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Age and growth of the great hammerhead, *Sphyrna mokarran*, in the western North Atlantic Ocean.

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Great hammerhead, *Sphyrna mokarran*, vertebrae were collected from various sources, including museum archives, fishery observer programs, and fisheries-independent surveys, to examine the age and growth of the species. Vertebrae and associated length information were obtained from 388 great hammerheads, including 204 females, 179 males and five individuals of unknown sex. Female sharks ranged in size from 42-357 cm fork length (FL) and males ranged in size from 40-297 cm FL (Figure 1). We received vertebrae stored in various manners (e.g. dry, submerged in ethanol, frozen and uncleaned). Individual vertebrae remained stored in their original state unless they had not been previously cleaned. In the latter case, all tissue were removed using a scalpel followed by soaking in a sodium hypochlorite solution (common household bleach) to remove remaining peripheral tissue prior to vertebrae being stored in 95% ethanol.

As the current study was an update to growth models presented in Piercy et al. (2010), we employed the identical ageing methods described in that study with the exception that no stain (i.e. crystal violet) was used to elucidate growth bands as bands were readily visible in non-stained vertebra (Figure 2). Briefly, 0.6 mm sagittal sections were removed from vertebrae using a low-speed saw and viewed under a dissecting microscope at magnifications ranging from 7-20X. We subtracted one from the total band count to account for the birthmark and assumed subsequent translucent bands were formed once a year, as validated by Passerotti et al. (2010). Marginal increment analysis conducted by Piercy et al. (2010) and a visual comparison of distal growth on the corpus calcareum of specimens caught throughout the year further supported the assumption and indicated translucent growth bands were deposited during the late spring/early summer (Figure 3). In all cases, when the birthmark was visible it was in association with a noticeable angle change on the corpus calcareum in proximity to the

focus, therefore, the angle change was considered to indicate the first growth band regardless if the birthmark was visible or not.

Band counts were similar between two independent readers with 84% of counts in agreement. In those cases when counts differed (96% of counts within one year and 100% of counts within 2 years) consensus was reached on all samples aged. Precision for inter-reader index of average percentage error (IAPE) was 0.92% and the coefficient of variation (CV) was 1.30%, lower than the typically acceptable level for ageing studies (5.5% IAPE and 7.6% CV, Campana, 2001). Age-bias plots for readings were symmetrical ($\chi^2 = 0.58$, $p = 0.50$) indicating that there was no systematic bias between readers (Figure 4).

Three parameter von Bertalanffy growth models were fitted to age and length data from both sexes and sexes combined using parameters reported by Piercy et al. (2010: Table 1) as initial estimates. As expected, females had a higher asymptotic length and lower growth constant than males (Figures 5, 6 and 7) and there was a significant difference among VBGF parameter estimates for male and female great hammerheads ($\chi^2 = 113.21$, $p < 0.01$). The maximum observed ages for females and males were 35 years and 38 years, respectively. These maximum observed ages were lower than those found by Piercy et al. (2010) who reported maximum observed ages of 44 years for females and 42 years for males. Theoretical maximum longevity for females and males from the current study were 31.5 years and 17.3 years, respectively. Theoretical longevity estimates from the Piercy et al. (2010) were 31.4 years for females and 21.6 years for males.

Literature cited:

Campana, S. E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59: 197–242.

Passerotti, M.S., Carlson, J.K., Piercy, A.N. and Campana, S.E. 2010. Age validation of great hammerhead shark (*Sphyrna mokarran*), determined by bomb radiocarbon analysis. Fishery Bulletin 108: 346-351.

Piercy, A.N., Carlson, J.K and Passerotti, M.S. 2010. Age and growth of the great hammerhead shark, *Sphyrna mokarran*, in the north-western Atlantic Ocean and Gulf of Mexico. Marine and Freshwater Research 61: 992-998.

