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Reproductive biology and diet of the grey sharpnose shark *Rhizoprionodon oligolinx* Springer, 1964 (Chondrichthyes: Carcharhinidae) from the north-eastern Arabian Sea

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ABSTRACT

Information on reproductive biology is presented for the grey sharpnose shark *Rhizoprionodon oligolinx* Springer, 1964 (Chondrichthyes: Carcharhiniformes), collected off the north-west coast of India in the Arabian Sea. A total of 711 individuals, of 27.0 to 93.0 cm total length (TL), 180 to 2600 g total weight (TW) were used for the study. The length-weight relationships were significantly different between the sexes. The size-at-maturity (Lm_{50}) for females and males was estimated to be 62.3 and 59.5 cm TL respectively. Number of embryos ranged from 1 to 7 and the size at birth was estimated between 25 to 30 cm TL. Overall sex ratio favoured the females slightly at the rate of 1.27:1. There was significant positive correlation between maternal TL and number of embryos ($p<0.001$). Dietary analysis of stomach contents (%IRI) revealed that *R. oligolinx* feeds primarily on teleosts (95.5%), cephalopods (3.2%) and crustaceans (1.2%). This study presents the first detailed biological observation on size, sex composition, size-at-maturity (Lm_{50}) and length-weight relationship of *R. oligolinx* from the northern Arabian Sea.

Keywords: Arabian Sea, Carcharhinidae, Diet, Embryo, Length-weight relationship, Reproductive biology, Size and sex compositions

Introduction

India is one of the major shark fishing nations of the world (Fowler *et al.,* 2005; FAO, 2013; Dent and Clarke, 2015), having a long history of shark fishing by variety of crafts and gears in its subsistence, traditional small-scale fisheries and in commercial targeted fishery (Day, 1863, Bonfil, 1994; Hanfee, 1997, 1999; Kizhakudan *et al.,* 2015). In 2014, estimated all India shark landings was 22479 t contributing 47.5% to all India elasmobranch landings (CMFRI, 2015) excluding those by illegal unreported and unregulated (IUU) catch. Even though sharks never formed a major component of traditional fishery in India contributing only 1% to the marine capture fishery, they support the livelihood of many fishers.

Indian shark fishery moved from traditional, subsistence fishery or bycatch to high level targeted fishery over time (Hanfee, 1997; Hausfather, 2004). Though fishery is huge, biological studies on the major exploited species for creating better management plans are limited. Most of the sharks are highly vulnerable to overexploitation due to their biological characters and as a result world over there is a concern over this group. The present Indian fishery is witnessing a decline in the shark catch, which has created concern and there are several initiatives (*e. g.* fin attached policy in landing, banning the trade of shark fins, protection of vulnerable species and awareness programs) for their conservation and management (Kizhakkudan *et al.,* 2015). Ebert *et al*. (2013) reported that of the 477 sharks worldwide, 45% (214) have been placed as Data Deficient under the IUCN Red List category, which hinders their management efforts. Currently India has a National Plan of Action for conservation and management of shark fisheries in India (NPOA) (BOBLME, 2015) and an advisory to NPOA by Kizhakudan *et al*. (2015). One of the major action plans in these reports were to identify gaps which limits management measures and improve studies on data limited vulnerable species.

The genus *Rhizoprionodon* Whitley, 1929, commonly called requiem sharks, is distributed worldwide, comprising small to moderately large sharks, which are most abundant in inshore coastal waters (Springer, 1964; Compagno, 1988; Simpfendorfer, 1992). Grey sharpnose shark *Rhizoprionodon oligolinx* Springer, 1964 is a small and common shark occurring in the littoral, inshore and offshore regions of continental and insular shelves in the tropical Indo-West Pacific (Ebert *et al.,* 2013). In the north-eastern Arabian Sea of Indian EEZ, *R. oligolinx* is one of the most common sharks having a relatively high economic value for fin and salted meat, caught dominantly by gillnetters operating in the inshore waters. Studies on the distribution and taxonomic account of *R. oligolinx* are limited (Springer, 1964; Nair *et al.,* 1974; Talwar, 1976; Raje *et al.,* 2007) and studies on biology are rare (Appukuttan and Nair, 1988; White, 2007; Moore *et al*., 2012) that can support management decisions.

In this paper, we provide new information on the biology including size and sex compositions, maturity, diet, length-weight relationship based on specimens of *R. oligolinx* caught as bycatch in gillnets operated in the north-eastern Arabian Sea.

Materials and methods

Samples of *R. oligolinx* were collected during weekly surveys at Satpati fish landing centre [19° 43’ 30.75” N, 72° 42’ 08.30” E] (Fig. 1) Palghar District, Maharashtra in north-west coast of India between January 2013 and December 2014, to determine the species and size compositions of the elasmobranchs landings along Maharashtra coast. The grey sharpnose shark was observed in the landings of the mechanised gillnetters operating at 40-60 m depth of continental shelf waters in the north-eastern Arabian Sea. The presence of rough weather during the south-west monsoon and a uniform mechanised fishing ban by the Government of India on the west coast from June 01 to July 31 accounts for no landings in June and July of each year.

The total length (TL) to the nearest mm, total body weight (TW) to the nearest g and sex of each individual were recorded. The length for each sex were tested and data conformed to a normal distribution using Shapiro-Wilk test (Shapiro and Wilk, 1965). 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 females and males were compared using χ^2 test with the size distribution divided into 5 cm size class intervals to the TL (Cochran, 1952). To test sex ratios being at parity and the distribution of females, males, juveniles, sub-adults and adults, χ^2 test was employed again. The criteria used to classify the juveniles, sub-adults and adults in females and males are follows:

