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MATURITY, REPRODUCTIVE CYCLE, AND FECUNDITY OF SPINY BUTTERFLY RAY, *GYMNURA ALTAVELA* (ELASMOBRANCHII: RAJIFORMES: GYMNURIDAE), FROM THE COAST OF SYRIA (EASTERN MEDITERRANEAN)

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Background. Captures of *Gymnura altavela* from the Syrian marine waters allowed to improve knowledge of size at first sexuality of males and females, reproductive period and fecundity.
Materials and methods. In all, 114 specimens were measured for disk width (DW) and weighed. Sexual maturity was determined in males from the length of claspers and aspects of the reproductive tract, and in females from the condition of ovaries and the morphology of the reproductive tract. Hepatosomatic index (HSI), gonadosomatic index (GSI) were calculated in males and females, and their variations related to size were considered in all categories of specimens. To investigate the embryonic development and the role of the mother during gestation, a chemical balance of development (CBD) was determined, based on the mean dry mass of fertilized eggs and fully developed oocytes. Test of normality was performed by using Shapiro–Wilk's test, with $P < 0.05$. Tests for significance ($P < 0.05$) were performed by using ANOVA, Student *t*-test and the chi-square test. The linear regression was expressed in decimal logarithmic coordinates. In the relation mass *versus* total length and liver mass *versus* total length, comparisons of curves were carried out by using ANCOVA.
Results. Females significantly outnumbered males throughout the year. Size at sexual maturity occurred for males at 771 mm DW and for females at 961 mm DW, and maximum size reached 893 mm DW and 1342 mm DW for males and females, respectively. Size at birth ranged between 281 and 367 mm DW. Relations size (DW) *versus* total body mass (M_T) did not show significant differences between males and females, relations size (DW) *versus* liver mass (M_L) were significantly different between males and females suggesting that liver plays a more important role in life cycle of the latter. HSI increased with size of specimens especially in females. Similar patterns were observed for GSI in males and females. Females with active vitellogenesis were found throughout the year, and females carrying developing embryos in spring and in autumn, suggesting two gestation periods each year. CBD reached 22.3 and showed that *G. altavela* is a matrotrophic species. Ovarian fecundity was significantly higher than uterine fecundity, and litter size ranged between 1 and 4.
Conclusion. The reproductive biology of *G. altavela* from the Syrian coast showed that a sustainable population is established in the area. The species develops *K*-selected biological characteristics as specimens from different marine areas and other elasmobranch species, it explained why it is endangered in the area.

Keywords: sustainable population, matrotrophy, Mediterranean form of *Gymnura altavela*, *K*-selected biological characteristics, endangered species

INTRODUCTION

Spiny butterfly ray, *Gymnura altavela* (Linnaeus, 1758), has a widespread amphi-Atlantic and Mediterranean distribution (McEachran and Capapé 1984). In the western

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Atlantic, the species is known from New England (Bigelow and Schroeder 1953) to Argentina (Roux 1979). Vooren (1997) classified *G. altavela* from the coast of Brazil as a breeding species resident, which locally formed the object of an intense fishing pressure and, at present, is rather considered critically endangered in the southwest Atlantic (Vooren et al. 2005) and probably throughout the world (Vooren et al. 2007). In the eastern Atlantic the species was recorded from the Bay of Biscay (Quéro et al. 2003) through Portugal (Albuquerque 1954), Morocco (Lloris and Rucabado 1998), Mauritania (Maurin and Bonnet 1970), Senegal (Capapé et al. 1995), Gulf of Guinea (Blache et al. 1970) to Angola (Fowler 1936).

Gymnura altavela has also been known in the Mediterranean Sea where its abundance and landings fluctuated spacially and in time (Capapé 1989, Capapé et al. 1992). To date, a drastic decline of captures of *G. altavela* was reported in the Mediterranean Sea (Vooren et al. 2007). Additionally, off the north-western Mediterranean shore, the species has never been recorded off the southern coast of France (Capapé 1977, Capapé et al. 2006), and captures of rare specimens were sporadically observed in marine areas such as the Adriatic Sea (Dulčić et al. 2003) and the Tyrrhenian Sea (Psomadakis et al. 2005). Conversely, in southern Mediterranean, the species was captured as a by-catch fish throughout the Maghreb shore (Capapé 1989, Lloris and Rucabado 1998). Off the Tunisian coast, *G. altavela* was rather caught in southern areas according to Quignard and Capapé (1971) and Bradai et al. (2004). Through surveys conducted in the area, Capapé (1989) and Capapé et al. (1992) reported the species northward in the Gulf of Tunis, and captures of two spiny butterfly rays in the Lagoon of Bizerte constituted its northernmost range extension in Tunisian waters (El Kamel et al. 2009), and also the first records of the species in a peri-Mediterranean lagoon (sensu Quignard and Zaouali 1980).

Gymnura altavela is known throughout the eastern Mediterranean, in Turkish Seas (Başusta and Erdem 2000, Bilecenoglu et al. 2002, Golani et al. 2006, Başusta et al. 2012), in the Levant Basin, off Lebanon (Mouneimne 1977, Golani 2005). Saad et al. (2005) reported the occurrence of *G. altavela* in the Syrian marine waters where the species is captured in relative abundance; spiny butterfly rays are generally targeted for human consumption, having a rather high economical value and are locally sold under the vernacular name of 'bakra', which means cow in Arabic. Surveys were recently carried out off the coast of Syria and allowed captures of specimens in order to enhance and improve knowledge of size at first sexuality of both males and females, to delineate the reproductive period and assess its fecundity. These parameters are commented, compared and contrasted with those reported in the marine areas cited above, especially the Tunisian coast (Capapé et al. 1992). Additionally, this study suggests a thorough reconsideration of the species occurrence in the area in order to assess its real status, and concomitantly prepare a local monitoring plan for elasmobranch species in the same region.

