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Length-weight relationship, growth and reproductive biology of *Narke impennis* (Annandale, 1909) (Pisces: Narkidae) of Visakhapatnam coast, Western Bay of Bengal, India

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Original Article

Abstract

A total of 250 spottail sleeper ray, *Narke impennis* caught from Visakhapatnam waters were analysed with respect to length frequency distribution, length -weight relationship, growth studies, length-at-first maturity, size-at- birth, sex ratio, gestation period and fecundity. Specimens ranging from 53 to 206 mm TL (132.833±0.132) including 137 males and 113 females, were collected from shrimp trawl and trammel net catches during June, 2015 to April, 2017. The length-weight relationship for females, males and combined sex was estimated as $b < 3$, the growth is considered to be negative allometric. The asymptotic length (L_∞) and VBGF growth constant (K) for spottail sleeper ray were estimated as 215.25 mm and 0.350 yr^{-1} respectively. Average condition factor was estimated as 2.514 for males, 2.449 for females, and 2.465 for combined sex. Length- at-first maturity for females was estimated as 120 mm TL and 115 mm TL for males and the size-at- birth was estimated to range between 42 to 46 mm TL. Mature females in full vitellogenic activity showed 2 to 8 yellow-yolked ovarian eggs. Number of embryos ranged from one to six. Overall sex ratio favoured males at the rate of 1:0.8. This study presents the first detailed biological observation and growth studies of the spottail sleeper ray in Indian waters.

Keywords: *Spottail sleeper ray, growth studies, length-weight relationship, reproductive biology*

Introduction

The sleeper rays are poorly known, slow-swimming, bottom-dwellers which constitute minor by-catch of trawl fisheries, but are not utilised as food. They are capable of delivering a moderate to strong defensive shock when handled (Compagno and Last (1999) and Last *et al*., 2016). The spottail sleeper ray, *Narke impennis* (Annandale, 1909) is a small ray represented in bottom trawl catches and caught along with deep water species such as upenoids, priacanthids at depth range of 40-90 meters. The scanty record of this species is attributed to the habitats that are not easily reached by conventional methods of catching demersal fish. Two species of sleeper rays, *N. dipterygia* and *N. impennis* are available in this region, latter being more common in artisanal and shrimp trawl by-catches of Visakhapatnam, has no commercial importance. *N. impennis* differs from its closely related congener *N. dipterygia* in various characters such as possessing a thick and fleshy oval disc, which might be a result of adaptation to its presumable habits of wriggling and squirming at the bottom, fins greatly reduced, small tubular mouth, eyes small and deeply sunk and disc brown above with diffuse blackish clouding medially.

Narke impennis and *N. dipterygia* are often misidentified in the catches due to several overlapping characters. *N. dipterygia* is

assessed as "Data Deficient" by IUCN Red list of threatened species version 2018-1 as little is known of its biology and insufficient information exists on its occurrence, population trends, capture in fisheries and conservation measures (Ishihara and Wang, 2009). This assessment is applicable to *N. impennis* also. In the light of published literature, there is no information on life history parameters such as length frequency distribution, length-weight relationship (LWR), 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 in this species. Previous studies reveal that sleeper rays have a low resilience and minimum population doubling time of 4 to 14 years (Froese and Pauly, 2018). Low fecundity combined with its typical life history traits make it vulnerable to overfishing, indicating that by-catch rates should be monitored and regulated. Hence, the present study aims at studying length frequency distribution, LWR, condition factor and reproductive biology that include description of male and female maturity stages, fecundity, gestation period, length- at- first maturity, sex ratio and size-at-birth.

Material and methods

A total of 250 *N. impennis* were collected from the by-catch landings of shrimp trawlers landed at Visakhapatnam fisheries harbor (Lat: 17°01′ N to 19°22′ N; Long: 83°23′ E to 85°14′E) and trammel net operated in the western Bay of Bengal during June, 2015 to April, 2017 and along Andhra Pradesh coast. Biweekly random samples collected from small trawlers (LOA 10 + m) the range of which does not exceed about 50 m, operate bottom trawl with mesh size ranging from 4.7 to 5.1 cm at the mouth and 1.3 to 1.8 cm at cod end. The total length (TL) of each individual was measured to the nearest mm, total body weight (TW) to the nearest g and their sex also were recorded.

The length for each sex were tested and data confirmed to a normal distribution using Shapiro-Wilk test (Shapiro and Wilk, 1965; Purushottama *et al.*, 2017). As the data followed normal distribution, size differences between females and males were tested using a two tailed *t*-test. To ascertain any sex- based differences in landings, size-frequency distributions of males and females were compared using χ^2 test with the size distribution divided into 10 mm size class intervals to the TL (Cochran, 1952).

LWR was calculated by least square method from logarithmically transformed data, employing the equation of Le Cren (1951) and Froese (2006) and the association degree between length-weight variable was calculated (r^2). The relationship between the length and weight of a fish is usually expressed by the equation, $W = aL^b$; Where, W = body weight (g); L = total length (mm); '*a*' is a coefficient related to body form and '*b*' is an exponent indicating isometric growth when equal to 3. Fulton's condition factor (K) was calculated according to Htun-Han (1978) equation as per formula $K = 100\ W/L^3$; Where, W= weight of fish (g), L= Length of fish (cm).

