Abstract—Age and growth of the night shark (*Carcharhinus signatus*) from areas off northeastern Brazil were determined from 317 unstained vertebral sections of 182 males (113–215 cm total length [TL]), 132 females (111.5–234.9 cm) and three individuals of unknown sex (169–242 cm). Although marginal increment (MI) analysis suggests that band formation occurs in the third and fourth trimesters in juveniles, it was inconclusive for adults. Thus, it was assumed that one band is formed annually. Births that occur over a protracted period may be the most important source of bias in MI analysis. An estimated average percent error of 2.4% was found in readings for individuals between two and seventeen years. The von Bertalanffy growth function (VBGF) showed no significant differences between sexes, and the model derived from back-calculated mean length at age best represented growth for the species (L_∞=270 cm, K= 0.11/yr, t_0=–2.71 yr) when compared to the observed mean lengths at age and the Fabens' method. Length-frequency analysis on 1055 specimens (93–260 cm) was used to verify age determination. Back-calculated size at birth was 66.8 cm and maturity was reached at 180–190 cm (age 8) for males and 200–205 cm (age ten) for females. Age composition, estimated from an age-length key, indicated that juveniles predominate in commercial catches, representing 74.3% of the catch. A growth rate of 25.4 cm/yr was estimated from birth to the first band (i.e. juveniles grow 38% of their birth length during the first year), and a growth rate of 8.55 cm/yr was estimated for eight- to ten-year-old adults.

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Age determination and growth of the night shark (*Carcharhinus signatus*) off the northeastern Brazilian coast

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The night shark (*Carcharhinus signatus*) is a deepwater coastal or semi-oceanic carcharhinid that is found in the western Atlantic Ocean along the outer continental or insular tropical and warm temperate shelves, at depths exceeding 100 meters (Bigelow and Schroeder, 1948). The species has been recorded from Delaware to Florida, the Caribbean sea (Cuba), and northern South America (Guayana) (Compagno, 1984). It has also been recorded in southern Brazil, Uruguay, and Argentina (Krefft, 1968; Compagno, 1984; Marín et al., 1998), and on the seamounts off northeastern Brazil (02°16′ to 04°05′S and 033°43′ to 037°30′W, Menni et al., 1995) where it is called "toninha."

Since 1991, tuna longline vessels have targeted the night shark in northeastern Brazil (Hazin et al., 1998) because of its highly prized fins, the increasing value of shark meat in the local market, and their relatively large abundance and accessability on seamounts (Menni et al., 1995). This species is most important in the area, making up 90% of catches over shallow banks (CPUE, in number, is 2.94/100 hook), and only 15% of catches on the surrounding deep area, yielding 0.04/100 hook (Amorim et al., 1998).

Information on this species is restricted to taxonomic descriptions (Bigelow and Schroeder 1948; Cadenat and Blache, 1981; Compagno, 1984, 1988), and some biological aspects (Guitart Manday, 1975; Hazin et al., 2000). Night sharks reach >270–280 cm maximum total length (TL) (Compagno, 1984; Branstetter, 1990). Off northeastern Brazil, females mature at 200–205 cm TL, males at 185–190 cm. Litter sizes range from 10 to 15 pups and the gestation period may last one year (Hazin et al., 2000). The assumed size-at-birth off the United States is 60–65 cm TL (Compagno, 1984; Branstetter, 1990). Age and growth have not been estimated.

The aim of this study is to present the first growth curve for *Carcharhinus signatus* from vertebral and length-frequency analyses. This information will permit the use of age-based stock assessment methods for the management of the species in the Exclusive Economic Zone (EEZ) off Brazil.

Materials and methods

Sampling data and vertebrae were collected from November 1995 to November 1999 from commercial landings (Natal, Brazil) caught in deep (Aracati, Dois Irmãos, Fundo, Sirius) and shallow (Pequeno, Leste, and Sueste) seamounts with depths between 38 to 370 m at the summits (Fig. 1).

