Updated reproductive parameters for sandbar sharks (*Carcharhinus plumbeus*) in US waters of the western North Atlantic Ocean

G. Walter Ingram, Jr.[1], William B. Driggers III[1], Bryan S. Frazier[2], Annsli Hilton[1], Heather Moncrief-Cox[1], Lisa J. Natanson[3], and Michelle S. Passerotti[3]

SEDAR101-DW-27

20 April 2026
Updated: 22 May 2026

Please cite this document as:

Ingram, Walter G. Jr., Driggers, Walter B. III, Frazier, Bryan S., Hilton, Annsli, Moncrief-Cox, Heather, Lisa J. Natanson and Michelle S. Passerotti. 2026. Updated reproductive parameters for sandbar sharks (*Carcharhinus plumbeus*) in US waters of the western North Atlantic Ocean. SEDAR101-DW-27. SEDAR, North Charleston, SC. 25 pp.

Updated reproductive parameters for sandbar sharks (*Carcharhinus plumbeus*) in US waters of the western North Atlantic Ocean.

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From 2016-2024, reproductive data were collected from 1,553 sandbar sharks during commercial fishing operations and fisheries-independent surveys. Maturity status was assigned to all but 17 individuals, including 1,019 females and 517 males. Males were considered mature if the claspers were elongated and fully calcified. Females were classified as mature if the uteri and oviducal glands were fully developed. Ovarian activity was not considered a criterion for maturity due to the uncertainty associated with the reproductive cycle. Reproductive data collected from females also included, among other measures, ovary weight, total number and diameter of the five largest vitellogenic follicles, width of one uterus in non-pregnant females, and oviducal gland width. If pregnant, the total brood size was recorded.

Length and age (see Driggers et al, SEDAR101-DW-24) data were used in conjunction with maturity data to generate sex and region-specific ogives. Records with missing maturity classification, fork length (FL), or age were removed from the analysis to ensure a consistent, 1:1 dataset for all model comparisons. Macroscopic maturity was binarized, assigning 0 to juvenile sharks and 1 to mature sharks. Appropriate binomial models against both FL (cm) and age (years) were fitted, and Likelihood Ratio Tests (LRTs) to compare spatial and temporal parameters were conducted, generating high-resolution visualizations.

The 50% maturity inflection points (L_{50} and A_{50}) were extracted algebraically by dividing the negative model intercept by the slope covariate. Confidence intervals (95%) were calculated natively on the link scale and back-transformed to the probability scale to produce structurally valid bounds. To definitively ascertain whether temporal shifts have occurred, sex- and area-specific ogives for each individual SEDAR assessment were constructed, followed by a statistical comparison (i.e., LRTs) encompassing all three time periods simultaneously for both length and age. R was used to construct ogives and statistically evaluate variations in parameter estimates using maximum-likelihood estimation (Ogle, 2016).

Age and length at maturity

The analysis of the SEDAR 101 dataset revealed distinct differences in the size and age at which male and female sandbar sharks reach 50% maturity (L_{50} and A_{50}).

- Length at Maturity: Females reached 50% maturity at a significantly larger fork length (147.26 cm FL) compared to males (142.87 cm FL). Likelihood Ratio Tests (LRT) confirmed that this sex-specific difference in length-based maturity is statistically significant (p = 0.0464). These length-at-maturity ogives are visualized in Figure 1, with associated model coefficients detailed in Table 1.

- Age at Maturity: There was a roughly one-year difference in the average age at 50% maturity, with females reaching A_{50} at 11.00 years and males at 10.05 years. However, statistical testing indicated that this difference in age at maturity between the sexes was not statistically significant (p = 0.1235). The age-at-maturity ogives are depicted in Figure 2.

A geographic comparison of the SEDAR 101 data showed that females in the Atlantic (ATL, n=427) matured at a larger size and an older age than those in the Gulf of America (GOA, n=339).

- Length Differences: Atlantic females had an estimated L50 of 148.73 cm FL, whereas GOA females had an L_{50} of 143.15 cm FL. LRT confirmed this regional difference in length-based ogives is statistically significant (p = 0.0314). These differences are modeled in Table 4 and visualized in Figure 3.
- Age Differences: Atlantic females reached A_{50} at 11.60 years, compared to 8.96 years for GOA females. This regional variation in age-based ogives was also highly significant (p = 0.0003). The comparative age ogives are shown in Figure 4.

Similar to females, male sandbar sharks in the Atlantic (n=109) generally matured at a larger size and greater age than their GOA (n=140) conspecifics, though the statistical significance of these variations differed.

- Length Differences: Atlantic males reached an L_{50} of 145.17 cm FL, compared to 138.54 cm FL for GOA males. However, LRT results indicated this spatial difference in length-based maturity for males was not statistically significant (p = 0.1956). These ogives are plotted in Figure 5, with parameters in Table 7.
- Age Differences: The A_{50} for Atlantic males was 10.65 years, while GOA males reached A_{50} at 8.65 years. As with the length analysis, this regional difference in male age-at-maturity was not statistically significant (p = 0.1501). The male age-at-maturity ogives across regions are illustrated in Figure 6.

Analysis across different SEDAR assessment periods (21, 54, and 101) indicated substantial temporal shifts in maturity ogives for both sexes and regions (Tables 10, 11 & 12, Figures 7 & 8).

- Length-based Shifts: Significant temporal differences in L_{50} were found for all groups: Females in the ATL and GOA (p < 0.0001), and males in the ATL and GOA (p < 0.0001). Generally, L_{50} tended to decrease in more recent assessments; for example, GOA females dropped from 154.64 cm (SEDAR 21) to 143.15 cm (SEDAR 101).
- Age-based Shifts: Significant temporal shifts in A_{50} were also observed across all sex and area combinations (p < 0.0001). Similar to length, the age at 50% maturity has declined over time, most notably in GOA males, where A_{50} decreased from 13.04 years (SEDAR 21) to 8.65 years (SEDAR 101).

Maturity schedules are provided in the Appendix.

Brood size and size at birth

Brood size counts from 201 female sandbar sharks were collected between 2016 and 2024. The mean brood size was 7.78 pups per brood (S.D. = 2.33, SE 0.13), which was not statistically different from the mean brood size in data used for SEDAR 21 (mean = 7.80, S.D. = 2.47; t = 0.11, p = 0.91). Data from all years (i.e., 2006-2024) were combined to compare mean brood size between the Atlantic and GOA, and there was no statistical difference between regions (t = 0.66, p = 0.511). Embryo sex data were available from 274 broods consisting of 986 males and 939 females. The sex ratio or female to male embryos was not different from the expected ratio of 1:1 (X2 = 1.15, p = 0.28). Length data from 70 neonate sandbar sharks with umbilical remains or an open umbilicus were available and the mean size at birth was calculated to 46.86 cm FL (S.D. = 2.92).

Gestation and parturition

Estimates of gestation time for sandbar sharks range from 8-12 months (e.g. Springer 1960). Based on examination of gravid females and associated embryo lengths, Baremore and Hale (2012) determined gestation occurs over an approximately 12-month period. Similarly, Castro (2011) suggested a longer range of 11-12 months. As the Castro (2011) and Baremore and Hale (2012) estimates are relatively recent, we believe gestation occurs over11-12 months.

