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Original article

Age and growth of *Zapteryx brevirostris* (Elasmobranchii: Rhinobatidae) in southern Brazil

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Age and growth studies are fundamental to successful fisheries management. *Zapteryx brevirostris* (Müller & Henle, 1841) is distributed off the Brazilian continental shelf and this species is assessed as "Vulnerable" in the Red List of the International Union for the Conservation of Nature (IUCN). Thus, the objective of this study was to present previously unknown information about the age and growth of *Z. brevirostris* that can be used for its management, conservation, and fisheries. A total of 162 specimens were sampled, with total lengths (TL) varying between 35.7 cm and 56 cm. The vertebrae were embedded in resin, sectioned in cuts with 0.5 mm thickness and the growth bands of the vertebrae were read under a light microscope. In the studied area, *Z. brevirostris* ages were estimated from 4 to 10 years according to vertebrae patterns. The species reaches its maximum asymptotic size (*Linf*) around 56 cm (56 cm for females and 50.37 cm for males). This is the first estimate of age and growth for a species of the *Zapteryx* genus, and the results support the hypothesis that this ray requires future management conservation, particularly due to its slow growth rate and consequent susceptibility to overexploitation.

Keywords: Back-calculation, Conservation, Growth rate, *k* value, Von Bertalanffy curves (VBGF)

Estudos de idade e crescimento são fundamentais para o sucesso da gestão pesqueira. *Zapteryx brevirostris* (Müller & Henle, 1841) distribui-se pela plataforma continental brasileira, sendo classificada como "Vulnerável" no livro vermelho da IUCN (International Union for the Conservation of Nature). Assim, o objetivo deste estudo foi apresentar informações previamente desconhecidas sobre a idade e o crescimento de *Z. brevirostris* que podem ser utilizados para sua gestão, conservação e pescas. No total foram amostrados 162 espécimes, com comprimento total (CT) variando de 35.7 cm a 56 cm. As vértebras foram incluídas em resina e seccionadas num corte com cerca de 0.5 mm de espessura, e as bandas de crescimento das vértebras foram lidas com microscópio de luz transmitida branca. Na área estudada, *Z. brevirostris* possui idades estimadas entre os 4 a 10 anos de idade, de acordo com seu padrão de vértebras. A espécie atinge seu *Linf* (comprimento máximo assintótico) em torno dos 56 cm (56 cm para fêmeas e 50.37 cm para machos). Essa é a primeira estimativa dos parâmetros de idade e crescimento para uma espécie do gênero *Zapteryx*, e os resultados obtidos corroboram a hipótese de que a espécie requer uma gestão de conservação adequada, devido sobretudo à sua lenta taxa de crescimento e consequente suscetibilidade à sobre-exploração.

Palavras-chave: Conservação, Curva de von Bertalanffy (VBGF), *k* value, Retrocálculo, Taxa de crescimento.

Introduction

Age and growth studies are fundamental to successful fishery management, since they act as a base to estimate important biological variables (Vazzoler, 1981; Campana, 2001; Goldman, 2004). Most of the analytical methods of stock evaluation deal mainly with age composition data (Sparre, Venema, 1997), where precise, exact and quality information are the key to obtaining growth estimates and other vital rates, such as natural mortality and longevity.

The determination of the age of a fish is usually conducted by counting seasonal growth marks present in several hard calcified structures. Most age and growth studies use otoliths or scales for teleosts. Regarding elasmobranchs, due to the lack of these structures, vertebrae and dorsal spines are most widely used to determine age (Campana, 2001; Goldman, 2004).

Elasmobranchs have become important fishery resources in recent years (Barker, Schluessel, 2005), whether through directed fishing or as bycatch (Shotton, 1999; Stevens *et al*., 2000). However, this increase in elasmobranchs' fisheries has not often been accompanied by information about the biology and ecology of these species (Stevens *et al*., 2000). Elasmobranchs generally possess a *K-style* life strategy, with life cycles characterized by low growth rates and low reproductive potential (Cortes, 2000; Coelho, Erzini, 2002, 2006). These characteristics make this group extremely vulnerable to fishery pressure, and overexploitation can often

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occur even at relatively low levels of fishing mortality (Smith *et al*., 1998). Hoff, Musick (1990) pointed out the lack of information regarding the age and growth of elasmobranchs as a limiting factor in the development of management plans, and Gomes *et al*. (2010) and Natanson *et al*. (2014) corroborates this assertion stating that data about age, growth, and maturity in elasmobranches are generally limited.

The species *Zapteryx brevirostris* (Müller, Henle, 1841) is distributed from the Brazilian continental shelf in Rio de Janeiro to the south of the province of Buenos Aires (Argentina) (Castello, 1971; Figueiredo, 1977; Menni, Stehmann, 2000). It is described as preferring cold waters (Gomes *et al*., 2010) and is the only species of the *Zapteryx* genus in the Atlantic Ocean (Batista, 1991). This species is frequently found in coastal waters (Figueiredo, 1977), reaches a maximum size of 59 cm TL (total length) for males and 65 cm TL for females (Colonello *et al*., 2011) and attains maturity between 42 and 43 cm TL (Batista, 1991; Santos *et al*., 2006). The species is commercially exploited by small-scale fishing on the coast of the state of Paraná (southern Brazil) (Santos *et al*., 2006; Bornatowski *et al*., 2009) and it is described as "vulnerable" in the red list of the International Union for the Conservation of Nature (IUCN) (Vooren *et al*., 2006).

