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Introduction

This document uses raw data from the SEFSC shark bottom longline observer program and the NEFSC and SEFSC bottom longline surveys to obtain estimates of vital reproductive parameters for blacktip sharks (*Carcharhinus limbatus*) in the western North Atlantic Ocean off the east coast of the United States.

Methods

Data from SEFSC shark bottom longline observer program and the NEFSC and SEFSC bottom longline surveys were combined to calculate estimates of size and age at median maturity, mean brood size and the relationship between maternal length and brood size. Specimens sampled on the NEFSC survey were caught between 2734.7° N 8004.9° W and 3532.9° N and 7508.7° W. Specimens sampled in the shark bottom longline observer program were caught on commercial fishing vessels operating in the approximate area between 2456.6° N 8025.6° W and 3711.0° N 7537.0° W. Ages for each sample were obtained from Deacy et al. (SEDAR 65-DW-02).

Maturity ogives were fitted to size and age using binomial maturity data. To estimate the median size or age-at-maturity, we modeled the probability that a given individual *i* was mature as the outcome of a Bernoulli random variable, where $y_i = 0$ for immature $y_i = 1$ mature individuals, respectively:

$$y_i \sim \text{Bernoulli}(p_i), \quad (1)$$

where p_i is the probability shark *i* is mature. We modeled p_i as a function of size (separately in terms of FL and age) as:

$$\text{logit}(p_i) = \beta_0 + \beta_1 Size_i \quad (2)$$

where the logit link function constrains p_i to values between 0 and 1; β_0 is an intercept term representing the mean probability that a shark is mature; and β_1 represents the effect of size in terms of either *FL* or age.

Models were fit to each sex separately and combined via maximum likelihood methods using functions available in R (R Core Team 2017). The median size (FL_{50}) of maturity was calculated based on the predicted relationship for each sex or combined sexes. Ninety-five

percent bootstrap confidence intervals were also calculated using the 'boot' package (Canty and Ripley 2017), following Harry et al. (2013). For each model fit, convergence was confirmed and residual diagnostic plots inspected. The percent deviance explained (Maunder and Punt 2004) was computed as a metric of the observed variation explained by size alone. Code was obtained courtesy of M. Winton.

Proportion of mature fish at size and age was calculated using:

$$= \frac{EXP(-a + b * FL)}{(1 + EXP(a + b * FL))}$$

Results

Data from 283 male (70.5- 158 cm FL) and 247 female (80-178 cm FL) blacktip sharks were used to calculate reproductive parameters. Median FL_{50} at maturity was 115.15 cm FL (*a*=-31.4125, *b*=0.2728) for males, 123.05 cm FL (*a*=-30.08569, *b*=0.24449) for females, and 117.48 cm FL (*a*=-27.16521, *b*=0.23123) for sexes combined (Tables 1&2; Supplemental Figure 1). Data from 242 male (87-153 cm FL) and 182 female (80-178 cm FL) with direct ages and reproductive conditions were used to obtain median age at maturity. Median Age_{50} at maturity was 5.34 years (*a*=-9.0872, *b*=1.7012) for males, 6.69 years (*a*=-12.0719, *b*=0.1.8042) for females, and 5.78 years (*a*=-8.5820, *b*=1.4859) for sexes combined (Tables 1&3; Supplemental Figure 2).

Brood size was available from 87 pregnant females. Brood size ranged from 1 to 7 with a mean of 4.09 (±0.13 S.D.; Figs1&2). The relationship between maternal length and brood size was best described by the following equation: Brood size = -5.82556 + 0.06857*FL ($r^2 = 0.19$) (Figure 3). Age data were available for a subset of 56 gravid females. The relationship was described by the following equation: Brood size = -5.82556+0.06857*FL (F-ratio = 21.79, $p < 0.01$, $r^2 = 0.19$) (Figure 4). Standard error around the intercept and slope estimates were 2.128 and 0.015, respectively.

