MORPHOLOGICAL AND BIOLOGICAL CHARACTERISTICS OF A GRAVID ANGULAR ROUGH SHARK (*OXYNOTUS CENTRINA*) AND ITS EMBRYOS FROM THE EASTERN MEDITERRANEAN SEA

by

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ABSTRACT. - The record of a specimen of gravid female angular rough shark, *Oxynotus centrina*, in the Aegean Sea is reported. It was captured in February 1999 by a commercial bottom trawl at a depth of 100 to 200 m on a muddy-sandy bottom near Kea Island. The specimen size was 69 cm in total length and 4.0 kg in weight. A total of fifteen embryos ranging from 9.0 to 11.2 cm in total length were observed. They all had a distinctive coloration of darker marks on a light brownish background. All the embryos were attached to sizeable yolk sacs but showed differences in development; some had already absorbed a significant part of yolk sac content, while others had not. All embryos had clearly formed external morphological characteristics, similar to the adult stage. No sign of clasper formation was observed, making sex identification impossible. One of the embryos was significantly smaller and malformed in the head area. A series of morphometric measurements were taken both for gravid female and embryos and compared to each other.

RÉSUMÉ. - Caractéristiques morphologiques et biologiques d'une femelle gravide de centrine commune, *Oxynotus centrina*, et de ses embryons, de la Méditerranée orientale.

Une femelle gravide de centrine commune, *Oxynotus centrina*, a été capturée dans la mer Égée en février 1999, dans un chalut de fond entre 100 et 200 m de profondeur, près de l'île de Kea, sur un fond sablo-vaseux. La femelle mesurait 690 mm LT et pesait 4,0 kg. Elle portait 15 embryons de 90 à 112 mm LT. Tous présentaient une coloration distincte constituée de marques sombres sur un fond brun clair. Les embryons possédaient encore leurs sacs vitellins mais à différents stades de développement ; certains avaient déjà résorbé une part importante de leurs sac vitellin tandis qu'il était encore bien visible chez d'autres. Tous les embryons avaient des caractéristiques morphologiques semblables à celles de l'adulte. Les ptérygopodes n'étaient pas encore visibles si bien que la détermination du sexe des embryons n'a pas été possible. Un des embryons était bien plus petit que ses congénères et présentait une malformation à la tête. Des mesures biométriques ont été prises sur la mère et ses 15 embryons, et comparées.

Key words. - Oxynotidae - *Oxynotus centrina* - MED - Aegean Sea - Morphology - Reproduction - Embryos.

Oxynotus centrina (Rafinesque, 1810), the angular rough shark, is an uncommon little-known bottom shark (family: Oxynotidae, order: Squaliformes). Its distribution covers the Mediterranean Sea and Eastern Atlantic from the British Isles to the north down to South Africa to the south. Usually, it is found on the continental shelf and upper slope at depths of 60 to 660 m. It can attain a size of 150 cm but common size of individuals caught is smaller. Since it is a relatively rare catch in bottom and pelagic trawl fisheries (Compagno, 1984; Fischer *et al.*, 2001) very little is known on its biology. Capapé *et al.* (1999) summarized some aspects of the reproductive biology of the angular rough shark caught in the Gulf of Lion (Northern Mediterranean) from 1988 to 1993, in the northern coasts of Tunisia (Central Mediterranean) from 1970 to 1985 and in the Eastern Tropical Atlantic Ocean from 1993 to 1998. They studied a total of 99 free living specimens and suggested that females, which probably mature later than males, begin sexual maturation at 560 mm TL and they are fully mature at 660 mm. They also concluded that angular rough shark is purely a lecithotrophic ovoviparous elasmobranch. Early descriptions of angular rough shark embryos were made by Lo Bianco (1909) in the Bay of Naples and more recently by Capapé *et al.* (1999, 2001) in the Cape Verde Peninsula, in Senegal, suggesting that the most probable litter size ranges from 9 to 12 specimens. No data exists for angular rough shark in the Eastern Mediterranean Sea where only few records of this species were accounted in trawl surveys during last years (Bertrand *et al.*, 2000). In this paper, we present in detail data on the first gravid female specimen caught in the Aegean Sea, in the Eastern Mediterranean Sea. Our main goal was to provide information on some biological and morphological characteristics of the specimen and its embryos.