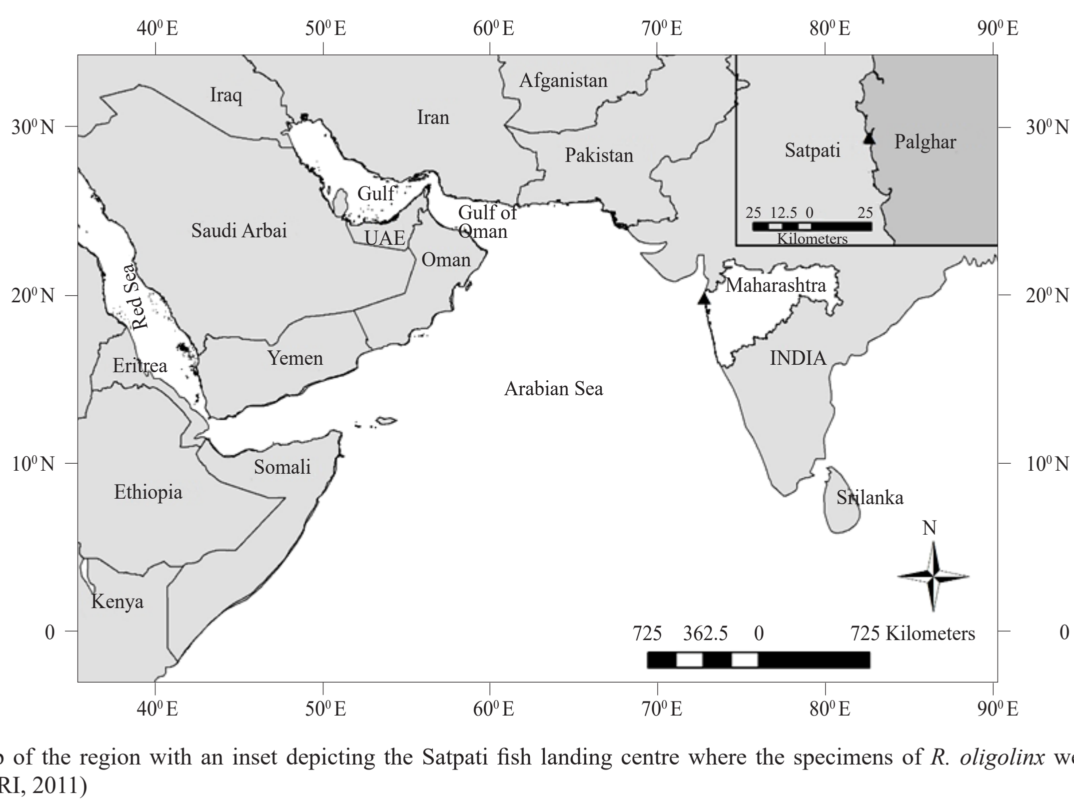

Fig. 1. Map of the region with an inset depicting the Satpati fish landing centre where the specimens of *R. oligolinx* were landed (ESRI, 2011)

all females <50 cm TL are juveniles and those between 51 and 61 cm TL are sub-adults; 50% of females are mature at 62.3 mm TL [Fig. 8a]. Similarly, the claspers of males of *R. oligolinx* become elongate at 48 cm TL and most were fully calcified and matured at 59.5 cm TL [Fig. 8b].

The relationships between maternal TL, number of embryo and mean embryo TL were investigated using correlation analysis. TL and TW relationship was estimated following the general exponential equation $TW = a\ TL^b$, where *a* is the intercept and *b* slope. The relationship between maximum litter size and maximum size was derived using the equation, litter size = -2.2 + (0.061 x maximum length, with the maximum length expressed in cm (Compagno, 1988). The maturity status was recorded for each individual following the maturity scale suggested by Stehmann (2002), based on ovarian and uterine condition for females and clasper calcification for males. For calculation of size-at-maturity (Lm_{50}) for females and males, individuals were classed as either immature (uncalcified or partially calcified claspers for males; ovaries not developed or with maturing oocytes, but uteri thin and ribbon-like for females) or mature (claspers fully calcified; ovaries and uteri both fully developed). The total length at which 50% of females and males attain maturity (Lm_{50}), was calculated using the methodology of White (2007).

The stomach of 711 individuals of *R. oligolinx* were examined. The level of fullness (0, ¼, ½ and full) of each stomach was recorded and prey items were identified to the lowest possible taxonomic unit, preferably to genus or species. To describe the diet, percent frequency of occurrence (%O), percent composition by number (%N), percent composition by weight (%M) and percent index of relative importance (%IRI) were used following [IRI =(%N +%M) %O] (Pinkas *et al*., 1971). The IRI was expressed as %IRI to allow for a comparison of values between prey groups (Cortes, 1997).

Results

Sex and size distributions

In all, 711 individuals of *R. oligolinx* were examined in the field and laboratory, comprising 369 females, 294 males and 48 unsexed specimens. Their length ranged from 36.4 to 93.0 cm TL (68.0±0.3) and weight from 200 to 2600 g (1520.2±21.8) for females and length ranged from 34.5 to 93.0 cm TL (62.4±0.4) and weight from 200 to 2100 g (1082.6±14.7) for males. The landings from gillnet comprised a wide size range of individuals and thirteen size classes (5 cm TL intervals) was used for the classification, from 31 to 95 cm TL (Fig. 2a and b). The χ^2 test revealed significant differences (p<0.001) in length frequency distributions between females and males, with more females between 66 and 70 cm TL and 61-65 cm TL for males captured.

The overall female to male ratio was 1.3:1 in favour of females and was significantly different from 1:1 (p=0.006) (Fig. 3). Seasonal sex ratio was estimated considering three monsoon periods; in pre-monsoon (February-May) sex ratio was 1.1:1, in monsoon (June-September) (1.6:1) and in post-monsoon (October-January) (1.3:1). The distribution of females and males of *R. oligolinx* was significantly different in sampling months (χ^2, d.f.=9, p<0.001). The size-frequency distribution of *R. oligolinx* is presented in Fig. 4. The sex ratio showed significant difference favouring males between 51 and 65 cm TL and females for the classes 66-75 cm and 86-90 cm TL. The distribution of the number of females and males differed significantly in the different sub-groups *viz.,* juveniles, sub-adults and adults (χ^2, d.f.=2, p<0.001). The sex ratio of female to male in juveniles (<50 cm TL), sub-adults