Study	Sex	L_∞ (cm)	k	t_o (year)	n
Piercy et al. 2010	Male	264.2 (5.61)	0.16 (0.01)	-1.99 (0.20)	111
	Female	307.8 (11.23)	0.11 (0.01)	-2.86 (0.44)	105
	Combined	286.9 (5.99)	0.13 (0.01)	-2.51 (0.15)	216
Current	Male	249.4 (3.36)	0.20 (0.01)	-1.37 (0.14)	179
	Female	323.9 (7.49)	0.11 (0.01)	-2.06 (0.20)	204
	Combined	283.8 (3.96)	0.15 (0.01)	-1.72 (0.14)	388

Table 1. von Bertalanffy growth model parameter estimate for the current study and Piercy et al. (2010) for great hammerheads, *Sphyrna mokarran*, in the western North Atlantic Ocean. L_∞ = theoretical maximum size (cm fork length), k = growth constant, and t_o = theoretical age at length zero.

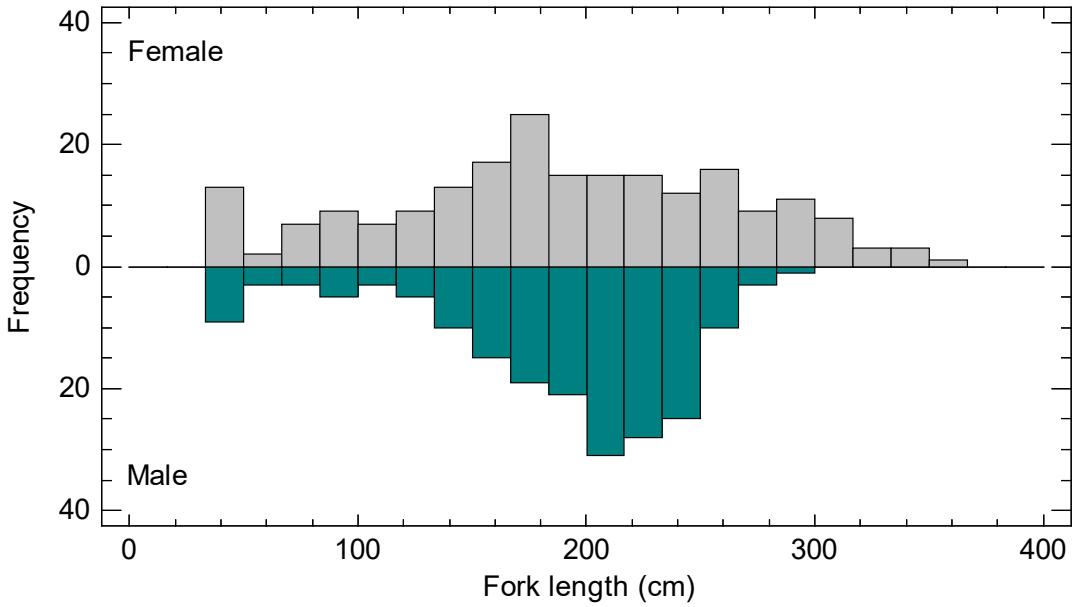


Figure 1: Length distribution of female (gray bars) and male (green bars) great hammerheads, *Sphyrna mokarran*, that were aged using vertebral centra during this study.

