Indian J. Fish., 61(1) : 16-20, 2014

Reproductive biology of the mottled electric ray, *Torpedo sinuspersici* Olfer, 1831 (Pisces: Torpedinidae) off Visakhapatnam, India

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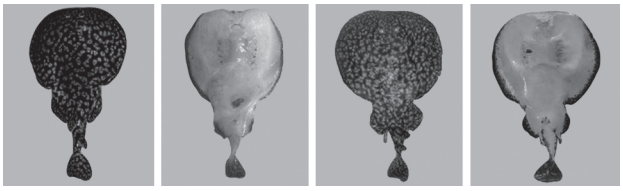
ABSTRACT

Among the four species of electric rays of the genus *Torpedo* recorded from the catches of Visakhapatnam, north Andhra region (lat 17°01'N to 19°22'N; long 83°23'E to 85°14'E), *Torpedo sinuspersici* Olfer, 1831 is the most commonly occurring species in trawl and trammel net bycatches. The present paper deals with various aspects of reproductive biology *viz.*, length at first maturity, size at birth, sex ratio, gestation period and fecundity of the mottled electric ray represented in the catches of Visakhapatnam. The study is based on 200 specimens measuring 118 – 500 mm TL that include 105 males and 95 females. The mode of reproduction in this ray is ovoviviparous. The two ovaries and the uteri are functional. Gestation period is estimated as 6-8 months approximately. Length at first sexual maturity is 325 mm TL for females and 300 mm TL for males. Embryo counts in uteri of pregnant females range from 8-16. Apparently low fecundity indicates that it is potentially vulnerable to overfishing and bycatch rates should be monitored closely.

Keywords: Length at first sexual maturity, Reproductive cycle, Sex ratio, *Torpedo sinuspersici*

Introduction

The sluggish electric rays (Elasmobranchii: Torpedinidae) represent a species complex of restricted endemics and susceptible to capture in trammel net and trawl fisheries where they are discarded as bycatch. Electric rays, thought to be the most primitive of the skates and rays, have stout tails but have rather expansive disc. This group is distinguished by the presence of powerful electric organs, derived from branchial muscles in head region. In species with strong electric organ discharge (*Torpedo* spp.), shock is produced to immobilise and capture the prey (Belbenoit, 1979; Bray and Hixon, 1986). According to Sujatha (2002), three species of genus *Torpedo* have been recorded from Visakhapatnam, on the east coast of India *viz.,* black spotted torpedo *T. fuscomaculata* Peters, 1855*;* leopard torpedo *T. panther* Olfers, 1831 and mottled electric ray *T. sinuspersici* Olfers, 1831. Among these, *T. sinuspersici* is the most commonly represented species throughout the year in the catches when compared to other species. The distinguishing characters of this species are stout length, approximately equal to the length of eyes, first dorsal extends beyond pelvic fin, chocolate brown or rusty brown with light or white coloured vermiculated spots on dorsal side (Fig. 1).



(a) Dorsal View (a) Ventral View (b) Dorsal View (b) Ventral View

Fig. 1. *Torpedo sinuspersici* (a) female 343 mmTL. (b) male 301 mm TL

Species of the genus *Torpedo* are not targeted commercially but are represented albeit in small numbers regularly as bycatch in commercial bottom trawl fisheries and shore seine catches. This species is assessed as Data Deficient (IUCN 2010) due to lack of information on distribution and biology. and this may be attributed to uncertainty over systematics. In IUCN Red list of threatened species version 2011.2 various life history parameters, like age at maturity, length at maturity, longevity, size at birth, average reproductive age, gestation time, reproductive periodicity, annual rate of population increase and natural mortality, are mentioned as unknown. Only average annual fecundity or litter size is given as 9 to 22 young ones per litter (Campagno *et al.,* 1989). Hence, the present study aims at studying several aspects of reproductive biology such as length at first sexual maturity, size at birth, sex-ratio, gestation period and fecundity of the mottled electric ray represented in the catches of Visakhapatnam.

