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Sexual dimorphism in the head, mouth, and body morphology of the smallspotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758) (Chondrichthyes: Scyliorhinidae) from Turkey

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Males of the smallspotted catshark, Scyliorhinus canicula*, have a longer and narrower mouth than females, resulting in pronounced sexual dimorphism. The length/width ratio of the mouth is 0.55 in males and 0.50 in females. Other head measurements also significantly differ between the sexes, i.e., the snout-spiracle and snout-pectoral distances. Body measurements that differ between the sexes include pelvic to anal, pectoral inner edge, pelvic to median tip, upper caudal, and total body lengths. Reasons for these differences are discussed.*

Key words: *Scyliorhinus canicula,* Elasmobranchii, sexual dimorphism, meristic, nanism

INTRODUCTION

The smallspotted catshark, *Scyliorhinus canicula* Linnaeus, 1758 (Family: Scyliorhinidae), is an Atlantic-Mediterranean demersal species that inhabits continental shelves and uppermost slopes. It is found on sandy, coralline, algal, gravel, or muddy bottoms at depths of 3-400 m (HUREAU & MONOD, 1973; CAPAPÉ, 1977; JARDAS, 1979; WHITEHEAD *et al*., 1984; FROESE & PAULY, 2004). The species is common in the Mediterranean (CAPAPÉ, 1977; JARDAS, 1979; CIHANGIR *et al*., 1997; BERTRAND *et al*., 2000; BAINO & SERENA, 2000; DE MADDALENA & BAENSCH, 2005) and widespread in the northeast Atlantic (WHITEHEAD *et al*., 1984).

Studies of the lesser spotted dogfish relate to biology (FAURE-FREMIET, 1942; CAPAPÉ, 1977; JARDAS, 1979; CIHANGIR *et al*., 1997), age and growth (RODRIGUEZ-CABELLO *et. al*., 1997; RODRIGUEZ-CABELLO & SÁNCHEZ, 2002), reproduction (HARRIS, 1952; CRAIK, 1978; SUMPTER & DODD, 1979; MELLINGER, 1983; ELLIS & SHACKLEY, 1997; RODRIGUEZ-CABELLO *et. al*., 1998), and feeding (MACPHERSON *et al*., 1989; ELLIS *et al*., 1996; SIMS *et al*., 1996; OLASO *et al*., 1998, 2002; KABASAKAL, 2001, 2002; VELASCO *et al*., 2001).

Differences in the selective pressures experienced by the sexes can result in the evolution of sexual dimorphism of morphological traits (CASSELMAN & SCHULTE-HOSTEDDE, 2004). Sexual dimorphism with respect to body size is common among shark species in which the females are viviparous or ovoviviparous (SIMS, 2003). ELLIS & SHACKLEY (1995) and ERDOGAN *et* *al.* (2004) demonstrated that sexual dimorphism can also occur in oviparous sharks such as *S. canicula*.

Morphological and dental differences are useful criteria for identifying the taxonomy of elasmobranch fish (ELLIS & SHACKLEY, 1995). However, intraspecific variations due to growth, sexual dimorphism, and geographical and individual differences have been little studied (STEFFENS & D'AUBREY, 1967; TANIUCHI, 1970; BASS, 1973; SIQUEIROS-BELTRONES, l990; KAJIURA & TRICAS, 1996; KAJIURA, 2001). In *S. canicula*, the head and mouth are narrower and the intermandibular separation is smaller in males than in females (BROUGH, 1937). Changes in the lower jaw structure correlate with sexual maturity and these sexually dimorphic characters are more pronounced during the breeding season and not present in sexually immature specimens (BROUGH, 1937). Sexual dimorphism in the length/width ratio of the mouth of *S. canicula* was briefly described by ARTHUR (1950). Sexual dimorphism occurs relatively suddenly at the onset of maturity (BROUGH, 1937). Morphometric studies of *S. canicula* from the Mediterranean have shown negative allometric growth of the head (BAS, 1964) and that males have longer heads than females (JARDAS, 1979; ERDOGAN *et al*., 2004).