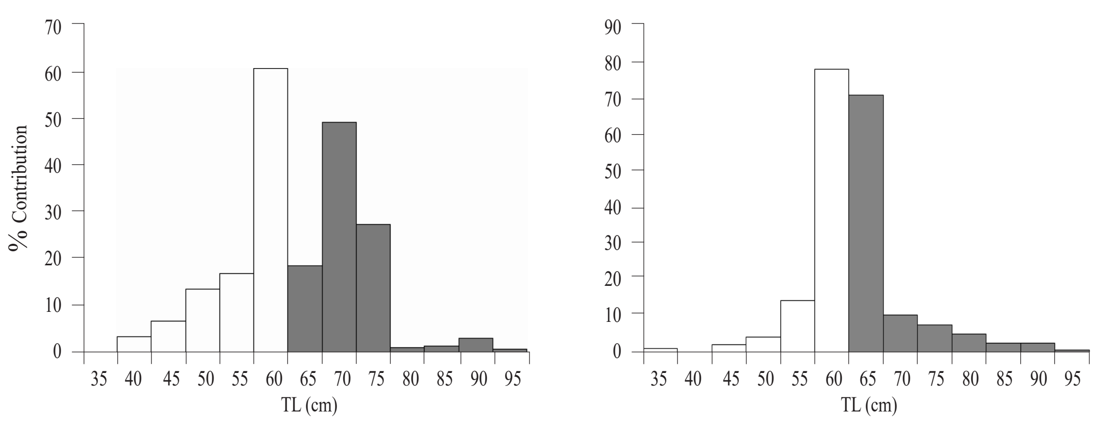

Fig. 2. Total length (TL)-frequency histograms for immature (□) and mature (■) *R. oligolinx* in gillnet (n = 663) at Satpati fish landing centre, Palghar from January 2013 to December 2014. All individuals in TL classes <62.3 cm and <59.5 cm were considered immature for (a) female and (b) male respectively based on estimates of size at maturity in this study

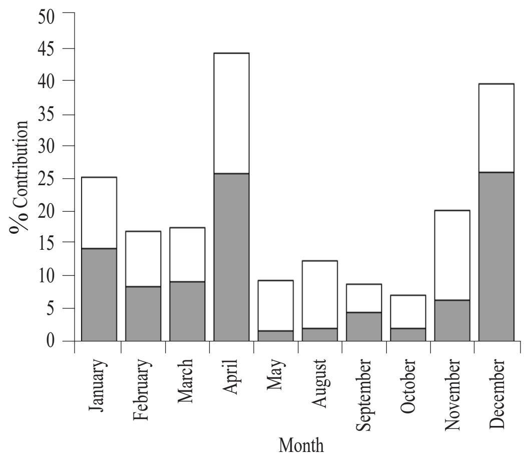

Fig. 3. Monthly percent contribution of females (□, *n*=369, to males (■, *n*=294) of *R. oligolinx* landings at Satpati fish landing centre, Palghar

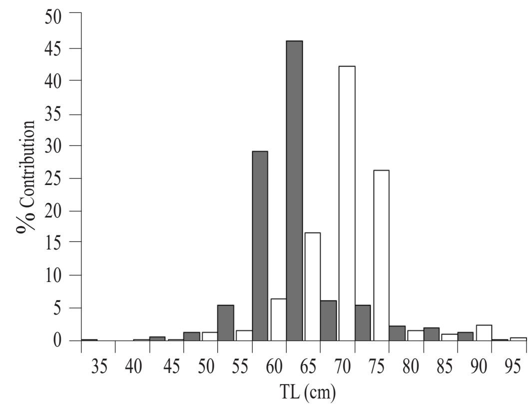

Fig. 4. Total length (TL) - frequency histogram of *R. oligolinx* [Female (□), *n* = 369; males (■), *n* =294] studied

(52-60 cm TL) and adults (>60 cm TL) were 1:0.83, 1:1.9 and 1:1.6 respectively. The monthly length frequency distribution (pooled years) shows no clear trends of females and males possibly due to fishing patterns.

The distribution pattern of *R. oligolinx* (females and males) juveniles, sub-adults and adults in different months (pooled data) shows that juveniles (<50 cm TL) had maximum distribution in November (50%) and August (30%), sub-adults (54-60 cm TL) in November (24%) and March (24%) and adults (>62 cm TL) in November-April with a peak in November (15%) for female [Fig. 5(a)], juveniles (<50 cm TL) maximum in January (25%) and August (25%), sub-adults (52-58 cm TL) in April (28%) and adults (>59 cm TL) between December and April with highest in April (22%) for male [Fig. 5(b)].

Length-weight relationships

The weight of *R. oligolinx* ranged from 200 to 2600 g in females and from 200 to 2100 g in males. The equations relating to total length (TL) and weight (TW) (TL *v.* TW) of *R. oligolinx* consisting of 279 females (36.4-76.0 cm TL) and 186 males (34.5-71.0 cm TL) are presented below, thus enabling approximate weight of sharks to be estimated from a given total length [Fig. 6 (a), (b) and (c)]. The slopes were found to be significantly different between the sexes (p<0.001).

Females: $Log_{10}TW = -7.23951 + 3.466747\ Log_{10}TL$ (R^2= 0.909, n=279)

Males: $Log_{10}TW = -4.17899 + 2.709603\ Log_{10}TL$ (R^2= 0.907, n=186)

Pooled: $Log_{10}TW = -6.88395 + 3.377588\ Log_{10}TL$ (R^2= 0.924, n=465)

There was significant difference between the length and weight of females and males collected (*t*-test, d.f. =661, p<0.001). For females and males, average length and weight were significantly different in all the sampling months (χ^2, d. f. =9, p<.001).