Materials and methods

Random samples were collected from Visakhapatnam Fisheries Harbour and other local landing centres like Lawson's Bay, Bheemunipatnam (lat $17^0$01´N to $19^0$22´N; long $83^0$23´E to $85^0$14´E) during the period from June 2010 to May 2012. A total of 200 specimens measuring 118 – 500 mm TL were observed, and this includes 105 males (length range 124 – 446 mm TL) and 95 females (length range 118 – 500 mm TL). Samples were obtained from catches of bottom trawl (with a trawl net of 20-22 mm cod end mesh dia, operating on soft bottom and also from trammel nets operated in Visakhapatnam waters.

The total length was taken from tip of snout to caudal fin end (TL) measured to the nearest millimeter and weighed to the nearest gram. Measurements also include diameter for oocytes and eggs as well as length and weight to the nearest decigram for embryos and fetuses. Developing oocytes were measured while they were still in the ovaries, whilst ripe oocytes were removed from the ovaries and undeveloped eggs, embryos and fetuses were removed from the uteri, then counted and weighed. Fetuses and also embryos were sexed whenever possible. Ovarian and uterine fecundity was defined as the number of oocytes and embryos respectively following Capapé *et al.* (2000). Maturity stages were determined by macroscopic study of reproductive organs following a scale proposed by Stehmann (2002). Three categories of female were considered:

Immature (I): juvenile having thin tubular structure and developed ovary with white ova and membranous oviduct.

Maturing (II): sub-adults with tubular structure enlarged with yolked ova in ovary and a differential genital duct.

Mature (III): adults having tubular structure distended with yolked eggs or visible embryos in uteri.

Males were assigned to three maturity stages based on testis development and clasper length in relation to pelvic fin and total length. Clasper length (CL, mm) was measured from the forward rim of the pelvic girdle to the tip of the claspers, according to Collenot (1969). Criteria for assessing reproductive status is in accordance with the work of Moreno *et al.* (2010).

Immature (I): juvenile: small claspers not reaching the posterior border of the pelvic fins, flaccid rotation less than 360°, rifiodón closed and no semen, small testes, constitution water, there are no efferent ducts or seminal vesicle.

Maturing (II): subadult: claspers reach the edge of the pelvic fins, less than 360^0 rotation, closed rifiodón, absence of semen, testicular content denser, there are efferent ducts and epididymis is presented in spirals at least half of the duct.

Mature (III): adult: total of clasper calcification, rotation of 360^0, beyond the edge of fins, pelvic open, rifiodón semen, testes lobes large, efferent epididymal spiral occupies the entire duct and seminal vesicle semen.

Length at first maturity

For female, length at sexual maturity was determined from the condition of the ovaries and the morphology of the reproductive tract. The onset of sexual maturity of male when was possible was determined by the relationship between clasper length and total length. The linear regression was expressed in decimal logarithmic coordinates. Correlations were assessed by least-square regression. According to Bass *et al.* (1975) and Stevens and Lyle (1989), the claspers of juvenile males are short and flexible. Males are considered to be mature when the claspers are elongated and calcified. Length at first maturity of females and males was determined by plotting a graph of percentage of mature fish against total length. Sex ratio (male/female) was calculated for length groups, chosen according to maturity class intervals.

Results and discussion

This species is dioecious showing internal (oviduct) fertilization and are internal live bearers. As mentioned by Capapé *et al.* (2000), Capapé (2001) and Consalvo *et al.* (2007), in other species of the genus *Torpedo,* the reproductive mode of this ray is ovoviviparous (aplacental viviparity), with 9 -12 embryos in a litter feeding initially on yolk, then receiving additional nourishment from the mother by indirect absorption of uterine fluid (milk) enriched with mucus, fat or protein through specialised structures. The month of collection, details of sex and condition of the observed specimens are described in Table 1.

