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OBSERVATIONS ON BIOMETRICAL PARAMETERS IN ELASMOBRANCH SPECIES FROM MAGHREBIN WATERS: A SURVEY

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ABSTRACT

Investigations conducted off the Maghrebin shore from 1969 to date allow us to observe significant changes in some biometrical parameters, such as size at sexual maturity and maximal size involving sexual dimorphism in size. Generally, the latter are larger than the former, and this phenomenon is more evident in viviparous than oviparous species. For instance, in some scyliorhinid species, males are larger than females. Environmental parameters could have an effect on the size at sexual maturity and maximal size in elasmobranch oviparous species; in the same species, specimens from cold areas are smaller than those from warmer waters. Similar patterns were not clearly observed in viviparous species and need further observations.

Key words: Elasmobranchs, sexual dimorphism, reproduction, Maghrebin waters, Mediterranean

ALCUNE CONSTATAZIONI SUI PARAMETRI BIOMETRICI DI SQUALI E RAZZE NELLE ACQUE MAGREBINE: RASSEGNA

SINTESI

Grazie alle ricerche effettuate nelle acque magrebine a partire dal 1969, è stato possibile osservare alcuni cambiamenti nei parametri biometrici degli squali e delle razze, come ad esempio la dimensione nella fase di maturità sessuale e la grandezza massima nel dimorfismo sessuale. In generale, gli esemplari più recenti sono di dimensioni maggiori rispetto a quelli precedenti, un fenomeno che è più evidente per le specie vivipare rispetto a quelle ovovivipare. Per esempio, presso alcune specie della famiglia dei gattucci Scyliorhinidae, i maschi sono più grandi delle femmine. Sulle dimensioni nella fase di maturità sessuale e sulla grandezza massima delle specie ovovivipare degli squali e delle razze potrebbe esserci un'influenza dei parametri ambientali; tra gli esemplari della stessa specie, quelli provenienti da acque fredde sono più piccoli di quelli che vivono in zone più calde. Campioni del genere o analoghi non sono stati registrati presso le specie vivipare e richiedono ulteriori ricerche.

Parole chiave: squali e razze, dimorfismo sessuale, riproduzione, acque magrebine, Mediterraneo

INTRODUCTION

Intraspecific geographic changes in size were suspected in rajid species by Borcéa (1906) and in scyliorhinid species by Fauré-Frémiet (1942): the Mediterranean specimens being smaller than the Atlantic ones. Similar patterns were also described by Leloup & Olivereau (1951) in scyliorhinids, such as the smallspotted catshark, *Scyliorhinus canicula* and the nursehound *S. stellaris*. They also suggested that the Mediterranean specimens matured at smaller size than the Atlantic ones and reached a smaller maximal size, with these changes due to environmental influences, especially light and temperature. Nevertheless, Dodd (1983) noted: *"Nothing is known of environmental influences on reproduction in viviparous species; however, the precision of the timing of their annual and biannual cycles indicates that such influences may play an important role in reproduction".*

Moreover, elasmobranch species show sexual dimorphism in size, females reach a larger maximal size than males, as they mature at a larger size. By contrast, it appears that in some species this was not exactly the case (Mellinger, 1989; Simpfendorfer & Unsworth, 1998).

Investigations conducted in the period of thirty years off the Maghrebin shore allow us to examine oviparous and viviparous elasmobranch species and to give, for several species, size at sexual maturity and maximal size for both males and females. The results are summarized and commented in this article.

MATERIAL AND METHODS

Investigations were conducted between 1969 and 2003 off the Maghrebin shore, off the Tunisian coast from the Libyan to the Algerian borders, and between 1996 and 2003 off the Algerian coast, from the Tunisian to the Moroccan borders (Fig. 1).

Observations were made at Algiers, Annaba, Tunis and Sfax fish markets: elasmobranchs were landed as by-catch species, rarely as targeted species. The observed specimens were collected by commercial vessels. They were caught by trawling, occasionally by bottom longlines, drift-lines and gill-netters. Moreover, specimens captured by artisanal fisheries, such as gill nets, seines, bottom longlines and anglers, were also observed at fishing sites along the Maghrebin shore.

In addition, data collected from elasmobranch species caught between 1988 and 2003 off the coast of Languedoc, southern France, and between 1993 and 2003 off the coast of Senegal, eastern tropical Atlantic, are also included in this article. As far as the first area is concerned, specimens were caught by trawling and craft fisheries, occasionally by artisanal fisheries, while in the second area all the specimens were caught by craft fisheries.

