Turk J Zool
31 (2007) 301-308

Maturity and Fecundity of Spiny Dogfish (*Squalus acanthias* L., 1758) in the Eastern Black Sea

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Received: 15.11.2005

Abstract: The maturity and fecundity of *Squalus acanthias* spiny dogfish sampled from the south-eastern Black Sea were studied. Age and length at 50% maturity were 10.49 years and 87.57 cm for males, and 11.99 years and 102.97 cm for females, respectively. Mean biennial fecundity was 19.4 eggs and 12.9 pups. A linear relationship between fecundities and length was found: $F_e = 0.09 \times TL_p + 2.12$ (r = 0.5) for pups and $F_o = 0.27 \times TL_p - 21.59$ (r = 0.7) for eggs.

Key Words: Maturity, fecundity, *Squalus acanthias*; south-eastern Black Sea

Doğu Karadeniz'deki Mahmuzlu Camgöz'ün (*Squalus acanthias* L., 1758) Eşeysel Olgunluğu ve Döl Verimliliği

Özet: Bu çalışmada Doğu Karadeniz'deki mahmuzlu camgözün eşeysel olgunluğa ulaşma boyu ve yaşı ile döl verimliliği araştırılmıştır. Eşeylerin % 50'sinin eşeysel olgunluğa ulaştığı yaş ve boy değerleri dişi ve erkek bireyler için sırayla 11,99 yıl ve 102,97 cm ile 10,49 yıl ve 87,57 cm olarak tespit edilmiştir. Dişi eşeyin iki yıllık döl verimliliği ise 19,4 yumurta ve 12,9 yavru olarak hesaplanmıştır. Embriyo ve yumurta üretkenliği ile birey boyları arasında doğrusal bir ilişki olduğu tespit edilmiştir (embryo üretkenliği için $F_e = 0{,}09 \times TL_p + 2{,}12$, r = 0,5 ve yumurta üretkenliği için $F_o = 0{,}27 \times TL_p - 21{,}59$, r = 0,7).

Anahtar Sözcükler: Eşeysel olgunluk, döl verimliliği, *Squalus acanthias*

Introduction

The spiny dogfish, *Squalus acanthias,* is a coastal squalid shark with a circumboreal distribution (Bigelow and Schroeder, 1953) including the Mediterranean and Black seas (Aksiray, 1987; Compagno, 1989; Avşar, 2001; Düzgüneş et al., 2005). In the Black Sea, there are 10 species of elasmobranches (Slastanenko, 1956; Mater et al., 2005). Among them, *S. acanthias* is the most common and abundant elasmobranches species in the area (DIE, 2003). Previous studies about spiny dogfish were concerned with taxonomy, growth, food composition, and distribution of the species in the study area (Carausu, 1952; Slastanenko, 1956; Ionescu and Serpoianu, 1958; Svetovidov, 1964; Karmanova et al., 1976; Compagno, 1989; Düzgüneş et al., 2005). No detailed information is available for reproduction of *S. acanthias* apart from Avşar (2001), who has also given only a brief account.

The aim of this study was to investigate and gain more information on the maturity and fecundity of spiny dogfish in the eastern Black Sea.

Materials and Methods

Spiny dogfish were caught off Çamburnu, Trabzon, located on the eastern Black Sea coast, near the Georgian border (Figure 1). Samplings were performed using longlines at 35-45 m depths in summer and 30-60 m depths in autumn. Spiny dogfish were also sampled from commercial purse seines operated in winter at 25-50 m depths. A few fish were also sampled in spring by longlines at depths between 80 and 120 m in the same

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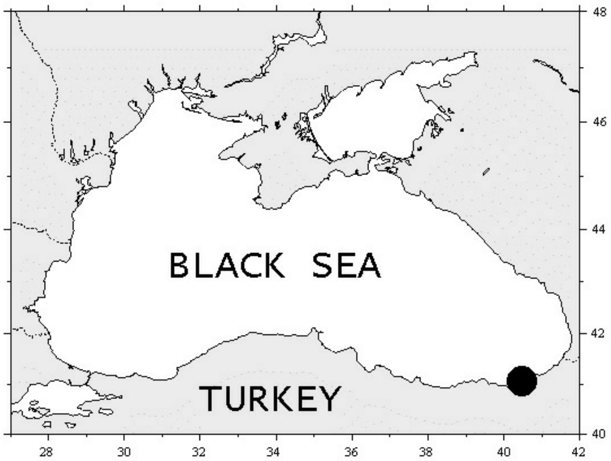

Figure 1. Sampling area.

area. Total lengths of parents (TL_p) were recorded to the nearest millimetre. Spines from the second dorsal fin were collected for ageing (Türkmen et al., 2005).

