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Biological observations on the smallspotted catshark *Scyliorhinus canicula* (Chondrichthyes: Scyliorhinidae) off the Languedocian coast (southern France, northern Mediterranean)

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Abstract. The smallspotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758) presents a wide Atlanto-Mediterranean distribution, being commonly captured off the Languedocian coast (southern France, northern Mediterranean). Production of egg capsules was observed throughout the year, except in September. Hepatosomatic index (HSI), gonosomatic index (GSI) and oviducosomatic index (OSI) significantly increased with size in both males and females. HSI reached the highest values in both sub-adult and adult specimens, reflecting the role of the liver in the gonadal production as well as in buoyancy, while GSI and OSI reached the highest values in adult females. HSI and GSI did not show significant monthly variations, suggesting that the reproductive activity occurred throughout the year in both males and females. This fact was enhanced in the females by the lack of significant monthly variations in OSI.

Key words: Chondrichthyes, Scyliorhinidae, *Scyliorhinus canicula*, liver, gonads, oviducal glands Mediterranean.

Resumen. Biological observations on the smallspotted catshark *Scyliorhinus canicula* (Chondrichthyes: Scyliorhinidae) off the Languedocian coast (southern France, northern Mediterranean). La pintarroja, *Scyliorhinus canicula* (Linnaeus, 1758) posee una distribucion Atlanto-Mediterranea amplia, siendo comunmente capturada aguas afuera de la costa de Languedocian (sur de France, norte del Mediterranean). La producción de capsulas ovigeras fue observada durante todo el año, excepto en Setiembre. Los indices hepatosomatico (IHS), gonosomatico (IGS) y oviductosomatico (IOS) aumentaron significativamente con el tamaño en ambos machos y hembras. El IHS alcanzó su valor mas alto en especimenes sub-adultos y adultos, reflejando el rol de higado en la produccion gonadal asi como en la flotacion, mientras que los indices gonadosomático y oviductosomatico alcanzaron su valor mas alto en las hembras. Los IHS e IGS no mostraron variación mensual, lo que sugiere que la actividad reproductiva ocurrió durante todo el año tanto en machos como en hembras. Este hecho es reforzado en las hembras por la falta de variaciones mensuales significativas en el IOS.

Palavras claves: Chondrichthyes, Scyliorhinidae, *Scyliorhinus canicula*, hígado, gónadas, glándula oviductal, Mediterráneo.

Introduction

The smallspotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758) is a typical Atlanto-Mediterranean species that occurs in the northeastern Atlantic and, south Strait of Gibraltar, from Morocco to the Gulf of Guinea (Blache et *al.* 1970), and probably off Angola (Quéro 1984). *S. canicula* is reported throughout the Mediterranean, especially in southern areas (Capapé *et al*. 2000).

Off the Languedocian coast, *S. canicula* is the most abundant elasmobranch species (Capapé *et al.* 2000) and generally targeted for consumption, and locally marketed under the vernacular name of 'saumonette': having a relatively high economical value. Some traits of the reproductive biology of the smallspotted catshark from the area were previously reported by Capapé *et al.* (1991, 2000, 2008).

In this paper, we provide additional observations on smallspotted catsharks by analyzing variations of gonadosomatic and hepatosomatic indexes in both sexes, and oviducosomatic index, only in females, in order to try to detect seasonal variations in the gonadal production. Our results are compared and contrasted with those carried out in smallspotted catsharks from other regions, such as off the northeastern Atlantic coast (Craik 1978, Sumpter & Dodd 1979, Ellis & Schakley 1997) and off the Mediterranean coast (Olivereau & Leloup 1950, Leloup & Olivereau 1951, Capapé 1978, Capapé *et al*. 1991, 2000, 2008).

Materials and Methods

Samples of *Scyliorhinus canicula* were collected off the Languedocian coast, between January 2000 and December 2006. Most of the examined specimens were landed at the fishing harbour of Sète, the fishing sites of Palavas-Les-Flots and Carnon (Fig. 1), at depths between 80 and 100 m, on sandy-muddy and detritic bottoms. In all, 816 specimens were caught by bottom trawling, in addition 90 specimens were captured by demersal gill-nets (see Capapé *et al*., 2008).