The onset of sexual maturity was studied in males and in females, separately.

Sexual maturity in males was determined from the size and condition of the claspers (Fig. 2). The size of claspers was measured following Collenot (1969) from the metapterygium to the tip of claspers. The relationship clasper-length (CL) *versus* total length (TL) was analysed in sharks, rhinobatids and torpedinids, the relationship clasper-length *versus* disk-width (DW) in skates and rays.

The linear regression was expressed in arithmetical co-ordinates: $y = bx^a$, $CL = bTL^a$ or $CL = b\ DW^a$, or in decimal logarithmic co-ordinates as log CL = a log TL + log b (Fig. 3), or log CL = a log DW + log b (Fig. 4).

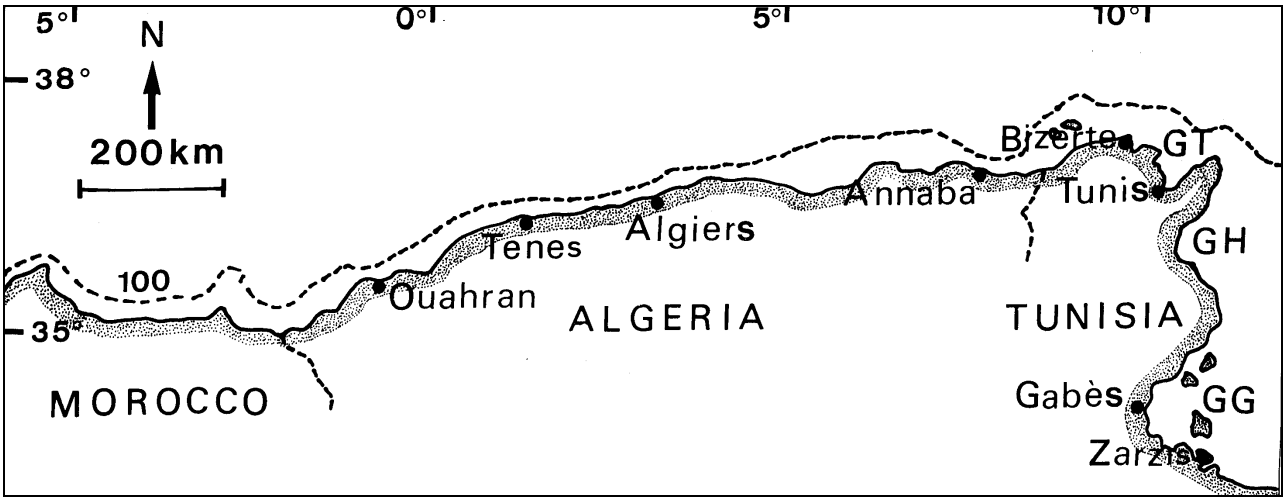

Fig. 1: Map of Maghrebine waters showing both the fishing site landings and observation sites of elasmobranch species.
Sl. 1: Zemljevid magrebskih voda z lokalitetami ulova morskih psov in skatov ter preučevanih območij.

In elasmobranch species, there are apparently no seasonal variations in clasper length according to Mellinger (1989). The CL to TL relationship shows two inflexions indicating the three stages of sexual development in males: juvenile, sub-adult and adult. During the first stage, the claspers grow allometrically and this is also the case in adults, throughout their life. By contrast, the claspers grow fastest during the second stage that could also be considered a maturation stage (Figs. 3, 4).

In order to avoid underestimation of size at sexual maturity, the condition of claspers was also examined. Three reproductive stages were recognized (Capapé *et al.*, 1990; Bridge *et al.*, 1998): juvenile, with claspers short, flexible and not calcified; sub-adult, with slight calcification of claspers; adult, with claspers elongated, rigid and completely calcified (Fig. 5).

Other features were used in order to complete the delineation of the onset of sexual maturity, such as condition of testes and genital duct. In juveniles, both testes and genital duct were membranous and inconspicuously developed.

During the sub-adult stage, the testes were developed, but without spermatocysts externally visible and no sperm in seminal vesicles. The genital duct was developed and the *ductus deferens* (*sensu* Hamlett *et al.*, 1999a) slightly convoluted.

During the adult stage, both testes and genital duct were well developed. Spermatocysts externally visible and sperm occurred in seminal vesicles. The *ductus deferens* was clearly twisted.

