Life history and population structure of blacknose sharks, *Carcharhinus acronotus*, in the western North Atlantic Ocean.

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Introduction

Various aspects of the life history of blacknose sharks in both the South Atlantic Bight (SAB) and northern Gulf of Mexico (GOM) have been examined (Carlson, 1999, 2007; Driggers et al., 2004a, 2004 b; Schwartz, 1984, 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 South Atlantic Bight and the northern Gulf of Mexico, compare important life history parameters reported in these studies and examine the population structure of 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 NMFS SEFSC bottom longline surveys 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blacknose sharks in the SAB and GOM, data were compiled from a number of sources (Carlson et al., 1999, 2007; Carlson, unpublished data; Driggers and Quattro, unpublished data; Driggers et al., 2004a, 2004b; Sulikowski et al., 2007; Ulrich et al., 2007). Sex specific length and age data used by Driggers et al. (2004 a) and Carlson et al. (2007) 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 US waters. 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 Carlson et al. (2007). 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.

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) 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.

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, $p < 0.01$).

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 3 and 4). 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 3 and 4). 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 5. 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, $p = 0.02$).

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 (Carlson et al., 2007). 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. 5) and there was a significant difference in the VBGF parameter estimates between the sexes (likelihood ratio = 18.67, $p < 0.01$).

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. 6 and 7; Tables 3 and 4). 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 6. 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 8). There was no significant difference between the size of the mother and the number of pups carried (ANOVA, $p > 0.05$).

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 9) 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, $p < 0.01$).

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 10 and 11; Tables 3 and 4). The predicted proportions of mature sharks by sex, size and age class are listed in Table 7. 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 ($p = 0.77$).

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 8). 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 ($p < 0.01$).

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., 2007; 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).

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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 (Carlson et al., 2007) and combined areas.

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

South Atlantic Bight

FL (mm)	Proportion mature Female	Male	Combined	Age (years)	Proportion mature 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 5. Predicted proportion of mature blacknose sharks by sex, size and age in the South Atlantic Bight.

Northern Gulf of Mexico

FL (mm)	Proportion mature Female	Male	Combined	Age (years)	Proportion mature 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 6. 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 7. 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 8. Haplotype frequencies and distribution between the South Atlantic Bight and the northern Gulf of Mexico based on mtDNA sequence data.

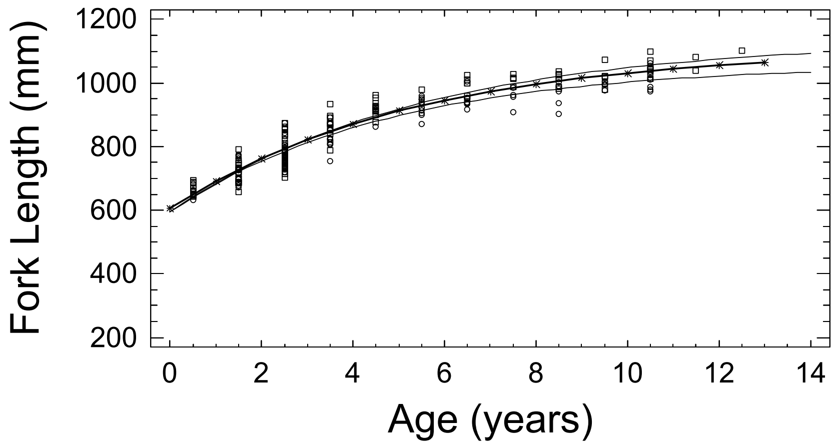

Figure 1. Von Bertalanffy growth models for blacknose sharks in the South Atlantic Bight based on size at capture and visual analyses of vertebral centra (Driggers et al., 2004a). Solid thin line with squares = female, dashed line with circles = male and thick solid line with asterisks = sexes combined.

