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# Age determination and growth of the smalltail shark, *Carcharhinus porosus*, from northern Brazil

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**Abstract.** Age and growth of *C. porosus* was estimated from seasonally formed marks in vertebrae of 504 specimens (30.0–101.0 cm total length), and from length–frequency data from 1128 individuals (29.4–120.5 cm). Estimated von Bertalanffy growth parameters were: from observed length-at-age,  $L_{\infty}$  125.1 cm,  $K$  0.101 year<sup>-1</sup> and  $t_0$  -2.89 year; from back-calculated lengths,  $L_{\infty}$  136.4 cm,  $K$  0.077 year<sup>-1</sup>,  $t_0$  -3.27 year; and from length–frequency analysis,  $L_{\infty}$  131.0,  $K$  0.080 and  $t_0$  -3.40. Growth did not differ significantly between sexes. Males and females were mature at 71.0 and 70.0 cm, respectively, corresponding to 6 years old. The largest shark aged from vertebrae was a 12-year-old female (101.0 cm). Growth rates calculated from mean observed lengths were 7.0 cm year<sup>-1</sup> for the first four years and 4.0 cm year<sup>-1</sup> after maturity. Lee's phenomenon was not apparent. The annulus forms from September to January. Parameters derived from back-calculated lengths were considered to best describe growth. Like most carcharhinids, *C. porosus* follows the general pattern of K-selected species, exhibiting slow growth, late maturity and low fecundity.

**Resumo.** A idade e o crescimento de *C. porosus* foram estimados a partir de marcas sazonais em vértebras de 504 indivíduos (30.0–101.0 cm comprimento total) e através de distribuição de frequências de comprimentos de 1128 indivíduos (29.4–120.5 cm). Os parâmetros de von Bertalanffy obtidos com comprimentos observados na captura foram:  $L_{\infty}$  125.1 cm,  $K$  0.101 ano<sup>-1</sup> e  $t_0$  -2.89 anos; com comprimentos retrocalculados:  $L_{\infty}$  136.4 cm,  $K$  0.077 ano<sup>-1</sup>,  $t_0$  -3.27 anos, e da distribuição de frequências de comprimentos obteve-se:  $L_{\infty}$  131.0 cm,  $K$  0.080 ano<sup>-1</sup> e  $t_0$  -3.40. O crescimento não difere entre sexos. Machos e fêmeas são maduras com 71 e 70 cm, respectivamente, correspondendo a idade de 6 anos. O maior espécime cuja idade foi estimada das vértebras tinha 12 anos (101.0 cm). As taxas de crescimento calculadas dos comprimentos médios observados foram 7.0 cm ano<sup>-1</sup> para os primeiros quatro anos e 4.0 cm ano<sup>-1</sup> após a maturidade. O fenômeno de Lee não ocorreu. O anel se forma entre setembro e janeiro. Os parâmetros obtidos do retrocálculo descreveram melhor o crescimento. Como muitos carcharhinídeos, *C. porosus* segue o padrão das espécies da seleção K, exibindo crescimento lento, maturidade tardia e baixa fecundidade.

## Introduction

The smalltail shark, *Carcharhinus porosus* (Ranzani), is a common inshore tropical shark on western Atlantic shelves, not exceeding 150.0 cm total length, TL (Compagno 1984). In the Atlantic, the species ranges from the northern part of the Gulf of Mexico (30°30'N) to southern Brazil (24°59'S). It is taken with longlines or gill-nets in shallow waters close to estuaries and near bottom, to 36 m (Garrick 1982; Compagno 1984).

Information on this species includes taxonomic descriptions (Bigelow and Schroeder 1948; Garrick 1982; Compagno 1984), male sexual development (Lessa 1986/87), and diet (Lessa and Almeida 1997). Batista and Silva (1995) carried out a preliminary age and growth study but did not derive a von Bertalanffy growth curve. Branstetter (1990), summarized the life histories of several species and referred to *C. porosus* as an 'intermediate-sized' fast-growing shark ( $K > 0.1$ ) attaining 140.0 cm TL.

