Reproductive biology of the Brazilian sharpnose shark (Rhizoprionodon lalandii) from southeastern Brazil

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The reproductive biology of the Brazilian sharpnose shark, Rhizoprionodon lalandii, off southeastern Brazil was investigated using data from gillnet landings. The size-at-maturity for males and females was estimated to be 59 and 62 cm total length (Lₜ), respectively. Ovarian fecundity ranged from 3 to 7 follicles (mean = 4.54), and uterine fecundity from 1 to 5 embryos (mean = 3.3). There was a slight positive relationship between female Lₜ and the number of ovarian follicles, but uterine fecundity was not related to female Lₜ. Embryonic growth is fast following fertilization during summer and autumn. Gestation requires 11–12 months, and peak parturition is between August and September. A comparison of size-at-maturity between animals from northeastern and southeastern Brazil suggests the existence of at least two stocks of R. lalandii along the Brazilian coast.

Keywords: Elasmobranchii, fecundity, reproduction, shark, size-at-maturity.

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Introduction

The genus Rhizoprionodon is represented worldwide by at least seven species of small coastal placental sharks (maximum length ~140 cm), identified among carcharhinids by their long upper labial furrow, and the second dorsal fin origin posterior to the origin of the anal and preanal ridges (Parsons, 1983; Compagno, 1984). Because of their abundance and habits, these sharks are caught in several parts of the world, with estimates varying from 46% to 81.7% (by numbers) of the total catch of sharks in coastal fisheries (Sadowsky, 1967; Cody and Avent, 1980; Lessa, 1986; Grace and Henwood, 1997; Trent et al., 1997; Castillo-Géniz et al., 1998; Thorpe et al., 2004; Motta et al., 2005). In the western Atlantic, three species have been recorded: R. terraenovae, known from the western North Atlantic, but probably also in the tropical western South Atlantic; R. porosus, from the central US to Uruguay and Brazil; and R. lalandii, from western Panama to Uruguay and Brazil (Figueiredo, 1977; Compagno, 1984).

The Brazilian sharpnose shark (R. lalandii) is the most common shark species of the continental shelf of southern Brazil, representing 60% of the total shark landings from small-scale fisheries there (Gadig et al., 2002; Motta et al., 2005). It attains a maximum size of 80 cm with a life cycle restricted to the continental shelf, from very shallow water to 70 m deep, usually over muddy and sandy seabed (Compagno, 1984). Off southern Brazil, the species has suffered from the effects of marine pollution (Sazima et al., 2002) and is listed by IUCN as data-deficient because of the paucity of biological information over its entire distribution (Rosa et al., 2004).

Despite the abundance and distribution of Rhizoprionodon along the continental shelf of Brazil, biological data on these sharks are limited. Ferreira (1988) reported that off southern Brazil (n = 314), the species attains sexual maturity at 60–65 cm Lₜ, and that the mean uterine fecundity is ~3 embryos. Lessa (1988) examined 294 sharks in Maranhão (northern Brazil) and concluded that R. lalandii reaches sexual maturity between 52 and 56 cm Lₜ and that the fecundity varies from 2 to 5 embryos. More recently, Motta et al. (2005) investigated the size and sex compositions, occurrence, and distribution patterns of R. lalandii along the coast of São Paulo State, providing insights into the life cycle and reproductive patterns, as well as nursery habitats. The aim of this study is to provide complementary information on the reproductive biology of R. lalandii based on fishery-dependent data. We estimated size-at-maturity, fecundity, and gestation period, and include data on embryo development and growth.

Material and methods

Our work is based on a study of the fishery biology of coastal sharks from southeastern Brazil (Projeto Cacação; Gadig et al., 2002), which has been ongoing since 1996. The data used in this analysis come from specimens landed at Fishermen’s Beach, Itanhaem city, south São Paulo (24°11'S 46°48'W), and in adjacent areas (Figure 1), between July 1996 and June 2002. The fishing fleet consists of 12 small motorized boats (4–10 m long), which fish with monofilament gillnets 1500 m long and stretched mesh sizes of 7, 12, and 14 cm on average. The nets are set at distances of 2–12 nautical miles from shore, in waters between 5 and 30 m deep, and checked once a day, usually in the morning.
All sharks were measured (total length, \( L_T \), in cm), weighed (total weight, \( W_T \), in g), and their sex was determined. From males, the clasper length was measured from the tip to the inner pelvic junction, and the stage of calcification was classified as flexible or rigid.

Maturity stages were assessed according to Castro (1993) and Simpfendorfer and Milward (1993) as follows: neonates, recognized by the presence of an open umbilical scar between their pectoral fins; juveniles, umbilical scar healed or absent, the males with flexible claspers and females with ovaries not clearly differentiated and filiform uteri; adults, males with elongated and calcified claspers and females carrying vitellogenic oocytes in the ovary and/or eggs or embryos in the uterine cavity.

