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Birth and growth of the shortnose guitarfish *Zapteryx brevirostris* (Müller & Henle, 1841) (Chondrichthyes, Rhinobatidae) in captivity

Bruna Larissa Maganhe[1,2] | Laura de Oliveira Camilo[1,2] | Rodrigo E. Kurokawa[1] | Hugo Gallo Neto[1] | Eduardo Gomes Sanches[2]

[1]Ubatuba Aquarium, Ubatuba, Brazil
[2]Marine Fish Laboratory, Fisheries Institute, Ubatuba, Brazil

Correspondence
Bruna Larissa Maganhe, Ubatuba Aquarium, Rua Guarani, 859, Ubatuba, São Paulo 11689-046, Brazil.
Email: brunamaganhe@live.com

Abstract

Endemic to the south-west Atlantic Ocean, the shortnose guitarfish (*Zapteryx brevirostris*) is a small species, classified as endangered by the IUCN. Although reproduction in captivity has been successful for some species, a range of factors can limit the success of captive breeding programmes for elasmobranchs. In Brazil, the Ubatuba Aquarium was the first public aquarium to reproduce small-sized elasmobranchs. Since 2018, at least five parturition events have been recorded for *Z. brevirostris* at the institution. From a total of 13 live neonates that rearing was attempted, the mean ± standard error of weight, total length (TL) and disc width at birth were 17.47 ± 1.6 g, 13.25 ± 0.7 cm and 6.53 ± 0.2 cm, respectively. The mean weight as well as mean TL were higher for females at all births, with 26.15 g and 15.07 cm for females in comparison with 17.09 g and 13.94 cm for males. Considering the increasing risk of extinction that the species is facing, age and growth studies are fundamental for the success of conservation, improving the knowledge of *Z. brevirostris* life cycle so that a more efficient and sustainable management can be carried out. This study provides important data, as well as directions for captive breeding of the species.

KEYWORDS
Captive breeding, Chondrichthyes, Elasmobranchs, Public aquaria

1 | INTRODUCTION

Endemic to the south-west Atlantic Ocean, the shortnose guitarfish (*Zapteryx brevirostris*) is a small species, distributed throughout the Brazilian continental shelf, from Rio de Janeiro, southeast Brazil, to the south of Buenos Aires, Argentina. Like other Chondrichthyes, it exhibits slow growth, late sexual maturity and low fecundity, presenting placental viviparity as reproductive mode (Caltabellotta *et al*., 2019). The species is classified as endangered by the IUCN because of its low fecundity rates and by-catch in trawling fisheries, which has led to a decline in its incidence (Barbini *et al*., 2011; Caltabellotta *et al*., 2019; Gonzalez, 2004). The species has low economic value; therefore, specimens are not usually retained for commercialization, but the guitarfish displays a high tolerance to capture (Wosnick & Freire, 2013). Nonetheless, a significant reduction in survival rates is thought to occur during the reproductive period, and, in more advanced stages of embryonic development, embryos are likely to be aborted after capture (Wosnick *et al*., 2018; Wosnick, Awruch, *et al*., 2019).

There are only a few studies on the reproduction of elasmobranchs, development and survival of neonates in captivity (Daly & Jones, 2017; Daochai *et al*., 2020; Gonzalez, 2004; Henningsen *et al*., 2017; Paiva *et al*., 2020; Santos-Ribeiro & Amorim, 2021). Although reproduction in captivity has been successful for some species and the adoption of reproductive technology for elasmobranchs is increasing, a range of factors, including suboptimal population structures and non-specific environmental influences, can limit the success of captive breeding programmes for elasmobranchs (Daly & Jones, 2017; Daochai *et al*., 2020; Kim *et al*., 2020; Wyffels *et al*., 2021).

Although captive breeding is a common practice in zoos, in public aquariums there is still little engagement regarding the sustainability of animal population, with few institutions that have implemented breeding programmes for aquatic organisms (Buckley *et al*., 2018; Daly & Jones, 2017; Henningsen *et al*., 2017). In Brazil, the Ubatuba Aquarium was the first public aquarium to reproduce small-sized elasmobranchs, such as *Rhinoptera bonasus* and *Z. brevirostris* (Baldassin *et al*., 2008; Cavalcante *et al*., 2016). From a conservation point of view, research and education are needed for the responsible management of elasmobranchs given the increasing declines in wild populations due to anthropogenic pressures (Daly & Jones, 2017; Kim *et al*., 2020; Wyffels *et al*., 2020). Thus, maintaining self-sustaining populations through captive breeding is a conservation measure aquariums are striving to achieve.