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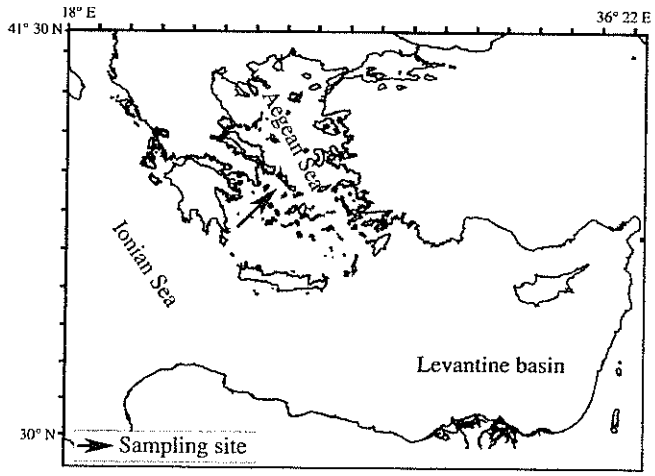

Figure 1. - Map of the Eastern Mediterranean Sea indicating the area where a gravid female *Oxynotus centrina* was caught in February of 1999.

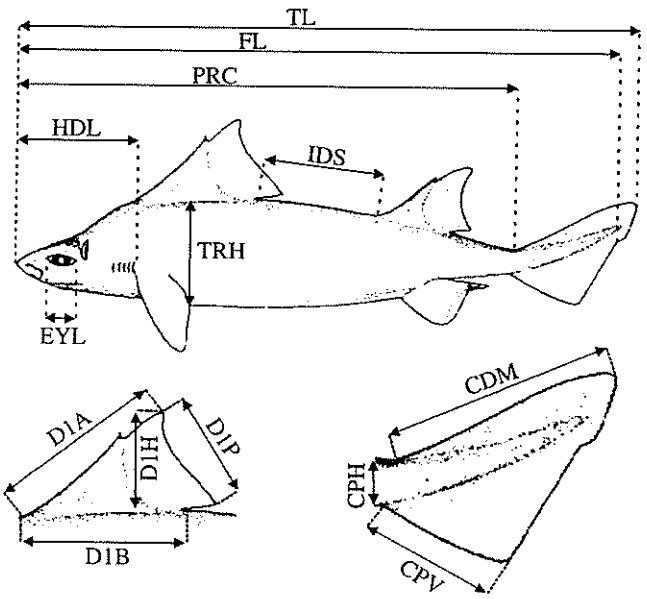

Figure 2. - Morphometric measurements and acronyms used.

MATERIAL AND METHODS

An angular rough shark was caught incidentally by a bottom trawl east of Kea Island in the Central Aegean Sea at a depth of 100 to 200 m, on a sandy-muddy bottom (Fig. 1). The specimen was landed on the first week of February 1999 at Rafina port. After the recording of operational data, the sample was transferred to the laboratory where it was identified, sexed and photographed. Total weight (W) was recorded to the nearest gram, while a series of morphometric measurements (Fig. 2) were taken to the nearest mm, according to FAO Sharks species Catalogue (Compagno, 1984).

