Updates to age and growth parameters for blacktip shark, *Carcharhinus limbatus*, in the Gulf of Mexico

Michelle S. Passerotti and Ivy E. Baremore

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Updates to age and growth parameters for blacktip shark, *Carcharhinus limbatus*, in the Gulf of Mexico

Michelle S. Passerotti

Ivy E. Baremore

NOAA, National Marine Fisheries Service

Southeast Fisheries Science Center

Panama City Laboratory

3500 Delwood Beach Rd

Panama City, FL 32408

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Summary

Age and growth data for 742 blacktip sharks were collected from both fishery-dependent and –independent sources in the Gulf of Mexico between 2006 and 2011. Three-parameter von Bertalanffy growth curves were generated for males (n=350), females (n=392), and both sexes combined. Growth parameters were different between sexes (females: L_∞ = 155.32 ± 2.57 cm FL, k = 0.16 ± 0.01, t_0 = -2.89 ± 0.16; males: L_∞ = 138.55 ± 2.21 cm FL, k = 0.21 ± 0.01, t_0 = -2.63 ± 0.16). Age and growth data from Carlson et al. (2006) were also obtained, and additional growth curves were generated pooling the previous data with that of the current study. This resulted in separate curves for females (n=599; L_∞ = 150.57 ± 1.85 cm FL, k = 0.19 ± 0.01, t_0 = -2.65 ± 0.12) and males (n=511; L_∞ = 138.18 ± 1.89 cm FL, k = 0.21 ± 0.01, t_0 = -2.60 ± 0.13). Log-likelihood ratios indicate parameters for males combined are not significantly different from those presented in Carlson et al. (2006) (χ^2 = 4.92, p = 0.179), whereas parameters for females are significantly different between combined and 2006 data (χ^2 = 8.99, p = 0.029). Maximum ages for the current study were 18.5 (females) and 23.5 (males), and represent an increase of 6 years and 12 years over those observed in Carlson et al. (2006) for females and males, respectively.

Introduction

The blacktip shark, *Carcharhinus limbatus*, is a common coastal species that occupies tropical and sub-tropical waters world-wide (Compagno et al. 2005). In US waters, it ranges from Massachusetts to Florida in the western North Atlantic Ocean and throughout the Gulf of Mexico (McEachran and Fechhelm, 1998). Carlson et al. (2006) previously estimated age and growth parameters for this species in the southeastern US and determined that differences in life history characteristics may exist between stocks from the south Atlantic Ocean and Gulf of Mexico. Additionally, the SEDAR 11 data workshop (NMFS 2006) determined the stocks were indeed different, and that populations should be assessed separately. Final recommendations from SEDAR 11suggested continued work to update life history parameters of all large coastal shark species. Herein, we report revised life history parameters and growth models for blacktip sharks collected 2006-2011 in the US Gulf of Mexico, as well as models combining current data with that previously reported.

Methods

Individuals used in age and growth analyses were collected from both fishery-dependent and –independent sources, including commercial fishing vessels and NMFS gillnet and longline research surveys. Fork length (FL, cm) for each individual was measured at sea, and vertebrae for age estimation were collected from the column either below the first dorsal fin or directly above the branchial chamber. Vertebrae were stored on ice during transit and frozen upon return to the laboratory. During processing, frozen vertebrae were thawed and cleaned of excess tissue, then soaked in a solution of 5% hypochlorite for up to 30 minutes to remove remaining tissue. Cleaned vertebrae were stored in 95% isopropanol. One vertebra was randomly selected, removed from alcohol and allowed to dry before sectioning with a Bueller isomet saw. Sections were taken longitudinally at a thickness of 0.6mm. One half of each section was stained with crystal violet, and both halves were dried before mounting to a glass microscope with Cytoseal mounting medium.

Ages were estimated independently and randomly by two readers viewing digital images of sections obtained using transmitted light on a Meiji Techno dissecting microscope equipped with a Hitachi KP-D50 digital camera. Vertebrae for which agers were in disagreement were viewed concurrently and counts made until a consensus could be reached. Vertebrae for which no consensus could be reached were discarded from analysis.