Total length (TL) of the specimens was measured to nearest millimetre and total mass (TM) recorded to the nearest gram. Liver mass (LM), gonad mass (GW) and oviducal gland mass (OM) were assessed to the nearest decigram. Developing and yolky oocytes, egg capsules were measured to the nearest millimetre and their masses recorded to the nearest decigram. Males and females were studied separately.

Three stages of male maturity were considered relative to the degree of calcification of claspers and the morphology of the genital duct, following Capapé *et al.* (2008). They were juvenile, sub-adult and adult. Similar stages were also considered in females from the condition of ovaries, the morphology of the reproductive tract and the mass of oviducal glands following Callard *et al*. (2005), Henderson *et al.* (2006) and Capapé *et al.* (2008). Hepatosomatic index (HSI), gonadosomatic index (GSI) were calculated in both males and females, as HSI = (LM/TM) * 100, GSI = (GM/TM) * 100, while the oviducosomatic index (OSI) was calculated only in females, as OSI = (OM/TM) * 100. Variations in HIS, GSI and OSI related to size were considered in all categories of specimens in both sexes, while monthly variations were only considered in adult males and females.

Tests for significance ($p < 0.05$) were performed by using ANOVA, with special regard to variations in HSI, GSI and OSI related to size, while monthly comparisons were performed using non-parametric H-test of Kruskal-Wallis. The linear regression was expressed in decimal logarithmic coordinates. Correlations were assessed by least-squares regression.

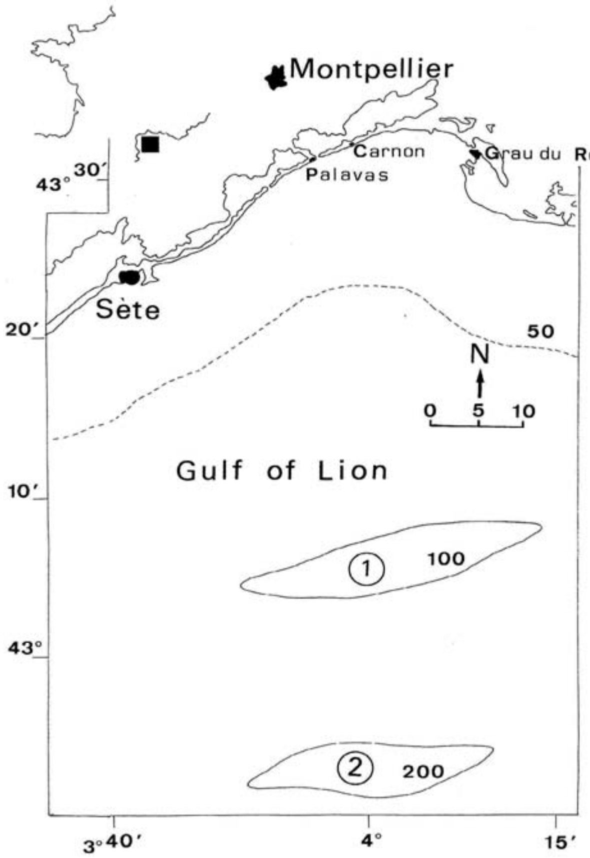

Figure 1. Map of France pointing out the coast of Languedoc and the captures sites of the small spotted catshark *Scyliorhinus canicula* in the 'pits' from off Sète where the smallspotted catshark *S. canicula* ① and the blackmouth catshark *Galeus melastomus* ② are the dominant elasmobranch species (redrawn from Capapé *et al*. 2000).

Results

Juvenile males ranged from 270 to 390 mm TL and weighed from 28 to 176 g; they were mostly caught in January, October and November (Table 1). Juvenile females, ranged from 220 to 390 mm TL and weighed between 24 and 192 g; captures occurred especially in February, May, October and November (Table 1). The TL of the observed sub-adult males ranged between 400 and 430 mm, and the mass between 190 and 315 g; sub-adult males

Table 1. Monthly collection of the observed *Scyliorhinus canicula* captured off the Languedocian coast.