MATERIALS AND METHODS

A total of 114 spiny butterfly rays, *Gymnura altavela*, were collected from July 2010 through March 2013. All specimens were captured off the Syrian coast, between Raas Albassit and Tartous, 35°55′N and 34°55′N, by trawling and with bottom longlines, on sandy and rocky bottoms, at depths ranging from 5 to 60 m (Fig. 1), and immediately after being captured, they were identified, sexed, measured, and weighed. In addition, 19 eggs and 41 embryos were examined. Developing embryos still exhibited an umbilical stalk and an external yolk sac (sensu Hamlett et al. 2005); in fully developed embryos, this latter was completely reabsorbed into an internal yolk sac and a scar marked the umbilical cord place.

Specimens were measured for disk width (DW) to the nearest mm following Capapé et al. (1992) and El Kamel et al. (2009) and weighed to the nearest g. Clasper length (CL, mm) was measured according to Collenot (1969), from the forward rim of pelvic girdle to tip of clasper. Oocytes were removed from ovaries and embryos from uteri; then diameter of the former and TL of the latter were recorded to the nearest mm, masses of oocytes and embryos were weighed to the nearest dg.

The onset of sexual maturity was determined in males from the condition and the length of claspers measured following Collenot (1969), and some aspects of the testes and other reproductive organs are given following Capapé et al. (1992) and Callard et al (2005). Size at sexual maturity was determined in females from the condition of ovaries and the morphology of the reproductive tract (Capapé et al. 1992, Callard et al. 2005, El Kamel-Moutalibi et al. 2013). In both males and females, speci-

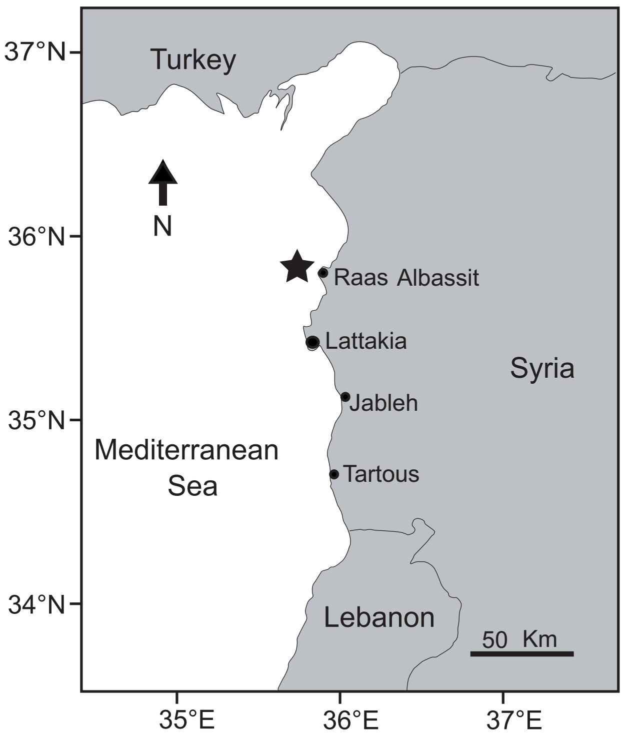

Fig. 1. Capture sites (black star) of *Gymnura altavela* off the coast of Syria

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

Hepatosomatic index (HSI) and gonadosomatic index (GSI) were calculated in both males and females, respectively as

$$HSI = 100M_L \cdot M_T^{-1}$$

and

$$GSI = 100M_G \cdot M_T^{-1}$$

where M_L is the liver mass, M_G is the gonad mass, and M_T is the total mass. Variations in HSI and GSI related to size were considered in all categories of specimens in both sexes. Tests for significance ($P < 0.05$) were performed by using ANOVA, with special regard to variations in HSI and GSI related to size.

To investigate the embryonic development and the role of the mother during gestation, a chemical balance of development (CBD) was determined. It is based on the mean dry mass of fertilized eggs and fully developed embryos and can be computed as the mean dry mass of fully developed embryos divided by the mean dry mass of yolky oocytes or eggs. Water content of 50% in eggs and 75% in fully developed embryos were standard values, based on chemical analyses of the small spotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758), by Mellinger and Wrisez (1989). The chemical balance of development is a tentative estimate of the degree of nutritional support provided by the mother aside yolk reserves.

Test of normality of the sample was performed by using Shapiro–Wilk's test, with $P < 0.05$. Tests for significance ($P < 0.05$) were performed by using ANOVA, Student's *t*-test and the chi-square test following Schwartz (1983). The linear regression was expressed in decimal logarithmic coordinates. Correlations were assessed by least-squares regression. In the relation of mass versus total length and liver mass versus total length, comparisons of curves were carried out by using ANCOVA. ANOVA and ANCOVA were performed by using logistic model STAT VIEW 05.

RESULTS

Sample description. A total of 114 specimens of *Gymnura altavela* were examined, with $W = 0.98$ and $P = 0.0001$ using Shapiro–Wilk's test, showing that the studied sample caught off the Syrian coast came from a normally distributed population; the monthly collection of this sample is given in Table 1. Of the total sample, 51 specimens were males and 63 were females, consequently the latter significantly outnumbered the former ($c^2 = 12.00$, df = 1, $P < 0.05$). Additionally, with special regard to the three categories of free-swimming specimens, males and females were not equally distributed in the sample: among juveniles and adults, females significantly outnumbered males with $c^2 = 18.00$, df = 1, $P < 0.05$ and males $c^2 = 8.00$, df = 1, $P < 0.05$). Additionally, among embryos males significantly outnumbered females ($c^2 = 8.9$, df = 1, $P < 0.05$).

Males. Eight juveniles (Fig. 2) were collected in January and July; they ranged from 350 to 595 mm DW and weighed from 280 to 1970 g. All specimens had short and flexible claspers. Testes and genital ducts were inconspicuously developed and thread-like. The observed sub-adults ranged from 680 to 760 mm DW, and weighed between 2315 and 3565 g. The claspers developed during the sub-adult stage; they were slightly longer than pelvic fins. The testes increased in mass, but had not spermatocysts externally visible, no sperm was observed in the seminal vesicles. The genital duct was slightly convoluted anteriorly. Of the 11 sub-adult males, 6 were captured in September.

The sampled adult males ranged from 771 to 893 mm DW, and weighed between 3795 and 5071 g. During the adult stage, the claspers were elongated, calcified, and rigid, and are slightly longer than the pelvic fins. Testes were well developed and exhibited gametes externally visible. The genital duct was twisted and sperm occurred in seminal vesicles. The 32 adult males were captured throughout the year, except March and August.