Commercial vessels were equipped with ~30 km Japanese-style multifilament longline gear (Suzuki et al., 1977). On average, each vessel used 970–980 hook per day; mainline sets began at ~02:00 h and ended at ~06:00 h. The retrieval of gear began at noon and finished by dusk. The Brazilian sardinella (*Sardinella brasiliensis)*, margined flyingfish (*Cypselurus cyanopterus*), and squid (*Loligo* sp.) were used as bait (Hazin et al., 1998).

A total of 1055 individuals, landed whole, eviscerated, or as carcasses (headless and finless), were sampled. The interdorsal space (posterior dorsal

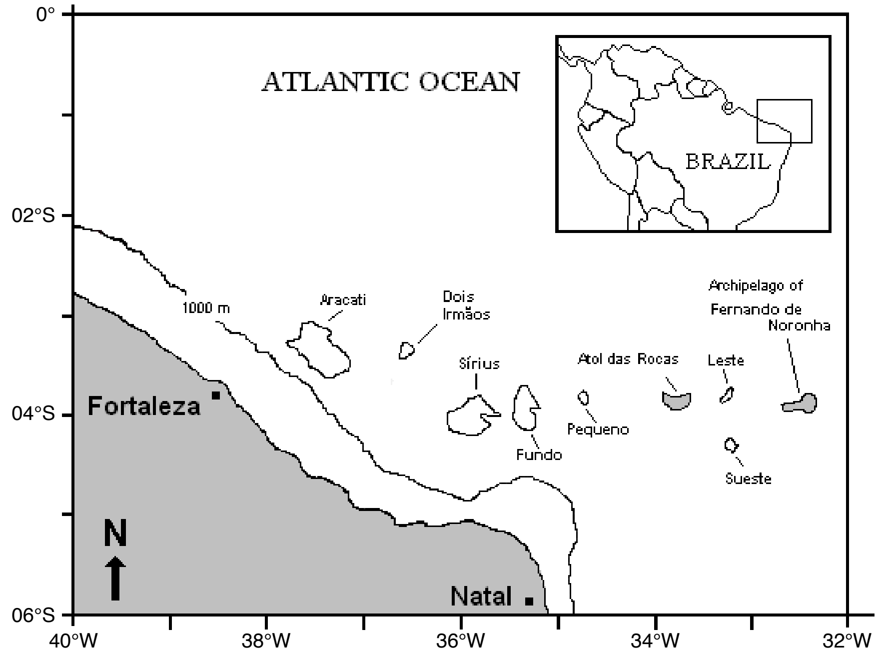

Figure 1

Location of the sampling area for the night shark (*C. signatus*) collected off northeastern Brazil.

fin base to origin of the second dorsal fin [IDS, cm]), total length (snout to a perpendicular line from the tip of the upper caudal fin [TL, cm]) and fork length (snout to fork of tail [FL, cm]) were measured. In carcasses, only IDS was measured, and IDS, FL, and TL were recorded for eviscerated or whole individuals. A set of five or six vertebrae were removed from below the first dorsal fin in 317 specimens. Total length was measured as the "natural length" (without depressing the tail) according to Garrick (1982).

To estimate TL for carcasses, relationships from subsamples of IDS versus TL and FL versus TL were established for males and females separately. Linear regressions derived for each sex were tested for homogeneity and analyzed for covariances (ANCOVA), resulting in TL=1.2049 FL + 1.7972 (r^2=0.944, n=668, P=0.41) and TL = 3.3467 IDS + 30.879 (r^2=0.824; n=764, P=0.161). Whenever length is mentioned hereafter, we always refer to TL.

Vertebrae were processed by removing excess tissue, fixed in 4% formaldehyde for 24 hours, and preserved in 70% alcohol. Each vertebra was embedded in polyester resin and the resulting block was cut to about a 1-mm thick section containing the nucleus by using a Buehler® low speed saw. Initially, alizarin-red-s stained sections (Gruber and Stout, 1983) were compared to unstained sections from the same individuals to define the best contrast for narrow and broad zones. In the first procedure, sections were immersed overnight in an aqueous solution of alizarin red s and 0.1% NaOH at a ratio of 1:9 and then rinsed in running tap water. In stained sections, narrow zones were visible as dark red and broad zones as light red, whereas in unstained sections translucent (narrow) and opaque (broad) zones were visible under transmitted light. Unstained sections produced comparable results to alizarin stained sections and were used for band observation in the study.