In Brazil the small-scale fisheries are growing, increasing the pressure on this species and enlarging the gaps in the biological knowledge of the elasmobranchs species. The increase in studies about this species life cycle is very necessary to enable a more efficient and sustainable management plan. Thus, the objective of this study was to present previously unknown information about the age and growth of *Z. brevirostris* that can be used for its management, conservation, and fisheries.

Material and Methods

Sampling. The collection of biological material was carried out in collaboration with the small-scale fishery on the coast of the state of Paraná, and occurred between May 2012 and November 2013. The small-scale fishers on this coast work in estuarine environments and open sea. The practices carried out in open sea by these communities consist especially of fishing using bottom otter trawls (with boards or doors), set nets and "caceio" nets. The set nets usually use 16 to 22 cm mesh sizes (the type used for data collection in this paper) and generally catch a greater diversity and a larger number of elasmobranchs than with other mesh sizes, with *Z. brevirostris* being the most abundant elasmobranch species (Robert, 2012).

As soon as the specimens were collected by a fisherman, they had their total length (TL - measurement in centimeters from the nose to the tail) measured and their sex determined by the presence or absence of claspers in males. The specimens were then anesthetized by medullary section and a section of 3 to 5 vertebrae were extracted from the region below the dorsal fin. The vertebrae were duly labeled and frozen until laboratory processing.

Preparation of the samples. In the laboratory, all organic residues from the vertebrae were extracted using scalpel and tweezers, after having individualized each vertebra. The vertebrae were then cleaned based on the following protocol: 5 minutes in bleach (commercial sodium hypochlorite), rinsed in water, manual cleaning of the organic remains using tweezers, 3 minutes in bleach and, lastly, tap water to eliminate bleach residues. The vertebrae were then placed and stored in 70% ethanol.

In order to facilitate the sectioning, and given their small size, the vertebrae were embedded in polyester resin. To accomplish this, the vertebrae were dried under a paper towel at room temperature about one hour before embedding in the resin. After being embedded in the resin, the vertebrae were sagitally sectioned using a low speed Buehler IsoMet cutter (with two saws spaced 0.5 mm apart), resulting in a cut similar to a "bowtie". These cuts were stained using a saturated solution of crystal violet for 3 minutes. They were then left to dry between absorbent papers and pressed by two microscope slides for 24 hours to keep the cut from rolling up. Once dry, the cuts were placed on microscope slides using Cytoseal 60.

The growth bands of the vertebrae were read using dissecting microscope with transmitted white light. Following the Caillet *et al*. (2006) methodology, two types of growth bands were considered in the cuts, a wider opaque band and a narrower translucent band. Each pair of bands was considered a ring. Three independent readings were carried out for each vertebra, without previous knowledge of the TL, sex or the number of rings of each individual, estimated in earlier readings. In order to calculate the precision of age estimates, the techniques of index of average percent error (APE), defined by Beamish, Fournier (1981), and the coefficient of variation (CV), defined by Chang (1982), were used.

Age and growth. In this study, the back-calculation techniques of body proportional hypothesis (BPH), Dahl-Lea, Fraser-Lee and scale proportional hypothesis (SPH) (Francis, 1990) were used to obtain the lengths of individuals at previous ages, since in the analyzed samples, length classes under 35 cm TL were not obtained. Back-calculation established linear regressions between the total length of the animals and the radius of the vertebrae and between the radius of the vertebrae and the total length for the sexes together and separately. These values obtained through back-calculation were used to produce the von Bertalanffy growth curves (VBGF).

In order to determine the size of the specimens at age zero (birth), ten embryos with near birth size (14 cm TL) (Carmo, Fávaro *in prep*.) had their vertebrae removed, cleaned and digitally microphotographed. The open-source Image J software (Abramoff *et al*., 2004) was used to take measurements that were then used to define as the birth band (age 0) in the remaining sample.

The von Bertalanffy growth model is the most commonly used equation in studies of age and growth of fish in general, including the Chondrichthyes (Cailliet *et al*., 2006). The growth curve to be studied for the species *Z. brevirostris* followed the traditional von Bertalanffy growth model and a modified version of the VBGF model with fixed size at birth (VBGF with fixed L_0), where: Von Bertalanffy growth model (VBGF):

$$L_t = L_{inf}\,(1 - e^{-k(t-t0)})$$

Modified VBGF model with fixed size at birth (VBGF with fixed L_0):

$$L_t = L_{inf}\,(1 - be^{-kt})$$

where: $b = (Linf - L_0)/Linf$. Lt: size (TL, cm) at age t (year); $Linf$: maximum asymptotic size (TL); L_0: size (TL, cm) at birth; k: growth coefficient (year^{-1}); t_0: theoretical age (year) at size zero.