The purpose of the present study was to determine the extent of sexual variation in the morphometrics of *S. canicula* and to assess possible functional significance.

MATERIAL AND METHODS

We collected 296 *S. canicula* specimens from the Foca trawl area in Izmir Bay (Aegean Sea, Turkey) in September and November 2002 at depths of 40-120 m with two commercial bottom trawls (Fig. 1). The sex, total length (TL), mouth length (ML), and mouth width (MW) of the 123 females and 173 males were measured to the nearest millimeter. All measurements were converted to percentages of the total length (%TL) and analyzed following

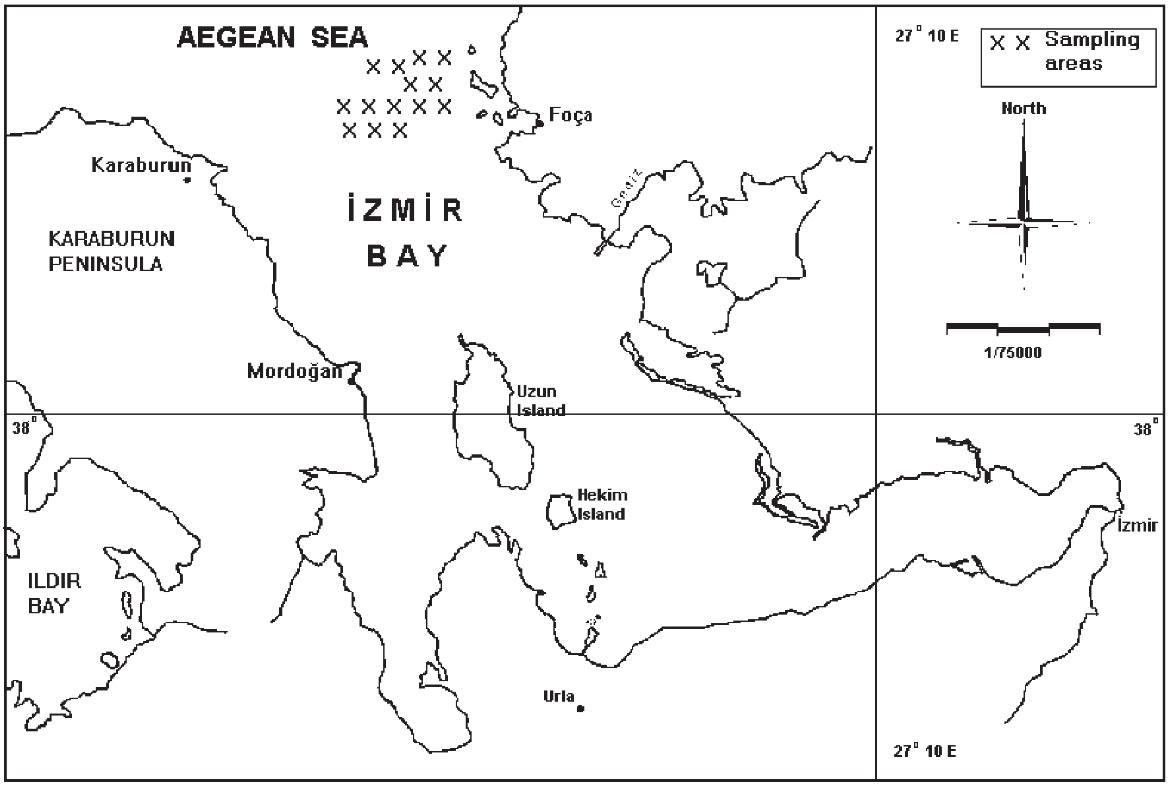

Fig. 1. Collection sites of smallspotted catshark, Scyliorhinus canicula*, specimens*

the methodology of ELLIS & SHACKLEY (1995). Significant differences between the sexes in mean ML/TL, MW/TL, and ML/MW were calculated by *t* test (SOKHAL & ROHLF, 1981). The data were divided into six groups according to TL (<275, 275-324, 325-374, 375-424, 425-474, >474 mm) and similar tests were used to determine significant differences between TL groups within each sex, and between the same TL groups of both sexes.

