MATURITY, FECUNDITY AND OCCURRENCE OF THE SMALLSPOTTED CATSHARK SCYLIORHINUS CANICULA (CHONDRICHTHYES: SCYLIORHINIDAE) OFF THE LANGUEDOCIAN COAST (SOUTHERN FRANCE, NORTH-WESTERN MEDITERRANEAN)

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SCYLIORHINIDAE,
SCYLIORHINUS CANICULA
REPRODUCTIVE BIOLOGY
LANGUEDOCIAN COAST
FRANCE
MEDITERRANEAN SEA

ABSTRACT – The smallspotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758) presents a wide Atlanto-Mediterranean distribution, it is commonly captured off the Languedocian coast (southern France, north-western Mediterranean). The male and female sexually matured between 430-440 mm and 410-450 mm total length (TL), respectively. The largest male and female were 550 mm and 510 mm TL, respectively and weighed 472 g and 527 g, respectively. The relationships between TL and total mass, and TL and liver mass are significantly different considering males and females. Diameter of the largest yolky oocytes ranged from 14 to 18 mm (mean ± SD = 14.8 ± 2.7 mm) and weighed from 1.4 to 1.8 g (mean ± SD = 1.6 ± 0.1 g). Production of egg cases was observed throughout the year, except in September. Egg cases had between 41 and 58 mm (mean ± SD = 47.1 ± 3.7 mm) in length, and between 16 and 20 mm (mean ± SD = 18.3 ± 1.2 mm) in width, and they weighed between 4.1 and 5.9 g (mean ± SD = 4.5 ± 0.3 g). Fecundity remained difficult to assess, an estimation based on production of egg cases the yolky oocytes by females, enabled us to consider it between 38 and 115.

INTRODUCTION

The smallspotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758) is a typical Atlanto-Mediterranean species known from the north-eastern Atlantic, Scandinavia (Duncker 1960), North Sea (Muus & Dahlstrøm 1964-1966), British Isles (Wheeler 1969), Bay of Biscay (Albuquerque 1954-1956) and south of the Strait of Gibraltar from Morocco (Collignon & Aloncle 1972) to the Gulf of Guinea (Blache *et al*. 1970), and off Angola (Quéro 1984). *Scyliorhinus canicula* is reported throughout the Mediterranean, especially in southern areas (Capapé 1989).

Off the Languedocian coast, *S. canicula* is the most abundant elasmobranch species (Capapé *et al*. 2000) generally targeted for consumption, and locally sold under the vernacular name of 'saumonette': it had a relatively high economical value. Some traits of its reproductive biology were previously reported by Capapé *et al*. (1991, 2000). Recent records made in the area provide additional data that allow us to enlarge and improve the knowledge of the local smallspotted catshark.

MATERIAL AND METHODS

Smallspotted catsharks were collected off the Languedocian coast, between 2000 and 2005, 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 80-100 m, sandy-muddy and detritic bottoms. Eight hundred and sixteen specimens were caught by trawling and 90 others by demersal gill-nets.

Total length (TL) of the specimens was measured to the nearest millimetre and mass recorded to the nearest gram. Liver, gonad and oviducal glands were weighed to the nearest decigram. Developing and yolky oocytes, egg cases were measured to the nearest millimetre and their masses recorded to the nearest decigram. Males and females were studied separately. Clasper length (CL) was measured from the forward rim of the pelvic girdle to the tip of the clasper following Collenot (1969). For both males and females, three stages were considered: juvenile, sub-adult and adult, following Capapé *et al*. (1990), Hamlett *et al*. (1999) and Henderson *et al*. (2006). Size at sexual maturity was determined in females from the condition of ovaries, the morphology of the reproductive tract and the mass of oviducal glands following Callard *et al*. (2005) and Henderson *et al*. (2006).

