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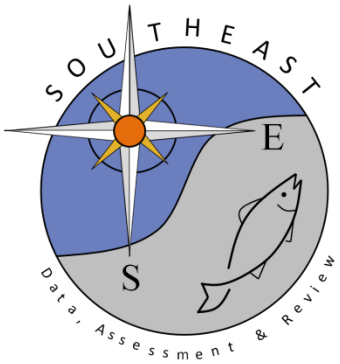
SEDAR54-WP-01

8 MAY 2017



Please cite this document as:

Driggers III, W.B., Bryan S. Frazier, John K. Carlson, Bethany M. Deacy, Michael P. Enzenauer and Andrew N. Piercy. Updated life history parameters for sandbar sharks, *Carcharhinus plumbeus*. SEDAR54-WP-01. SEDAR, North Charleston, SC. 11 pp.

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SEDAR54-DW-01

2 May 2017

Updated life history parameters for sandbar sharks, *Carcharhinus plumbeus.*

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Introduction:

During the Data Evaluation Workshop for SEDAR 21 in 2010 (sandbar, dusky and blacknose sharks), four working papers were submitted that provided life history information that would, in part, ultimately be used as model inputs (Baremore and Hale, 2010; Hale and Baremore, 2010; Piercy 2010; Romine and Musick, 2010). Since that time, three of the studies were published in peer-reviewed journals (Baremore and Hale, 2012; Hale and Baremore, 2013; Piercy et al. 2016). Since 2010, additional information regarding the growth rates and maximum longevity of sandbar sharks in the western North Atlantic Ocean has become available. The purpose of this document is to summarize new findings and provide updated life history information for SEDAR 54.

Methods and Results:

New data includes additional age at length information, collected as part of NOAA Fisheries Service-Shark Research Fishery and the Panama City Laboratory Observer Program (Enzenauer et al. 2015 and references therein), and longevity estimates, based on tag-recapture information presented in Andrews et al. (2011). Additionally, data from Baremore and Hale (2012), Hale and Baremore (2013), and Piercy et al. (2016) were obtained and utilized as outlined below.

Age and Growth:

Von Bertalanffy Growth Function (VBGF) parameter estimates from Hale and Baremore (2013) and updated data are summarized in Table 1. Vertebral samples and sex-specific length data from both sources were primarily collected by observers aboard commercial vessels with additional data obtained through fishery-independent sources. During the SEDAR 54 Data Scoping Conference Call in February 2017, it was decided that data from Hale and Baremore (2013) should be combined with the updated data as the latter lacked samples from smaller size classes. Sex-specific and combined sexes VBGF parameter estimates from the resulting combined data are presented in Tables 2, 3 and 4 and Figures 1, 2 and 3.

Updated maximum age estimate:

The maximum observed age utilized in SEDAR 21 was 27 years based on growth increment counts reported by Hale and Baremore (2010, 2013). However, Andrews et al. (2011) reported a recapture of a sandbar shark after 27.7 years at liberty. The value of 27.7 years was provided within the text of Andrews et al. (2011), however, within Table 3 of the same paper that value was reported as 27.8 years at liberty. The authors reported that the last three digits of the tag were worn away and not legible. However, other legible numbers indicated the recaptured shark was one of 10 sharks, which ranged in size from 99-122 cm fork length (FL) when tagged. Using the VBGF parameter estimates presented in Casey et al. (1985), Andrews et al. (2011) estimated the age of the shark at capture/tagging ranged from 5-8 years. During the SEDAR 54 Data Scoping Conference Call in February 2017 we were asked to estimate time at tagging based on updated VBGF parameter estimates using the combined Hale and Baremore (2013) and updated datasets. As the sex of the shark reported in Andrews et al. (2011) was unknown, the age at tagging estimates and maximum age (=backtransformed age at tagging + 27.7 years) are provided in Table 5 for combined sexes, females and males, separately. This was done for the low and high FL values of the shark reported by Andrews et al. (2011).