Similar to the males, three categories of females were considered: juvenile, sub-adult and adult. The onset of sexual maturity in females could be determined by using vagina length *versus* total length or disk-width according to Steven (1936). The linear regression could be expressed in arithmetical co-ordinates or in decimal logarithmic co-ordinates. This method is useful but it must be only used in fresh specimens immediately observed after their capture. However, the vagina could be retracted after their death or distended after parturition. This method was used only for the marbled torpedo *Torpedo marmorata*.

Size at sexual maturity in females was assessed by examination of ovaries, oviducal glands and genital duct (see Hamlett *et al.*, 1999b).

During the juvenile stage, females had whitish ovaries, oocytes of only microscopic size, membrane-like oviducts and inconspicuous oviducal glands. Sub-adult females exhibited primarily white, translucent oocytes, a well-differentiated genital duct and oviducal glands visible and slightly rounded. In adult females, developing oocytes were observed in non-gravid females. The genital tract was fully developed and in some specimens both uteri contained eggs or embryos at different stages of development.

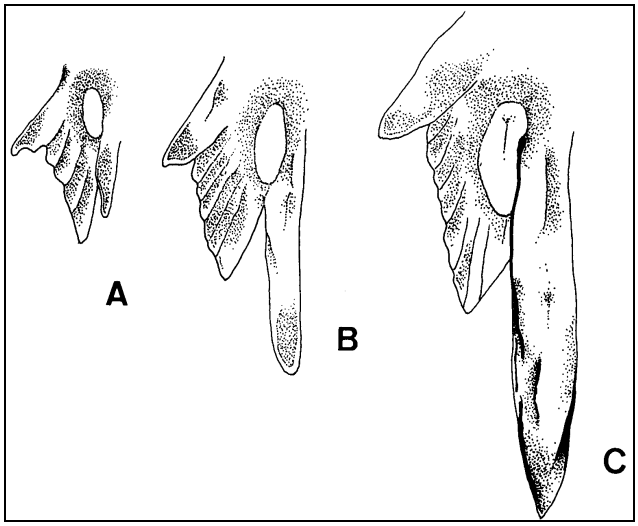

Fig. 2: Morphology of claspers observed in the rough ray, *Raja radula****, during the three stages of development: A – juvenile, B – sub–adult, C – adult.***
Sl. 2: Morfologija spolnih organov vrste *Raja radula* ***v treh stopnjah njenega razvoja: A – mladostni osebek, B – skoraj odrasel osebek, C – odrasel osebek.***

RESULTS AND DISCUSSION

All the results are summarized in Tables 1, 2 and 3. They show that among the scyliorhinid, species size at sexual maturity are different between specimens from the Atlantic and those from the Tunisian coast, corroborating the previous observations of Leloup & Olivereau (1951). Therefore, the specimens from the Tunisian coast matured at a smaller size and reach a smaller size than those from the Atlantic. By contrast, different patterns were observed between *S. canicula* from the Tunisian and Languedocian coasts. This suggests that the *S. canicula* from the Atlantic and the Mediterranean could be at least two different forms of *S. canicula*, an Atlantic form and a Mediterranean form, as this was probably the case for *Dasyatis centroura* (see Capapé, 1993). Moreover, the biometrical changes observed between the *S. canicula* from off Tunisia and from off the Languedocian coast suggest the occurrence of different populations in these two Mediterranean areas. Nevertheless, this opinion requires further investigations, as it could not be based only on biometrical parameters. By contrast, the latter ones played an important role and contribute to separate three sympatric dasyatid species recorded in Tunisian waters, *Dasyatis pastinaca*, *D. tortonesei* and *D. marmorata*, which show significant differences between them regarding the size at sexual maturity and maximal size (Tab. 3).

In migratory large sharks, such as carcharhinid species, *Carcharhinus brevipinna, C. limbatus* and *C. plumbeus*, significant changes in size at sexual maturity and

Tab. 1: Size (in mm) at sexual maturity (sex. m.) and maximal size (max. size) in males and females of ten oviparous elasmobranch species.
Tab. 1: Velikost (v mm) pri spolni zrelosti (sex. m.) in maksimalna velikost (max. size) samcev in samic desetih jajcerodnih vrst morskih psov in skatov.