This species represents 43% of all elasmobranch landings (Lessa 1986) in Maranhão State (northern Brazil). Caught in areas between Tubarão Bay and Turiaçu Bay, *C. porosus* landings at São Luis are about 400 t year<sup>-1</sup>. The smalltail shark is generally a by-catch species in fisheries directed at more valuable resources such as *Scomberomorus brasiliensis* (Collette, Russo and Zavala-Camin) and *Cynoscion acoupa* (Block and Schneider) (Lessa 1986).

A survey was conducted in northern Brazil, 1984–87, to supply information on general aspects of life histories required for the management of coastal species. Among these, *C. porosus*, *Rhizoprionodon porosus* (Poey), *Sphyrna tiburo* (Linnaeus), *Isogomphodon oxyrinchus* (Muller and Henle), *S. lewini* (Griffith and Smith), and *R. lalandii* (Valenciennes) were the most abundant (Lessa 1986).

In this study ages of smalltail sharks were determined by examining vertebral annuli and analysing length frequencies.

Growth parameters were estimated by statistical fit to the von Bertalanffy growth function.

### Materials and methods

In all, 1128 smalltail sharks were collected from June 1984 to November 1987 in the western part of Maranhão State coast, between Tubarão Bay and Turiacú Bay (Fig. 1). Sailing boats were used, with floating gill-nets up to 900 m in length and 7.5 m in height, with 8.0 cm stretched mesh. Samples were obtained at depths of 6–40 m, during trips lasting about one week. The climate is influenced by the Amazonian region, with a rainy season from January to June and a dry season from July to December. Salinity values obtained during the survey were between 20.0 in March and 34.4 in July (Lessa and Menni 1994).

Vertebrae were removed from below the first dorsal fin of 504 individuals. Sex was recorded and total length (cm) of each specimen was measured according to Compagno (1984), with total length being measured as 'stretched' length (with tail depressed to be in line with the body axis). The terminology regarding vertebrae followed Wilson *et al.* (1983) and Cailliet *et al.* (1983).

A set of five or six vertebrae were excised from each specimen. After being cleaned of excess tissue they were stored in 4% formaldehyde for 24 h, and finally preserved in 70% alcohol for up to 5 years. Because vertebrae were deeply concave, they were sectioned sagittally (Cailliet *et al.* 1983). The two halves were immersed in an aqueous solution of alizarin red-S (Gruber and Stout 1983) for a period of several minutes to several hours (depending on the thickness of vertebrae) and then rinsed in running tap water. Cedarwood oil was applied to surfaces to increase the contrast between translucent (narrow) and opaque (broad) annuli. Bands, composed of a translucent and an opaque zone, were counted in each vertebra. The distance from the notochordal remnant, or focus, to the internal margin of each translucent red-stained annulus was recorded (Batista and Silva 1995). The vertebral radius (the distance from the focus to the outer edge of the vertebra) was measured under a binocular dissecting microscope equipped with an ocular micrometer. Measurements were made under 12× magnification (1 micrometer unit = 1.2 mm) with reflected light.

Vertebrae from the same specimen were read twice, each reading at different times and always by the same reader. All counts were made without knowledge of the individual size and previous count. Whenever the counts differed between the two readings, a consensus was determined and measurements were used for back-calculation of size-at-age.

The index of average percentage error, IAPE (Beamish and Fournier 1981), was estimated from

$$[IAPE] = 1/N \sum (1/R \sum (|X_{ij} - X_j|/X_j) 100,$$

where  $N$  is the number of fish aged,  $R$  is the number of readings,  $X_{ij}$  is the  $i$ th age determination of the  $j$ th fish and  $X_j$  is the average age calculated for the  $j$ th fish.

To determine the time of formation of the annuli in vertebrae, marginal increment analysis was performed. The marginal increment ratio (MIR) (Natanson *et al.* 1995) was calculated from the following equation:

$$[MIR] = (V_R - R_n)/(R_n - R_{n-1}),$$

where  $V_R$  is the vertebral radius,  $R_n$  is the radius of the last complete band and  $R_{n-1}$  is the radius of the penultimate complete band.