The growth parameters L_∞ (asymptotic length) and K (growth rate) were assumed to follow Von Bertalanffy Growth Function (VBGF). These were estimated by using ELEFAN I and Powell-Wetherall method. The mortality parameter, total instantaneous mortality rate (Z) was estimated using length converted catch curve. Natural mortality rate (M) was estimated using Pauly's M equation, using a mean surface temperature (T) of 28°C. The relative yield per recruit (Y'/R) was estimated following the knife-edge selection fitted in the FISAT II tool (Gayanilo *et al.*, 2005) where E_{max} depicts the exploitation rate producing maximum yield, $E_{0.1}$ indicates the exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock with $E_{0.5}$ indicating exploitation rate under which the stock is reduced to half of its virgin biomass.

Measurements also include diameter for oocytes and eggs, length in mm and weight to the nearest gram for embryos and fetuses. Developing oocytes were measured while they were still in the ovaries, whilst ripe oocytes were removed from the ovaries. Undeveloped eggs, embryos and fetuses were removed from the uteri, then counted and weighed. Fetuses as well as embryos were sexed whenever possible. Description of embryos and fetuses was also given. Ovarian and uterine fecundity was defined as the number of oocytes and embryos respectively following Capape *et al.* (2002).

For males and females, maturity stages were determined by macroscopic study of reproductive organs. Based on morphological and macroscopic observations, females were categorized into three maturity stages following Stehmann (2002) as given below.

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

Stage II: Maturing: sub-adult with tubular structure enlarged with yolked ova in ovary and a differential genital duct.

Stage III: Mature: adult having tubular structure distended with yolked eggs or visible embryos/fetuses in uteri.

Resting stage: During ovarian resting stage, the ova in the ovaries do not show active vitellogenesis whereas in uterine resting stage, no fertilized eggs or embryos and fetuses were found in the uterus.

Males were assigned to three maturity stages based on testicular development and clasper length in relation to pelvic fin and

total length. Criteria for assessing reproductive status is in accordance with Moreno *et al.* (2010).

Stage I: Immature: juvenile having 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.

Stage II: Maturing: sub-adult having claspers reaching the edge of the pelvic fins, less than 360° rotation, rifiodón closed and no semen, testicular content denser, efferent ducts present and epididymis wavy in appearance, occupies at least half of the duct.

Stage III: Mature: adult having claspers that are completely calcified, rotation of 360°, claspers extend beyond the edge of pelvic fins, rifiodón open with semen, testes lobes large, efferent ducts and epididymis appear wavy, occupies the entire duct and seminal vesicle with semen.

Paired claspers are present in males as specialized elongations on the posterior side of pelvic fins which act as intromittent organs for sperm transfer during copulation (O'Shaughnessy *et al.*, 2015). Clasper length (CL, mm) was measured from the forward rim of the pelvic girdle to the tip of the claspers (Collenot, 1969).

For female, length-at-maturity was determined from the condition of ovaries and morphology of the reproductive tract. The onset of sexual maturity of male 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 Stevens and Lyle (1989), the claspers of juvenile males are short and flexible whereas males are considered to be mature when the claspers are elongated and calcified. Length- at- 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. To test sex ratios being at parity and the distribution of females and males chi-square test was employed. The approximate size- at- birth was estimated based on the occurrence of fully developed fetuses in the uterus of mature females which are about to be released and also occurrence of young ones in the catches.

Results and discussion

Stock structure

The present study is based on 250 specimens of *Narke impennis* ranging in size from 53 to 206 mm TL (132.833±0.132) and total weight varying from 3.5 to 201 gm (62.57±0.153). This includes 137 males [length range 53-194 mm TL (134.5±0.240), weight 3.5-176 gm (63.276±0.254)] and 113 females [(length range 61-206 mm TL (130.823±0.296), weight 10-201 gm (61.717±0.376)]. The weight of mature females include the weight of developing pups.

Length-frequency distribution

The spottail sleeper ray (Fig. 1, 2) is represented in the trawl catches throughout the year except in the months of February, May and October. Pooled length frequency histogram of *Narke impennis* during the period June, 2015 to April, 2017 shows females of length groups 115-125 mm TL and males of length group 125-135 mm TL are dominant in catches. The common size in the catches range from 112 to 140 mm TL (Fig. 3). Chi-square