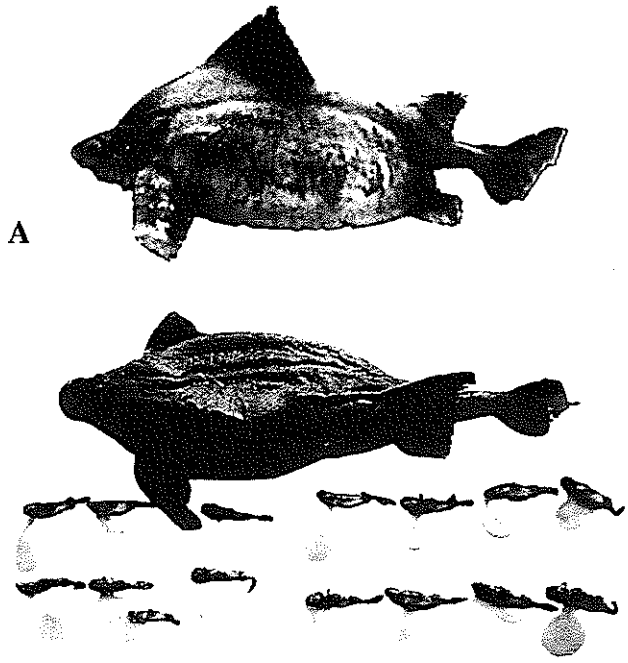

Figure 3. - Gravid female *Oxynotus centrina*, 69 cm TL. **A**: Before dissection; **B**: After dissection with 15 embryos.

After dissection, the stomach was removed and examined for food remains. Each liver lobe was measured separately. Liver lobe weight was measured in g and length in tenths of cm. Hepatosomatic index (HSI) as defined by Francis (1997) was calculated using the formula:

$$\text{HSI (\%)} = \frac{\text{liver weight (g)}}{\text{dressed weight (g)}} \times 100$$

Finally, embryos were removed and weighed with and without their yolk sacs to the nearest cent of a gram (0.01 g). Sex determination of embryos was attempted by macroscopic observation for the presence of claspers in males. Morphometric measurements of embryos analogous to their mother were made with calipers at the nearest tenth of mm (0.1 mm). After examination, embryos were preserved in 70% ETOH. All samples were included in the fish collection of the Zoological Museum of the National and Kapodistrian University of Athens (catalog number: ZMUA 4500).

Regression analysis was used to assess correlations between total length and weight of embryos as well as between total length and other morphometric measurements. Moreover, the % ratios of the morphometric measurements in total length were calculated and embryos ratios were compared to the ones of their mother. Wilcoxon signed-rank tests were performed to test for significant differences between mother and embryos ratios.

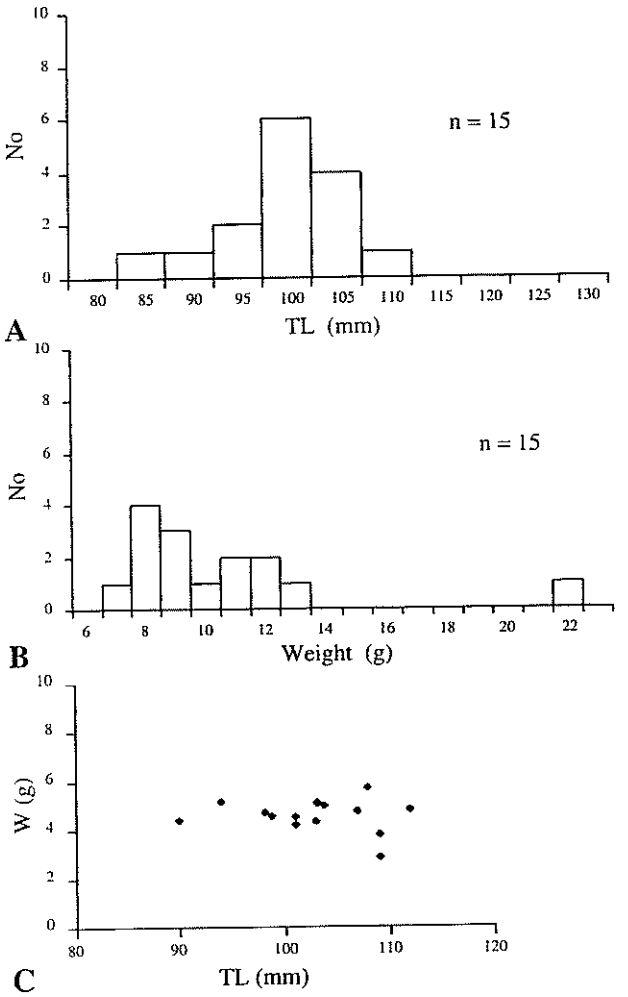

Figure 4. - Length (TL) (**A**), weight (**B**) and distribution of individual lengths and weights (**C**) for 15 embryos found in a gravid female *Oxynotus centrina* caught in the Aegean Sea in 1999.