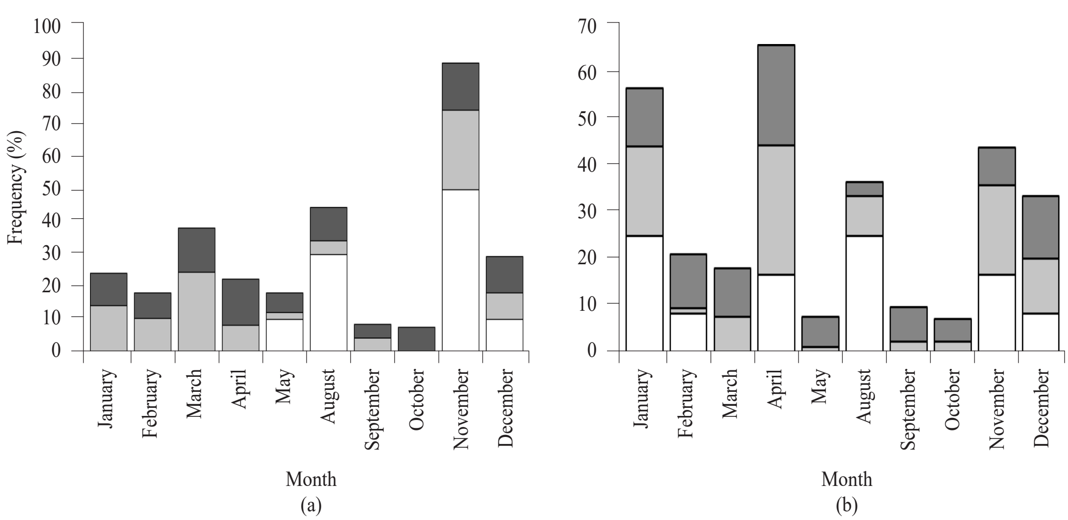

Fig. 5. The monthly frequency of occurrence of *R. oligolinx* sampled from Satpati, Palghar between January 2013 to December 2014 (Pooled data) for juveniles (□), sub-adults (■) and adults (■) for (a) female and (b) male

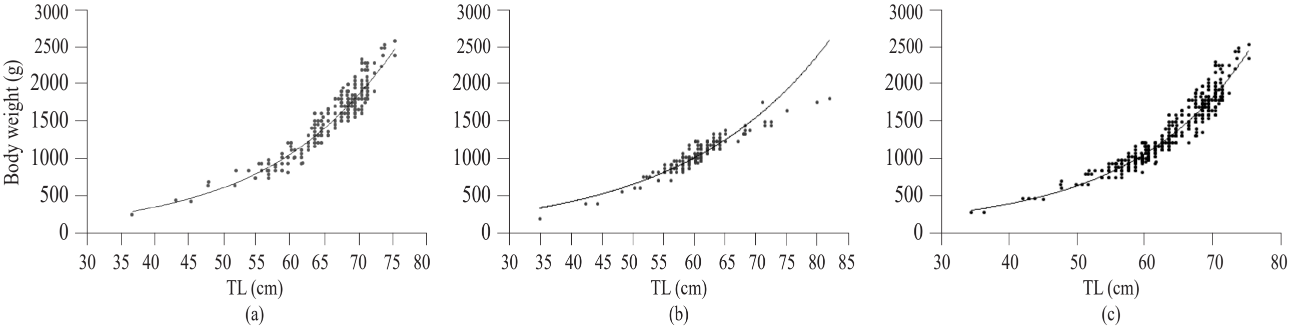

Fig. 6. The length-weight (TL *v.* TW) relationship of *R. oligolinx* for (a) female, (b) male and (c) combined sexes

Reproductive biology

A total of 663 (females = 369; males = 294) specimens were used for the reproductive biology studies. Mature females, with ovaries containing maturing oocytes (maximal ovarian fecundity) ranged between two to six (4.0±1.3) and oocyte diameter measuring from 11to 22 mm (14.7±3.2). Functional uteri, was observed in specimens ranging from 60 to 93 cm TL (Fig. 7). The largest immature female was 73 cm TL. Female *R. oligolinx* matured between 60 and 65 cm, with 50% maturity occurring at 62.3 cm TL (95% C.I) [Fig. 8(a)]. The smallest mature male *R. oligolinx* recorded was 48 cm in TL, whereas largest immature male was of 72 cm TL. Male matured in different size range (55-60 cm) and 50% maturity occurred at 59.5 cm TL (95% C.I.) [Fig. 8(b)].

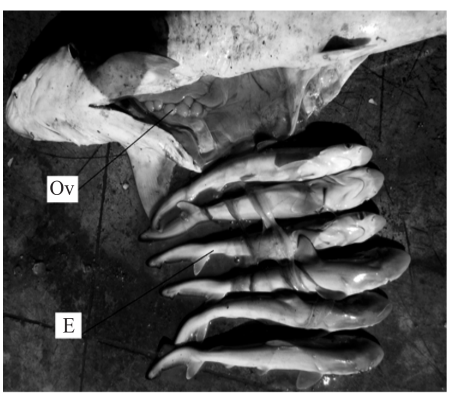

Fig. 7. Pregnant 710 mm total length (TL) female *R. oligolinx* with large oocytes in the ovary (Ov) and late-term embryos *in utero* (E) at Satpati fish landing centre, Palghar

The claspers of males of *R. oligolinx* become elongate and rigid at approximately 48 cm TL and most of them were fully calcified at >55 cm TL. Size of maturity classes for *R. oligolinx* were up to <50 cm TL (2.6%, n=10) for juveniles, 54.0-61.0 cm TL (13%, n=49) for sub-adults and >62 cm TL for mature (adults) (84%, n=319) for female and <50 cm TL (4%, n=12) for juveniles, 52-58 cm TL for sub-adults (31%, n=94) and >59.0 cm TL for mature (adults) (65%, n=199) male. The classification was done based on 50% maturity (Lm_{50}) in this study (Fig. 9).

