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Reproductive parameters of great hammerhead sharks (*Sphyrna mokarran*) and scalloped hammerhead sharks (*Sphyrna lewini*) from the western North Atlantic Ocean

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Introduction

Reproductive biology characteristics for hammerhead species (*Sphyrna spp.*) is limited for the western North Atlantic Ocean, including the Gulf of Mexico, with the exception of the bonnethead shark (*S. tiburo*). To provide estimates of these parameters for the great hammerhead shark (*S. mokarran*) and scalloped hammerhead shark (*S. lewini*), data was compiled from multiple collaborators across the eastern United States, representing both fishery-dependent and -independent sources.

Methods

In order to calculate estimates of size at maturity and age at maturity, data from the NOAA Fisheries Southeast Science Center (SEFSC), NOAA Fisheries Northeast Science Center (NEFSC), South Carolina Department of Natural Resources (SCDNR), Mote Marine Laboratory, Dauphin Island Sea Lab, individual Gulf of Mexico Shark Pupping and Nursery (GULFSPAN) survey contributors, and multiple universities across the region was compiled. Only data that included direct maturity assignation were included for analysis, excluding any data where maturity was estimated based on length. Regarding length, only animals in which measured fork

length was available were used. All ages used in analysis were obtained from Driggers et al. (2021) for great hammerhead and Frazier et al. (2021) for scalloped hammerhead.

Scalloped hammerhead maturity data from the east coast of the United States ("Atlantic") included data for the Carolina hammerhead, *Sphyrna gilberti* (n = 78), as well as genetically-confirmed hybrids (n = 24) since accurate field identification of these species is considered unreliable. It is acknowledged that this inclusion may affect maturity estimates, however all but one confirmed Carolina hammerhead and one hybrid were immature and under four years of age.

The statistical software R was used for all analyses conducted (R Core Team 2021). Models were fit by species, either great hammerhead or the scalloped hammerhead species complex. Within individual species analysis, regions (Gulf of Mexico or western North Atlantic Ocean) were analyzed combined and separately using maximum likelihood methods. This was repeated for the sexes, which were also analyzed separately and combined.

Binomial maturity data was fit to length and age maturity ogives using generalized linear models with a logit link, following the methods of Natanson et al. (2019). To accomplish this, probability that an individual i was mature (p_i) was modeled as the outcome of a Bernoulli random variable, with $y_i = 0$ or $y_i = 1$, for immature and mature individuals, respectively (Natanson et al., 2019):

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

The value of p_i is then modeled as a function of both fork length and age separately as:

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

where p_i is constrained between 0 and 1 via the logit link function, β_0 is the mean probability that a shark is mature, and β_1 is the effect of $Size_i$, which is either fork length or age of an individual (Natanson et al., 2019).

Length at 50% maturity (L_{50}) and age at 50% maturity (A_{50}) were calculated for sexes combined and separately. The 'boot' package in R was used to calculate 95% confidence intervals (Canty and Ripley, 2021; Davidson and Hinkley, 1997). Code was modified from that used in Natanson et al. (2019).

Results

Maturity status information was available for a total of 751 great hammerhead sharks to evaluate length at maturity (Table 1). Of these, the majority of specimens came from the Gulf of Mexico (n = 617). No males under 100 cm and no females below 200 cm were available for the Atlantic region, (Table 1). Median length at maturity was 200.56 cm (L_{50} SE = 1.63, a = -19.144, b = 0.095) and 206.83 cm (L_{50} SE = 2.89; a = -21.286, b = 0.103) for males and females, respectively (Table 2).There was a significant difference in length at 50% maturity between the Atlantic and Gulf of Mexico for sexes combined (p = 0.04), which was influenced by males (p = 0.04) but not females (p = 0.21), due to the low number of females (n = 13) that came from the Atlantic coast, of which only two were immature (Table 2, Figure 1). The largest immature male

was 225.0 cm, and the smallest mature male was 170.0 cm (Table 1). Size of immature females ranged from 48.0 – 222.0 cm, and mature females were 173.0 – 360.0 cm in length (Table 1).

For age-at-maturity, only 86 great hammerhead sharks had associated ages (Table 4), with no Age-0 individuals present in the dataset, and a higher proportion coming from the Gulf of Mexico (n = 55). Therefore, additional samples are needed in order to increase confidence in the results presented in Table 5 and Figure 2. The age at which 50% of males were mature for both regions combined was 7.8 (A_{50} SE = 0.49, a = -8.876, b = 1.137) years, and it was 8.1 (A_{50} SE = 0.70, a = -7.569, b = 0.937) years for females (Table 5). Both males and females were immature up to 9 years of age, and both sexes matured as young as 6 years of age (Tables 4 and 6). Of the 21 pregnant females in the dataset, only four had pup information available, so no evaluation of brood size at length was conducted (Table 7).