Fixed size at birth was determined based on Carmo, Fávaro (*in prep*.) as being 14 cm TL, and confirmed by Gomes *et al*. (2010) who verified neonates between about 13 and 16 cm long.

All of the growth models were created in the open-source software R (R core team, 2014) using nonlinear least squares (NLS). The parameters were calculated for each growth model, with the respective standard errors (SE) and confidence intervals (CI, 95%). The plots were created in R, in some cases using the package ggplot2 (Wickham, 2009).

The results of the sizes-at-age obtained by the VBGF growth curve and produced from the results of the different back-calculation techniques, were tested for normality using the Lilliefords test (Lilliefors, 1967), and tested for homogeneity of the variances using Levene tests (Levene, 1960). The back-calculation method is used to fill the gaps of a sample with reduced size in certain classes (*e.g.* young individuals), when the sample size is small or if the samples were not obtained every month, thus obtaining a reliable value (Goldman, 2004). Additionally, it is a robust method that increases the quantity of information of the sample and also allows the monitoring of mean growth rates of distinct age groups (Smith, 1983), using the proportionality between the size of the fish and the radius of the structure (Whitney, Carlander, 1956; Goldman, 2004). Since the assumption of normality was not verified for all age classes, nonparametric (Kruskal-Wallis) tests were used to verify significant statistical differences between the mean lengths at each age. The difference between the sexes was also tested using these hypothesis tests.

In order to evaluate the adequacy of the model to the data and the quality of the fit, the Akaike information criterion (AIC) (Akaike, 1974) was calculated for each of the models created, including the VBGF growth curves and VBGF with fixed L_0. The model with the best fit was defined as that which presented the lowest AIC value (Katsanevakis, 2006).

The likelihood ratio test (LRT), as defined by Kimura (1980) and recommended by Cerrato (1990), was used to compare the growth curves of males and females. It tested the null hypothesis that there are no differences in growth parameters of males and females. This test was also used among the four back-calculation techniques, grouped two by two, to observe if they presented significant differences.

Results

A total of 162 specimens of *Z. brevirostris*, 71 females (44%) and 91 males (56%), were sampled. The length of the sampled individuals varied from 35.7 cm to 56 cm TL (the largest female: 56 cm; the largest male: 50.37 cm), with mean size in females reaching 46.15 ± 2.86 cm (mean + SD) and in males 44.81 ± 2.70 (mean + SD). The frequency of occurrence of the specimens was greater in the intermediate size classes, with few individuals in the maximum and minimum size classes (Fig. 1).

The graph obtained between TL and size of the radius of the vertebra for the grouped sexes suggests a direct relationship between the growth of the animal and the growth of the vertebra (Fig. 2). In the sample that was obtained, the analyzed specimens presented ages varying from 4 to 10 years, for both males and females. In terms of precision indexes in the age estimates, the APE was estimated to be 9.71 and the CV was estimated to be 13.7.

The values of the mean sizes at each age, obtained through the several back-calculation techniques showed that these sizes did not differ statistically except at ages 9 and 10 for the grouped data, and at ages 8 to 10 for the sexes separately (Tab. 1).

In the VBGF curves for the values directly observed from the samples (vertebrae), there were some convergence problems in the models, with the values estimated to present elevated standard errors and unreasonable values. Therefore, the study accepted only the values obtained through back-calculation using the four techniques described above (Tab. 2). The Kimura test, carried out among the four back-calculation techniques used, revealed a $P \leq 0.05$, showing that its results presented significant differences in relation to the VBGF curves obtained.

In terms of goodness of fit of the models (using the AIC), regarding the estimated growth curves, the three-parameter VBGF curve (in the grouped data and for males and females) presented the lowest AIC, and therefore the best quality of fit of the model, justifying the preference for discussing the results obtained with the three-parameter VBGF curve (Tab. 2). The Kimura test was carried out in the four back-calculation techniques used, and significant differences were found between the VBGF growth curves and between the sexes ($P \leq 0.05$). In turn, the VBGF curve obtained by the Fraser-Lee technique also presented lower AIC values and in general biological parameters that are more feasibly observed in nature (for grouped data, and for males and females separately) and was thus chosen as the most feasible and final growth curve for the species. Note that the AIC can be used only to compare different models within the observed values or within the different back-calculation techniques due to different sample sizes using each technique. Similarly, the AIC can only be used to compare models only within each sex (or for the sexes combined) as the sample size is different for each sex.