In addition, eight measurements of the head region and seventeen measurements of the body were taken to the nearest millimeter and converted to %TL for statistical analysis as above (Fig. 2; BASS *et al.*, 1975).

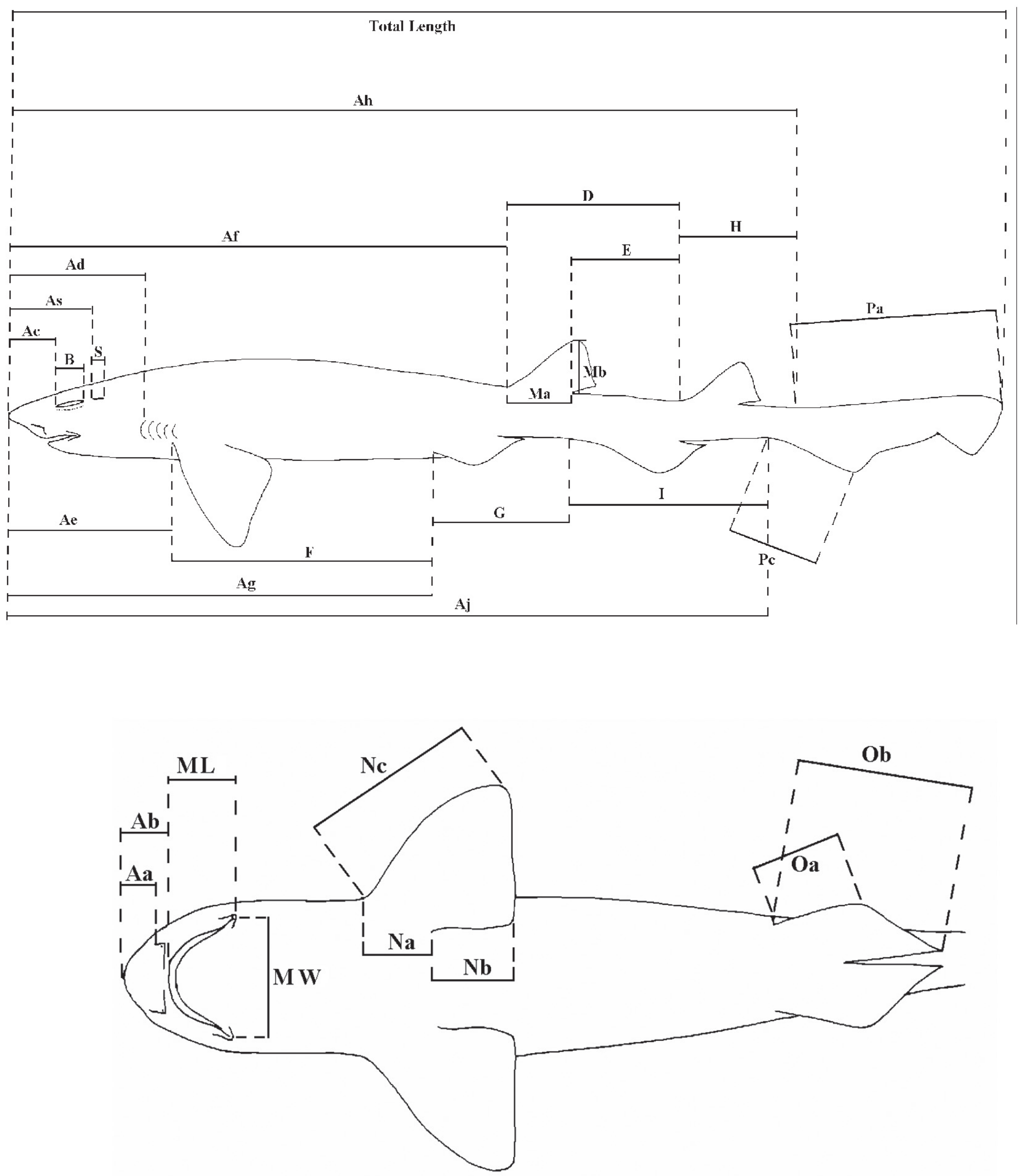

Fig. 2. Some of the measurements taken in the present study. Aa: snout to nostrils; Ab: snout to mouth; Ag: snout to pelvic; Aj: snout to lower caudal lobe; F: pectoral to pelvic; ML: mouth length; MW: mouth width; Na: pectoral base; Nb: pectoral inner edge; Nc: pectoral length; Oa: pelvic to lateral lobe; Ob: pelvic to median tip; Pa: upper caudal; Pc: lower caudal (according to BASS et al., 1975)