Age at tagging ranged from 3.3 years (combined sexes VBGF for 99 cm FL individual) to 6.1 years (male VBGF for 122 cm FL individual). Corresponding age estimates after the 27.7 years at liberty were 31.0 years and 33.8 years. If the shark was assumed to be a female then the maximum age would be estimated as 31.1 to 33.7 years. Since the sex of the shark was unknown, we felt it most prudent to use the combined sexes VBGF parameter estimates and smallest FL at tagging and consider the maximum age to be 31.0 years.

Updated size at maturity estimates:

Criteria for assessing maturity and samples protocols are described in Baremore and Hale (2012) and Piercy et al. (2016). Datasets for these two independent studies were analyzed to produce estimates of length at 50% maturity (L_{50}) and 95% confidence intervals around those estimates. Additionally, datasets were combined to produce a combined L_{50} and 95% confidence intervals. To determine FL (L_{50}) at which 50% of the population was considered mature, a logistic model $Y=1/1(e^{-(a+bx)})$ was fitted to binomial maturity data using nonlinear least squares regression, where 0=immature, and 1=mature. Median L_{50} at maturity was determined by $-a/b$ (Mollet *et al.* 2002). Confidence intervals were generated by bootstrapping (5,000 samples).

The number of samples by sex, study and combined studies as well as estimates of L_{50}, model parameter estimates and associated 95% confidence intervals are reported in Table 6. Sandbar sharks in the Piercy et al. (2016) study matured at smaller lengths and 95% C.I.s for study specific L_{50} did not overlap. The smallest mature female for the combined dataset was 135 cm fork length (FL) and the largest immature shark was 182 cm FL. The smallest mature male was 124 cm FL and the largest immature shark was 175 cm FL. The predicted proportion mature by size and sex from the combined datasets is reported in Table 7. The logistic models using the combined dataset predicted 50% of females mature at 152.8 cm FL (Figure 4) and 50% of males mature at 142.8 cm FL (Figure 5).

Reproductive parameters:

There were no new data that suggested any update was warranted in sex ratio of embryos (1:1), pupping month (June), relationship between maternal FL and brood size (Brood size = 0.0634FL-2.173) or reproductive periodicity (2.5 years).

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	Hale and Baremore (2013)		Updated data		
	Female	Male	Female	Male	Combined
n	701	493	1197	503	1702
L_∞ (cm FL)	181.2	172.9	177.8	164.8	175.1
k	0.12	0.15	0.14	0.21	0.15
t_0 (years)	-3.1	-2.3	-3.1	-0.9	-2.7
Max observed age (years)	27	22	23	20	23

Table 1. von Bertalanffy growth parameter estimates used for SEDAR 21 (Hale and Baremore 2013) and updated data.

			Asymptotic	*95.0%*
		Asymptotic	*Confidence*	*Interval*
Parameter	*Estimate*	*Standard Error*	*Lower*	*Upper*
L_∞ (cm FL)	181.081	0.75108	179.609	182.554
k	0.128816	0.00251389	0.123889	0.133743
t_0 (years)	-2.83978	0.112514	-3.06031	-2.61926

Table 2. VBGF parameter estimates for combined sexes sandbar sharks based on combining data from Hale and Baremore (2013) and updated data (n = 2896, r^2 = 0.82).

			Asymptotic	*95.0%*
		Asymptotic	*Confidence*	*Interval*
Parameter	*Estimate*	*Standard Error*	*Lower*	*Upper*
L_∞ (cm FL)	175.531	0.980064	173.61	177.451
k	0.142625	0.00376923	0.135238	0.150013
t_0 (years)	-2.38807	0.13291	-2.64857	-2.12757

Table 3. VBGF parameter estimates for male sandbar sharks based on combining data from Hale and Baremore (2013) and updated data (n = 996, r^2 = 0.87).