Mean MIR  $\pm$  s.d. was plotted monthly in order to locate periodic trends in annulus formation. Variance analysis–ANOVA was performed to detect significant differences throughout the year.

Lengths at previous ages were back-calculated from vertebral measurements by a modification of the Fraser–Lee equation proposed by Campana (1990), which considers the biologically derived intercept, defined as the size of fish and size of structure at which proportionality of growth of the fish and the structure is initiated. In this way, vertebrae may be used for ageing and proportional back-calculation (Campana 1990; Sminkey and Musick 1995). Thus,

$$L_a = L_c + [(O_a - O_c)(L_c - L_0)/(O_c - O_0)]$$

where  $L_0$  is size of the fish at the biological intercept,  $O_0$  is size of the vertebra at the biological intercept,  $L_a$  is length at age  $a$ ;  $O_a$  is distance from focus to annulus  $a$ ,  $L_c$  is length at capture and  $O_c$  is vertebral radius at capture.

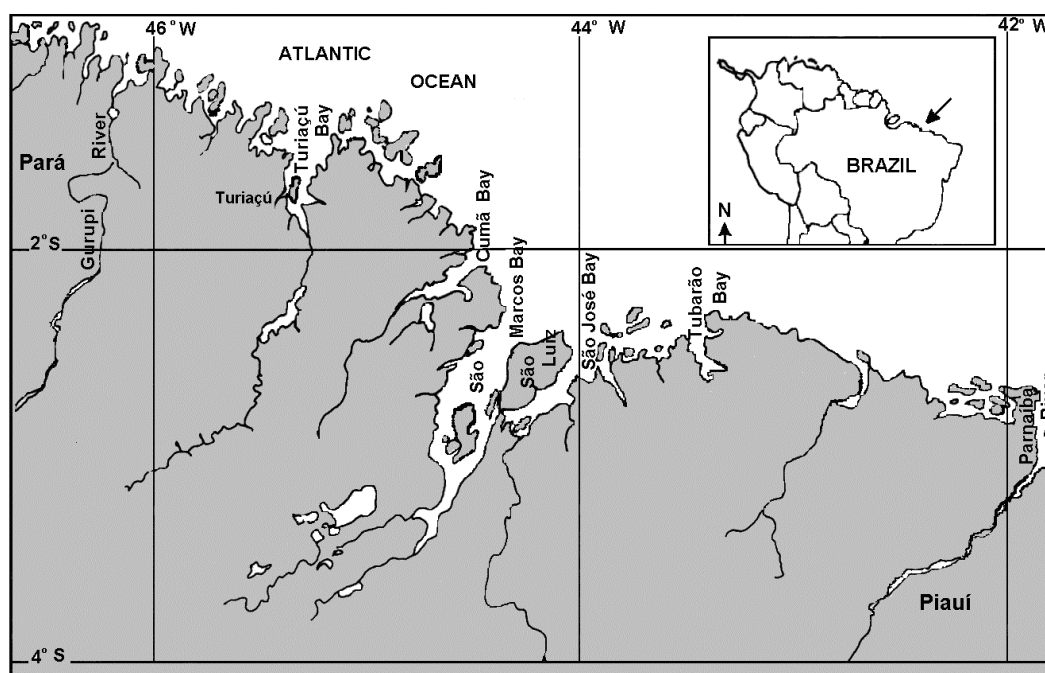


Fig. 1. Sampling area for smalltail shark, *C. porosus*, in northern Brazil.

In this study,  $L_0$  was 31.0 cm, the average size at birth.  $O_0$  was the corresponding size of the vertebrae at birth (2.4 micrometer units). For back-calculation, the biological intercept was 31.0 cm for both sexes. Neonates caught in the wild accorded in size with the birth length observed by Compagno (1984), Lessa (1986/1987) and Branstetter (1990).