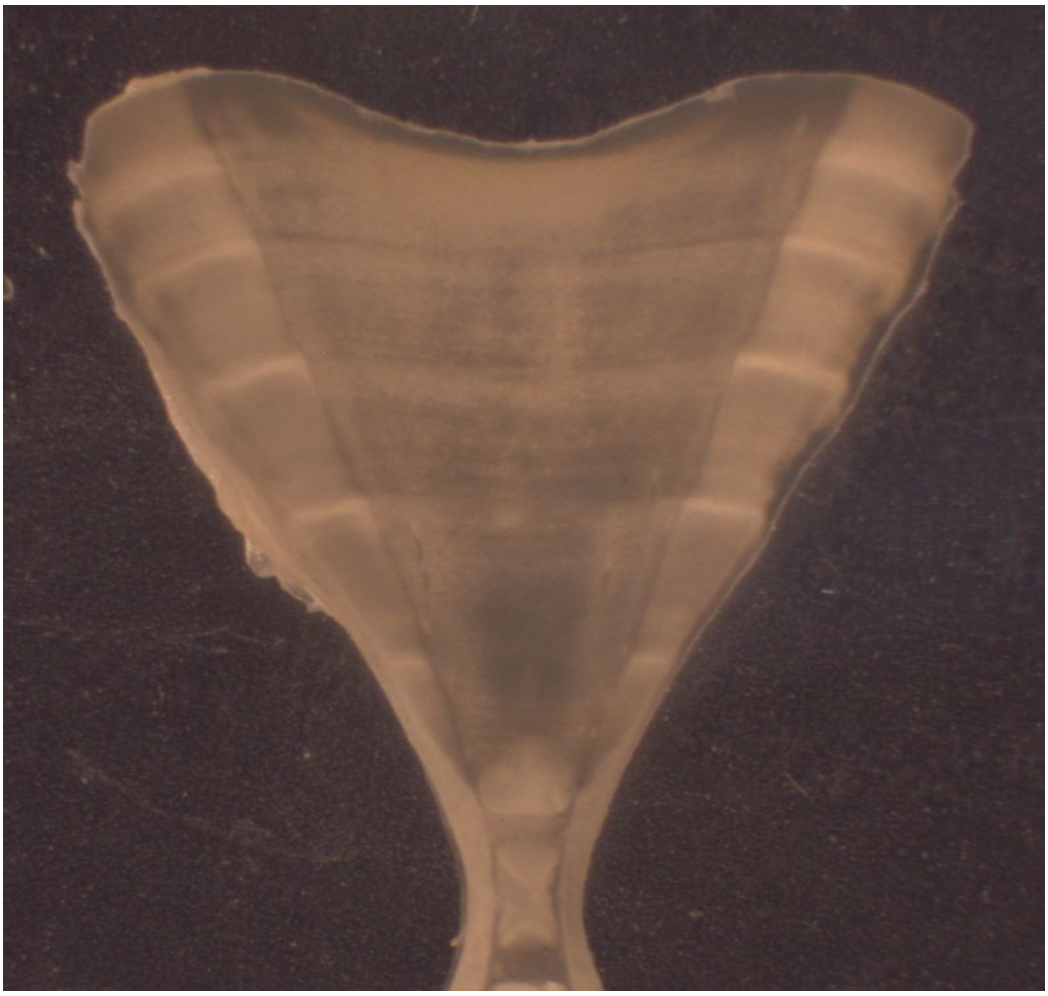


Figure 2. Sectioned vertebra with five growth bands from a 152 cm fork length, male great hammerhead, *Sphyrna mokarran*.