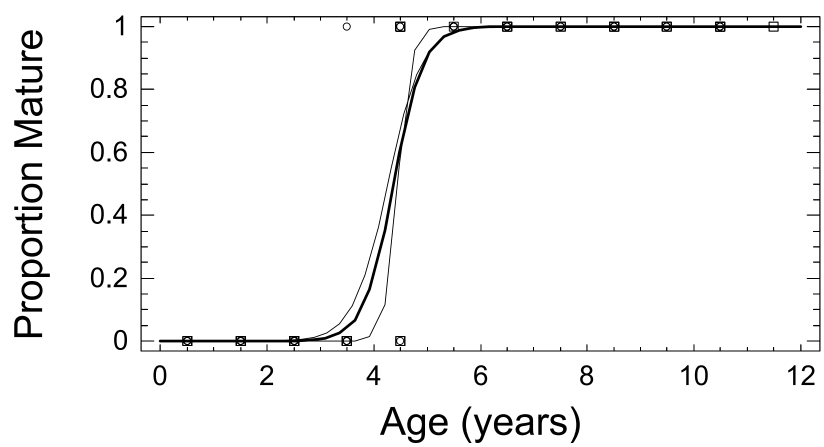

Figure 2. Age at 50% maturity for female, male and sexes combined for blacknose sharks in the South Atlantic Bight. Solid thin line and squares = female, dashed line with circles = male and thick line = sexes combined.

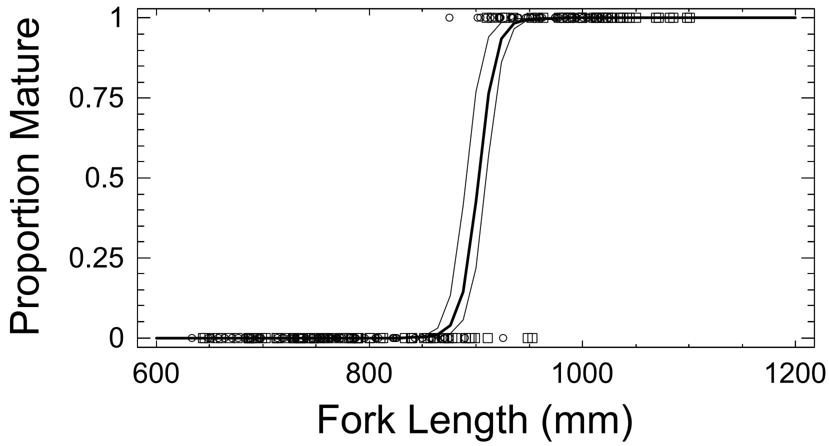

Figure 3. Size at 50% maturity for female, male and sexes combined for blacknose sharks in the South Atlantic Bight. Solid thin line and squares = female, dashed line with circles = male and thick line = sexes combined.