Maturity status information was available for 1,537 scalloped hammerhead specimens, of which 945 were captured in the Gulf of Mexico (Table 8). Length at median maturity for males was 158.31 cm FL (L_{50} SE = 1.99, a = -21.937, b = 0.139) in the Atlantic, which includes Carolina hammerhead sharks and hybrids, and 142.94 cm (L_{50} SE = 1.55, a = -17.544, b = 0.123) in the Gulf of Mexico (Table 9). For females, L_{50} was 187.54 cm (L_{50} SE = 3.13, a = -45.626, b = 0.243) and 176.50 cm (L_{50} SE = 16.80, a = -4941.910, b = 28.000) for the Atlantic and Gulf of Mexico, respectively (Table 9). High levels of uncertainty in Gulf of Mexico values for females was due to the low sample size. Generalized linear models fit to the data showed a significant difference in L_{50} between the Atlantic and Gulf of Mexico with sexes combined ($p < 0.001$), due to a significant difference in males ($p < 0.001$; Table 9, Figure 3). No significant difference was detected for females between regions ($p = 0.13$). Immature males ranged in size from 27.6 – 192.0 cm, and immature females were 27.0 – 196.0 cm in length (Table 8). The smallest mature male was 134.0 cm, and the smallest female was 177.0 cm in length (Table 8).

Ages were available for 633 animals to estimate age-at-maturity in scalloped hammerhead sharks (Table 11). In the Atlantic region, 50% of males matured at 12.4 years (A_{50} SE = 0.44, a = -7.670, b = 0.619), and females at 16.2 years (A_{50} SE = 0.78, a = -11.652, b = 0.721; Table 12). Within the Gulf of Mexico, male median maturity at age was 8.6 years (A_{50} SE = 0.57, a = -8.080, b = 2.84), and female A_{50} was 13.9 years (A_{50} SE = 6797.88, a = -55.677, b = 4.009; Table 12). Only one mature female was aged in this region, resulting in high levels of uncertainty. Males were immature up to 16.5 years of age, while females were immature up to 17.5 years (Table 11). Earliest maturity was seen at 7.5 years of age for males, and at 14.5 years for females (Tables 11 and 13). A significant difference between regions was also present for A_{50} with sexes combined ($p < 0.001$), again due to males ($p < 0.001$; Table 12, Figure 4). No significant difference was detected for females ($p = 0.80$). A total of 47 females were pregnant, however only seven had pup information available, which are catalogued in Table 14.

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Table 1. Sex, capture location, maturity status and fork lengths used to evaluate potential differences in length-at-maturity for great hammerhead (*Sphyrna mokarran*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	Immature	2	207.0	214.5	202	48.0	222.0	204	48.0	222.0
	Mature	11	228.0	309.0	58	173.0	360.0	69	173.0	360.0
	Combined	13	207.0	309.0	260	48.0	360.0	273	48.0	360.0
Male	Immature	31	100.0	225.0	254	50.0	221.0	285	50.0	225.0
	Mature	90	180.0	291.0	103	170.0	298.0	193	170.0	298.0
	Combined	121	100.0	291.0	357	50.0	298.0	478	50.0	298.0
Combined	Immature	33	100.0	225.0	456	48.0	222.0	489	48.0	225.0
	Mature	101	180.0	309.0	161	170.0	360.0	262	170.0	360.0
	Combined	134	100.0	309.0	617	48.0	360.0	751	48.0	360.0

Table 2. Great hammerhead (*Sphyrna mokarran*) sex-specific, combined sex and region-specific lengths at which 50% of the specimens were mature (L_{50}), with minimum and maximum fork lengths (FL) reported.

	Sex	L_{50} (SE)	*a* (SE)	*b* (SE)	Min FL (cm)	Max FL (cm)
Atlantic	Female	221.29 (6570.27)	-707.87 (692543.91)	3.20 (3116.02)	207.0	309.0
	Male	194.10 (3.76)	-16.83 (3.39)	0.09 (0.02)	100.0	291.0
	Combined	195.36 (3.74)	-16.43(3.23)	0.08 (0.02)	100.0	309.0
Gulf of Mexico	Female	203.64 (1.64)	-21.53 (3.70)	0.10 (0.02)	48.0	360.0
	Male	202.67 (1.98)	-19.26 (2.30)	0.10 (0.01)	50.0	298.0
	Combined	203.64 (1.64)	-19.91 (1.94)	0.10 (0.01)	48.0	360.0
Combined	Female	206.83 (2.89)	-21.29 (3.53)	0.10 (0.02)	48.0	360.0
	Male	200.56 (1.63)	-19.14 (1.89)	0.10 (0.01)	50.0	298.0
	Combined	202.11 (1.41)	-19.64(1.65)	0.10 (0.01)	48.0	360.0

Table 3. Proportion of mature great hammerhead sharks (*Sphyrna mokarran*) in 5 cm length bins. Size bins where no data was available are represented by "NA".