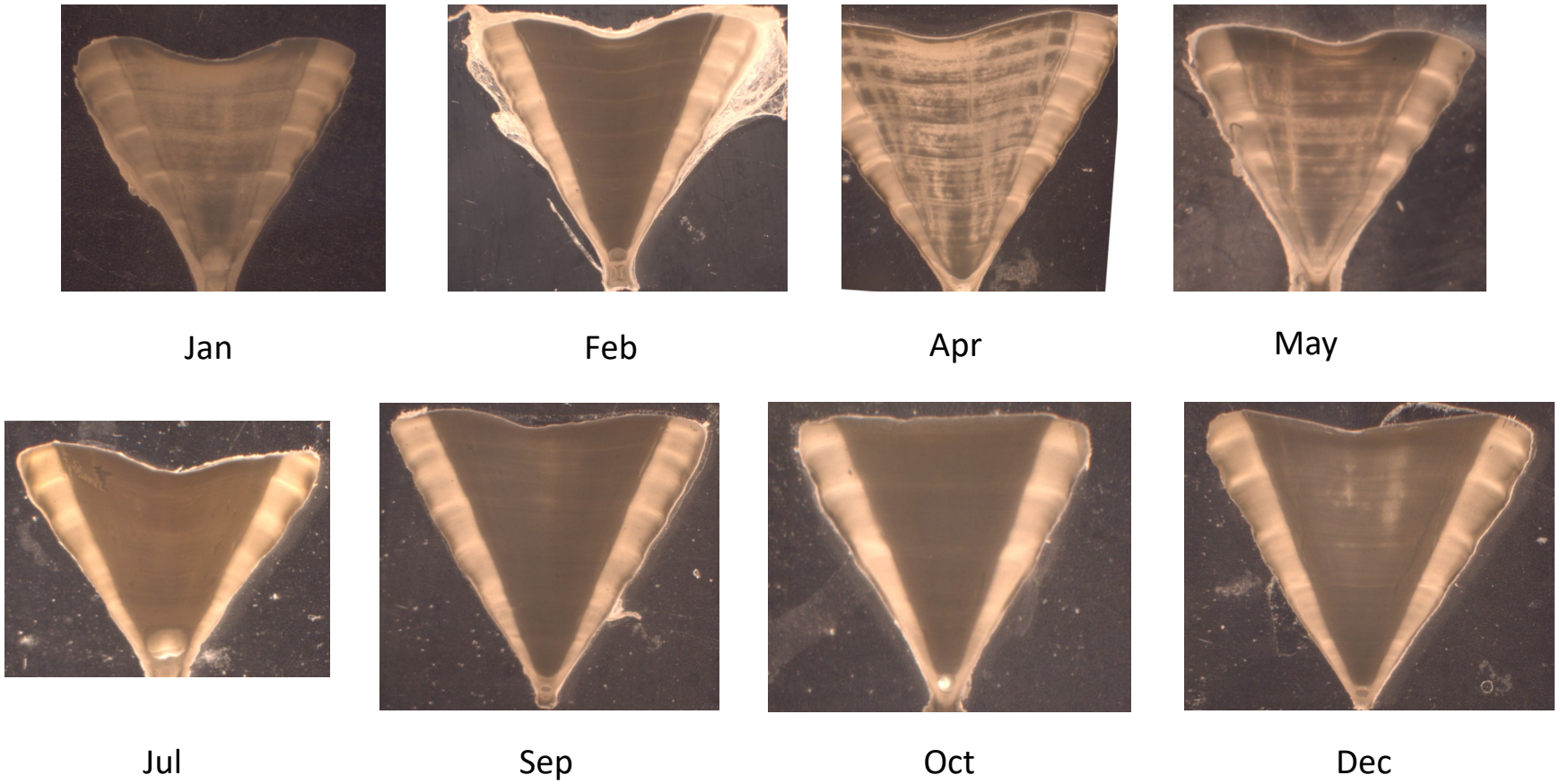


Figure 3. Vertebral centra from great hammerheads, *Sphyrna mokarran*, collected during various months of the year demonstrating translucent (light) growth band deposition during late spring to early summer.