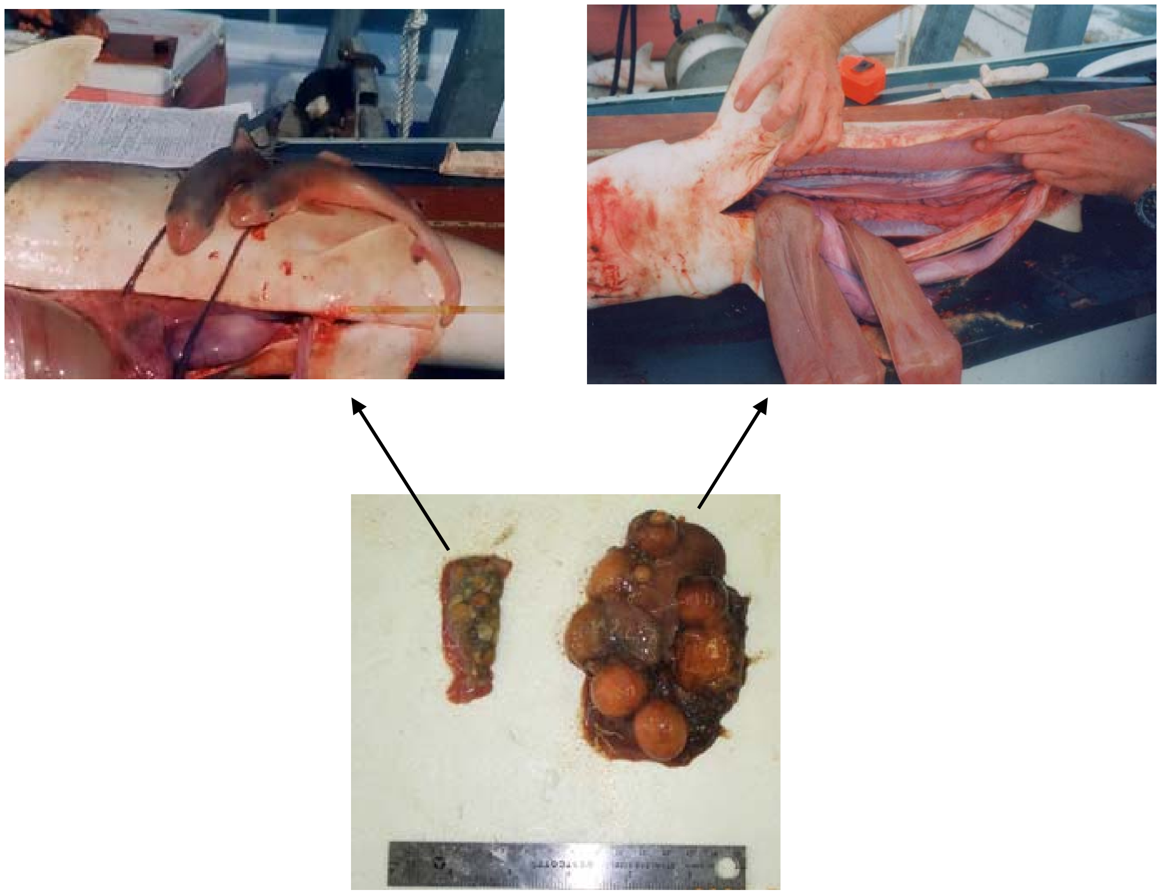

Figure 4. The reproductive systems of two female blacknose sharks caught in the South Atlantic Bight, off the coast of Charleston, SC during May of 1999. The picture in the upper left shows near term embryos removed from the left uteri. The picture on the upper right shows the reproductive tract of a 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.

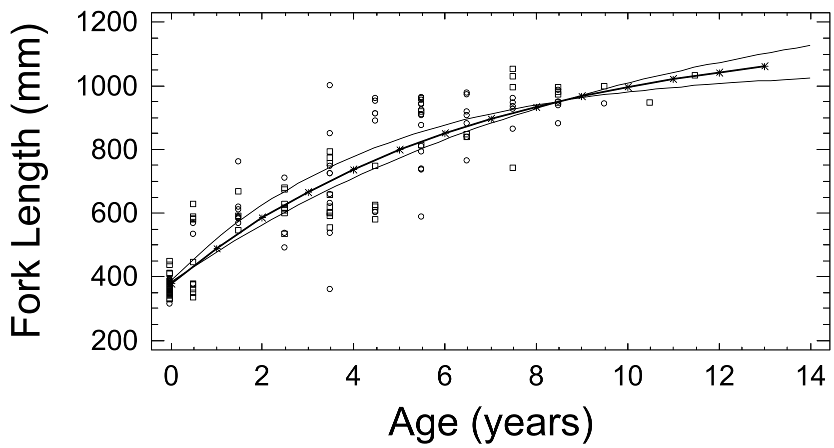

Figure 5. Von Bertalanffy growth models for blacknose sharks in the northern Gulf of Mexico based on size at capture and x-radiography analyses of vertebral centra (Carlson et al. 2007). Solid thin line with squares = female, dashed line with circles = male and thick solid line with asterisks = sexes combined.

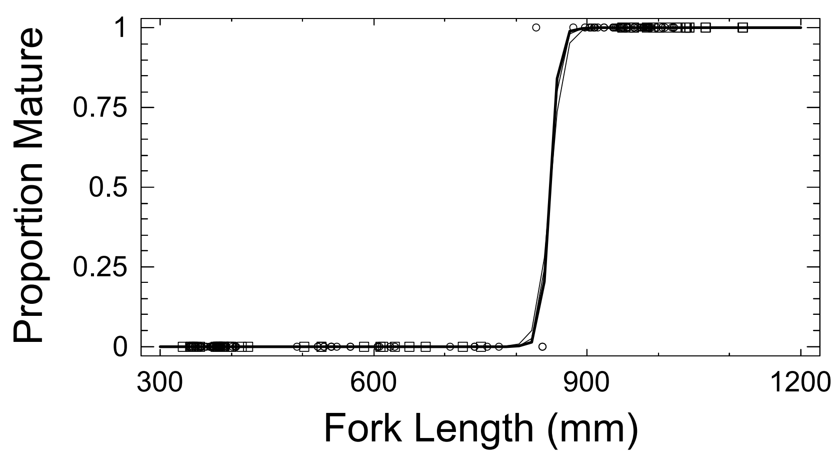

Figure 6. Size at 50% maturity for female, male and sexes combined for blacknose sharks in the northern Gulf of Mexico. Solid thin line and squares = female, dashed line with circles = male and thick line = sexes combined.