Fork Length (cm)	Females	Males	Sexes Combined
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	0.00	0.00	0.00
100	0.00	0.00	0.00
105	0.00	NA	0.00
110	0.00	0.00	0.00
115	0.00	0.00	0.00
120	0.00	0.00	0.00
125	0.00	0.00	0.00
130	0.00	0.00	0.00
135	0.00	0.00	0.00
140	0.00	0.00	0.00
145	0.00	0.00	0.00
150	0.00	0.00	0.00
155	0.00	0.00	0.00
160	0.00	0.00	0.00
165	0.00	0.00	0.00
170	0.00	0.04	0.03
175	0.08	0.09	0.09
180	0.13	0.13	0.13
185	0.00	0.14	0.11
190	0.33	0.38	0.37
195	0.00	0.30	0.22
200	0.45	0.54	0.51
205	0.40	0.67	0.61
210	0.33	0.38	0.37
215	0.80	0.84	0.83
220	1.00	0.84	0.85
225	0.67	0.84	0.80
230	1.00	1.00	1.00
235	1.00	1.00	1.00

Table 3 *continued*.

Fork Length (cm)	Females	Males	Sexes Combined
240	1.00	1.00	1.00
245	1.00	1.00	1.00
250	1.00	1.00	1.00
255	1.00	1.00	1.00
260	NA	1.00	1.00
265	1.00	1.00	1.00
270	1.00	1.00	1.00
275	1.00	1.00	1.00
280	NA	1.00	1.00
285	NA	1.00	1.00
290	1.00	NA	1.00
295	1.00	1.00	1.00
300	1.00	1.00	1.00
305	1.00	NA	1.00
310	1.00	NA	1.00
315	NA	NA	NA
320	1.00	NA	1.00
325	1.00	NA	1.00
330	NA	NA	NA
335	NA	NA	NA
340	NA	NA	NA
345	NA	NA	NA
350	1.00	NA	1.00
355	NA	NA	NA
360	1.00	NA	1.00

Table 4. Sex, capture location, maturity status and estimated ages used to evaluate potential differences in age-at-maturity for great hammerhead (*Sphyrna mokarran*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)
Female	Immature	2	7	9	13	2	9	15	2	9
	Mature	6	11	32	13	6	24	19	6	32
	Combined	8	7	32	26	2	24	34	2	32
Male	Immature	6	4	9	20	1	9	26	1	9
	Mature	17	6	26	9	8	25	26	6	26
	Combined	23	4	26	29	1	25	52	1	26
Combined	Immature	8	4	9	33	1	9	41	1	9
	Mature	23	6	32	22	6	25	45	6	32
	Combined	31	4	32	55	1	25	86	1	32

Table 5. Great hammerhead (*Sphyrna mokarran*) sex-specific, combined sex and region-specific ages at which 50% of the specimens were mature (A_{50}), along with minimum and maximum ages observed for individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

	Sex	A_{50} (SE)	*a* (SE)	*b* (SE)	Min Age (yr)	Max Age (yr)
Atlantic	Female	10.0 (1086.59)	-221.90 (243225.34)	22.22 (24132.29)	7	32
	Male	7.2 (0.77)	-6.35 (3.22)	0.88 (0.41)	4	26
	Combined	7.7 (0.71)	-6.46 (2.90)	0.84 (0.35)	4	32
Gulf of Mexico	Female	7.6 (0.77)	-7.49 (2.85)	0.99 (0.38)	2	24
	Male	8.6 (0.80)	-12.72 (6.63)	1.48 (0.79)	1	25
	Combined	8.0 (0.56)	-9.06 (2.51)	1.12 (0.32)	1	25
Combined	Female	8.1 (0.70)	-7.57 (2.67)	0.94 (0.32)	2	32
	Male	7.8 (0.49)	-8.88 (2.61)	1.14 (0.34)	1	26
	Combined	7.9 (0.41)	-8.21 (1.84)	1.04 (0.23)	1	32

Table 6. Proportion of mature great hammerhead sharks (*Sphyrna mokarran*) in 1 year age bins. Age bins where no data was available are represented by "NA".

Age (yr)	Females	Males	Sexes Combined
0	NA	NA	NA
1	NA	0.00	0.00
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	0.25	0.14	0.18
7	0.33	0.50	0.40
8	NA	0.67	0.67
9	0.00	0.60	0.43
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	NA	1.00	1.00
15	1.00	NA	1.00
16	1.00	1.00	1.00
17	1.00	1.00	1.00
18	NA	1.00	1.00
19	NA	NA	NA
20	NA	1.00	1.00
21	NA	NA	NA
22	NA	NA	NA
23	NA	NA	NA
24	1.00	NA	1.00
25	1.00	1.00	1.00
26	NA	1.00	1.00
27	NA	NA	NA
28	NA	NA	NA
29	NA	NA	NA
30	NA	NA	NA
31	NA	NA	NA
32	1.00	NA	1.00

Table 7. Maternal fork length, maternal age, catch month, and number of pups for pregnant Great hammerhead (*Sphyrna mokarran*) females collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico. Individuals without pup counts (n = 17) are excluded from the table.

