Life history traits of bonnethead sharks, *Sphyrna tiburo*, from the eastern Gulf of Mexico

Linda A. Lombardi-Carlson, NOAA Fisheries Service, 3500 Delwood Beach Road
Panama City, FL 32408, Email: Linda.Lombardi@noaa.gov

Abstract

Life-history traits (size at age, growth rates, size and age at maturity, and fecundity estimates) of bonnethead sharks, *Sphyrna tiburo*, were analyzed for sharks collected along Florida's Gulf of Mexico coastline between March 1998 and September 2000. A total of 539 sharks were collected. Females obtained a larger predicted asymptotic size (1139 mm and 907 mm TL, respectively) at a slower rate (0.22 mm yr^{-1} and .36 mm yr^{-1}, respectively) than males for areas combined. Males reached median size at a smaller size (721 mm TL and 821 mm TL, respectively) and at a younger age than females (2.0+ yrs and 3.0+ yrs, respectively). A fecundity estimate of 10 (std. ± 3) pups per year was determined from 50 litters.

Introduction

Sphyrna tiburo inhabits shallow, inshore waters of the Western Atlantic and the Eastern Pacific (Compagno 1984). This species feeds mainly on benthic prey items such as crustaceans and mollusks (Cortés *et al.* 1996, Bethea et al. *In Review*). Evidence suggests that the bonnethead shark is highly site-attached exhibiting little or no long-distance migratory behavior and thus, little or no mixing of populations (Heupel et al. 2006). Preliminary evidence from mitochondrial DNA suggests no sharp genetic discontinuities (M.S. Shivji, Nova Southeastern University, personal communication). Studies on bonnethead sharks include age and growth, reproduction, metabolism, diet, demography and paternity types (Parsons 1993a, Parsons 1993b, Manire et al. 1995, Cortés and Parsons 1996, Cortés et al. 1996, Carlson and Parsons 1997, Parsons and Carlson 1998, Lombardi-Carlson et al. 2003, Chapman et al. 2004, Bethea et al. *In Review*). This report summarizes the most recent study of bonnethead sharks life history from three areas along Florida's Gulf of Mexico coastline (northwestern Florida, Tampa Bay, and Florida Bay; Lombardi-Carlson et al. 2003).

Materials and Methods
Sampling

Sharks were collected from three areas along the eastern Gulf of Mexico from March 1998 to September 2000: northwest Florida, Tampa Bay and Florida Bay. Sharks were collected with gill nets. For detailed explanation of sampling protocol, see Lombardi-Carlson et al. 2003.

Age and growth

One vertebra was randomly selected from each shark, fixed to a slide and thin sectioned using a Buehler Isomet low-speed saw. The number of narrow translucent bands was recorded to estimate age from each vertebral section. Alternating pairs of bands (one opaque and one translucent) represent 1 year of growth (Parsons 1993b). The birthmark (translucent band) is

deposited in late summer/early fall (July – September) therefore, only six months of growth are represented between the first and second translucent zones. Thus, a shark with one band (the birthmark) was assigned an age of 0+ years old, and a shark with 2 bands was 0.5+ years old.

Determination of growth curves

Growth curves were constructed for females and males from each area separately, sexes combined by area, sexes combined, and sexes and areas combined using the von Bertalanffy theoretical growth model. Parameters were estimated using least squares non-linear regression (SAS V.8, SAS Institute, Inc.). The parameters of the von Bertalanffy growth equation (L_∞, K, t_o) were compared using maximum likelihood ratio tests as proposed by Haddon (2001).   This method was used to determine differences between sexes within and between areas and areas combined.

Maturity estimates for size and age

A logistic regression model was fitted to binomial maturity data (immature = 0, mature = 1) for males and females separately by area, sexes combined by area, and sexes and areas combined to determine maturity estimates (Mollet *et al*. 2000). The model was fitted using the method of maximum likelihood (PROC LOGISTIC, SAS V.8, SAS Institute, Inc). The effect of area was added to the logistic model to test for similarities in size and age at maturity between areas by sex (SAS V.8, SAS Institute, Inc).

Results and Discussions

Age and growth

A total of 539 sharks were collected during the study (207 in northwest Florida, 176 in Tampa Bay, and 156 in Florida Bay; Table 1). Due to reader disagreement of vertebral sections, ten percent (n = 40) were discarded.

Females reached their theoretical maximum size (L_∞) at a slower rate (K) than males in northwest Florida, Tampa Bay, and areas combined, but not in Florida Bay (Table 1). The predicted asymptotic length (L_∞) was larger for females than males in each area. The largest predicted asymptotic lengths for males and females were for sharks from northwest Florida (1007 and 1398 mm TL, respectively; Table 1). Significant differences in the von Bertalanffy parameters were observed between sexes within and between areas and areas combined (Table 2).