Bands counted in each section and distances from the focus to the margin of each narrow zone were recorded. Vertebral radius (VR) was measured by using a binocular dissecting microscope equipped with an ocular micrometer. Measurements were made at 10× magnification (1 micrometer unit=1 mm) with both reflected and transmitted light. The same reader read sections from the same specimen twice at different times without knowledge of the individual size or previous count. Whenever the counts differed between the two readings, a third reading was used for back-calculation of size-at-age.

The index of average percentage error (IAPE) (Beamish and Fournier, 1981) to compare reproducibility of age determination between readings was calculated.

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

where N = the number of fish aged;
R = the number of readings;
X_{ij} = the mean age of j^{th} fish at the i^{th} reading; and
X_j = the mean age calculated for the j^{th} fish.

Marginal increment (MI) analysis to determine the time of band formation was used. The analysis was restricted to 1995–97, when samples were collected every month. The distance from the final band to the vertebral's edge (MI) was expressed as a percentage of the distance between the last two bands formed on vertebrae (Crabtree and Bullock, 1998). The distance between the last and the penultimate band was divided by the distance between the nucleus and the last band for each vertebra that was measured, and we then calculated the mean of this number for the entire sample:

$$\sum\left((R_{n-1}) - R_n\right) / n = 0.13\,(\mathrm{SE}=0.0009).$$

The expected distance between the last (R_n) and the penultimate (R_{n-1}) bands was estimated as a function of the distance between the vertebral nucleus and the last band (MI). The percent marginal increment (PMI) was calculated as

$$PMI = \left[MI / (0.13 \times R_n)\right] \times 100.$$

Analysis of variance to test for differences in PMI by month was used. *Post-hoc* tests (Tukey honest significant differences ([HSD]) were performed to indicate which months were different.

Characterization of the vertebral edge was used to determine the time period of band formation (Carlson et al., 1999). Under reflected light, a narrow dark zone (MI 0), a narrow light zone (MI 0.1 to 0.5), and a broad light zone (MI 0.6 to 1) were observed. Absolute marginal increments (MI) were also analyzed by trimester for juveniles aged four and five years, and for adults (more than eight years) to confirm the time of translucent zone formation.

The relationship between VR and TL was calculated by sex, tested for normality, and compared by ANCOVA (Zar, 1996). The final regression in both sexes did not pass through the origin, thus suggesting that the Fraser-Lee method was the most appropriate for back-calculation (Ricker, 1969).

$$[TL]_n = (R_n / VR)\left([TL] - a\right) + a,$$

where $[TL]_n$ = the back-calculated length at age n;
R_n = vertebral radius at the time of the ring n;
VR = the vertebral radius at capture;
TL = the length at capture; and
a = the intercept on the length axis.

A von Bertalanffy growth function (VBGF) (von Bertalanffy, 1938) was fitted to back-calculated and observed length-at-age data with the following equation.

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

where L_t = predicted length at age t;
L_∞ = mean asymptotic total length;
K = growth rate constant; and
t_0 = the age when length is theoretically zero.

To obtain parameters of VBGF, data were analyzed by using FISHPARM (Prager et al., 1987) for nonlinear least-squares parameter estimation. The Kappenman's method (1981), based on the sum of squares of the differences between observed and predicted lengths from a growth model, was used for comparing male and female growth curves. In addition, likelihood-ratio tests were used to compare parameter estimates of the von Bertalanffy equation between sexes (Cerrato, 1990).

