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REPRODUCTIVE BIOLOGY OF THE THORNBACK RAY *RAJA CLAVATA* (CHONDRICHTHYES: RAJIDAE) FROM THE COAST OF LANGUEDOC (SOUTHERN FRANCE, NORTHERN MEDITERRANEAN)

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RAJIDAE
RAJA CLAVATA
REPRODUCTIVE BIOLOGY
COAST OF LANGUEDOC
FRANCE
MEDITERRANEAN SEA

ABSTRACT. – The thornback ray, *Raja clavata* L., 1758 had a wide Atlanto-Mediterranean distribution. However at present captures of the species showed a constant decline, especially off the coast of Languedoc (southern France, northern Mediterranean) where rare specimens were caught throughout the year. The smallest male and female adults were 420 mm and 540 mm disc width (DW), respectively and weighed 2130 g and 4950 g, respectively. The largest male and the largest female were 510 mm and 690 mm DW, respectively and weighed 4500 g and 5980 g, respectively. There was a significant relationship of total mass versus DW between males and females. The diameter of the largest yolky oocytes ranged from 24 to 27 mm (mean = 25.9 ± 0.9) and weighed from 3.2 to 3.7 g (mean = 3.5 ± 0.2). Vitellogenic activity occurred practically all year round, a bit less in April and August. Production of egg cases was observed throughout the year, except in April and August. Egg cases had between 122 and 127 mm (mean: 124.1 mm ± 1.3) in length with horns; and between 61 and 66 mm (mean: 63.6 mm ± 1.4) in length without horns, their width were between 50 and 56 mm (mean: 52.9 mm ± 1.5) and they weighed between 19.5 and 22.5 g (mean: 20.9 g ± 1.4). Fecundity remained difficult to assess, an estimation based on production of egg cases and/or number of yellow yolky oocytes during year counted in adult females, enable to consider it between 108 and 262.

INTRODUCTION

The thornback ray, *Raja clavata* L., 1758 presented a wide distribution in the Atlantic Ocean and the Mediterranean Sea. The species was reported in northern waters of eastern Atlantic, from Scandinavia (Duncker 1960), around British Islands (Wheeler 1969), off France (Bougis 1959) and Portugal (Albuquerque 1954-1956). South the Strait of Gibraltar, *R. clavata* was recorded off the Atlantic coast of Morocco (Collignon & Aloncle 1972) and Mauritania (Maurin & Bonnet 1970). The species was also recorded off the South African coast (Smith & Heemstra 1986). The thornback ray is also reported in the Mediterranean (see Capapé 1989) and entered the Black Sea according to Banarescu (1969) and Kabasakal (2002).

The reproductive biology of *R. clavata* was previously studied from specimens caught off the British coasts (Steven 1936), the Atlantic coast of France (Du Buit 1968), Adriatic Sea (Zupanovic 1961, Jardas 1973) and the coast of Tunisia (Capapé 1976). Investigations conducted during a sixteen year period off the coast of Languedoc (Mediterranean shore of France) allow us to collect specimens of *R. clavata* and to provide additional data on some traits of its reproductive biology, such as size at sexual maturity, reproductive cycle and fecundity.

MATERIAL AND METHODS

A total of 257 specimens, 120 males and 137 females, was collected off the coast of Languedoc, between 1988 and 2004. The monthly collection of observed specimens is presented in Table I.

Samples were collected by gill-netters and trawlers at depths up to 80 m, on sandy and muddy bottoms. They were generally landed at the harbours of Palavas-les-Flots and Sète (Fig. 1). Moreover, research surveys were conducted in the same areas on board of the oceanographic trawler 'Georges Petit', in November 1988 and 1990 and May 1992 and 1993.

Disc width (DW) of the specimens was measured to the nearest millimetre following Clark (1926) and mass (TM) was measured to the nearest gram, liver, gonads and oviducal glands masses to the nearest decigram. Developing and yolky oocytes, egg cases were measured to the nearest millimetre and their masses to the nearest decigram, when possible.

Clasper length was measured from the forward rim of the pelvic girdle to the tip of the clasper following Collenot (1969).

Some aspects of the testes and other reproductive organs are given following Capapé & Quignard (1975), Hamlett *et al.* (1999) and Capapé *et al.* (2004). 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 (see Capapé *et al.* 2004, Jones *et al.* 2005). In both male

Table I. – Monthly collection of the observed *Raja miraletus* captured off the coast of Senegal.