Although captive birth for females that were captured pregnant from the wild was reported by Gonzalez (2004), this is the first published report of captive birth with a full cycle occurring under human care, including copulation. Thus, considering that up to date there are no data available on the rearing of captive-born shortnose guitarfish, the objective of this study was to report the birth history at the Ubatuba Aquarium and to document for the first time the ideal conditions for the reproductive cycle of *Z. brevirostris*, from copulation to the rearing of young-of-the-year (YOY).

2 | MATERIALS AND METHODS

2.1 | Breeders

The breeders, eight animals in a 1:1 male:female proportion, were transported to the Ubatuba Aquarium in 2017 after being caught in an incidental capture in trawling fisheries carried out in Ubatuba-SP. After a quarantine period, the fish were kept in a shallow tank of 5200 m^2 of area, with no substrate. The enclosure was under recirculation in an 80,000 l system, equipped with two sand filters, ozone injection, biological filter, UV, nitrate filter, skimmer and chiller. Physical and chemical parameters of water were monitored twice a week using a commercial probe (Hanna model HI98194). Water parameters were kept at 31PSU of salinity, 22°C and pH 8.2. Nitrogen levels were measured by commercial tests being adjusted to the values proposed by Mohan and Aiken (2004). The guitarfish were feed frozen shrimp *ad libitum* on a daily basis.

In 2021, after pregnancy was confirmed using ultrasonography, a pregnant female (1.056 kg, 50 cm) was transferred to a maternity system consisting of a 1000 l polyethylene tank in an air-conditioned environment with room temperature maintained at 24°C and a submersible thermostat set at 25°C, a physical filter (polypropylene bag of 150 μm) and a biological filter of fluidized sand. Physical–chemical parameters of water were monitored daily using a commercial probe, and water, which was maintained at 30 PSU, 25°C and pH 8.1. Nitrogen levels were measured by commercial tests to maintain optimal levels, following the values of reference proposed by Mohan and Aiken (2004). If necessary, adjustments were made by additional water exchanges from 20% to 30% of the system volume. The female was feed frozen shrimp *ad libitum* on a daily basis; after feeding, a water exchange of 10% was performed by siphon of the bottom of the tank aiming to remove food remains and excreta.

2.2 | Ultrasound

Once in a tray with water, the female was placed in ventral recumbency. Ultrasonography was performed using a Mindray M6 veterinary ultrasound machine with a 3.5 MHz convex sector/linear scanner (Figure 1). A plastic bag was wrapped around the probe to protect it from damage caused by the guitarfish skin and sea water.

The ovary is located at the anterior end of the body cavity on the left, caudal to the stomach and just cranial to the uterus. In most viviparous rays, only the left ovary is functional (Hamlett, 1999). The uterus, in turn, lies dorsal to the liver and gastrointestinal tract. In *Z. brevirostris* both ovaries and uterus are functional.

2.3 | Newborn care

Birth was reported on 20 April 2020, in autumn, 38 days after the last ultrasound. It is estimated that the gestational period ranged from 9 to 12 months. After birth, three neonate *Z. brevirostris* were kept apart from the adults, as previous attempts of keeping the neonates in the same system with the breeders resulted in bacterial infections, inappetance and death. The neonates were kept in a recirculating system of 1500 l with sand substrate, biological and mechanical filters, heat exchangers and skimmer, in an air-conditioned environment with room temperature maintained at 24°C and a submersible thermostat set at 25°C, a physical filter (polypropylene bag of 150 μm) and biological filter of fluidized sand. The life support system was kept in a separate compartment (sump), to avoid harm to the neonates. Physical–chemical parameters of water were kept the same as the maternity system and monitored accordingly.

The neonates were fed on consecutive attempts of feeding with live *Artemia* sp., amphipods, fish fillets, cut cocked mussel and frozen shrimp fillets, all suitable for the species' mouth size. Feeding was attempted in the mornings and late afternoons when animals showed to be more active. For inert food items, plastic tweezers were used for leading the food to the mouth during morning feedings. In the afternoon, feedings were conducted with no interactions, leaving the items at the bottom of the tank for 20 min. Considering that premature birth may occur, with animals showing considerable amounts of yolk (Figure 2), feeding should be delayed until the complete absorption or until the animals show interest in the items presented.