Criteria used for ageing followed that of Carlson et al. (2006), and all age estimates were based on the hypothesis of annual growth band deposition (Branstetter 1987, Killam and Parsons 1989). Ages were calculated as band count – 1.5. Estimates of reader precision were calculated using percent agreement (PA = (# agreed / # read)*100) and PA ± 1year (Caillet and Goldman 2004, Goldman 2004). Bowker's test of symmetry (Hoenig et al. 1995) was used to evaluate reader bias. The Index of Average Percent Error (Beamish and Fournier 1981) was calculated to assess between-reader error:

$$\text{IAPE} = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{|x_{ij}-x_j|}{x_j}\right]$$

where N = number of sharks aged; R = number of readings; x_{ij} = i_{th} age estimation of j_{th} shark at i_{th} reading, and x_j = mean age calculated for the j_{th} shark.

Growth parameters for the current study were estimated for males, females, and all sharks combined using the von Bertalanffy growth model (vBGF; von Bertalanffy 1938, Beverton and Holt 1957) fitted to age at length data:

$$L_t = L_\infty(1-e^{-k(t-t_o)})$$

where L_t = mean fork length at time t; L_∞ = theoretical asymptotic length; k = growth coefficient; and t_o = theoretical age at zero length. χ^2 tests of likelihood ratios (Kimura 1980) were used to test for differences in vBGFs between sexes. Additionally, χ^2 tests of likelihood ratios were used to test for differences between sex-specific vBGFs from Carlson et al. (2006) and those from the current study. Although there were significant differences between the two studies ($p<0.001$ for both males and females), these are likely driven by the large increase in maximum observed age for both sexes in the current study over the previous one. Further, when data from the two studies are combined, growth parameters generated for males are not significantly different from those of the previous study ($p=0.178$), and those of females are only slightly significantly different ($p=0.029$). Thus, we also calculated vBGF's for both sexes individually as well as sexes combined with pooled data from both studies. Goodness of fit for growth models was evaluated by examining the residual sums of squares and the Akaike Information Criterion (AIC) (Goldman 2004; Carlson & Baremore 2005). All model parameters were estimated using a least-squares non-linear regression in R (R Development Core Team 2010). The results from the current study, Carlson et al. (2006) data, and from the pooled data analyses are presented.

Results

Age and growth analysis for the current study utilized 742 blacktip sharks (females = 392, males = 350) ranging in size from 40cm FL – 161cm FL (Fig. 1A). A map of sampling locations can be found in Baremore and Passerotti (2012). Maximum ages were estimated as 18.5 years for females and 23.5 years for males (Fig. 2A). Overall APE was low (7.66%) and PA and PA ± 1 between readers was moderate (51.9% and 84.1%, respectively). Bowker's test of symmetry did indicate some bias between readers ($\chi^2 = 116.1$, df = 52, $p<0.005$), but bias plots showed error to be fairly symmetric with age (unpublished). Pooled data yielded analysis of 1110 individuals (females = 599, males = 511) within the same size (Fig. 1B) and age (Fig. 2B) ranges.

Calculated growth parameters are listed in Table 1. Likelihood ratios indicated that growth parameters differed between sexes in the current study ($\chi^2 = 81.5$, df = 3, $p<0.005$), thus separate curves were plotted for females and males (Fig. 3). Growth parameters were also different between sexes when utilizing pooled data from Carlson et al. (2006) and the current study ($\chi^2 = 113.8$, df = 3, $p<0.005$)(Fig. 4). The vBGF's estimated for the current study fit the data slightly better than the ones estimated for pooled data, as evidenced by the AIC and residual sums of squares (Table 1).

Discussion

This work was done to better describe the age and growth of blacktip sharks in the Gulf of Mexico, in an effort to fulfill research recommendations set forth by SEDAR 11 (NMFS 2006). Overall, the current study data present an improvement in sample size and age range over the previous study. The vBGF's generated for the current study reflect an increase in estimates of L_∞ and decreases in k and t_0 estimates from those presented for blacktips in the Gulf of Mexico by Carlson et al. (2006), and are closer to those of blacktip sharks from the South Atlantic Bight in the same study (females: $L_\infty = 158.5 \pm 5.71$ cm FL, $k = 0.16 \pm 0.02$, $t_0 = -3.43 \pm 0.50$; males: $L_\infty = 147.4 \pm 2.60$ cm FL, $k = 0.21 \pm 0.02$, $t_0 = -2.58 \pm 0.24$), although the data were not directly compared.

As was the case with the previous data, L_∞ values for both current and pooled data were lower than the maximum observed size (161 cm). This was likely due to the majority of large sharks being in the 120-150 cm range. Given that no difference was detected between pooled and current parameters for males, and only a slight difference detected between pooled and current parameters for females, utilizing pooled data as a way to form a more comprehensive data set for the Gulf of Mexico may warrant consideration. Additional information on age at maturity and reproductive parameters utilizing these data can be found in Baremore and Passerotti (2012).

