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Length/weight relationships and life history data for *Mustelus canis* off of the Atlantic coast of the U.S.

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Introduction:

We present updated information on length/weight and length/length relationships and size-at-maturity for the Atlantic population of the smooth dogfish, *Mustelus canis*, based on historical data (Conrath et al., 2002, Conrath and Musick, 2002) and more recent data collected by the Virginia Institute of Marine Science Shark Longline Survey, the Northeast Area Monitoring Assessment Program (NEAMAP) bottom trawl survey (2007-2013), the Georgia Department of Natural Resources (GADNR) Shark Longline Survey (2006-2013), and the University of North Florida (UNF) Shark Longline Survey (2009-2013).

Material and Methods

Length-length and length-weight relationships

Multiple measurements of length including PCL, fork length (FL), total length (TL), and stretched total length (STL) were obtained from VIMS, GADNR and UNF surveys and used to generate length/length relationships. Weight and precaudal length (PCL) were available from 5,821 *M. canis* obtained from the NEAMAP survey. Lengths were converted to FL and used to generate length/weight relationships.

Size-at-maturity

Conrath and Musick (2002) generated maturity ogives based on 260 males and 406 females collected between Massachusetts and South Carolina. Maturity for males was assigned based on elongation and rigidity of the claspers. Females were considered mature if they had large vitellogenic ova in the ovaries, embryos present in the uteri, or expanded uteri indicating past pregnancy. Maturity ogives in Conrath and Musick (2002) were based on the proportion of mature *M. canis* within 2-cm length bins (stretched total length) for each sex.

We generated new size at maturity ogives using recent data collected by the NEAMAP survey. In the NEAMAP survey, a subset of captured *M. canis* were selected for full work-up including dissection and maturity assignment. In total, 1,259 females and 2,692 males were assigned as immature or mature. Maturity in females was based on relative uterine width. Those with narrow, ribbon-like uteri were assumed to be virgins and immature. Those with expanded uteri that appeared to have gone through pregnancy were assumed mature. Maturity assessment using uterine width alone may lead to inaccurate assignments due to uterine contraction between pregnancies and for females that are mature and entering their first reproductive season. However, due to the large sample size, such inaccurate assignments likely have little effect on the maturity ogives. The narrow confidence intervals on the maturity ogive support this assumption. Male maturity was assessed based on elongation and calcification of claspers. It was noted that a number of males were likely inaccurately assigned maturity state (i.e. very small males assessed as mature and very large males assessed as immature). Again, the very large sample size and narrow confidence intervals on the maturity ogive suggest these inaccuracies were of little consequence. Ogives were generated using binary (mature or immature) raw data.

Age-at-maturity

Conrath and Musick (2002) generated age-at-maturity ogives using maturity stages as described previously and age at length data from Conrath et al. (2002). Ogives were generated using the proportion mature for each year of age for each sex. Age data are not available for more recently collected samples from the NEAMAP survey; therefore, we did not generate new age-at-maturity ogives and recommend use of the published ogives from Conrath and Musick (2002). An updated age and growth study using samples collected by NEAMAP would be useful.

Additional age, growth and reproductive data

Additional reproductive information for *M. canis* including brood size, sex ratios, maternal length to brood size relationship, identification of pupping season, reproductive periodicity, and gestation period were obtained from Conrath and Musick (2002) and presented in the results. Age and growth information from *M. canis* in the Atlantic, including growth parameter (L_∞, k, t_o) and maximum observed age were obtained from Conrath et al. (2002) and are presented in the results.

Results

Length-length and length-weight relationships

A total of 269 *M. canis* were collected where multiple length measurements were obtained. The sample size varied by measurement and ranged from 23 (FL to TL) to 269 (FL to STL). Length-weight relationships were developed based on 5,821 smooth dogfish (2,270 females, 3,551 males). Length-length and sex-specific length-weight relationships are listed in Table 1.

Size at maturity

Size at maturity data for each species is summarized in Tables 2 and 3 and Figure 1 and 2. Conrath et al. (2002) reported the sizes at 50% maturity for female and male *M. canis* as 88.7 and 74.5 cm FL, respectively. The smallest mature female *M. canis* was 84.3 cm FL and the largest immature female was 99.4 cm FL. The largest immature male was 84.3 cm FL and the smallest mature male was 70.0 cm FL. In contrast, the NEAMAP data suggested the sizes at 50% maturity for female and male *M. canis* were 78.2 and 68.0 cm FL, respectively. The smallest mature female smooth dogfish was 39.1 cm FL and the largest immature female was 96.1 cm FL. The largest immature male was 102.1 cm FL and the smallest mature male was 38.5 cm FL. The smaller sizes at maturity in the NEAMAP data set may be due in part, to inconsistencies in maturity assignment methodology between the two data sets.