RESULTS

The mouth was significantly longer (4.02 vs 3.75%TL; p<0.000l) and narrower (7.42 vs 7.51%TL; p<0.0001) in males than in females, resulting in significantly different ML/MW ratios (0.55 for males and 0.50 for females; p<0.000l; Table 1). ML/MW was almost constant in the three smallest length groups for both sexes, then significantly decreased for females and increased for males after length group 4 (375-424 mm; Fig. 3). In group 4, ML significantly differed between sexes but MW and ML/MW did not. In group 5 (425-474 mm), ML and ML/MW significantly differed between sexes. In group 6 (>474 mm), all three variables significantly differed (Table 2).

Table 1. Differences between male and female smallspotted catshark, Scyliorhinus canicula*, specimens in mouth length (ML), mouth width (MW), and ratio of mouth length to width (ML/MW), expressed as percentages of total length, means± SD, with ranges in parentheses*

	Males				Females			
TL group (mm)	n	ML	MW	ML/MW	n	ML	MW	ML/MW
<275	15	3.85±0.59 (3.11-5.60)	8.16±1.91 (5.83-14.20)	0.49±0.12 (0.25-0.74)	16	3.69±0.42 (2.78-4.48)	7.60±1.11 (4.63-9.85)	0.49±0.07 (0.38-0.63)
275-324	26	3.81±0.39 (2.97-4.55)	7.50±0.57 (6.67-9.02)	0.51±0.07 (0.34-0.65)	29	3.84±0.69 (2.67-5.97)	7.59±0.73 (5.87-9.09)	0.51±0.09 (0.36-0.85)
325-374	35	3.84±0.37 (3.22-4.86)	7.51±0.59 (5.48-8.49)	0.51±0.06 (0.40-0.65)	28	3.75±0.38 (3.06-4.51	7.51±0.83 (5.03-8.82)	0.51±0.07 (0.36-0.70)
375-424	30	4.19±0.65 (3.21-6.31)	7.50±1.12 (5.98-12.59)	0.57±0.11 (0.32-0.90)	21	3.85±0.38 (3.05-4.45)	7.25±0.76 (5.94-8.32)	0.53±0.05 (0.44-0.67)
425-474	46	4.17±0.48 (3.32-6.24)	7.30±0.49 (6.28-8.94)	0.57±0.06 (0.44-0.84)	20	3.68±0.38 (3.12-4.42)	7.42±0.64 (6.17-8.37)	0.50±0.05 (0.39-0.63)
>474	21	4.12±0.32 (3.59-4.84)	6.80±0.65 (5.46-7.80)	0.61±0.07 (0.49-0.77)	9	3.59±0.37 (3.04-4.17)	7.85±0.48 (6.84-8.42)	0.46±0.05 (0.41-0.55)
Total	173	4.02±0.50 (2.97-6.31)	7.42±0.92 (5.46-14.20)	0.55±0.09 (0.25-0.90)	123	3.75±0.47 (2.67-5.97)	7.51±0.79 (4.63-9.85)	0.50±0.07 (0.36-0.85)