Maturity estimates for size and age

The largest median size and age at maturity for males and females were those from northwest Florida (830 mm, 3.0+ yrs; 944 mm TL, 4.0+ yrs, respectively; Tables 1, 3, 4, and 5). Median size and age at maturity for areas combined was 721 mm TL and 2.0+ yrs (males) and 821 mm TL and 3.0+ yrs (females) (Tables 1 and 6). Significant differences in size at maturity estimates were found for males and females between northwest Florida and Tampa Bay, Tampa Bay and Florida Bay, and northwest Florida and Florida Bay (Table 7). Significant differences in age at maturity estimates were also found for males and females between northwest Florida and Tampa Bay and northwest Florida and Florida Bay, however, no significant differences in age at maturity were detected for males or females between Tampa Bay and Florida Bay (Table 7).

Fecundity

Bonnethead sharks have an annual reproductive cycle with a fairly short gestation period (4-5 months, Parsons 1993a). A total of 50 pregnant females were collected (14 in northwest Florida, 19 in Tampa Bay, and 17 in Florida Bay). There was no significant difference in average litter size among the areas (NWFL 11 ± 3, TB 10 ± 3, FB 10 ± 3). The overall fecundity for all pregnant females was 10 (std. ± 3) pups per year.

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Table 1. Life-history parameter estimates ± standard error for male (M), female (F), and sexes combined (C) bonnethead sharks from northwest Florida (NWFL), Tampa Bay (TB), Florida Bay (FB) and areas combined. Size reported as total length in mm. Reported age adjusted from band counts.

Parameters	NWFL	TB	FB	Combined Areas
Sample size	92 (M)	84 (M)	69 (M)	245 (M)
	99 (F)	79 (F)	76 (F)	254 (F)
	191 (C)	163 (C)	145 (C)	499 (C)
L_∞	1007 ± 85 (M)	868 ± 43 (M)	858 ± 92 (M)	907 ± 46 (M)
	1398 ± 186 (F)	1277 ± 203 (F)	939 ± 58 (F)	1139 ± 70 (F)
	1343 ± 144 (C)	1394 ± 288 (C)	1008 ± 98(C)	1155 ± 71 (C)
K	0.35 ± 0.10 (M)	0.44 ± 0.13 (M)	0.25 ± 0.12 (M)	0.36 ± 0.08 (M)
	0.18 ± 0.05 (F)	0.16 ± 0.07 (F)	0.29 ± 0.09 (F)	0.22 ± 0.04 (F)
	0.18 ± 0.04 (C)	0.11 ± 0.05(C)	0.19 ± 0.06(C)	0.20 ± 0.03 (C)
t_o	-0.31 ± 0.38 (M)	-1.04 ± 0.64 (M)	-2.66 ± 1.26 (M)	-0.99 ± 0.40 (M)
	-0.93 ± 0.44 (F)	-2.39 ± 1.01 (F)	-1.79 ± 0.82 (F)	-1.25 ± 0.37 (F)
	-1.01 ± 0.35 (C)	-3.32 ± 1.08(C)	-2.83 ± 0.93(C)	-1.68 ± 0.35 (C)
Median size	830 (M)	707 (M)	655 (M)	721 (M)
at maturity	944 (F)	823 (F)	770 (F)	822 (F)
	877 (C)	747 (C)	696 (C)	769 (C)
Median age	3.0+ yrs (M)	1.6+ yrs (M)	1.6+ yrs (M)	2.0+ yrs (M)
at maturity	4.0+ yrs (F)	2.9+ yrs (F)	2.9+ yrs (F)	3.0+ yrs (F)
	3.4+ yrs (C)	2.1+ yrs (C)	2.1+ yrs (C)	2.5+yrs (C)
Observed	930 (M)	910 (M)	850 (M)	930 (M)
maximum size	1100 (F)	1040 (F)	1000 (F)	1100 (F)
Observed	5.5+ yrs (M)	5.5+ yrs (M)	5.5+ yrs (M)	5.5+ yrs (M)
maximum age	6.5+ yrs (F)	6.5+ yrs (F)	7.5+ yrs (F)	7.5+ yrs (F)

Table 2. Results of pair-wise comparisons of von Bertalanffy growth parameters for bonnethead sharks between sexes within and between areas and areas combined, as determined from likelihood-test ratio. Significant levels [*], $P < 0.05$; [**] $P < 0.01$; [***], $P < 0.001$.