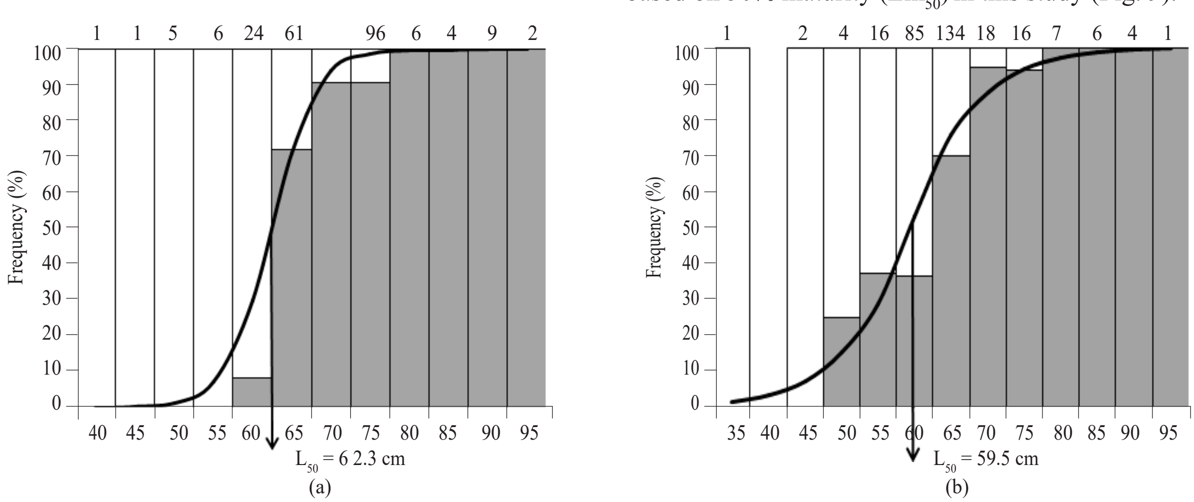

Fig. 8. Percentage frequency of occurrence of immature (□) and mature (■) *R. oligolinx* at Satpati fish landing centre, Palghar in sequential total length (TL) classes for (a) females and (b) males. Numbers above each bar represent the sample size in each sequential TL class. Logistic curves were derived from the following equation: $P_L = [1+e^{-\ln 19 (L_T - L_{T50}) (L_{T95} - L_{T50})^{-1}}]^{-1}$. Arrows indicate the TL at which 50% of females and males attain maturity (Lm_{50})

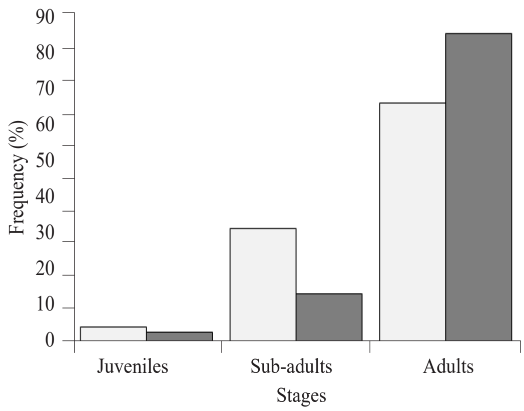

Fig. 9. Percentage frequency of occurrence of juveniles, sub-adults and adults of *R. oligolinx* for female (■) and male (□) at Satpati fish landing centre, Palghar

One hundred thirty-eight pregnant female *R. oligolinx* (59-83 cm TL; mean±S.D. 68.8±3.2 cm) were dissected and each contained one to seven (4.1±1.2) fully formed embryos of 23.0-29.2 cm TL (24.6±2.3 cm) and weight ranging from 69 to 180 g (110±37 g) (Fig. 10). The reproductive mode is placental viviparity (yolk-sac placenta). The size-frequency distribution of pregnant *R. oligolinx* is presented in Fig. 11. Pregnant females of *R. oligolinx* were observed in all months, which exhibited a non-seasonal reproductive cycle and the maximum pregnant females were observed in the length classes of 61-65, 66-70 and 71-75 cm TL (Fig. 12). Near-term embryos, ranging in size from 15-24 cm TL had the yolk-sac stalk still attached and the late term (near to parturition) embryos of 25-29 cm TL were with umbilical scar. Smallest specimen observed in the fishery was 27 cm TL, however, the number of new born/juveniles observed in gillnet catch was very low (in the trawler landings at Sasoon Dock, Maharashtra, more number of new borns in the length range of 27-35 cm TL were observed, but not included in this study). Based on current dataset, the size at birth of *R. oligolinx* in

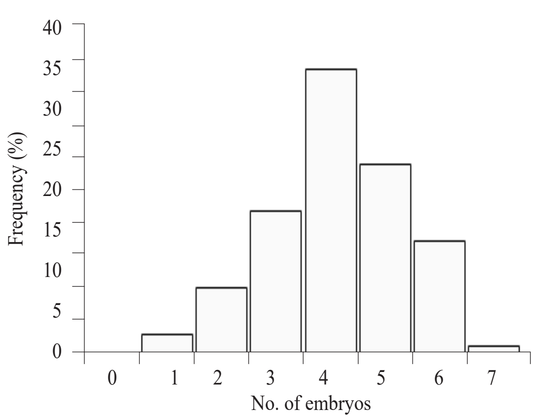

Fig. 10. Frequency of females with their corresponding number of embryos for *R. oligolinx* at Satpati fish landing centre, Palghar

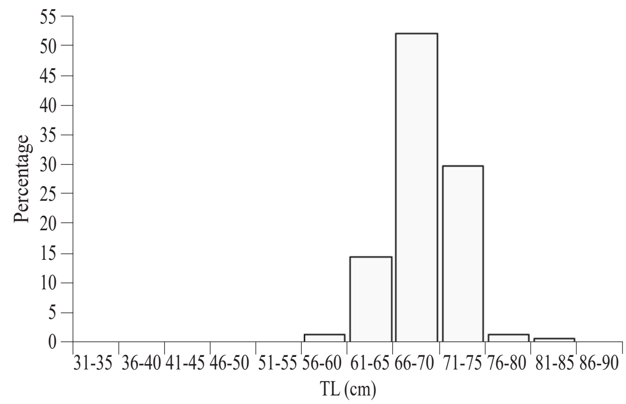

Fig. 11. Total length (TL) - frequency histogram of pregnant *R. oligolinx* at Satpati fish landing centre, Palghar