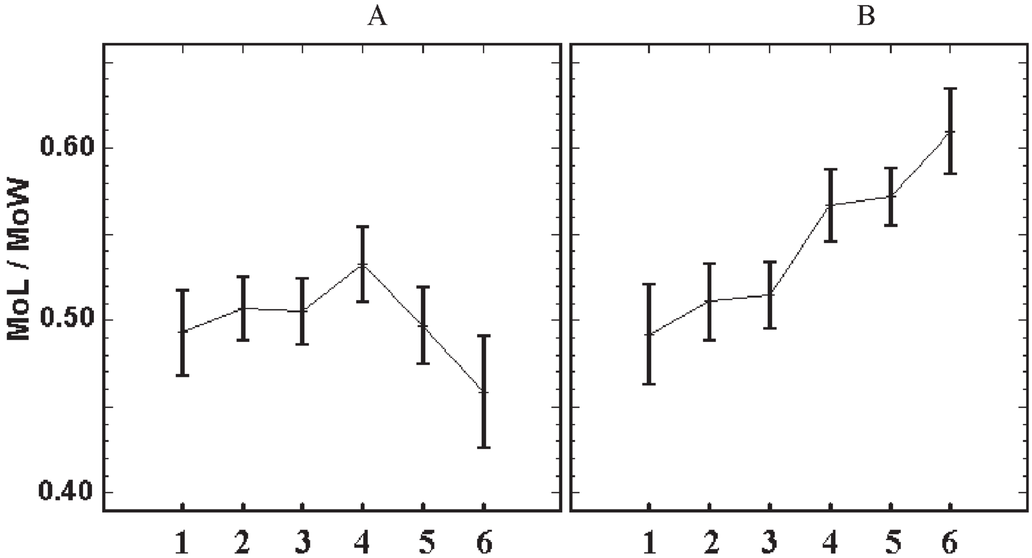

Fig.3. Relationship between mean ratio of mouth length to mouth width (ML/MW; ± SD) and size group in (A) female and (B) male Scyliorhinus canicula*. Size groups are 1: <275 mm, 2: 275-324 mm, 3: 325-374 mm, 4: 375-424 mm, 5: 425-474 mm, 6: >474 mm*

Table 2. Probability values showing statistical differences of between mouth length (ML), mouth width (MW) and ML/MW between male and female Scyliorhinus canicula *of different size groups (measurements converted to percentages of total length)*

Size group	ML	MW	ML/MW
<275 mm	0.382	0.317	0.975
275-324 mm	0.880	0.628	0.850
325-374 mm	0.317	0.992	0.573
375-424 mm	0.033*	0.374	0.175
425-474 mm	0.001*	0.403	0.000*
>474 mm	0.000*	0.001*	0.000*
Total	0.000*	0.417	0.000*

* significantly different at $p<0.05$

Significant size-based differences were observed within each sex, more so for male fish. ML/MW in males ranged 0.49-0.61 (Table 1), with significant differences occurring between the smallest size (group 1) and the three largest sizes (groups 4-6; p = 0.0005, 0.0004, and 0.0001, respectively). This difference can be attributed to an increase in the ML and decrease in MW as the males grew. The ML of males in groups 1-3 significantly differed from the ML of males in groups 4-6 ($p<0.005$) while the MW of males in group 1 significantly differed from the MW of the other five groups ($p<0.005$). In females, ML and MW changed very little.

ML and MW positively correlated with TL in both males and females (Fig. 4). The linear relationships are described by the following equations. For females: ML = 0.035TL + 0.738 (r^2 = 71.99, n = 123) and MW = 0.074TL + 0.452 (r^2 = 79.26, n = 123). For males: ML = 0.047TL – 2.505 (r^2 = 76.99, n = 173) and MW = 0.060TL + 5.174 (r^2 = 67.28, n = 173).

Among the head measurements, the distances from the snout to the spiracle and from the snout to the pectoral fin were significantly greater in males than in females (Table 3). The length between the snout and the first gill-slit tended to be shorter in females, although this difference was not statistically significant (p = 0.057). Five other measurements (total body length, pelvic to anal, pectoral inner edge, pelvic to median tip, upper caudal) significantly differed between males and females (Table 4).