Males were classified into maturity stages according to the relative sizes of pelvic fin and claspers, as measured from the anterior edge of the cloak. Fish were classed based on Templeman (1944). Females were classified into maturity stages according to the structure and ingredients of the uterus and ovarian egg diameter (Ketchen, 1972; Jones and Geen, 1977; Karataş et al., 2005). Age (A_{50}) and total length at median sexual maturity (L_{50}) for males and females separately were estimated using nonlinear regression.

The number of eggs (N_o) in each ovary and embryos (N_e) in each uterus were recorded separately. To estimate the fecundity of spiny dogfish by egg (F_o) and embryo (F_e), the relationships between total length of parents (TL_p) and number of eggs (N_o) and embryos (N_e) were established.

Results

Maturity

Maturity onset of spiny dogfish in the study area was investigated using data available at the time; samplings were performed over 3 years. It is thought that the data were good enough to construct a knife-edge relationship between % maturity against length and age. We found that the age and the length at which 50% of spiny dogfish are mature differed between the sexes. They were estimated as 10.5 years old and about 103 cm in length for females, whereas 50% of males become sexually mature when they reach 12 years old and about 88 cm in total length (Figure 2a and b).

The investigation of the relationships between some metric characteristics of claspers (CL) and total length of males and maturity showed that males start becoming sexually mature when they are about 68 cm in total length. We also found that all males above 100.2 cm in total length in the sample were mature (Figure 3). In addition, it was found that clasper lengths from the base of the pelvic fin and base of the body were 2.6 and 5.8 cm at the beginning of maturation. When they were about 5.6 and 8.6 cm, all males became mature.

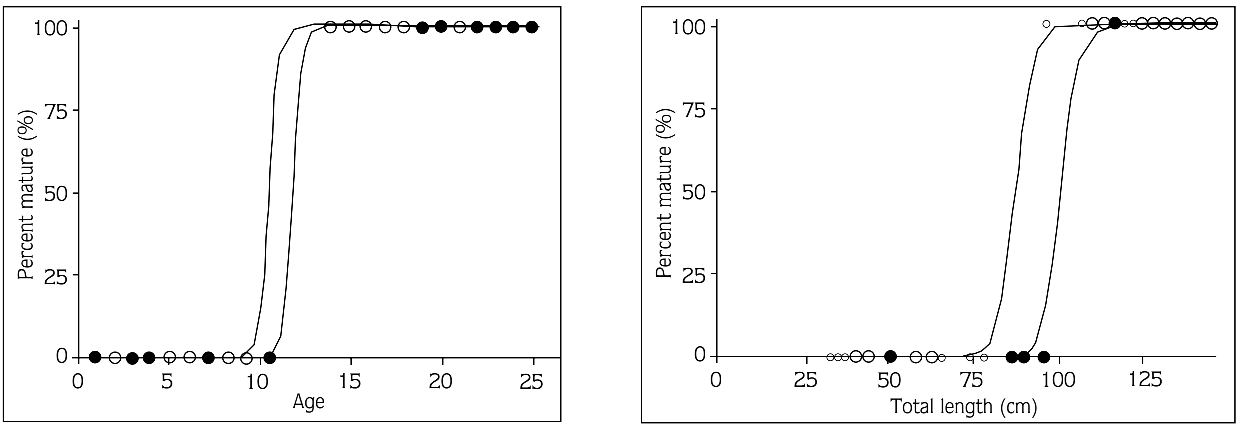

Figure 2. The length and age at which 50% of spiny dogfish are mature.