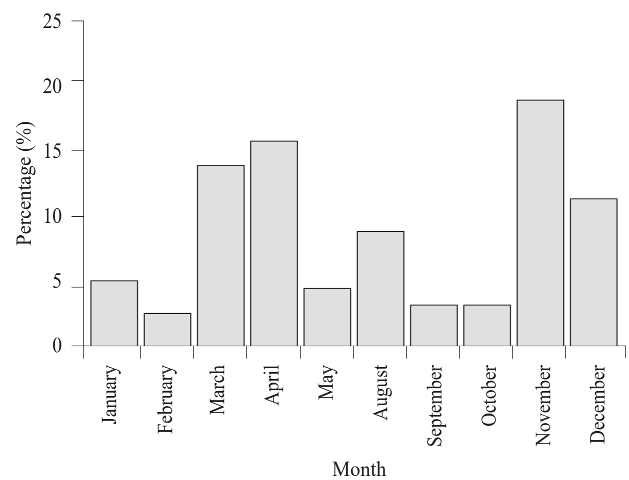

Fig. 12. Percent frequency of occurrence of pregnant females of *R. oligolinx* at Satpati fish landing centre, Palghar

north-west coast of India is estimated to be between 25 to 30 cm TL. The largest number of embryos, containing 7 embryos (left - 4 and right - 3) with mean size of 18.4 cm TL and sex ratio 1.3:1 (female: male) was recorded from *R. oligolinx* (71.0 cm TL; 900 g) in this study. The overall sex ratio of 570 embryos (from 138 females) within these individual embryos was not significantly different from parity (χ^2 d.f.=1, p>0.05), sex ratio of embryos was observed to be 1:0.77 (female to male), the largest embryo was observed in female of 29.2 cm TL and male of 28.5 cm TL. Mixed sex embryos were observed in 83.3% of pregnant females, completely male embryos were found in 10.8% and only female embryos recorded in 5.7%. There was a significant positive correlation between maternal TL and no. of embryos (Pearson r =0.306, n=138, p<0.001) but no relationship was established for maternal TL with the largest females producing the largest embryos (Pearson r =0.449, n=138, p>0.05). A significant functional relationship between maternal TL and mean embryos TL was also found (Pearson r = 0.216, n = 138, p<0.05).

The mean embryo size differed among seasons for *R. oligolinx*. Seasonal differences in embryo length for *R. oligolinx* were significant (ANOVA, d.f=2, n=570, p<0.01), which is explained by the significantly smaller embryos in post-monsoon season compared to pre-monsoon and monsoon seasons (critical difference = 1.43) (Fig. 13).

A total of 711 specimens (27-93 cm TL) were examined for understanding the prey selection including 48 unsexed. Of these, only 11.25% (n = 80) contained prey items and analysed for the index of relative importance (IRI). 20.68% (n = 147) contained either semi-digested or highly digested and trace food that could not be identified and 68.07% (n = 484) were empty. The fullness of the stomach revealed that 68% (n = 484) were empty, 17.5% (n = 125) were a quarter full, 7.3% (n = 52) were half full, 3.9% (n = 28) contained trace amounts only and 3% (n = 22) were full (Fig. 14). The prey items were identified to the species level in the length range between 57 and 70 cm TL of female and male stomachs (n=80) and analysed for the index of relative importance (IRI). The analysis of stomach contents (%IRI) revealed that *R. oligolinx* feeds primarily on teleosts (95.5%), cephalopods (3.2%) and crustaceans (1.2%). The major prey items were *Cynoglossus* sp. (3.3% IRI), *Loligo* sp. (3.1%IRI), *Decapterus* sp. (1.9% IRI) and *Acetes* sp. (0.8% IRI) (Table 1).

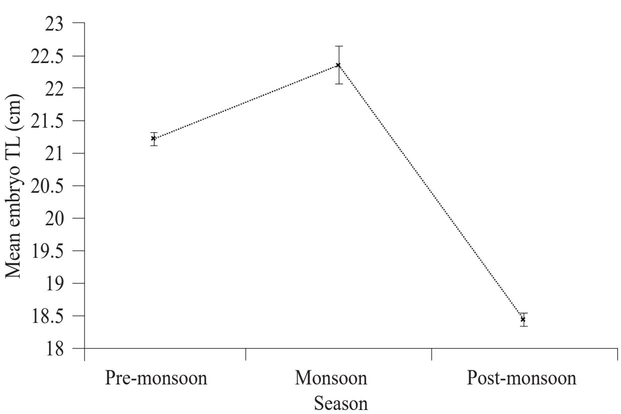

Fig. 13. Seasonal mean embryo total length (TL) in gravid female *R. oligolinx* (*n* = 138) at Satpati fish landing centre, Palghar

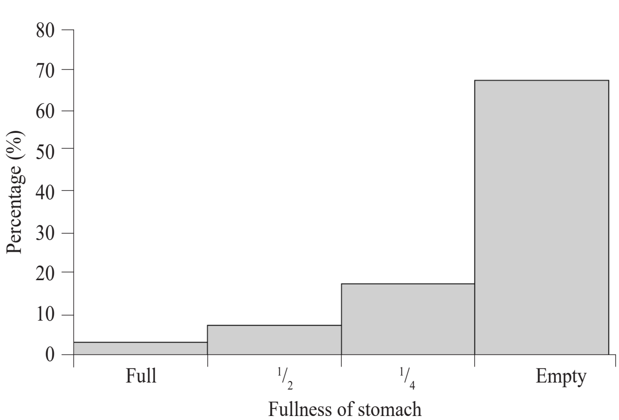

Fig. 14. Fullness of stomach analysed for *R. oligolinx* (n=711) at Satpati fish landing centre, Palghar

Table. 1. Prey composition of *R. oligolinx* from the Satpati fish landing centre, Palghar, north-west coast of India