		Months												
Sex	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Males														
	Juveniles	-	4	8	-	10	12	9	8	5	-	-	2	58
	Sub-adults	4	3	2	3	3	3	3	1	2	2	2	-	28
	Adults	2	3	2	4	3	2	2	2	3	3	2	6	34
	Total	6	10	12	7	16	17	14	11	10	5	4	8	120
Females														
	Juveniles	4	6	3	-	3	3	2	8	3	4	14	5	55
	Sub-adults	3	3	1	-	7	2	2	-	2	2	2	-	24
	Adults	3	4	4	2	5	6	5	2	7	4	10	6	58
	Total	10	13	8	2	15	11	9	10	12	10	26	11	137
	Grand total	16	23	20	9	31	28	23	21	22	15	30	19	257

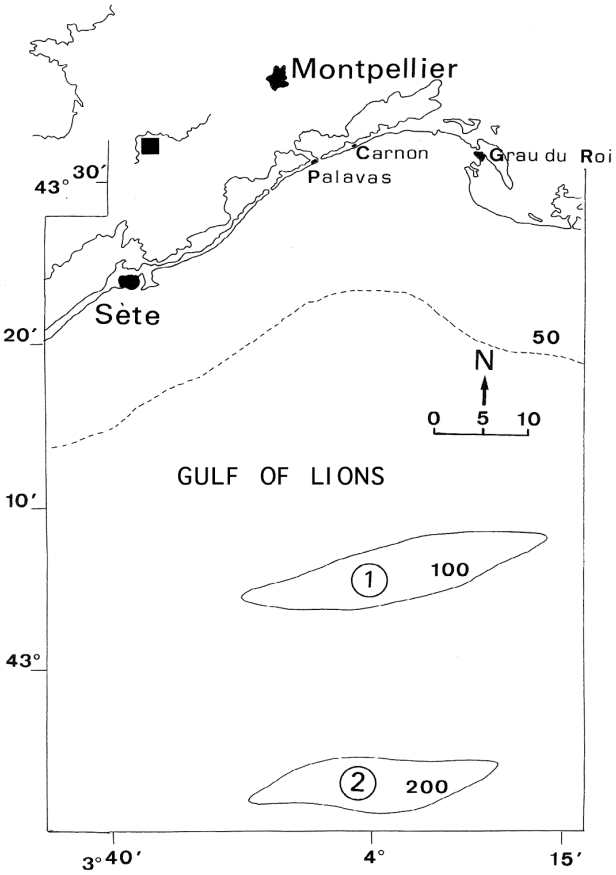

Fig. 1. – Map of France pointing out the coast of Languedoc and the capture sites of *Raja clavata* in the 'pits' from off Sète where the small spotted catshark *Scyliorhinus canicula* ① and the blackmouth catshark *Galeus melastomus* ② are the dominant elasmobranch species (redrawn from Capapé *et al.*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

and female, specimens were divided in three categories: juveniles, sub-adults and adults.

Fecundity was assessed by using the method of Holden (1975), based on estimation of the average number of eggs produced by adult females and on the method of Capapé & Quignard (1975) based on the maximal number of oocytes counted in both ovaries in adult females.

In relationship size mass-total length, comparisons of curves were made by ANCOVA.

Tests for significance ($p < 0.05$) were performed by using ANOVA t-test and chi-square test.

RESULTS

Size at sexual maturity

Males

Development of males comprised three stages: juvenile, sub-adult and adult (Fig. 2 top & middle and Table I).

Fifty-eight juveniles were collected, ranging in size between 110 and 370 mm and weighing between 31 and 985 g. Juveniles were generally caught in March and between May and August.

The observed specimens had flexible and short claspers, smaller than pelvic fins. Testes and genital ducts were membranous and inconspicuously developed. Twenty-eight sub-adults were caught, with some specimens per month throughout year except in December. The smallest sub-adult observed was 350 mm DW and weighed 840 g, the largest 440 mm DW and weighed 2598 g. During the sub-adult stage, the claspers were slightly calcified and elongated, they were slightly larger than the pelvic fins. The testes increased in mass (Fig. 2 middle), but had not spermatocysts externally visible; no sperm was observed in the seminal vesicles.