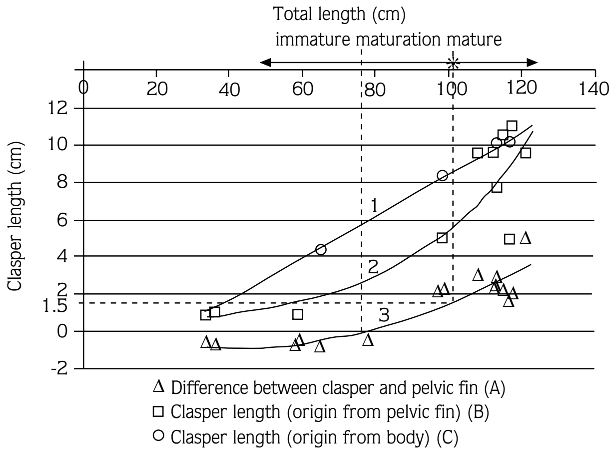

Figure 3. Relationships between some characters about claspers and total length of males.

Fecundity

Fecundity of spiny dogfish by egg was investigated within the gestation period of parents. Egg diameters increase from 10 to 12 months of the pregnancy. Before this period diameters of eggs smaller than 1.5 cm and eggs that will be fertilized next year cannot be distinguished from other eggs in the ovaries. The relationships between number of eggs and parent lengths are given in Table 1.

Fecundity of spiny dogfish by embryo was evaluated for the gestation period of parents. Relationships between the number of embryos and parent length are given in Table 2.

The fecundity of spiny dogfish by embryo increased with the increase in length of the fish. The correlation coefficients of regression between number of embryos and total length of parents in the post-candle stage II-III and candle stage were higher than those in the post-candle stage I and full-term embryo stage.

Discussion

The length and age at first maturity of spiny dogfish in the recent study were different from those in some previous studies. The reasons for the differences between studies about the maturity of *S. acanthias* could be related to different regions studied and different criteria for ageing of specimens (Table 3).

In addition, the differences could be attributed to the inadequate number of juvenile (immature) spiny dogfish caught. According to Beamish and Smith (1976), most juvenile spiny dogfish less than 10 years old and smaller than 50 cm are distributed in the surface or mid-water. In this study, samples of spiny dogfish were obtained from bottom longlines and as it was not possible to catch a sufficient number of smaller spiny dogfish as yet it has not been possible to determine definitely the size of first maturity for each sex. The high rate occurrence of mature spiny dogfish in neritic waters along the SE Black Sea may indicate that older spiny dogfish are distributed in shallower water in greater numbers than younger specimens.

Clasper length, in other words relative size of pelvic fin and claspers, is thought to be the indicator for maturity stages in males (Nammack et al., 1985). Hanchet (1988) validated the use of the CL/PFL (clasper length/pelvic fin length) ratio for deciding maturation stages of males by microscopic examination of the testes. Maturing males with a length of claspers equal or 1.5 cm greater than pelvic fin length are capable of mating. Some

Table 1. Relationships between number of egg and parent length (F_o is the fecundity of spiny dogfish for egg, TL is the total lengths of parent) (Regressions marked with an asterisk were statistically significant, $P < 0.05$).

Gestation period	Mean egg diameter (mm)	Mean egg weight (g)	Number of eggs used	Number of parents used	Relationships	r
Candle stage	6.70 (±7.93)	0.64 (±0.42)	45	7	$F_o = -0.77 \times TLp + 119.2$	0.78
Post-candle stage I, II, III	21.60 (±6.89)	6.89 (±3.63)	65	38	$F_o = 0.38 \times TLp + 30.7$ *	0.99
Full-term embryo stage	41.06 (±7.04)	25.55 (±7.93)	18	15	$F_o = 0.18 \times TLp + 3.41$	0.45
Spent stage	56.50 (±1.97)	34.72 (±5.05)	6	6	$F_o = 2.88 \times TLp - 347.7$	1.00
Total	21.28 (±14.31)	11.39 (±9.95)	134	66	$F_o = 0.10 \times TLp + 2.1$	0.47

Table 2. Relationship between number of embryos and parent length (F_e is the fecundity of spiny dogfish for embryo, TL is the total length of parent) (Regressions marked with an asterisk were statistically significant, $P < 0.05$).

Gestation period	Mean embryo length (cm)	Mean embryo weight (g)	Number of embryos used	Number of parents used	Relationships	r
Candle stage	6.70 (±7.93)	0.64 (±0.42)	45	7	$F_o = -0.77 \times TLp + 119.2$	0.78
Candle stage	1.48 (±0.76)	0.13 (±0.05)	23	15	$F_e = 0.30 \times TLp + 25.3$ *	0.80
Post-candle stage I	8.24 (±1.37)	3.58 (±1.62)	5	5	$F_e = 0.18 \times TLp + 10.2$	0.37
Post-candle stage II, III	15.96 (±2.81)	15.53 (±7.18)	60	57	$F_e = 0.25 \times TLp + 20.3$ *	0.95
Full-term embryo stage	25.83 (±2.12)	53.80 (±8.82)	18	17	$F_e = 0.23 \times TLp + 17.29$	0.32
All specimens	11.55 (±9.28)	13.76 (±18.69)	106	84	$F_e = 0.27 \times TLp - 21.57$ *	0.70

Table 3. Length and age of maturity values of *S. acanthias* for different locations in the world.