Bias between readers was indicated in the current study, and is likely due to several factors. Readers estimated ages from images as opposed to direct viewing, aged from separate locations such that periodic intercalibration of band counts was difficult to perform, and aged over a protracted time span. However, most of the bias came from small misinterpretations that were extrapolated through all ages, and final counts were easily agreed upon by both readers. Thus, we feel the study was not negatively impacted by the presence of bias.

Acknowledgements

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Literature Cited

Baremore, I.E., and Passerotti, M.S. 2012. Reproduction of the blacktip shark *Carcharhinus limbatus* in the Gulf of Mexico. SEDAR-29-WP-09.

Beamish, R.J., and D.A. Fournier. 1981. A method for comparing the precision of a set of age determinations. Canadian Journal of Fisheries and Aquatic Sciences. 38:982-983.

Beverton, R.J.H., and Holt, S.J. 1957. On the dynamics of exploited fish populations. Ministry of Agriculture. Fisheries and Food Fishery Investigation Series II XIX. 533 pp.

Branstetter, S. 1987. Age and growth estimates for the blacktip, *Carcharhinus limbatus*, and spinner, *C. brevipinna*, sharks from the northwestern Gulf of Mexico. Copeia 4:964-974.

Cailliet, G., and Goldman, K. 2004. Age determination and validation in chondrichthyan fishes. In: Biology of sharks and their relatives. (J. Carrier, J. Musick and M. Heithaus, eds). CRC Press, San Diego. p. 399-447.

Carlson, J. K. & Baremore, I. E. 2005. Growth dynamics of the spinner shark (*Carcharhinus brevipinna*) off the United States southeast and Gulf of Mexico coasts: a comparison of methods. Fishery Bulletin 103, 280–291.

Carlson, J. K., Sulikowski J. A., and Baremore I. E. 2006. Do differences in life history exist for blacktip sharks, *Carcharhinus limbatus*, from the United States South Atlantic Bight and Eastern Gulf of Mexico? Environ. Biol. Fishes 77:279-292.

Compagno, L. J. V., Dando M., and Fowler S. L. 2005. A field guide to the sharks of the world, Harper Collins.

Goldman, K. 2004. Age and growth. *In* Elasmobranch fisheries management techniques (J. Musick and R. Bonfil eds.), APEC Fisheries Working Group. p. 97- 132.

Hoenig, J., Morgan, M., and Brown, C. 1995. Analyzing differences between two age determination methods by tests of symmetry. Canadian Journal of Fisheries and Aquatic Sciences 52: 364-368.

Killam, K. A., and Parsons G. K. 1989. Age and growth of the blacktip shark, *Carcharhinus limbatus*, near Tampa Bay, Florida. Fish Bull 87:845-857.

Kimura, D. 1980. Likelihood methods for the von Bertalanffy growth curve. Fishery Bulletin 77(4): 765-773.

McEachran, J. D., and Fechhelm J. D. 1998. Fishes of the Gulf of Mexico, University of Texas Press, Austin, TX.

NMFS (2006). Stock assessment report: Large coastal shark complex, blacktip and sandbar shark. In *SEDAR 11*. Silver Spring, MD: NOAA.

R Development Core Team 2010. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

von Bertalanffy, L. 1938. A quantitative theory of organic growth (inquiries on growth laws. II). Human Biology 10:181-213.