Using FISHPARM (Prager *et al.* 1987), von Bertalanffy growth functions (VBGF) were fitted to the back-calculated and observed length-at-age data in order to provide estimates of parameters for the equation (von Bertalanffy 1938):

$$L_t = L_\infty[1 - e^{-k(t-t_0)}],$$

where  $L_t$  is predicted length-at-age  $t$ ,  $L_\infty$  is mean asymptotic total length,  $K$  is growth rate constant ( $\text{year}^{-1}$ ),  $t_0$  is the theoretical age at which the fish would have been zero length.

FISHPARM, used for obtaining length parameters, is an IBM-compatible program which implements Marquardt's algorithm, allowing parameters to be estimated without transforming the data into linear form (Prager *et al.* 1987).

Bernard's (1981) multivariate analysis, based on Hotelling's  $T^2$ , was performed for comparing growth curves by testing the hypothesis that differences between male and female vertebral growth curves were not significant.

Data on lengths of 1128 individuals (584 males and 544 females), divided at 5 cm intervals (Fig. 2), were analysed by Shepherd's (1987) method with the length frequency data analysis package (LFDA). Initial values of  $L_\infty$  were based on biological parameters obtained from our own data;  $K$  values ranging from 0.05 to 1.7 were entered into the program, which was run repeatedly until the highest score function was obtained. Runs were performed on the pooled database.

The  $L_\infty$  and  $K$  values were used to calculate  $t_0$  (Natanson *et al.* 1995):

$$t_0 = t + (1/K)(\ln[L_\infty - L_t]/L_\infty),$$

where  $t_0$  is time 0 (birth) and  $L_t$  is mean size at birth.

Linear regressions were compared by ANCOVA (Zar 1996). All statistical inferences were made at a significance level of 0.05, except those related to Bernard's method where 0.01 was used.

## Results

### Vertebral samples

Vertebrae were collected from 268 males (30.0–100.0 cm) and 236 females (31.0–101.0 cm). Alizarin red-S stained vertebrae provided consistent differentiation of the banding pattern, allowing broad light-coloured opaque annuli and narrow translucent or dark-red annuli (Bonfil *et al.* 1993) to be discerned clearly. Considering 498 vertebrae, which excludes de 0 age-class individuals, an average IAPE of 6.0% was obtained from two readings (Table 1).

Regression equations for vertebral radius *v.* total length did not differ significantly between sexes; the regression for the overall sample showed a linear relationship ( $r = 0.97$ ;  $n = 504$ ) (Fig. 3).

The maximum mean MIR occurred in July and the minimum in January (Fig. 4), although there were no significant differences among any of the monthly means. The pattern suggests that the formation of the annulus might last for a long period from September to the following January. An increase in the mean MIR value in December is attributable to a single individual, and for this reason December was not taken into account in the evaluation of the mean MIR.

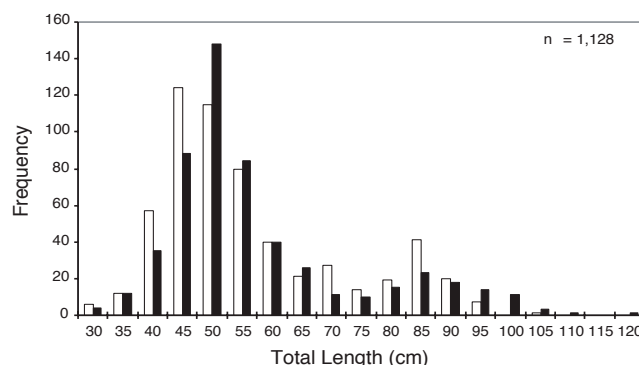


Fig. 2. Length-frequency distribution for (□) male and (■) female smalltail shark, *C. porosus*, caught between 1984 and 1987 off northern Brazil.