Literature cited

Canty, A. and Ripley, B. 2017. boot: Bootstrap R (S-Plus) Functions. R package version 1.3-20. h ttps://cran.r-project.org/web/packages/boot/boot.pdf.

Harry, A. V., Tobin, A. J., and Simpfendorfer, C. A. 2013. Age, growth, and reproductive biology of the spot-tail shark, *Carcharhinus sorrah*, and the Australian blacktip shark*, C. tilstoni*, from the Great Barrier Reef World Heritage Area, north-eastern Australia. *Marine and Freshwater Research,* 64, 277–293. http://dx.doi.org/10.1071/MF12142.

Maunder and Punt 2004. Standardizing catch and effort data: A review of recent approaches. *Fisheries Research*, 70,141-159. doi: 10.1016/j.fishres.2004.08.002.

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Table 1. Parameters for age and length ogive analysis for Atlantic blacktip sharks. Numbers in parentheses are standard error.

					95% CI on L_{50}	
		a (SE)	*b (SE)*	L_{50}	Lower	Upper
Age ogive (years)	Combined	-8.58(1.16)	1.48(0.18)	5.78	5.42	7.28
	Female	-12.07(2.52)	1.80(0.35)	6.69	6.23	7.52
	Male	-9.09(1.72)	1.70(0.29)	5.34	4.92	6.24
Fork length ogive (cm)	Combined	-27.16(3.14)	0.23(0.03)	117.48	115.28	127.27
	Female	-30.09(4.66)	0.24(0.04)	123.05	120.60	130.90
	Male	-31.41(5.34)	0.27(0.04)	115.15	111.22	123.00

Table 2. Proportion of mature blacktip sharks (*Carcharhinus limbatus*) in 5 cm size classes by sex.

Fork length (cm)	Sexes Combined	Females	Males
40	0.00	0.00	0.00
45	0.00	0.00	0.00
50	0.00	0.00	0.00
55	0.00	0.00	0.00
60	0.00	0.00	0.00
65	0.00	0.00	0.00
70	0.00	0.00	0.00
75	0.00	0.00	0.00
80	0.00	0.00	0.00
85	0.00	0.00	0.00
90	0.00	0.00	0.00
95	0.01	0.00	0.00
100	0.02	0.00	0.02
105	0.06	0.01	0.06
110	0.16	0.04	0.20
115	0.37	0.12	0.49
120	0.65	0.32	0.79
125	0.85	0.62	0.94
130	0.95	0.85	0.98
135	0.98	0.95	1.00
140	0.99	0.98	1.00
145	1.00	1.00	1.00
150	1.00	1.00	1.00
155	1.00	1.00	1.00
160	1.00	1.00	1.00
165	1.00	1.00	1.00
170	1.00	1.00	1.00
175	1.00	1.00	1.00
180	1.00	1.00	1.00

Table 3. Proportion of mature blacktip sharks (*Carcharhinus limbatus*) in 1 year age classes by sex.

Age (years)	Sexes Combined	Females	Males
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.02	0.00	0.02
4	0.07	0.01	0.09
5	0.24	0.05	0.36
6	0.58	0.22	0.75
7	0.86	0.64	0.94
8	0.96	0.91	0.99
9	0.99	0.98	1.00
10	1.00	1.00	1.00
11	1.00	1.00	1.00
12	1.00	1.00	1.00
13	1.00	1.00	1.00
14	1.00	1.00	1.00
15	1.00	1.00	1.00
16	1.00	1.00	1.00
17	1.00	1.00	1.00