RESULTS

The specimen of angular rough shark examined was female with a total length of 69 cm and a total weight of 4 kg. The two liver lobes occupied a significant part of its internal body cavity having a pooled weight of 600 g. The hepatosomatic index reached 18.8%. An asymmetry between the liver lobes was observed with the left lobe larger than the right one. The left lobe was 350 g in weight and 390 mm in length while the right lobe was 250 g in weight and 411 mm in length. Stomach was shrunk and void of contents probably due to the advanced stage of gestation. Gonads were small and in a quiescent phase. A total of fifteen embryos were positioned symmetrically in the oviduct. They all had a distinctive coloration of darker marks on a light brownish background and were attached to sizeable yolk sacs (Fig. 3).

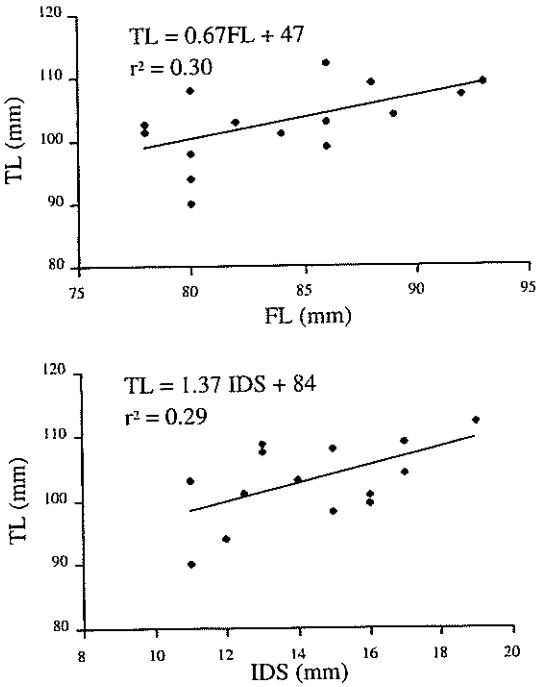

Figure 5. - Relationships between total length-fork length and total length-interdorsal space for *Oxynotus centrina* embryos.

Embryos ranging from 90 to 112 mm in total length revealed a mean total length of 103 mm and a mean weight with yolk sac of 9.8 g (Fig. 4A, B). Yolk sacs were large and the yolk sac weight to embryo weight ratio, ranged from 0.26 to 1.21 with a mean value of 0.67. Length-weight information for embryos measured without yolk sac are shown in figure 4C.

Fourteen out of fifteen embryos had clear shaped external characteristics like fins (dorsal, pectoral, pelvics and caudal), five gill slits, eyes and teeth, but no clasper formation, making sex determination impossible. One of the embryos was significantly smaller and malformed in the head area.

The relationship between total length and other morphometric measurements of embryos was weak with r^2 ranging from 0.25 to 0.30. Higher correlations were found between total length and fork length as well as between fork length and interdorsal space (Fig. 5).

Mean, SD, minimum and maximum values of all morphometric measurements obtained both for mother and embryos are given in table I while morphometric measurement ratios expressed as percentage (%) of total length are given in table II. Wilcoxon signed-rank test showed significant differences between embryos and mother for most of the morphometric ratios ($p < 0.05$). Only a few ratios regarding mainly dorsal and pelvic fin measurements showed no significant differences (Tab. II).

