and sexes combined for blacknose sharks in the northern Gulf of Mexico. Blue line and squares = female, black and circles = male and red line = sexes combined.

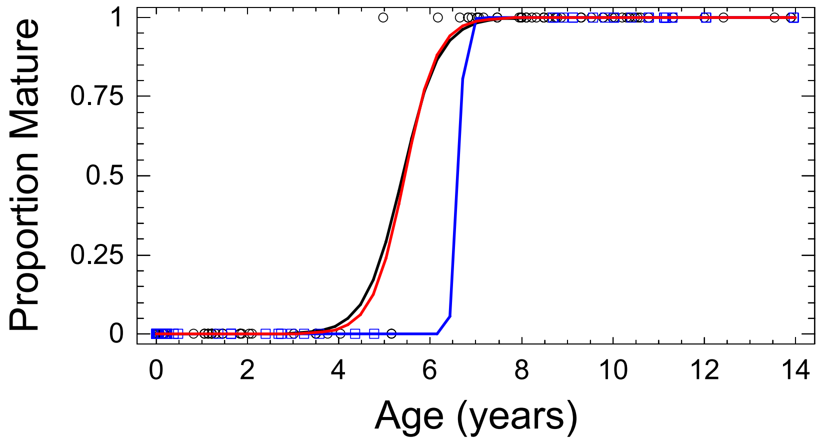

Figure 9. Age at 50% maturity for female, male and sexes combined for blacknose sharks in the northern Gulf of Mexico. Blue line and squares = female, black line and circles = male and red line = sexes combined.

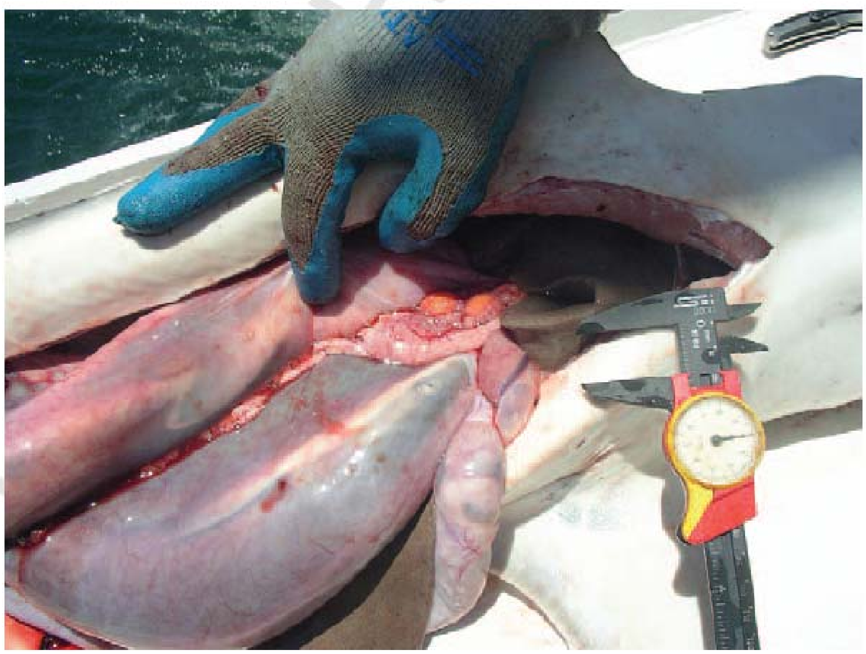

Figure 10. The uteri, embryos and ovary of a female blacknose shark captured in the northern Gulf of Mexico, off the coast of Pascagoula MS, on 18 May 2006. The simultaneous presence of near term embryos and preovulatory ovarian follicles indicates an annual reproductive cycle.