Available information of the time of parturition for sandbar sharks indicates pupping occurs over a relatively protracted period. For example, Springer (1960) stated that parturition occurs from March through early August. Similarly, Baremore and Hale (2012) reported the presence of postpartum females from April through September but noted a peak in parturition May and June. This agrees with Castro (2011) who reported females give birth off South Carolina in June.

Maternal size/age and brood size relationships

To evaluate potential relationships between brood size and maternal length/age, we analyzed brood size as count data. Because the dependent variable (brood size) consists of discrete, non-negative integers, we employed Generalized Linear Models (GLMs) specifying a Poisson distribution with a log link function.

To maximize the statistical power of the dataset while accounting for missing data in the age records, we developed two separate models. The first model evaluated maternal age as the primary predictor, along with geographic area (GOA vs. ATL) and the SEDAR assessment timeframe as covariates. The second model evaluated maternal FL as the primary predictor, utilizing the same spatial and temporal covariates.

The relationship between maternal characteristics and reproductive output was modeled using Poisson GLMs (Tables 13 & 14). Brood size was positively and significantly correlated with both maternal age and maternal length. As mothers grew older and larger, the predicted brood size increased (Figures 9 & 10). The relationship between brood size and maternal age is described by: Brood Size = exp(1.630 + 0.025(AGE)). The relationship between brood size and maternal length is described by: Brood size = exp(0.544 + 0.009(FL)) (Tables 15 and 16). Geographic area (GOA vs. ATL) and temporal timeframe (SEDAR) did not have a statistically significant effect on brood size ($p > 0.05$).

Reproductive Periodicity

To evaluate reproductive periodicity, we examined reproductive assessments collected from 2015-2024 from the sandbar research fishery and NMFS Apex Predator Program (NEFSC). Previous data (2007-2014) were also examined, however methodological differences existed in ova measurements, precluding the use of previous data, except for determination of percentage of the population that was gravid and resting. From 2007 to 2014, only maximum ova diameter was recorded, whereas from 2015 to 2024 the five largest ova were recorded allowing mean follicle diameter calculation. Examination of all data from 2007-2024 (n=980) showed that maximum follicle diameter measurements could include atretic ova rather than viable follicles, therefore data from ≤2014 were excluded for analysis of reproductive periodicity.

For 2015-2024, a total of 830 reproductive assessments were available for use. Initially we examined individuals over 170 cm FL (>L100, n=225) to exclude potential juveniles. Of these, 104 were gravid (46.6%). To examine differences in ovarian condition, this dataset was truncated to January-April (n=66). Differences in ovarian condition are most apparent in late winter/spring and parturition begins as early as late April, therefore these months are the most informative to determine reproductive periodicity. Mean ova diameter of pregnant individuals (n=31, 46.9%) was 6.4 mm (range 3.5-9.9 mm). For non-gravid individuals (n=35) mean ova diameter was 24.4 mm (range 13.7-40.0 mm), indicating follicle diameter was increasing and vitellogenesis was occurring in all non-gravid individuals (Figure 11.). These data provide strong support for a biennial reproductive cycle with two distinct life states observed.

Following this assessment, we examined data from females >L50 (147 cm FL), for the full 2007-2024 dataset (n=980), 33.4% of individuals were gravid (n=340), although this increased to 46.7% with inclusion of individuals classified as postpartum. As above, data were truncated to January-April, and 2015-2024 samples only, resulting in a sample size of 120 individuals. For gravid individuals a mean ova diameter of 6.3 mm (n=35) was observed. For non-gravid individuals we found there were two size classes of ova found. The majority (n=69) had developing ovaries with mean follicle sizes of 23.0 mm, and a minority of individuals (n=9) had small, non-vitellogenic ova, with a mean diameter of 8.4mm (Figure 12). Data from these 9 individuals was scrutinized to try to ascertain if maturity status was correctly assigned. We found that two individuals met the conditions of maturity (oviducal gland width >25mm and uterine width >30mm, Baremore and Hale 2012). The remaining individuals (n=7) only met one of the two conditions for maturity; therefore, we cannot be certain that these individuals were mature.

Given the reproductive condition of the two anomalous individuals, we cannot entirely rule out that triennial reproduction could occur in sandbar sharks. That said, the group concluded that biennial reproduction is the primary reproductive mode of sandbar sharks. Based on the presence of the 9 individuals (7.5%) with differing reproductive states (7 of which may not be mature), we recommend exploring an axis of uncertainty of 2.2 years in the MSE analysis.

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Table 1. Length and age at maturity model coefficients & model *p*-values for SEDAR101 data.

Analysis	n	Parameter	Estimate	LCI_95	UCI_95	Parameter *p*-value	Model *p*-value
Female-FL	766	*a*	-37.1393	-44.6201	-29.6585	<0.00001	<0.00001
		b	0.2522	0.2032	0.3012	<0.00001	
Male-FL	249	*a*	-26.1467	-35.8293	-16.4640	<0.00001	<0.00001
		b	0.1830	0.1189	0.2471	<0.00001	
Female-Age	766	*a*	-8.7015	-10.4183	-6.9848	<0.00001	<0.00001
		b	0.7913	0.6567	0.9259	<0.00001	
Male-Age	249	*a*	-5.7782	-8.0528	-3.5037	<0.00001	<0.00001
		b	0.5750	0.3930	0.7569	<0.00001	

Table 2. Sex-specific age and length at 50 % maturity (with 95 % CI) for SEDAR101 data.

Analysis	n	Value	LCI_95	UCI_95
Female-L_{50}	766	147.26	145.62	148.90
Male-L_{50}	249	142.87	139.19	146.54
Female-A_{50}	766	11.00	10.55	11.44
Male-A_{50}	249	10.05	9.05	11.05

Table 3. Likelihood Ratio Tests for differences in sex-specific age- and length-based ogives for SEDAR101 data.

Comparison	n	Term	#Df	LogLik	Df	Chisq	Pr(>Chisq)
Sex-FL	1,015	1	2.0000	-205.5289			
	1,015	2	4.0000	-202.4594	2.0000	6.1390	0.0464
Sex-Age	1,015	1	2.0000	-251.9416			

Comparison	n	Term	#Df	LogLik	Df	Chisq	Pr(>Chisq)
	1,015	2	4.0000	-249.8503	2.0000	4.1825	0.1235