The fecundity in *Scyliorhinus canicula* cannot be directly determined as in viviparous elasmobranch species. Fecundity estimation was assessed by using the method of Holden (1975), based on the estimation of the average number of eggs laid by adult females. Holden *et al*. (1971) noted that the rate of egg case laying by the thornback ray, *Raja clavata,* in aquaria was one egg case every 24 hours and this rate was maintained during 26 days. Holden (1975) considered that the month in which this

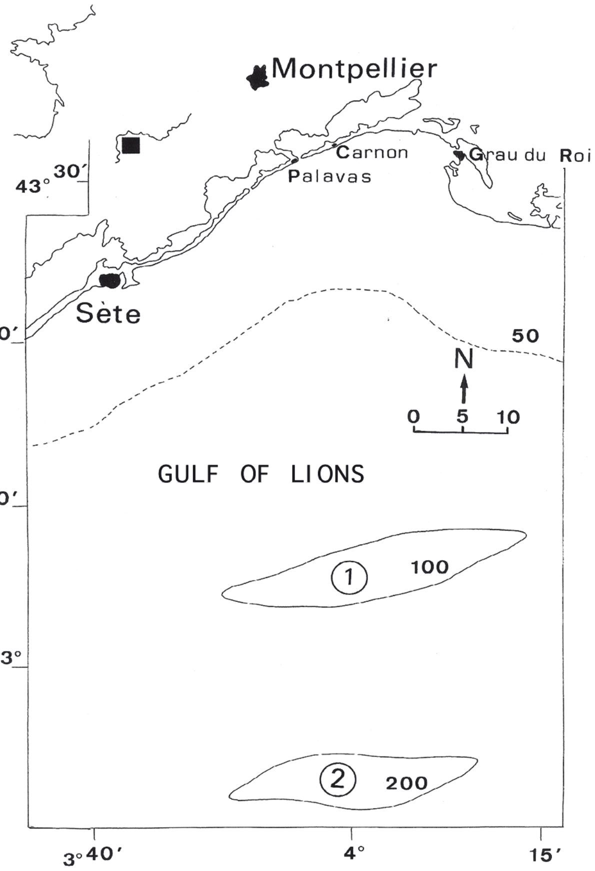

Fig. 1. – Map of France pointing out the coast of Languedoc and the capture sites of the small spotted catshark *Scyliorhinus canicula* in the 'pits' from off Sète where *S. canicula* (1)and the blackmouth catshark *Galeus melastomus* (2) are the dominant elasmobranch species (redrawn from Capapé *et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

production was at a maximum could be taken as corresponding to a rate of one egg capsule laid per day; then the rate for any other month will be proportional to the occurrence of egg cases in that month multiplied by the number of days in each month. Similar counts were carried out for *S. canicula*.

Tests for significance ($p < 0.05$) were performed by using ANOVA and chi-square test. The linear regression was expressed in decimal logarithmic coordinates. Correlations were assessed by least-squares regression. In the relationship total mass *versus* total length and liver mass *versus* total length, comparisons of curves between male and female were carried out by ANCOVA.

RESULTS

Sample description

906 smallspotted catsharks, 377 males and 529 females were studied. The monthly collection of observed specimens is presented in Table I. In the three categories of free-swimming specimens, male and female juveniles were not equally distributed in our sample. However, among sub-adults and adults, females significantly outnumbered males (chi-square, $p < 0.05$).