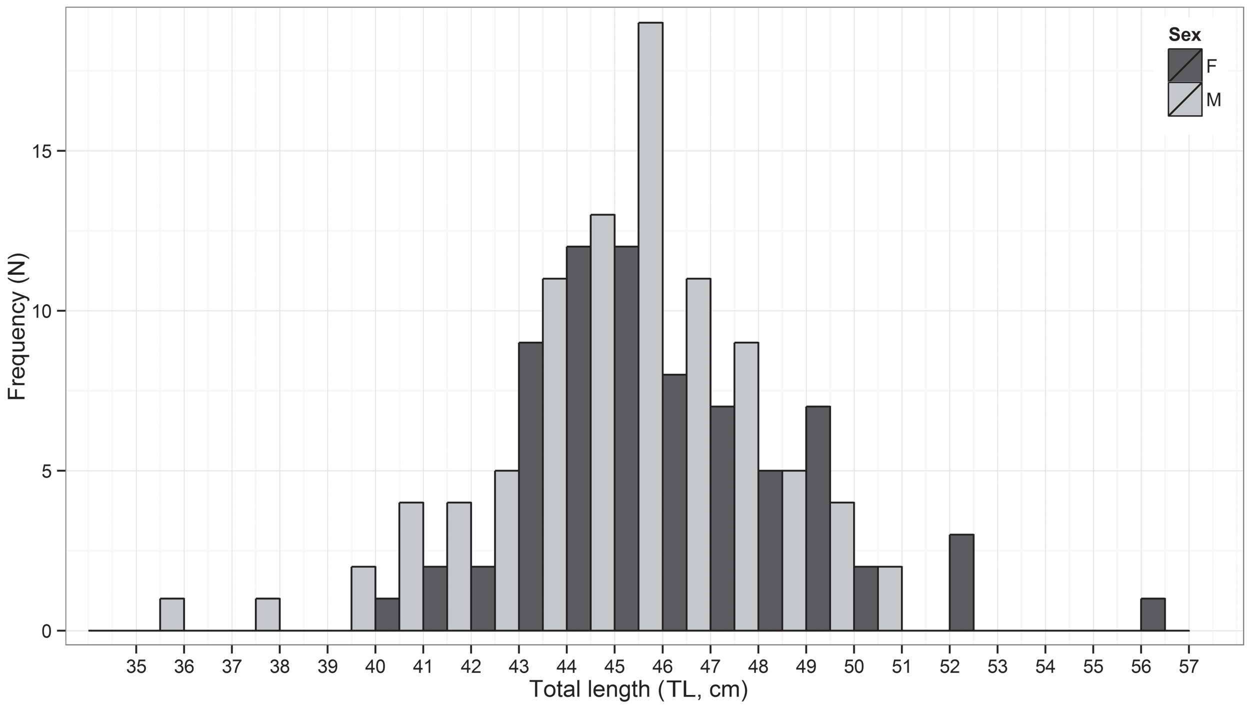

Fig. 1. Distribution of length frequencies (1cm TL size classes) of the sample of *Zapteryx brevirostris* collected in the southern coast of Brazil and used in this study. M refers to males and F to females.

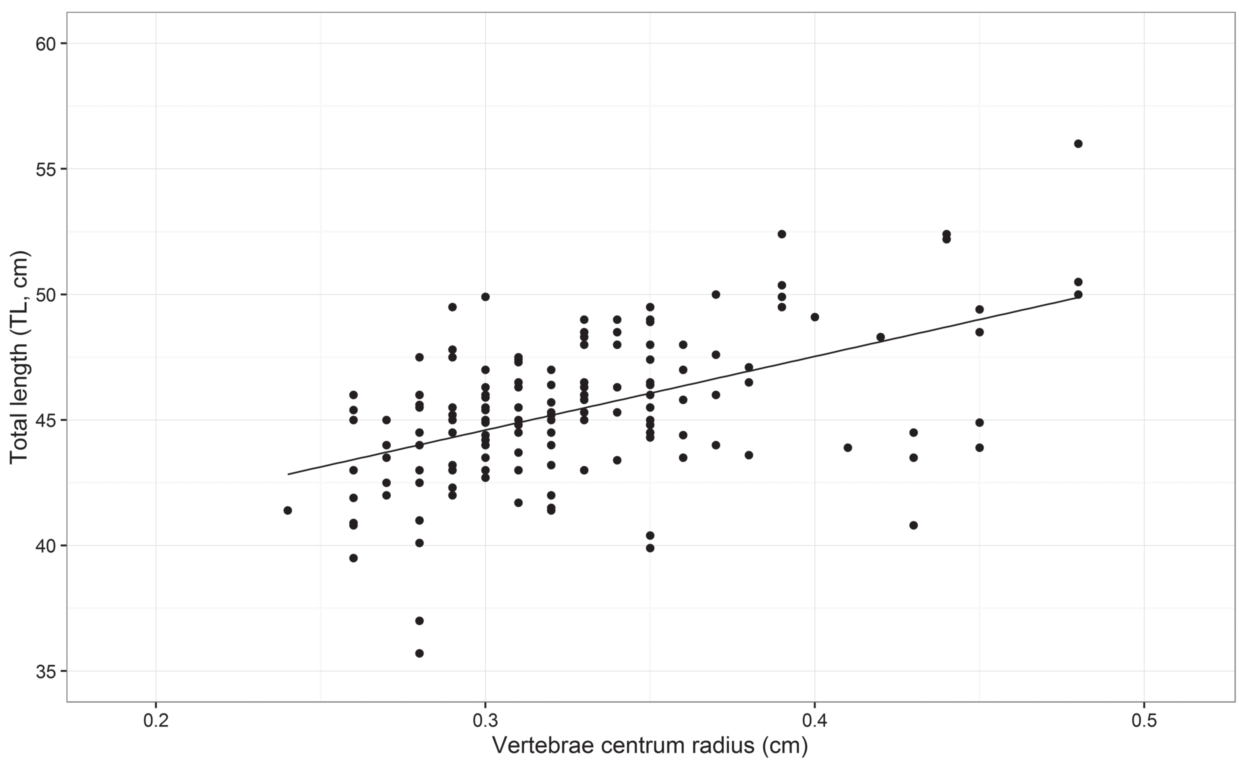

Fig. 2. Relationship between total length (TL, cm) and radius of the vertebra (cm) for *Zapteryx brevirostris* with the sexes grouped, using free-swimming adult individuals. The line represents a linear regression ($R^2 = 0.75$).