	FL (cm)	Age (yr)	Catch Month	Female Pups	Male Pups	Total Pups
Atlantic	272	--	July	13	18	31
	298	16	October	16	10	26
	303	25	April	16	19	35
Gulf of Mexico	237	--	May	--	--	29
	325	--	--	--	--	14

-- information not available

Table 8. Sex, capture location, maturity status and fork lengths used to evaluate potential differences in length-at-maturity for scalloped hammerhead (*Sphyrna lewini*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	Immature	153	27.0	196.0	254	31.0	176.0	407	27.0	196.0
	Mature	31	188.0	243.0	35	177.0	255.0	66	177.0	255.0
	Combined	184	27.0	243.0	289	31.0	255.0	473	27.0	255.0
Male	Immature	206	27.6	183.0	377	28.0	192.0	583	27.6	192.0
	Mature	202	144.0	287.0	279	134.0	289.0	481	134.0	289.0
	Combined	408	27.6	287.0	656	28.0	289.0	1064	27.6	289.0
Combined	Immature	359	27.0	196.0	631	28.0	192.0	990	27.0	196.0
	Mature	233	144	287.0	314	134.0	289.0	547	134.0	289.0
	Combined	592	27.0	287.0	945	28.0	289.0	1537	27.0	289.0

Table 9. Scalloped hammerhead (*Sphyrna lewini*) sex-specific, combined sex and region-specific lengths at which 50% of the specimens were mature (L_{50}), with minimum and maximum fork lengths (FL) reported. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals.

	Sex	L_{50} (SE)	*a* (SE)	*b* (SE)	Min FL (cm)	Max FL (cm)
Atlantic	Female	187.54 (3.13)	-45.63 (19.93)	0.24 (0.10)	27.0	243.0
	Male	158.31 (1.99)	-21.94 (3.24)	0.14 (0.02)	27.6	287.0
	Combined	161.58 (1.80)	-19.66 (2.43)	0.12 (0.01)	27.0	287.0
Gulf of Mexico	Female	176.50 (16.80)	-4941.91 (166040.49)	28.00 (940.67)	31.0	255.0
	Male	142.94 (1.55)	-17.54 (1.81)	0.12 (0.01)	28.0	289.0
	Combined	145.42 (1.40)	-18.05 (1.68)	0.12 (0.01)	28.0	289.0
Combined	Female	183.93 (3.18)	-35.35 (10.57)	0.19 (0.06)	27.0	255.0
	Male	147.48 (1.35)	-16.13 (1.30)	0.11 (0.01)	27.6	289.0
	Combined	151.02 (1.23)	-15.60 (1.10)	0.10 (0.01)	27.0	289.0

Table 10. Proportion of mature scalloped hammerhead sharks (*Sphyrna lewini*) in 5 cm length bins. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals. Size bins where no data was available are represented by "NA".

	Females			Males			Sexes Combined		
Fork Length (cm)	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined
30	0.00	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	NA	0.00	NA	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
130	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
135	0.00	0.00	0.00	0.00	0.23	0.20	0.00	0.16	0.14
140	0.00	0.00	0.00	0.00	0.57	0.44	0.00	0.44	0.35
145	0.00	0.00	0.00	0.13	0.63	0.46	0.07	0.53	0.33
150	NA	0.00	0.00	0.43	0.71	0.64	0.43	0.65	0.60
155	0.00	NA	0.00	0.33	0.80	0.69	0.20	0.80	0.60
160	0.00	0.00	0.00	0.50	0.85	0.72	0.40	0.77	0.62
165	0.00	NA	0.00	0.60	1.00	0.88	0.50	1.00	0.83
170	NA	NA	NA	0.60	0.90	0.81	0.60	0.90	0.81
175	0.00	NA	0.00	0.96	0.96	0.96	0.88	0.96	0.92
180	0.00	0.50	0.33	0.92	0.94	0.93	0.89	0.91	0.90
185	NA	NA	NA	0.96	1.00	0.98	0.96	1.00	0.98
190	0.67	1.00	0.75	1.00	1.00	1.00	0.94	1.00	0.98
195	0.80	1.00	0.83	1.00	0.96	0.97	0.95	0.96	0.96
200	0.86	NA	0.86	1.00	1.00	1.00	0.96	1.00	0.98
205	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 10 *continued.*

Fork Length (cm)	Females			Males			Sexes Combined		
	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined
210	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
215	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
220	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
225	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
230	1.00	1.00	1.00	1.00	NA	1.00	1.00	1.00	1.00
235	NA	1.00	1.00	1.00	NA	1.00	1.00	1.00	1.00
240	NA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
245	1.00	1.00	1.00	1.00	NA	1.00	1.00	1.00	1.00
250	NA	1.00	1.00	1.00	NA	1.00	1.00	1.00	1.00
255	NA	1.00	1.00	NA	NA	NA	NA	1.00	1.00
260	NA	NA	NA	NA	NA	NA	NA	NA	NA
265	NA	NA	NA	NA	NA	NA	NA	NA	NA
270	NA	NA	NA	NA	NA	NA	NA	NA	NA
275	NA	NA	NA	NA	NA	NA	NA	NA	NA
280	NA	NA	NA	NA	NA	NA	NA	NA	NA
285	NA	NA	NA	NA	NA	NA	NA	NA	NA
290	NA	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00