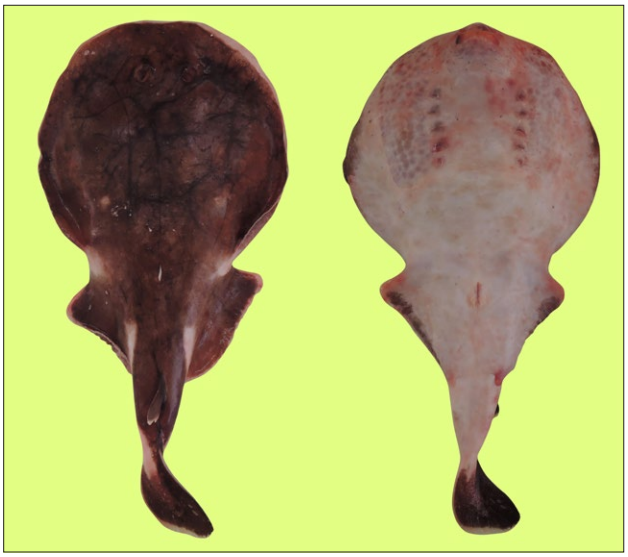


Fig 1. *Narke impennis* – Female (182 mm TL) a. Dorsal view, b. Ventral view

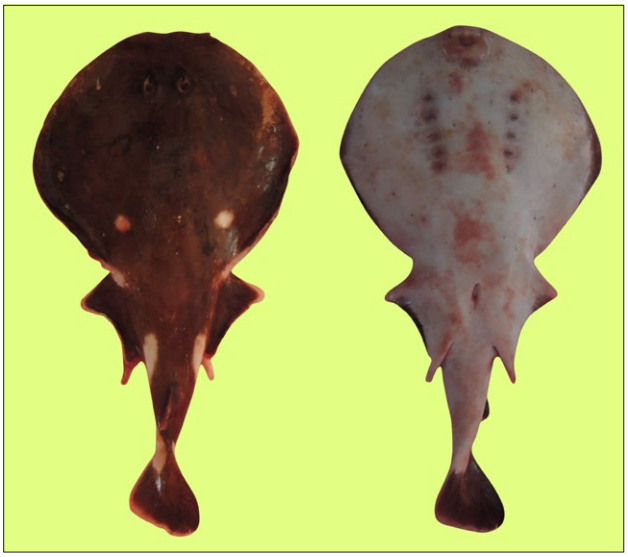


Fig. 2. *Narke impennis* – Male (194 mm TL) a. Dorsal view; b. Ventral view

test revealed that there is no significant difference ($p<0.001$) in length frequency distributions between females and males, however more males in 125-206 mm TL and females in 61-125 mm TL represented in length groups captured.

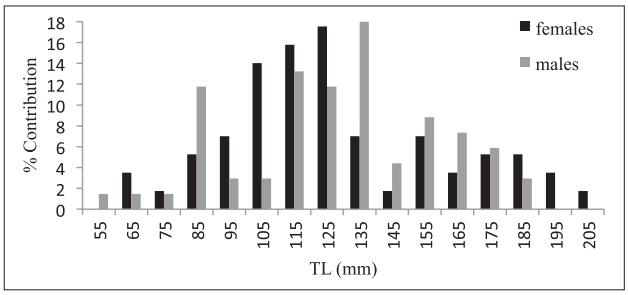


Fig. 3. Pooled length frequency histogram of *Narke impennis* from June, 2015 to April, 2017

According to Annandale (1909) the species grows to 175 mm TL and the present study records the largest size of 206 mm TL for female and 194 mm TL for male.

Length-weight relationship (LWR)

The LWR for females, males and pooled samples given in Table 1. As the estimated b value for females, males as well as pooled samples is less than 3 the growth is considered to be allometric negative for this species. LWR in least square line regression ($y= 2.470x - 3.494$) provides a good fit to length and weight data with regression coefficient value ($r^2= 0.953$) for females, $y= 2.549x - 3.673$ and $r^2= 0.963$ for males and $y= 2.528x - 3.62$ and $r^2= 0.951$ for pooled samples. LWR for females, males and combined sex given in Fig. 4a, 4b and 4c.

Condition factor (K)

The condition factor of a fish reflects physical and biological circumstances and fluctuations by interaction among feeding conditions, parasitic infections and physiological factors (Le Cren, 1951). Average condition factor was estimated as 2.449 for females, 2.514 for males and 2.465 for combined sex. The lowest condition factor value was found to be 1.836 in March and the highest value was 3.053 in November (Fig. 5). Condition factor of greater than one indicates the well being of fishes suggesting that the species under study were in good condition.

Table 1. Length-weight relationship of *Narke impennis* off Visakhapatnam

	Length range (mm)	Weight range (gm)		LWR parameters	r^2
		a	b		
Females	61-206	10-201	0.00032	2.470	0.953
Males	53-194	3.5-176	0.00021	2.549	0.963
Combined sex	53-206	3.5-201	0.00024	2.528	0.951