Tab. 1. Result of the Kruskal-Wallis test for mean sizes at ages obtained by the different back-calculation techniques. The ages that did not present statistical differences with α = 0.05 are represented in bold.

Age	Grouped		Females		Males		Mean TL according to each technique (grouped sexes)			
	x^2	P value	x^2	P value	x^2	P value	BPH	Dahl Lea	Fraser Lee	SPH
0	555.91	P ≤ 0.05	240.2	P ≤ 0.05	317.35	P ≤ 0.05	19.98	7.14	18.93	13.99
1	529.85	P ≤ 0.05	220.78	P ≤ 0.05	309.53	P ≤ 0.05	23.45	12.39	22.55	18.29
2	420.62	P ≤ 0.05	168.87	P ≤ 0.05	252.79	P ≤ 0.05	26.86	17.53	26.11	22.51
3	264.43	P ≤ 0.05	110.98	P ≤ 0.05	159.56	P ≤ 0.05	30.40	22.89	29.81	26.91
4	143.96	P ≤ 0.05	70.71	P ≤ 0.05	80.07	P ≤ 0.05	33.90	28.18	33.47	31.25
5	69.25	P ≤ 0.05	43.3	P ≤ 0.05	31.95	P ≤ 0.05	36.87	32.67	36.57	34.94
6	41.81	P ≤ 0.05	27.61	P ≤ 0.05	18.01	P ≤ 0.05	38.90	35.67	38.69	37.42
7	23.2	P ≤ 0.05	14.48	P ≤ 0.05	9.28	P ≤ 0.05	40.53	38.04	40.39	39.41
8	11.39	P ≤ 0.05	6.85	**0.07684**	5.23	**0.1558**	41.92	40.06	41.83	41.08
9	5.41	**0.1439**	4.39	**0.2221**	1.82	**0.6111**	42.85	41.50	42.79	42.25
10	0.97	**0.8095**	1.3	**0.7288**	3	**0.3916**	44.12	43.31	44.09	43.76

Tab. 2. Growth parameters estimated for *Zapteryx brevirostris* (grouped sexes, and females and males separately), obtained with the VBGF growth curve and the VBGF with fixed size at birth (L_0 = 14 cm TL). The parameters are given for each model, with their respective standard errors (SE) and 95% confidence intervals (CI).

DATA		AIC	Parameter	Estimated value	SE	CI	
						higher	lower
GROUPED	Observed Values	802	Linf	47.9	16.0	16.2	79.6
			k	0.16	0.87	-1.23	1.44
			Lo	-20.71	117.55	-252.88	211.46
	Estimated Values Lo Fixed	801.10	Linf	45.7	0.4	45.1	46.4
			k	0.74	0.14	0.46	1.01
	BPH	6565.38	Linf	56.0	2.0	52.1	59.8
			k	0.12	0.01	0.1	0.14
			Lo	-3.48	0.18	-3.83	-3.14
	BPH Lo Fixed	7100.39	Linf	45.0	0.6	43.9	46.1
			k	0.27	0.01	0.25	0.29
	Dahl Lea	6785.06	Linf	58.1	2.1	54.0	62.2
			k	0.12	0.01	0.11	0.14
			Lo	-2.11	0.1	-2.3	-1.91
	Dahl Lea Lo Fixed	6790.11	Linf	61.0	2.2	56.7	65.4
			k	0.11	0.01	0.1	0.13
	Fraser Lee	6433.59	Linf	56.4	1.9	52.8	60.1
			k	0.12	0.01	0.1	0.14
			Lo	-3.21	0.15	-3.5	-2.92
	Fraser Lee Lo Fixed	6843.78	Linf	46.4	0.6	45.2	47.7
			k	0.24	0.01	0.22	0.25
	SPH	7241.59	Linf	60.4	2.4	55.6	65.2
			k	0.13	0.01	0.11	0.14
			Lo	-0.89	0.06	-1.01	-0.77
	SPH Lo Fixed	7274.53	Linf	69.1	3.5	62.3	75.9
			k	0.1	0.01	0.08	0.11

Tab. 2. (continued).