		Months												
Sex	Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Males														
	Juveniles	10	2	2	-	5	-	-	4	4	7	14	-	48
	Sub-adults	4	3	3	-	2	-	-	-	3	5	9	2	31
	Adults	28	32	28	22	56	19	27	18	15	14	21	18	298
	Total	42	37	33	22	63	19	27	22	22	26	44	20	377
Females														
	Juveniles	2	3	4	-	6	1	2	-	2	6	7	6	39
	Sub-adults	2	5	7	-	2	5	2	2	6	10	18	8	67
	Adults	24	25	53	55	41	33	31	34	16	40	33	38	423
	Total	28	33	64	55	49	39	35	36	24	56	58	52	529
	Grand total	70	70	97	77	112	58	62	58	46	82	102	72	906

were caught especially in November (Table 1). The observed sub-adult females ranged from 280 to 430 mm TL and weighed from 150 to 305 g (Table 1); sub-adult females were mostly caught from October to December. The smallest sexually mature male observed was 430 mm TL and weighed 245 g; all males above 440 mm TL were adult. The largest male was 550 mm TL and weighed 472 g, the heaviest specimen weighed 485 g and had 540 mm TL; adult males were collected throughout year, mostly from January to April with a peak in May (Table 1). The smallest sexually mature female had 410 mm TL and weighed 250 g. All females above 450 mm TL were adult. The 10 largest females were all 510 mm TL; they weighed 430-527 g. Adult females were collected throughout the year, mostly in April and May, a bit less in September (Table 1).

Of the 423 collected adult females, two categories were distinguished, non egg capsule bearing and egg capsule bearing, the latter occurring all year round, except in September (Table 2). The oviducal gland mass of 352 adult females was recorded. In the sample, 71 females exhibited egg capsule in formation, consequently the oviducal gland mass was not recorded in these females. The relationship TL and OG Mass was: log OG Mass = 8.801 log TL - 22.65; r = 0. 90; n = 352 (Fig. 2).

The HSI of males exhibited high values in the smallest free-swimming specimens, and decreased from TL of about 300 TL onward (Fig. 3). Then, HSI globally significantly increased when males entered maturation stage and become sub-adults (df = 2, $p < 0.001$); although HSI reached the highest values in adult specimens, it did not significantly differ from values recorded in sub-mature specimens (df = 2, p = 0.545). HSI of females related to TL (Fig. 4) significantly changed when juveniles entered the stage of maturation and became sub-adults (df = 2, $p < 0.001$), also from sub-adults into adult stage (df = 2, p = 0.043). GSI of both males and females increased with TL of specimens and significantly reached the highest values in adult specimens (Fig. 5, 6), for both males and females (df = 2, $p < 0.001$). Concomitantly, similar pattterns were observed in OSI (Fig. 7), which significantly reached the highest values in adult females (df = 2, $p < 0.001$).

The monthly mean values of mature male HSI plotted in Fig. 8 did not showed significant variations throughout year and although the highest values were observed in March and September (df = 11, $p > 0.05$). Additionally, GSI of adult males did not show significant monthly variations (df = 11, $p > 0.05$), although it exhibited low values in June and July (Fig. 9).

The HSI of adult females did not showed significant monthly variations (df = 11; $p > 0.05$), although reached low values especially in June and July (Fig. 10). All the observed adult females had a permanent vitellogenic that occurred throughout year. The ovary contained two batches of yellow oocytes: one batch of yolky oocytes, generally ready to be ovulated and one batch of developing oocytes. Concomitantly, the sampled adult female *S. canicula* had a permanent production of egg capsules, except in September (see Table 2). The GSI of adult females did not present significant monthly variations throughout the year (df = 11, $p > 0.05$), while in June and August, it reached low values (Fig. 11). The OSI did not present significant monthly variations throughout year (df = 11, $p > 0.05$), it reached the lowest value in June (Fig. 12).