Table I. - Morphometric data of a gravid female *Oxynotus centrina* caught in the Aegean Sea in 1999 and its 15 embryos

Morphometric characteristics	Morphometrics in mm				
	Adult	Embryos			
		Mean	S.D.	Min.	Max.
FL (fork length)	640	84	4.9	78	93
HDL (head length)	104	24	1.7	22	27
IDS (interdorsal space)	146	14	2.3	11	19
PRC (precaudal length)	560	71	3.7	66	79
PD1 (prefirst dorsal fin length)	165	28	1.6	25	31
PD2 (presecond dorsal fin length)	425	54	2.9	49	59
PP1 (prepectoral fin length)	103	24	2.0	21	28
P1A (pectoral fin anterior margin)	132	12	1.4	10	14
D1A (first dorsal anterior margin)	133	17	1.5	15	20
D1H (first dorsal height)	94	11	1.7	9	15
D1B (first dorsal base)	86	12	1.5	9	14
D2A (second dorsal anterior margin)	104	12	2.4	7	15
D2H (second dorsal height)	112	8	1.0	6	9
D2P (second dorsal posterior margin)	69	7	1.6	3	9
D2B (second dorsal base)	63	8	1.5	5	10
P2A (pelvic anterior margin)	69	8	1.6	6	11
P2H (pelvic height)	63	7	1.1	6	9
P2P (pelvic posterior margin length)	73	6	0.9	5	8
P2B (pelvic base)	50	7	1.9	6	12
CDM (dorsal caudal margin)	119	23	1.4	21	26
CPU (upper postventral caudal margin)	79	13	3.2	9	19
CTR (terminal caudal margin)	40	7	3.2	3	9
CPL (lower postventral caudal margin)	25	7	2.3	4	12
CPV (preventral caudal margin)	78	13	4.4	7	22
CPH (caudal peduncle height)	28	4	0.5	4	5
HDH (head height)	58	10	2.0	7	13
TRH (trunk height)	126	12	1.5	10	15
ABH (abdomen height)	100	11	1.7	8	13
EYL (eye length)	25	8	0.7	7	9

DISCUSSION

The present study reports for the first time a gravid female in the Eastern Mediterranean. The size of the studied specimen caught in the Aegean Sea, was in the range of sizes reported for the Western Mediterranean and very close to the average size of females studied in other areas of the Eastern Tropical Atlantic. Out of a sample of 99 individuals, from Tunisia, France and Senegal, a size range of 21 to 73 cm was observed, with an average length of 62.2 cm for males and 70.4 cm for females (Capapé *et al.*, 1999, 2001).

No study on morphometric measurements of angular rough shark was found in literature to use for comparison. The only data reported in Fish Base (www.fishbase.org) were obtained from a specimen photograph using image analysis methods.

Gravid females of angular rough shark have been recorded in the Bay of Naples, Gulf of Lion, and Senegal, in the Eastern Tropical Atlantic Ocean. Most of them had fertilized ova but very few bore embryos. Especially in the Mediterranean Sea gravid females with embryos in different devel-

Table II. - Comparison of morphometric character ratios expressed as percentage (%) of total length in a gravid female *Oxynotus centrina* and its 15 embryos. Wilcoxon signed-rank test results for significant differences are shown in the last two columns.