DATA		AIC	Parameter	Estimated value	SE	CI	
						higher	lower
FEMALES	Observed Values	3217.01	Linf	46.8	2.6	41.6	52.1
			k	0.32	1.07	-1.8	2.45
			to	-6.09	30.71	-67.38	55.19
	Observed Values Lo Fixed	3218.79	Linf	46.4	0.5	45.5	47.3
			k	0.75	0.21	0.33	1.16
	BPH	3129.99	Linf	59.3	3.6	52.3	66.3
			k	0.11	0.01	0.08	0.14
			Lo	-3.61	0.28	-4.16	-3.06
	BPH Lo Fixed	3322.25	Linf	46.7	0.9	44.8	48.6
			k	0.23	0.01	0.21	0.26
	Dahl Lea	3217.01	Linf	61.8	3.8	54.4	69.2
			k	0.11	0.01	0.08	0.13
			Lo	-2.24	0.17	-2.57	-1.92
	Dahl Lea Lo Fixed	3218.79	Linf	66.0	4.2	57.8	74.3
			k	0.09	0.01	0.07	0.11
	Fraser Lee	3053.03	Linf	59.5	3.3	53.0	66.0
			k	0.11	0.01	0.08	0.13
			Lo	-3.42	0.24	-3.9	-2.95
	Fraser Lee Lo Fixed	3223.19	Linf	47.7	1.0	45.8	49.6
			k	0.21	0.01	0.19	0.24
	SPH	3420.44	Linf	64.9	4.4	56.2	73.7
			k	0.11	0.01	0.08	0.13
			Lo	-0.94	0.1	-1.13	-0.74
	SPH Lo Fixed	3435.56	Linf	77.8	7.0	64.0	91.5
			k	0.08	0.01	0.06	0.1
MALES	Observed Values	3554.00	Linf	44.9	0.5	44.0	45.8
			k	1.36	4.51	-7.61	10.32
			to	0.97	10.60	-20.09	22.03
	Observed Values Lo Fixed	3555.28	Linf	44.9	0.4	44.1	45.7
			k	0.98	0.53	0.08	2.03
	BPH	3405.86	Linf	54.3	2.4	49.5	59.1
			k	0.13	0.01	0.11	0.16
			Lo	-3.41	0.23	-3.85	-2.96
	BPH Lo Fixed	3766.53	Linf	43.8	0.7	42.4	45.3
			k	0.3	0.02	0.27	0.33
	Dahl Lea	3554.00	Linf	56.8	2.7	51.4	62.1
			k	0.13	0.01	0.11	0.16
			Lo	-2.03	0.13	-2.28	-1.77
	Dahl Lea Lo Fixed	3555.28	Linf	59.1	2.8	53.6	64.7
			k	0.12	0.01	0.1	0.14
	Fraser Lee	3372.98	Linf	54.9	2.4	50.2	59.6
			k	0.13	0.01	0.11	0.16
			Lo	-3.07	0.19	-3.45	-2.7
	Fraser Lee Lo Fixed	3616.96	Linf	45.5	0.8	43.8	47.1
			k	0.26	0.01	0.23	0.28
	SPH	3799.58	Linf	59.3	3.2	53.0	65.6
			k	0.13	0.01	0.11	0.16
			Lo	-0.87	0.08	-1.02	-0.71
	SPH Lo Fixed	3815.66	Linf	66.9	4.4	58.2	75.5
			k	0.11	0.01	0.08	0.13

Analyzing this final VBGF curve for the species *Z. brevirostris*, *Linf* presented 56.4 cm of TL for grouped data, 59.5 cm TL for females, and 54.9 cm TL for males. The value of k was 0.12 for the grouped sexes, 0.11 for females and 0.13 for males. The final VBGF curves are presented in Fig. 3.