Age at maturity

Size at maturity data for each species is summarized in Table 2. Ages at 50% maturity were only reported by Conrath and Musick (2002) and were 4.05 and 3.28 years for female and male *M. canis*, respectively. The youngest mature female and oldest immature female were 4 and 7 years old, respectively. The youngest mature male and oldest immature male were 2 and 3 years old, respectively. Since the more recent NEAMAP data only includes size at maturity and not age at maturity, we recommend using the age at maturity information from Conrath and Musick (2002).

Brood size and reproductive cycle

Based on Conrath and Musick (2002) brood size ranged from 3 to 17 for *M. canis* (mean = 9.35, n = 178). The ratio of female to male embryos was not different from the expected 1:1. There was a weak but significant relationship between maternal length and brood size ($p < 0.01$, $r2 = 0.28$) (Brood = -31.31 + 42.47(1- e^-0.496(age)). Ovaries of all gravid females examined had vitellogenic follicles indicating that female *M. canis* reproduce annually, and the pupping season occurs in May with an 11-12 month gestation period. Based on more recent data collected by the NEAMAP survey, brood size in Atlantic *M. canis* ranged from 1 to 20 with a mean brood size of 8.28 (S.D. = 0.249, median brood size = 8, n=196).

Age and growth information

Based on Conrath et al. (2002), ages were assigned to 894 (363 male, 531 female) *M. canis*. A summary of sex-specific VBGF parameter estimates is presented in Table 4. The oldest observed ages for female and male *M. canis* were 10 and 16 years, respectively.

References:

Conrath, C.L. and J.A. Musick. 2002. Reproductive biology of the smooth dogfish, *Mustelus canis*, in the northwest Atlantic Ocean. Environmental Biology of Fishes 64: 367-377.

Conrath, C.L., J.Gelsleichter, J.A. Musick. 2002. Age and growth of the smooth dogfish (*Mustelus canis*) in the northwest Atlantic Ocean. Fishery Bulletin 100: 674-682.

Table 1: Length-length and length-weight relationships for *Mustelus canis* specimens collected off the Atlantic coast of the United States. All lengths are measured in cm. FL = fork length, PCL = precaudal length, TL = natural total length, and STL = stretched total length.

Conversion	n	Equation	r^2
Combined: FL to PCL	253	(0.9371 * FL) - 0.8375	0.99
Combined: FL to TL	23	(0.9001 * FL) + 11.9	0.79
Combined: FL to STL	269	(1.1209 * FL) + 2.5432	0.99

Conversion	n	Equation	r^2
Female: FL to Wt	2270	$6.0 \times 10^{-6} (FL^{3.0084})$	0.98
Male: FL to Wt	3551	$1.0 \times 10^{-5} (FL^{2.8076})$	0.98

Table 2. Summary of age and size at maturity for *Mustelus canis* from the Atlantic coast of the United States as reported in Conrath et al. (2002) and calculated from the NEAMAP data.

Source	Sex	Age (years) at 50% maturity (a, b, n)	Size (cm FL) at 50% maturity (a, b, n)
Conrath et al. (2002)	Female	4.05 (7.486, -1.697, 409)	88.7 (40.61, -0.397, 277)
Conrath et al. (2002)	Male	3.28 (7.486, -1.697, 260)	74.5 (37.14, -0.435, 166)
NEAMAP	Female	NA	78.2 (-17.50, 0.22, 1,259)
NEAMAP	Male	NA	68.0 (-16.17, 0.24, 2,692)

Table 3. Size at maturity schedule for *Mustelus canis* collected during NEAMAP surveys.

Percent	Female (cm FL)	Male (cm FL)
10	68.37	58.77
20	72.00	62.19
30	74.41	64.45
40	76.38	66.31
50	78.19	68.02
60	80.01	69.72
70	81.98	71.58
80	84.39	73.85
90	88.01	77.26
100	109.06	97.08

Table 4: von Bertalanffy Growth Function parameter estimates for *Mustelus canis* from the Atlantic coast of the United States as reported from Conrath et al. 2002. L_∞ and t_o are reported in cm FL and years, respectively.