Table 2. Monthly collection of the observed adult female *Scyliorhinus canicula* captured off the Languedocian coast.

	Months												
Category of adult females	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Non egg capsules bearing	14	18	21	20	23	17	14	18	16	27	23	12	223
Egg capsules bearing	10	7	32	35	18	16	17	16	-	13	10	26	200
Total	24	25	53	55	41	33	31	34	16	40	33	38	423

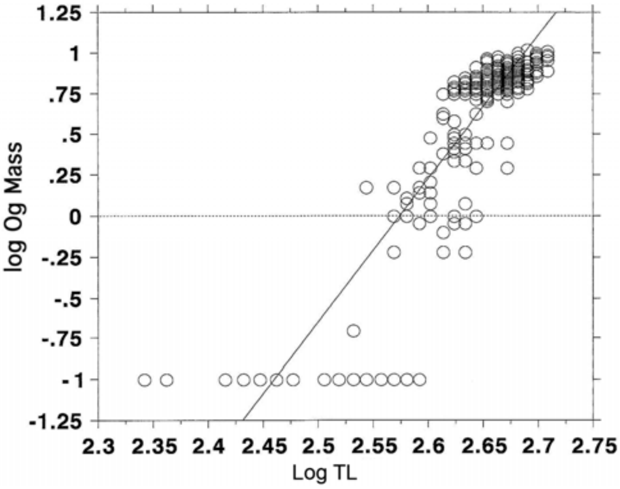

Figure 2. Relationship between Oviducal Gland Mass (OG Mass) and Total Length (TL) expressed in logarithmic co-ordinates for female *Scyliorhinus canicula*.

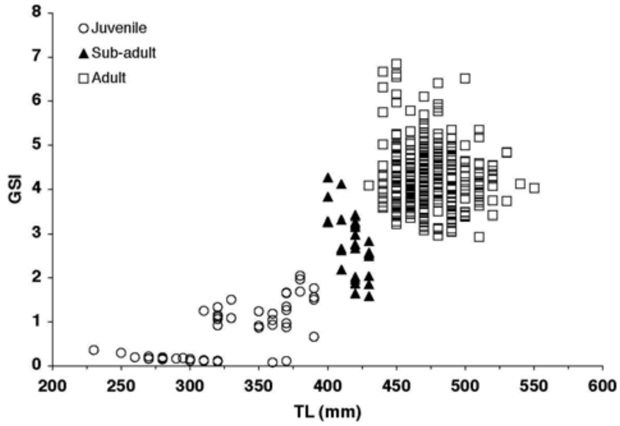

Figure 5. Variations in gonosomatic index (GSI) vs Total length (TL) in male *Scyliorhinus canicula*.

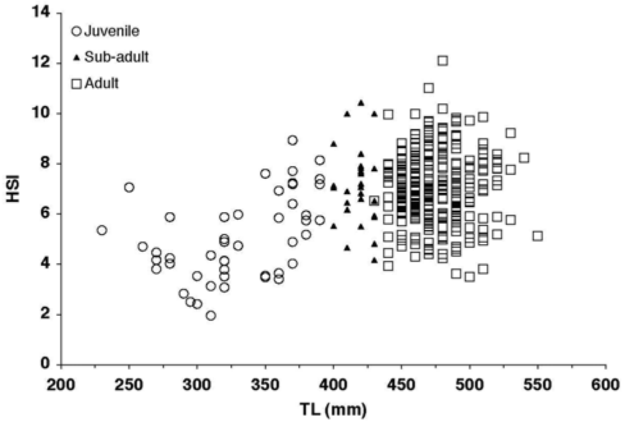

Figure 3. Variations in hepatosomatic index (HSI) vs Total length (TL) in male *Scyliorhinus canicula*.