Comparison	Areas	Test statistic
Males vs Females	NWFL	8.93[*]
	TB	23.09[***]
	FB	35.81[***]
Males	NWFL vs TB	30.70[***]
	TB vs FB	55.11[***]
	NWFL vs FB	56.84[***]
Females	NWFL vs TB	19.76[***]
	TB vs FB	39.52[***]
	NWFL vs FB	58.61[***]
Males vs Females	Areas Combined	30.17[***]

Table 3. Predicted proportion mature for bonnethead sharks from northwest Florida for male, female and sexes combined.

TL	Males	Females	Combined	Band Count	Age (yr)	Males	Females	Combined
400	0.00	0.00	0.00	1.0		0.00	0.00	0.00
450	0.00	0.00	0.00	1.5	0.0	0.01	0.00	0.01
500	0.00	0.00	0.00	2.0		0.02	0.01	0.02
550	0.00	0.00	0.00	2.5	1.0	0.04	0.01	0.03
600	0.00	0.00	0.01	3.0		0.09	0.02	0.06
650	0.00	0.00	0.01	3.5	2.0	0.18	0.05	0.12
700	0.02	0.00	0.04	4.0		0.32	0.10	0.22
750	0.09	0.00	0.08	4.5	3.0	0.51	0.19	0.36
800	0.29	0.01	0.19	5.0		0.70	0.34	0.54
850	0.64	0.06	0.38	5.5	4.0	0.84	0.52	0.70
900	0.89	0.21	0.60	6.0		0.92	0.70	0.83
950	0.97	0.54	0.80	6.5	5.0	0.96	0.83	0.91
1000	0.99	0.84	0.91	7.0		0.98	0.91	0.95
1050	1.00	0.96	0.96	7.5	6.0	0.99	0.96	0.98
1100	1.00	0.99	0.98	8.0		1.00	0.98	0.99
1150	1.00	1.00	0.99	8.5	7.0	1.00	0.99	0.99
1200	1.00	1.00	1.00	9.0		1.00	1.00	1.00

Table 4. Predicted proportion mature for bonnethead sharks from Tampa Bay for male, female and sexes combined.

TL	Males	Females	Combined	Band Count	Age (yr)	Males	Females	Combined
400	0.00	0.00	0.00	1.0		0.02	0.00	0.02
450	0.00	0.00	0.00	1.5	0.0	0.04	0.00	0.04
500	0.00	0.00	0.00	2.0		0.11	0.00	0.09
550	0.00	0.00	0.00	2.5	1.0	0.24	0.01	0.17
600	0.00	0.00	0.02	3.0		0.45	0.04	0.30
650	0.05	0.00	0.07	3.5	2.0	0.68	0.11	0.47
700	0.40	0.00	0.22	4.0		0.85	0.30	0.65
750	0.90	0.00	0.52	4.5	3.0	0.94	0.59	0.80
800	0.99	0.07	0.81	5.0		0.97	0.83	0.89
850	1.00	0.96	0.94	5.5	4.0	0.99	0.94	0.95
900	1.00	1.00	0.98	6.0		1.00	0.98	0.97
950	1.00	1.00	1.00	6.5	5.0	1.00	0.99	0.99
1000	1.00	1.00	1.00	7.0		1.00	1.00	0.99
1050	1.00	1.00	1.00	7.5	6.0	1.00	1.00	1.00
1100	1.00	1.00	1.00	8.0		1.00	1.00	1.00
1150	1.00	1.00	1.00	8.5	7.0	1.00	1.00	1.00
1200	1.00	1.00	1.00	9.0		1.00	1.00	1.00

Table 5. Predicted proportion mature for bonnethead sharks from Florida Bay for male, female and sexes combined.

TL	Males	Females	Combined	Band Count	Age (yr)	Males	Females	Combined
400	0.00	0.00	0.00	1.0		0.02	0.00	0.02
450	0.00	0.00	0.00	1.5	0.0	0.04	0.00	0.04
500	0.00	0.00	0.01	2.0		0.10	0.01	0.08
550	0.01	0.00	0.03	2.5	1.0	0.24	0.02	0.15
600	0.07	0.00	0.10	3.0		0.45	0.06	0.28
650	0.45	0.00	0.26	3.5	2.0	0.68	0.17	0.45
700	0.90	0.00	0.53	4.0		0.85	0.37	0.64
750	0.99	0.18	0.78	4.5	3.0	0.94	0.62	0.80
800	1.00	0.90	0.92	5.0		0.97	0.83	0.89
850	1.00	1.00	0.97	5.5	4.0	0.99	0.93	0.95
900	1.00	1.00	0.99	6.0		1.00	0.98	0.98
950	1.00	1.00	1.00	6.5	5.0	1.00	0.99	0.99
1000	1.00	1.00	1.00	7.0		1.00	1.00	0.99
1050	1.00	1.00	1.00	7.5	6.0	1.00	1.00	1.00
1100	1.00	1.00	1.00	8.0		1.00	1.00	1.00
1150	1.00	1.00	1.00	8.5	7.0	1.00	1.00	1.00
1200	1.00	1.00	1.00	9.0		1.00	1.00	1.00

Table 6. Predicted proportion mature for bonnethead sharks from all three areas combined for male, female and sexes combined.