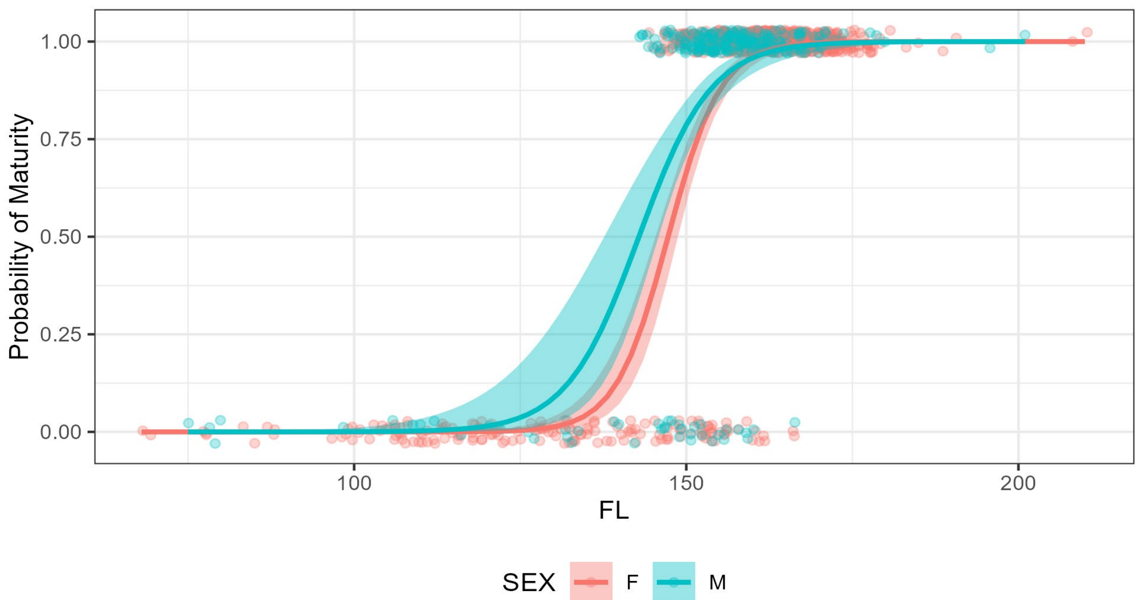

Figure 1. Sex-specific length-at-maturity ogives (with 95% CL) for sandbar sharks (*Carcharhinus plumbeus*) in the western North Atlantic Ocean based on SEDAR101 data.

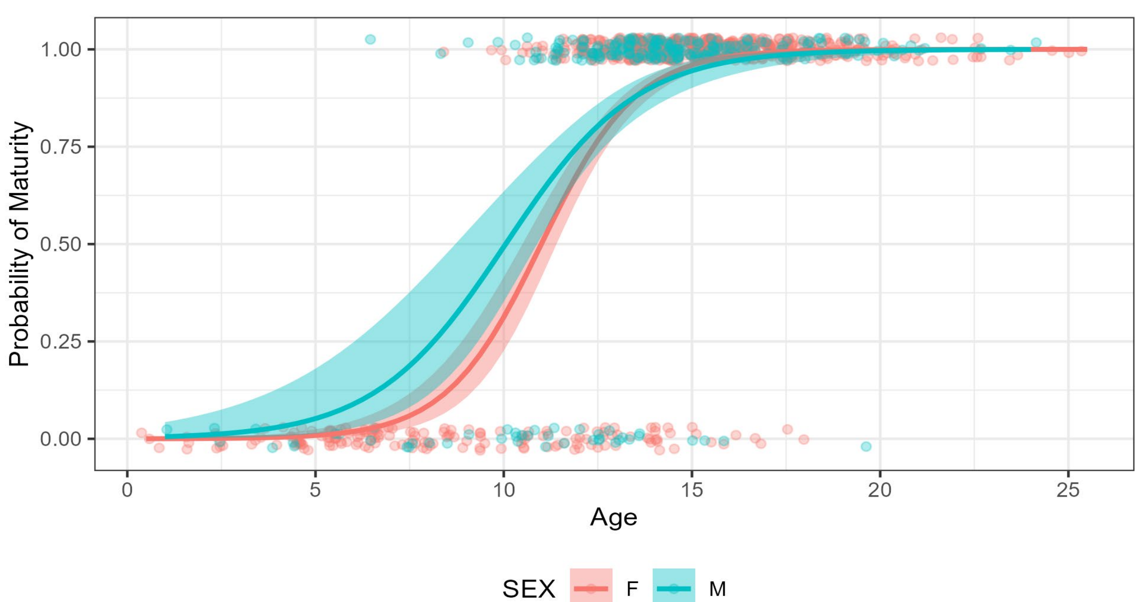

Figure 2. Sex-specific age-at-maturity ogives (with 95% CL) for sandbar sharks (*Carcharhinus plumbeus*) in the western North Atlantic Ocean based on SEDAR101 data.

Table 4. Model Coefficients & Model *p*-values for females (ATL vs GOA) (SEDAR 101).

Analysis	n	Parameter	Estimate	LCI_95	UCI_95	Parameter *p*-value	Model *p*-value
Females ATL-Len	427	*a*	-40.1917	-50.4557	-29.9277	0.0000	0.0000
		b	0.2702	0.2029	0.3376	0.0000	0.0000
Females GOA-Len	339	*a*	-28.0962	-39.6899	-16.5024	0.0000	0.0000
		b	0.1963	0.1212	0.2713	0.0000	0.0000
Females ATL-Age	427	*a*	-10.0922	-12.5129	-7.6714	0.0000	0.0000
		b	0.8701	0.6817	1.0584	0.0000	0.0000
Females GOA-Age	339	*a*	-4.8184	-7.7750	-1.8618	0.0014	0.0000
		b	0.5376	0.3143	0.7609	0.0000	0.0000

Table 5. Area-specific age and length at 50 % maturity (with standard error) for females (ATL vs GOA) (SEDAR 101).

Analysis	n	Value	LCI_95	UCI_95
ATL Female-L_{50}	427	148.73	146.93	150.52
GOA Female-L_{50}	339	143.15	138.15	148.15
ATL Female-A_{50}	427	11.60	11.12	12.08
GOA Female-A_{50}	339	8.96	7.05	10.88

Table 6. Likelihood Ratio Tests for differences in age- and length-based ogives for females (ATL vs GOA) (SEDAR 101).

Comparison	n	Term	#Df	LogLik	Df	Chisq	Pr(>Chisq)
Females Area-FL	766	1	2.0000	-131.0972			
		2	4.0000	-127.6353	2.0000	6.9237	0.0314
Females Area-Age	766	1	2.0000	-172.3278			
		2	4.0000	-164.2909	2.0000	16.0739	0.0003

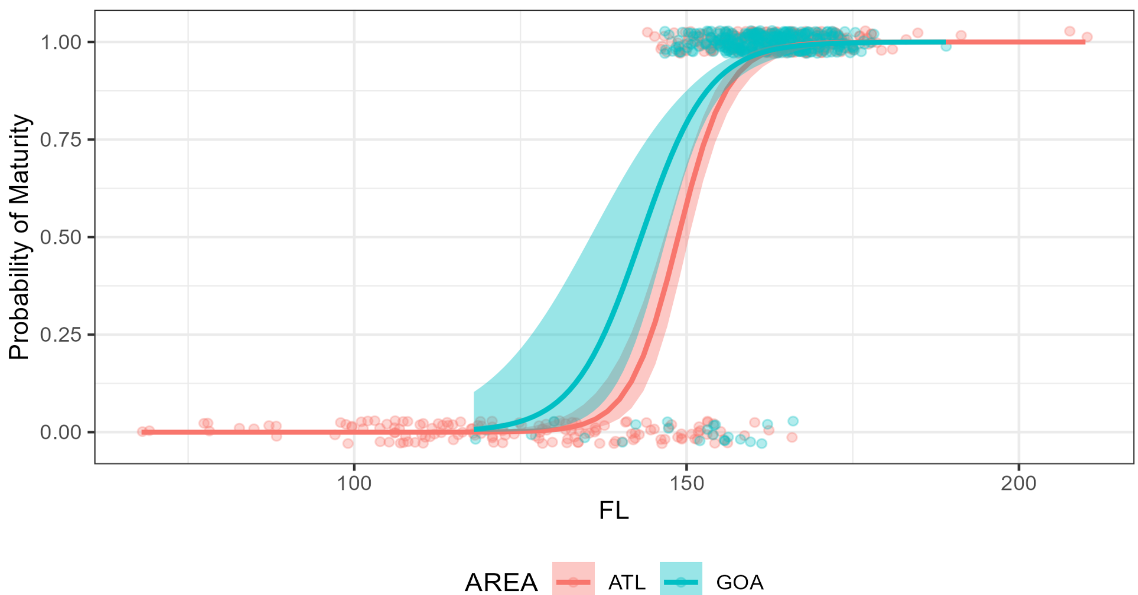

Figure 3. Female length-at-maturity ogives (with 95% CL) for sandbar sharks (*Carcharhinus plumbeus*) (ATL vs GOA) (SEDAR 101).