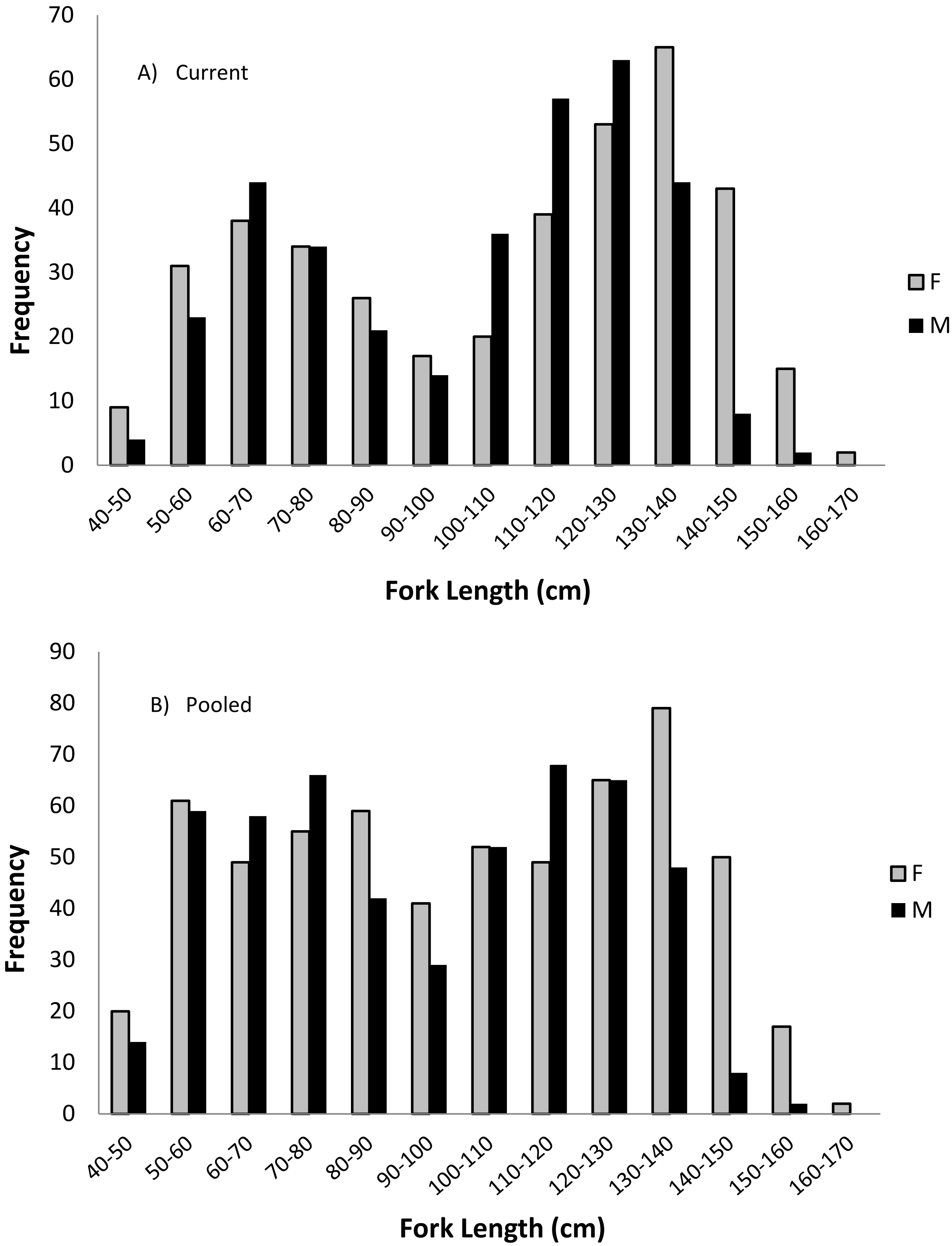