Species	Males		Females		Areas	References
	sex. m.	max. size	sex. m.	max. size		
Scyliorhinus canicula	400	530	350	430	Northern Tunisia	Capapé (1977b)
	440	550	410-470	510	Gulf of Lion	Capapé *et al.* (1991)
S. stellaris	800	1080	820	1150	Northern Tunisia	Capapé (1977c)
Galeus melastomus	430	620	460	660	Northern Tunisia	Capapé & Zaouali (1977)
Raja miraletus	230	320	240-280	330	Gulf of Tunis	Capapé & Quignard (1974a)
R. clavata	480	540	490	570	Northern Tunisia	Capapé (1976b)
R. asterias	370	420	440	450	Northern Tunisia	Capapé (1977a)
R. radula	330	380	360	420	Northern Tunisia	Capapé (1974a)
R. polystigma	340	450	380	410	Northern Tunisia	Capapé & Quignard (1978)
R. melitensis	190	220	230	240	Northern Tunisia	Capapé (1977d)
R. alba	910	1160	980	1280	Northern Tunisia	Capapé (1976c)

in maximal size were not observed between specimens from Tunisian coastal waters and those from other marine areas, *e.g.* South Africa (Bass *et al.*, 1973), Australia (Stevens & McLoughlin, 1991), Senegal (Cadenat & Blache, 1981; Capapé *et al.*, 2003c), Gulf of Mexico (Branstetter, 1981) and probably throughout the world (Garrick, 1982; Compagno, 1984a, b). During their migration, these species seek waters where environmental parameters are practically homogeneous and pregnant females ending gestation approach nurseries where neonates could find sufficient food to assume the first period of their extra-uterine life, as well as could avoid the predation risk of adult sharks (Muñoz-Chapuli, 1984).

A comparison between data collected from the same species caught off the Tunisian and Senegalese coasts (see Capapé *et al.*, 1996) show that these species could be divided into three categories: the first category comprises the species, whose specimens, caught off Tunisia, are larger than those caught off Senegal: *Mustelus mediterraneus*, *T. marmorata*, *Rhinobatos rhinobatos* and *Pteromylaeus bovinus*.

By contrast, the second category includes species, whose specimens, caught off Senegal, are larger than those caught off Tunisia: *Squatina oculata*, *R. cemiculus*, *Raja miraletus*, *Torpedo torpedo*, *Dasyatis chrysonota* and *D. tortonesei*.

The third category comprises species which do not show changes in size at sexual maturity and maximal size in both areas, with the three carcharhinid species cited above among them, *C. brevipinna*, *C. limbatus* and *C. plumbeus*, *Oxynotus centrina*, *Etmopterus spinax* and *Squatina aculeata*.

These observations are not completely in agreement with Leloup & Olivereau's opinion (1951). Moreover, specimens of the single oviparous species, *R. miraletus* captured off Senegal are larger than those captured off Tunisia, while water temperature is higher along the Senegalese coast, than Tunisian waters.

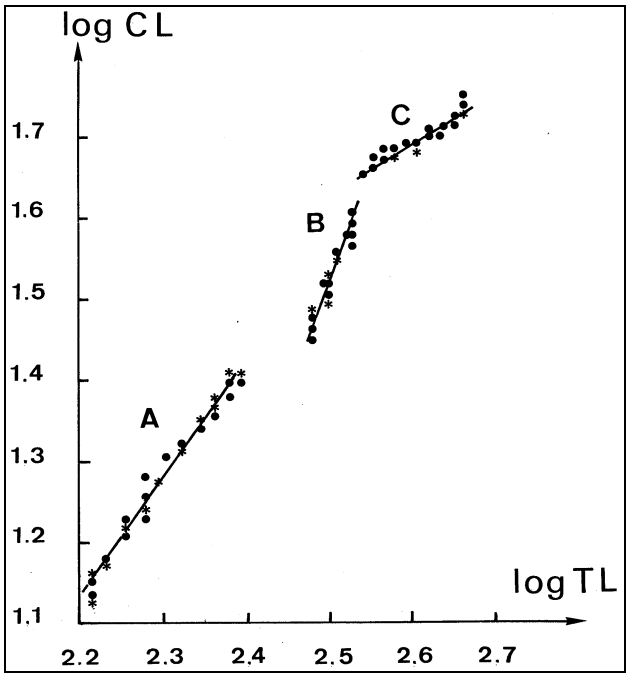

Fig. 3: Velvet belly** Etmopterus spinax **from the Mediterranean. Clasper length (CL)** vs. **total length (TL) expressed in decimal logarithmic coordinates: A – juvenile stage, B – sub–adult stage, C – adult stage (redrawn from Capapé** et al.**, 2001a).
Sl. 3: Žametni morski pes** Etmopterus spinax**. Dolžina spolnega organa (CL) v primerjavi s celotno dolžino (TL), izražena v decimalnih logaritmičnih koordinatah: A – mladostni osebek, B – skoraj odrasli osebek, C – odrasel osebek (povzeto po Capapé** et al.**, 2001a).