References	Region	Female Age	Length	Male Age	Length
Recent study	Black Sea	12	103	10.5	87
Avşar, 2001	Black Sea	5	88-79	5	82
Templeman, 1944	NW Atlantic	7-8	74-77		64
Ketchen, 1972	NE Pacific	20	93.5	11	72
Jones and Geen, 1977	NE Pacific	29	93		78
Ford, 1921	NE Atlantic		75		60
Hickling, 1930	NE Atlantic		64		59-60
Kaganovskaia, 1937	NW Pacific	19	100		
Bonham et al., 1949	NE Pacific	20	92		72
Yamamato and Kibezaki, 1958	NW Pacific		90-95		75
Holden and Meadows, 1964	NE Atlantic	11	82.0	5	60
Jensen, 1965			75		60
Bass et al., 1976	S Atlantic		60		49
Sosinski, 1978	NE Atlantic	7	70		
Kondyurin and Mygakov, 1982	S Atlantic		71		51
Slauson et al., 1982	NW Atlantic	18-19	92.8	14	75.7
Nammack et al., 1985	NW Atlantic	12.1	79.9		59
Hanchet, 1988	S Pacific		74		57.5
Fahy, 1989	NE Atlantic	14	74		
Saunders and McFarlane, 1993	NE Pacific	35.5	93.9		
Steinberg, 1977	NE Atlantic	12-13	77		54
Moore, 1996	NW Atlantic	17	85.1		

of these males have empty ampullae. Ford (1921) and Nammack et al. (1985) showed that there is a rapid increase in clasper length at maturity, in agreement with our findings. The CL above this rapid growth interval (determined from a CL-TL_p plot) was considered to be the CL at maturity. He stated that all clasper lengths greater than or equal to this length were considered to be from mature males.

There is evidence that the spiny dogfish has a low reproductive potential and there must exist a serious possibility that fishing could reduce the mature stock below the level at which it would replace itself. Holden and Meadows (1964) found that fecundity increases as stock density decreases in spiny dogfish. This mechanism can provide a higher degree of response than density-dependent changes in growth rates (Holden, 1973). Fecundity of spiny dogfish in the SE Black Sea was found to be higher than that elsewhere (Table 4). This is thought to be because of increasing fishing pressure on the spiny dogfish populations in the SE Black Sea (DIE, 2003).

The result of this study has shown that the fecundity of spiny dogfish increases with increasing parent length. This is in agreement with Holden and Meadows (1964), Ketchen (1972), Gauld (1979), and Nammack et al. (1985). The information provided from the literature together with the current findings is given in Table 5.

Differences observed in the values of fecundities as seen in the table are probably the result of abortion during capture. The same conclusion was also drawn by Nammack et al. (1985). However, a small percentage of dead or abnormal embryos has been recorded for elasmobranches (Templeman, 1944; Pratt and Tanaka, 1994).

Table 4. Competition of the fecundity of spiny dogfish.