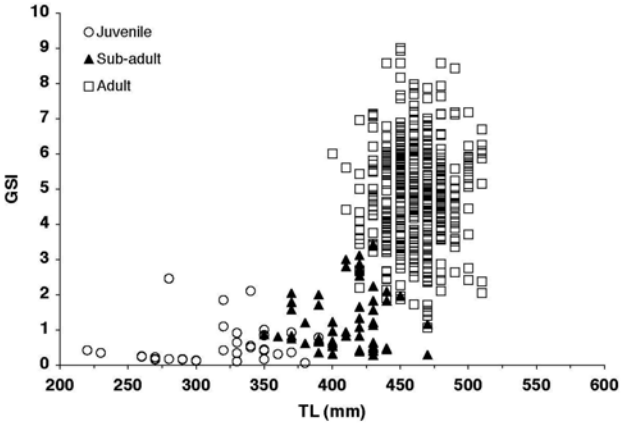

Figure 6. Variations in gonosomatic index (GSI) vs Total length (TL) in female *Scyliorhinus canicula*.

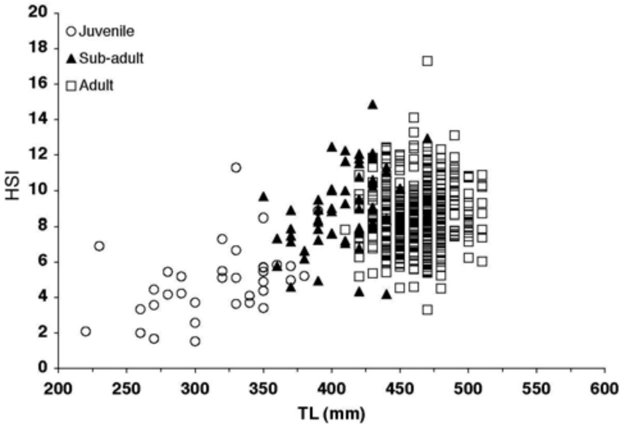

Figure 4. Variations in hepatosomatic index (HSI) vs Total length (TL) in female *Scyliorhinus canicula*.

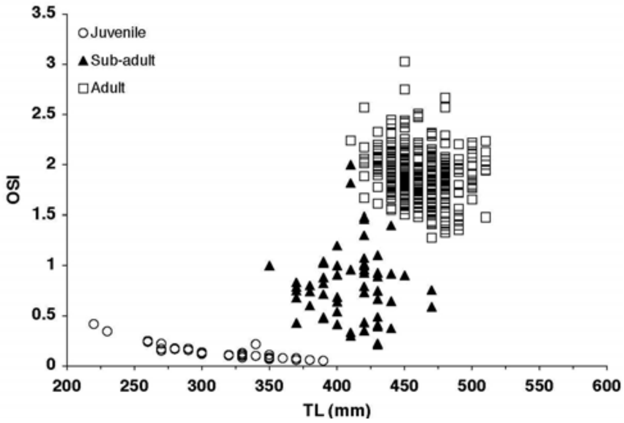

Figure 7. Variations in oviducosomatic index (HOI) vs Total length (TL) in female *Scyliorhinus canicula*.

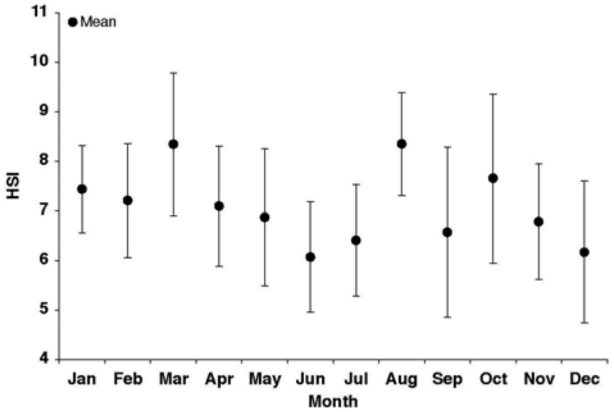

Figure 8. Monthly variations in hepatosomatic index (HSI) in male *Scyliorhinus canicula*.