Table 11. Sex, capture location, maturity status and estimated ages used to evaluate potential differences in age-at-maturity for scalloped hammerhead (*Sphyrna lewini*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)
Female	Immature	152	0	17.5	55	0	8.5	207	0	17.5
	Mature	12	14.5	25.5	1	19.5	19.5	13	14.5	25.5
	Combined	164	0	25.5	56	0	19.5	220	0	25.5
Male	Immature	188	0	16.5	50	0	10.5	238	0	16.5
	Mature	107	9	39.5	68	7.5	37.5	175	7.5	39.5
	Combined	295	0	39.5	118	0	37.5	413	0	39.5
Combined	Immature	340	0	17.5	105	0	10.5	445	0	17.5
	Mature	119	9	39.5	69	7.5	37.5	188	7.5	39.5
	Combined	459	0	39.5	174	0	37.5	633	0	39.5

Table 12. Scalloped hammerhead (*Sphyrna lewini*) sex-specific, combined sex and region-specific ages at which 50% of the specimens were mature (A_{50}), along with minimum and maximum ages observed for individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals.

	Sex	A_{50} (SE)	*a* (SE)	*b* (SE)	Min Age (yr)	Max Age (yr)
Atlantic	Female	16.2 (0.78)	-11.65 (3.84)	0.72 (0.25)	0	25.5
	Male	12.4 (0.44)	-7.67 (1.31)	0.62 (0.10)	0	39.5
	Combined	13.3 (0.38)	-7.68 (1.06)	0.58 (0.08)	0	39.5
Gulf of Mexico	Female	13.9 (6797.88)	-55.68 (62741.45)	4.01 (4967.34)	0	19.5
	Male	8.6 (0.57)	-8.08 (2.84)	0.94 (0.32)	0	37.5
	Combined	8.9 (0.50)	-9.09 (2.94)	1.02 (0.34)	0	37.5
Combined	Female	16.1 (0.75)	-11.98 (3.80)	0.74 (0.24)	0	25.5
	Male	11.3 (0.40)	-6.32 (0.82)	0.56 (0.07)	0	39.5
	Combined	12.3 (0.36)	-6.51 (0.70)	0.53 (0.05)	0	39.5

Table 13. Proportion of mature scalloped hammerhead sharks (*Sphyrna lewini*) in 1 year age bins. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals. Age bins where no data was available are represented by "NA".

	Females			Males			Sexes Combined		
Age (yr)	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.40	0.22	0.00	0.29	0.17
9	0.00	0.00	0.00	0.14	0.60	0.33	0.13	0.50	0.29
10	0.00	NA	0.00	0.00	0.50	0.20	0.00	0.50	0.13
11	0.00	NA	0.00	0.33	0.50	0.38	0.20	0.50	0.25
12	0.00	NA	0.00	0.43	1.00	0.64	0.27	1.00	0.47
13	0.00	NA	0.00	0.50	NA	0.50	0.43	NA	0.43
14	0.00	NA	0.00	0.71	1.00	0.79	0.59	1.00	0.68
15	0.50	NA	0.50	0.88	1.00	0.93	0.75	1.00	0.84
16	0.67	NA	0.67	0.88	1.00	0.91	0.82	1.00	0.86
17	0.00	NA	0.00	0.70	1.00	0.82	0.64	1.00	0.78
18	0.50	NA	0.50	1.00	1.00	1.00	0.85	1.00	0.87
19	1.00	NA	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 13 *continued.*

	Females			Males			Sexes Combined		
Age (yr)	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined	Atlantic	Gulf of Mexico	Areas Combined
21	1.00	NA	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	NA	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00
23	1.00	NA	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	1.00	NA	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25	NA	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00
26	1.00	NA	1.00	1.00	NA	1.00	1.00	NA	1.00
27	NA	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00
28	NA	NA	NA	1.00	NA	1.00	1.00	NA	1.00
29	NA	NA	NA	1.00	NA	1.00	1.00	NA	1.00
30	NA	NA	NA	1.00	NA	1.00	1.00	NA	1.00
31	NA	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00
32	NA	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00
33	NA	NA	NA	NA	1.00	1.00	NA	1.00	1.00
34	NA	NA	NA	1.00	NA	1.00	1.00	NA	1.00
35	NA	NA	NA	NA	NA	NA	NA	NA	NA
36	NA	NA	NA	NA	NA	NA	NA	NA	NA
37	NA	NA	NA	NA	NA	NA	NA	NA	NA
38	NA	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00
39	NA	NA	NA	NA	NA	NA	NA	NA	NA
40	NA	NA	NA	1.00	NA	1.00	1.00	NA	1.00

Table 14. Maternal fork length, maternal age, catch month, and number of pups for pregnant scalloped hammerhead (*Sphyrna lewini*) females collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico. Individuals without pup counts (n = 40) are excluded from the table.