Von Bertalanffy parameters (L_∞, K) were also estimated by the method of Fabens (1965) usually employed for recapture data and which takes into account the size at birth (L_0) instead of t_0. This method reconfigures VBGF and forces the regression through a known size at birth:

$$L_t = L_\infty(1 - be^{-Kt}),$$

where $b = (L_\infty - L_0) / L_\infty$.

We used Fabens routine for growth increment data analysis of the FAO-ICLARM stock assessment tools (FISAT) program (Gayanilo et al., 1996), assuming that the time intervals ($=\Delta t$) for each size-at-age class were equal and had a periodicity identical to that obtained from the vertebral analysis.

The lengths of 1055 individuals were divided into 5-cm intervals and analyzed by the Shepherd method (1987) with the length-frequency data analysis program (LFDA). Initial values of L_∞ were based on results from maximal lengths in the sample and from literature (Compagno, 1984). K values ranging from 0.05 to 1.8 were used as input into the program, which was run repeatedly until the highest score function was obtained. The L_∞ and K values were then used to calculate t_0 (Sparre et al., 1989):

$$t_0 = t + (1/K)\left(\ln[L_\infty - lt]\right) / L_\infty).$$

Using an age-length key, based on 317 individuals for which vertebrae were read, we evaluated the age composition of the sample (Bartoo and Parker, 1983). Maximal ages in the sample were calculated by employing the inverted VBGF (Sparre et al., 1989). Further, the formula by Fabens (1965) [5(ln2)/K] for longevity estimation was used. All statistical inferences were made at a significance level of 0.05.

Results

The total sample size consisted of 1055 individuals: (551 males [93–248 cm], 499 females [110–252 cm], and 5 individuals of undetermined sex [169–260 cm]) (Fig. 2). Of these, vertebrae were removed from 317 specimens (182 males [113–215 cm], 132 females [111.5–234.9 cm], and 3 individuals of undetermined sex [169–242 cm]).

Differences in the relationship between VR and TL between sexes were not found to be significant (P=0.811). The regression for the overall sample showed a linear relationship: $TL = 13.523VR + 41.824$ (r^2=0.89; n=317), indicating that vertebrae are suitable structures for age determination, and methods based on direct proportion are appropriate for back-calculation.

The average percentage error, calculated between two readings, ranged from 0% to 4.5% in vertebrae with 2 to 17 bands and the average IAPE for the overall sample was 2.4%. Coefficient of variation (CV) between readings for total sample was 6.88%.

Monthly PMI analysis, for the entire sample, indicated that bands were formed from June to October, when high-

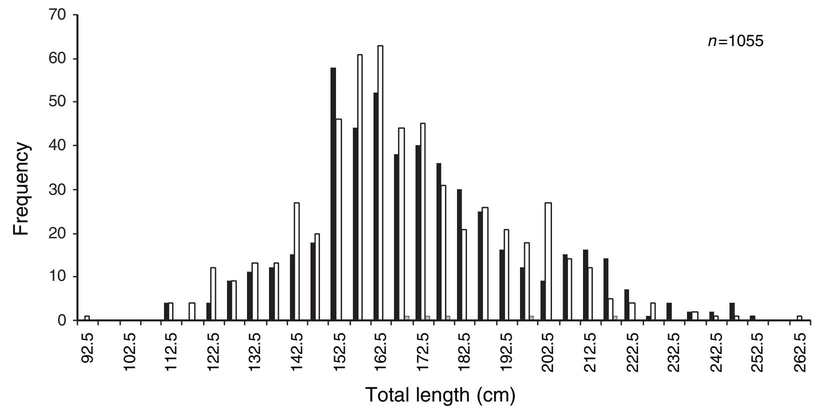

Figure 2

Length-frequency distribution for the night shark (*C. signatus*) caught off northeastern Brazil between 1995–99 (black bars=females; white bars = males; grey bars = undetermined sex).