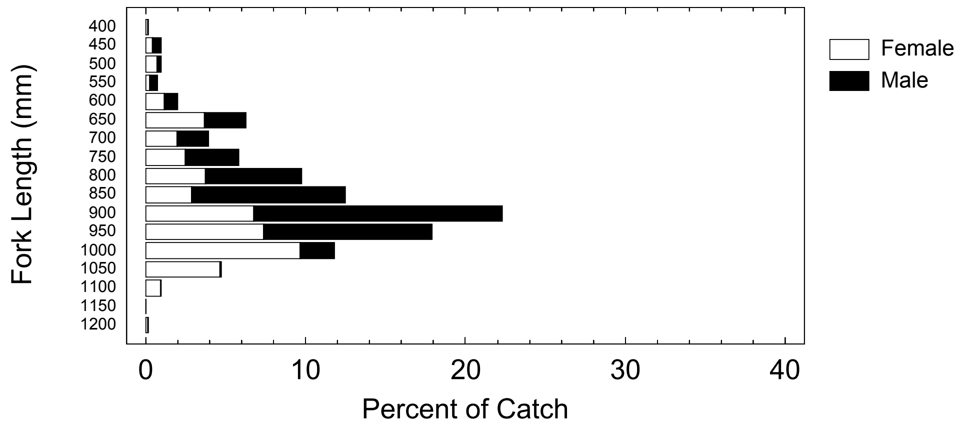

Figure 11. Length frequency distribution of blacknose sharks caught in the northern Gulf of Mexico between 9 and 366 m during NMFS MS Labs bottom longline surveys, 1995-2006 (n = 1236).

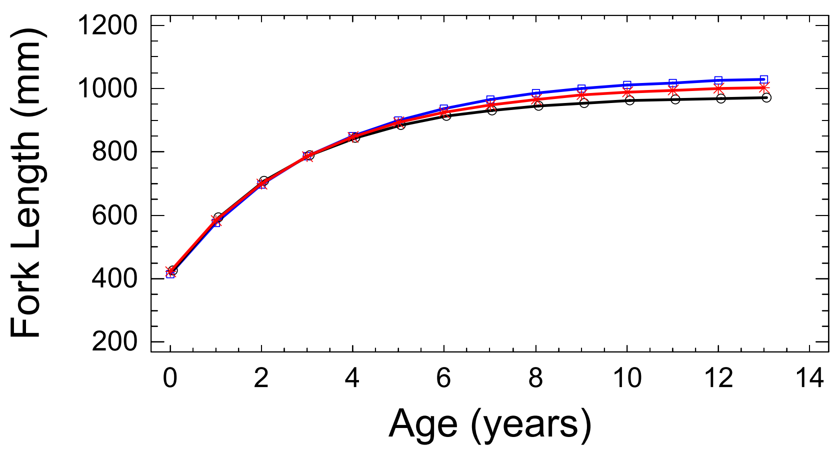

Figure 12. Von Bertalanffy growth models for blacknose sharks in the South Atlantic Bight and the northern Gulf of Mexico resulting from combining the data presented in Driggers et al. (2004a) and Middlemiss et al. (in review). Blue line and squares = female, black line and circles = male and red line and asterisks = sexes combined.

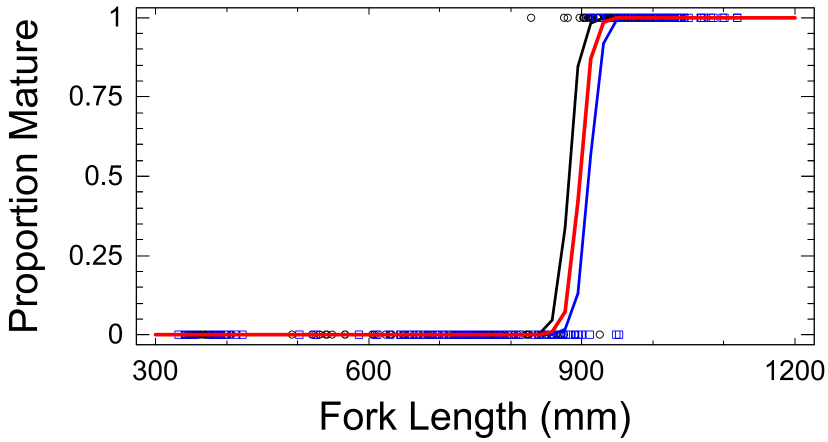

Figure 13. Size at 50% maturity for male, female and sexes combined for blacknose sharks in the South Atlantic Bight and the northern Gulf of Mexico. Blue line and squares = female, black line and circles = male and red line = sexes combined.