After evisceration, the reproductive organs of some sharks were removed and fixed in a solution of 10% formaldehyde in fresh water. In the laboratory, the length and width of epididymides and testes from males were measured, and the latter were weighed. For females, the following data were collected: width of the oviducal gland, number of ovarian follicles, and diameter of the largest ones. For pregnant females, the numbers of eggs or embryos were counted. Embryos were measured, weighed, and the sex was determined.

Size-at-maturity was estimated from the allometric growth patterns (against \( L_T \)) of clasper, testis, and epididymides in males, and from the oviducal glands and follicles in females. The length at which 50% of the sharks from both sexes were sexually mature (\( L_{50} \)) was estimated from a logistic curve fitted to the data by maximum-likelihood procedures, based on maturity proportion by 1-cm length class (Roa et al., 1999).

**Results**

**General compositions of size, weight, sex, and state of maturity**

In all, 7330 *R. lalandii* were examined in the field (3912 males, 3418 females). The total length of males ranged from 30 to
77.5 cm, and of females from 30 to 80 cm (Figure 2). Total weight of males was 75–1925 g, and of females 75–2950 g. We found 2031 (27.7%) neonates, 3049 (41.6%) juveniles, and 2250 (30.7%) adults. Between November and March, juveniles were most frequent. From April to July, adults were most common, but in June, neonates started to appear, then dominated in August and September (the birth season; Figure 3).

Maturation
The relationship between clasper length and total length of males was characterized by a sigmoid pattern (Figure 4a) corresponding to three phases of clasper growth. The first comprised sharks up to 46 cm $L_T$, with flexible clasps measuring 0.5–1.5 cm, with slow growth relative to $L_T$. The second phase included animals from 46 to 58 cm $L_T$, whose clasps ranged from 0.7 to 5 cm, showing fast positive allometric growth and becoming calcified. In the third phase, the clasps showed negative allometric growth and varied from 3.6 to 6.1 cm in mature sharks $>58$ cm $L_T$. Additionally, all males with clasps $<3.5$ cm were unable to copulate, because the organs were flexible, i.e. lacking skeletal support. Maturity was attained by 79.6% of sharks with rigid clasps $>4$ cm. The growth in length of testes was gradual, ranging from 1.41 to 6.3 cm ($\text{mean} = 4.29 \pm 1.21 \text{ s.d.}$) in juveniles, and from 5.8 to 12.19 cm ($\text{mean} = 8.97 \pm 1.32 \text{ s.d.}$) in mature sharks $>59$ cm $L_T$ (Figure 4b). The width and the weight of the testes increased as males exceeded 58 cm $L_T$ (Figure 4c and d), but there was great variation in both parameters in mature sharks, probably because of the presence in the sample of sharks at different phases of their reproductive cycle. Width of the epididymides ranged from 0.48 to 1.2 cm ($\text{mean} = 0.83 \pm 0.14 \text{ s.d.}$) in mature sharks $>59$ cm $L_T$ (Figure 4e). On the basis of previous analysis and on the fact that the smallest mature male measured was 56 cm $L_T$ and the largest immature was 63 cm $L_T$, the size at first maturity was recorded as being near 59 cm $L_T$. This estimate was corroborated by the value calculated for $L_{50}$, which was 58.65 cm (Figure 5).

Figure 2. Length frequency distribution of *Rhizoprionodon lalandii* sampled from Itanhaém’s artisanal fisheries in southeastern Brazil between July 1996 and June 2002 (pooled data; males $n = 3912$; females $n = 3418$).

Figure 3. Monthly frequency of occurrence of *R. lalandii* sampled from Itanhaém’s artisanal fisheries in southeastern Brazil between July 1996 and June 2002 (pooled data). The number of individuals sampled per month is shown above the vertical bars.
The width of the female oviducal gland ranged from 0.24 to 0.85 cm (mean $\mu = 0.41 \pm 0.22$ s.d.) in juveniles. Adult females could be divided into three groups: pregnant females at the onset of gestation (caught between October and February), whose glands ranged from 0.32 to 1.34 cm (mean $= 0.89 \pm 0.25$ s.d.); females at first ovulation, between 61 and 68.5 cm $L_T$ (caught between March and June), whose glands ranged from 0.9 to 1.83 cm (mean $= 1.37 \pm 0.26$ s.d.); and post partum females and females carrying term embryos between 67 and 78.5 cm $L_T$ (caught between June and August), whose glands ranged from 0.95 to 1.81 cm (mean $= 1.45 \pm 0.21$ s.d.) (Figure 6a). A similar dispersion of data was observed relative to the diameter of the ovarian follicles (Figure 6b). Pregnant females at the start of gestation had follicles ranging from 0.12 to 0.7 cm (mean $= 0.41 \pm 0.20$ s.d.). The follicles of ovulating females ranged from 1.04 to 2.08 cm (mean $= 1.65 \pm 0.23$ s.d.). The smallest female with vitellogenic activity was 58 cm $L_T$, the smallest pregnant female was 65 cm $L_T$, and the largest immature was 63.5 cm $L_T$. Therefore, we conclude that females mature between 60 and 63 cm $L_T$ (Figure 7).