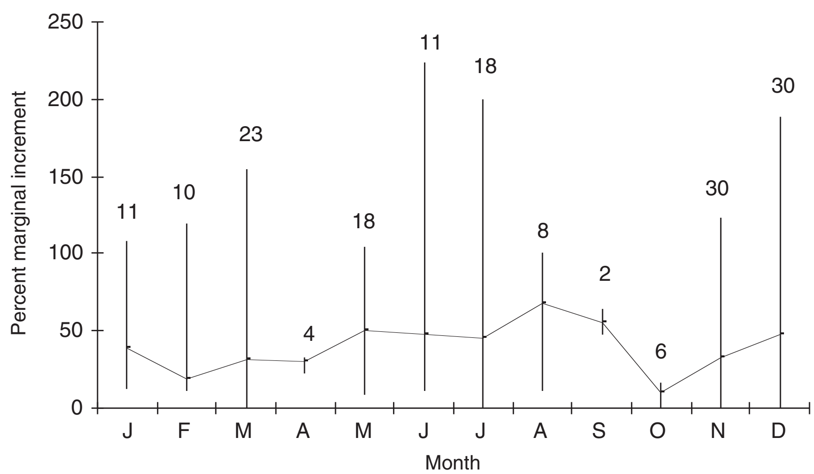

Figure 3

Percent marginal increments means (-) with the minimum and maximum values for the night shark (*C. signatus*) caught from 1995 to 1997 off northeastern Brazil (n=171). The number of individuals sampled per month is shown above the vertical bars.

est mean values are reached (Fig. 3). These values are followed by the lowest mean PMI in October, indicating that the new translucent zone forms from that point on. Monthly PMIs showed significant differences throughout the year (P=0.0463) and *post-hoc* comparisons detected differences in February, April, September, and October. Furthermore, monthly categorization of vertebral edges indicated that the highest frequency of broad light edges (MI 0.6–1) appears from July through December and narrow dark edges (MI 0) from March through December, with the exception for months of May and August (Fig. 4). Trimonthly frequency distribution of absolute marginal increments (MIs) was carried out for juveniles, revealing four and five bands, and for adults, revealing more than eight bands. For the former group, a higher number of broader increments and fully formed bands in the third and fourth trimesters were observed (Fig. 5). For adults, an unclear pattern was observerd perhaps because a smaller sample size was obtained.

Because there was no complete agreement on the time of band formation among different MI analysis for juveniles and adults, age was assigned by assuming an annual pattern of band deposition. The birth mark present in all analyzed vertebrae was not taken into account for age assignation. Under this assumption, band counts indicate relative age (years).

Mean observed lengths-at-age were higher than mean back-calculated lengths for males and females and were likely due to the strong variation in size for each age class (Table 1). The tendency of back-calculated lengths of older

Table 1

Mean back-calculated (BC) and observed length-at-age (OL) data for male and female night sharks (*C. signatus*) collected off northeastern Brazil (SD=standard deviation).

	Females		Males	
Age (yr)	BC (cm) ±SD	OL (cm) ±SD	BC (cm) ±SD	OL (cm) ±SD
0	66.8 ±1.78	—	67.3 ±1.41	—
1	91.9 ±1.31	—	92.3 ±1.37	—
2	113.4 ±2.13	122.5 ±16.93	113.3 ±1.48	120.1 ±4.21
3	128.8 ±2.21	132.9 ±9.77	128.6 ±1.54	135 ±8.91
4	142.7 ±2.41	149.8 ±7.75	142.4 ±1.94	151.5 ±9.72
5	154.7 ±2.92	160.7 ±7.21	154.5 ±2.7	157.5 ±7.86
6	165.9 ±3.46	166.8 ±10.32	166.3 ±3.25	167.5 ±8.1
7	176.8 ±3.4	179.8 ±9.56	177.4 ±2.64	177.6 ±9.34
8	185.9 ±3.71	184.9 ±9.12	187.4 ±2.22	189.8 ±6.53
9	194.8 ±3.82	197.1 ±6.49	195.8 ±2.25	199.9 ±5.26
10	202 ±4.75	208.2 ±3.89	202.4 ±2.78	204.3 ±3.13
11	206.9 ±5.56	202	209.8	212.5 ±3.54
12	215.7 ±2.4	218	—	—
13	222.2	—	—	—
14	226.9	—	—	—
15	231.7	234.4 ±0.63	—	—

fish in the early years to be systematically lower than younger ones at the same age (Lee's phenomenon) was not evident (Tables 1 and 2).