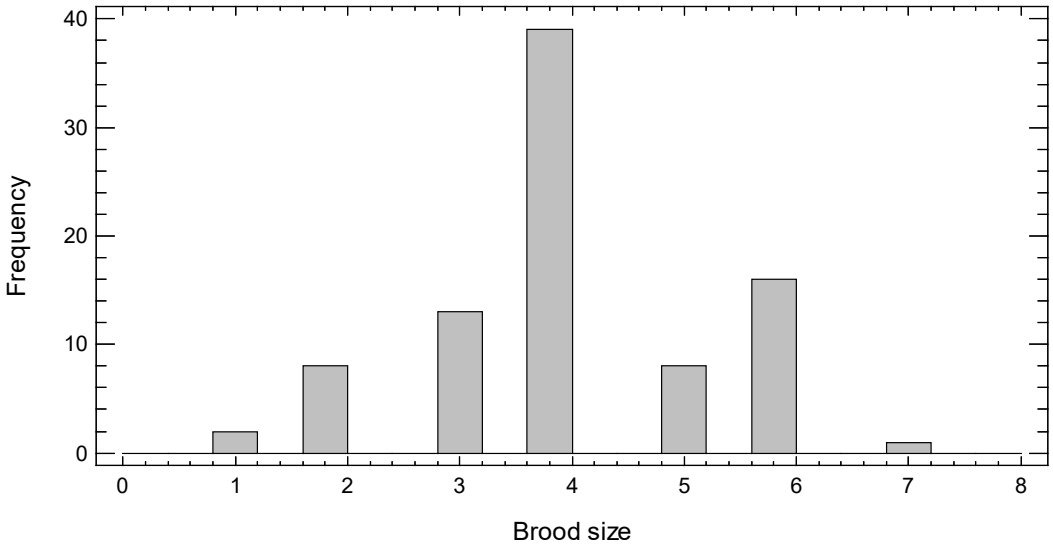


Figure 1. Distribution of brood sizes for blacktip sharks (*Carcharhinus limbatus*) in the western North Atlantic Ocean.

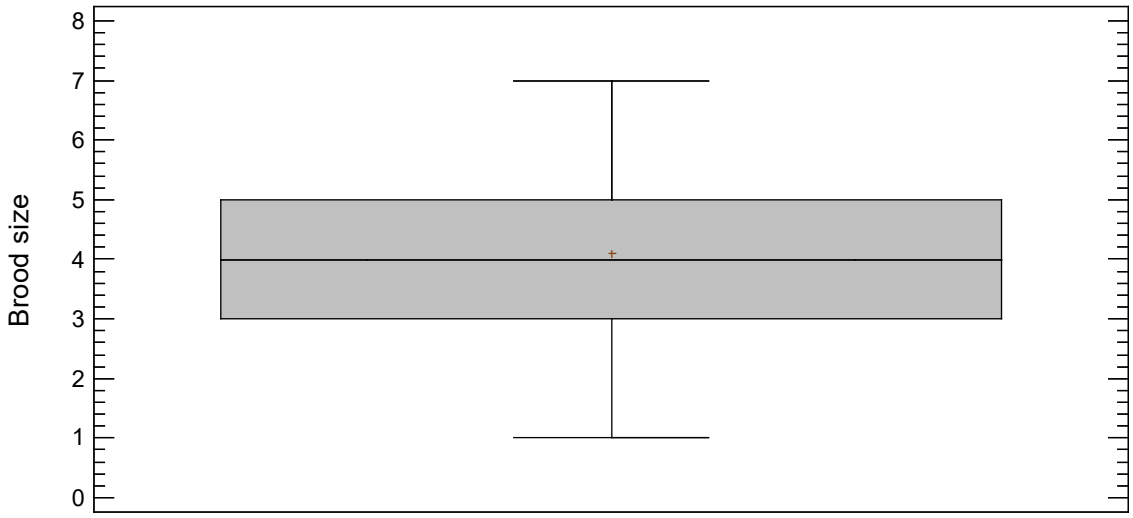


Figure 2. Box and whisker plot of brood sizes of gravid (n=93) blacktip sharks (*Carcharhinus limbatus*) in the western North Atlantic Ocean. Bars represent minimum and maximum observed values, grey box represents lower and upper quantiles, + indicates the mean, and center line represents the median.