Prey item	% N	% M	% O	% IRI
Crustacea				
Sergestidae	22.0	1.1	1.7	0.80
Acetes sp.				
Palaemonidae	9.0	0.7	1.7	0.30
Nematopalaemon tenuipes				
Squillidae	0.6	0.5	0.8	0.02
Oratosquilla spp.				
Other	1.1	0.8	1.7	0.07
Unidentified shrimp				
Mollusca (Cephalopoda)				
Loliginidae	7.3	7.1	10.1	3.10
Loligo spp.				
Other	0.6	0.8	0.8	0.02
Unidentified squid				
Unidentified Cephalopoda	1.1	1.5	1.7	0.10
Teleostei				
Apogonidae	1.7	1.2	2.5	0.20
Apogon spp.				
Cynoglossidae	8.5	8.3	9.2	3.30
Cynoglossus spp.				
Mullidae	0.6	0.8	0.8	0.03
Upeneus spp.				
Serranidae	0.6	2.3	0.8	0.05
Epinephelus diacanthus				
Sciaenidae	2.3	4.6	3.4	0.50
Johnius borneensis (=*Johnieps vogleri*)				
Carangidae	4.5	10.5	5.9	1.90
Decapterus spp.				
Sciaenidae	1.1	2.0	1.7	0.10
Johnius spp.				
Clupeidae	1.1	0.8	1.7	0.07
Sardinella spp.				
Platycephalidae	0.6	1.1	0.8	0.03
Platycephalus spp.				
Myctophidae	0.6	0.0	0.8	0.01
Myctophum spp.				
Nemipteridae	0.6	0.5	0.8	0.02
Nemipterus randalli				
Trichiuridae	2.8	4.1	3.4	0.49
Trichiurus lepturus				
Other	33.33	51.30	49.58	88.90
Unidentified fishes				

Published information on the occurrence of *R. oligolinx* in fishery are limited (Table 2) and from many regions perhaps unreported. The two northern states, Maharashtra and Gujarat together contributes major share of *R. oligolinx* catch in India.

The size range of *R. oligolinx* observed in the gillnet fishery of northern Arabian Sea (27-93 cm TL) differed slightly from those reported from other regions,

Table. 2. Earlier records of *R. oligolinx* globally and from Indian waters

Study area	Numbers observed	Reference
UAE	12	Jabado *et al.* (2014)
Kuwait	226	Moore *et al*. (2012)
Bahrain	32	Moore and Pierce (2013)
Bangladesh	10	Roy *et al.* (2013)
Indonesia	1190	White (2007)
Satpati, India	711	Present study

by Moore *et al*. (2012) in Kuwait waters, (45-85 cm TL for females and 45-64 cm TL for males) and by White (2007) in Indonesian waters (26-65 cm TL for females, 29.5-52.0 cm TL for males). The differences could be the result of several factors like fishing gear selectivity and/or sample size, regional differential growth based on habitat (Motta *et al.,* 2005). Furthermore, *R. oligolinx* from this study attained a greater maximum size (93.0 cm TL) than previously reported from elsewhere (80 cm TL by Abdul Nizar *et al*., 1988; 70 cm TL by Compagno *et al*., 2005; 85 cm TL by Moore *et al*., 2012). The difference detected between size-frequency distributions of females and males is probably a consequence of sexual segregation, a general characteristic of shark populations that is normally associated with reproduction, migration or competition (Springer, 1967; Klimley, 1987; Stevens and Mcloughlin, 1991; Motta *et al*., 2005).

The landings from gillnet comprised a wide size range of individuals (27-93 cm TL), however, very few juveniles <35.0 cm TL were observed. Females and males of *R. oligolinx* landings were dominated by large size individuals of 60-75 cm TL and 50-65 cm TL respectively. The average size of females of this species was significantly larger than males and 37.3% of recorded landings were pregnant females. Moore *et al*. (2012) reported similar results in Kuwait waters where females (mostly pregnant stage) dominated the landings.

The overall sex ratio of females to males recorded from the landings (1.27:1), showed sexual segregation in this species in the north-eastern Arabian Sea and unequal trends in monthly sex ratios. Seasonal and size class sex ratio analyses indicated that the sub-adults and adults of *R. oligolinx* show a sex and size segregation. Females appear to be more vulnerable to fishing than males. Unequal sex ratios in sharks can be the result of sexual segregation by depth or area, gear selectivity or possibly even a natural phenomenon (Motta *et al.,* 2005).

The Lm_{50} of females at maturity determined in this study was 62.3 (60-65) cm TL. Information on the size at maturity for females of *R. oligolinx* is limited, but Compagno (1984) and Appukuttan and Nair (1988) reported females of *R. oligolinx* maturing between 32 and 41 cm TL.

The Lm_{50} of males in this study was 59.5 (55-60) cm TL, which is larger than previously reported for this species by Springer (1964) who reported males maturing as small as 38 cm TL. Length at maturity of males were estimated at 29-38 cm TL in India (Appukuttan and Nair, 1988); 43-45 cm TL with Lm_{50} at 53 cm in Indonesia (White, 2007), Lm_{50} at 53 cm TL in Kuwait (Moore *et al.,* 2012) and 55 cm TL in Bahrain (Moore and Pierce, 2013).

Interestingly, in the same genus, Motta *et al.* (2007) reported size-at-first maturity of *Rhizoprionodon lalandii* as 62 cm TL for females, 59 cm TL for males in south-eastern Brazil, which were quite similar to our estimates of the same genus; where as Lessa (1988) reported 56 cm TL for females and 52 cm TL for males for same species in Maranhao (north), Brazil. In this study, the females and males were found to be mature at a larger size, compared to previous studies and it is possible that differences could have resulted from distinctive oceanographic conditions in the region, or fisheries influence, regional differences, or sampling difference which could cause differences in biological parameters between populations, such as maximum size, growth rate, size-at-maturity and fecundity (Parsons, 1993; Lombardi-Carlson *et al*., 2003; Motta, *et al*., 2007). Size at birth estimated in the study was 25-30 cm TL which was larger than those reported (as 21-26 cm TL) earlier by Appukuttan and Nair (1988). Smallest specimen examined by Springer (1964) was 21.9 cm TL and the largest embryo observed was 26 cm TL from Bombay, which also suggested variation in size at birth.

R. oligolinx female juveniles were observed in the months of May, August and November-December. Juveniles of males were observed in the catch except during March, May and September-October, whereas sub-adults and adults of females and males were found during the entire course of study.

The length-weight relationships (TL *vs.* TW) of *R. oligolinx* were significantly different between the sexes, indicating considerable ontogenetic weight increase in females (b>3) than in males (b<3) (Lessa, 1988; Motta, *et al*., 2005). According to Stevens and Wiley (1986), these variations between length-weight relationships of females and males may be a result of different sample sizes, an unequal distribution of sizes within each data set of each sex or even of non-pregnant females being lighter due to the inclusion of spent fish, which have a lower condition factor. Lessa (1988), Stevens and Wiley (1986) and Motta *et al*. (2005) also noted that the changes in the body density have important implications for swimming in sharks; females might normally be lighter than males to offset subsequent weight increases due to pregnancy.