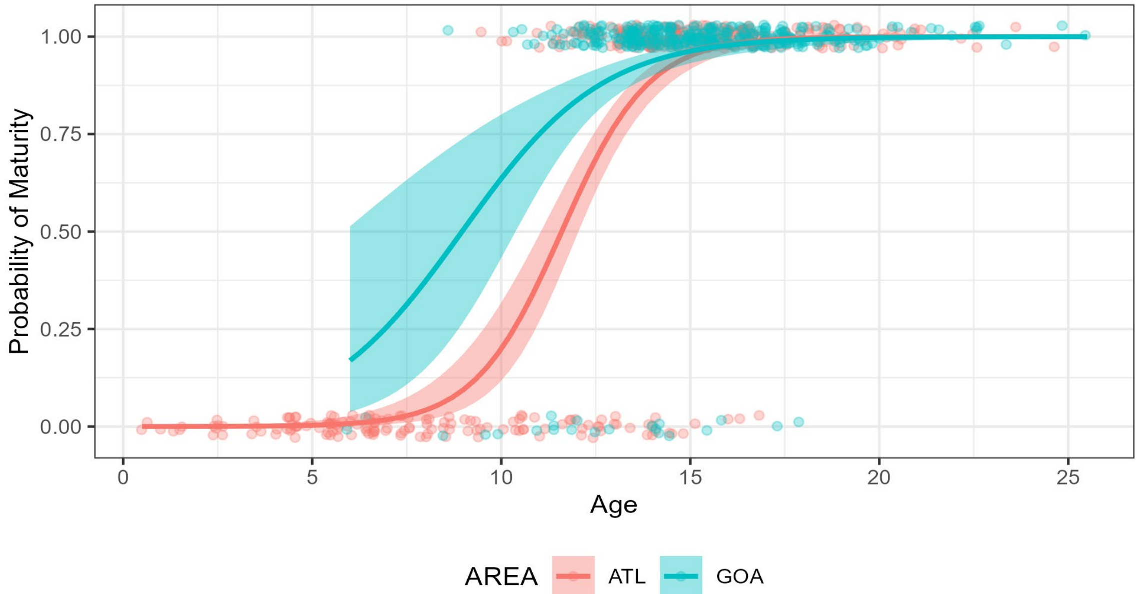

Figure 4. Female age-at-maturity ogives (with 95% CL) for sandbar sharks (*Carcharhinus plumbeus*) (ATL vs GOA) (SEDAR 101).

Table 7. Model Coefficients & Model *p*-values for males (ATL vs GOA) (SEDAR 101).

Analysis	n	Parameter	Estimate	LCI_95	UCI_95	Parameter *p*-value	Model *p*-value
Males ATL-Len	109	*a*	-27.7511	-41.1681	-14.3341	0.0001	0.0000
		b	0.1912	0.1023	0.2800	0.0000	0.0000
Males GOA-Len	140	*a*	-21.0334	-36.7370	-5.3299	0.0087	0.0002
		b	0.1518	0.0487	0.2550	0.0039	0.0002
Males ATL-Age	109	*a*	-6.0892	-9.0449	-3.1334	0.0001	0.0000
		b	0.5718	0.3313	0.8124	0.0000	0.0000
Males GOA-Age	140	*a*	-4.2092	-7.9573	-0.4611	0.0277	0.0001
		b	0.4865	0.1973	0.7758	0.0010	0.0001

Table 8. Area-specific age and length at 50 % maturity (with standard error) for males (ATL vs GOA) (SEDAR 101).

Analysis	n	Value	LCI_95	UCI_95
ATL Male-L_{50}	140	145.17	141.11	149.23
GOA Male-L_{50}	109	138.54	128.37	148.70
ATL Male-A_{50}	140	10.65	9.54	11.76
GOA Male-A_{50}	109	8.65	5.87	11.44

Table 9. Likelihood Ratio Tests for differences in area-specific age- and length-based ogives for males (ATL vs GOA) (SEDAR 101).

Comparison	n	Term	#Df	LogLik	Df	Chisq	Pr(>Chisq)
Males Area-FL	249	1	2.0000	-71.3622			
		2	4.0000	-69.7306	2.0000	3.2631	0.1956
Males Area-Age	249	1	2.0000	-77.5225			
		2	4.0000	-75.6261	2.0000	3.7929	0.1501

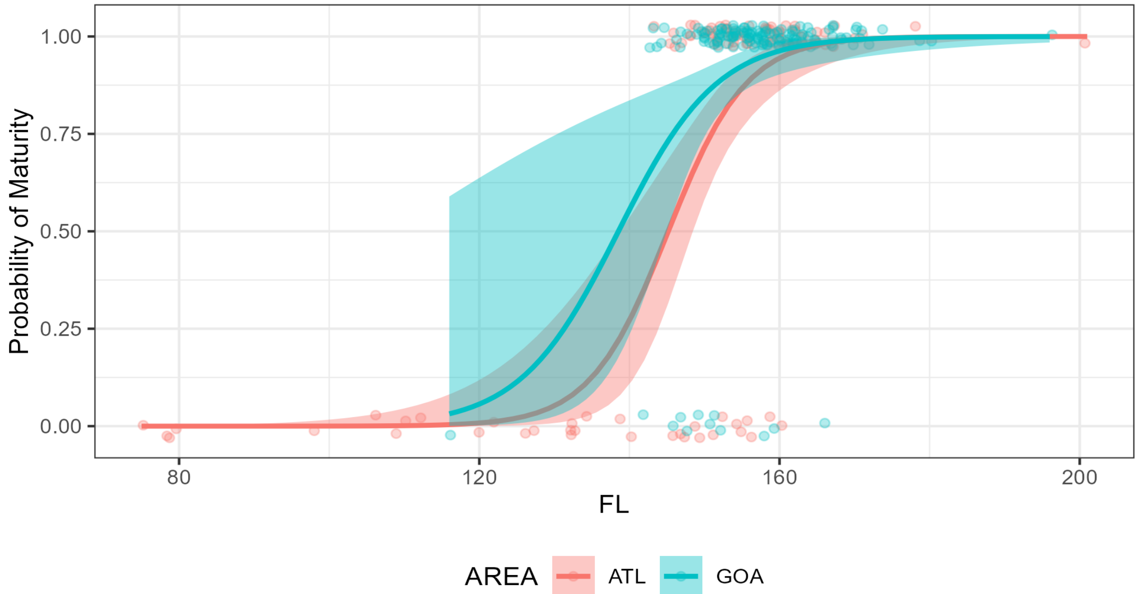

Figure 5. Length-at-maturity ogives (with 95% CL) for male sandbar sharks (*Carcharhinus plumbeus*) (ATL vs GOA) (SEDAR 101).