			Asymptotic	*95.0%*
		Asymptotic	*Confidence*	*Interval*
Parameter	*Estimate*	*Standard Error*	*Lower*	*Upper*
L_∞ (cm FL)	183.322	1.01656	181.33	185.315
k	0.123685	0.00327444	0.117267	0.130103
t_0 (years)	-3.09851	0.162953	-3.4179	-2.77913

Table 4. VBGF parameter estimates for female sandbar sharks based on combining data from Hale and Baremore (2013) and updated data (n = 1898, r^2 = 0.79).

FL at tagging	Age (years) at tagging		
	Female	Male	Sexes combined
99 cm FL	3.4	3.5	3.3
122 cm FL	6.0	6.1	5.8

FL at tagging	Age (years) after 27.7 years at liberty		
	Female	Male	Sexes combined
99 cm FL	31.1	31.2	31.0
122 cm FL	33.7	33.8	33.5

Table 5. Backtransformed age at tagging and recapture for sandbar sharks reported in Andrews et al. (2011) using VBGF estimates from combined Hale and Baremore (2013) and updated data.

Study	Sex	n	FL range (cm)	L_{50} (cm)	95 C.I.	*a*	95 C.I.	*b*	95 C.I.
Piercy et al. 2016	F	383	113-187	148.9	(147.0, 150.7)	-28.0	(-35.5, -22.7)	0.187	(0.153, 0.237)
	M	1086	69-202	139.9	(138.8, 140.9)	-23.3	(-26.1, -20.7)	0.166	(0.149, 0.187)
Baremore and Hale 2012	F	658	48-202	154.9	(153.9, 155.9)	-36.6	(-43.3, -31.4)	0.236	(0.203, 0.280)
	M	449	39-178	151.6	(150.5, 152.6)	-43.4	(54.3, -35.9)	0.286	(0.237, 0.358)
Combined	F	1041	48-202	152.8	(151.9, 153.7)	-32.3	(-37.1, -28.5)	0.211	(0.187, 0.242)
	M	1535	39-202	142.8	(141.9, 143.7)	-21.7	(-24.1, -19.7)	0.152	(0.138, 0.168)

Table 6. Logistic analysis of size at maturity (cm fork length) by sex, study and studies combined for sandbar sharks.

Proportion Mature		
FL (mm)	Female	Male
30		0.00
40	0.00	0.00
50	0.00	0.00
60	0.00	0.00
70	0.00	0.00
80	0.00	0.00
90	0.00	0.00
100	0.00	0.00
110	0.00	0.05
120	0.00	0.27
130	0.05	0.54
140	0.14	0.85
150	0.61	0.98
160	0.90	0.98
170	0.99	1.00
180	0.95	1.00
190	1.00	1.00
200	1.00	1.00

Table 7. Maturity schedule using combined data from Baremore and Hale (2012) and Piercy et al. (2016).