Tab. 2: Size (in mm) at sexual maturity (sex. m.) and maximal size (max. size) in males and females of fifteen viviparous shark species.
Tab. 2: Velikost (v mm) pri spolni zrelosti (sex. m.) in maksimalna velikost (max. size) samcev in samic petnajstih živorodnih vrst morskih psov.

Species	Males		Females		Areas	References
	sex. m.	max. size	sex. m.	max. size		
Heptranchias perlo	930	1180	1050	1390	NorthernTunisia	Capapé (1980)
Hexanchus griseus	3540	5000?	3940	5000?	Mediterranean	Capapé *et al.* (2003a)
Galeorhinus galeus	1130	1780	1250	1950	Gulf of Tunis	Capapé & Mellinger (1988)
Mustelus asterias	760	1260	800	1280	Gulf of Tunis	Capapé (1983)
M. mediterraneus	910	1820	1040	1910	Tunisia	Capapé & Quignard (1977)
Carcharhinus plumbeus	1670	2250	1710	2480	Gulf of Gabès	Capapé (1984)
C. brevipinna	1720	1960	2630	2750	Tunisia	Capapé *et al.* (2003c)
C. limbatus	1670	2160	1780	2450	Senegal	Capapé *et al. (in press* a)
Oxynotus centrina	600	650	640	780	Mediterranean	Capapé *et al.* (1999b)
Centrophorus granulosus	810	1250	800	1250	NorthernTunisia	Capapé (1985)
Squalus blainvillei	510	640	700	840	Gulf of Tunis	Capapé (1974b)
Etmopterus spinax	380	460	400	460	NorthernTunisia	Capapé *et al.* (2001a)
Squatina aculeata	1200	1370	1520	1750	Senegal-Tunisia	Capapé *et al. (in press* b)
S. oculata	710	1210	900	1210	Gulf of Tunis	Capapé *et al.* (1990)
	820	1450	890	1570	Senegal	Capapé *et al.* (2002)
S. squatina	800	1320	1280	1690	Gulf of Tunis	Capapé *et al.* (1990)

The environmental factors probably play a role with regard to size at sexual maturity and maximal size in elasmobranch species but remain difficult to be determined. However, the biological environment cannot be neglected. It appears more important and diversified in eastern tropical Atlantic waters than in the Mediterranean waters. The competition pressure for food seems to be less evident in the first than in the second area (Diatta *et al.*, 2001, 2002). Moreover, Capapé *et al.* (2003b) showed that the reproductive mode considerably reduced intraspecific and interspecific competition for food in deep-sea waters, where the biological environment is poorly represented. Consequently, if the role of both environmental and biological factors could not be totally neglected, it formed the object of changes according to the species. This could explain, *pro parte*, why *R. miraletus* specimens from Senegal waters are larger than Tunisian specimens, and why, by contrast, this is not the case for *M. mediterraneus*, caught in both same areas.

Cadenat & Blache (1981) suggested the hypothesis of distinct subspecies or at least distinct forms, such as for the spinner shark *C. brevipinna* from the coastal waters of Senegal. Similar patterns were observed for *D. centroura* by Capapé (1993) and Hemida *et al.* (2003) for the pelagic stingray *D. violacea*.