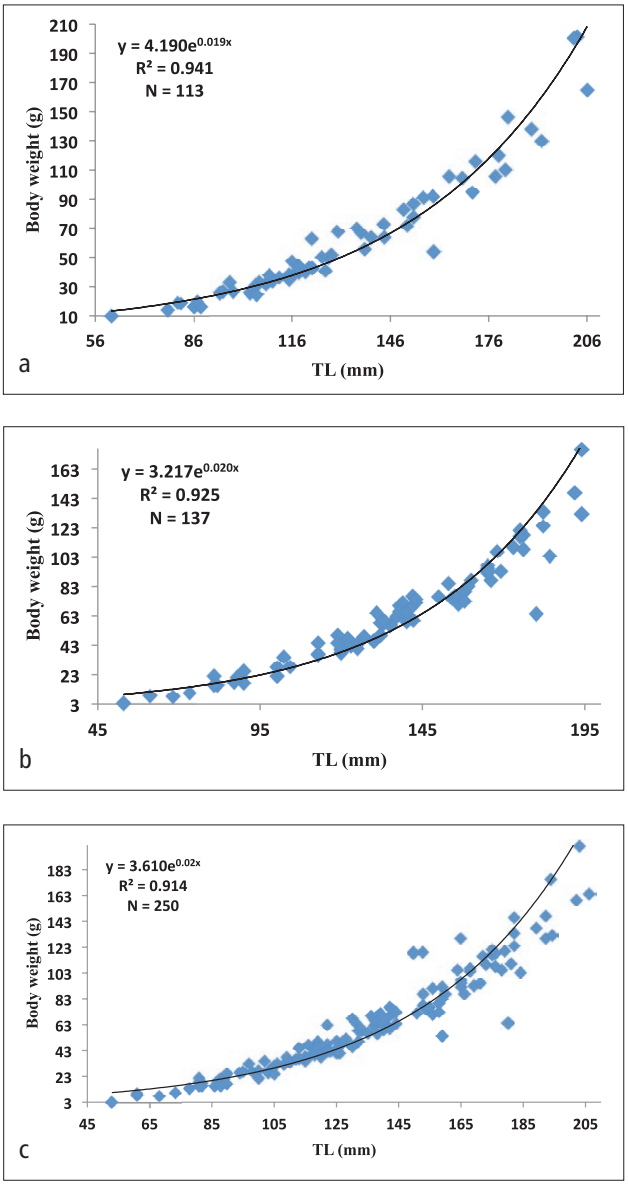


Fig. 4. The length-weight (c) relationship (LWR) of *Narke impennis* for (a) female, (b) male and (c) combined sex

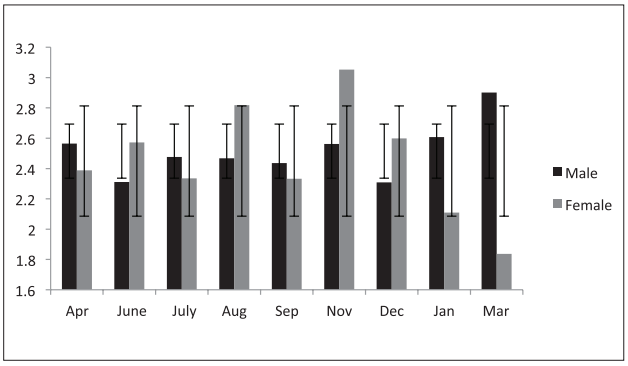


Fig. 5. Monthly mean condition factor of *Narke impennis* during the period June, 2015to April, 2017.

Growth parameters

The asymptotic length (L_∞) and VBGF growth constant (K) for spottail sleeper ray were estimated as 215.25 mm and 0.350 yr^{-1} respectively.

Mortality coefficients and current exploitation rate

The calculated mortalities from FISAT II output of the length converted catch curve (Fig. 6) reveals the instantaneous total mortality coefficient (Z) as 0.9 $year^{-1}$. The natural mortality (M) and fishing mortality (F) were estimated as 0.52 $year^{-1}$ and 0.38 $year^{-1}$ respectively. The current exploitation rate was estimated as E = 0.42.

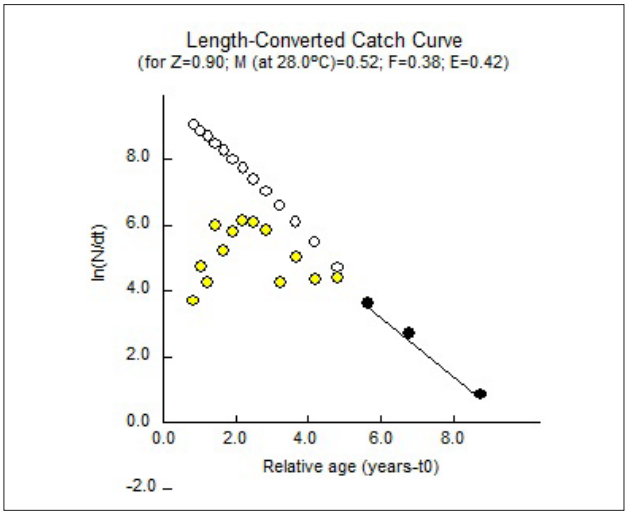


Fig. 6. Length-Converted Catch Curve of *Narke impennis*

Relative yield per recruit (Y'/R)

The Beverton and Holt relative yield per recruit model (Fig. 7) showed the indices for sustainable yield as 0.278 for optimum sustainable yield ($E_{0.5}$), 0.421 for maximum sustainable yield (E_{max}) and 0.355 for the economic yield target ($E_{0.1}$). This value however does not represent targeted sample.

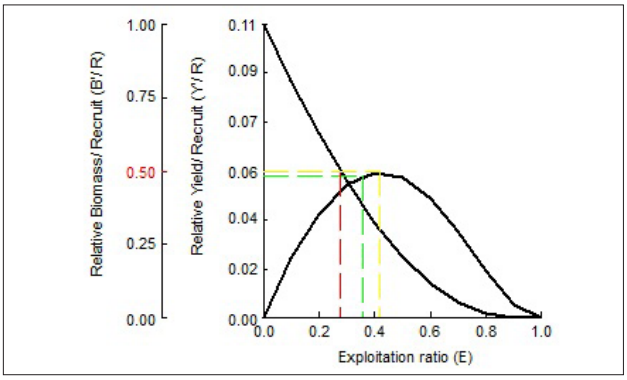


Fig. 7. Stock status of *Narke impennis* using Beverton and Holt's relative Y'/R analysis from Visakhapatnam coast

Reproductive biology

This species is dioecious showing internal (oviduct) fertilization and are internal live bearers. Mode of reproduction is ovoviviparous and the two ovaries and uteri are functional. Ovarian fecundity higher than uterine fecundity. The month of collection, details of sex and maturity condition of the observed specimens are given in Table 2.

Description of female gonads

The two ovaries and the two uteri in the species are functional. The ovaries produced cohorts of oocytes similar in size and weight which develop into ripe oocytes. The diameter and weight of ripe oocytes, ready to be ovulated, increase with size of the female (Table 3; Fig. 8 d-g). However, these oocyte features reduced with increase in the number of oocytes. Same is the case with fertilized eggs found in the uteri.