TL	Males	Females	Combined	Band Count	Age (yr)	Males	Females	Combined
400	0.00	0.00	0.00	1.0		0.02	0.00	0.01
450	0.01	0.00	0.01	1.5	0.0	0.05	0.00	0.03
500	0.02	0.00	0.02	2.0		0.09	0.01	0.06
550	0.05	0.00	0.04	2.5	1.0	0.18	0.02	0.11
600	0.12	0.00	0.07	3.0		0.31	0.05	0.20
650	0.23	0.01	0.14	3.5	2.0	0.48	0.12	0.33
700	0.41	0.04	0.26	4.0		0.66	0.26	0.50
750	0.61	0.14	0.43	4.5	3.0	0.80	0.48	0.67
800	0.78	0.36	0.61	5.0		0.89	0.70	0.80
850	0.89	0.67	0.77	5.5	4.0	0.95	0.86	0.89
900	0.95	0.87	0.88	6.0		0.97	0.94	0.94
950	0.98	0.96	0.94	6.5	5.0	0.99	0.98	0.97
1000	0.99	0.99	0.97	7.0		0.99	0.99	0.99
1050	1.00	1.00	0.99	7.5	6.0	1.00	1.00	0.99
1100	1.00	1.00	0.99	8.0		1.00	1.00	1.00
1150	1.00	1.00	1.00	8.5	7.0	1.00	1.00	1.00
1200	1.00	1.00	1.00	9.0		1.00	1.00	1.00

Table 7. Results of pair-wise comparisons of length and age at 50% mature for bonnethead sharks between areas by sex, as determined from maximum likelihood estimates. Significant levels [NS], not significant; [*], $P < 0.05$; [**] $P < 0.01$; [***], $P < 0.001$.

Comparison	Areas	Test statistic
Males Length	NWFL vs TB	-2.42[***]
	TB vs FB	1.31[***]
	NWFL vs FB	3.31[***]
Females Length	NWFL vs TB	-2.82[***]
	TB vs FB	2.26[**]
	NWFL vs FB	3.96[***]
Males Age	NWFL vs TB	-1.16[***]
	TB vs FB	-0.01 [NS]
	NWFL vs FB	1.16[***]
Females Age	NWFL vs TB	-0.98[**]
	TB vs FB	0.10 [NS]
	NWFL vs FB	0.99[***]

Table 8. Meristic regressions for bonnethead sharks from the eastern Gulf of Mexico.

Conversion and Units	Equation	n	r^2	Data Ranges
FL (mm) to TL (mm)	TL = 1.18 * FL – 23.34	538	0.99	TL (mm): 340 – 1190 FL (mm): 280 – 960
PCL (mm) to TL (mm)	TL = 1.24 * PCL – 42.24	537	0.98	TL (mm): 340 – 1190 PCL (mm): 250 – 920
STL (mm) to TL (mm)	TL = 0.98 * STL + 2.54	536	0.99	TL (mm): 340 – 1190 STL (mm): 360 – 1220
PCL (mm) to FL (mm)	FL = 1.04 * PCL – 21.28	537	0.98	FL (mm): 280 – 960 PCL (mm): 250 – 920
TL (mm) to Wt (kg)	W. Wt $= 9.52 \times 10^{-11} * (TL^{3.59})$	457	0.99	TL (mm): 340 – 1190 Wt (kg): 0.20 – 8.35

Table 9. Observed mean size-at-age ± standard error for bonnethead sharks from the eastern Gulf of Mexico for all three areas combined for male, female and sexes combined (samples sizes in parentheses).

Band.Count	Males	Females	Combined
1	496 ± 24 (n = 9)	506 ± 18 (n = 10)	501 ± 15 (n = 19)
2	586 ± 9 (n = 72)	574 ± 11 (n = 60)	581 ± 7 (n = 132)
3	694 ± 9 (n = 61)	706 ± 12 (n = 44)	699 ± 7 (n = 105)
4	759 ± 10 (n = 58)	783 ± 12 (n = 39)	769 ± 8 (n = 97)
5	809 ± 10 (n = 37)	875 ± 13 (n = 39)	843 ± 9 (n = 76)
6	798 ± 35 (n = 5)	919 ± 14 (n = 36)	904 ± 14 (n = 41)
7	797 ± 50 (n = 3)	971 ± 20 (n = 20)	948 ± 22 (n = 23)
8		946 ± 48 (n = 5)	946 ± 48 (n = 5)
9		850 (n = 1)	850 (n = 1)