Pregnant females were observed throughout the year with peaks in November-December and March-April. Appukuttan and Nair (1988), who reported pregnant females with advanced embryos during January-April, July and October suggest breeding throughout the year, which is similar to our results. The observation of *R. oligolinx* females simultaneously carrying term embryos and vitellogenic follicles indicates an annual reproductive cycle with concurrent ovarian and gestation cycles. This aspect has also been observed for other *Rhizoprionodon* species (Parsons, 1983; Stevens and Mcloughlin, 1991; Simpfendorfer, 1992; Castro and Wourms, 1993; Motta, *et al*., 2005). In this study, we observed ovarian fecundity and uterine fecundity ranging from 2 to 6 follicles (mean = 4) and from 1 to 7 embryos (mean=4.1) respectively. There is very little information on the biology of *R. oligolinx* to compare our results. Appukuttan and Nair (1988) reported uterine fecundity as 3 to 5 embryos. In the same genus, for *R. lalandii*, off Rio de Janeiro, Ferreira (1988) reported mean values of 4.7 for ovary and 2.9 for uteri. Estimates from northern Brazil ranged from 2 to 6 follicles and from 2 to 5 embryos (Lessa, 1988). Motta *et al*. (2007) reported ovarian and uterine fecundity ranging from 3 to 7 follicles and from 1 to 5 embryos respectively off south-eastern Brazil. Simpfendorfer (1992) reported 1 to 10 embryos for *Rhizoprionodon taylori* off Cleveland Bay, Northern Queensland. Carlson and Baremore (2003) reported 5 embryos for *Rhizoprionodon terraenovae* in Gulf of Mexico. Krishnamoorthi and Jagadis (1986) and Henderson *et al*. (2006) reported embryos of size 1 to 6 off Madras and Oman waters respectively in *Rhizoprionodon acutus*.

There is a significant positive correlation between maternal TL and number of embryos but no relationship is established for maternal TL with large females producing the largest embryos. In general, a significant functional relationship between number of embryos and body size/total length of females has been recorded for other *Rhizoprionodon* species (Parsons, 1983; Stevens and Mcloughlin, 1991; Simpfendorfer, 1992; Castillo-Geniz *et al*., 1998; Mattos *et al*., 2001; Motta *et al*., 2007). According to Stevens and Mcloughlin (1991) and Motta *et al*. (2007), the relationship between embryo size and female size should not be considered as a rule for Carcharhinids. An equal sex ratio in the embryo would be expected if the 1:1 adult population sex ratio, often observed in many elasmobranch species was maintained (Jennings *et al*., 2001; Henderson *et al*., 2006). The present study found that *R. oligolinx* produces mostly mixed litters (83.3%). The overall sex ratio of 570 embryos recorded was not significantly different from parity. In related species such as *R. acutus,* the sex ratio in embryos has been reported as 2.3:1 (Henderson *et al*., 2006) and 1:1 in *R. terraenovae* (Loefer and Sedberry, 2003). The smallest neonates recorded in this study differs in the upper range of known birth size reported by Compagno *et al*. (2005) and White (2007).

In the light of published data, the viviparous species of the families Carcharhinidae, Hemigaleidae and Sphyrnidae follows positive correlation established between the maximum length of a species and the maximum number of embryos produced (Compagno, 1988). Fig. 15 illustrates this relationship for the family Carcharhinidae, genus *Rhizoprionodon* and includes two values for *R. oligolinx,* one given by Compagno (1984) and the other from the present study. Although, most *Rhizoprionodon* species fit the relationship proposed by Compagno (1988), in this study, the number of embryos was larger than predicted by the equation. Simpfendorfer (1992) reported similar results for *R. taylori* from Cleveland Bay, northern Queensland (78.4 cm TL; no. of embryos 10).

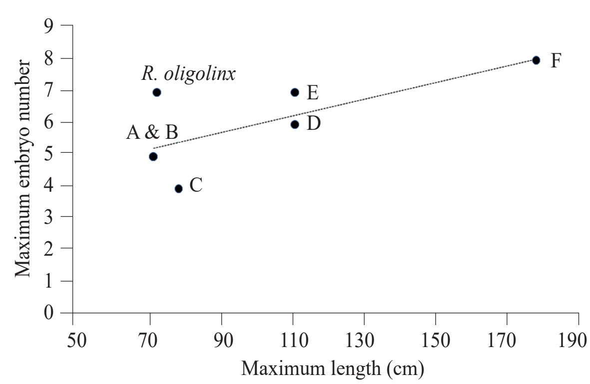

Fig. 15. Relationship between maximum length and maximum embryo number for species in the genus *Rhizoprionodon*. Data for *R. oligolinx* are from this study; all other data are from Compagno (1984). Dotted line fitted by the equation: Litter size = -2.2 + (0.061 x maximum length). (A) *R. oligolinx* (Compagno's estimate); (B) *R. taylori;* (C) *R. lalandii;* (D) *R. porosus;* (E) *R. terraenovae;* (F) *R. acutus* [Data deficient for *R. longurio*]

The ecology and life histories of chondrichthians of Indian waters are not well understood and information is scarce (Akhilesh *et al*., 2013). In an advisory to Indian NPOA, Kizhakkudan *et al.* (2015) suggested that the primary objective of the NPOA should be addressed at filling the gap in regional fishery and biology of the heavily exploited species for their better management in consultation with all stakeholders. The study provided the first detailed information on biological observations including size and sex compositions, maturity, diet, length-weight relationship and occurrence of *R. oligolinx* and also provided details of the large bycatch of this species from inshore waters off the north-west coast of India. This species was landed throughout the year in relatively high numbers, indicating that non-seasonal reproductive cycle and continuous recruitment as well as the ecological peculiarities of the northern Arabian Sea favours the species to sustain their stocks in the region. However, the dynamics of the fishery are unpredictable and the fishery needs to be carefully monitored and managed. The insight into the biological aspects provides cue for the development of management strategies for the less monitored and studied elasmobranch fisheries in India.

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