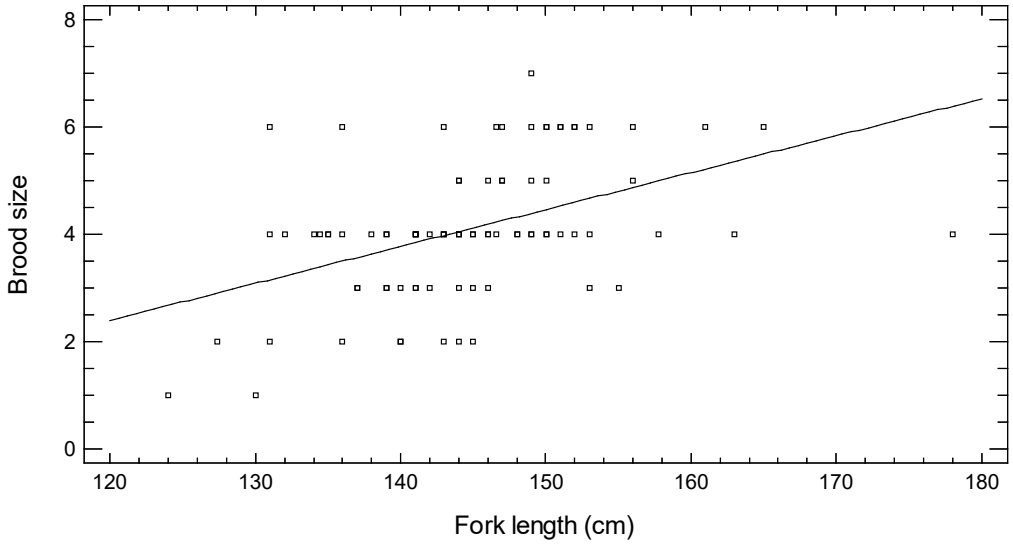


Figure 3. Relationship between maternal length and brood size for gravid female (n=87) blacktip sharks (*Carcharhinus limbatus*) from the western North Atlantic Ocean.
Brood size = -5.82556+0.06857*FL (r^2 = 0.19).