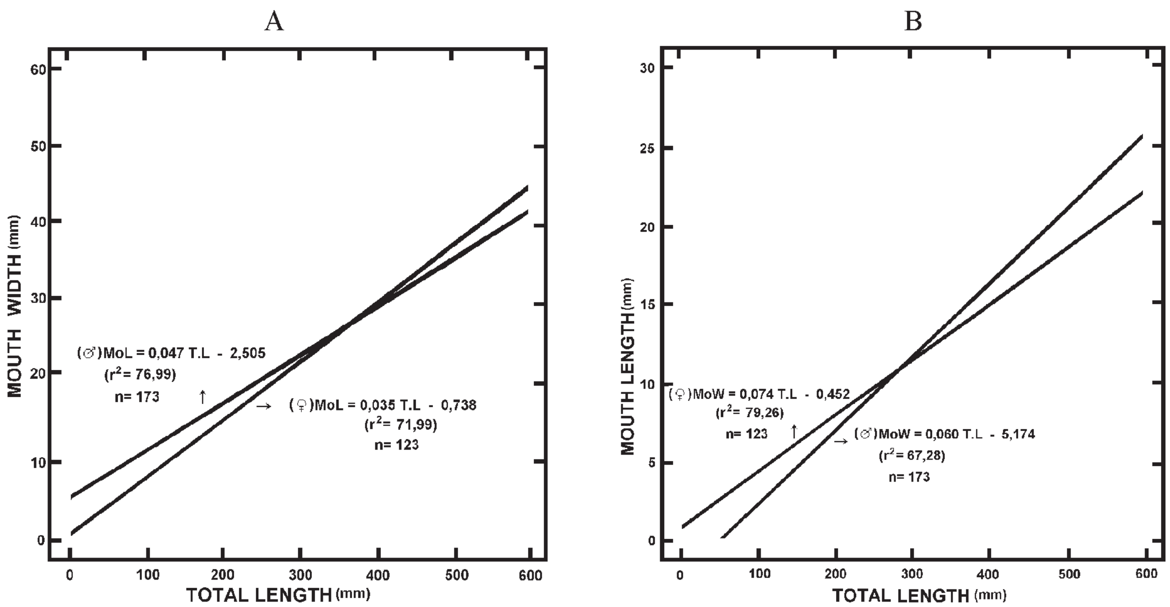

Fig.4. Relationships between (A) mouth length and total length and (B) mouth width and total length for male and female Scyliorhinus canicula

Table 3. Comparison between males (n = 173) and females (n = 123) of eight measurements in the head region, values are converted to percentages of total length, means± SD, with ranges in parentheses

Measurement	Male	Female	*p*
Snout to nostrils (Aa)	2.44±0.39 (1.79-3.73)	2.46±0.40 (1.70-4.71)	0.653
Snout to mouth (Ab)	3.91±0.37 (2.33-5.48)	3.96±0.37 (2.54-5.16)	0.298
Snout to eye (Ac)	5.68±0.50 (3.15-7.80)	5.60±0.56 (3.28-7.19)	0.113
Snout to first gill-slit (Ad)	12.48±0.89 (10.17-18.40)	12.25±1.18 (9.94-21.82)	0.057
Snout to pectoral (Ae)	16.55±1.47 (7.39-24.00)	16.20±1.13 (13.70-20.06)	0.026*
Snout to spiracle (As)	9.50±0.55 (7.22-13.40)	9.33±0.83 (3.92-11.11)	0.037*
Eye diameter (B)	3.68±0.75 (0.96-6.58)	3.65±0.65 (2.18-5.24)	0.744
Spiracle length (S)	0.85±0.15 (0.53-1.40)	0.84±0.17 (0.42-1.48)	0.824

* significantly different at $p<0.05$

Table 4. Comparison between males (n = 173) and females (n = 123) of eighteen body measurements, values are converted to percentages of total length, means± SD, with ranges in parentheses