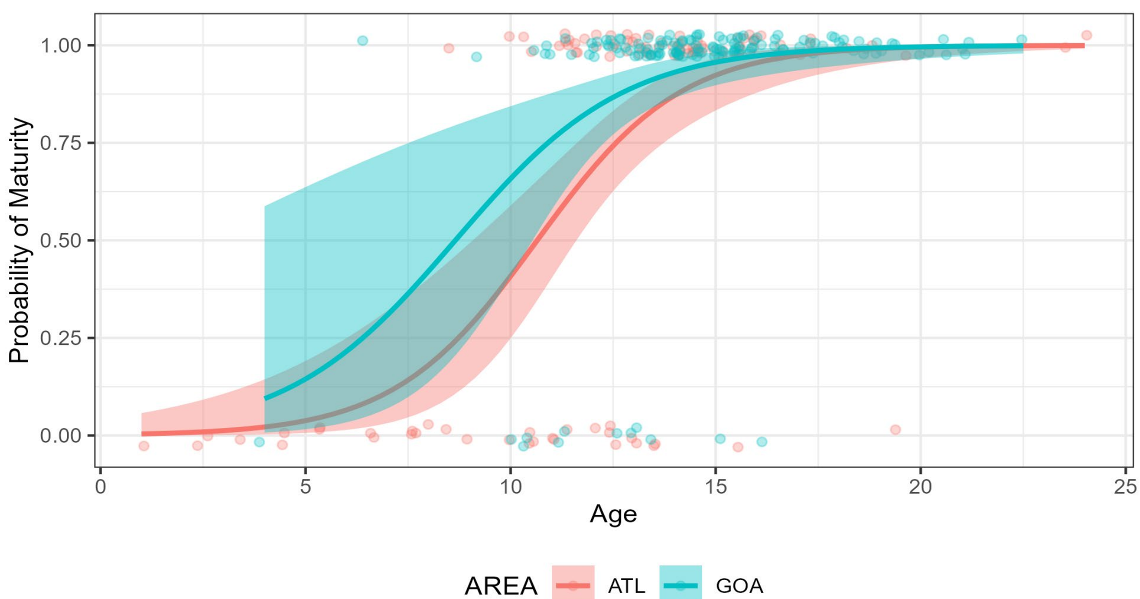

Figure 6. Age-at-maturity ogives (with 95% CL) for male sandbar sharks (*Carcharhinus plumbeus*) (ATL vs GOA) (SEDAR 101).

Table 10. Sex-, area- and SEDAR-specific age and length at 50 % maturity (with standard error).

SEX	AREA	SEDAR	*n*	L_{50} (cm)	L_{50}SE	A_{50} (year)	A_{50}SE
F	ATL	21	439	154.66	0.68	14.14	0.24
F	ATL	54	277	149.71	0.57	12.19	0.25
F	ATL	101	427	148.73	0.92	11.60	0.25
F	GOA	21	279	154.64	0.74	13.86	0.25
F	GOA	54	168	149.94	0.80	10.57	0.51
F	GOA	101	339	143.15	2.55	8.96	0.98
M	ATL	21	209	151.54	0.84	13.15	0.26
M	ATL	54	149	149.49	55.54	11.87	0.27
M	ATL	101	109	145.17	2.07	10.65	0.57
M	GOA	21	316	151.47	0.63	13.04	0.23
M	GOA	54	71	147.90	0.99	10.90	0.64
M	GOA	101	140	138.54	5.18	8.65	1.42

Table 11. Likelihood Ratio Tests for differences in area-, sex-, and SEDAR-specific length-based ogives.

Females ATL (n=427)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-291.3999			
2	6.0000	-256.5750	4.0000	69.6498	0.0000

Females GOA (n=339)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-196.1576			
2	6.0000	-159.5947	4.0000	73.1257	0.0000

Males ATL (n=109)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-140.1170			
2	6.0000	-104.8927	4.0000	70.4487	0.0000

Males GOA (n=140)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-137.3033			
2	6.0000	-114.3604	4.0000	45.8857	0.0000

Table 12. Likelihood Ratio Tests for differences in area-, sex-, and SEDAR-specific age-based ogives.

Females ATL (n=427)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-442.3593			
2	6.0000	-394.2728	4.0000	96.1730	0.0000

Females GOA (n=339)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-270.9931			
2	6.0000	-211.3839	4.0000	119.2184	0.0000

Males ATL (n=109)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-196.1945			
2	6.0000	-181.1964	4.0000	29.9961	0.0000

Males GOA (n=140)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)
1	2.0000	-192.0629			
2	6.0000	-167.4078	4.0000	49.3103	0.0000

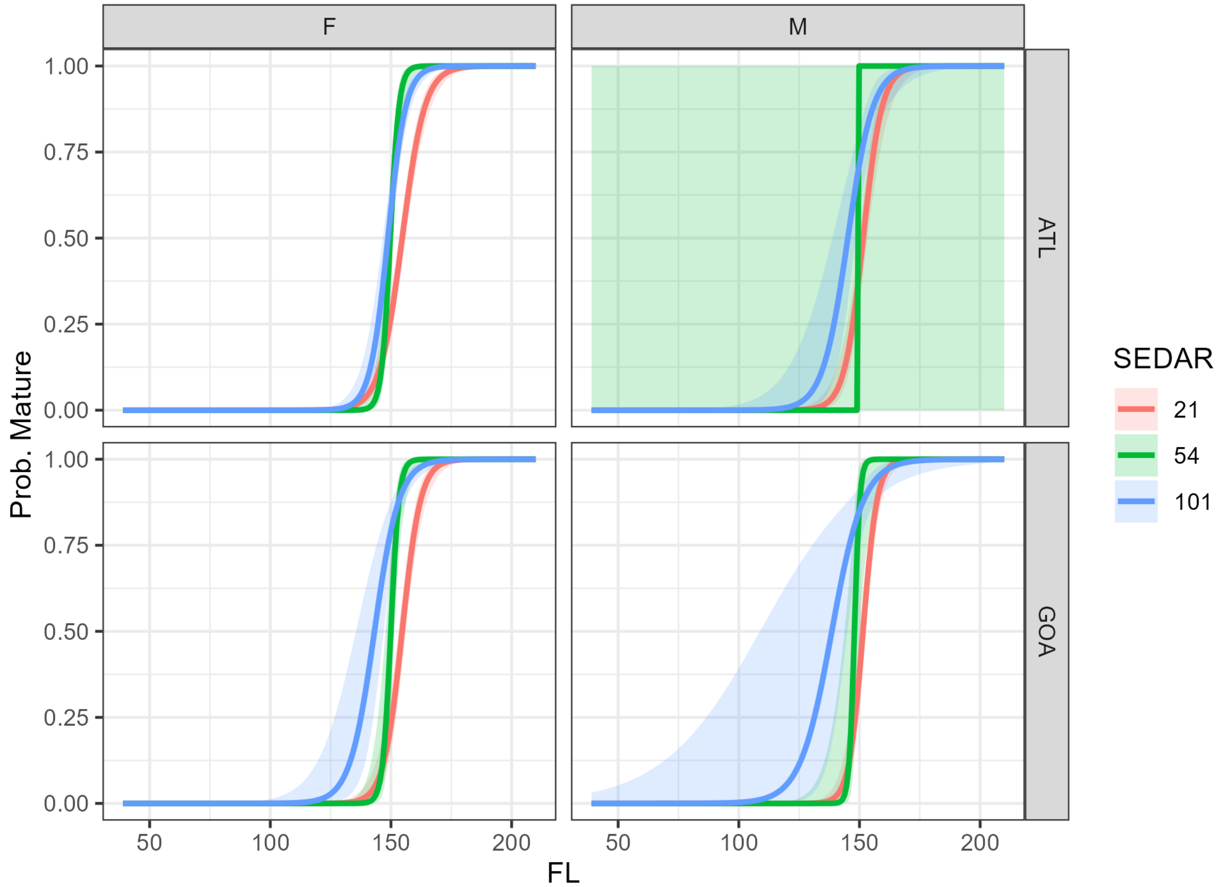

Figure 7. Area-, sex-, and SEDAR-specific length-at-maturity ogives (with 95% CL) for sandbar sharks (*Carcharhinus plumbeus*) in the western North Atlantic Ocean.