Table 1. Month-wise representation of specimens of *Torpdo sinuspersici* in the catches of Visakhapatnam

Months	J	F	M	A	J	J	A	S	O	N	D	Total
Female												
Juvenile	4	-	-	-	3	-	-	-	6	-	-	13
Sub-adult	2	-	-	-	10	3	2	2	10	12	11	52
Adult	1	2	3	3	-	-	-	-	-	-	19	28
Spent	-	-	-	2	-	-	-	-	-	-	-	2
Male												
Juvenile	2	-	-	-	-	-	2	4	5	9	1	23
Sub-adult	2	1	1	2	6	2	2	2	6	16	12	52
Adult	2	-	-	1	4	5	9	1	3	-	4	29

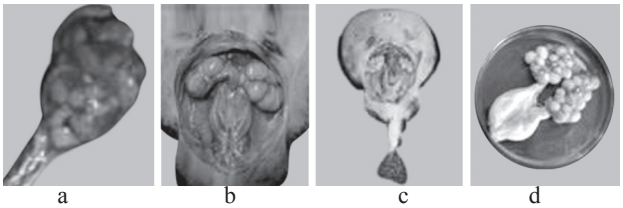
The two ovaries and the two uteri in the species are functional. The ovaries produced cohorts of oocytes similar in size and weight. One of these cohorts develop into ripe oocytes and the other degenerated. The diameter and the weight of ripe oocytes, ready to be ovulated, increase with the size of the female (Table 2; Fig. 2 b-d). However, these oocyte features reduced with increase in the number of oocytes. Same is the case with fertilized eggs found in the uteri. All the pregnant females were caught during the period October to April. Females with oocytes in the ovary and with fertilized eggs in their uteri were captured during November and December and females with fully developed fetuses were captured during March to April (Fig. 3 a, b). These observations suggest that gestation begins in October and ends in March/April. Gestation probably lasts for a minimum of 6 months to a maximum of 8 months.

Out of the 68 females, it was observed that in 56 females, the ovaries are in a resting phase during gestation period (Fig. 2 a). In contrast, 12 adult females exhibited a phase of active vitellogenesis, with developing or ripe oocytes in their ovaries, whilst their uteri are in a resting phase (Table 2). Vitellogenic activity lasted for approximately six months and the complete reproductive cycle did not exceed one year. Moreover, the females exhibit a block to oocyte growth during gestation and

Table 2. Length range, reproductive stages, condition of ovaries and uteri during gestation of female *Torpedo sinupersici*.

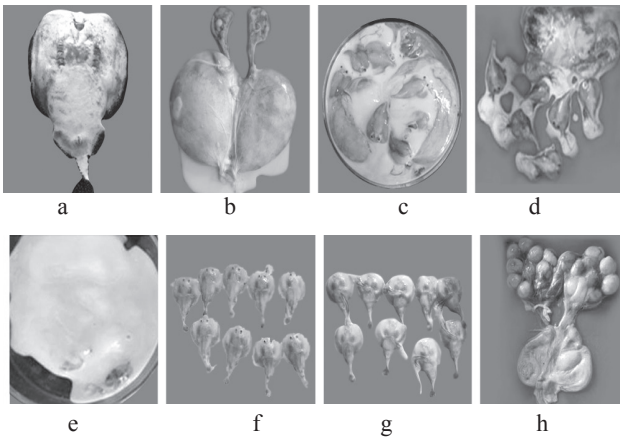
Month of capture	No. of females	Size range of females (TL, mm)	Ovarian activity	Oocyte condition	Oocyte diameter range (mm)	Uteri content	Uteri content length range (TL, mm)
June	8	360-387	Vitellogenesis	Developing	3-8	Resting	-
July	2	316,384	Vitellogenesis	Develping	7-12	Resting	-
August	2	350, 484	Vitellogenesis	Developing	13-18	Resting	-
September	2	340, 361	Vitellogenesis	Developing	18-24	Resting	-
October	6	326-428	Vitellogenesis	Ripe	25-32	Resting	-
November	10	373-433	Resting	-	-	Eggs	-
December	24	380-491	Resting	-	-	Eggs	-
January	4	378-400	Resting	-	-	Embryo	25-30 (57)
February	2	401, 416	Resting	-	-	Embryo	45-46 (28)
March	3	440	Resting	-	-	Fetuses	60-99 (44)
April	5	397-500	Resting	-	-	Fetuses	102-118 (62)