Females. The juvenile females (Fig. 3) ranged from 340 to 670 mm DW and weighed from 300 to 2505 g. They presented whitish and undeveloped ovaries, thread-like oviducts and inconspicuous oviducal glands. The 17 juvenile females observed were mostly sampled in March and July (Table 1). The observed sub-adults ranged from 701 to 865 mm DW and weighed from 2810 to 4740 g. They

Table 1

Monthly collection of *Gymnura altavela* captured off the Syrian coast

Sex	Category	Months												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Males	Juveniles	2	—	—	—	—	—	6	—	—	—	—	—	8
	Sub-adults	—	2	2	—	—	—	1	—	6	—	—	—	11
	Adults	4	2	—	2	6	2	4	—	4	4	2	2	32
	Total	6	4	2	2	6	2	11		10	4	2	2	51
Females	Juveniles	—	—	4	3	—	—	6	—	2	—	2	—	17
	Sub-adults	—	—	2	1	2	—	—	—	2	—	1	2	10
	Adults	—	5	6	2	4	2	2	2	—	—	11	2	36
	Total	—	5	12	6	6	2	8	2	4	—	14	4	63
	Grand total	6	9	14	8	12	4	19	2	14	4	16	6	114

exhibited primarily white translucent follicles and a well differentiated genital duct. The oviducal glands were slightly visible and rounded. Ten specimens only were sampled.

The adult females exhibited a single functional ovary on the left side containing batches of yolky oocytes and exhibited fully developed genital ducts. The oviducal glands were conspicuously rounded and the mass considerably increased in adults. The smallest sexually mature female had 961 mm DW and weighed 7410 g, it carried developing oocytes. Additionally, the smallest pregnant female was 1012 mm DW and weighed 9000 g, while the largest gravid female observed was 1342 mm DW and weighed 20 170 g. In all, 36 adult females were continuously collected from February to August and some specimens in November and December (Table 1).

Total length–mass relations. By using ANCOVA, the relation between disk width (DW) and total body mass (M_T) did not show significant differences between males and females (F = 0.319, P = 0.57, df = 1). Consequently, males and females were included in the same relation plotted in Fig. 4, as follows:

$$\log M_T = 3.136 \cdot \log DW - 5.503$$

r = 0.99, n = 114. Conversely, by using ANCOVA, the relation between disk width (DW) and liver mass (M_L), plotted in Fig. 5, differed significantly between sexes (F = 4.987, P = 0.027, df = 1), as follows, it was for males:

$$\log M_L = 3.191 \cdot \log DW - 7.205$$

r = 0.90, n = 51; and for females:

$$\log M_L = 3.643 \cdot \log DW - 8.44$$

r = 0.98, n = 63.

Hepato- and gonadosomatic indices. Considering the whole sample, by using ANOVA, it appeared that female HSI values (Fig. 6), were significantly higher than those of male HSI (F = 12.752, df = 1, p = 0.0005). Conversely, no significant differences were recorded in GSI values plotted in Fig. 7, between females and males (F = 0.105, df = 1, P = 0.747). The HSI of males exhibited low values in the smallest free-swimming specimens, and increased from DW of about 600 onward, and globally increased when males entered maturation stage and become sub-adults, conversely HSI of adult males did not reach high values, and lower values were recorded in the largest males. Additionally, it appeared significant differences in HSI values among the three categories of males, between juveniles and sub-adults (F = 2.9, df = 2, P = 0.03), and also, between sub-adults and adults (F = 2.9, df = 2, P = 0.04). Female HSI increased with DW, it appeared significant changes between juveniles and sub-adults, and between sub-adults and adults (F = 16.52, df = 2, P < 0.001). The male GSI increased with TL of specimens and reached highest values in adults; however, they did not show significant differences between juveniles and sub-adults (F = 8.53, df = 2, P = 0.21), conversely they showed significant differences between sub-adults and adults (F = 8.53, df = 2, P = 0.0002). Similar patterns were recorded for female GSI, they significantly increased in sub-adult specimens, they did not show significant differences between juve-

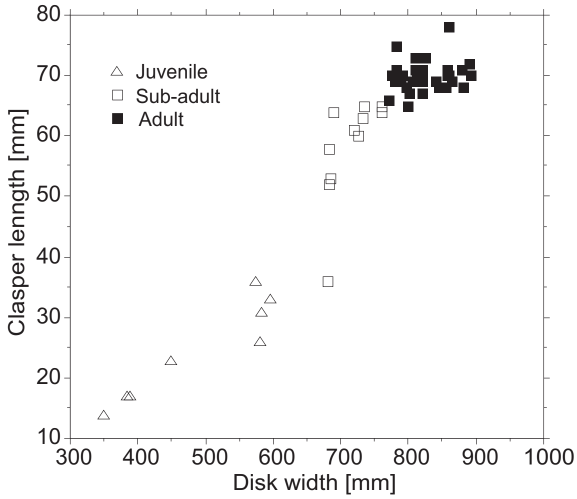

Fig. 2. Relation between the clasper length and the disk width for males *Gymnura altavela* captured in Syrian waters

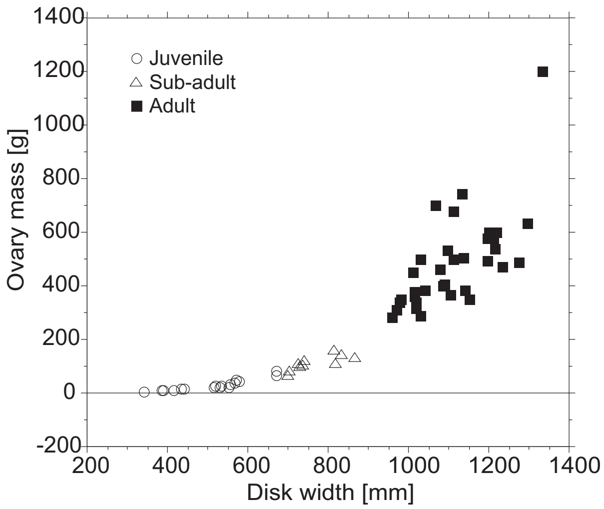

Fig. 3. Relation between the ovary mass and the disk width for females *Gymnura altavela* captured in Syrian waters