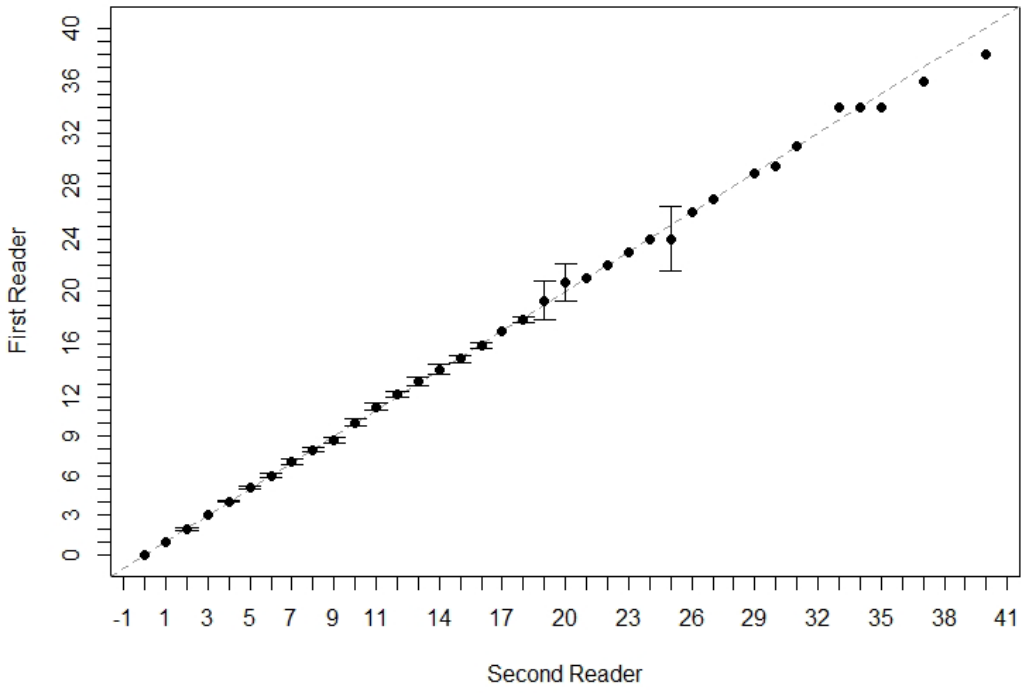


Figure 4. Age bias plot for age estimates generated in the current study from great hammerheads, *Sphyrna mokarran*, collected in the western North Atlantic Ocean. Error bars represent the 95% confidence interval.