During the adult stage, the claspers were elongated, calcified and rigid. They were obviously larger than the

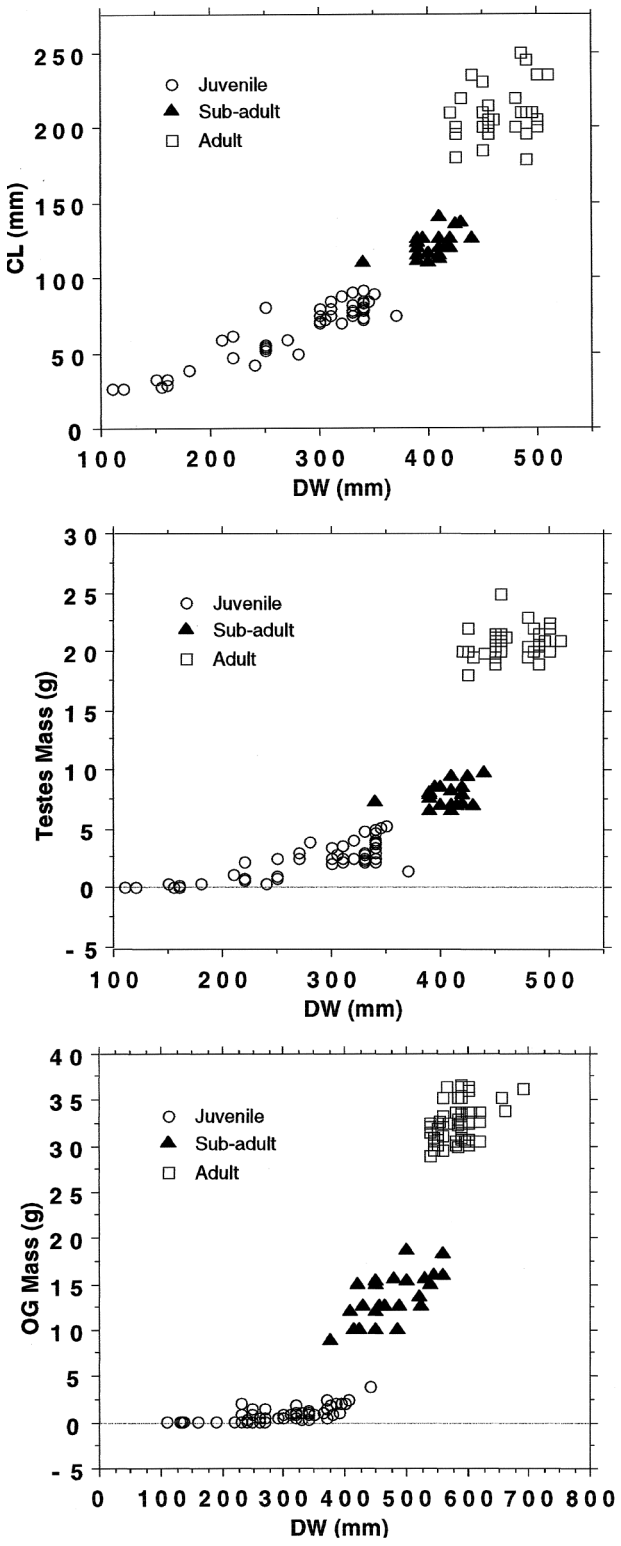

Fig. 2. – Top, Clasper Length (CL) vs Disc Width (DW) in male *Raja clavata*. Middle, Testes Mass (TM) vs Disc Width (DW) in male *Raja clavata*. Bottom, Oviducal Gland Mass (OG Mass) vs Disc Width (DW) in female *Raja clavata.*

pelvic fins. The testes were well-developed (Fig. 2 middle) and exhibited spermatocysts externally visible. The genital duct was twisted and sperm was observed in the seminal vesicles. The smallest adult male was 420 mm DW and weighed 2130 g, the largest was 510 mm DW and weighed 4500 g. In all, 34 adult males were collected, some specimens per month, and 6 specimens maximum in December.

Females

Similarly to males, development stages of females comprised juveniles, sub-adults and adults (Fig. 2 bottom).

Juvenile females ranged between 110 and 440 mm DW and weighed between 440 and 1645 g. They had whitish and membranous ovaries, membrane like oviducts and inconspicuous oviducal glands. Fifty five juveniles were collected all year round except in April. A maximum of 14 specimens was recorded in November.

Twenty-four sub-adult females were captured, a maximum of ten specimens was recorded in May none in April, August and December. They exhibited white translucent follicles and a well-differentiated genital duct. The oviducal glands were visible and slightly rounded. The smallest sub-adult was 410 mm DW and weighed 3300 g; the largest specimen was 540 mm DW and weighed 4950 g.