Table 1. Index of average percentage error between two readings (IAPE) and number of specimens of *C. porosus* ( $n$ ) by age class ( $t$ )

$t$	IAPE (%)	$n$
1	7.6	47
2	2	145
3	5	236
4	5.5	22
5	9.8	11
6	6	10
7	7.1	8
8	7.8	5
9	6.2	6
10	8.6	4
11	2.2	2
12	4.1	2
Total	6	498

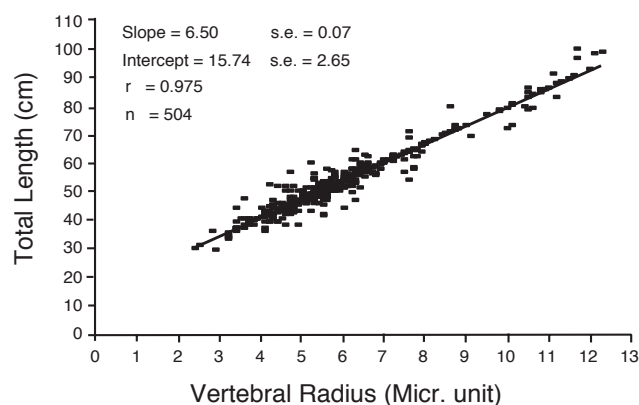


Fig. 3. Relationship between total length and vertebral radius (micrometer units) for smalltail shark, *C. porosus*, from northern Brazil.

Parameters of the VBGF derived for both sexes from back-calculated and observed length-at-age (Table 2) are shown in Table 3 and Fig. 5. Growth curves obtained on the

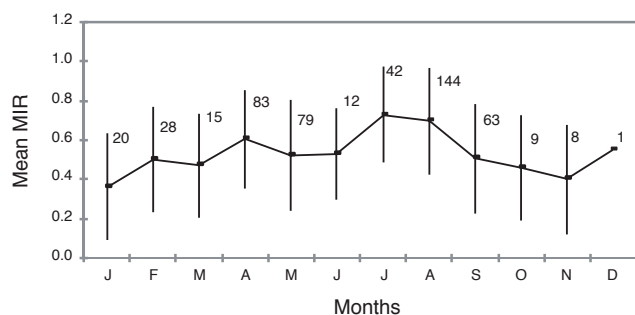


Fig. 4. Mean vertebral marginal increment ratios (MIR)  $\pm$  s.d. by month for the smalltail shark, *C. porosus*.

basis of back-calculated lengths (Table 3) did not differ significantly between sexes ( $T^2 = 9.53$ ; df 3;  $P > 0.01$ ) (Table 4).

The youngest male in the vertebral sample was 30.0 cm and the youngest females were 31.0 cm. These newborn specimens, showing fresh umbilical scars, appeared in catches from September to November (Lessa 1986/87). From this observation, 1 October was defined as the birthday of the species.

Size at maturity for males and females is 71.0 and 70.0 cm, respectively (Lessa 1986/87; Lessa and Almeida 1997), corresponding to 6-year-old individuals. The oldest specimen whose vertebrae were used both for the back-calculated growth curve and for the curve based on observed length-at-age was a 12-year-old female of 101.0 cm, and the oldest male was also 12-year-old measuring 100.0 cm. The

oldest female in the sample (120.5 cm) was estimated to be 24 years and the oldest male (103.0 cm) 15 years.

Growth rates, from back-calculated length-at-age over the first four years, were 7 cm year<sup>-1</sup> (in a 5-year-old specimen) and 4.5 cm year<sup>-1</sup> in a 6-year-old specimen, when maturity is reached (Table 2a). After maturity the growth rate declined to 4.0 cm year<sup>-1</sup>.

Lee's phenomenon (Ricker 1980), a tendency for lengths in the early years of life back-calculated from older fish to be systematically lower than lengths at the same age back-calculated from younger fish, was not evident.

#### Length frequency

In all, 1128 sharks (544 females 30.0–120.5 cm; 584 males 29.4–103.0 cm) were used to calculate the von Bertalanffy parameters on the basis of the length–frequency analysis (Figs 2 and 5) with the LFDA package (Shepherd 1987). Results from back-calculation and length–frequency analysis were similar, with  $L_{\infty}$  values slightly lower and  $t_0$  and  $K$  values slightly higher (Table 3). This suggests the robustness of the vertebral method.