When feeding was not accepted by the animals for consecutive days, even after live feed alternatives were offered, tube-feeding was

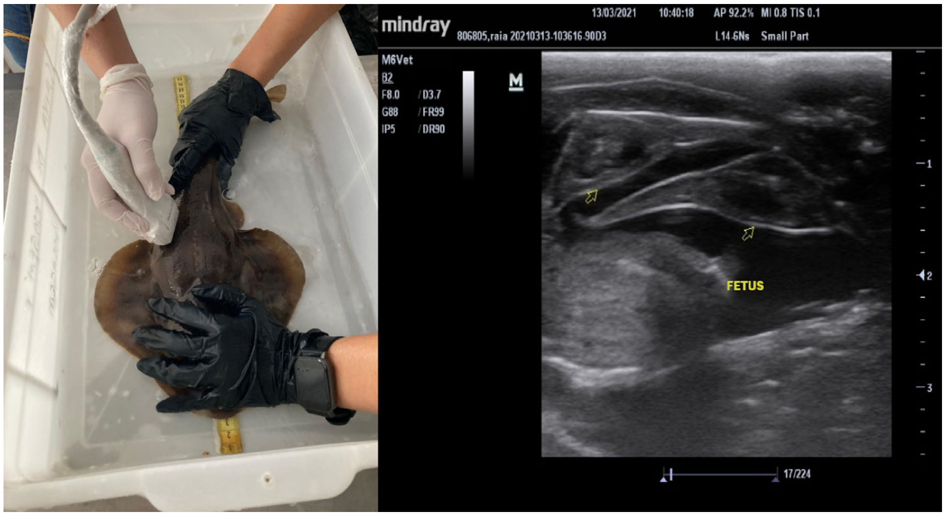

FIGURE 1 The ultrasound procedure, showing the ray in ventral recumbency and ultrasound being performed (left). Fetus on ultrasound indicated by yellow arrows (right)

FIGURE 2 Neonate of *Zapteryx brevirostris* showing absorption of yolk after the healing of yolk sac, with pictures taken 7 days apart

performed once a week, especially when a sharp weight loss was noted. For tube-feeding, a urethral tube no. 6 was cut to a 2 cm probe attached to a 1 ml syringe, which, after emerged in mineral oil, was introduced through the mouth, reaching the stomach. To avoid traumatic injuries, only a small portion of the probe was introduced into the mouth, and it was then expected that the neonates' swallowing reflexes would lead to the probe though the oesophagus. For this procedure, fish fillet, shrimp and cocked mussel were processed and diluted in glycated serum and then strained to obtain a solution that would easily pass through the probe. The size of the probe was determined from the autopsies of previous neonates born at the Ubatuba Aquarium.

2.4 | Newborn data

Total length (TL), disc width (DW) and total weight (TW) were recorded weekly for each neonate, including data recorded for previous birth. In this study, animals from three independent births events were considered: 1 female and 5 males born in 2018, 1 female and 3 males born in 2020 and 2 females and 1 male born in 2021. Measurements were taken using an ichthyometer and a digital scale with precision of 1 g. All measurements were taken before feeding and by the same person, avoiding bias. During the procedure, no sedative or anaesthetic was used as the animals showed tolerance to short periods out of the water.

From the data collected, a growth curve was developed with values from birth to 14 months of age for the remaining juveniles, following a logarithmic regression, and the specific growth rate (SGR) and daily weight gain (DWG) were calculated according to the following equations:

$$\mathrm{SGR}(\%) = ((\ln \mathrm{Wf} - \ln \mathrm{Wi})/\mathrm{noof\ days}) \times 100;$$

$$\mathrm{DWG} = ((\mathrm{final\ weight} - \mathrm{initial\ weight})/\mathrm{noof\ days}).$$

The length-to-weight ratio was calculated by the formula PT $= a^*$ TL^b, where PT $=$ total weight in g; TL $=$ total length in cm; a $=$ intersects with the y-axis; b $=$ regression coefficient. In the length-weight relation, the constant a is related to weight gain and b to the type of growth, with values ranging from 2 to 4.

2.5 | Statistical analysis

The length-to-weight ratio was calculated using the least squares method after logarithmic transformation of the data using the equation log10 PT $=$ log10a $+$ b * log10LT (Ricker, 1975). This transformation also made it possible to compare the regressions of the neonates. For this purpose, an F test of parallelism was performed between the regression lines, which allowed the authors to verify the null hypothesis of the homogeneity of the pending regressions (Valle & Rebelo, 2002). The regression diagnosis was preliminarily performed by checking the subjects of normality and homogeneity of the variances with the F tests. The elaborations were carried out with Microsoft Excel 2016.