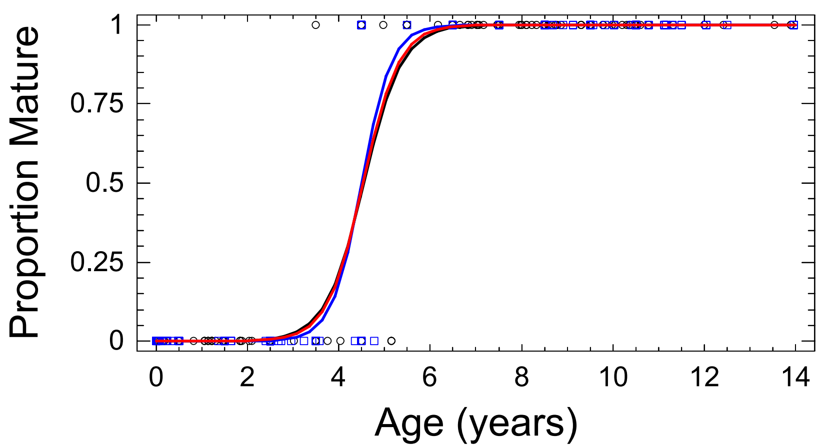

Figure 14. Age at 50% maturity for male female and sexes combined for blacknose sharks in the South Atlantic Bight and the northern Gulf of Mexico. Blue line and squares = female, black line and circles = male and red line = sexes combined.

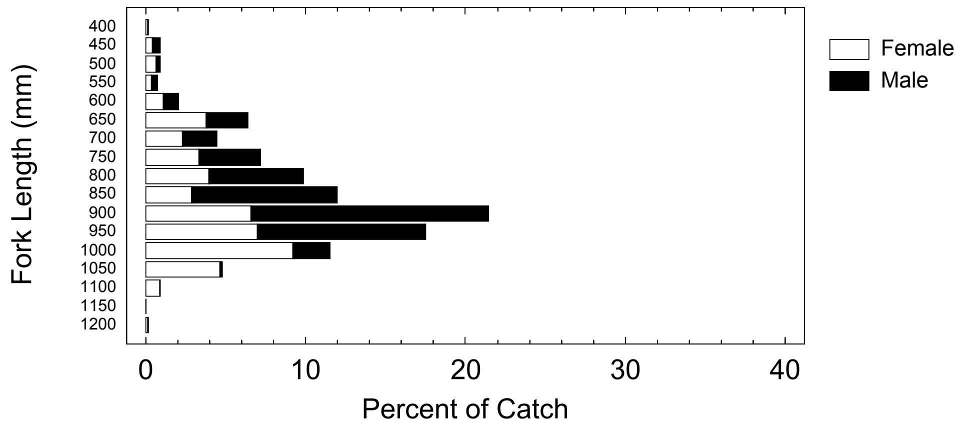

Figure 15. Length frequency distribution of blacknose sharks caught in the South Atlantic Bight and the northern Gulf of Mexico between 9 and 366 m during NMFS MS Labs bottom longline surveys, 1995-2006 (n = 1307).

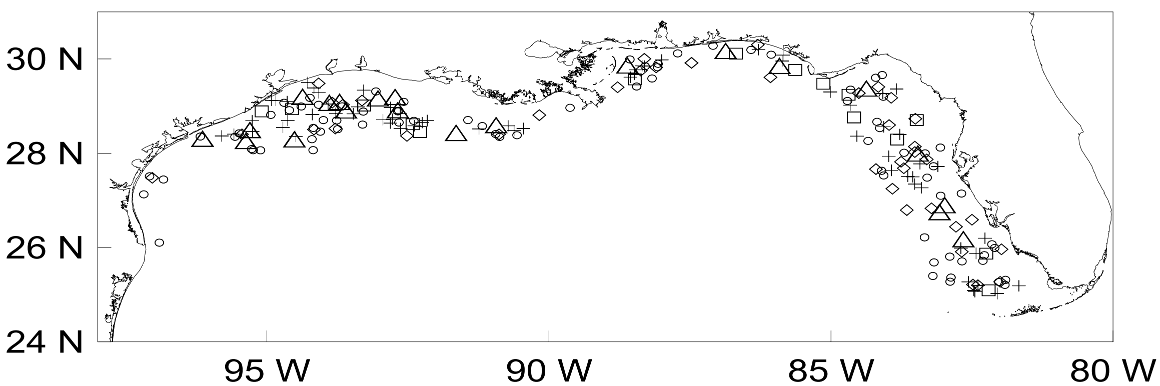

Figure 16: Distribution of blacknose sharks in the northern Gulf of Mexico during August and September based on NMFS Mississippi Laboratories bottom longline survey data, 1996-2003. Symbols indicate the location of non-zero catches with various shapes indicating varying values of CPUE: O= 01.to 1, ◊= 1.1 to 2, Δ= 2.1 to 3, □= 3.1 to 4, + = 4.1 to 34.