#### Discussion

Batista and Silva (1995) presented an age and growth analysis for *C. porosus* from the same area as the present study. They used whole alizarin red-S stained vertebrae but did not calculate von Bertalanffy growth parameters. Although their sample size was smaller ( $n = 257$ ), it

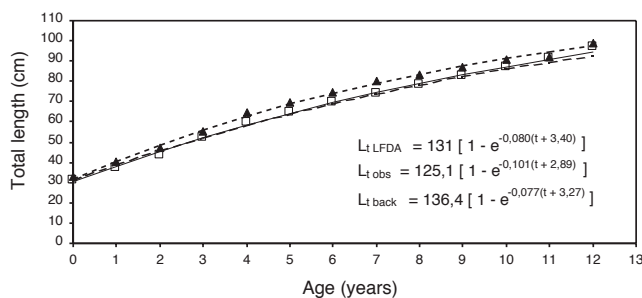
Table 2. Length-at-age (cm) data for combined sexes of the smalltail shark, *C. porosus*  
(a) back-calculated and (b) observed.  $t$ , age class

(a)														
$t$	$n$	0	1	2	3	4	5	6	7	8	9	10	11	12
		504	498	451	306	70	48	37	27	19	14	8	4	2
0	6	31.1												
1	47	31	37.1											
2	145	31.2	37.3	43										
3	236	31	37.3	43.3	51.3									
4	22	31	37.1	43.1	51.5	59.1								
5	11	31.1	37.4	43.3	51.6	59.6	64.5							
6	10	31.5	37.8	43.8	52.4	60.5	65.2	69.3						
7	8	31.5	37.5	43.1	51	58.5	63	67.4	71.4					
8	5	31.4	37.4	43.3	51.8	59.7	64.3	68.8	73.2	77				
9	6	31.1	37.2	43.2	51.7	59.6	64.2	68.9	73.2	77.2	81.1			
10	4	31.5	37.7	43.7	52.2	59.8	64.7	69.4	73.7	77.7	81.4	84.8		
11	2	31.2	37.4	43.3	51.5	59.5	64.1	68.7	72.9	77.3	81.2	85	88.5	
12	2	31	38.1	44.7	54.1	63	68.7	73.6	78.6	82.8	87.1	90.6	93.9	97.2
Mean TL		31.2	37.4	43.4	51.9	59.9	64.9	69.4	73.8	78.4	82.7	86.8	91.2	97.2
s.d.		0.20	0.29	0.48	0.86	1.28	1.67	1.96	2.47	2.49	2.91	3.31	3.85	0
(b)														
$t$		0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+
$n$		6	47	145	236	22	11	10	8	5	6	4	2	2
Mean TL		32.8	40.4	47	55.1	64.4	69.6	74.4	79.9	83.5	87.1	90.8	92.2	99.1
s.d.		1.91	2.28	2.65	3.85	1.97	2.09	3.46	3.23	2.87	1.51	1.36	1.59	1.01



**Table 3.** von Bertalanffy parameters derived from back-calculated and observed length-at-age FISHPARM for males, females and both sexes combined; length-frequencies data analysis (LFDA) package for the pooled database

Methods		$L_{\infty}$ (cm)	s.d.	$K(\text{year}^{-1})$	s.d.	$T_0(\text{year})$	s.d.	$n$	$r^2$
Back-calculated									
	Males	135.2	9.25	0.078	0.01	-3.21	0.26	268	0.99
	Females	136.3	9.69	0.076	0.01	-3.28	0.26	236	0.99
	Both	136.4	9.63	0.077	0.01	-3.27	0.26	504	0.99
Observed	Both	125.1	6.12	0.101	0.01	-2.90	0.26	504	0.99
LFDA	Both	131	—	0.080	—	-3.40	—	1128	—



**Fig. 5.** von Bertalanffy growth curves generated from vertebral data: (—▲—) mean observed length-at-age; (—□—) mean back-calculated length-at-age and (—) length-frequency analysis (LFDA) for combined sexes of smalltail shark, *C. porosus*.