2.6 | Ethical statement

This study was approved by SMA/SP AM2856440 and Ethics Committee in the Use of Animals of the Ubatuba Aquarium (no. 03/2021). This study is justified by the need to expand knowledge about the reproduction of elasmobranchs in captivity. The minimum possible number of individuals needed to obtain the information was used.

FIGURE 3 Stillborn *Zapteryx brevirostris* showing incomplete development and externalized yolk sac

3 | RESULTS

At least five parturition events were record in the institution in the past 4 years, with most of them occurring during autumn in the Southern Hemisphere, although births in the spring were also recorded. From these, two abortions were noted, with foetus being expelled before full development (Figure 3). The mean number of embryos per gestation in this study was four, with rare cases of six neonates being born. The majority of neonates were male, with a mean of one female per birth.

From a total of 13 live neonates, the mean ± standard error for weight, TL and disc width at birth were 17.47 ± 1.6 g, 13.25 ± 0.7 cm and 6.53 ± 0.2 cm, respectively. Considering that the animals were born in 2021, data for the first 12 months of development for one male and one female that survived were recorded. The female of 2021, although smaller at birth, showed a significantly higher weight-length ratio than the male ($P < 0.05$). Considering all neonates evaluated from 2018 to 2021, however, the mean weight, as well as mean TL, was higher for females at all births, with 26.15 g and 15.07 cm for females in comparison with 17.09 g and 13.94 cm for males. SGR and DWG data were significantly higher for neonates reared in 2021 ($P < 0.05$) (Table 1).

For previous attempts, growth and daily gains might be expressed as negative values, as the neonates, although accepting food, lost weight until death was recorded. For neonates born in 2018, development was monitored until 20 days after birth, when animals began to die, which, later found in post-mortem examinations, was associated to amoebiasis. In 2020, animals survived to a mean of 50 days; all neonates evaluated that year showed atrophy or total absence of kidneys, probably associated to a malformation or genetic disorders. In 2021, besides a premature female that did not survive, two animals

TABLE 1 Growth data recorded through different attempts of rearing *Zapteryx brevirostris* at the Ubatuba Aquarium in 2018, 2020 and 2021

Year	Sex	SGR	DWG	DAB	Final weight (g)	Final TL (cm)
2021	Female	0.32613	0.0963	297+	46.1	18.6
2021	Male	0.13176	0.0306	297+	28.1	15.8
2020	Female	−0.1741	−0.031	50	17.04	13.10
2020	Male	−0.1356	−0.025	50	18.10	14.10
2020	Male	−0.5211	−0.087	50	14.58	13.60
2020	Male	−0.1209	−0.023	50	18.45	13.90
2018	Female	0.43778	−0.07	20	15.30	13.5
2018	Male	0.53344	−0.085	20	15.10	13.5
2018	Male	0.03195	−0.005	20	15.60	13.9
2018	Male	0.64606	−0.1	20	14.50	13.5
2018	Male	1.07329	−0.17	20	14.20	13.6
2018	Male	0.19357	−0.03	20	15.20	13.6

Abbreviations: +: indicates that animals are still alive; DAB: days after birth, referring to the day of the last biometry; DWG: daily weight gain; SGR: specific growth rate; TL: total length.

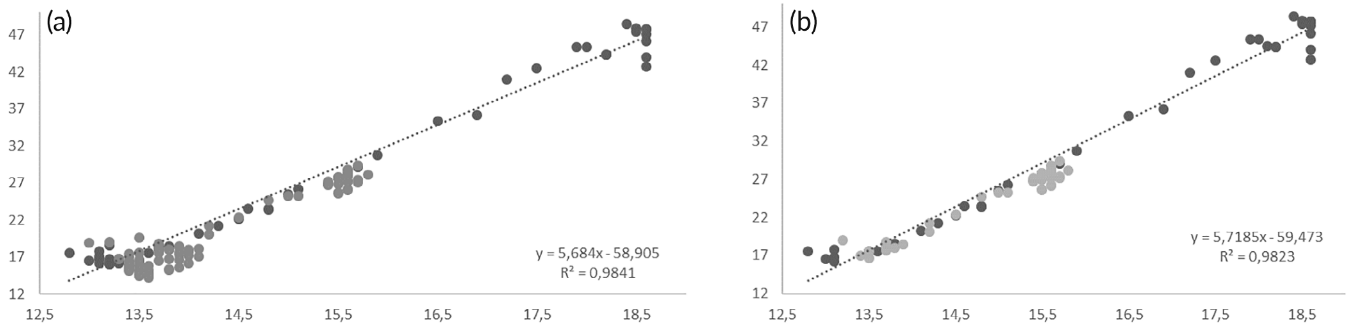

FIGURE 4 Length-weight relation for male and female *Zapteryx brevirostris* neonates reared in the Ubatuba Aquarium in 2021 (left). ● Female 2021. ● Male 2021. ········ Linear (Female 2021). Length-weight relation for male and female *Z. brevirostris* neonates reared in the Ubatuba Aquarium in all attempts (2018, 2020, 2021). *Y*-axis refers to weight (g), and *X*-axis refers to total length (cm) (right).