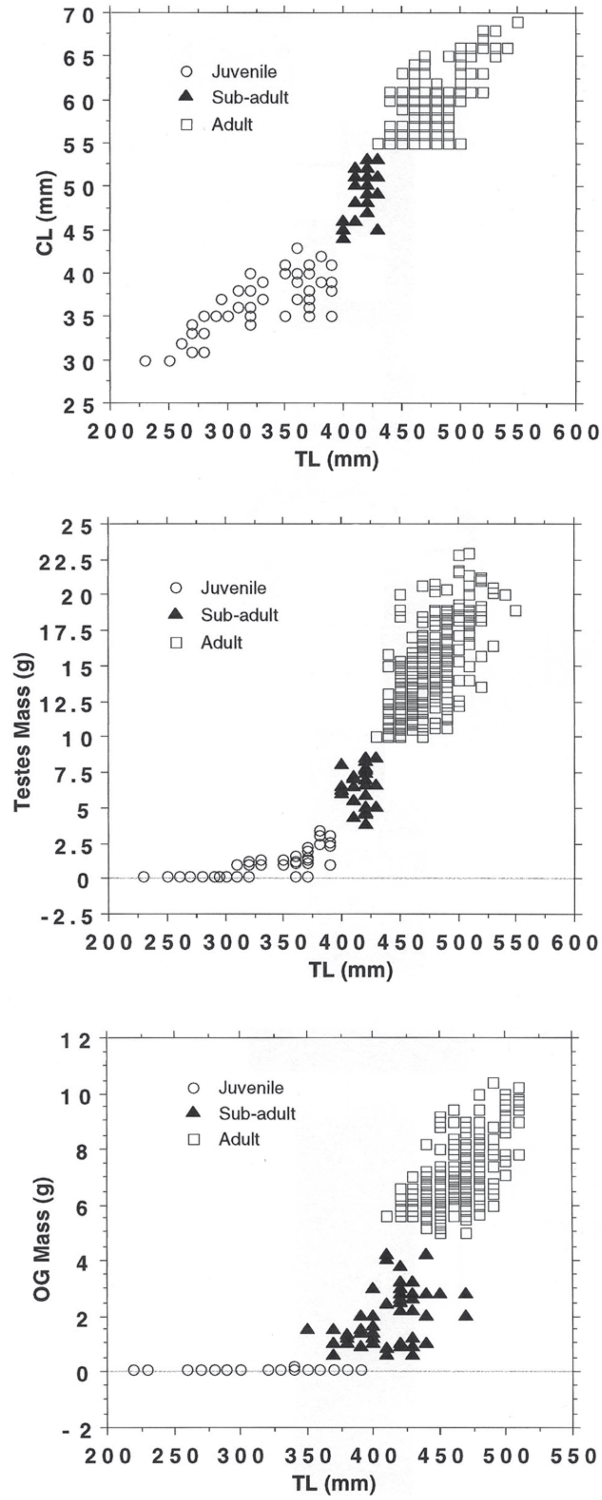

Fig. 2. – Top, Clasper Length (CL) *vs* Total Length (TL) in male *Scyliorhinus canicula*. Middle, Testes Mass (TM) *vs* Total Length (TL) in male *Scyliorhinus canicula*. Bottom, Oviducal Glands Mass (OG Mass) *vs* Total Length (TL) in female *Scyliorhinus canicula*.

Males (Fig. 2, top, middle)

The juveniles ranged from 270 to 390 mm TL and weighed from 28 to 176 g. Specimens had short and flexible claspers. Testes and genital ducts were inconspicuously developed and thread-like. Juveniles were mostly caught in January, October and November (Table I).

The TL of sub-adults was between 400 and 430 mm, and the mass was between 190 and 315 g. During the sub-adult stage, the claspers developed, they were slightly longer than pelvic fins. The testes increased in mass, but had no visible spermatocysts externally, no sperm was observed in the seminal vesicles. The genital duct was slightly convoluted anteriorly. Some sub-adults were caught especially in November (Table I).

During the adult stage, the claspers were elongate, calcified, and rigid. They were enveloped by the pelvic fins. Testes were well-developed and exhibited visible spermatocysts externally. In all, 298 adults sperm occurred in seminal vesicles when genital duct was twisted. 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 the year, mostly from January to April with a peak in May (Table I).

Females (Fig. 2, bottom)

Juvenile females, ranged from 220 to 390 mm TL and weighed between 24 and 192 g, had whitish and undeveloped ovaries, thread-like oviducts and inconspicuous oviducal glands. Captures occurred especially in February, May, October and November (Table I).

The observed sub-adults ranged from 280 to 430 mm TL and weighed from 150 to 305 g (Table I). They exhibited primarily white translucent follicles and a well-differentiated genital duct. The oviducal glands were visible and slightly rounded (Table I). Sub-adults were mostly caught from October to December.

between total length (TL) and total mass (TM), plotted in Fig. 3 (left), showed significant differences between males and females ($F = 24.1$, $p < 0.001$). The relationships were for males: $\log TM = 3.39 \log TL - 6.55$; $r = 0.98$; $n = 377$, and for females $\log TM = 3.64 \log TL - 7.15$; $r = 0.97$; $n = 529$.

Similary, the logarithmic relationship between (TL) and liver mass (LM), plotted in Fig. 3 (right), differed significantly between males and females ($F = 30.6$, $p < 0.001$). The relationships were for males: $\log LM = 4.311 \log TL - 10.161$; $r = 0.92$; $n = 325$, and for females $\log LM = 5.08 \log TL - 12.05$; $r = 0.91$; $n = 520$.