**Table 4.** Results of comparison of the vertebral von Bertalanffy growth equations for male and female smalltail shark, *C. porosus*, using Bernard's (1981) multivariate analysis

Shown is the estimated variance-covariance matrix (S),  $T^2$

	$L_{\infty}$	$K$	$T_0$	
	89.473	-0.0973	-2.1776	$L_{\infty}$
S =		0.0001	0.0025	$K$
			0.0684	$T_0$
$T^2 = 9.537$ ns		$T^2_{0.01;3,500} = 11.385$		

consisted of a similar size range and sex composition as our sample, because the same type of fishing gear was employed.

Our results are, nevertheless, somewhat different. Our mean back-calculated lengths at age are consistently higher than those of Batista and Silva (1995). For example, back-calculated lengths at age 5, 7 and 9 were 64.8, 73.8, and 82.7 cm in the present study compared with 50.7, 58.3 and 69 cm in Batista and Silva (1995). These differences may, perhaps, be attributed to the use of the whole vertebrae in that study; these, being strongly concave, resulted in different measures to each annulus. Also, different equations were used for back-calculation in the two studies. It appears that the back-calculated lengths obtained by those authors may have been underestimations.

Marginal incremental analysis was performed differently in the two studies. Batista and Silva (1995) split marginal increment (MI) into two classes, 0.6–1.0 and 0–0.59, and the frequency of individuals with large MI was then considered. The authors stated that the translucent annulus is on the edge of vertebrae from March to June, thus indicating deposition shortly earlier. These results are similar to those of the present study; here, it is assumed that the formation of the annulus occurs when mean MIR dropped rapidly from the peak to the minimum. Although mean MIR reaches the peak in July, it does not decrease until January and mean MIRs did not differ significantly between months; this suggests a long period of annulus deposition from September to January. This result may be comparable to other studies in which, unfortunately, statistical comparisons were not made (Branstetter 1987; Branstetter *et al.* 1987; Bonfil *et al.* 1993; Natanson *et al.* 1995). In such studies, interpretations were simply based on the highest and the lowest MI values to indicate the time of annulus deposition. However, considering the range of MIs or MIR presented in those studies, some would probably not produce significant differences. Moreover, those results (including the conclusion that annulus deposition was in winter) were based on few MI records, particularly those for *C. falciformis* (Bonfil *et al.* 1993) and *C. obscurus* (Natanson *et al.* 1995).

Since no difference in growth rate was found between the sexes in the present study, the fact that females attain larger sizes than males may be explained by causes such as differential mortality rates between sexes, or reduced growth of males after maturity, as suggested by Natanson *et al.* (1995) for *C. obscurus*.

Fecundity was 2–7 embryos in the present survey and 4–9 in another study in the same area (Stride *et al.* 1992). The length class that defines the onset of sexual maturity is 71.0 and 70.0 cm for males and females, respectively (Lessa 1986/87). Thus, sexual maturity occurs in 6-year-old specimens.

Vertebrae of neonates had only a birth mark, and back-calculated length at age 0 was 31.1 cm, close to observed lengths; this confirmed that the mark was formed at birth. The first annulus would have been formed about one year

after birth, considering the mean MIR analysis, which suggests the start of the annulus from September to January. Subsequent bands would represent annual growth with one annulus deposited every year.

Gruber and Stout (1983) implied that length frequencies would be inappropriate for separating age classes beyond the second or third year, because most species grow slowly. Results obtained with the LFDA package in the present study revealed only small differences in parameters relative to those derived from back-calculation. Coherent results may be obtained from length–frequency analysis provided that a great deal of previous knowledge on growth can be supplied to the program, as suggested by Basson *et al.* (1988).

The three methods used in the present study produced consistent results. However, observed length-at-age yielded the most varying VBGF parameters, leading to a  $L_{\infty}$  value lower than the maximum length recorded in the study area of 128.0 cm, corresponding to a female collected in November 1983 (personal observation) and to a  $K$  higher than that obtained by the two other analyses. Differences between mean observed lengths at age and back-calculated ones (Table 3, Fig. 5) may have arisen because observed lengths at age are based on length at capture, whereas back-calculated lengths correspond to length at the moment of annulus deposition (Branstetter *et al.* 1987; Bonfil *et al.* 1993; Wintner and Cliff 1996).