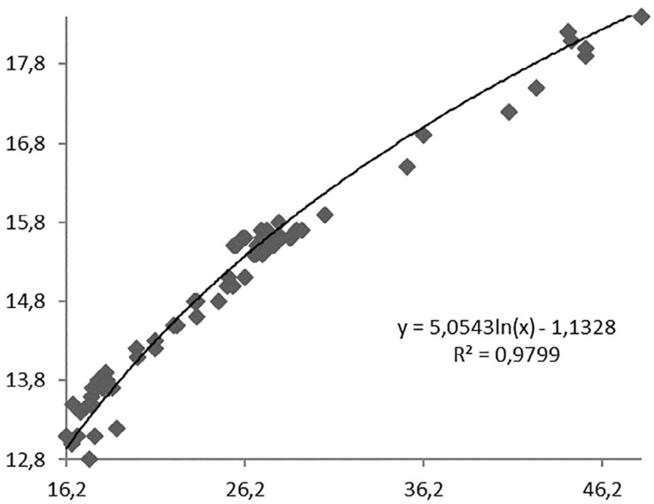

FIGURE 5 Logarithmic regression of growth curve for 2021 neonates *Zapteryx brevirostris* reared at the Ubatuba Aquarium, sexes combined. *Y*-axis refers to weight (g), and *X*-axis refers to total length (cm)

were evaluated along the first year of life. Both animals reached 1.5 years of age and are still healthy and growing well.

Comparisons among different litters, reared in 2018, 2020 and 2021, were also analysed showing a pattern for females to develop faster than males, which was better observed in the last attempt once more data were collected through time (Figure 4, left). Nonetheless, by grouping the data from all neonates, it can be assured that weight gain for males tends to be below the tendency line expected for females at the same size (Figure 4, right).

From the current data, a growth curve was plotted following a logarithmic model (Figure 5). Considering the values obtained in the equation, when the value of *b* is below 3, it is expected that the growth is negative allometric, indicating that the increase in length is higher than the growth in other dimensions, in which individuals will appear thinner and longer. Although the modelling suggests a continuous growth, both male and female stagnated in growth and weight gain from the 4th and 6th months after birth, respectively (Figure 6). Despite that, a clear improvement in rearing conditions can be assessed by the comparison of growth curves throughout the years (Figure 7).

Aiming to estimate the growth to maturity, data from adult *Z. brevirostris* housed in the institution as well as published morphometric data from adult animals were included in the curve (Figure 8). The results indicate slow rates of development and a clear gap of data still to be filled.

4 | DISCUSSION

The reproduction of elasmobranchs in captivity is rarely documented, being restricted to reports with little information (Gonzalez, 2004; Santos-Ribeiro & Amorim, 2021; Paiva *et al*., 2020). Although captive birth for females that were captured pregnant from the wild was reported by Gonzalez (2004), this is the first published report of captive birth with copulation occurring under human care. Births for the *Z. brevirostris* have been recorded in the Ubatuba Aquarium since 2002 (Baldassin *et al*., 2008; Cavalcante *et al*., 2016). From previous attempts of newborn care, the species seems to require a substrate that allows the animals to bury themselves, a natural behaviour that promotes greater welfare, once representing a camouflage behaviour against predators (Sousa Lima *et al*., 2021). When reared in glass aquariums, animals were constantly demonstrating a "shaking" behaviour, which latter was related to a movement of burying, behaviour that was also stated by Gonzalez (2004). Although studies report that the maintenance of adult *Z. brevirostris* with no substrate might lead to a 100% survival rate, weight loss might be observed, indicating a positive effect of a sand substrate (Sousa Lima *et al*., 2021).