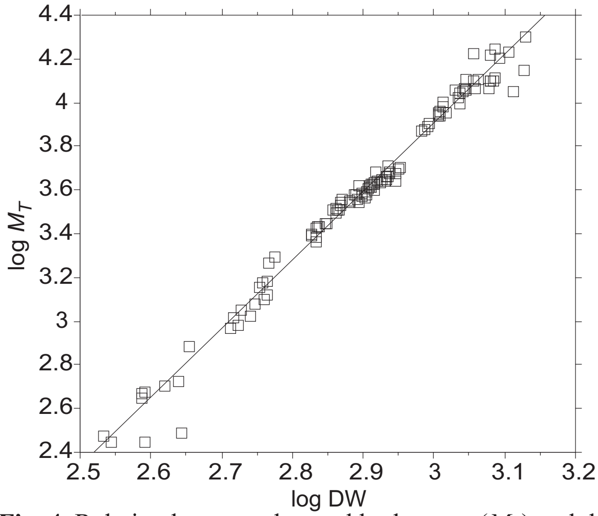

Fig. 4. Relation between the total body mass (M_T) and the disk width (DW) of *Gymnura altavela* captured in Syrian waters, expressed in logarithmic co-ordinates for the total sample

niles and sub-adults (F = 11.22, df = 2, P = 0.32), and showed significant differences between sub-adults and adults (P = 11.22, df = 2, P = 0.0086).

Reproductive cycle. Throughout the year, all sampled adult males of *Gymnura altavela* were found with running ripe spermatozoa and sperm occurred in the seminal vesicles. *G. altavela* is an aplacental viviparous elasmobranch species and juvenile females had two ovaries similar in size and mass, however as they grew, a single ovary, the left developed and became functional, the right being rudimentary or absent. Conversely, both uteri were observed in juveniles, sub-adults, and adults. The studied sample of 36 adult females, collected off the Syrian coast, is presented in Table 2. Among these females, 15 were non-pregnant and 21 were pregnant. The latter group, was arbitrarily subdivided into three categories. The first category was represented by seven pregnant females at the beginning of the gestation and captured in February and March; they contained encapsulated, fertilized eggs in both uteri, (Table 2, records 1 through 7). The second category included females carrying developing embryos, including 4 specimens collected in March (Table 2, records 8 through 11) and 8 specimens collected in November and December (Table 2, records 29 through 36). The former were larger and heavier than the latter. Two pregnant females carrying near term embryos were caught in May (Table 2, records 16 and 17). The eleven non-pregnant females exhibited an active vitellogenic activity, and their uteri were empty. The uteri of the remaining non-pregnant females (records:14, 15, 18, and 20; May through July) were not distended and these females have never produced offspring. Conversely, the uteri of the other non-pregnant females were distended and suggested that they probably were post-partum specimens. However, it could not be ruled out that among them, some specimens have probably aborted during fishing and handling, such inconvenient often occurred in viviparous elasmobranch species (Mellinger 1989).

Twenty-six non-pregnant females were caught between January and May and 110 between July and December, all these females presented an active vitellogenic activity, exhibiting oocytes progressively charged with yolk, with their both mass and diameter concomitantly increasing. Thirty-six ripe oocytes, fully yolked, and ready to be ovulated were examined; their diameter ranged between 19.34 and 31.28 mm (24.60 ± 4.12) and their mass between 3.9 and 9.0 g (5.97 ± 1.41). Each ovary contained two categories of oocytes: translucent oocytes and yellow yolky oocytes. Translucent oocytes were less than 3–4 mm in diameter and their number could not be assessed with precision, due to the fact that they were fragile and generally spilled when removed from ovaries. Additionally, the observed yellow yolky included three or four cohorts, similar in size, the largest yellow yolky oocytes, generally about to be ovulated, reached between 15 and 28 mm maximum (see Table 2), the other non-ovulated oocytes became atretic. The ovarian fecundity is defined as number of yellow yolky oocytes counted in

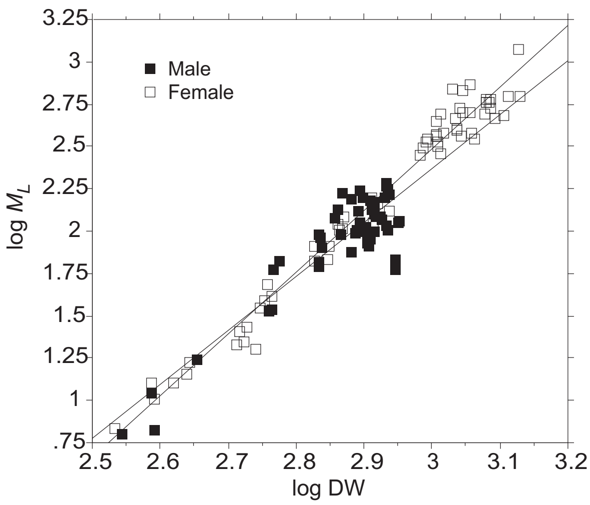

Fig. 5. Relation between the liver mass (M_L) and the disk width (DW) for the male and female of *Gymnura altavela* captured in Syrian waters (expressed in logarithmic co-ordinates)

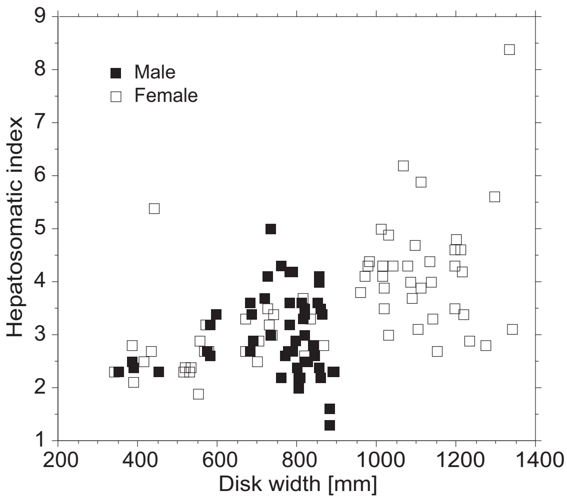

Fig. 6. Relation between the hepatosomatic index and the disk width for the male and for female of *Gymnura altavela* captured in Syrian waters