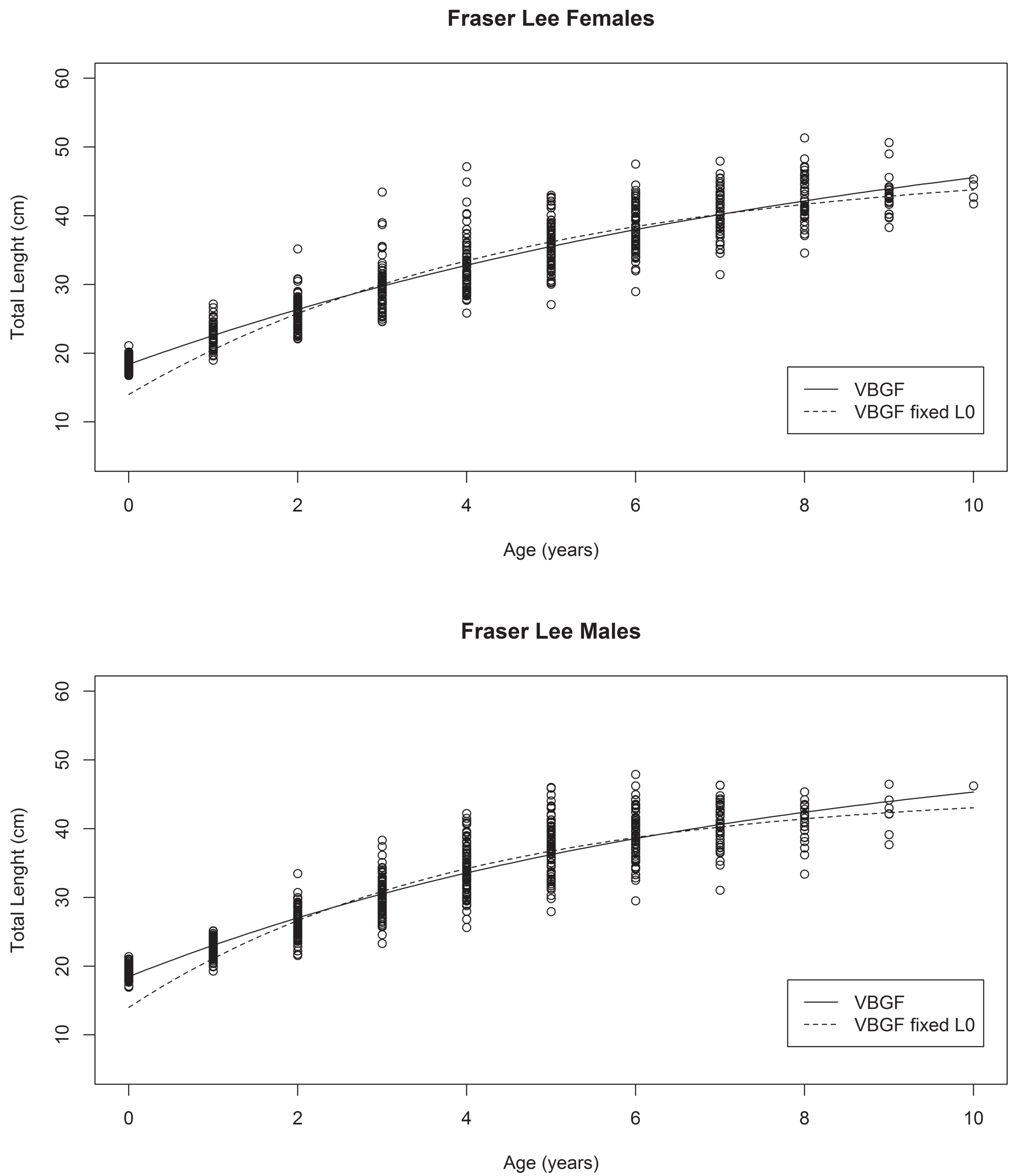

Fig. 3. Von Bertalanffy growth curves (VBGF) according to the Fraser-Lee back-calculation technique. Data for females and males separately: VBGF and VBGF with fixed L_0 at 14 cm.

Discussion

The age and growth parameters for a species of the genus *Zapteryx* were estimated for the first time in this study. Taking this into account, the results were compared to studies of another species of the same family (Rhinobatidae) and elasmobranchs in general, given the absence of more specific information for this species from the southern Atlantic Ocean.

The maximum size obtained (56 cm for females and 50.37 cm for males) was found within the maximum length described for the species by Colonello *et al*. (2011) and Bornatowski, Abilhoa (2012): 59 cm of TL for males and 65 cm of TL for females.

The growth difference between the sexes that was presented in this study is well-documented among elasmobranchs, with generally larger females than males, including *Z. brevirostris* (Casey *et al*., 1985; Ismen, 2003; Skomal, Natanson, 2003; Yamaguchi *et al*., 2005; Santos *et al*., 2006). As typical in elasmobranchs, females reach the larger size because it is necessary to support embryonic young, so the body size required for female gestation is greater than that for male, because male does not need to support embryos (Klimley, 1987)

Estimates of growth models are strongly affected by the absence of very young and/or old individuals (Campana, 2001; Cailliet, Goldman, 2004). Therefore, it is probable that the factor that most influenced the discrepancy between the values obtained in the sample (observed values) and the values obtained by back-calculation is the composition of the sample, where there is a lack of individuals with ages less than 4 (smaller than 35 cm of TL). The lack of these individuals is the result of a common problem in elasmobranch collections: the fishing gear is not selective for every length class, as observed by Branstetter (1987), and Thorson, Simpfendorfer (2009) also considered fishing gear to be a factor that greatly influences sample composition. However, it could also be a natural behavior of the species to not occur at the collection site when smaller than 35 cm, searching for another habitat during its initial phases of development, since, according to Espinoza *et al*. (2011), the patterns of fidelity to a certain site and its inter-annual use remain uncertain for many coastal elasmobranchs, due to the lack of quantitative behavioral data, including for this species.

The lack of convergence that the VBGF curve presented for the observed data was likely due to this absence of young individuals in the samples, which represented ages less than 4 (TL less than 35 cm). This led to the choice of using back-calculated data, which, according to Smith (1983), is a robust method to use. Thorson, Simpfendorfer (2009) suggested that in order to produce a reliable curve in age and growth studies, the minimum sample size would be 200 individuals. In several cases where the number of samples was less than the suggested number, the use of back-calculation has been observed. Several authors (*e.g*. Bonfil *et al*., 1993; Natanson *et al*., 1995; Sminkey, Musick, 1995; Lessa *et al*., 1999; Lessa *et al*., 2004; Başusta *et al*., 2008; Santana, Lessa, 2004; Natanson *et al*., 2007) have presented back-calculated growth curves to describe the growth of elasmobranchs.