Fifty-eight adult females were collected, a maximum of 10 specimens was recorded in November. They had both ovaries and oviducts functional. Ovaries contained batches of yolky oocytes and the genital ducts were fully developed. Several adults contained one or two egg cases, a single egg case per oviduct. The smallest specimen was 540 mm DW and weighed 4950 g and contained egg cases; the largest was 690 mm in length and weighed 5980 g. All females above 560 mm DW were adult.

Size and mass relationships

The relationships between disc width (DW) and total mass (TM) showed significant differences between males and females ($F = 16.8$; $p < 0.001$). The relationships were: for males $\log TM = 3.51 \log DW - 5.89$; $r = 0.98$; $n = 120$ and for females: $\log TM = 3.21 \log DW - 5.14$; $r = 0.98$; $n = 137$.

Reproductive status of females

In female *Raja clavata*, both ovaries and genital tracts are functional (Capapé 1976). In adult females, the ovaries comprised two categories of oocytes: translucent oocytes and yellow oocytes. Several translucent oocytes were observed in both ovaries and their number cannot be assessed with precision, they had small diameter, generally less than 3-4 mm, and they were fragile and generally spilled when removed from ovaries. Three batches of yellow oocytes were distinguished: one batch of large oocytes, yolky oocytes gen-

Table II. – Measurements carried out on the three categories of oocytes from adult *Raja clavata* females from the coast of Languedoc.

		Diameter (mm)		Mass (g)	
Category of oocytes	Number	Range	Mean	Range	Mean
Yolky oocytes	24	24-27	25.9 ± 0.9	3.2-3.7	3.5 ± 0.2
Larger developing oocytes	21	11-15	12.8 ± 1.4	1.2-1.6	1.4 ± 0.2
Smaller developing oocytes	16	8-10	8.5 ± 0.9	0.7-1.0	0.9 ± 0.1

Table III. – Monthly collection of the observed adult *Raja clavata* females captured off the coast of Languedoc.

	Months												
Category of adult females	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
No carrying egg capsules													
With yolky and developing oocytes	-	1	-	-	1	3	1	1	-	-	2	2	11
With only developing oocytes	-	-	1	2	-	1	1	1	2	2	3	-	13
Total	-	1	1	2	1	4	2	2	2	2	5	2	24
Carrying egg capsules													
With yolky and developing oocytes	3	3	3	-	3	2	2	-	5	2	6	2	31
With only developing oocytes	-	-	-	-	1	-	1	-	-	-	-	1	3
Total	3	3	3	0	4	2	3	-	5	2	6	3	34
Grand total	3	4	4	2	5	6	5	2	7	4	11	5	58

Measurements	Coast of Languedoc (This study)		Gulf of Tunis (Capapé 1976)	
	Range	Mean	Range	Mean
Length with horns (mm)	122-127	124.1 ± 1.3	121-135	128 ± 1.5
Length without horns (mm)	61-66	63.6 ± 1.4	70-78	75 ± 1.8
Width (mm)	50-56	52.9 ± 1.5	50-54	52 ± 1.2
Mass (g)	19.5-22.5	20.9 ± 1.4	13-18	15.3 ± 1.5

Table IV. – Measurements carried out on 35 egg cases removed from adult *Raja clavata* females caught off coast of Languedoc. A comparison is made with those removed from *R. clavata* from the Gulf of Tunis (northern Tunisia) according to Capapé (1976)

erally ready to be ovulated, and two batches of large and small developing oocytes. Each batch contained oocytes similar in diameter and mass; measurements are detailed in Table II, moreover diameter and mass did not show significant differences in relation to females DW. Consequently, Table III shows that adult females comprised two major categories of specimens: not carrying egg cases and carrying egg cases in a single or both uteri. In both categories, two other categories of specimens were distinguished: a first category with yolky and developing oocytes and a second category with only developing oocytes (Table II). Vitellogenic activity occurred practically all year round, a bit less in April and August. Production of egg cases was observed throughout the year, except in April and August. Yolky oocytes were successively ovulated as oviducal glands produced egg cases. During ovulation, the ovaries did not produce oocytes and were probably in a resting phase. After all egg capsules were deposited to the exterior; vitellogenesis started again and ovaries produced a new batch of yolky oocytes by increasing of large developing oocytes, concomitantly the small developing oocytes enlarged and the translucent ones started to develop a vitellogenic activity. During vitellogenesis, reproductive tract (oviducal glands, oviducts and uteri, Callard *et al.* 2005) entered in a rest phase. The scheme of *R. clavata* reproductive cycle comprised two phases as follows:

First phase. Vitellogenic activity concomitant to rest

Table V. – Estimation of the average number of egg capsules laid by a mature female *Raja clavata* following the method of Holden (1975).