Morphometric characteristics	In % of total length (TL)						Test statistic	*P*-value
	Adult	Embryos						
		Mean	S.D.	Min.	Max.	Median		
FL (fork length)	93	88	4	82	94	87	2.943	0.003
HDL (head length)	15	25	2	22	28	26	3.145	0.002
IDS (interdorsal space)	21	14	2	11	17	15	3.145	0.002
PRC (precaudal length)	81	74	2	71	79	74	3.021	0.003
PD1 (prefirst dorsal fin length)	24	29	1	27	31	29	3.146	0.002
PD2 (presecond dorsal fin length)	62	56	2	53	59	56	3.147	0.002
PP1 (prepectoral fin length)	15	25	2	22	30	25	3.021	0.003
P1A (pectoral fin anterior margin)	19	12	1	11	14	12	2.450	0.014
D1A (first dorsal anterior margin)	19	18	1	16	20	18	2.707	0.007
D1H (first dorsal height)	14	12	2	9	15	11	2.628	0.009
D1B (first dorsal base)	12	13	1	10	15	12	0.350	0.727
D2A (second dorsal anterior margin)	15	12	2	7	15	12	2.629	0.009
D2H (second dorsal height)	16	8	1	6	9	9	3.026	0.002
D2P (second dorsal posterior margin)	10	7	3	7	9	8	2.895	0.004
D2B (second dorsal base)	9	8	2	5	11	9	1.188	0.235
P2A (pelvic anterior margin)	10	9	2	6	11	9	1.939	0.052
P2H (pelvic height)	9	7	1	6	9	7	2.754	0.006
P2P (pelvic posterior margin length)	11	6	1	5	8	6	2.752	0.006
P2B (pelvic base)	7	7	2	6	12	7	0.306	0.760
CDM (dorsal caudal margin)	17	24	2	22	28	24	3.021	0.003
CPU (upper postventral caudal margin)	11	13	3	9	19	13	1.190	0.234
CTR (terminal caudal margin)	6	7	3	3	9	8	0.267	0.789
CPL (lower postventral caudal margin)	4	7	2	4	12	7	2.609	0.009
CPV (preventral caudal margin)	11	14	5	8	24	13	1.530	0.126
CPH (caudal peduncle height)	4	5	1	4	5	4	1.844	0.065
HDH (head height)	8	11	2	7	14	11	3.145	0.002
TRH (trunk height)	18	12	2	11	16	12	2.606	0.009
ABH (abdomen height)	14	11	2	9	13	11	2.282	0.022
EYL (eye length)	4	8	1	7	9	8	3.147	0.002

opmental stages were observed only in the Bay of Naples. Compagno (1984), Quéro (1984), Springer (1990) and Capapé *et al.* (1999) observed that the number of embryos *in uteri* ranged from 9 to 12, while Risso (1826) reported 23 embryos in a female. Our finding for 15 embryos is within this range.

The lack of claspers in embryos could be an indication that in this stage of embryonic development (103 mm mean total length) external characteristics of males have not been developed yet. The smaller and malformed embryo was most likely due to the convolution of the umbilical stalk around the head and the prevention of nutrients to flow from the yolk sac to the fetus. Pratt (1979), studying the viviparous shark species blue shark, *Prionace glauca*, reported that almost in every gestation there was a similar case of embryonic development obstruction even to the level of disintegration of the embryo *in uteri*.

The calculated HSI value (18.8%) in our sample was quite low compared to values found in other females studied so far, ranging from 25 to 40% (Capapé *et al.*, 1999). It is possible that a portion of the hepatic reserves could be used for gonadal products at the breeding period. Craik (1978) found that variations in HSI in *Scyliorhinus canicula* were linked to vitellogenesis and argued that the primary reason must be the deposition of lipid at times of food abundance and utilization of these reserves when food is scarce. Our observation of empty stomach and low HSI in gravid females are enforced by Tanaka *et al.* (1990) who suggested that feeding in pregnant sharks is impaired because of lack of space in the body cavity and consequently lipids would not be available for deposition in the liver. Absence of vitellogenetic activity in gravid females was also observed by Capapé *et al.* (1999). This piece of evidence suggests that vitellogenesis does not coincide with gestation, as in numerous other viviparous elasmobranches. An important aspect of the reproduction cycle of many deep-water sharks is that they do not carry ripe or ripening oocytes during gestation. Tanaka *et al.* (1990) considered that oocytes do not develop during gestation because of lack of space in the body cavity.

The reproductive cycle of the angular rough shark has not been fully described. Risso (1826) reported that off Nice this species mated in February and parturition occurred three months after. Lo Bianco (1909), studying specimens fished in the Bay of Naples, observed embryos 3 cm of total length in February and more advanced embryos of 15 cm with large yolk sacs in March. Capapé *et al.* (1999) report new born pups only during the months of April, July and September with a size range of 21 to 24 cm total length. Considering the above observations, our data on embryos size and date of capture suggest that parturition would have probably taken place by the end of spring. However, more data on gravid females and embryos are needed to evaluate the reproductive cycle of this rare species in the Mediterranean Sea.

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