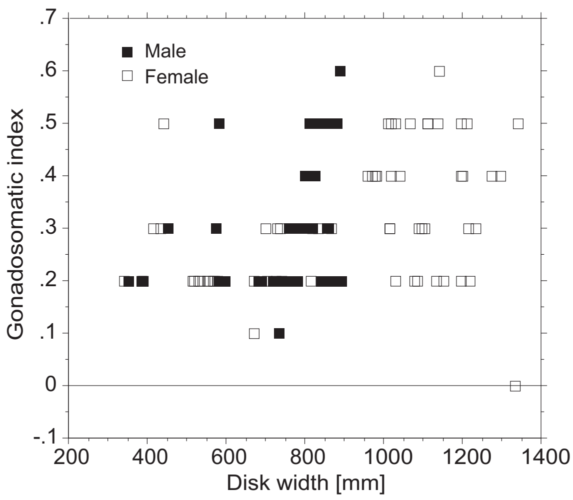

Fig. 7. Relation between the gonadosomatic index and the disk width for the male and for female of *Gymnura altavela* captured in Syrian waters

ovary; it ranged from 2 to 20 (13.06 ± 9.79) and there was no apparent relation between the size (DW, mm) and the ovarian fecundity.

Eggs and developing embryos in earlier stages were surrounded by a case that ceased to exist in larger developing embryos. The cases were diaphanous or amber in colour with a ridge on each side. The ends of the case formed slightly twisted and thickened tendrils. The corpus case was rounded and usually contained a single egg, rarely two eggs, and we were not able to record more than that (Fig. 8). Two eggs were removed from a female (see Table 2, record 3), they weighed 6 and 6.5 g, respectively, the egg case itself weighed 5.5 g. In all, 61 eggs and embryos were not symmetrically distributed in the uteri, 34 in the left uterus and 27 in the right uterus, however, these differences were not significant. (χ^2 = 2.78, df = 1, $P < 0.05$); additionally, 40 embryos were sexed as 21 females and 19 males, however, the former did not significantly outnumbered the latter (χ^2 = 0.1, df = 1, $P < 0.05$). Additionally, the six smallest specimens collected in July, 3 males and 3 females, exhibited on the ventral surface a scar showing the place of the resorbed umbilical stalk an

Table 2

Condition of ovary and uteri during gestation of female *Gymnura altavela* from the coast of Syria

Record	Month	Female size (DW) [mm]	Female mass [g]	Ovarian activity	Oocyte diameter [mm]	Oocyte number	Uterine content	Embryo size (DW) [mm]	Embryo mass [g]	Embryo or egg (left + right)	Sex of embryos
1	Feb	1012	9000	Vitellogenesis	19	5	Embryos	5–10	5.6–12.0	1 + 1	—
2	Feb	1068	11400	Vitellogenesis	21	5	Eggs	—	—	2 + 1	—
3	Feb	1137	12550	Vitellogenesis	22	6	Eggs	—	—	2 + 2	—
4	Feb	1198	12710	Vitellogenesis	22	6	Eggs	—	—	2 + 1	—
5	Feb	1029	10100	Vitellogenesis	20	5	Eggs	—	—	1 + 1	—
6	Mar	1017	9225	Vitellogenesis	21	6	Eggs	—	—	2 + 1	—
7	Mar	1210	12625	Vitellogenesis	22	7	Eggs	—	—	2 + 2	—
8	Mar	1088	11055	Vitellogenesis	21	7	Embryos	267–273	168.8–208.8	1 + 1	1M + 1F
9	Mar	1275	17150	Vitellogenesis	25	6	Embryos	226–267	117.6–189.4	1 + 2	1M + 2M
10	Mar	1195	11610	Vitellogenesis	22	8	Embryos	269–277	182.9–215.3	1 + 1	1M + 1F
11	Mar	1110	12759	Vitellogenesis	22	9	Embryos	270–281	201.2–224.5	2 + 1	2M + 1F
12	Apr	1110	11485	Vitellogenesis	22	6	Empty	—	—	—	—
13	Apr	1199	12550	Vitellogenesis	20	7	Empty	—	—	—	—
14	May	976	7850	Vitellogenesis	18	5	Empty	—	—	—	—
15	May	982	8010	Vitellogenesis	20	6	Empty	—	—	—	—
16	May	1342	20170	Vitellogenesis	28	20	Embryos	291–319	254.8–322.8	3 + 1	3M + 1F
17	May	1140	11630	Vitellogenesis	21	12	Embryos	287–301	248.7–302.8	2 + 2	1M + 3F
18	Jun	961	7410	Vitellogenesis	20	7	Empty	—	—	—	—
19	Jun	1015	8820	Vitellogenesis	22	11	Empty	—	—	—	—
20	Jul	970	7590	Vitellogenesis	21	7	Empty	—	—	—	—
21	Jul	1020	8750	Vitellogenesis	22	6	Empty	—	—	—	—
22	Aug	1040	9010	Vitellogenesis	21	5	Empty	—	—	—	—
23	Aug	1150	12800	Vitellogenesis	28	6	Empty	—	—	—	—
24	Nov	1014	8805	Vitellogenesis	21	4	Empty	—	—	—	—
25	Nov	1105	11735	Vitellogenesis	12	—	Empty	—	—	—	—
26	Nov	1215	12940	Vitellogenesis	14	—	Empty	—	—	—	—
27	Nov	1235	16120	Vitellogenesis	21	4	Empty	—	—	—	—
28	Nov	1295	11350	Vitellogenesis	18	3	Empty	—	—	—	—
29	Nov	1335	14210	Ovary lost	—	—	Embryos	195–242	89.7–136.8	2 + 1	2M + 1F
30	Nov	1079	10655	Vitellogenesis	17	2	Embryos	237	128.7	0 + 1	0M + 1F
31	Nov	1030	9585	Vitellogenesis	9	—	Embryos	161–213	35.2–92.1	3 + 1	1M + 3F
32	Nov	1133	16750	Vitellogenesis	16	2	Embryos	169–211	40.7–88.0	2 + 2	3M + 1F
33	Nov	1219	17600	Vitellogenesis	15	3	Embryos	170–221	53.8–101.6	2 + 1	0M + 3F
34	Nov	1095	11350	Vitellogenesis	16	2	Embryos	187–217	81.3–100.0	1 + 1	1M + 1F
35	Dec	1197	16535	Vitellogenesis	18	7	Embryos	178–213	57.8–90.3	1 + 2	0M + 3F
36	Dec	1085	9950	Vitellogenesis	14	—	Embryos	179–210	55.6–89.9	1 + 1	1M + 1F