Measurement	Males	Females	*p*
Total length (TL)	385.83±73.70 (210.00-525.00)	357.89±72.59 (210.00-508.00)	0.001*
Snout to first dorsal (Af)	49.51±2.14 (45.46-70.00)	49.32±3.10 (45.20-76.27)	0.533
Snout to pelvic (Ag)	39.29±2.08 (27.65-56.00)	39.81±3.02 (35.00-58.68)	0.083
Standard length (Ah)	79.90±3.64 (68.66-114.00)	79.54±2.02 (76.09-93.14)	0.311
Snout to lower caudal lobe (Aj)	78.06±3.03 (68.00-110.00)	77.98±3.22 (72.36-102.63)	0.820
First to second dorsal (D)	18.20±1.19 (15.09-26.80)	18.14±1.01 (14.88-21.57)	0.648
Between dorsal bases (E)	12.78±1.05 (10.50-19.20)	12.90±0.99 (10.79-17.11)	0.338
Pectoral to pelvic (F)	23.54±1.73 (18.52-36.00)	23.79±1.46 (20.00-27.78)	0.193
Pelvic to anal (G)	19.30±1.27 (16.67-26.00)	18.91±1.42 (15.24-23.26)	0.013*

Table 4. Cont'd

Measurement	Males	Females	*p*
Second dorsal to upper caudal (H)	12.44±1.02 (10.19-16.80)	12.62±1.26 (9.36-16.67)	0.176
Anal to lower caudal (I)	20.17±1.25 (16.67-29.20)	20.26±1.24 (17.05-24.00)	0.576
Pectoral base (Na)	5.20±0.60 (3.88-8.00)	5.24±0.59 (3.68-7.46)	0.571
Pectoral inner edge (Nb)	5.95±0.71 (4.00-8.22)	6.18±0.80 (4.32-9.47)	0.008*
Pectoral length (Nc)	12.13±0.98 (9.33-15.71)	12.19±0.84 (10.29-15.03)	0.576
Pelvic to lateral lobe (Oa)	5.97±0.64 (4.27-8.40)	5.97±0.61 (4.14-8.37)	0.966
Pelvic to median tip (Ob)	12.63±1.23 (9.43-17.20)	10.76±0.81 (8.24-12.67)	0.000*
Upper caudal (Pa)	20.49±1.43 (16.81-28.00)	21.11±2.06 (17.78-34.72)	0.003*
Lower caudal (Pc)	9.32±1.29 (4.67-14.80)	9.39±1.15 (4.12-11.63)	0.619

* significantly different at $p<0.05$

DISCUSSION

Sexual dimorphism with respect to body size appears more common among shark species in which the females are viviparous or ovoviviparous (SIMS, 2003). Although *S. canicula* is oviparous, earlier studies have shown that such dimorphism can occur in this species also (BROUGH, 1937; ARTHUR, 1950; BAS, 1964; JARDAS, 1979; ELLIS & SHACKLEY, 1995; ERDOGAN *et al.*, 2004), and our findings support these studies.

The ML/MW values in the present study (0.55 for males and 0.50 for females) coincide with the values of 0.59 for males and 0.53 for females given by ARTHUR (1950) and 0.67 for males and 0.57 for females given by ERDOGAN *et al.* (2004) for *S. canicula*. Thus sexual dimorphism in ML/MW is statistically confirmed by the present study. The values given by ARTHUR (1950) and ERDOGAN *et al.* (2004) significantly differ from those of ELLIS & SHACKLEY 1995; (0.49 for males and 0.43 for females) who claimed that this might be because ARTHUR (1950) had used a small sample size. Sexual dimorphism in ML/MW is due to the increase in mouth length and decrease in mouth width in males as the fish grow. If this change in morphology is related to reproductive changes, it can be considered a secondary sex characteristic (ELLIS & SHACKLEY, 1995). In the present study, ML/MW significantly differed between sexes only in the larger size groups and not for fish under 425 mm. Differences in intermandibular separation have been related to sexual maturity (BROUGH, 1937). In *S. canicula*, both sexes attain maturity at 57-60 cm (FORD, 1921). Assessing maturity by clasper length, nidamental gland width and weight, and appearance of gonads, ELLIS & SHACKLEY (1997) suggested that males and females mature at approximately 52 and 55 cm, respectively. ELLIS & SHACKLEY (1995) suggested that the changes in mouth morphology of male fish and subsequent sexual dimorphism in ML/MW are related to sexual maturity, since fish below 500 mm were immature, those within 500-549 mm were maturing, and larger fish were mature. In *Schroederichthys bivius* (Smith), the ML/MW in females and juvenile males was 0.50

while in mature males it was 0.80 (GOSZTONYI, 1973).