The observed juveniles ranged from 61 to 110 mm TL and weighed between 10.0 and 38.0 gm, had small, undeveloped ovaries, no oocytes differentiated or all uniformly small. Oviducts (uteri) narrow, thread-like and membranous. Of the 35 juvenile females captured, 12 were sampled in April (Fig. 8 a-c, Table 2).

Table 2. Month-wise representation of juvenile, sub-adult and adult specimens of *Narke impennis* in the catches off Visakhapatnam during June, 2015 to April, 2017

Months	Jan	Mar	Apr	Jun	Jul	Aug	Sep	Nov	Dec	Total
Female										
Juvenile	2	-	-	2	2	12	6	3	8	35
Sub-adult	-	-	2	6	-	3	3	-	3	17
Adult	5	2	3	5	10	6	20	5	5	61
Male										
Juvenile	2	5	-	3	3	2	6	-	2	23
Sub-adult	-	-	2	9	2	10	5	3	3	34
Adult	2	8	-	10	22	8	12	8	10	80

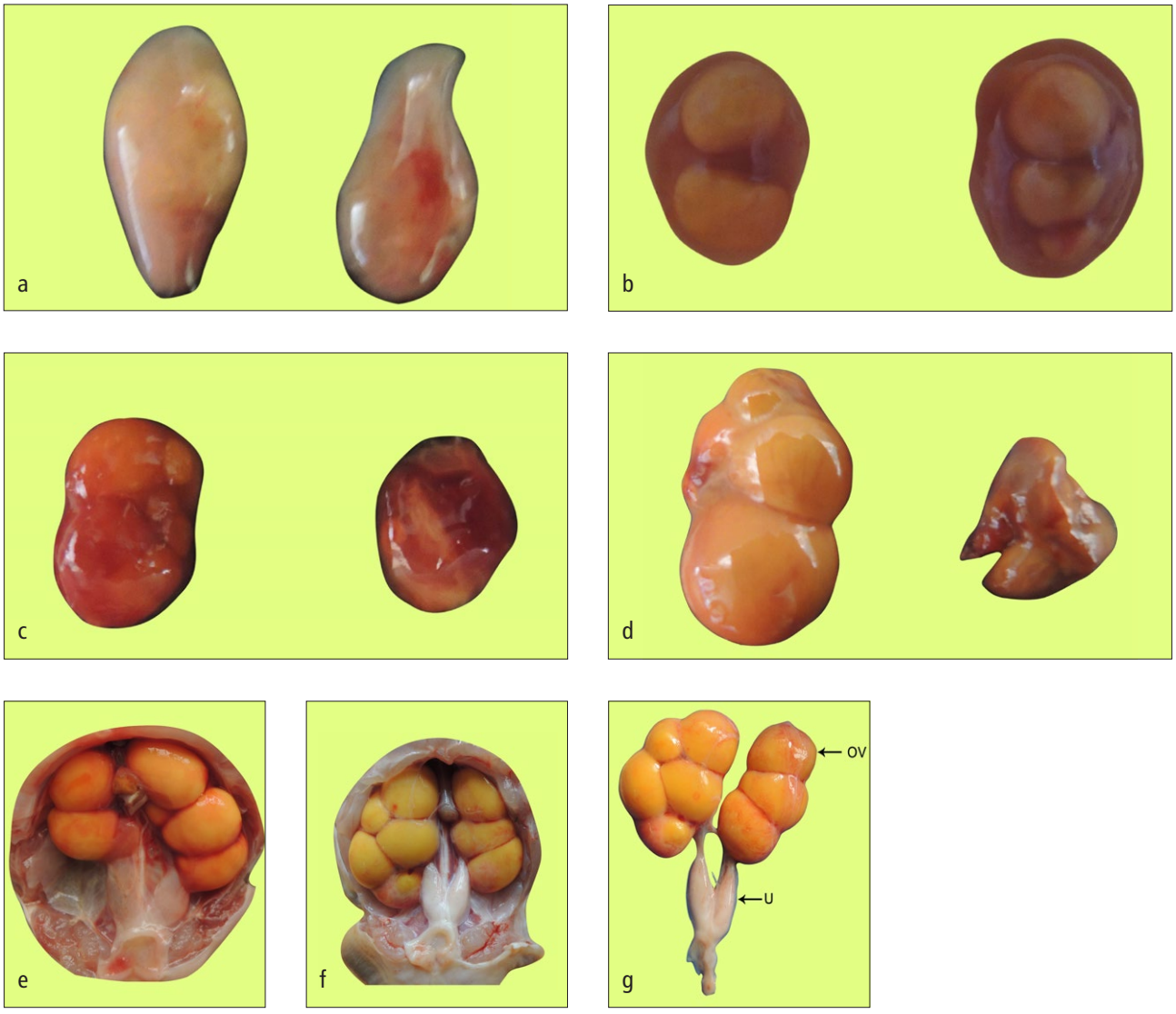


Fig. 8. Oocytes developmental stages of *Narke impennis* (a) – (c) resting (4-6 mm); (d) – (g) active vitellogenesis (9-14 mm)

The observed sub-adults ranged from 112 to 120 mm TL and weighed between 35.0 and 48.0 g, exhibited two functional ovaries containing yellow-yolked oocytes of various sizes, which differentiate and develop into cohorts of oocytes similar in size and a differential genital duct. Uteri largely as stage I but may widen posteriorly. Of the 17 sub-adult females captured, 6 were sampled in June. Females with only ripe oocytes in the ovaries were captured in September.