M = male, F = female.

remains of internal vitelline vesicle (Fig. 9); their DW measured from 340 to 390 mm and they weighed between 280 and 465 g. All specimens probably were neonates or at least born of the year. Litter size or uterine fecundity ranged from 1 to 4 (2.85 ± 0.96). Additionally, a paired *t*-test showed that ovarian fecundity was significantly higher than litter size ($t = 2.69$, df = 7, $P = 0.01$). A total of 8 near-term embryos were removed from two females (Table 2, records 16 and 17), they ranged from 287 and 319 mm DW (300.5 ± 11.08) and weighed between 248.7 and 322.8 g (287.7 ± 27.9). Consequently, CBD based on dry masses calculated for *Gymnura altavela* from the Syrian coast was 22.5.

DISCUSSION

Spiny butterfly ray, *Gymnura altavela*, has been considered a strongly threatened species (Vooren et al. 2007), although it is widely distributed on both sides of the Atlantic Ocean and in some areas of the Mediterranean Sea. The species suffered from a strong fishing pressure, especially off the southern coast of Brazil where a drastic decline of captures was recently reported by Vooren et al. (2007). The *G. altavela* is sporadically captured in some areas of the Mediterranean such as the Strait of Sicily (Psomadakis et al. 2005); conversely, it appears as commonly captured in the Tunisian waters, rather in southern areas (Capapé et al. 1992, Bradai et al. 2004), however, it recently expanded its distribution by migrating toward northern areas and was recorded in the brackish waters of the Lagoon of Bibans (El Kamel et al. 2009). Additionally, the data reported in the present paper showed that a sustainable population is established off the Syrian coast, where findings of pregnant females carrying near term embryos and small free-swimming specimens probably neonates or born of the year suggest that the area

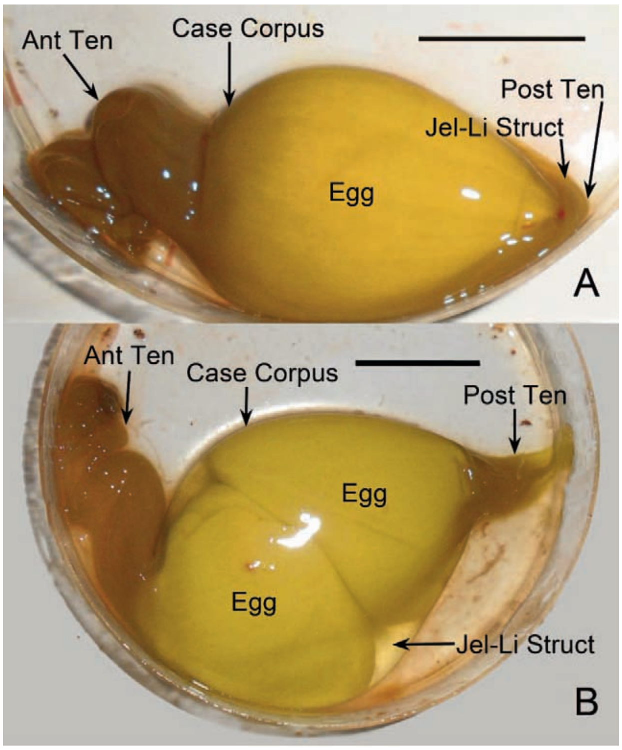

Fig. 8. Egg case of *Gymnura altavela*:. Including a single egg (**A**) (scale bar = 20 mm);. Including two eggs (**B**) (scale bar = 20 mm), showing anterior tendril (ant ten), posterior tendril (post ten), jelly-like structure (jel-li struct), egg, and case corpus