	FL (cm)	Age (yr)	Catch Month	Female Pups	Male Pups	Total Pups
Atlantic	204	19.5	May	16	14	30
	204	23.5	April	6	5	11
	210	14.5	April	10	8	18
	221	20.5	April	4	3	7
	226	25.5	April	11	10	21
Gulf of Mexico	229	--	April	--	--	15
Unknown^	216	18.5	September	8	7	15

^Excluded from analysis due to region not being known

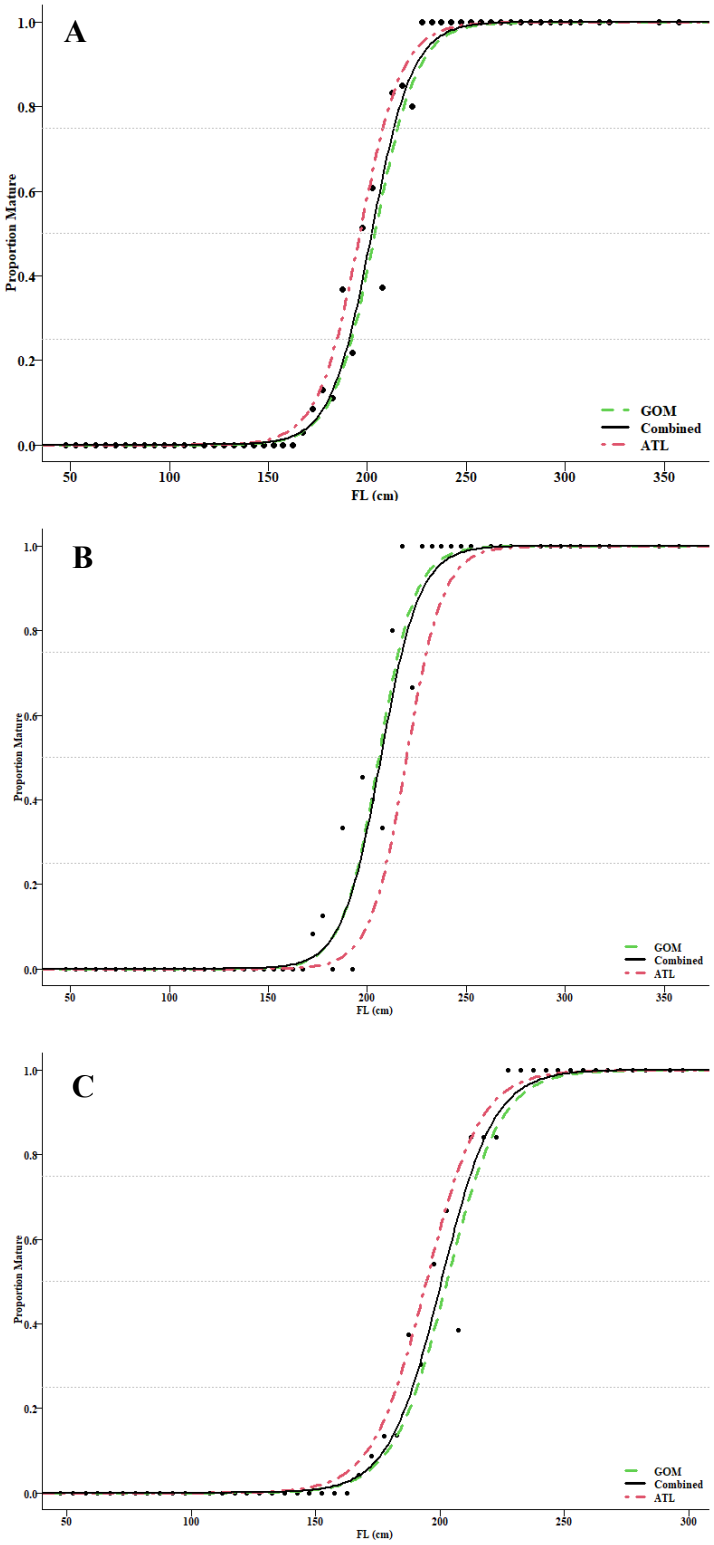

Figure 1. Proportion mature at length for great hammerhead (*Sphyrna mokarran*) for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line.