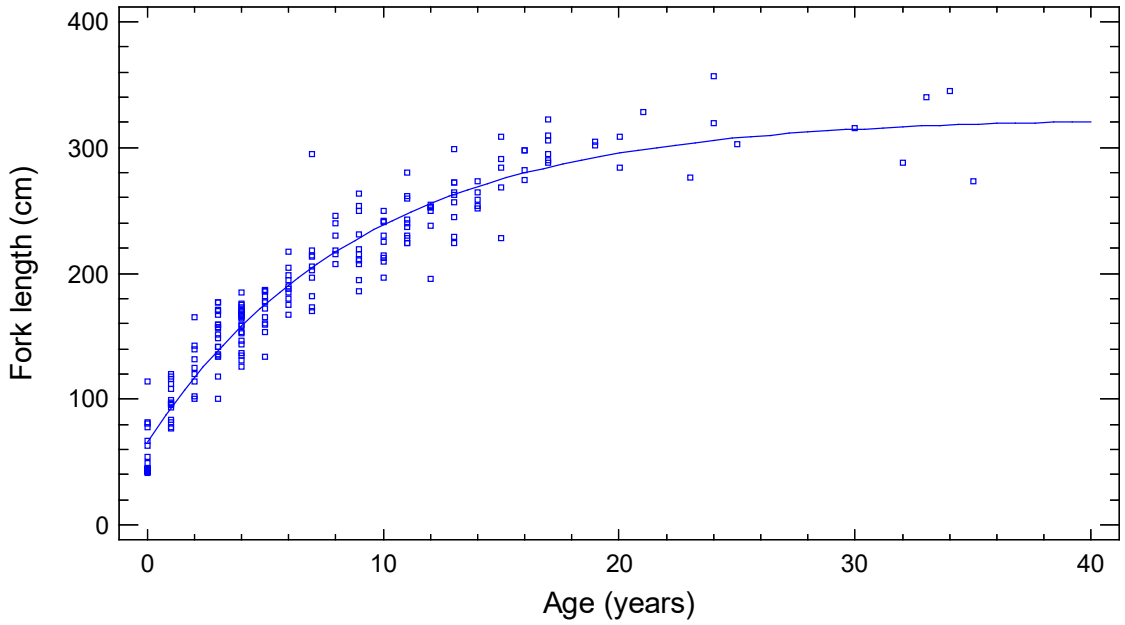
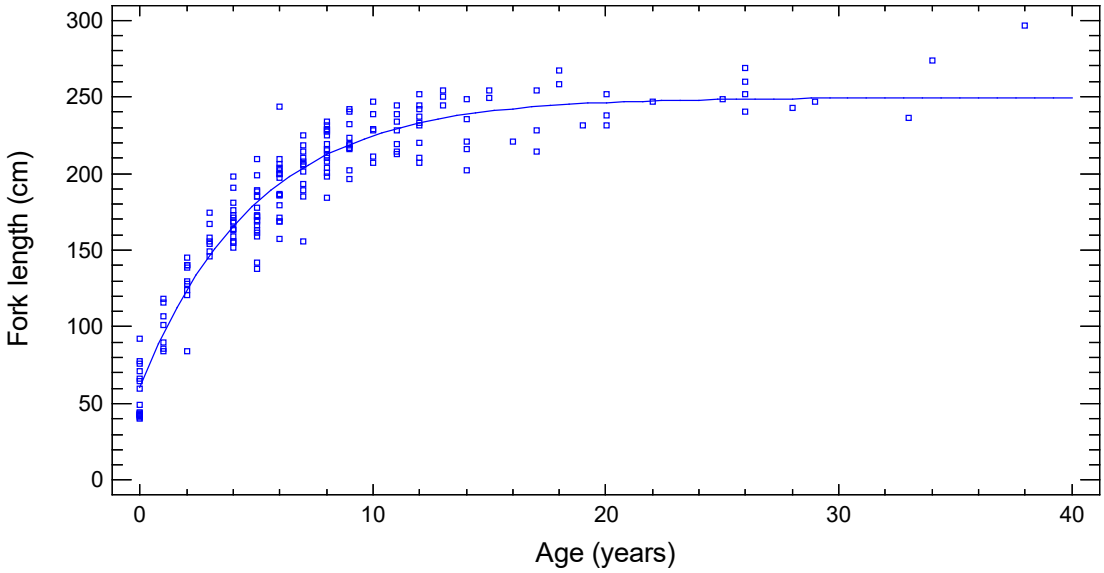
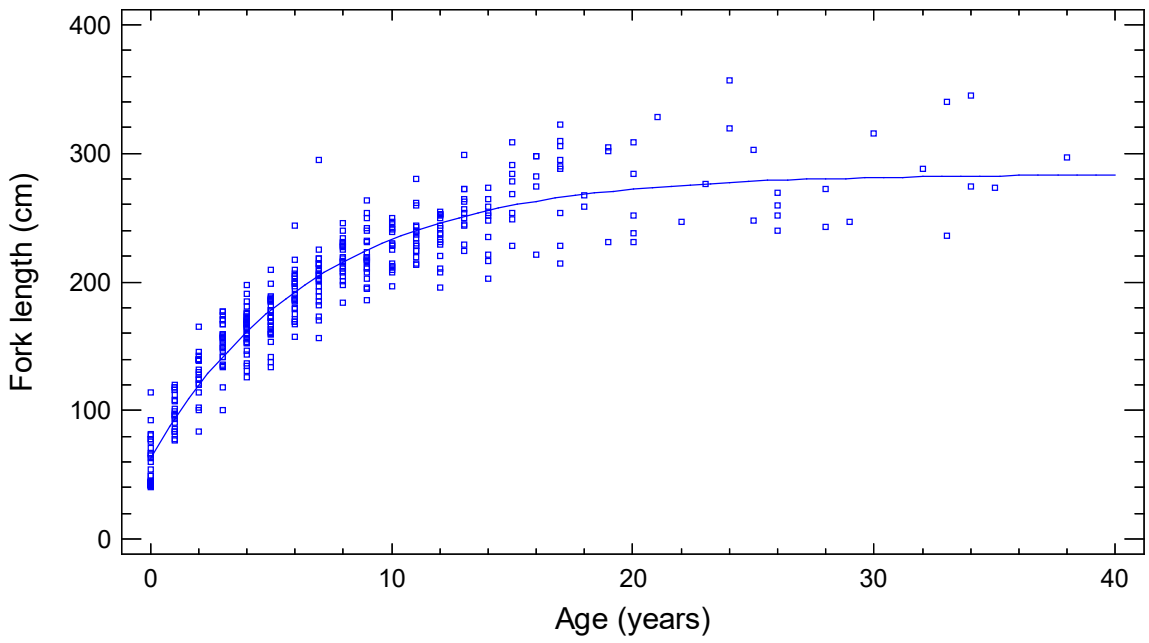


Figure 5. von Bertalanffy growth model for female great hammerheads, *Sphyrna mokarran*, in the western North Atlantic Ocean from the current study (n = 204, L_∞ = 323.9, k = 0.11, t_o = -2.06).




Fork length (cm)
400
300
200
100
0
0
10
20
30
40
Age (years)