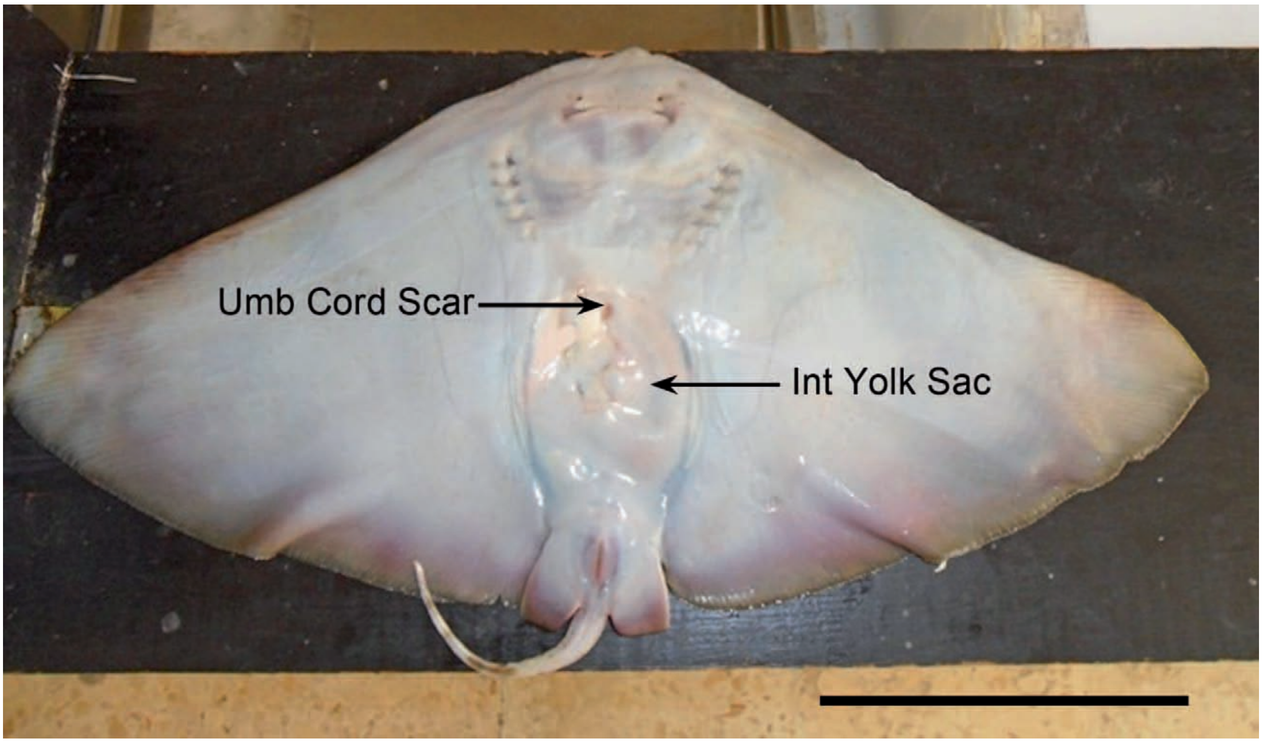

Fig. 9. Ventral surface of a neonate or born of the year of *Gymnura altavela* with a scar showing the place of the umbilical cord scar (umb cord scar) and the internal yolk sac (int yolk sac); Scale bar = 100 mm

could be considered as a possible nursery area sensu Castro (1993) for *G. altavela*. Such patterns could explain why females significantly outnumbered males, especially among adults. Females approach shallow coastal waters to find favourable hydrobiological environment for parturition and, consequently, avoiding the new free-swimming specimens to be affected by both intra and interspecific pressure for food, and also from cannibalism, segregation for sex is a rule for viviparous elasmobranch species during post partum period (Muñoz-Chapuli 1984, Capapé et al. 2003).

The sample of spiny butterfly rays used in the presently reported study came from a normally distributed population collected off the Syrian coast (Tables 3 and 4). Males from the latter area matured at a smaller size than females did, and consequently reached a smaller maximal size. Similar patterns were observed for *G. altavela* populations from the Tunisian coast and the eastern Atlantic. In viviparous elasmobranch species, sexual dimorphism in size is favourable to females and such phenomenon could be considered as a rule (Mellinger 1989), conversely sizes at birth recorded for *G. altavela* were practically the same. The general pattern of latitudinal variation in maturity and maximum size was reported in several other chondrichthyan species (Leloup and Olivereau 1951, Mellinger 1989, Capapé et al. 2004, Capapé and Reynaud 2011). Lombardi-Carlson et al. (2003) noted that latitudinal differences are thought to be the results of environmental factors, but may be also due to physiological constraints or genetic factors; the fishing pressure cannot be ruled out and the drastic decline of captures of the species in marine waters and especially in the Mediterranean Sea reduced the size of specimens (Table 3).

However, very important differences in size at birth, size at sexual and maximum size occurred between Mediterranean spiny butterfly rays and specimens collected off the western Atlantic coast (Table 3). Similar patterns were reported for thorny stingray, *Dasyatis centroura* (Mitchill, 1815) by Capapé (1993) who noted that size at birth occurred at 137 mm DW for the specimens from the Tunisian waters while it reached between 340 and 370 mm DW for those from the south-eastern United States (Bullis and Struhsaker 1961). Bigelow and Schroeder (1953) noted the smallest specimen they have examined was 394 mm DW, and specimen smaller than 500 mm DW were rarely found in the area. In the former area, the size at sexual maturity was 800 mm DW and 1000 m DW for males and females, respectively, and the maximal size reached 1450 mm DW (Capapé 1993), while for the latter area, the size at sexual maturity was 800 mm DW and 1000 m DW for males and females, respectively, and the maximal size amounted to 1450 mm DW. Consequently, Županović (1961), Bullis and Struhsaker (1961), and Capapé (1993)—in total agreement with

Table 3

Biological parameters recorded for *Gymnura altavela* from different localities

Body of water	Area	Size at birth [mm]	Size at sexual maturity [mm]		Maximal size [mm]		Source
			Males	Females	Males	Females	
Western Atlantic	Cape Lookout	382–444	—	—	1208	2082	Bigelow and Schroeder 1953
Western Atlantic	Delaware Bay	—	1016	1549	1244	2032	Daiber and Booth 1960
Western Atlantic	North Carolina	—	—	—	—	2600	Schwartz 1984
Western Atlantic	—	—	1020	1550	—	—	Henningsen 1996
Mediterranean	Tunisian coast	294	760	1020	1140	1620	Capapé et al. 1992
Mediterranean	Syrian coast	267–281	771	961	893	1342	This study

Sizes are given as the disc width.

Table 4

Litter size and gestation period recorded for *Gymnura altavela* from the coast of Syria compared with the same recorded from other western Atlantic and Mediterranean areas

Body of water	Area	Gestation period length [month]	Litter size	Source
Western Atlantic	Cape Lookout	6 (?)	4	Coles 1915
Western Atlantic	Cape Lookout	—	4	Bigelow and Schroeder 1953
Western Atlantic	Delaware Bay	6–12	4–7	Daiber and Booth 1960
Western Atlantic	—	—	8	Musick et al. in Vooren et al. 2007
Western Atlantic	Southern Brazil	—	5	Vooren et al 2007
Mediterranean	Italian Seas	—	1–3	Tortonese 1956
Mediterranean	Tunisian coast	4–9	2–6	Capapé et al. 1992
Mediterranean	Syrian coast	4–12	1–4	This study

Tortonese (1956)—noted that these three variables (i.e., size at birth, size at sexual maturity and maximum size) allow distinguishing the American form from the Mediterranean form of *D. centroura*. Similarly, the data included in Table 3 suggest that it could also exist an American form and a Mediterranean form of *G. altavela*, however the question is posed to know if whether or not the two forms are distinct or cognate species. The use of three morphometric variables is helpful but not sufficient for definitive statement, and consequently, molecular method should be also used to carry out a discrimination between specimens from different marine areas.