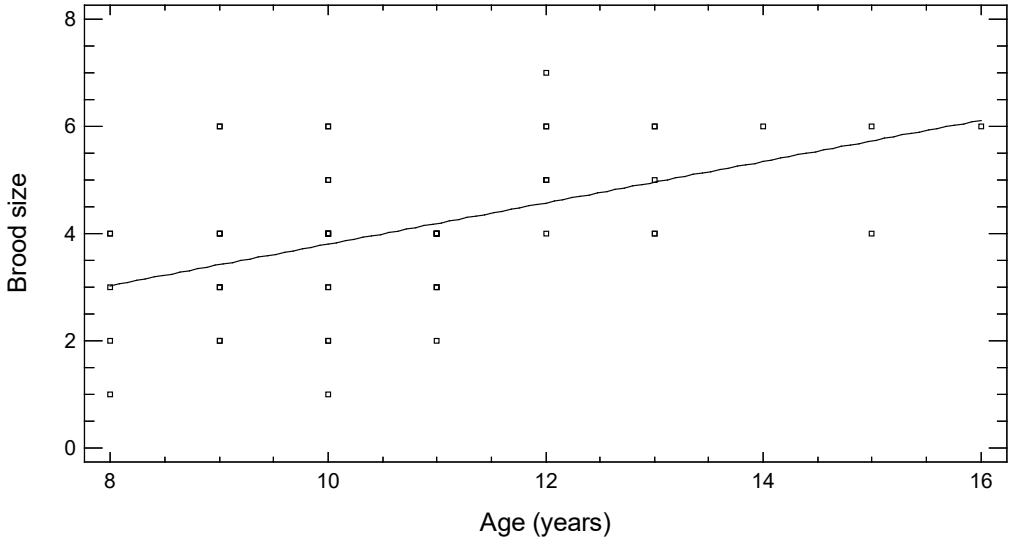
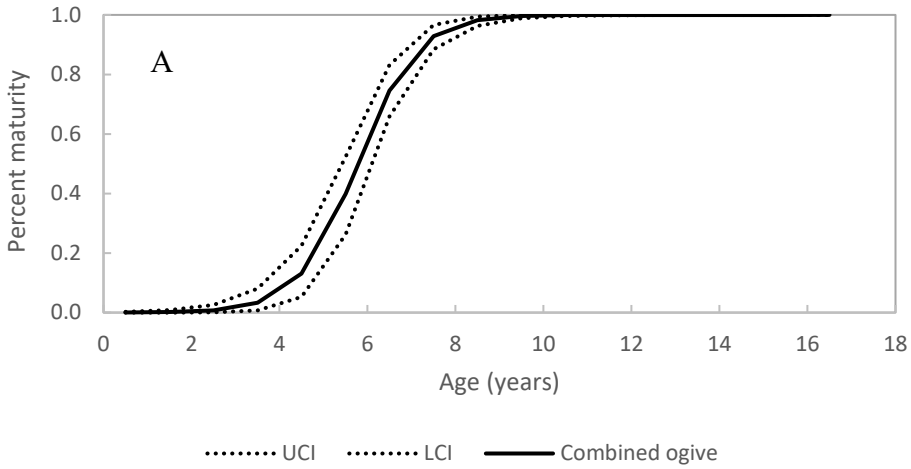
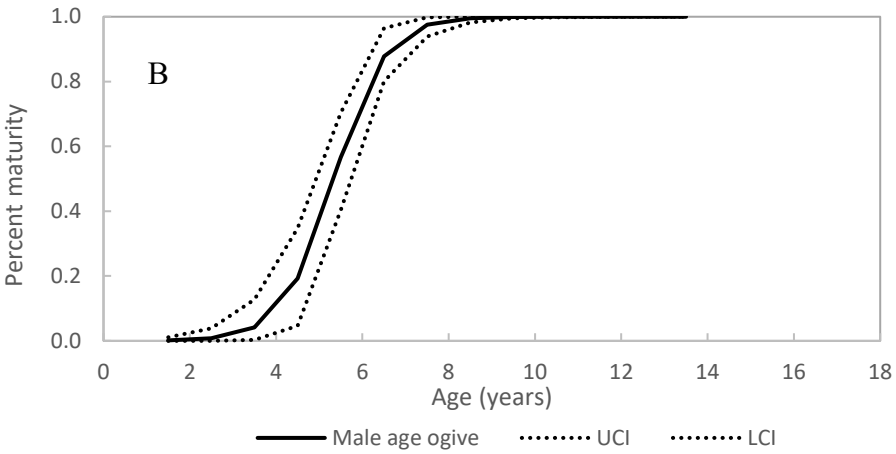
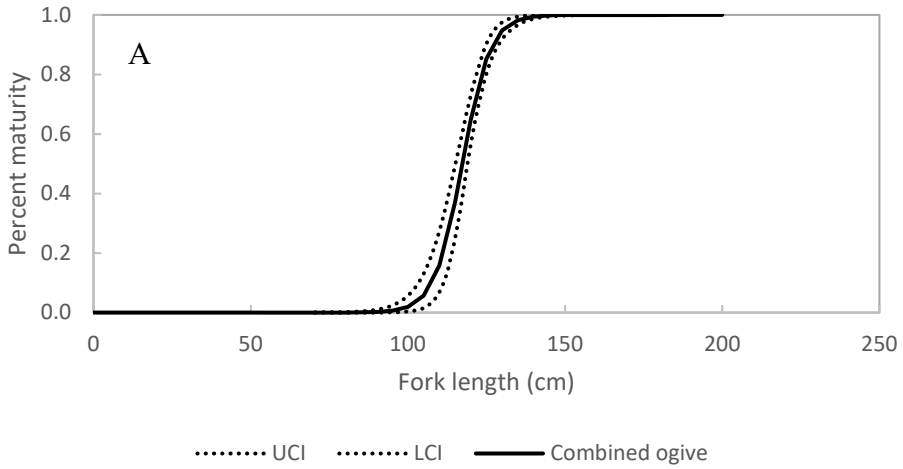