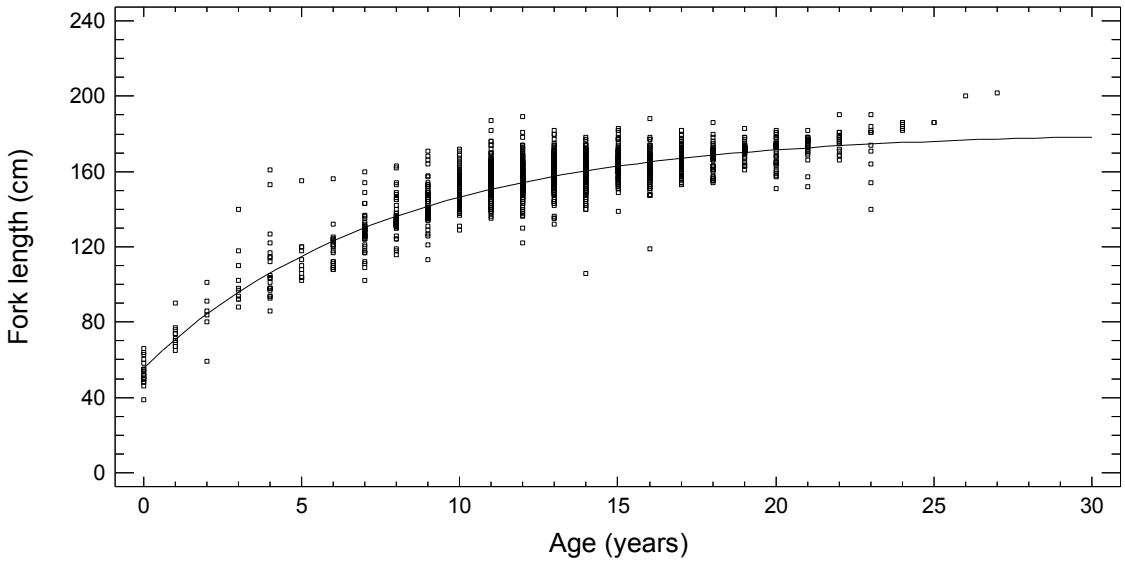

Figure 1. von Bertalanffy growth curve for combined sexes sandbar sharks based on data from Hale and Baremore (2013) and updated data.

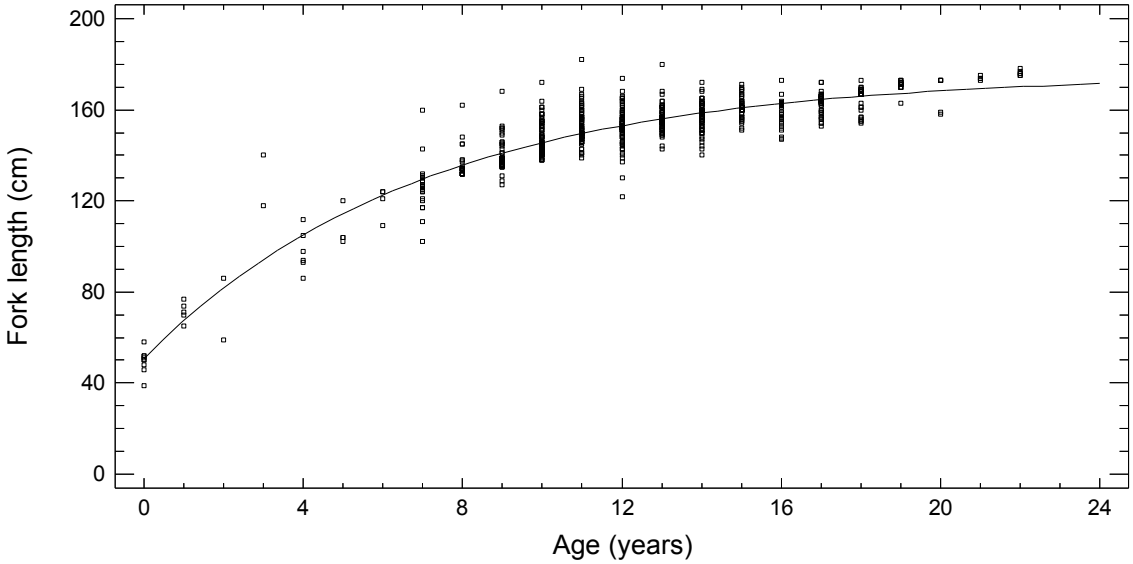

Figure 2. von Bertalanffy growth curve for male sandbar sharks based on data from Hale and Baremore (2013) and updated data.