Regarding the feeding routine, a suitable diet for the specie should be based on crustaceans and polychaetes, considering that *Z. brevirostris* inhabits selectively sandy bottoms (Barbini *et al*., 2011). Based on the last three attempts of rearing neonates, the authors strongly advice the use of frozen post larvae of marine shrimp and live amphipods as a suitable primary food item. Even though there was acceptance for alternative food items such as fish and shrimp fillets in the first rearing attempt, the weight gain observed showed lower

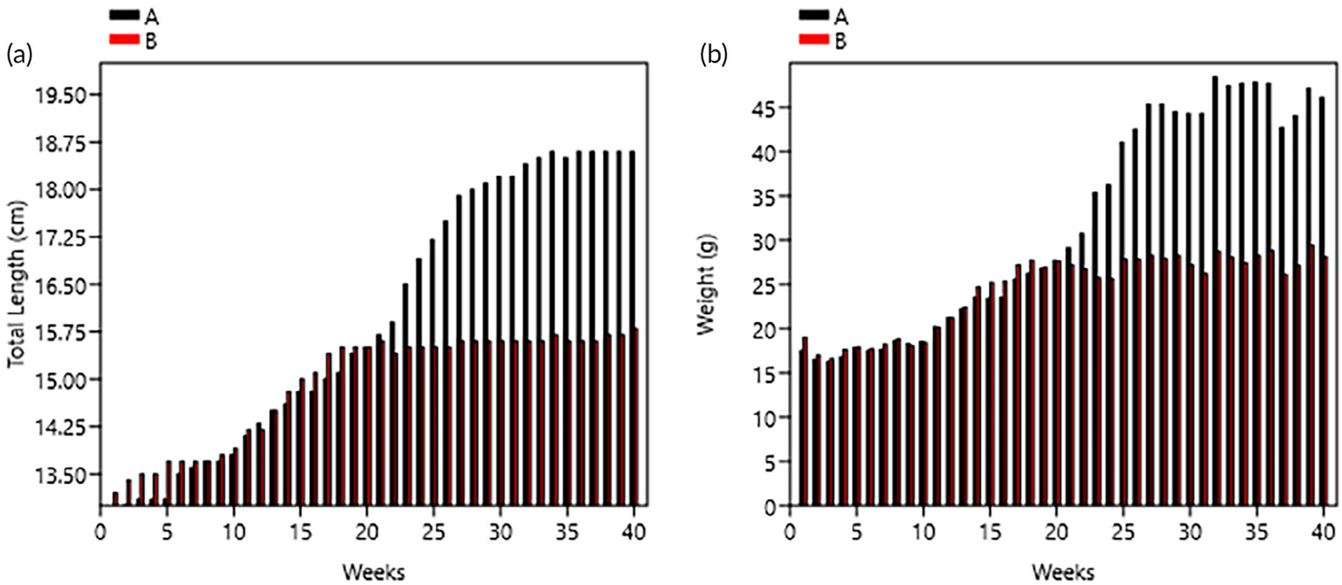

FIGURE 6 Growth through time for female (a) and male (b) neonates *Zapteryx brevirostris* reared at the Ubatuba Aquarium in 2021. *Y*-axis refers to total length (cm) and *X*-axis refers to time (40 weeks) (left). Weight gain through time for male and female neonates in 2021. *Y*-axis refers to total weight (g), and *X*-axis refers to time (40 weeks) (right). ■ A. ■ B

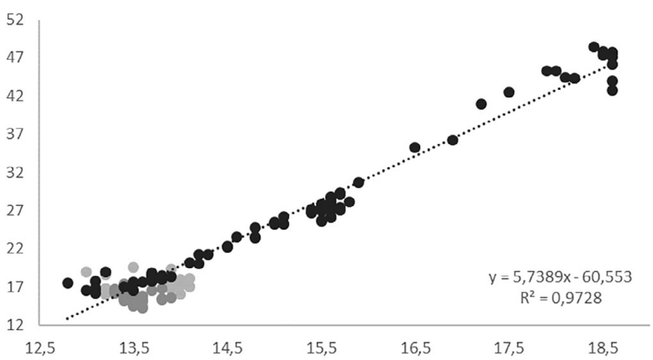

FIGURE 7 Length-weight relation for neonates *Zapteryx brevirostris* reared at the Ubatuba Aquarium in all attempts (2018, 2020, 2021), sexes combined. *Y*-axis refers to weight (g), and *X*-axis refers to total length (cm). ● 2020. ● 2018. ● 2021. ········ Linear (2021)