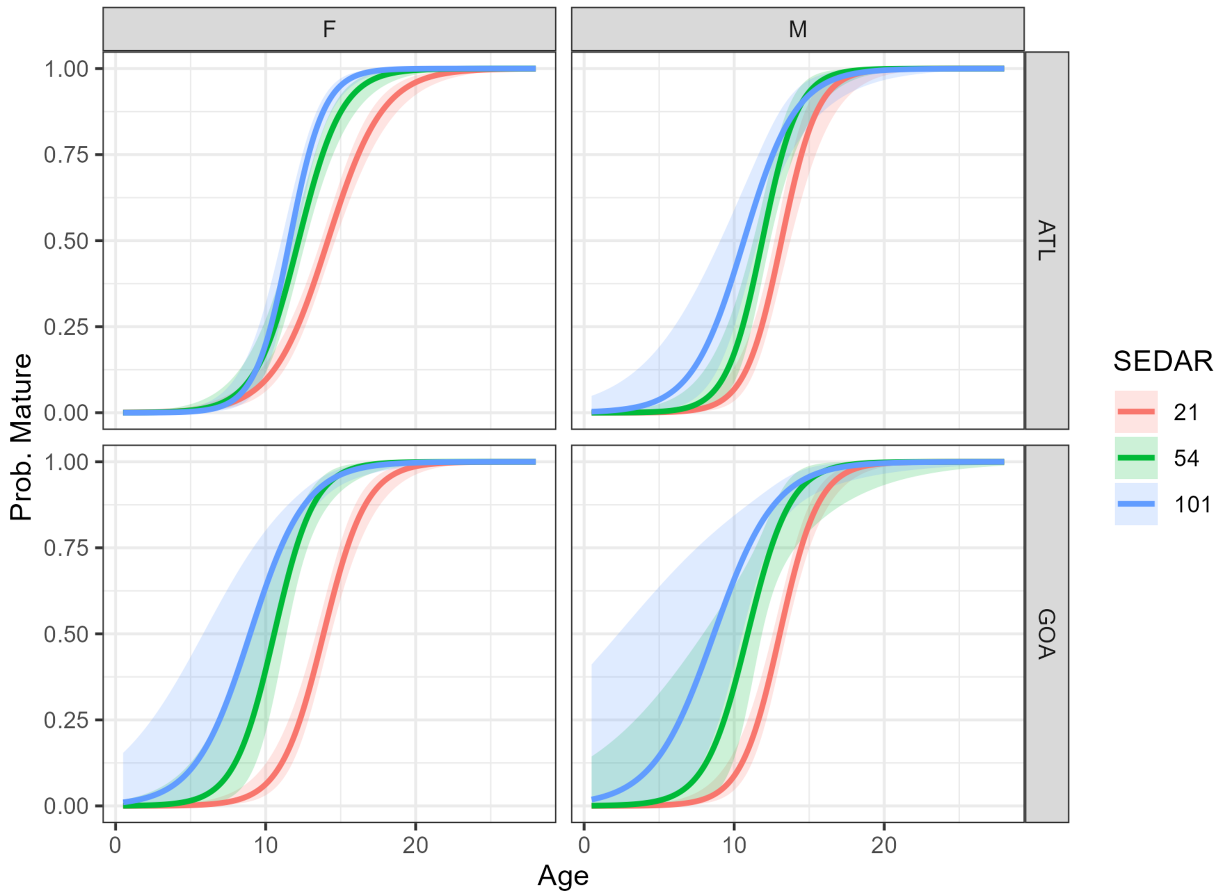

Figure 8. Area-, sex-, and SEDAR-specific age-at-maturity ogives (with 95% CL) for sandbar sharks (*Carcharhinus plumbeus*) in the western North Atlantic Ocean.

Table 13. Model parameter evaluation with maternal age as the primary predictor and geographic area (GOA vs. ATL) and the SEDAR assessment timeframe as covariates.

term	estimate	std.error	statistic	p.value	conf.low	conf.high
(Intercept)	1.523	0.152	10.010	0.000	1.225	1.822
AGE	0.028	0.008	3.522	0.000	0.012	0.044
AREAGOA	0.040	0.046	0.879	0.380	-0.049	0.130
SEDAR101	0.052	0.049	1.079	0.281	-0.043	0.148

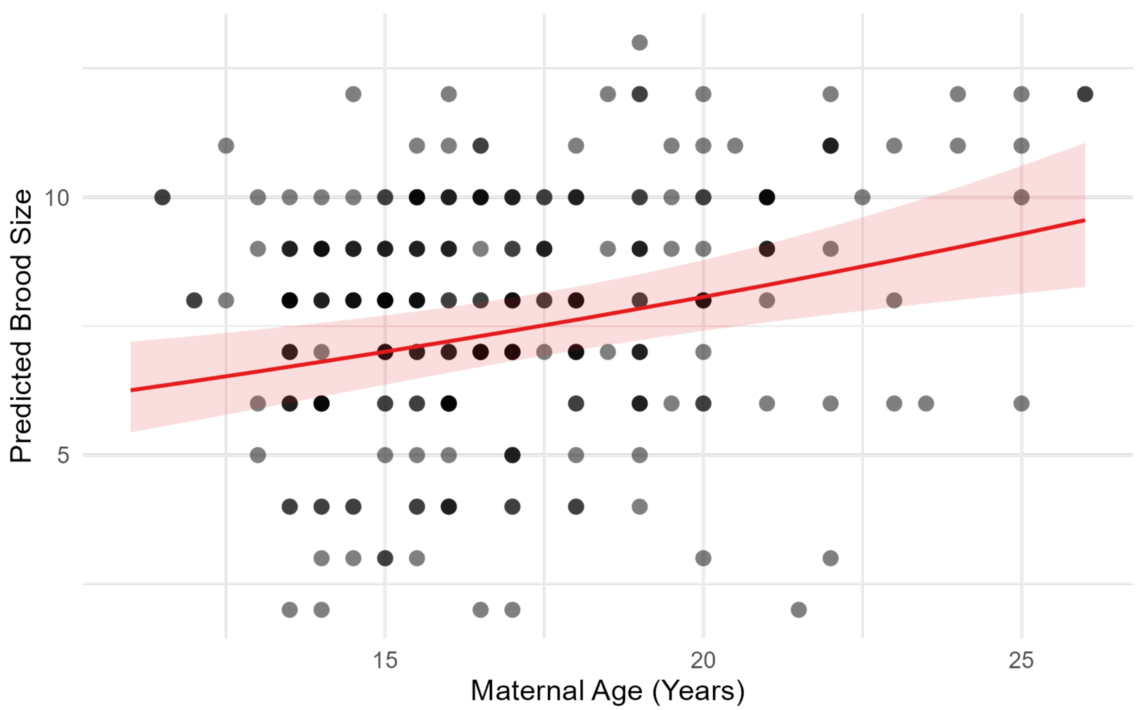

Figure 9. Relationship between brood size and maternal age for sandbar sharks (*Carcharhinus plumbeus*) in US waters of the western North Atlantic Ocean based on the Poisson GLM (with 95 % CL). Brood size = exp(1.630 + 0.025(Age)).