The observed adults ranged from 121 to 206 mm TL and weighed between 41.0 and 201 g, exhibited large ovaries containing enlarged yolky oocytes, some being very large and fully developed genital duct. Uteri enlarged showing widening along the entire length and with fertilized eggs or visible embryos/fetuses. All pregnant females were caught during November to January. Females with oocytes in the ovary and fertilized eggs in their uteri were captured in November (Fig. 9 a) and females with fully developed fetuses were captured in January (Fig. 9 g).

Resting stage mature females with spent uteri and small-sized oocytes in their ovaries indicating the onset of vitellogenesis were captured in the months of March and April. Out of the 54 females of length range 103-200 mm TL, it was observed that in 17 females, the ovaries are in a resting phase and the uterus had fertilized eggs, embryos and fetuses. In contrast, 37 adult females exhibited a phase of active vitellogenesis, with developing or ripe oocytes in their ovaries, whilst their uteri are in resting phase (Table 3). Vitellogenic activity lasted for approximately six months.

During gestation period, eggs, embryos and fetuses are not

Fig. 9. Uterus and uterine contents of *Narke impennis* (a). uterine pouch with fertilized eggs (25 mm); (b)– (d) developing stage in uteri (33-35 mm); (e) embryo dorsal view (31-35 mm TL) (f) embryo ventral view; (g) gravid female (200 mm TL) with fully developed fetuses (h) fetus dorsal view (42-46 mm TL); (i) fetus ventral view Abbreviations: OV. ovary, U. uterus, YS. yolk sac

encapsulated but are free in the uteri and their numbers were slightly greater in the right uteri than in the left. Gestation period estimated as 7 months approximately. Gestation probably lasts for a minimum of 6 months to a maximum of 7 months. Uterine gestation starts with the release of eggs in the uterus after fertilization till the end of release of fetuses. The interior wall of the uterus is provided with numerous fiber-like outgrowths. Throughout gestation, the uterine contents were protected by a jelly-like structure (uterine milk) (Fig. 9 b-d). Embryos still had an umbilical stalk and a yolk sac (Fig. 9 e, f). These features are completely reabsorbed in fully developed fetuses, and a scar marked the site of the umbilical stalk. The size of fully developed fetuses ranged from 42 to 46 mm TL (Fig. 9 h, i). The samples between the lengths 46-61 mm TL could not be collected indicating that the mature females might release their fetuses in the months of May and June. Reproductive cycle of female, condition of ovaries and uteri of *N. impennis* during gestation is given in Table 3. Present observations suggest that gestation begins in September and ends in March/April. 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 of 118-192 mm TL in full vitellogenic activity showed 2 to 8 yellow-yolked ovarian eggs (for ovarian fecundity, oocytes of diameter above 2 mm were counted). Count of embryos/fetuses in uteri of

Table 3. Length range, reproductive stages, condition of ovaries and uteri during gestation of female *Narke impennis*

Month of capture	No. of females	Size range of females (TL, mm)	Ovarian activity	Oocyte condition	Oocyte diameter range (mm)	Condition of uteri content	Embryos and fetuses length range (TL, mm)
June	2	119, 127	Vitellogenesis	Developing	2-5	Resting	-
July	10	122-171	Vitellogenesis	Developing	3-7	Resting	-
August	8	103-144	Vitellogenesis	Developing	3-10	Resting	-
September	12	106-179	Vitellogenesis	Ripe	9-14	Resting	-
November	7	118-139	Resting	-	-	Eggs	-
December	7	121-168	Resting	-	-	Embryos	31-35 (7)
January	3	150-200	Resting	-	-	Fetuses	42-46 (20)
March	2	186, 192	Vitellogenesis	Developing	3-5	Resting	-
April	3	120-128	Vitellogenesis	Developing	2-6	Resting	-

Figures in parenthesis indicate number of embryos/fetuses

pregnant females ranged from 1 to 6. Embryos and fetuses ranged in size from 31 to 35 mm TL and 42 to 46 mm TL respectively. 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 behaviour of pregnant female, which lose their brood when they are caught. Similar condition was observed and reported by Lo Bianco (1888) in *Torpedo marmorata* off Naples. Male embryos and fetuses are more numerous than female embryos and fetuses. This species 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 (El Kamel-Moutalibi *et al.*, 2013).

Description of embryos and fetuses

Disc round, eyes well developed, black in colour, oval shaped and larger than spiracles. Dorsal surface is pinkish in embryos and chocolate brown in fully developed fetuses as in adult whereas ventral surface is rose pink in colour. Mouth, nostrils and electric organs are poorly developed but kidney shaped outline is visible in both embryos and fetuses. Embryos show fiber-like outgrowths on the body and yolk stalk attachment with a large yolk sac present outside whereas in fully developed fetuses, the yolk sac may be completely reabsorbed into the body or a small portion is left outside, leaving a scar on the body showing the point of attachment of the yolk sac.

A single male specimen of 43 mm TL was collected in March 2016 which might be a fully developed fetus lost by its mother. This may be because mature females are known to undergo abortion under stress (Rolim *et al.*, 2016). Therefore, this specimen has not been included in the present study.