Reproductive cycle of females

Adult females comprised two categories: egg-bearing and non egg-bearing (Table II). In both categories of females, we distinguished two categories of oocytes: translucent oocytes and yellow ones. Translucent oocytes were small, generally less than 3 mm in diameter, so both mass and number remained difficult to measure. Yellow oocytes exhibited an important vitellogenetic activity. Two batches of yellow oocytes were distinguished: one batch of yolky oocytes, generally ready to be ovulated and one batch of developing oocytes. For each batch, oocytes were similar in diameter and mass; measurements are detailed in Table III, diameter and mass of yolky oocytes did not show significant differences related to the total length of females.

Numbers of yolky oocytes ranged between 1 and 18 in egg-bearing females and slightly less in non egg-bearing females, between 4 and 16. Yolky oocytes were successively ovulated as oviducal glands produced egg cases in which they were further included, until the batch was completely consumed. During the production of egg cases, there was apparently no vitellogenetic activity, and the ovary was probably in a resting phase. After all egg

Table I. – 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

Table II. – 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-bearing	14	18	21	20	23	17	14	18	16	27	23	12	**223**
Egg-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**

Table III. – Measurements carried out on the two categories of oocytes from adult female *Scyliorhinus canicual* from the Languedocian coast.

		Diameter (mm)		Mass (g)	
Category of oocytes	Number	Range	Mean ± SD	Range	Mean ± SD
Yolky oocytes	32	14-18	14.8 ± 2.7	1.4 - 1.8	1.6 ±0.1
Developing oocytes	24	8-11	10.1 ± 1.1	1.2 -0.8	1.0 ± 0.1

Table IV. – Measurements carried out on 32 egg cases removed from adult female *Scyliorhinus canicula* caught off coast of Languedoc.

Measurements	Range	Mean
Length (mm)	41-58	47.1 ± 3.7
Width (mm)	16-20	18.3 ± 1.2
Mass (g)	4.1-5.9	4.5 ± 0.3

Fecundity estimation

As in other oviparous elasmobranch species, egg case production cannot be directly determined as in viviparous species. Holden (1975) considered the month when this production was at a maximum in April (see Table V): 0.64, taken as corresponding to a rate of one egg case laid per day, then the rate per month will be proportional to the occurrence of egg capsules in this month relative to April, multiplied by the number of days in each month. This will give an estimate of the average of egg capsule production for a mature *S. canicula*, a total of 230 egg cases during a year. Based on observations made on specimens from other marine areas, Harris (1952), Capapé (1978) and Mellinger (1983) suggested that one egg case is produced every three days, two days and six days, respectively, if we consider that similar rates could be applied for specimens from the Languedocian coast, production of egg cases was between 38 and 115 during a year.

DISCUSSION

Adults of both sexes significantly outnumbered juveniles and sub-adults of both sexes. The former were targeted by fishermen because they have economic value while the latter are generally discarded at sea, when caught. Among the females recorded in our study, several egg-bearing specimens were found each month, except in September. Egg-bearing females probably approached shallow coastal waters to lay egg cases in the best environmental conditions. Larger specimens, more than 250 mm TL migrated towards deeper water of 150 m depth, together with blackmouth catsharks, *Galeus melastomus* (Capapé *et al*. 1991, 2000). Similar observations were reported by Muñoz-Chapuli (1984) for *S. canicula* from Spanish waters. In contrast, D'Onghia *et al*. (1995) noted that small specimens were caught at depths up to 200, together with the largest specimens. Additionally, among the adult specimens, females significantly outnumbered the males in agreement with previous reports (Ellis & Shackley 1997, Rodríguez-Caballo *et al*. 1998). Segregation by sex avoids cannibalism by adult males on juveniles after hatching (Muñoz-Chapuli 1984, D'Onghia *et al*. 1995, Capapé *et al*. 2003). In the North Aegean Sea, D'Onghia *et al*. (1995) noted that other parameters such as geomorphology and temperature favoured development of nursery areas at the lowest depths (*sensu* Castro 1993). In contrast, spawning in deep areas was also reported in the eastern Atlantic (Harris 1952, Rodríguez-Caballo *et al*. 1998).