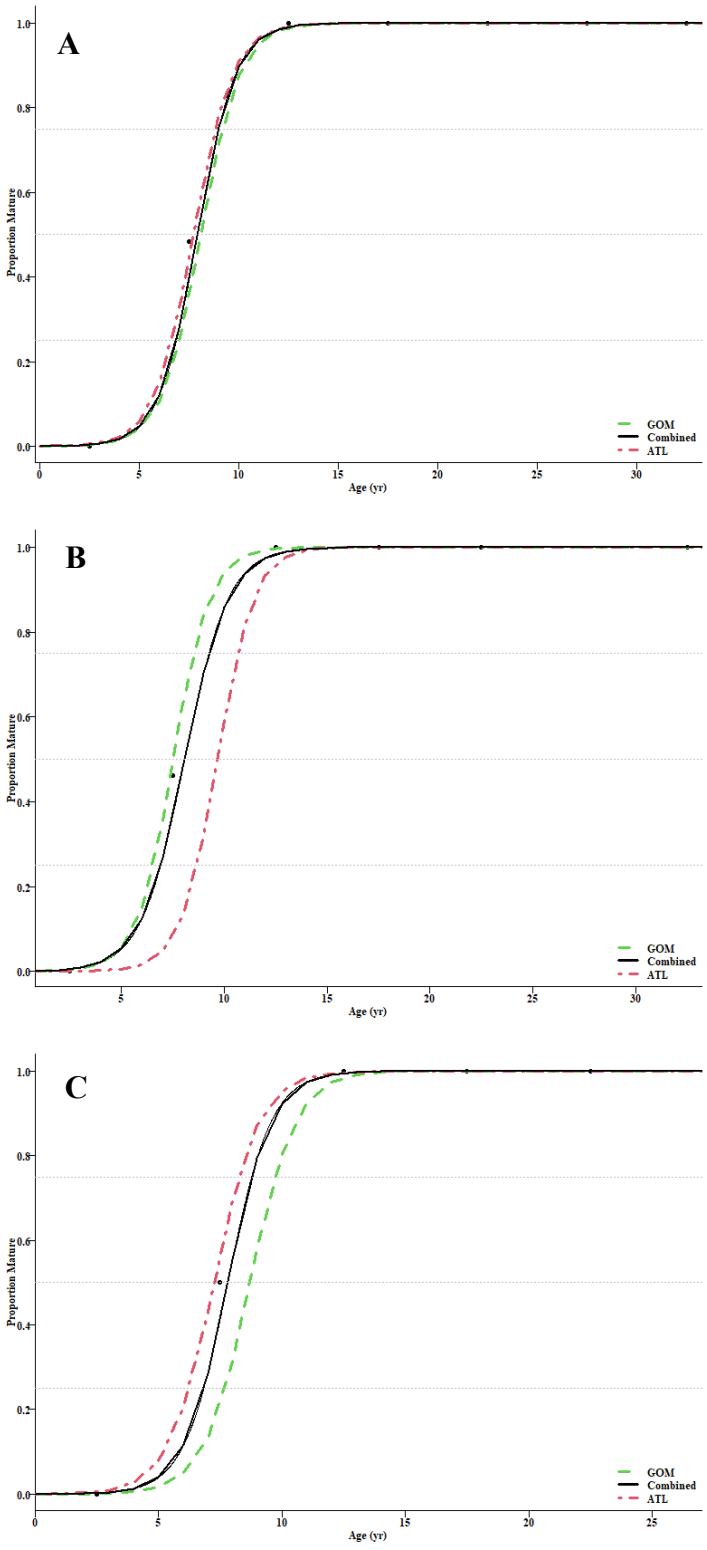

Figure 2. Proportion mature at age for great hammerhead (*Sphyrna mokarran*) for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line.