Males

The observed juveniles ranged from 43 to 100 mm TL and weighed between 3.5 and 28.0 gm, had short and flexible claspers. Testes and genital ducts were small, inconspicuously developed and thread-like. Of the 23 juvenile males captured, 6 were sampled in September.

The observed sub-adults ranged from 102 to 131 mm TL and weighed between 29.0 and 65.0 gm, had claspers reaching the edge of the pelvic fins. The testes were larger, developed and the genital duct appeared wavy. Of the 34 sub-adult males captured, 10 were sampled in August.

The observed adults ranged from 132 to 194 mm TL and weighed between 50.0 and 176.0 gm, had elongated, calcified and rigid claspers, extending beyond the edge of pelvic fins. Testes were well-developed, the genital duct was wavy with semen in the seminal vesicles. Of the 80 adult males captured, 22 were sampled in July.

The CL to TL regression shows two inflexions, indicating the three growth phases of sexual development in males (Fig. 10).The first phase included juveniles, the second sub-adults and third adults.

The first phase includes the juveniles and the relationship is:

$\text{Log [CL]} = 0.722 \log \text{TL} - 0.527$; N=14, $r^2=0.847$

The second phase concerns sub-adults and the relationship is:

$\text{Log [CL]} = 0.821 \log \text{TL} - 0.742$; N=20, $r^2=0.607$

The third phase concerns adults and the relationship is:

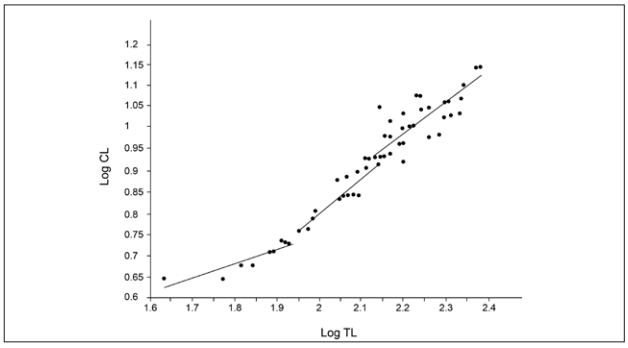


Fig. 10. Clasper length (CL) versus total length (TL) in male *Narke impennis*

Log [CL] = 0.958 log TL – 1.035; N=48, r^2=0.735

According to these relations, the claspers grew faster during the second stage (Fig. 11). The three relations show that they grew allometrically throughout life. Male specimens measuring above 130 mm TL were all adults.

Length- at- maturity

The recorded size of smallest mature female was 112 mm TL and male was 104 mm TL. Length- at- maturity for females was estimated as 120 mm TL and 115 mm TL for males (Fig. 12a, b). It was inferred from the graph that females attained maturity in larger size than the males.

Sex ratio

In a total sample of 250 free living specimens, males were more abundant than females and the pooled ratio was 1:0.8. Conversely, sex ratio was observed in the range 1:0.4 to 1:0.8 among different size groups, except in the length range 101-120 mm TL where it was found to be 1:1.9 (Table 4). The distribution of the number of females and males differed significantly among the three stages *viz.,* immature, maturing and mature specimens (χ^2, d. f. = 6, $p<0.001$). The sex ratio of male to female in juveniles (61-110 mm TL), sub-adults (102-131 mm TL) and adults (121-206 mm TL) were 1:1.15, 1:0.5 and 1:0.7 respectively.

Size-at-birth

Fully developed fetuses (length range 42-46 mm TL) were observed in the month of January in specimens of length range 150-200 mm TL. Based on the above observation, the approximate size-at- birth may be 42-46 mm TL as samples could not be collected in the month of May due to trawl ban period in this region.