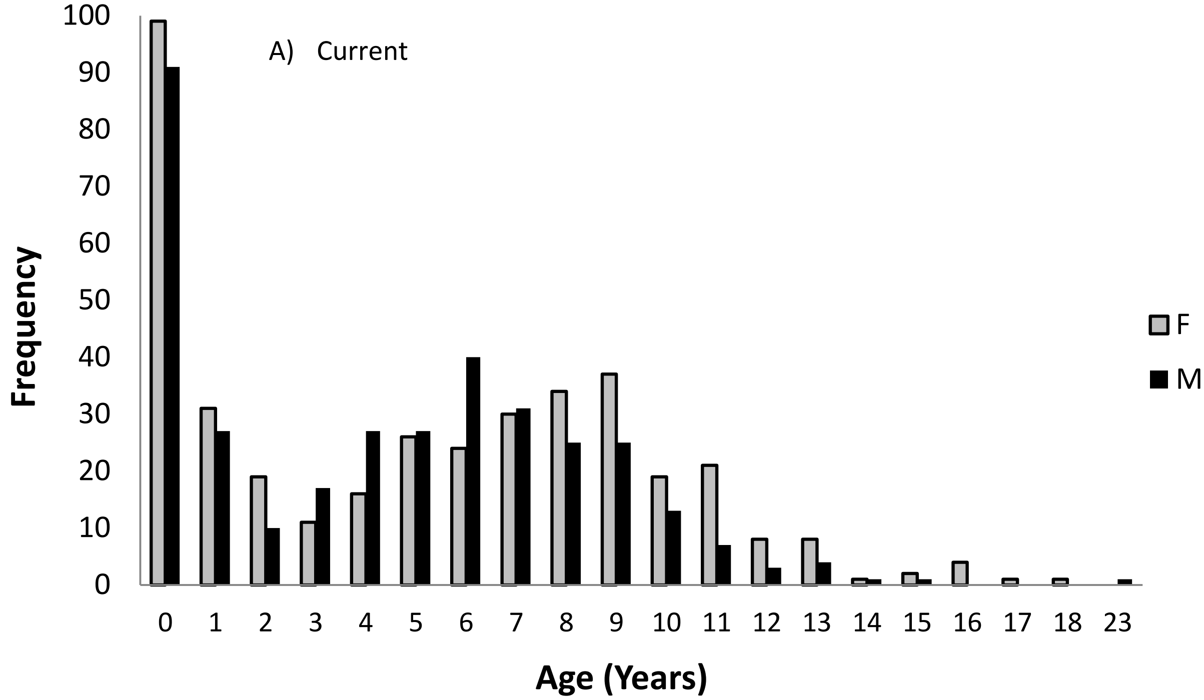