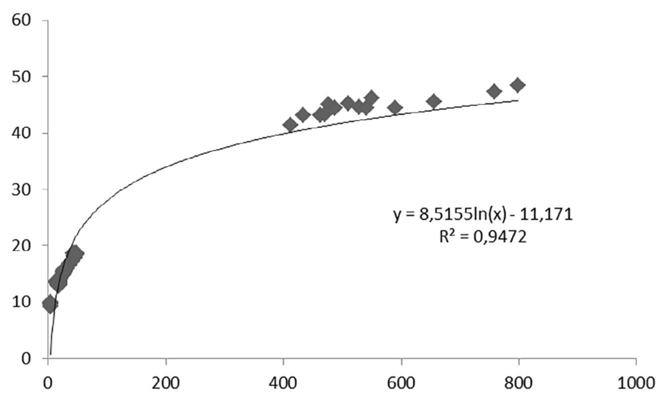

FIGURE 8 Length-weight relation data of *Zapteryx brevirostris* extrapolated from birth to adulthood accounting data from animals reared at the Ubatuba Aquarium at all attempts and published mean morphometric data for the species, sexes combined. *Y*-axis refers to total length (cm), and *X*-axis refers to weight (g)

nutritional use by the neonate, probably due to lack of appropriate enzymes for digesting such items.

Aiming to stimulate feeding, animal might be put in a restricted area, such as a plastic tray, to reduce the foraging space, increasing the chances of the neonate to encounter the prey. Another strategy that might work is to direct the animals above food on a glass surface in a way that allows the keeper to assure the feeding.

Although natural periods of food deprivation might be common for many animals, few species can survive prolonged starvation without affecting homeostasis (Zaldúa & Naya, 2014). Knowing that prolonged periods of starvation in elasmobranchs may lead to hepatic steatosis with the presence of inflammatory infiltrate, ballooning hepatocytes and necrosis, techniques for forced feeding in neonates with prolonged inappetence might be necessary, preventing dehydration and extreme body weight loss. Considering that tube-feeding is a potentially stressful procedure, it should be delayed as long as possible, without getting to the point of no return, where the elasmobranch cannot recover from the chronic lack of nutrients. Thus, it is advised to start tube-feeding as a last resource, when sharp decreases in body weight is noted and even attempts with live feed is refused.

When attempted as a last resource in 2020, the use of tube-feeding for neonates of shortnose guitarfish promoted weight gain for all animals subjected to this protocol. After the death of one individual from causes unrelated to tube-feeding, the absence of traumatic injuries in the gastrointestinal tract and the presence of food content in the stomach and intestinal segments was observed, reinforcing the possibility of using the technique, even in such small and delicate species. Nevertheless, it should be clearly stated that those results should be interpreted with caution, considering that animals that underwent this practice did not survive, even when presenting weight gain. Thus, the causes of inappetence should also be explored to guarantee survival.

Elasmobranchs are organisms with a K-strategist tendency, presenting slow growth, late sexual maturity and low fecundity (Caltabellotta *et al*., 2019; Carmo *et al*., 2018; Colonello *et al*., 2011). As reported in the literature, fully grown *Z. brevirostris* reaches a total size of 59 cm for males and 65 cm for females, reaching maturity between 42 and 43 cm in TL (Colonello *et al*., 2011). The size at first sexual maturation is 420 mm TL for females and 437 mm TL for males (Batista, 1987; da Silva Batista, 1987). Although diapause is expected for the species, the gestational period ranged from 9 to 12 months for all births recorded in this study (Colonello *et al*., 2011). Comparatively gestation period of *Z. exasperata* is 3 to 4 months, but diapause might also occur (Colonello *et al*., 2011; Villavicencio-Garayzar, 1995).

In this study, birth was recorded in autumn and spring. For free-ranging animals, although autumn might be considered the period of copulation and summer the birth season for some authors, Batista (1991) has indicated that the reproductive cycle in the wild can be desynchronized, with pregnant females all over the year (Abilhoa *et al*., 2007; Carmo *et al*., 2018; Wosnick *et al*., 2018). The differences in the reproductive cycle might be related to a loss of seasonality in captivity, once energy intake, temperature and photoperiod are constant. Other authors, however, might argue that variations in the reproductive cycle of the same species might be common, reflecting a temporal variation in the development of the gonads, copulation period and gestation (Colonello *et al*., 2011). Yet, Wyffels *et al*. (2022) discuss that, under managed care, environmental, social, demographic and/or physiological differences from *in situ* populations, besides endocrine dysfunction and poor gamete quality, are likely to contribute to shifts in reproductive success in captivity.

The mean number of neonates per gestation in this study was four, with rare cases of six live guitarfishes being born. According to Batista (1991), for the species the maximum fecundity observed in wild animals was six embryos, which is affected by the size of the female. In a more recent study, however, Abilhoa *et al*. (2007) has observed from four to nine embryos per pregnant female, although no birth records were cited.