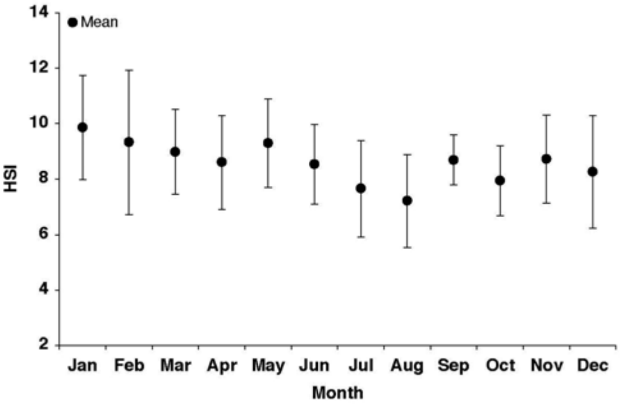

Figure 9. Montly variations in hepatosomatic index (HSI) in female *Scyliorhinus canicula*.

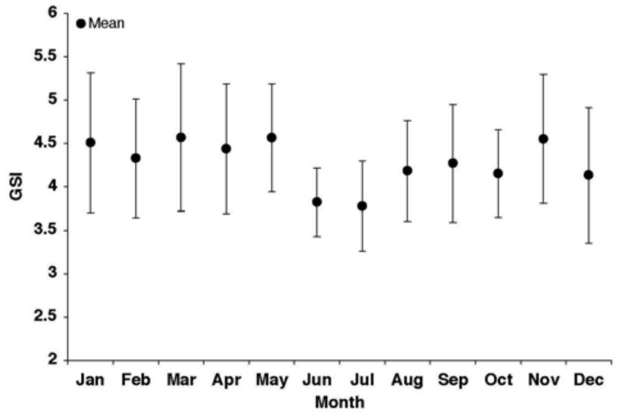

Figure 10. Monthly variations in gonosomatic index (GSI) in male *Scyliorhinus canicula*.

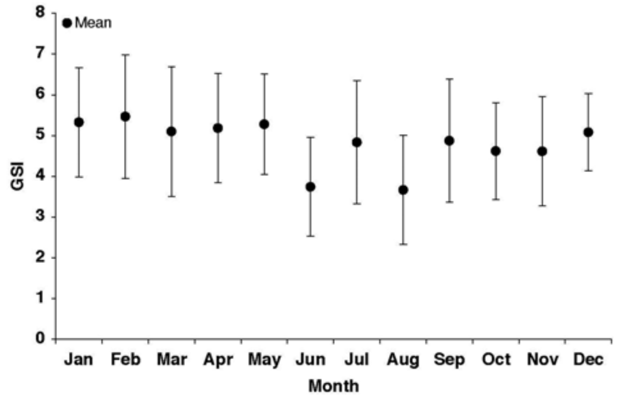

Figure 11. Montly variations in gonosomatic index (GSI) in female *Scyliorhinus canicula*.

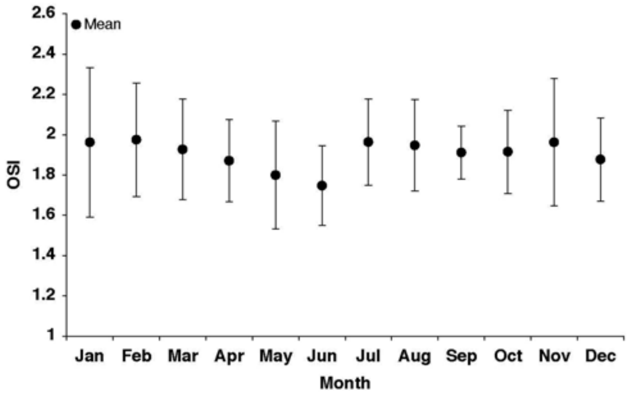

Figure 12. Monthly variations in oviducosomatic index (OSI) in female *Scyliorhinus canicula.*