Figure 1. Size frequency (cm FL) by sex of blacktip sharks from current (A, n=742 total, males=350, females=392) and pooled (B, n=1110 total, males=511, females=599) analyses.



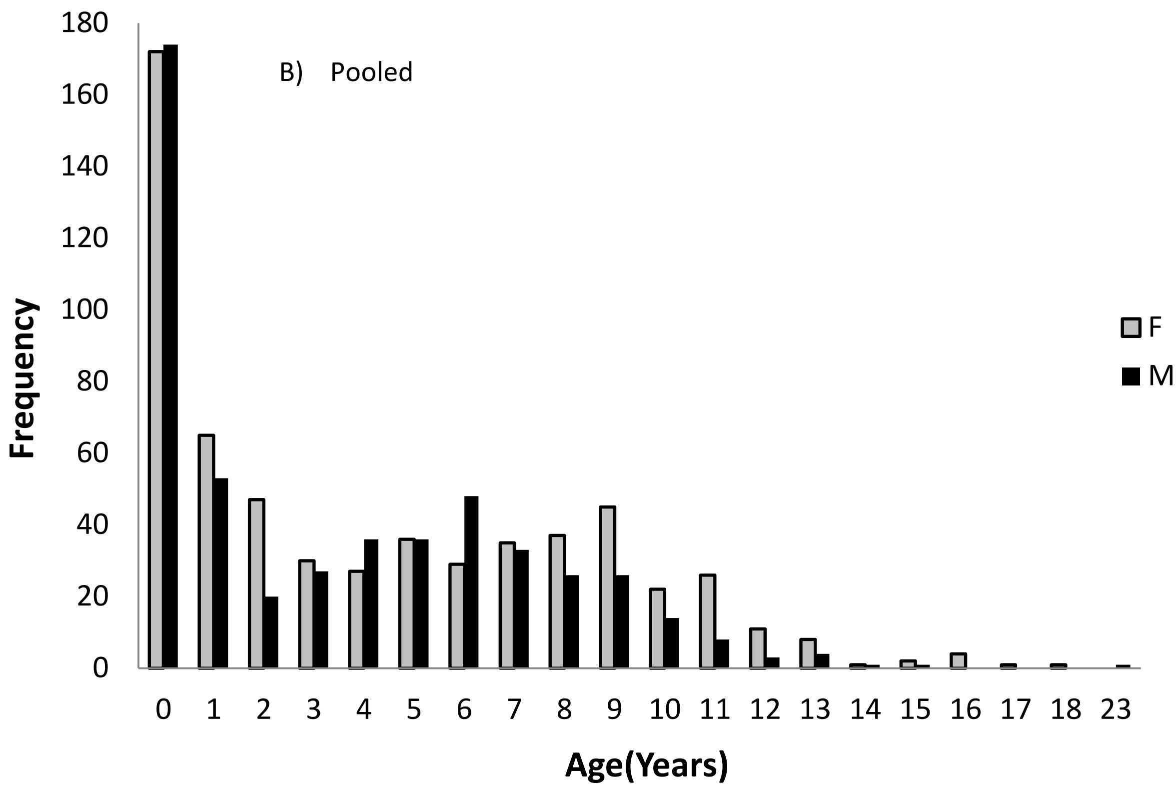
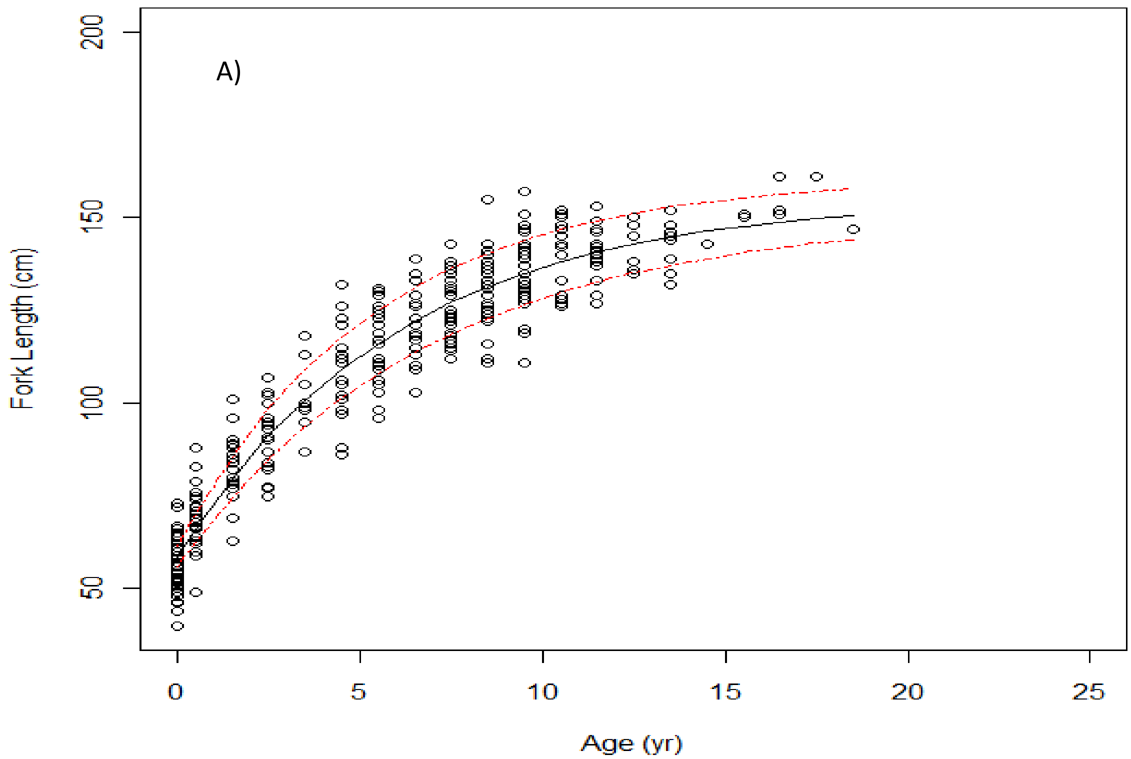