Species	Sex	L_∞	k	t_o	n	r^2
M. canis	Female	108.95	0.292	-1.94	531	0.95
M. canis	Male	91.6	0.440	-1.52	363	0.92

Figure 1. Size at maturity ogive for female *Mustelus canis* collected during NEAMAP surveys.

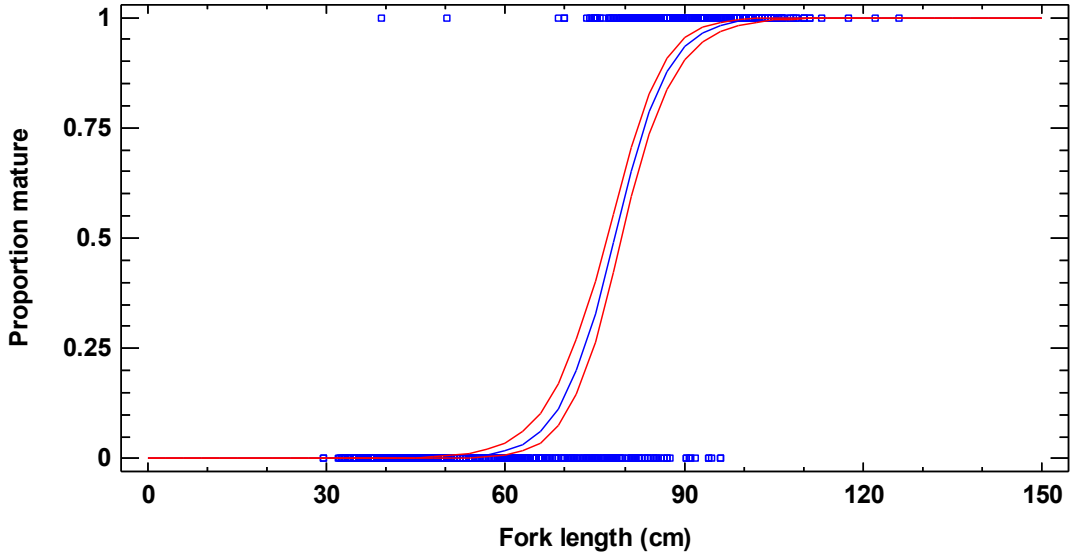
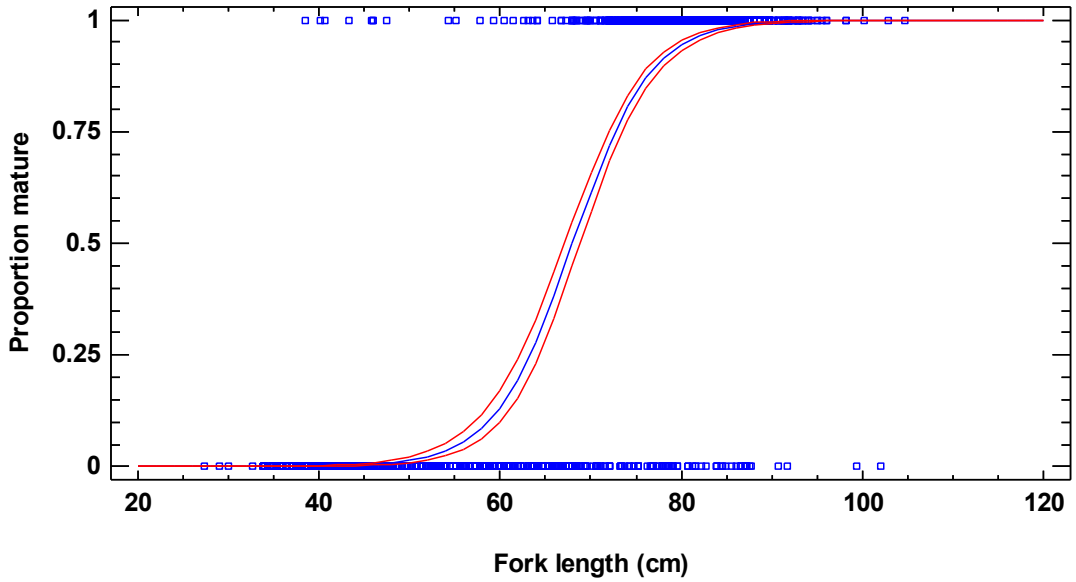


Figure 2. Size at maturity ogive for male *Mustelus canis* collected during NEAMAP surveys.


Proportion mature
1
0.75
0.5
0.25
0
20
40
60
80
100
120
Fork length (cm)