Regarding growth, wild specimens of *Z. brevirostris* evaluated in other studies, showed a negative allometric growth ($b < 3$), which means that the species invests more in its growth in length than in mass, which agrees with the results found in this study (Pasquino *et al*., 2016). Size at birth was also in accordance with literature, with values among 13 cm, as expected *for Z. brevirostris*, which neonates' ranges from 13 to 16 cm in length (Wosnick, Rios, *et al*., 2019; Caltabellotta *et al*., 2019).

The difference in growth between the sexes presented in this study is well documented among elasmobranchs, with females being generally larger than males, including the species *Z. brevirostris* (Colonello et al., 2011; Carmo *et al*., 2018). In fact, Araya and Cubillos (2006) have demonstrated that for 7 out of 10 species, size at different ages is expected to be higher for females, as females reach maturity at a larger size than males. Although the greater length of females is an expected occurrence for viviparous species, characteristic of the species *Z. brevirostris* (Bornatowski *et al*., 2009), normally, for elasmobranchs females grow at slower rates and mature at later ages than males (Simpfendorfer, 2000; Smith *et al*., 2007). Furthermore, despite differences in growth rates being common for elasmobranchs, these differences are most commonly observed at ages close to maturity (Simpfendorfer, 2000). Considering that the mean number of females per birth in this study was low, no conclusions could be drawn.

Growth in elasmobranchs is often characterized by the Von Bertalanffy growth function (VBGF), where the change in weight or length over time is expressed as a function of the asymptotic (maximum) weight or length in relation to age. Considering the data in this study are mostly concentrating on young animals, it is not possible to have an asymptotic weight figure and no data are found in literature on the specific growth rate on elasmobranchs.

Few information is available on the captive breeding of elasmobranchs, development and survival of newborns. This study illustrates an opportunity for public aquariums to engage breeding programmes aimed at a sustainable animal population mostly for small threatened species. In a long-term scenario, those animals, besides being a constant source of information for growth and rearing protocols, represent the possibility for implementation of integrated and *ex-situ* conservation programmes. Nevertheless, although great results were achieved, mortality rates for neonates of the species were high at the first two attempts of rearing, in 2018 and 2020. Thus, there are clear limitations for working with neonates, and improvements in rearing protocols are needed. In addition, general growth rates for elasmobranchs are low, in a way that long-term studies are necessary to elucidate gaps in the knowledge of the species. Therefore, the collaborative effort with other institutions would be a proper solution for enhancing protocols and increasing the number of individuals being evaluated.

Meanwhile, considering the increasing fishing pressure to the species in southern Brazil, age and growth studies are fundamental for the success of fisheries management, as they act as a basis for estimating important biological variables and improve knowledge of a species life cycle so that a more efficient and sustainable management can be carried out. In view of the current gaps in the knowledge of the biology of the *Z. brevirostris*, mostly concerning the growth curve from neonate to juvenile, although more specific studies need to be carried out, this study provides important data upon the development of juveniles, as well as directions for captive breeding of the species.

The sustainability of the exploitation of aquatic resources is an issue that has been considered in recent studies (Bergamo *et al*., 2021; Kuhnen *et al*., 2019). Brazilian technologies have been developed to contribute for sustainability advances in captive marine fish. Examples of such technologies are the use of new materials in net tanks to reduce environmental impacts (Santos *et al*., 2020) and innovative food management practices to reduce feed waste in recirculation aquatic systems (Sousa *et al*., 2019; Spandri *et al*., 2020). Reproduction of elasmobranchs in captive is still little known and studied. Nonetheless, the results presented here reinforce the importance of future studies on the elasmobranch reproduction in public aquariums.

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AUTHOR CONTRIBUTIONS

B.L.M., L.O.C. and R.E.K. were responsible for data collection, statistical analyses and interpretation of data and drafted paper. H.G.N. helped with analysis, study design, interpretation of data and financial support. E.G.S. was responsible interpretation of data, statistical analyses and wrinting supervision . All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

CODE AVAILABILITY

Not applicable.

ORCID

Bruna Larissa Maganhe https://orcid.org/0000-0001-9064-8596
Laura de Oliveira Camilo https://orcid.org/0000-0001-9228-970X
Rodrigo E. Kurokawa https://orcid.org/0000-0001-6732-5502
Hugo Gallo Neto https://orcid.org/0000-0001-7769-5638
Eduardo Gomes Sanches https://orcid.org/0000-0001-9976-9271

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