Off the Languedocian coast, male *S. canicula* matured

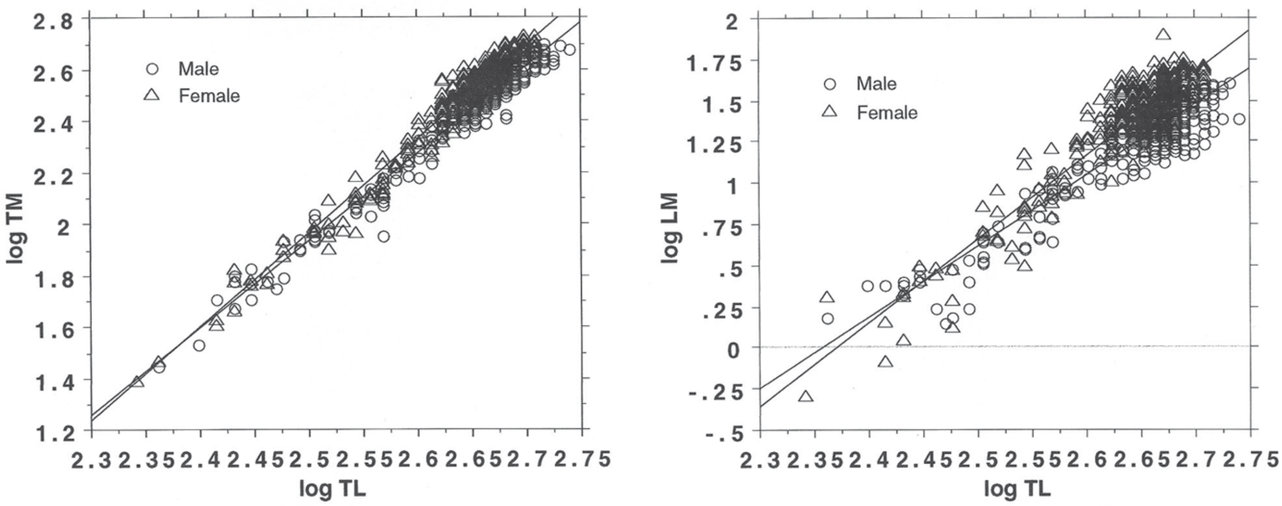

Fig. 3. – Left, Relationships Total Mass (TM) *vs* Total Length (TL) expressed in logarithmic co-ordinates for male and for female *Scyliorhinus canicula*. Right, Relationships Liver Mass (LM) *vs* Total Length (TL) expressed in logarithmic co-ordinates for male and for female *Scyliorhinus canicula*.

Table V. – Estimation of the average number of egg-cases laid by a mature female *Scyliorhinus canicula* following the method of Holden (1975)

	Egg case and rate of laying			
Month	Proportion with egg-cases	Relative proportion	Days	Number of egg-cases laid
Jan	0.42	0.62	31	19
Feb	0.21	0.31	28	9
Mar	0.60	0.88	31	27
Apr	0.64	0.94	30	28
May	0.44	0.65	31	20
Jun	0.49	0.72	30	21
Jul	0.55	0.81	31	25
Aug	0.47	0.69	31	21
Sep	0.00	0.00	30	00
Oct	0.33	0.49	31	15
Nov	0.30	0.44	31	14
Dec	0.68	1.00	31	31
Total				230

between 430 and 440 mm TL while females matured between 410 and 450 mm TL. Moreover, among the sampled females, some juveniles reached 390 mm TL and some sub-adults 430 mm TL. Similar cases of delayed sexual maturity was reported in *S. canicula* from the Cantabrian Sea by Rodríguez-Caballo *et al*. (1998) who noted that this phenomenon 'could be attributable to a sterility disorder or simply to natural variation'. Abnormalities, such as hermaphroditism and abnormal states were described in *S. canicula* and the causes of such abnormal cases were discussed and commented by Vivien (1941) and Olivereau (1949) but remain still obscure according to Ellis & Shackley (1997) and Rodríguez-Caballo *et al*. (1998).