Figure 2. Age frequency (years) by sex of blacktip sharks from current (A, n=742 total, males=350, females=392) and pooled (B, n=1110 total, males=511, females=599) analyses.



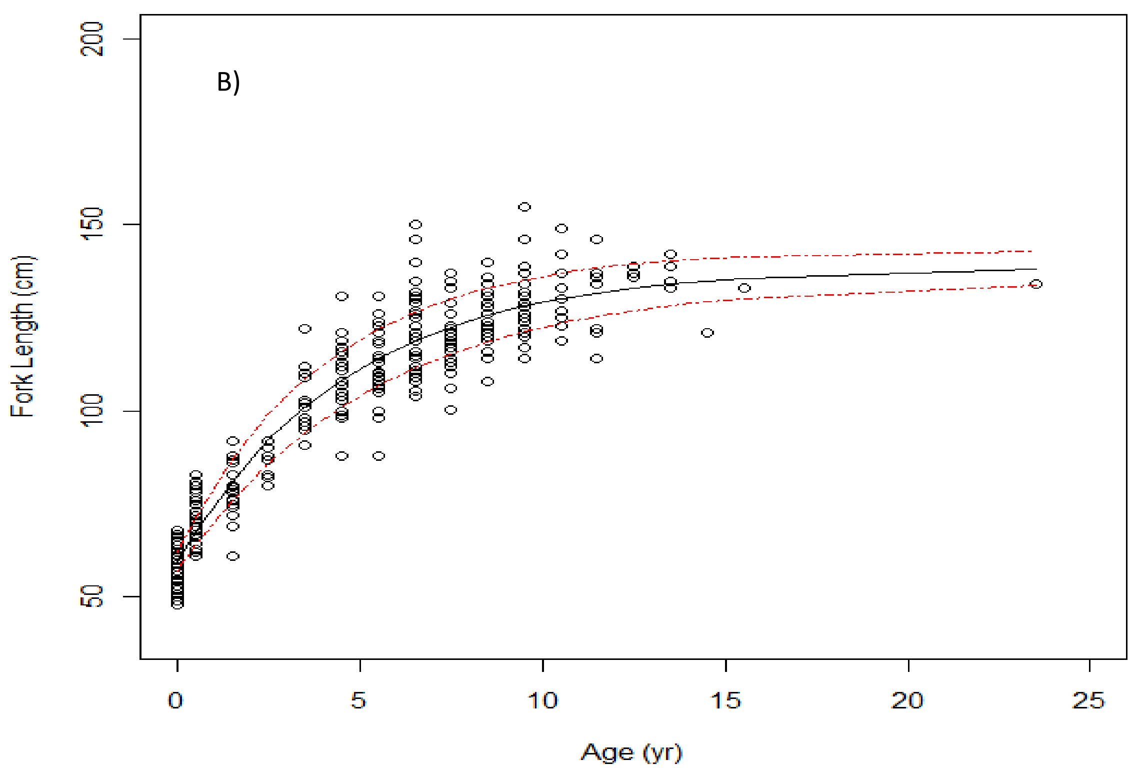
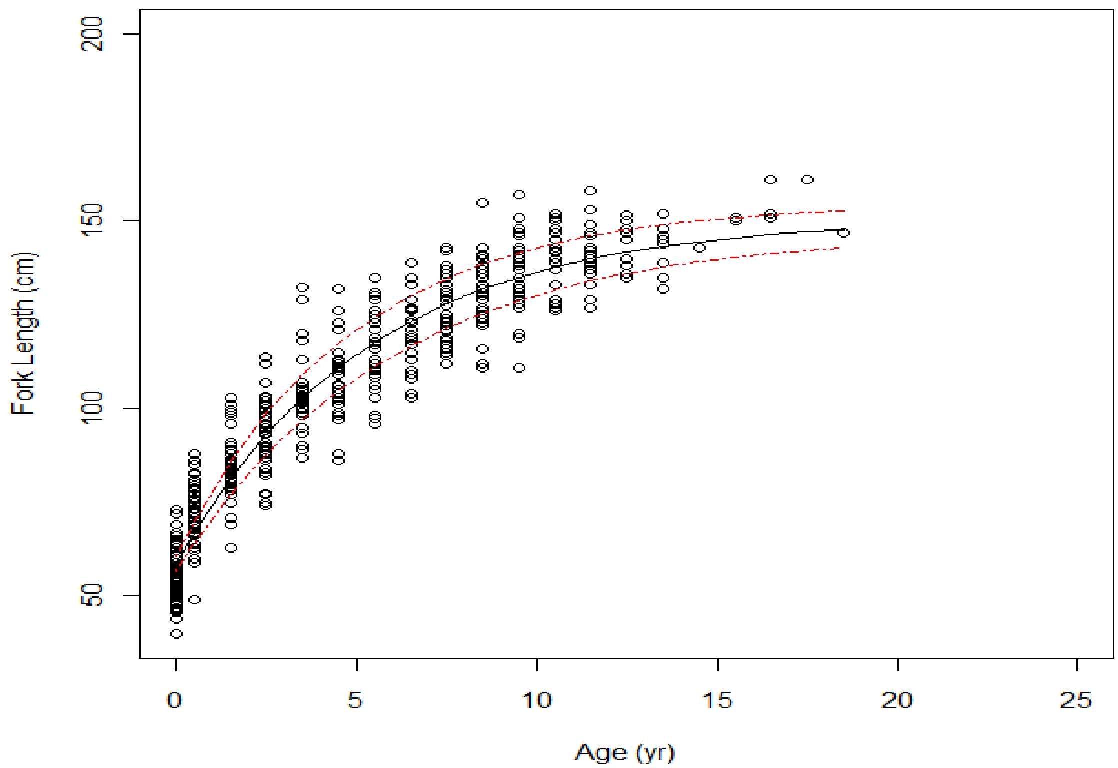


Figure 3. von Bertalanffy growth curves for female (A, n=392) and male (B, n=350) blacktip sharks in current study, with 95% confidence intervals in red.