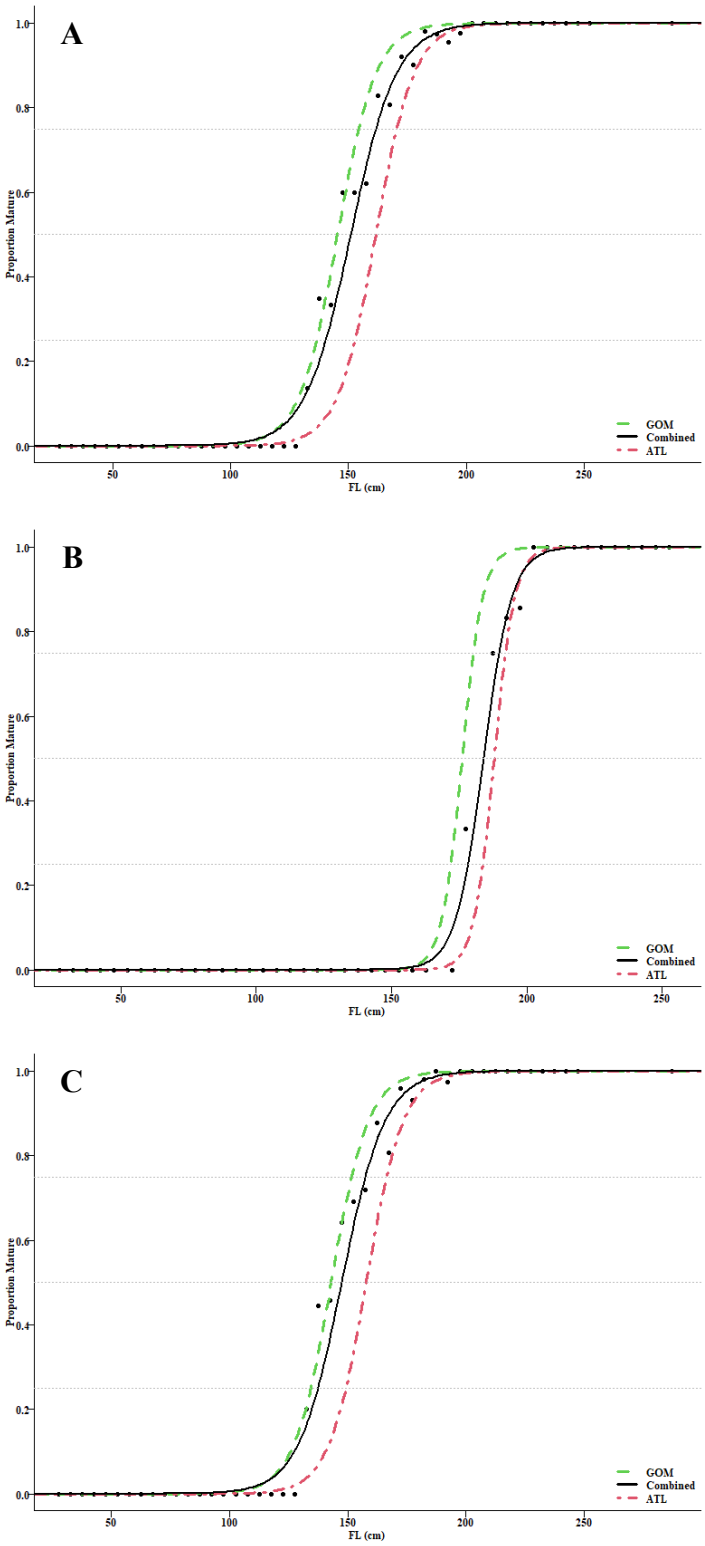

Figure 3. Proportion mature at length for scalloped hammerhead (*Sphyrna lewini* for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals.

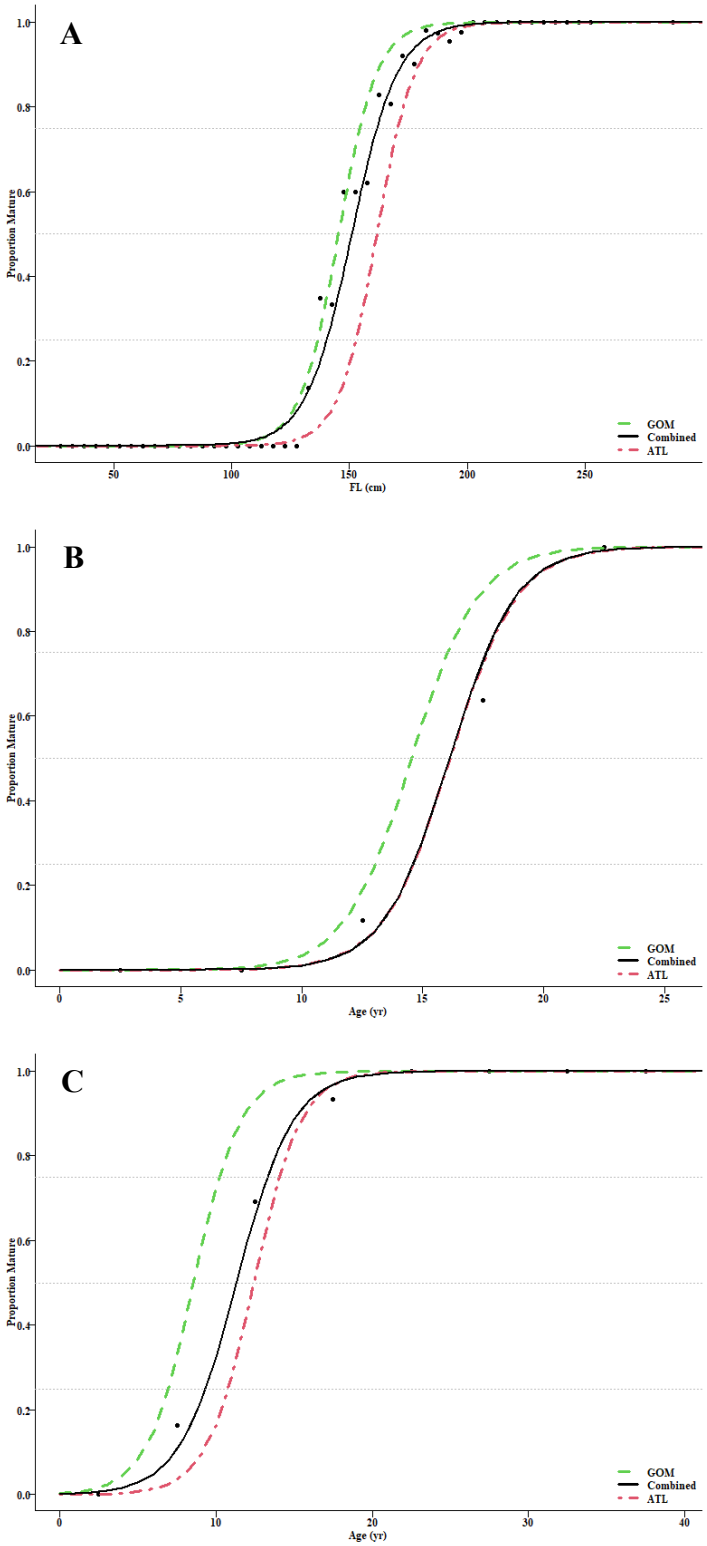

Figure 4. Proportion mature at age for scalloped hammerhead (*Sphyrna lewini*) for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line. Atlantic region also includes Carolina hammerhead (*Sphyrna gilberti*) and hybrid individuals.