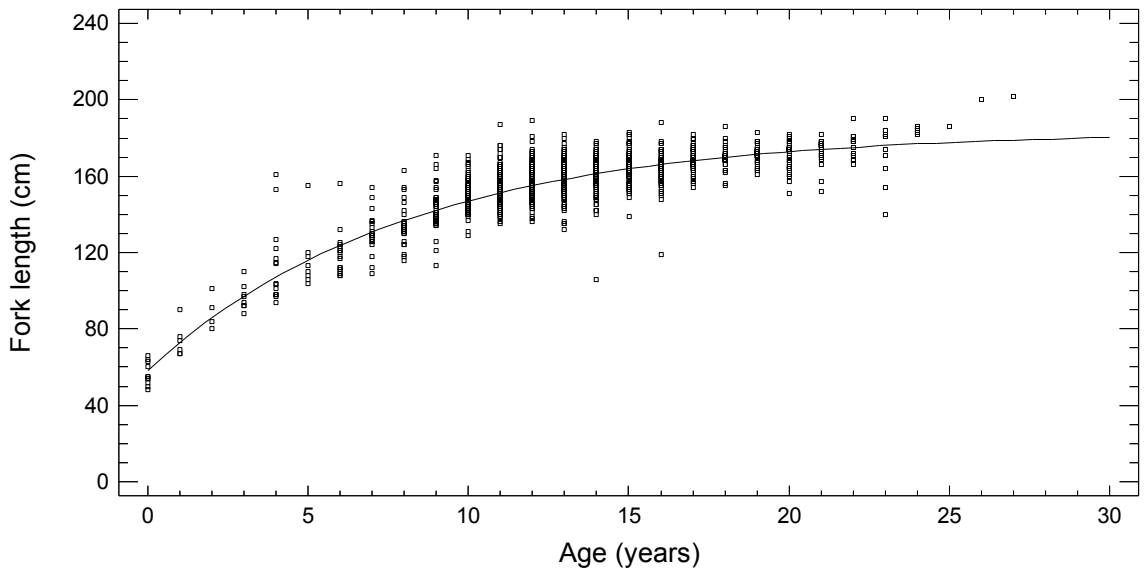

Figure 3. von Bertalanffy growth curve for female sandbar sharks based on data from Hale and Baremore (2013) and updated data.