Both ML and MW positively correlated with TL in both sexes, however, the present study lacks information on specimens below 210 mm and above 525. BASS (1973), who studied the relationship between ML and TL, reported an initial decrease and subsequent increase in ML for larger fish in a sample of 119 male and female *Carcharhinus leucas*. ELLIS & SHACKLEY (1995) suggested that the initial decrease in ML after birth was probably due to the head region being better developed at birth than the rest of the body.

According to ELLIS & SHACKLEY (1995), the mouth dimensions in male *S. canicula* change during maturation and males have longer teeth than females, perhaps due to differential feeding habits or adaptations for reproductive behavior. The diet of *S. canicula* is composed primarily of decapod crustaceans, mollusks, and teleosts (FORD, 1921; LYLE, 1983) with no significant dietary differences between males and females in Isle of Man waters (LYLE, 1983). On the other hand, precopulatory behavior and copulation in scyliorhinids may involve the male biting the fins and body of the female (CASTRO *et al.,* 1988) and the mouth of the male may have adapted to this function by changing shape and dentition (ELLIS & SHACKLEY, 1995).

We could not determine any statistical difference between pre-oral lengths (snout to mouth) of males and females. However, ELLIS & SHACKLEY (1995) and ERDOGAN *et al.* (2004) found that pre-oral length was significantly shorter in males and suggested it was a result of the increased mouth length. Similarly, they suggested that significant differences in pre-branchial lengths, head lengths, and head widths might be due to sexual differences in the pattern of growth of the whole head region. Our snout to spiracle measurements almost coincide with results of ELLIS & SHACKLEY (1995). Although the pre-branchial lengths of males and females did not statistically differ, the snout to first gill-slit and snout to pectoral distances were longer in males than in females.

Regarding body measurements, the pelvic-anal and pelvic-median tip distances were longer in males than in females while the pectoral inner edge and upper caudal lengths were shorter in males. ELLIS & SHACKLEY (1995) recorded a total body length of 586 for males and 555 mm for females. Sexual dimorphism in total body length was confirmed in our study, however, the mean values given by ELLIS & SHACKLEY (1995) are significantly higher than those obtained in the present study (385 for males, 357 mm for females). Apparently, *S. canicula* are much smaller in the Aegean Sea than in the Swansea and Oxwich Bays of the Bristol Channel and the Irish Sea. By studying the length range and lengths at sexual maturity of *S. canicula* in the northern Aegean, CIHANGIR *et al.* (1997) suggested that Mediterranean dogfish grow more slowly than Atlantic dogfish and that they reach sexual maturity at a smaller length. Compared to the Atlantic, Mediterranean marine communities have more species with generally smaller individuals (Mediterranean nanism; ZENETOS *et al.,* 2002). The smaller lengths observed in this study could be a result of the nanism observed in eastern Mediterranean species (MACHIAS *et al.,* 1998). LITVINOV (2003), who studied sexual dimorphism as an index of the isolation of West African populations of *S. canicula*, noted significant morphological differences between west African catsharks and west European and Mediterranean catsharks and suggested that comparative morphological studies on these populations are needed to determine whether the west African catshark is an independent species or a subspecies.

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Spolni dimorfizam glave, ustiju i tijela mačke bljedice, *Scyliorhinus canicula* Linnaeus, 1758 iz Turske

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SAŽETAK

Mužjaci mačke bljedice imaju dužu i užu gubicu od ženki što ukazuje na naglašen spolni dimorfizam. Odnos dužina/širina gubice je 0,55 kod mužjaka i 0,50 kod ženki. Druga mjerenja glave su također signifikantno različita kod spolova, tj. gubica-dišni otvor i udaljenost gubica-prsne peraje. Mjerenja tijela, koja su različita kod spolova, uključuju prsni do analnog dijela, prsni nutarnji rub, prsni do srednjeg dijela, gornju repnu i ukupnu dužinu tijela. U radu je diskutirano o razlozima tih razlika.

Ključne riječi: *Scyliorhinus canicula*, Elasmobranchii, spolni dimorfizam, meristika, nanizam