Table 14. Model parameter evaluation with maternal FL as the primary predictor and geographic area (GOA vs. ATL) and the SEDAR assessment timeframe as covariates.

term	estimate	std.error	statistic	p.value	conf.low	conf.high
(Intercept)	0.407	0.316	1.288	0.198	-0.210	1.028
FL	0.010	0.002	5.230	0.000	0.006	0.013
AREAGOA	0.051	0.033	1.556	0.120	-0.013	0.116
SEDAR101	0.013	0.039	0.339	0.735	-0.062	0.089

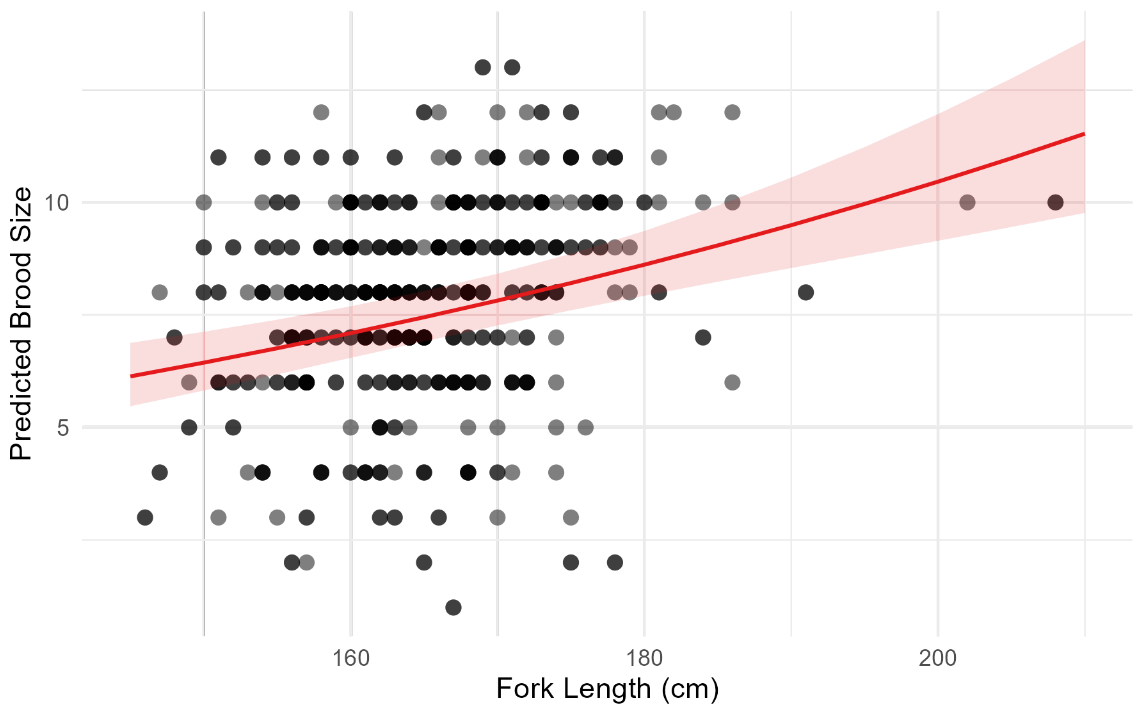

Figure 10. Relationship between brood size and maternal fork length (FL) for sandbar sharks (*Carcharhinus plumbeus*) in US waters of the western North Atlantic Ocean based on the Poisson GLM (with 95 % CL). Brood Size = exp(0.544 + 0.009(FL)).

Table 15. Reduced Maternal Age Model: Model Equation: ln(Brood Size) = 1.630 + 0.025(AGE), Overall Model *p*-value = < 0.001.

Predictor	Estimate	Standard Error	Z-Value	P-Value	95% CI Lower	95% CI Upper
(Intercept)	1.630	0.131	12.476	0.000	1.374	1.887
AGE	0.025	0.007	3.340	0.001	0.010	0.040

Table 16. Reduced Maternal Length (FL) Model: Model Equation: ln(Brood Size) = 0.544 + 0.009(FL),

Overall Model *p*-value = < 0.001.

Predictor	Estimate	Standard Error	Z-Value	P-Value	95% CI Lower	95% CI Upper
(Intercept)	0.544	0.300	1.810	0.07	-0.043	1.135
FL	0.009	0.002	5.037	0.00	0.006	0.013

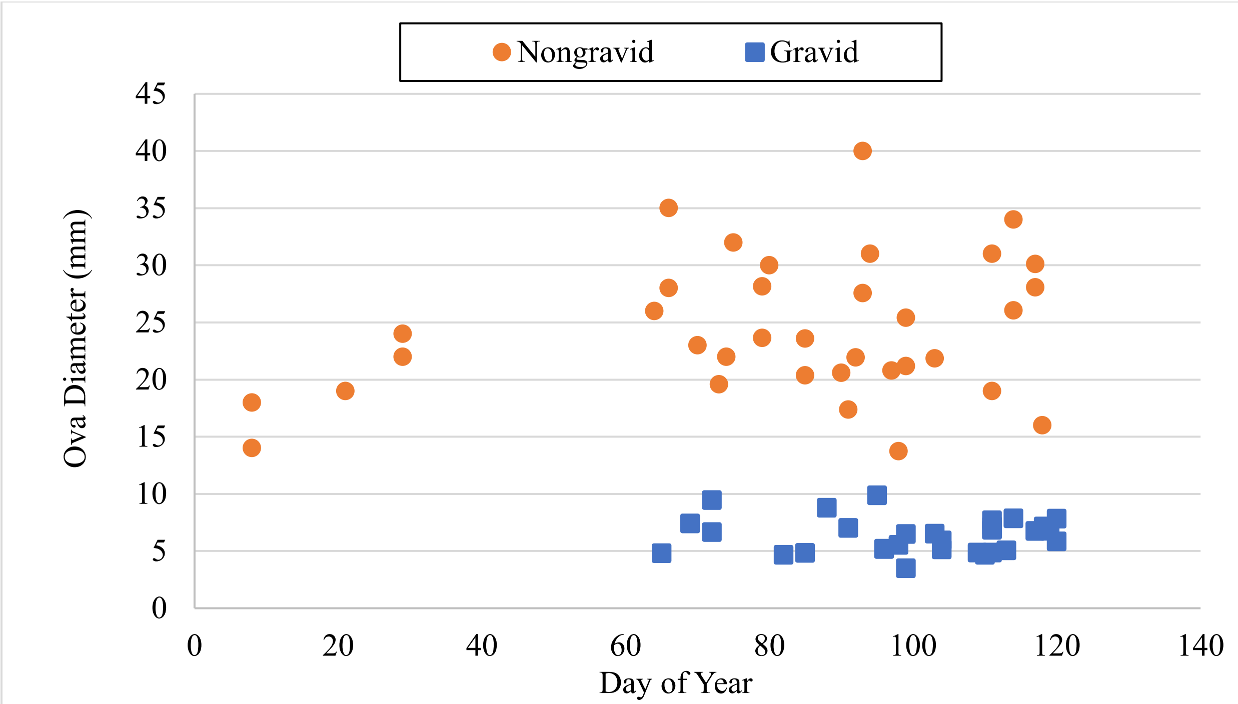

Figure 11. Mean ova diameter of gravid (2015-present) and nongravid female sandbars sharks with fork lengths greater than 170 cm (>100% maturity). Data were restricted to January to April to best describe ovarian activity prior to parturition.