	Egg capsule and rate of laying			
Months	Proportion with capsules	Relative proportion	Days	Number of eggs laid
Jan.	1.00	1.00	31	31.00
Feb.	0.75	0.75	28	21.00
Mar.	0.75	0.75	31	23.00
Apr.	0.50	0.50	30	15.00
May	0.80	0.80	31	25.00
Jun.	0.33	0.33	30	9.90
Jul.	0.60	0.60	31	18.60
Aug.	0.00	0.00	31	0.00
Sep.	0.71	0.71	30	21.30
Oct.	0.50	0.50	30	15.00
Nov.	0.55	0.55	30	16.50
Dec.	0.60	0.60	31	18.60
Total				214.9

phase of the reproductive tract;

Second phase. Activity of the reproductive tract concomitant to delayed vitellogenesis.

The duration of both phases remains difficult to assess with precision.

All year round, yellow oocytes were found in adult females, although vitellogenic activity of some specimens was in a rest phase during a short period. Production of egg cases occurred throughout the year except in January.

Measurements carried out on egg cases removed from adult female *R. clavata* are given in Table IV. Production of yellow oocytes (developing and yolky oocytes) are not related to adult females DW.

Fecundity

As other oviparous elasmobranch species, *R. clavata* is a serial spawner (Holden 1975), so egg cases production cannot be directly determined as in viviparous species. In order to assess egg case production, Holden (1975) considered the month in which this production was maximum: 1.00 in January (Table V), taken as corresponding to the rate of one egg case laid per day, then the rate per month will be proportional to the occurrence of egg cases in this month relative to April, multiplied by the number of days of each month. This will give an estimate of egg cases production for an adult *R. clavata*, a total of 215 egg cases during a year, if we consider that one egg case was produced per day (Table V). In agreement with Holden (1975), Ellis & Shackley (1995) noted that the daily interval between deposition of successive pairs of eggs ranged from 0 to two days. Capapé & Quignard (1975) noted the rate of egg cases produced by *R. miraletus* kept in aquaria was one capsule every two days, this rate being constant during 10 days. Egg-case production stopped during approximately a week, then it started again and lasted some days after the specimen died. So, the egg case production could be assessed to 108 per year.

We have considered the number maximum of oocytes observed per month in adult female *R. clavata* whatever DW. The maximum number counted during one year was 262 (Table VI).

Sex ratio

In juveniles and sub-adults, male *R. clavata* slightly outnumbered females (Table I). In contrast, adult females significantly outnumbered males. For the total sample, numbers of males and females were practically similar.

DISCUSSION

Formerly, the thornback ray was considered as rather abundantly landed in all fishing sites of the coast of Languedoc (Euzet 1960, Quignard *et al.* 1962, Granier 1964, Quignard 1965); the rare landings of specimens collected in the area in a sixteen year period showed a decline of captures. Similar patterns were reported for specimens from the Strait of Sicily (central Mediterranean) by Garofalo *et al.* (2003), from Caernarfon Bay (off north Wales) by Whittamore & McCarthy (2005) and by Hunter *et al.* (2005 a, b). This obvious decline is concomitant to an intensive fishing pressure in these areas. However, Garofalo *et al.* (2003) noted an increasing abundance trend of *R. clavata* on the southwest side of the Sicilian shelf, due to fishing pressure which considerably decreased in this area in the last ten years.

Off the coast of Languedoc, male *R. clavata* matured at a smaller size than females and attained a smaller maximal size, in agreement with observations reported from other marine areas located in the Mediterranean Sea and in the Atlantic (see Table VII). However, Mediterranean *R. clavata* are smaller than those of the Atlantic and North Sea. Similar patterns were reported on oviparous elasmobranch species since Leloup & Olivereau (1951) and confirmed by further observations carried out by Capapé (1974, 1976), Ellis & Shackley (1997), Capapé *et al.* (2004). Mellinger (1989) suggested that these intraspecific variations depend on environmental influences, especially light and temperature. However, habitat quality and resource availability cannot be neglected. Furthermore, specimens from southern Mediterranean areas such as the coast of Tunisia were larger than specimens from northern areas such as the Adriatic Sea (Zupanovic 1961, Jardas 1973), different populations probably occurred in the Mediterranean. Moreover, egg cases found in *R. clavata*

Table VI. – Monthly maximum number of yolky oocytes counted in adult *Raja clavata* females from the coast of Languedoc in total sample whatever the size (disc width).

Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Maximum number	28	30	22	12	30	22	22	2	32	15	18	29	262

Table VII. – Sizes at sexual maturity and maximal sizes of *Raja miraletus* reported from different areas.

Size at sexual maturity (mm)		Maximal size (mm)		Area	Authors
Males	Females	Males	Females		
500	720	-	-	Off British coasts	Steven (1936)
600	-	-	-	North Sea	Muus and Dahlstrøm (1964-1966)
500	> 500	-	-	North-eastern Atlantic	Du Buit (1968)
400	-			Adriatic Sea	Zupanovic (1961)
360	480	-	-	Adriatic Sea	Jardas (1973)
460-480	540	640	680	Coast of Tunisia	Capapé (1976)
410-440	540-560	540	690	Coast of Languedoc	Present study

from the coasts of Languedoc and Tunisia had similar size, however their masses were slightly different (Table IV). Moreover, Lo Bianco (1909) recorded 60 x 45 mm for *R. clavata* from off Naples (southern Italy) and Le Danois (1913), 80 x 60 mm, for *R. clavata* from off French coast of Channel.

Sizes recorded in newly-hatched specimens differ according to the areas: Clark (1922) noted 125.9 mm (118-136.5 mm) for *R. clavata* from British seas; Ellis & Shackley (1995) reported 118, 75 mm and 8.92 g as mean body length, disc width and mass respectively. They added that mean length reported by Clark (1922) was significantly greater than the mean of the lengths they reported, although disc widths were not significantly different. Similar patterns were reported by Capapé (1976) for two *R. clavata* from the Tunisian coast: 127-128 mm in total body length, 75-76 in disc length and 7.9 and 8.0 g in weight. Incubation period was 16-20 weeks approximately for both areas.

Capture of females with vitellogenic activity and/or carrying egg cases throughout year suggests a semi-permanence of reproductive activity in the *R. clavata* population off the coast of Languedoc, although this activity appeared to be more evident in spring and a bit less in winter (Table IV), also concomitant to egg cases production. Off the Tunisian coast, *R. clavata* showed an obvious vitellogenic activity at the end of autumn with an important production of egg cases. Seasonal changes in vitellogenic activity were described in rajid species, such as the brown ray *R. miraletus*, from the Tunisian coast (Capapé 1974), and *Psammobatis exenta* off Argentina (Braccini & Chiaramonte 2002), as well as in scyliorhinid species such as catsharks, *Scyliorhinus canicula* and *S. stellaris* from the Gulf of Lions (Capapé *et al.* 2000).

Females *R. clavata* were heavier than the male ones as a consequence of gonad mass in adults which generally developed a high vitellogenic activity and produced egg cases (Table II).

Raja clavata is a serial spawner (*sensu* Holden 1975) such as other oviparous elasmobranch species, and a reproductive cycle could not be clearly estimated. Holden (1975) noted that the rate of egg laying attained by *R. clavata* kept in aquaria was one egg capsule per day and this rate was constant during 26 days. The fecundity of *R. clavata* previously assessed by Holden *et al.* (1971) and Holden (1975) were 150 eggs per year and 140 eggs per year respectively; Capapé (1976) reported 141-167 eggs per year, Ryland & Ajayi (1984) 100 eggs per year (minimum of 62-74). However, the rate of egg cases in captivity and in wild environment are probably different. So, the two rates of egg cases production remained possible and a large production of egg cases ranging between 108 and 215 could be considered as a suitable hypothesis. The fecundity of *R. clavata* exclusively based on production of yolky oocytes reaching 262 (*cf supra*) was overestimated, as this was the case for all elasmobranch species; generally, some oocytes were not ovulated and became atretic.

Capapé & Quignard (1975) took in consideration yolky oocytes produced in the sample per month. They noted that there is no relation between numbers of oocytes and disc width, pro parte due to ovulation which occurred quasi-permanently in rajid species. Similar patterns were observed in *R. clavata* from the Languedocian coast.

Locally considered as by-catch species, *R. clavata* is generally researched by fishermen for human consumption. However, population structures could not be

assessed, although similar proportions of males and females in each category of specimens and the relative high proportions of both adult males and females (among them females carrying egg cases) could not suggest that a sustainable population is established in the area. This confirms that the recent decline of *R. clavata* captures is due to an intensive capture pressure in the area over the last ten years.

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