Off the Languedocian coast, females reached a smaller maximum size than males, the largest male and the largest female observed were 540 mm and 510 mm TL, respectively. Similar patterns were reported in *S. canicula* from other Mediterranean areas (Table VI). Intraspecific changes in the size at sexual maturity occurred between *S. canicula* from the Atlantic and the Mediterranean. The form matured at a greater size than the latter and reached a greater maximal size (Table VI). These observations are in agreement with Leloup & Oliv-

Table VI. – Sizes at sexual maturity and maximal sizes of *Scyliorhinus canicula* reported from different areas.

Ocean or Sea	Area	Size at sexual maturity		Maximal size		Authors
		Males	Females	Males	Females	
Channel	Off Plymouth	570-600	570-600	700	700	Ford 1921
Atlantic	Off Roscoff	520-600	520-600	-	660-720	Fauré-Frémiet 1942
Atlantic	Off Concarneau	580	-	-	-	Collenot 1969
Mediterranean	Off Banyuls	370-475	370-475	-	-	Leloup & Olivereau 1951
Mediterranean	Off Croatia	340	340	-	-	Zupanovic 1961
Mediterranean	Northern Tunisia	400	400-450	580	560	Capapé 1977
Mediterranean	Gulf of Lion	440	400-450	550	510	Capapé *et al.* 1991
Mediterranean	North Aegean Sea	-	-	550	502	D'Onghia *et al.* 1995
Channel	Bristol Channel	520	550	-	-	Ellis & Shakley 1997
Atlantic	Cantabrian Sea	-	542	-	-	Rodrìguez-Cabello *et al.* 1998
Mediterranean	Turkish Seas	-	-	558	478	Aka Erdogan *et al.* 2004
Mediterranean	Languedocian coast	430-440	410-450	550	510	This study

Table VII. – Measurements recorded in egg-cases of *Scyliorhinus canicula* from different areas.

Ocean or Sea	Area	Egg case		Authors
		length (mm)	width (mm)	
Channel	Off Plymouth	53-64	21-29	Ford (1921)
Atlantic	Off Roscoff	53-64	21-26	Leloup & Olivereau (1951)
Atlantic	Off Roscoff	51-65	19-24	Collenot (1969)
Mediterranean	Off Banyuls	41-52	15-19	Leloup & Olivereau (1951)
Mediterranean	Off Banyuls	43-55	14-19	Foulley & Mellinger (1980)
Mediterranean	Northern Tunisia	38-48	14-19	Capapé (1977)
Mediterranean	Canal of Sicily	38-49	13-18	Ragonese & Jereb (1990)
Mediterranean	Gulf of Lion	35-57	15-20	Capapé *et al.* (1991)
Mediterranean	Languedocian coast	41-58	16-20	This study

ereau's (1951). The general pattern of latudinal variation in maturity and maximum size was reported in several other chondrichthyan species (Mellinger 1989). Lombardi-Carlson *et al*. (2003) reported similar patterns in bonnethead sharks *Sphyrna tiburo*, from the eastern Gulf of Mexico, they noted that latitudinal differences are thought to be the results of environmental factors, but may be also due to physiological constraints or genetic factors. With special regard to the angular angel shark *Squatina guggenheim* Marini, 1936 from South America, Colonello *et al*. (2006) noted, in agreement with Blackburn *et al*. (1999), that a larger body size in higher latitudes might allow a specimen to have more energy stored for the season of low resource availability.

Generally, *S. canicula* had an extended laying period subjected to changes according to the area (Capapé 1977, Mellinger 1989). Off the Languedocian coast, egg laying occurred throughout the year except in September, and it peaked between April and August; moreover all the analysed females exhibited an active vitellogenetic activity some juveniles reached 390 mm TL and some sub-adults 430 mm TL. Similar cases of delayed sexual maturity was reported in *S. canicula* from the Cantabrian Sea by Rodríguez-Caballo *et al*. (1998) who noted that this phenomenon 'could be attributable to a sterility disorder or simply to natural variation'. Abnormalities, such as hermaphroditism and abnormal states were described in *S. canicula* and the causes of such abnormal cases were discussed and commented by Vivien (1941) and Olivereau (1949) but remain still obscure according to Ellis & Shackley (1997) and Rodríguez-Caballo *et al*. (1998).