The lowest AIC value indicates the greatest goodness-of-fit (Burnham, Anderson, 2002; Katsanevakis, 2006). The AIC was carried out using the three and two-parameter VBGF curves, always with the three-parameter curve presenting the lowest AIC, whether in the observed data or in the data obtained by back-calculation. Therefore, in the two tested models, the three-parameter VBGF curves better represent the growth model of the species *Z. brevirostris*.

The *Linf* obtained for the data presented 56.4 cm TL for grouped data, 59.5 cm TL for females and 54.9 cm of TL for males, which corroborates the values obtained in the sampling, where the largest TL was 56 cm for females and 50.37 cm for males. Therefore, the *Linf* derived from back-calculation is in conformity with maximum lengths observed in the region, corroborating the choice of the three-parameter VBGF curve obtained with back-calculated data by the Fraser-Lee technique, as the best to describe the growth of the species *Z. brevirostris*.

The value of *k* for males (0.13) was a little larger than the value for females (0.11). This type of dimorphism, with females growing at smaller rates than males has been described for other batoids species, such as *Leucoraja ocellata* (Sulikowski *et al*., 2003), *Amblyraja radiata* (Mcphie, Campana, 2009) and *Malacoraja senta* (Mcphie, Campana, 2009). The growth difference between sexes, verified by the Kimura test, coincides with the fact that females are larger than males and grow at lower growth rates. Here the females of *Z. brevirostris* showed larger size than males, a situation also reported by Batista (1987; 1991), Santos *et al*. (2006), Abilhoa *et al.* (2007) and Carmo, Fávaro (*in prep*). According to Bornatowski, Abilhoa (2012) this is an expected occurrence for viviparous species, characteristic of the species, with the largest length for females being a reflection of the bodily need to promote embryonic development during the gestation period (Santos *et al*., 2006). The value of k for the grouped data was 0.12, which is similar to the values found for a few other batoids such as *Aetobatus flagellum* (0.11; Yamaguchi *et al*., 2005), *Malacoraja senta* (0.12; Natanson *et al*., 2007; Mcphie, Campana, 2009) and *Raja undulata* (0.11; Coelho, Erzini, 2002). Comparing the value of *k* obtained for the growth of *Z. brevirostris* with other species of the same family, *Rhinobatos rhinobatos* (Başusta *et al*., 2008) the value of *k* of *Z. brevirostris* is smaller than the value obtained for *R. rhinobatos* (0.15). However, both present a high *k* compared with the value of *k* of other species of rays: 0.02 for *Bathyraja minispinosa* (Ainsley *et al*., 2011), 0.04 for *Raja binoculata* (McFarlane, King, 2006), 0.07 for *Amblyraja radiata* (Mcphie, Campana, 2009) and *Raja rhina* (McFarlane, King, 2006), and 0.08 for *Dasyatis pastinaca* (Ismen, 2003). The rays of the family Rhinobatidae present lower values of *k* than *L. ocellata* (0.18; McPhie, Campana, 2009) and

Leucoraja erinacea (0.19; McPhie, Campana, 2009), for examples. With these results, the species *Z. brevirostris* can be considered to have a relatively high growth rate compared with most other species of rays.

Marginal increment analysis as a verification technique for the periodicity of growth band deposition did not present significant data in this study, since there were months with no sampling. This corroborates with Cailliet (1990) and Campana (2001), who cited the factor sampling size as an error related to marginal increment analysis. Validation or verification of age is important in age and growth studies, through, for example, marginal increment analysis (Cailliet *et al*., 1986, 2006; Cailliet, 1990; Campana, 2001). However, the lack of marginal increment analysis, for several reasons, can also be found in other studies related to elasmobranchs (*e.g*. Wintner, Cliff, 1999; Başusta *et al*., 2008; Fernandez-Carvalho *et al*., 2011). Up to now, verification of the annual periodicity of vertebral bands has not been done for species of the family Rhinobatidae. It is assumed, therefore, that a pair of growth bands, constituted by a hyaline ring and an opaque ring, is deposited in this species each year, as verified for other elasmobranchs (Bonfil *et al*., 1993; Cailliet *et al*., 1983; Lessa *et al*., 1999; Oshitani *et al*., 2003; Santana, Lessa, 2004; Romine *et al*., 2006). However, this is a question that should be dealt with and studied in the future for this species.

The ray *Z. brevirostris* was found from 4 to 10 years of age in the study area. The species reaches its *Linf* at about 59.5 cm for females and 54.9 cm for males. The age and growth parameters for this species, presented in this study, corroborate the hypothesis that this ray requires future management conservation due to its slow growth rate and susceptibility to overexploitation, as f other elasmobranchs (Sulikowski *et al*., 2003; Natanson *et al*., 2007). This group should have its fisheries closely monitored in order to conserve its members as important components of the marine ecosystem (Vooren, 2012). In a review of the life history characteristics of long-life marine species, Musick (1999) concluded that species with k coefficients ≤ 0.10 year^{-1} are extremely susceptible to decline due to overexploitation, a value that is near to the one obtained for *Z. brevirostris*. As such, the current population status and fishing effort for this species should be monitored and assessed in future stock assessments.

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