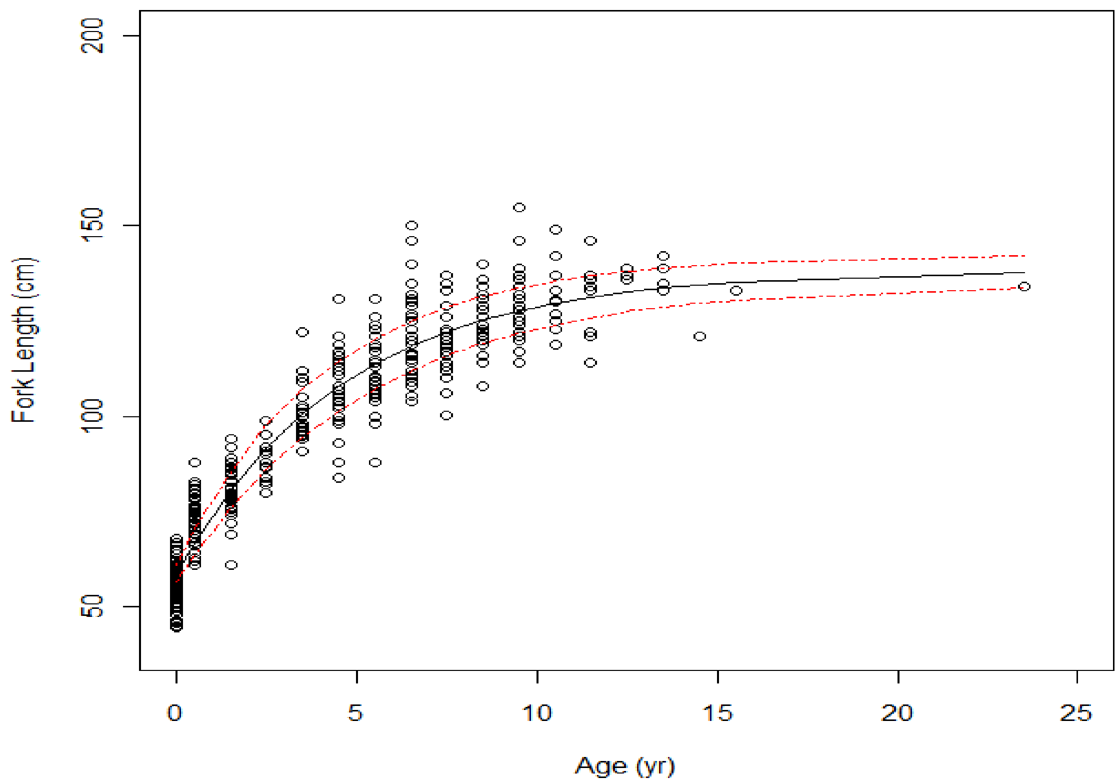


Figure 4. von Bertalanffy growth curves for female (A, n=599) and male (B, n=511) blacktip sharks, current study and Carlson et al. (2006) data pooled, with 95% confidence intervals in red.

Table 1. von Bertalanffy growth curve parameters estimated for the blacktip shark (fork length in cm).

Study	Sex	Sample Size	L∞ (± SE)	k (± SE)	t_0 (± SE)	AIC	Residual sums of squares
Carlson et al. 2006	F	207	141.60 ± 2.99	0.240 ± 0.02	-2.18 ± 0.16	--	--
Carlson et al. 2006	M	161	126.00 ± 3.50	0.270 ± 0.02	-2.21 ± 0.18	--	--
Carlson et al. 2006	Combined	368	139.40 ± 2.61	0.230 ± 0.01	-2.33 ± 0.13	--	--
Current study	F	392	155.32 ± 2.57	0.164 ± 0.01	-2.89 ± 0.16	2782.75	27223
Current study	M	350	138.55 ± 2.21	0.213 ± 0.01	-2.63 ± 0.16	2474.24	23540
Current study	Combined	742	149.80 ± 1.89	0.174 ± 0.01	-2.90 ± 0.12	5301.56	54483
Current & Carlson et al. Combined	F	599	150.57 ± 1.85	0.187 ± 0.01	-2.65 ± 0.12	4283.28	43674
Current & Carlson et al. Combined	M	511	138.18 ± 1.89	0.214 ± 0.01	-2.60 ± 0.13	3558.128	31129
Current & Carlson et al. Combined	Combined	1110	147.18 ± 1.46	0.187 ± 0.01	-2.74 ± 0.09	7907.26	79633