Moreover, there are not only intraspecific changes in size related to the area. In agreement with Mellinger *et al.*'s opinion (1984), larger specimens produce larger eggs and larger neonates; moreover, in numerous species fecundity is related to mother's size. In most elas-

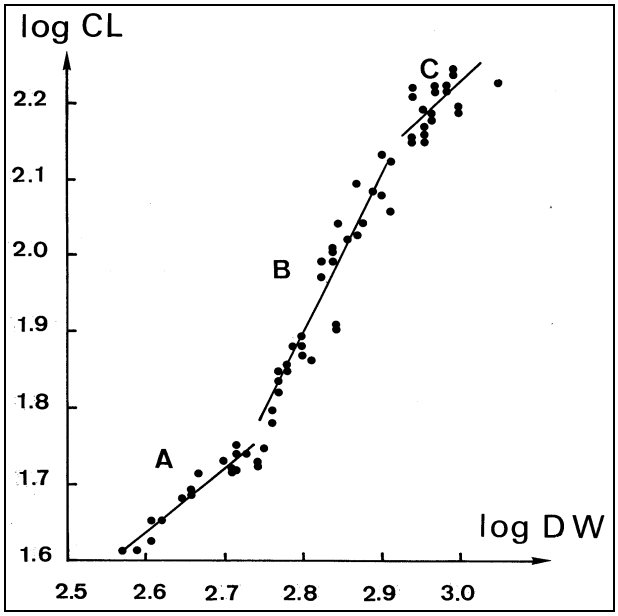

Fig. 4: Butterfly ray** Gymnura altavela **from Tunisian coastal waters. Clasper length (CL)** vs. **disk width (DW) expressed in decimal logarithmic coordinates: A – juvenile stage, B – sub–adult stage, C – adult stage (redrawn from Capapé** et al.**, 1992).
Sl. 4:** Gymnura altavela **iz tunizijskih voda. Dolžina spolnega organa (CL) v primerjavi s širino diska (DW), izražena v decimalnih logaritmičnih koordinatah: A – mladostni osebek, B – skoraj odrasli osebek, C – odrasel osebek (povzeto po Capapé** et al.**, 1992).

Tab. 3: Size (in mm) at sexual maturity (sex. m.) and maximal size (max. size) in males and females of thirteen viviparous ray species.
Tab. 3: Velikost (v mm) pri spolni zrelosti (sex. m.) in maksimalna velikost (max. size) samcev in samic trinajstih živorodnih vrst skatov.

Species	Males		Females		Areas	References
	sex. m.	max. size	sex. m.	max. size		
Rhinobatos rhinobatos	750	1400	850	1620	Gulf of Tunis	Capapé *et al.* (1997)
	660	1180	780	1530	Senegal	Capapé *et al.* (1999a)
R. cemiculus	1010	1920	1010	1950	Gulf of Gabès	Capapé & Zaouali (1994)
	1550	1630	2330	2450	Senegal	Seck *et al.* (*in press*)
Torpedo mackayana	315	350	382	500	Senegal	Capapé *et al.* (2000a)
T. marmorata	290	340	395	580	Gulf of Tunis	Capapé (1979)
	270	380	260	580	Senegal	Capapé *et al.* (2001b)
T. torpedo	160	290	190	360	Gulf of Tunis	Quignard & Capapé (1974)
	230	365	230	410	Gulf of Gabès	Ennajar *et al.* (2002)
	300	310	445	550	Senegal	Capapé *et al.* (2000b)
Dasyatis centroura	800	1000	1040	1345	Tunisia	Capapé (1993)
D. chrysonota	300	320	400	440	Gulf of Gabès	Capapé & Zaouali (1995)
D. pastinaca	310	570	380	680	Gulf of Tunis	Capapé (1976a)
D. tortonesei	380	570	460	600	Tunisia	Capapé (1978)
D. violacea	420	580	450	610	Mediterranean	Hemida *et al.* (2003)
Gymnura altavela	780	1000	1140	1620	Tunisia	Capapé *et al.* (1992)
Myliobatis aquila	410	550	580	850	Gulf of Tunis	Capapé & Quignard (1974b)
Pteromylaeus bovinus	800	1600	1000	>2000	Gulf of Gabès	Capapé & Quignard (1975)
	820	1150	900	1480	Senegal	Seck *et al.* (2002)

mobranch species we have generally observed a relationship size *versus* ovarian and uterine fecundity. Both categories of fecundity increased with mother's size and in the same species intraspecific changes appeared according to the area with regard to fecundity. For instance, common torpedoes from Senegal (Capapé *et al.*, 2000b) were larger than those of Tunisia, Gulf of Tunis (Quignard & Capapé, 1974) and Gulf of Gabès (Ennajar *et al.*, 2002). It is interesting to note that the specimens from the Gulf of Tunis live in temperate waters, the specimens from the Gulf of Gabès in subtropical waters, and those of Senegal in tropical waters. Moreover, the greatest common torpedoes were observed in the Gulf of Lion *(unpubl. data),* although the waters of this latter area are slightly colder than those of the three previous areas.