Present study shows that females attained maturity in larger size

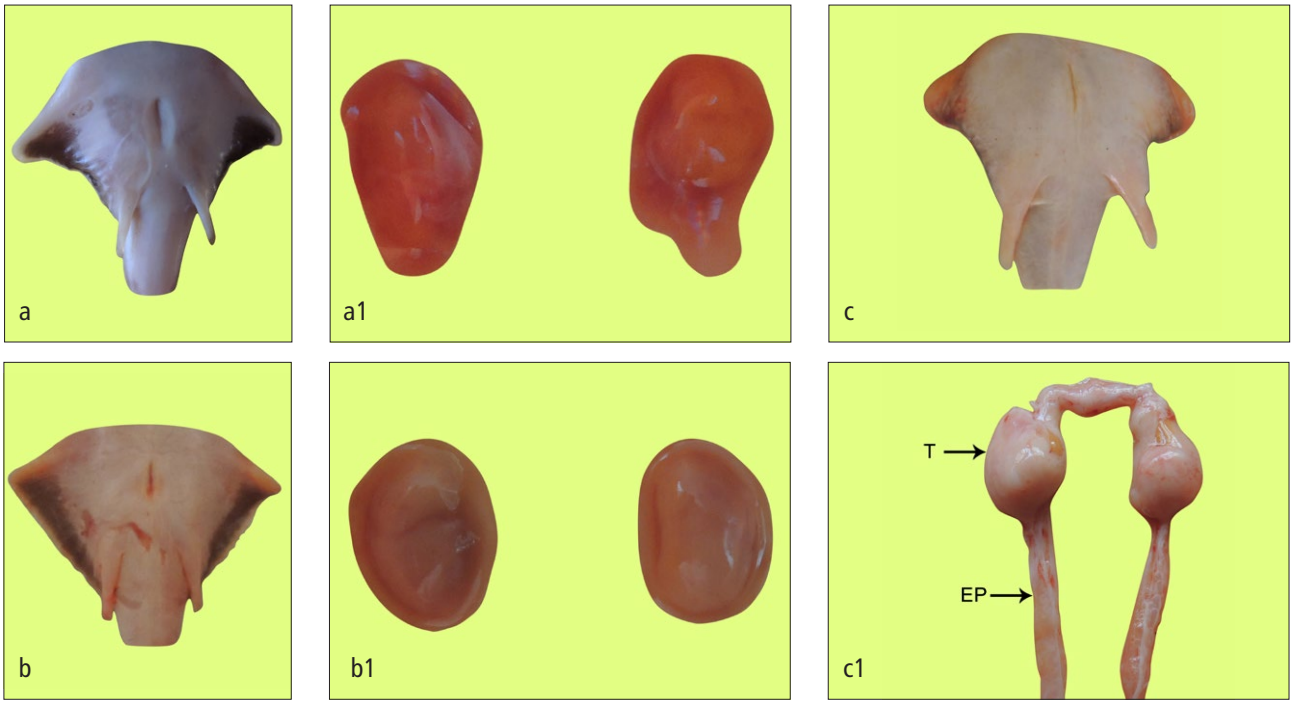
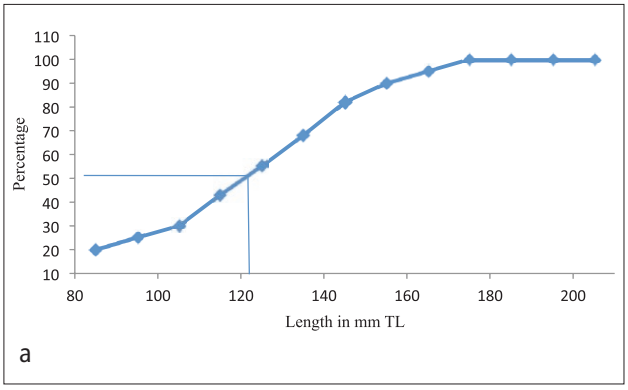


Fig. 11. Maturity stages of clasper and testes of *Narke impennis* (a) and (a1) Immature (I) – juvenile (88 mm TL), (b) and (b1) Maturing (II) – sub-adult (152 mm TL), (c) and (c1) Mature (III) – adult (173 mm TL)

Abbreviations: T. testis, EP. epididymis, VD. vas deferens, SV. seminal vesicle



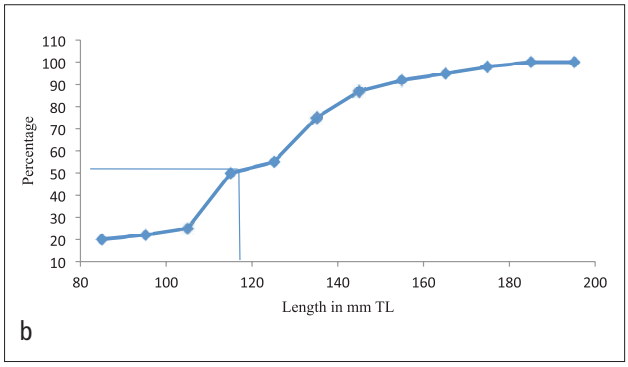


Fig. 12. Length- at- maturity of *Narke impennis* – (a) females (b) males

Table 4. Sex ratio at different length groups of *Narke impennis* represented in the catches of Visakhapatnam

Length range (mm TL)	♂	♀	Sex ratio
40-60	2	0	1:0
61-80	5	3	1:0.6
81-100	17	15	1:0.8
101-120	17	33	1:1.9
121-140	42	23	1:0.5
141-160	23	17	1:0.7
161-180	21	10	1:0.4
181-200	10	7	1:0.7
201-220	0	5	0:5

than the males in the sleeper ray. The frequently observed larger size in female elasmobranchs facilitates the accommodation and nourishment of embryos (Hamlett, 2005). The females exhibit a block to oocyte growth during gestation and also they lack egg capsules as described by Shrikanya and Sujatha (2014) in torpedinids. These were also observed in other elasmobranch species (Yano and Tanaka, 1988).

The embryos in a litter are found to feed initially on yolk, then receiving additional nourishment from the mother by indirect absorption of uterine fluid (milk) enriched with mucus, fat or protein through specialized structures as described by Consalvo *et al.* (2007) in species of the genus *Torpedo*. According to Yamada *et al.* (2007) females of *N. dipterygia* give birth to litters of 4-6 pups, measuring ~10 cm TL and in the present study the ovarian fecundity of *N. impennis* was in the range 2-8 and the uterine fecundity observed was 1 to 6. Vitellogenesis does not proceed in parallel with gestation. Apparently low fecundity indicates that this species is potentially vulnerable to overfishing and by-catch rates should be monitored closely.

Chondrichthyan research is limited in India despite its rich diversity, long history and huge fishery (Akhilesh *et al.*, 2014). Previous studies reveal that *Narke impennis* is endemic to Indian waters and research on biology of this species has not been carried out till date. The present study thus helps in generating detailed data on various aspects of biology of *Narke impennis* off Visakhapatnam. This species is taken as by-catch in bottom trawl and gillnet fisheries where they may be discarded at sea or on the dock side and so, they may therefore require particularly careful management if they are to be protected from population collapse. As stated by Yamada *et al.* (2007) this species can also be used for the scientific study of the electric organ.

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