Using back-calculated lengths-at-age (Table 3), we plotted male and female growth curves separately and then tested the data; no indication of significant differences in growth was observed between sexes with both the Kapenman's (P>0.05) and likelihood ratio tests (Table 4). Data were then treated together, incorporating individuals of undetermined sex. VBGFs derived from observed length at age were not tested because of missing values in different age classes. The method of Fabens for combined sexes, fitted to back-calculated data, provided L_∞ and K, by using b = 0.781, L_0= 62.5 cm (Compagno, 1984) and, Δt = 1 year (Table 2).

Parameters from back-calculation were close to those derived from length-frequency analysis for 1055 specimens, whereas observed lengths and the Fabens method, provided the most varying parameters with lowest correlation and highest coefficients of variation (Table 2).

The smallest specimen in the vertebral sample showing two complete bands in sections was 111.5 cm, close to the estimated mean back-calculated length at age two of 113.7 cm (Table 3). Size at maturity, 185–190 cm for males and 200–205 cm for females, corresponded to 8- and 10-year-old individuals, respectively (Fig. 6). The largest and oldest specimen whose vertebrae were used, was 242 cm, which corresponded to 17-year-old individual.

A growth rate of 25.4 cm/yr was estimated from birth to the first band—a rate that corresponded to 38% of the birth length (the length at birth being 66.8 cm). Also, a mean rate of 8.55 cm/yr was calculated for 8- to 10-year-old individuals, when maturity is achieved (Table 3).

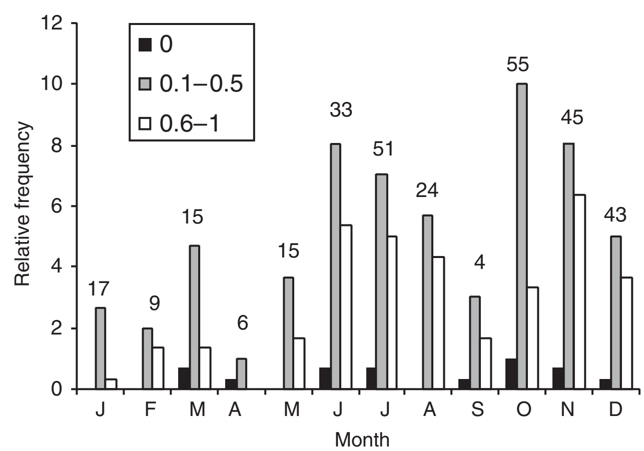

Figure 4

Categorization of edges by month for the night shark (*C. signatus*) off northeastern Brazil.

Considering mature individuals >185 cm, the age composition for the vertebral samples (n=317) indicated that 17.3% of specimens were adults (Table 5). Instead, for the total sample (n=1055), where the age ranged between 2 to ≥17 years, adults corresponded to 25.3% of the total sample