The relation between the size (DW) and total body mass (M_T) presented a positive allometry and did not show significant differences between males and females, so, the regular growth increasing of both male and female *G. altavela* suggests that the species found favourable hydrobiological parameters to develop in its life area; similar patterns were observed for the specimens from Iskanderun Bay (Başusta et al. 2012). Conversely, the relation between the size (DW) and the liver mass (M_L) significantly differed between males and females, it was significantly higher in the former than in the latter and these significant differences between males and females suggested that liver plays a more important role in life cycle of the latter (Lucifora et al. 2005). Liver size is sexually dimorphic in both oviparous and viviparous chondrichthyan species. A larger liver may allow females to maximize the production of yolk such as in the viviparous. 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). The highest value of HSI was recorded in juvenile male and female specimens suggested that liver constituted a reserve of nutriments for free-swimming specimens soon after parturition, this hypothesis was corroborated by decreasing of HSI values in larger juveniles. Both HSI and GSI values were lower in *G. altavela*, similar to those recorded by Capapé et al. (2007) for the eagle ray, *Myliobatis aquila* (Linnaeus, 1758), a matrotrophic species (sensu Hamlett et al. 2005) in which the mother supplements yolk from other sources such as uterine secretions, the phenomenon was called histotrophy by Hamlett et al. (2005). Additionally, the high CBD value, 22.5, of *G. altavela* from the Syrian coast is lower than this calculated for the Tunisian specimens which reached 30.6; such difference is due to the fact that mass of fully yolky oocytes were used for calculate CBD of latter specimens, while in the presently reported study we have used the mass of fertilized eggs, which was slightly higher because they were surrounded during ovulation by a jelly-like structure which did not exist in fully yolky oocytes. These high values of CBD corroborate the mother's role during embryonic development and allow to state the *G. altavela* is a matrotrophic species (sensu Hamlett et al. 2005), and not a lecithotrophic species (sensu Hamlett et al. 2005), in which values of calculated CBD were very low, generally less than 1.00, such as in torpedinid species, for instance (El Kamel-Moutalibi et al. 2013).

Gymnura altavela is an aplacental viviparous species which produces eggs included in a case. This was described by Daiber and Booth (1960) but was not observed by Capapé et al. (1992). The egg cases illustrated in this paper constitute the first documented record (Fig. 8). Data presented in Table 2 show occurrence of females carrying fertilized eggs in February (Table 2, records 2 to 7), and near term females in May (Table 2, records 16 and 17), suggesting that gestation started at this period of the year, additionally, near-term females were caught in May, and consequently a gestation of four months could be a suitable hypothesis. On the other hand, the second lot of pregnant females was caught in November and December (Table 2, records 26 through 36), these females carried developing embryos, it could suggest that a second gestation period occurred during the year. Conversely, no females carrying fertilized eggs were examined between May and November, so a second gestation period remains questionable even if such hypothesis cannot be totally ruled out. The data summarized in Table 1 show that a gestation period lasting appeared to be more suitable and three phases could be distinguished. The first phase was the ovulation that occurred in the earlier months of the year, starting in January–February and ending in March as shown by records 2 to 7. The second phase included embryonic development from March to May. The developing embryos were found in November and December (Table 2, records 29 through 36), embryos at the end of their development—in March (Table 2, records 8 through 11), and near-term embryos—probably close to be expelled by their mothers (Table 2, records 12 and 13). So the gestation period extending over a year appeared to be the most suitable hypothesis. Capapé et al. (1992) considered a gestation period of 4 months as the most probable hypothesis for the Tunisian *G. altavela*, but did not exclude a complete reproductive cycle of one year. Coles (1915) noted that for specimens from North Carolina parturition occurred in late winter and early summer and females carrying egg cases were observed during mid-summer and mid-winter, suggesting two gestation periods per year. However, we totally agree with Daiber and Booth (1960) who noted that two such periods of reproduction or a prolonged period of reproductive activity for the species is still an open question, even if we tend to prefer the latter hypothesis, following our observations. Capapé et al (1992) noted that until mid-gestation the vitellogenic activity is blocked and then started again and continued after parturition, considering that it was a case of semi-delayed vitellogenesis similar to those previously described for squatinid species (Capapé et al. 1990). In the studied sample vitellogenesis occurred throughout the year in pregnant females proceeding simultaneously with gestation. The ripe oocytes are ready for ovulation at the time of parturition.

Additionally, previous observations made on Tunisian *Gymnura altavela* showed that ovarian fecundity is generally higher that litter size which is in agreement with the data included herein (Table 2). Stenberg (2005) stated it is due to the fact that yolky oocytes were not ovulated and became atretic, some eggs were not fertilized and did not develop; additionally, abortion could not be excluded, naturally, during embryonic development, or under human pressure during fishing, handling, and landing (Dodd and Duggan 1982). Embryos were free during a large period of their development; the uteri were not divided into chambers, and were not attached to uterine wall by umbilical stalk, such as in carcharhinid and triakid species (Hamlett et al. 2005). Additionally, the litter size range observed was in agreement with other studies carried out elsewhere, globally litter size ranges were not very large and showed that the species is not very prolific regardless the marine area. However, the litter size ranges recorded in our study was slightly higher than this from the two other Tunisian areas, such differences could be explained by changes of the environmental factors, but also sampling bias could not be totally neglected.

All data presented in this paper, concerning some traits of the reproductive biology of Syrian *Gymnura altavela*, showed that a sustainable population of this species was probably established in the area such as in the Tunisian waters (Capapé et al. 1992, El Kamel et al. 2009). However, the low values of both fecundities, the length of the reproductive cycle which probably lasted one year and the size at sexual maturity reached at a larger size showed *G. altavela* from the Syrian coast developed *K*-selected biological characteristics (sensu McAuley et al. 2007), as other specimens from different marine areas (see Tables 3 and 4) and other elasmobranch species (Mellinger 1989). However, Vooren et al. (2005, 2007) considered the species as strongly endangered in the areas where it was formerly commonly captured. Consequently, if *Gymnura altavela* described in this paper from Syrian waters, did not appear as threatened, some substantial efforts need to be implemented in order to preserve the species in the region, following recommendations of UICN and Aldebert (1997). Similar measures are also needed in other Mediterranean regions (Cavanagh and Gibson 2007, Ferretti et al. 2008).

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