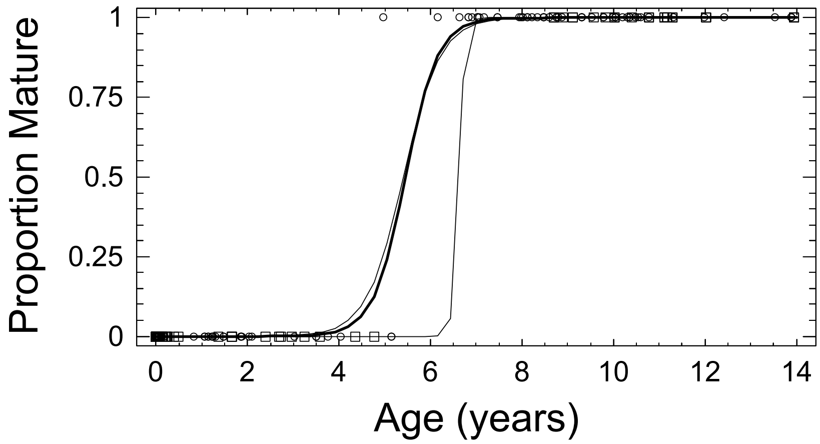

Figure 7. Age at 50% maturity for female, male and sexes combined for blacknose sharks in the northern Gulf of Mexico. Solid thin line and squares = female, dashed line with circles = male and thick line = sexes combined.

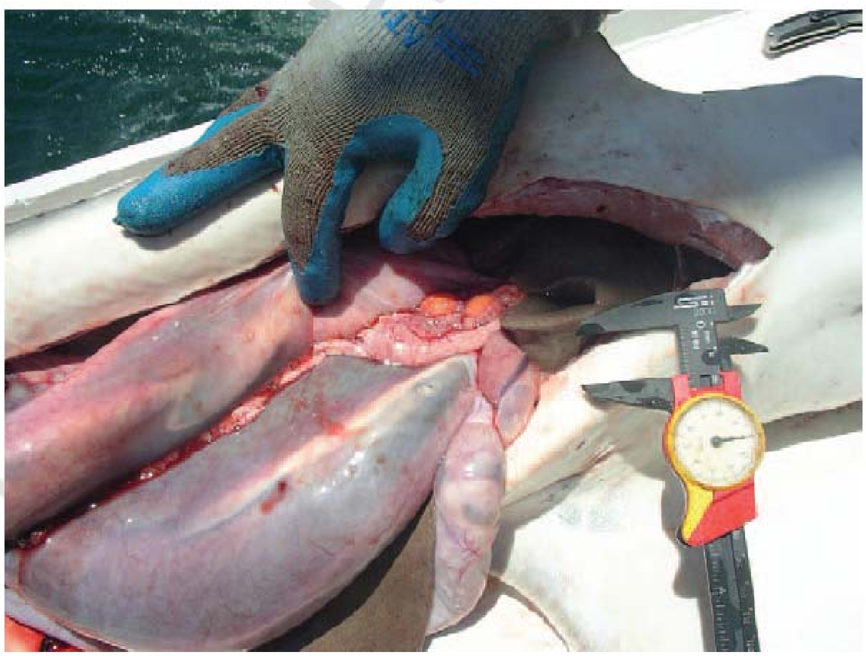

Figure 8. The uteri, embryos and ovary of a female blacknose shark captured in the northern Gulf of Mexico, off the coast of Pascagoula MS, on 18 May 2006. The simultaneous presence of near term embryos and preovulatory ovarian follicles indicates an annual reproductive cycle.