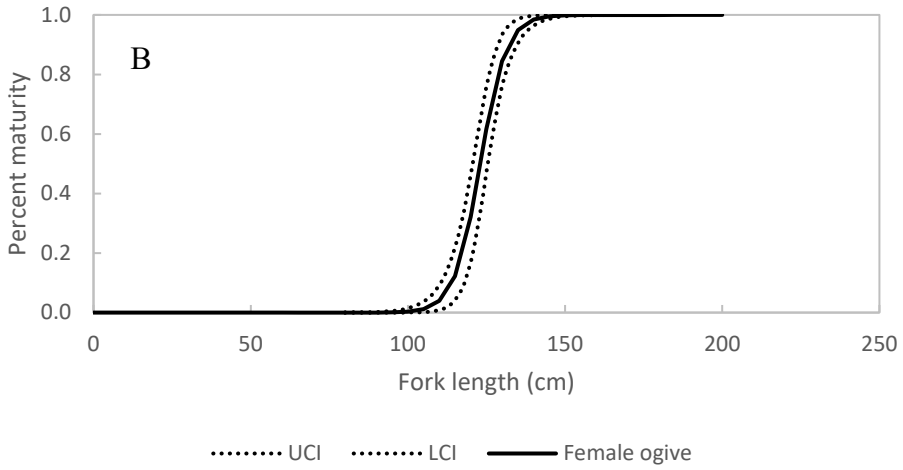
Figure 4. Relationship between maternal age and age for gravid female (n=56) blacktip sharks (*Carcharhinus limbatus*) from the western North Atlantic Ocean.
Brood size = -0.04078 + 0.38445*Age (r^2 = 0.24).

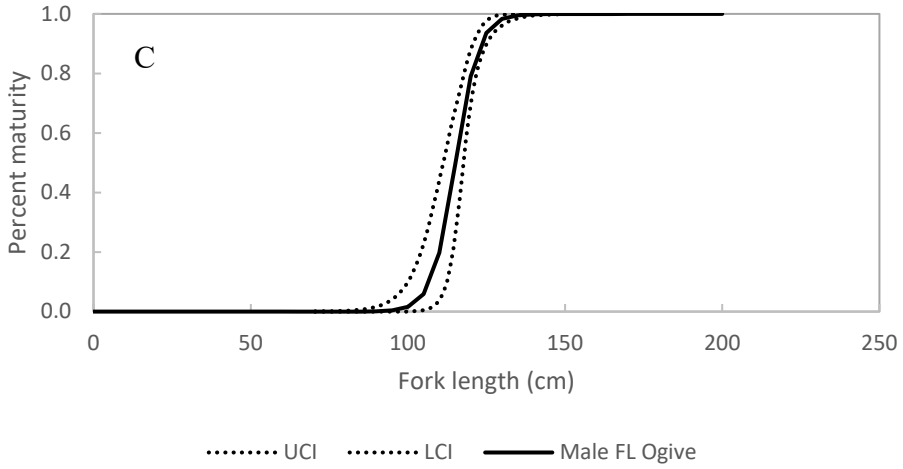




Supplemental Figure 1.Maturity ogives for A) combined (n=424); B) male (n=242), and C) female (n=182) blacktip sharks (*Carcharhinus limbatus*) from the western North Atlantic Ocean based on age (years). Dotted lines indicate 95% confidence intervals.







Supplemental Figure 2.Maturity ogives for A) combined (n=530); B) male (n=283); and C) female (n=247) blacktip sharks (*Carcharhinus limbatus*) from the western North Atlantic Ocean based on fork length (cm). Dotted lines indicate 95% confidence intervals.