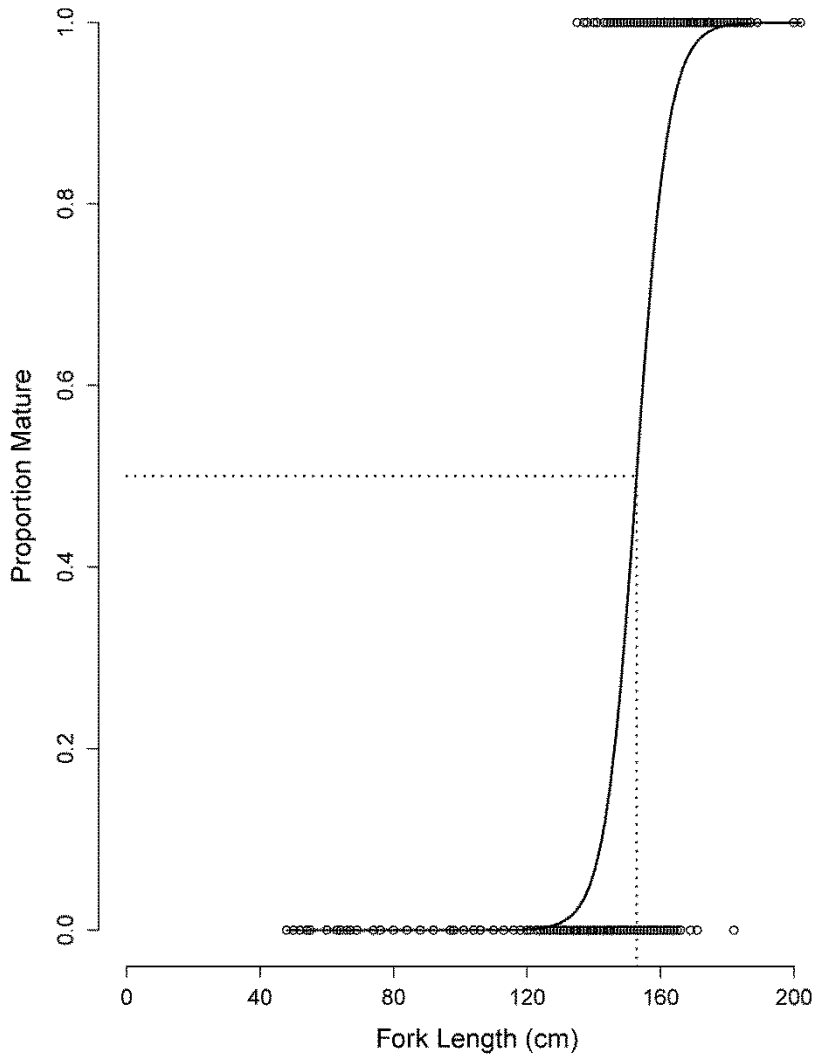

Figure 4. Proportion of female sandbar sharks mature by size (cm fork length) for combined datasets from Baremore and Hale (2012) and Piercy et al. (2016). Solid line is the logistic curve and dotted line is size at which 50% of sandbar sharks are mature.

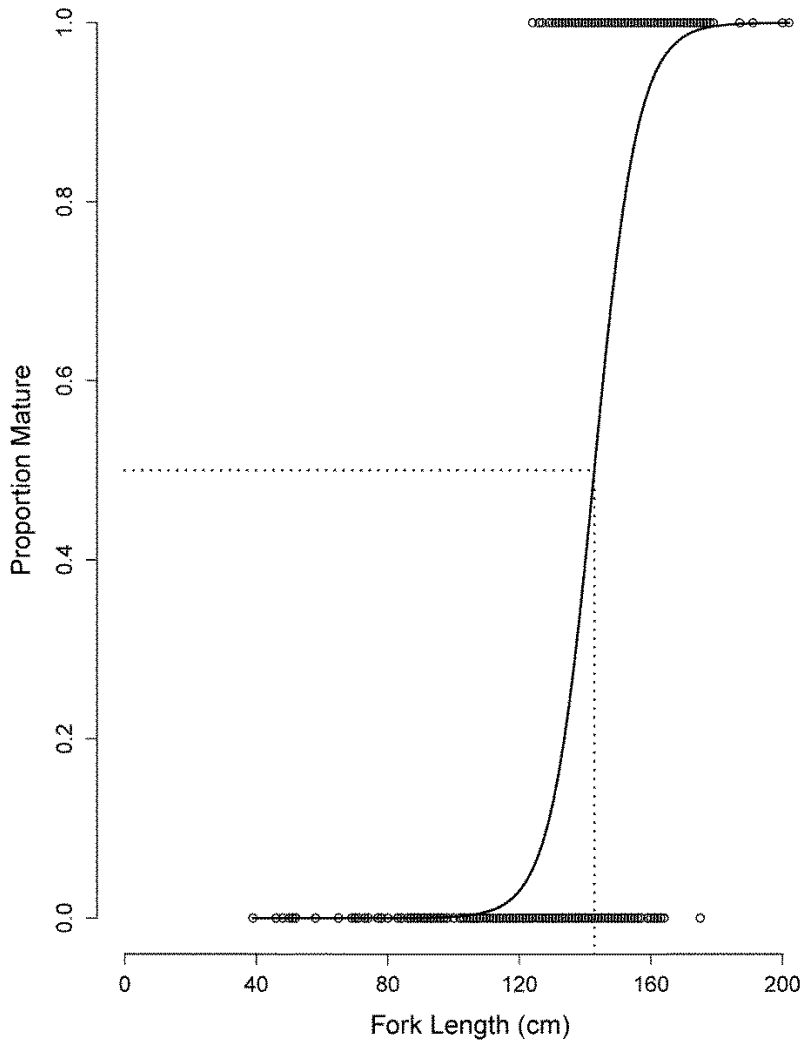

Figure 5. Proportion of male sandbar sharks mature by size (cm fork length) for combined datasets from Baremore and Hale (2012) and Piercy et al. (2016). Solid line is the logistic curve and dotted line is size at which 50% of sandbar sharks are mature.