Off the Languedocian coast, females reached a smaller maximum size than males, the largest male and the largest female observed were 540 mm and 510 mm TL, respectively. Similar patterns were reported in *S. canicula* from other Mediterranean areas (see Table VI). Intraspecific change throughout the year confirming previous data carried out for *S. canicula* from the Gulf of Lion (Capapé *et al*. 1991). 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 eggs in the oviducts in all months, except August and September, with a peak in June and July. Lo Bianco (1909) off Naples and Zupanovic (1961) in the northern Adriatic reported two peaks, in spring and in winter. Off the Tunisian coast, Capapé (1977) noted that egg laying started in spring, peaked in summer and slightly decreased in autumn. In *S. canicula* from the Gulf of Lions, egg laying occurred from March to June and in December.

Ellis & Schakley (1997) noted that large oocytes measured in *S. canicula* were 19 mm in diameter, larger than those we have measured in our sample (Table III). Measurements of egg cases recorded from several areas are summarized in Table VII. Egg cases from the English Channel and the Atlantic are larger in both length and width than those of the Mediterranean; larger specimens probably produce larger egg cases, and consequently larger egg cases provide larger specimens (see Mellinger *et al*. 1984).

Females were heavier than males, and relationship total mass *vs* total length showed significant differences between males and females. This may be the consequence of reproduction on females. The gonad mass increased because it generally developed a high vitellogenetic activity and produced large and heavy yellow oocytes while oviducal glands produced egg cases.

The relationship liver mass *vs* total mass also showed significant differences between males and females, this suggests that the liver plays an important role in the life cycle of the latter. Liver size is sexually dimorphic in chondrichthyan species. Larger live may allow females to maximize the production of yolk, as in the viviparous lesser guitarfish *Rhinobatos annulatus* Müller & Henle, 1841 (Roussow 1987), and in the small spotted catshark (García-Garrido *et al*. 1990, Magrabaña *et al*. 2002) and the thornback ray (Capapé *et al*. 2007). Additionally, cartilaginous fish store energy as lipids in the liver (Craik 1978). Liver accumulated hepatic lipids for metabolic functions such as gonadic products, this phenomenon is more evident in females during vitellogenesis and egg case production (Lucifora *et al*. 2002). A larger liver observed in females may be related to the increased energy expenditure during vitellogenesis, oocyte maturation and gestation; females store large quantities of lipids in the liver during the reproductive cycle (Lucifora *et al*. 2005). However, Bone & Roberts (1969) and Baldridge (1970, 1972) showed the role of liver in buoyancy for some elasmobranch species, especially for both deep sea and pelagic sharks. Braccini & Chiaramonte (2002) suggested 'that bottom dwelling elasmobranchs required little static lift and hence the liver would not play such a very significant role in buyoancy'.

Scyliorhinus canicula is a serial spawner (*sensu* Holden 1975) and fecundity estimation remains difficult to delineate. Coste (1867) reported that one females laid 18 eggs in one month, while Mellinger (1983) reported that annual egg cases production ranged between 48 and 86. Capapé (1977) and Capapé *et al*. (1991) estimated annual fecundity at 96-115 and 45-190, respectively for specimens from Tunisian and from the Gulf of Lion, respectively. Ellis & Shackley (1997) estimated *S. canicula* fecundity at 26-62. In the present study, fecundity estimation of *S. canicula* based on the method of Holden (1975) is lower than the previous data reported by Capapé *et al*. (1991); 38 and 115 *versus* 45 190. Ellis & Shackley (1997) noted that the upper values may be overestimated because stress during trawling may induce ovulation (Dodd & Duggan 1982). Generally, an early stage at maturity and a permanent reproductive activity throughout the year could explain the relative abundance of a chondrichthyan species in an area, such as *S. canicula* off the Languedocian coast (Sadovy 2001, Cortès 2002). However, a high rate of fecundity cannot be excluded, it could also partially explain the abundance of the species in the area. The present study confirmed the previous study carried out 16 years ago in an adjacent area (see Capapé *et al*. 1991): although it was targeted off the Languedocian coast, *S. canicula* seems to be abundantly caught, while several elasmobranch species previously common in the area have completely disappeared (Quignard *et al*. 1962, Quignard & Raibaut 1993, Capapé *et al*. 2000, 2006). The distribution of *S. canicula* population structures could not be assessed, however similar proportions of males and females in each category and the relative high proportions of both adult males and females were found in our sample. It remains difficult to state that a sustainable population was established in the area before a proper analysis will be done.

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