Length–frequency analyses using the Shepherd (1987) method with the LFDA program have yielded VBGF parameters similar to the back-calculated values in *C. falciformis* (Bonfil *et al.* 1993) and slightly different in *C. obscurus* (Natanson *et al.* 1995). Despite these results, VBGF parameters based on length–frequency analysis were considered only for comparison, as a method of validating vertebral analysis. In the present study, VBGF obtained using these two methods were remarkably similar, almost overlapping each other (Fig. 5). The success of the length–frequency analysis in the present study is attributed to the size of the sample ( $n = 1128$ ) which comprised from newborn to adult specimens. In this study too, back-calculated parameters were the best for describing growth, because the robustness of the method greatly increased the amount of information derived from each specimen and allowed the monitoring of average growth rates of various age classes, including inferences on the Lee phenomenon (Smith 1983).

Considering the reliability of the growth parameter  $L_{\infty}$ , calculated from back-calculated lengths as 136.4 cm, Bigelow and Schroeder (1948) mention a 123.5 cm female as the largest observed specimen; and Compagno (1984) mentions that females reach 134 cm. The largest female caught in the present study was 120.5 cm, with 128 cm the maximum recorded in the area.

Concerning the  $K$  parameter, inferences on life-history were made by Branstetter (1990), who grouped *C. porosus* with *Rhizoprionodon terraenovae*, *S. tiburo*, *Carcharhinus brevipinna*, *C. acronotus*, and *Carcharhinus isodon*, which

show a relatively fast growth rate ( $K > 0.1$ ). He further suggested that *C. porosus* has the same growth strategy as *R. terraenovae*, which grows by 69% of its birth length in its first year, probably to reduce predation. However, the present data for *C. porosus* indicate a  $K < 0.1$  and growth by only 23% of the birth length by the end of the first year, suggesting slower-growth more similar to that of *C. leucas*, *C. plumbeus* and *Negaprion brevirostris*, species which show a  $K < 0.1$  (Branstetter 1990). Species with low  $K$  values do not have the advantage of fast growth to avoid predation. *C. porosus* seems to cope with predation by remaining in protected shallow waters throughout its life, without undergoing any migration. The fact that specimens of all sizes can be caught throughout the year in coastal areas supports this hypothesis.

It is possible that our estimates of the von Bertalanffy growth parameters are biased and the shape of the growth curve distorted by the effects of long and intensive use of gill-nets in the fishery for *C. porosus*. Such biases and distortions referred to as the ‘phenomenon of apparent change of growth rate’ can be caused by length-selective fishing mortality (Lee 1912; Ricker 1969). Length-selective fishing mortality from gill-nets has the effect of fishers culling a greater proportion of the large (fast-growing) sharks than the small (slow-growing) sharks from the young age-classes and of culling a greater proportion of the small (slow-growing) sharks than the large (fast-growing) sharks from the old age-classes. Studying growth of *Mustelus antarcticus* in the gill-net fishery of southern Australia, Walker *et al.* (1998) have demonstrated how the magnitude of the von Bertalanffy growth parameters  $L_{\infty}$  and  $t_0$  tend to increase and  $K$  tends to decrease as gill-net fishing effort increases, thereby explaining how these parameter biases, common for sharks in the scientific literature, can occur. In addition, the use of gill-nets to catch sharks for biological sampling from a wild population can cause length-selective sampling bias. This occurs when the length-frequency composition of sharks in a sample collected for age determination in any age-class is not representative of the length-frequency composition of sharks in that age-class in the wild population (Ricker 1969; Walker *et al.* 1998).

In summary, the smalltail shark has  $K$ -selected characteristics including slow growth, late maturity and low fecundity, possibly making it subject to high natural mortality rates. Most of the catch are juveniles, which may lead to growth overfishing under any increased fishing pressure. In such a context, any fishery policy for northern Brazil which would include an increase in fishing efforts directed at any of the targeted species should take into account the life-history characteristics of the smalltail shark, which point towards a rather fragile resource.

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