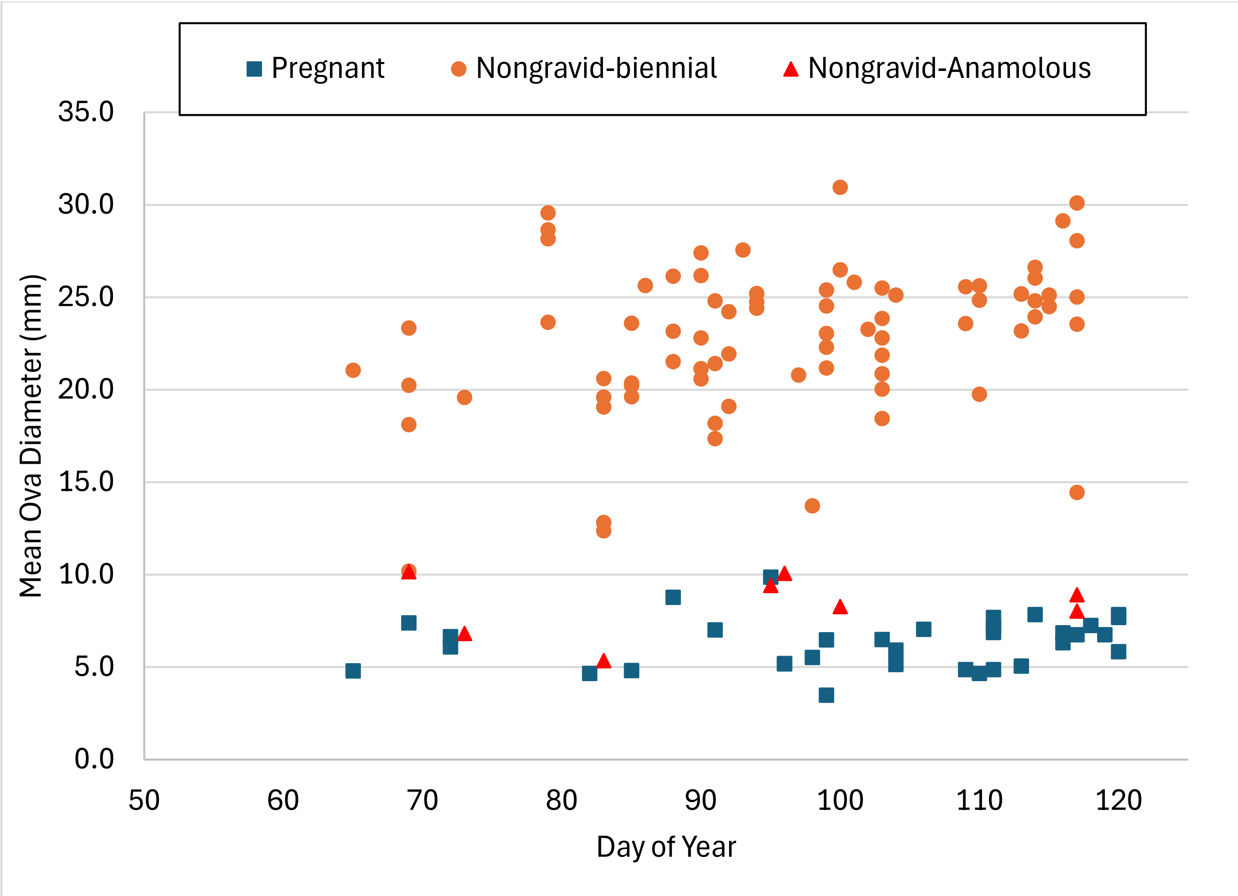

Figure 12. Mean ova diameter of gravid (2015-present) and nongravid female sandbars sharks > 50% maturity (147 cm FL) from 2015 to 2024 by day of year.

Appendix

Table A1. Predicted Proportions Mature by Sex for SEDAR 101 Combined Areas**.**

FL (cm)	Female	Male	Age (years)	Female	Male
50	0	0	0	0	0
60	0	0	0.5	0	0
70	0	0	1.5	0	0.01
80	0	0	2.5	0	0.01
90	0	0	3.5	0	0.02
100	0	0	4.5	0.01	0.04
110	0	0	5.5	0.01	0.07
120	0	0.01	6.5	0.03	0.11
130	0.01	0.09	7.5	0.06	0.19
140	0.14	0.37	8.5	0.12	0.29
150	0.67	0.79	9.5	0.23	0.42
160	0.96	0.96	10.5	0.4	0.56
170	1	0.99	11.5	0.6	0.7
180	1	1	12.5	0.77	0.8
190	1	1	13.5	0.88	0.88
200	1	1	14.5	0.94	0.93
210	1	1	15.5	0.97	0.96
			16.5	0.99	0.98
			17.5	0.99	0.99
			18.5	1	0.99
			19.5	1	1
			20.5	1	1

Table A2. Predicted Proportions Mature by Sex for SEDAR 101 for ATL.

FL (cm)	Female	Male	Age (years)	Female	Male
50	0	0	0	0	0
60	0	0	0.5	0	0
70	0	0	1.5	0	0.01
80	0	0	2.5	0	0.01
90	0	0	3.5	0	0.02
100	0	0	4.5	0	0.03
110	0	0	5.5	0	0.05
120	0	0.01	6.5	0.01	0.09
130	0.01	0.05	7.5	0.03	0.14
140	0.09	0.27	8.5	0.06	0.23
150	0.59	0.72	9.5	0.14	0.34
160	0.95	0.94	10.5	0.28	0.48
170	1	0.99	11.5	0.48	0.62
180	1	1	12.5	0.69	0.74
190	1	1	13.5	0.84	0.84
200	1	1	14.5	0.93	0.9
210	1	1	15.5	0.97	0.94
			16.5	0.99	0.97
			17.5	0.99	0.98
			18.5	1	0.99
			19.5	1	0.99
			20.5	1	1

Table A3. Predicted Proportions Mature by Sex for SEDAR 101 for GOA.

FL (cm)	Female	Male	Age (years)	Female	Male
50	0	0	0	0.01	0.01
60	0	0	0.5	0.01	0.02
70	0	0	1.5	0.02	0.03
80	0	0	2.5	0.03	0.05
90	0	0	3.5	0.05	0.08
100	0	0	4.5	0.08	0.12
110	0	0.01	5.5	0.13	0.18
120	0.01	0.06	6.5	0.21	0.26
130	0.07	0.21	7.5	0.31	0.36
140	0.35	0.56	8.5	0.44	0.48
150	0.79	0.85	9.5	0.57	0.6
160	0.96	0.96	10.5	0.7	0.71
170	0.99	0.99	11.5	0.8	0.8
180	1	1	12.5	0.87	0.87
190	1	1	13.5	0.92	0.91
200	1	1	14.5	0.95	0.95
210	1	1	15.5	0.97	0.97
			16.5	0.98	0.98
			17.5	0.99	0.99
			18.5	0.99	0.99
			19.5	1	0.99
			20.5	1	1