Figures in parenthesis indicate number of embryos/fetuses



a b c d

Fig. 2. Oocytes developmental stages of *Torpedo sinuspersici* (a) resting, (b) - (d) active vitellogenesis



a b c d

e f g h

Fig. 3. Uterus and uterine contents of *Torpedo Sinusperisici* : (a) gravid female, (b) uterine pouch with fetuses, (c) - (e) developing stage in uteri (uterine milk), (f) embryo dorsal view, (g) embryo ventral view; (h) spent sac and starting of vitellogenesis activity

also they lack egg capsules. According to Mellinger and Wrisez (1989) these phenomena are the rule in torpedinids. These were also observed in other elasmobranch species (Yano and Tanaka, 1988). Consequently, the duration of the reproductive cycle remains particularly long in torpedinids, whatever may be the species and Mellinger (1971) in *T. marmorata* from Bay of Biscay and Capapé (1979) in *T. torpedo* from Tunisian coast stated that the reproductive cycle lasted for two years and three years respectively.

Eggs, embryos and fetuses are not encapsulated but are free in the uteri and their numbers were slightly more in the right uteri than in the left. Embryos still had an umbilical stalk and a yolk stalk. These features are completely reabsorbed in fully developed fetuses, and a scar marked the site of the umbilical stalk. Throughout gestation, the uterine contents were protected by a jelly like structure (uterine milk) (Fig. 3 c-e). The size of fully developed fetuses ranged from 102 to 118 mm TL (Fig. 3 f, g). Reproductive cycle of female, condition of ovaries and uteri of *T. sinuspersici* during gestation is given in Table 2. Gestation period is estimated as 6-8 months approximately. During the present study, asymmetry of abdominal viscera was observed during the gestation period. This morphological character is due to the fact that the right genital tract is more developed than the left.

Fecundity

The analysis of mature females in the length range 360 – 484 mm TL in full vitellogenic activity showed 12 to 33 yellow-yolked ovarian eggs (for ovarian fecundity, oocytes diameter of above 9 mm were counted). Count of embryos in uteri of pregnant females ranged from 8 to 16. Ovarian fecundity is higher than uterine fecundity, indicating that either some ripe oocytes are not ovulated but degenerated or a bias exists due to the behavior of pregnant female, which lose their brood when they are caught. Similar condition was observed and reported by Lo Bianco (1888) in *T. marmorata* off Naples. Male embryos and fully developed fetuses are more numerous than female embryos and fetuses. This species probably breeds once in a year and fecundity appears to increase with size and age of the female. Oocytes and /or eggs, embryos and fully developed fetuses were more numerous on the right side than on the left side as in all torpedinid species studied till date (Mellinger, 1974).

According to Compagno *et al.* (1989) the average annual fecundity for *T. sinuspersici* is 9 to 22 young and in the present observation the ovarian fecundity of *T. sinuspersici* was in the range12-33 and the uterine fecundity observed was 8 to 16. Off Naples, Lo Bianco (1888) stated that common torpedos bore 3 to 6 embryos. Vitellogenesis does not proceed in parallel with gestation. Apparently low fecundity indicates that it is potentially vulnerable to overfishing and bycatch rates should be monitored closely.

Males

The CL to TL regression shows two inflexions, indicating the three growth phases of sexual development in males (Fig. 4). The first phase included 11 juveniles between 124 to 240 mm TL, the second 38 subadults between 256 to 367 mm TL and third 14 adults between 370 – 446 mm TL.

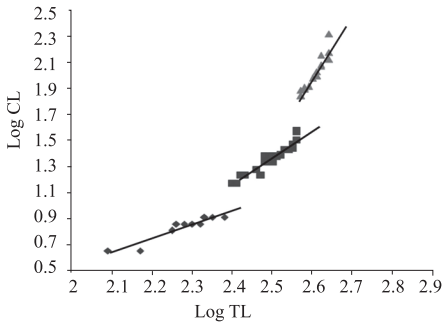


Fig. 4 Clasper length (CL) versus total length (TL) in male *Torpedo sinuspersici*

The first phase includes the juveniles and the relationship is :
Log [CL] = 1.079 log TL – 1.579; n = 11, R^2 = 0.89

The second phase concerns subadults and the relationship is :
Log [CL] = 2.000 log TL – 3.610; N = 38, R^2 = 0.914

The third phase concerns adults and the relationship is :
Log [CL] = 4.694 log TL – 10.21; N=14: R^2=0.879

According to these relations, the claspers grew faster during the second stage. Juveniles and subadults had short, uncalcified flexible claspers. Those of adults were elongated, calcified, rigid and functional (Fig. 5). The third relation shows that they grew allometrically throughout life. Male specimens measuring above 300 mm TL were all adults.