With regard to sexual dimorphism in size, Tables 1, 2 and 3, show that females are larger than males and reach a larger size, except in *S. canicula*. Mellinger (1989) noted that similar patterns were observed in other scyliorhinid species. By contrast, to our knowledge, this phenomenon was not reported in other oviparous elasmobranch species. For instance, in rajid species, males are significantly smaller than females because they matured at a smaller size; moreover, sexual dimorphism in size appears to be related to the species size (Capapé, 1977d). However, sexual dimorphism in size is more evident in the largest rajid species, such as *R. clavata*, than in the smallest species, such as *R. melitensis*, as this was reported for specimens from Tunisian waters (Capapé, 1977d).

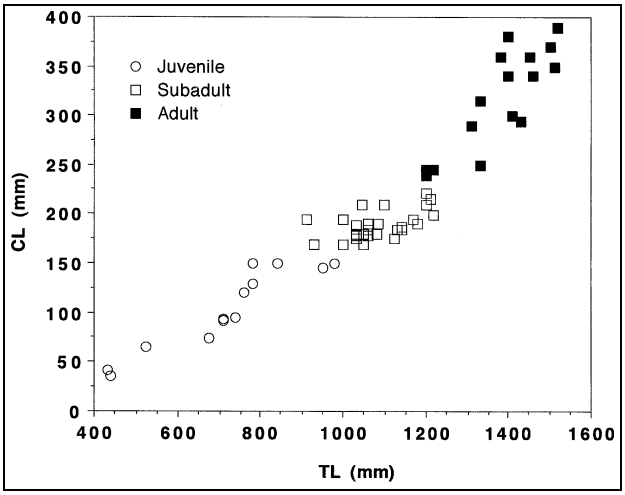

Fig. 5: Clasper length (CL)** vs. **total length (TL) in male** Squatina aculeata **based on the condition of the claspers (redrawn from Capapé** et al.**,** in press **b).
Fig. 5: Dolžina spolnega organa (CL) v primerjavi s celotno dolžino (TL) pri samcu vrste** Squatina aculeata **na osnovi stanja spolnih organov (povzeto po Capapé** et al.**,** in press **b).

Sexual dimorphism in size is especially marked in viviparous species. This is due to the fact that the females carried the brood during all the gestation and consequently contributed to the development of embryos by providing organic and inorganic nutrients. Nevertheless, our observations showed that in carcharhinid species, the phenomenon is less marked than in dasyatids, gymnurids and myliobatids. For instance, the female bull rays, *Myliobatis aquila* and *P. bovinus*, exhibit internal uterine wall which was strongly developed at gestation end with the presence of uterine villi providing uterine milk for embryos (Hamlett *et al.*, 1985). This could explain why these species had a short gestation period, which lasted between two and six months (Ranzi & Zezza, 1936; Capapé & Quignard, 1974a, b, 1975; Hemida *et al.*, 2003) *vs.* one year, at least, in carcharhinid species (Capapé *et al.*, 2003c).

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NEKAJ UGOTOVITEV GLEDE BIOMETRIČNIH PARAMETROV PRI MORSKIH PSIH IN SKATIH IZ MAGREBSKIH VODA: PREGLED

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POVZETEK

Po zaslugi raziskav, opravljenih v magrebskih vodah vse od leta 1969 pa do danes, je bilo mogoče zaslediti nekaj pomembnih sprememb v biometričnih parametrih morskih psov in skatov, kot na primer v velikosti, ko dosežejo spolno zrelost, in maksimalni velikosti pri spolnem dimorfizmu. Na splošno so novejši primerki večji kot starejši, ta pojav pa je bolj očiten pri živorodnih kot jajcerodnih vrstah. Pri nekaterih vrstah iz družine morskih mačk Scyliorhinidae, na primer, so samci večji od samic. Na velikost ob spolni zrelosti in maksimalno velikost pri jajcerodnih vrstah morskih psov in skatov bi utegnili vplivati okoljski parametri; med osebki iste vrste so manjši tisti iz mrzlih voda kot tisti iz toplejših območij. Takšnih ali podobnih vzorcev ni bilo zaslediti pri živorodnih vrstah in terjajo nove raziskave.

Ključne besede: morski psi in skati, spolni dimorfizem, razmnoževanje, magrebske vode, Sredozemlje

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