Discussion

Generally, *Scyliorhinus canicula* had an extended egg laying period subjected to changes according to the area (Capapé *et al*. 1991, 2008, Mellinger 1989). Off the Languedocian coast, egg laying occurred throughout the year except in September, and it peaked between April and August; additionally, all the analysed females exhibited an active vitellogenesis throughout the year confirming previous data carryed out for *S. canicula* from off the Mediterranean coast of France (Capapé *et al.* 1991, 2008). In British waters, egg laying especially occurred in spring with a gap between August and October (Ford 1921, Metten 1939, Harris 1952, Craik, 1978), while Ellis & Shackley (1997) observed egg capsules in the oviducts in all months, except August and September, with a peak in June and July. Off the Tunisian coast, Capapé (1977) noted that egg laying started in spring, peaked in summer and slightly decreased in autumn. In *S. canicula* off the Mediterranean coast of France, egg laying occurred from March to June and in December. Similar patterns were reported for oviparous skates by several authors (Holden *et al*. 1971, Ebert 2005, Oddone & Vooren 2005, Oddone *et al*. 2007, 2008), these instances allowed Oddone *et al*. (2007) to consider that in rajids, ‘egg-laying is an annual event, and females may lay continuously until senescence or possible resting period’. This phenomenon seems to be confirmed by GSI high values attained by adult female *S. canicula* throughout year. Females' *S. canicula* were heavier than the males, and the relationship between total mass and total length showed significant differences between males and females (Capapé *et al*. 2008). This may be the consequence of reproductive cycle of females, the gonad mass increased because it generally developed a high vitellogenic activity and produced large and heavy yellow oocytes while oviducal glands produced egg capsules. In addition, the male reproductive cycle may be annual as demonstrated by the slight variations of GSI throughout year, which decreased in June in July. Similar patterns were observed in adult females from June to September.

The relationship between liver mass and total mass also showed significant differences between males and females (Capapé *et al*. 2008), suggesting that liver plays an important role in life cycle of the latter (Oddone & Velasco 2006). Liver size is sexually dimorphic in chondrichthyan species. A larger liver may allow females to maximize the production of yolk such as in the viviparous lesser guitarfish *Rhinobatos annulatus* Müller & Henle, 1841 (Rossouw 1987), as well as in the small spotted catshark (García-Garrido *et al.* 1990), the smallnose fanskate *Sympterygia bonapartii* (Magrabaña *et al.* 2002) and the thornback ray *Raja clavata* (Capapé *et al*. 2007). Moreover, cartilaginous fish store energy as lipids in the liver (Craik 1978). In viviparous females larger liver observed may be related to the increased energy expenditure during vitellogenesis, oocyte maturation and gestation as well as females store large quantities of lipids in the liver during the reproductive cycle (Lucifora *et al.* 2005).

In both sexes, HSI monthly reached high values, between 6.2 and 8.3 for males and between 6.5 and 10.0 for females. Similar values were reported by Capapé (1978) for *S. canicula* from the Tunisian coast. In Mediterranean smallspotted catsharks, the HSI ranged from 6.3 to 11.0 in females and 4 to 6 in males according to Kollman *et al.* (1929), while Olivereau & Leloup (1950) reported from 4 to 7 in females and from 3.5 to 5.5 in males. However, these HSI values are lower that those reported by literature in aplacental viviparous elasmobranch species, probably because in the latter, females produce larger oocytes, for instance Capapé *et al.* (1999) noted that HSI values ranged between 15 and 45 in the angular rough shark *Oxynotus centrina*.

Moreover, Capapé *et al*. (1999) considered as a suitable hypothesis the transfers of nutriments from liver to ovaries in *O. centrina*, these transfers appear to be less evident in *S. canicula* from the Languedocian coast: the monthly variations of HSI and GSI did not clearly correspond in both males and females. Similar patterns were reported in *S. canicula* from the Tunisian coast (Capapé 1978). Moreover, Capapé *et al*. (1999) delineated the allocation of nutriments from the liver to the ovaries in *O. centrina* which appear to be less evident in *S. canicula* from the Languedocian coast, as the monthly variations of HSI and GSI did not clearly correspond in both males and females. However, according to Oddone *et al.* (2007), such transfers should not be ignored during reproductive cycle of both males and females in oviparous elasmobranch species, like rajids. Furthermore, similar patterns were noted in *S. canicula* from the Tunisian coast (Capapé 1978).

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