**Figure 4.** Relationship between total length and (a) clasper length ($n = 1770$), (b) length of testis ($n = 132$), (c) width of testis ($n = 145$), (d) weight of testis ($n = 116$), and (e) width of epididymides ($n = 113$) in male *R. lalandii* from Itanhaém, southeastern Brazil.

**Figure 5.** Proportion of mature male *R. lalandii* per 1 cm total length intervals. Dashed lines mark the total length at which 50% of the sharks are mature.

**Fecundity**

The ovarian fecundity of *R. lalandii* varied from 3 to 7 follicles (mean $= 4.54 \pm 0.9$ s.d.), and the uterine fecundity (litter size) from 1 to 5 embryos or eggs (mean $= 3.3 \pm 0.91$ s.d.). There was a positive linear relationship between total length and the number of ovarian follicles (Figure 8a), but the relationship between uterine fecundity and total length was not significantly correlated (Figure 8b).
In all, 137 embryos from 47 females were examined. Their total length and weight ranged from 3.5 to 35 cm and from 4.5 to 175 g, respectively. The length–weight relationship was described by the equation $W_T = 0.0025 L_T^{3.14}$ ($r^2 = 0.965; n = 105$). Of the total examined, the sex of 115 was determined, 57 (49.6%) being males and 58 (50.4%) females, a sex ratio (1:1.02) not significantly different from 1:1 ($p = 0.936$).

Eggs were present in the uteri between October and January. In January, embryos measuring an average of 4.0 cm $L_T$ (+ 0.49 s.d.) were also registered. With eggs in the uteri between October and January and looking at the plot of embryo mean total length against month (Figure 9a), we conclude that embryonic development takes 11–12 months in $R. lalandii$. Increase in the length of embryos approximates a sigmoid curve, indicating that after fertilization there is a period of rapid growth between summer and autumn (January–June), when embryos grow from 3.5 to 29.7 cm $L_T$. Embryonic development ended in July and September (winter), when the embryos had attained an average of 30.6 ($\pm$ 2.6 s.d.) and 32.1 cm ($\pm$ 1.5 s.d.) $L_T$, respectively, and parturition took place. The increase in weight (Figure 9b) differed from the increase in total length. Embryo weight increased slowly during the first few months (until May), embryos increasing from 4.5 to 23.0 g. During the final three months of gestation, growth in weight was the greatest, embryos reaching 120–160 g.

Discussion

The largest female (80 cm $L_T$) examined in our study is the maximum size recorded for the species. The peak occurrence of neonates indicates a birth season between August and September (winter), consistent with the results of previous studies (Ferreira, 1988; Motta et al., 2005).

The relationship between clasper length and $L_T$ can be used to determine sexual maturation in male sharks. Stable allometric or isometric relationships are shown during the growth of these organs, with reference to that of the body, at least during the
Brazil, Lessa (1988) observed two phases in clasper growth of *R. lalandii*; three phases were identified. Off northern Brazil, although here, possibly because of the large sample size, a similar pattern was verified for growth (slow growth) when claspers attain their functional length. But that then there is a period of negative allometric growth (mean = 2.54) and from 1 to 5 embryos (mean = 3.3), respectively. Off Rio de Janeiro, Ferreira (1988) reported mean values of 4.7 for the ovary and 2.9 for the uterus. Estimates from northern Brazil ranged from 2 to 6 follicles and from 2 to 5 embryos (Lessa, 1988).

A significant relationship between litter size and total length of females has been recorded for other *Rhizoprionodon* species (Parsons, 1983; Stevens and Mcloughlin, 1991; Simpfendorfer, 1992; Castro and Wourms, 1993). Matings of *R. lalandii* in Brazilian waters takes place between April and June for first-maturing females, and between July and September for post partum females (Motta et al., 2005). All females caught between July and September are pregnant or with characteristic signs of recent parturition, which may indicate that there is no resting phase between pregnancies.

Our fecundity estimates for *R. lalandii* were similar to those in the literature. We observed ovarian and uterine fecundity ranging from 3 to 7 follicles (mean = 4.54) and from 1 to 5 embryos (mean = 3.3), respectively. Off Rio de Janeiro, Ferreira (1988) reported mean values of 4.7 for the ovary and 2.9 for the uterus. Estimates from northern Brazil ranged from 2 to 6 follicles and from 2 to 5 embryos (Lessa, 1988).

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growth after conception, and a difference between the increases in length and in weight) were similar to those reported for R. terraenovae (Parsons, 1983). However, a more detailed study on embryonic development of R. lalandii will be required for the main morphological and physiological changes that occur during gestation to be described adequately.

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