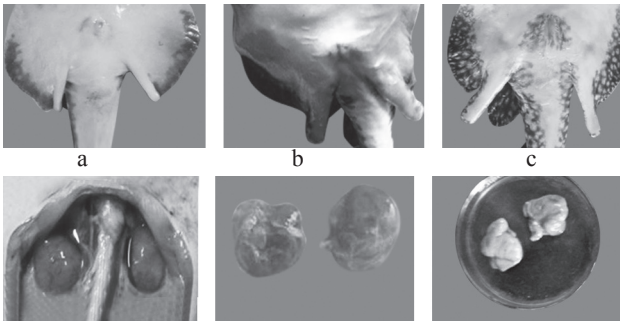


Fig. 5. Maturity stages of clasper and testes of *Torpedo sinuspersici* (a) and (a1) Immature (I) – juvenile; (b) and (b1) Maturing (II) – subadult; (c) and (c1) Mature (III) – adult

Length at first maturity

The recorded size of smallest mature female was 316 mm TL and male was 270 mm TL. The estimated length at first maturity for females was 325 mm TL and for males 300 mm TL respectively (Fig. 6). The length at first sexual maturity shows that the females were generally larger and heavier than the males.

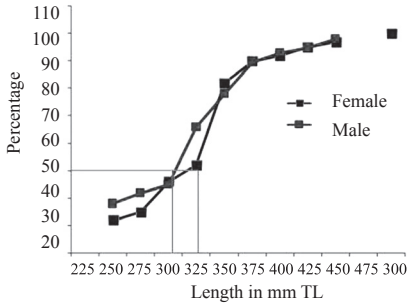


Fig. 6. Length at first matunity of *Torpedo sinuspersici*

Sex ratio

In a total sample of 200 free living specimens, the males were more abundant than the females and the pooled ratio was 1:0.9. Conversely, sex ratio was observed in the range 1:0.3 to 1: 0.8 among different size groups (Table 3), except in the size group 301 – 325 mm TL and 401 – 425 mm TL.

Size at birth

Fully mature fetuses (length range 102 – 118 mm TL) were observed in the month of April in specimens of length range 397 – 500 mm TL. Based on the above observation, the approximate size at birth may be 102 – 118 mm TL as samples could not be collected in the month of May due to trawl ban period in this region. According to Capapé *et al.* (2000) in *T. torpedo,* the birth size of young ones occurred when term pups were between 102 to 118 mm TL and weight 20.5 – 25.5 g.

The frequency distribution of sexes showed that females attained larger size than the males in the mottled electric ray. They have low fecundity, and because of their size, shape and geographic distribution young rays are liable to be caught by many fishing methods targeting other species. They may therefore require particularly careful management if they are to be protected from population collapse or conversely they may provide a sensitive indicator that an area is being heavily fished.

Table 3. Sex ratio at different length groups of *Torpedo sinuspersici* represented in the catches of Visakhapatnam

Length range (mm TL)	♂	♀	Sex ratio
100-125	1	1	1:1
126-150	1	1	1:1
151-175	1	-	1:0
176-200	1	1	1:1
201-225	3	1	1:0.3
226-250	4	2	1:0.5
251-275	15	13	1:0.8
276-300	8	7	1:0.8
301-325	4	14	1:3.5
326-350	17	14	1:0.8
351-375	14	10	1:0.7
376-400	19	12	1:0.6
401-425	6	9	1:1.5
426-450	11	8	1:0.7
476-500	-	2	0:2

Acknowledgements

The authors are thankful to the Head, Department of Marine Living Resources, Andhra University for providing facilities to carry out the research work.

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Date of Receipt : 03.11.2013
Date of Acceptance : 25.11.2013