	Length groups of parents (TL)								
	70-79	80-89	90-99	100-109	110-120	120-130	130-140	140>	Mean
References	Mean Number of Eggs in the Length Groups (No)								
Recent study	-	-	-	-	19	17.25	21.4	20.5	19.5
Ketchen, 1972	-	-	-	-	-	-	-	-	6.8
Ford, 1921	3.4	5.3	7.3	-	-	-	-	-	-
Holden and Meadows, 1964	3.5	5.2	7.4	12.5	-	-	-	-	6.6
Nammack et al., 1985	4.0	5.4	7.8	10.3	-	-	-	-	7.8
Fahy, 1989	-	6.1	8.1	10.1	-	-	-	-	8.1
Steinberg, 1977	6.6	7.3	9.3	11.5	-	-	-	-	8.1
Gauld, 1979	5.4	7.8	9.9	12.5	-	-	-	-	8.9
Kirnosova, 1989									22
	Mean Number of Embryos in the Length Groups (Ne)								
Recent study	-	-	-	-	10	11.3	14.2	19	13.6
Avşar, 2001	2	-	-	-	-	-	17	-	8.2
Ketchen, 1972	-	3.8	5.8	7.8	-	-	-	-	6.6
Holden and Meadows, 1964	3.4	4.8	6.6	8.7	-	-	-	-	5.8
Sosinski, 1974	-	-	-	-	-	-	-	-	
Nammack et al., 1985	-	3.9	6.2	8.6	-	-	-	-	6.6
Hanchet, 1988	-	-	-	-	-	-	-	-	5.2
Fahy, 1921	-	4.6	6.0	7.3	-	-	-	-	6.0
Steinberg, 1977	4.9	4.9	6.8	8.5	-	-	-	-	5.8
Moore, 1996	-	-	-	-	-	-	-	-	5.23
Gauld, 1979	1.9	5.4	8.8	12.2	-	-	-	-	7.1
Kirnosova, 1989	-	-	7.4	10.1	-	-	-	-	14

Table 5. Relationships between fecundity and parent length, where F_o is the fecundity of spiny dogfish for egg; F_e is the fecundity of spiny dogfish for embryo; TLP is the total length of parent; Wp is the weight of parent; A is the age of parent.

References	Fecundity of egg	(r)	Fecundity of embryo	(r)
Recent study				
Candle stage	$F_o = -3.83 \times TLp + 32.5$	(0.78)	$F_e = 0.30 \times TLp + 25.3$	(0.80)
Post-candle stage I	---		$F_e = 0.89 \times TLp + 9$	(0.37)
Post-candle stage II and III	$F_o = 0.38 \times TLp + 30.6$	(0.99)	$F_e = 0.25 \times TLp + 20.3$	(0.95)
Full-term embryo stage	$F_o = 0.88 \times TLp + 16.4$	(0.45)	$F_e = 0.23 \times TLp + 17.29$	(0.32)
Spent stage	$F_o = 2.88 \times TLp - 347.7$	(1.00)	---	
All females	$F_o = 0.1 \times TLp + 2.1$	(0.47)	$F_e = 0.27 \times TLp - 21.57$	(0.70)
Avşar, 2001				
number/parent length	---		$F_e = -17.08 + 0.24 \times TL_p$	(0.93)
number/parent weight	---		$F_e = 0.3780 + 0.0018 \times Wp$	(0.89)
number/parent age	---		$F_e = -0.79 + 1.6 \times A$	(0.94)
Gauld, 1979				
Candle stage	---		$F_e = -16.5 + 0.28 \times TL_p$	(0.76)
All post-candle stages	---		$F_e = -23.88 + 0.34 \times TL_p$	(0.77)
All females	$F_o = -12.47 + 0.24 \times TL_p$	(0.77)	---	
Fahy, 1921				
Small egg (5 g)	$F_o = -8.85 + 0.19 \times TL^p$	(0.70)	---	
Large egg (16 g)	$F_o = -10.02 + 0.2 \times TL_p$	(0.76)	---	
Candle stage	---		$F_e = -13.19 + 0.23 \times TL_p$	(0.68)
All females	---		$F_e = -6.1 + 0.13 \times TL_p$	(0.49)
Holden and Meadows, 1964				
Large egg	$\log F_o = -6.64 + 3.15 \times \log TL_p$		---	
Post-candle stage	---		$\log F_e = -7.06 + 3.94 \times \log TLp$	

Consequently, the Northern hemisphere populations of *S. acanthias* were extremely vulnerable to over-fishing, as the collapse of fisheries in the north-east Pacific and north-east Atlantic indicated (Aasen, 1964; Holden, 1977; Wood et al., 1979; Fahy, 1989). The reproductive characteristics of the SE Black Sea population are similar, in essence, to those of Northern hemisphere populations. However, some degree of density-dependent compensation could be achieved by increased fecundity or decreased reproductive abnormalities.

Abbreviations

A,	age
A_{50},	Age at 50% maturity
CL,	Clasper length
F_e,	Fecundity for embryos
F_o,	Fecundity for eggs
L_{50},	Length at 50% maturity
N_e,	Number of embryos
N_o,	Number of eggs
PFL,	Length of pelvic fin
TL_p,	Total lengths of parents

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