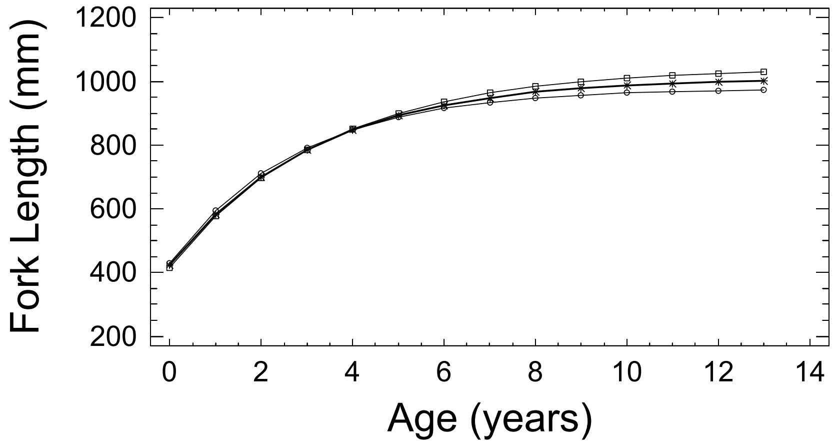

Figure 9. Von Bertalanffy growth models for blacknose sharks in the South Atlantic Bight and the northern Gulf of Mexico resulting from combining the data presented in Driggers et al. (2004a) and Carlson et al. (2007). Solid thin line with squares = female, dashed line with circles = male and thick solid line with asterisks = sexes combined.

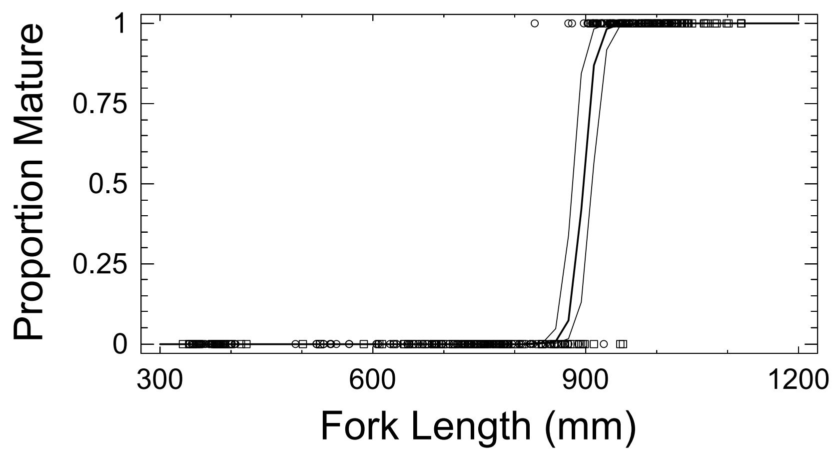

Figure 10. Size at 50% maturity for male, female and sexes combined for blacknose sharks in the South Atlantic Bight and the northern Gulf of Mexico. Solid thin line and squares = female, dashed line with circles = male and thick line = sexes combined.

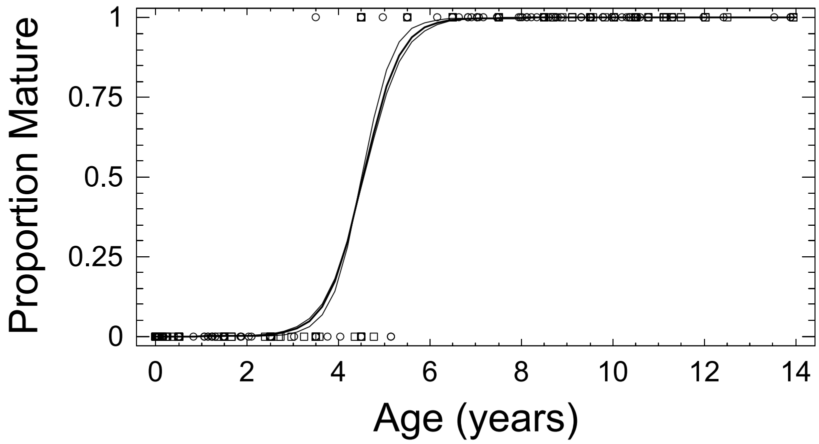

Figure 11. Age at 50% maturity for male female and sexes combined for blacknose sharks in the South Atlantic Bight and the northern Gulf of Mexico. Solid thin line and squares = female, dashed line with circles = male and thick line = sexes combined.