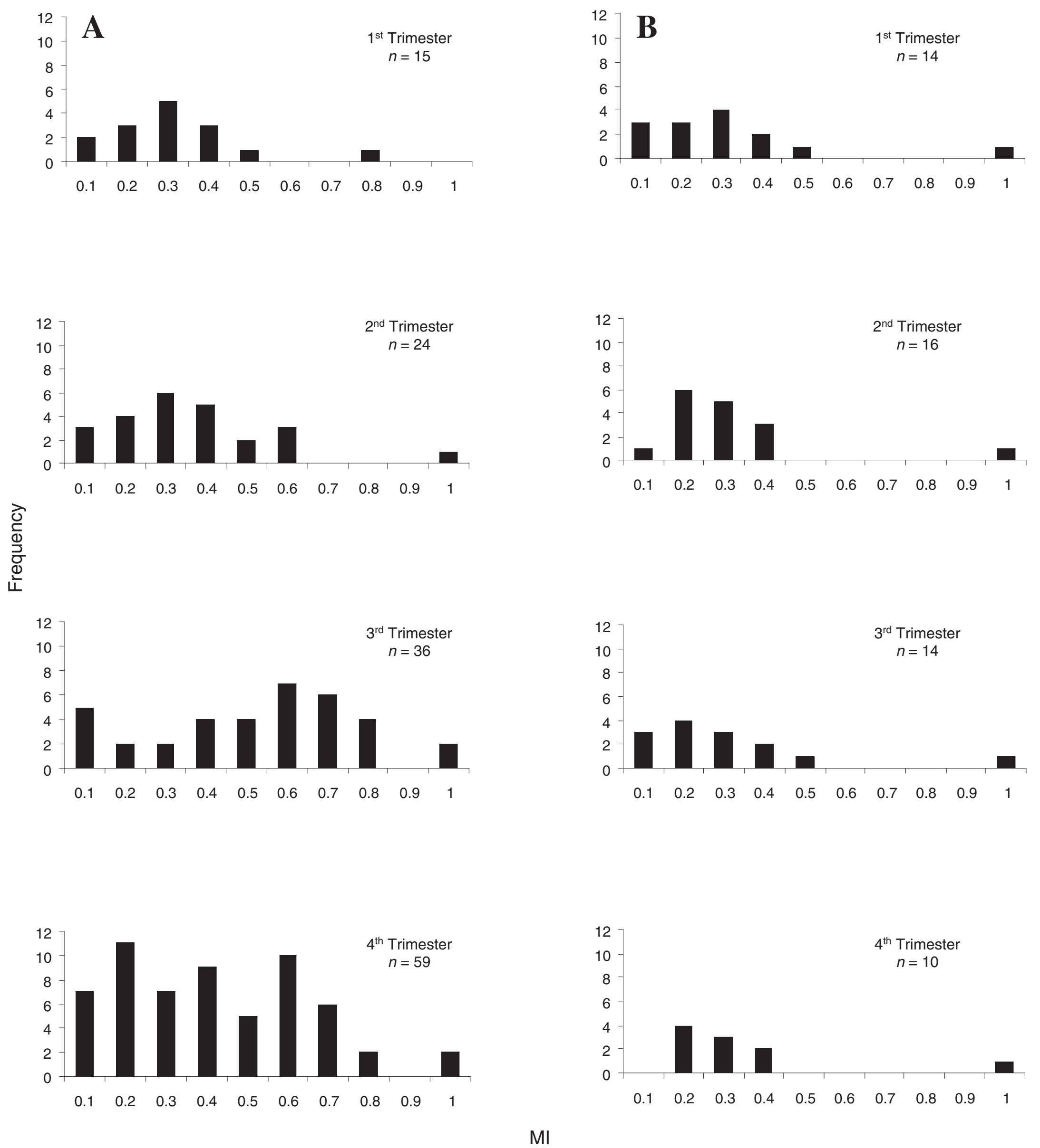

Figure 5

Marginal increments (MI) by trimester for ages 4 and 5 (n=139) (**A**) and ≥8 (**B**) (n=54) for the night shark (*C. signatus*) from northeastern Brazil.

(Fig. 7). According to the inverted back-calculated VBGF the oldest specimen in the sample was 31.7 years old (260 cm), whereas longevity was 31.5 years.

Discussion

Validating the time of band formation is considered critical when using hard parts for age estimates (Brothers, 1983), and validation is successful when growth zones are shown to form annually in all age groups of the population (Beamish and McFarlane 1983). Marginal increment analysis, carried out on younger and faster growing individuals, cannot always be used for validating older age groups, and therefore all ages must be ascertained (Brothers, 1983). In the present study, we obtained significant differences in marginal increments for the total sample. However, the significance level of the test (P=0.046) was close enough to 0.05 to cause us to suspect that the distributions could have been similar. The time of band formation varied when different age groups were analyzed separately, despite suggestions that bands are completed in the third and

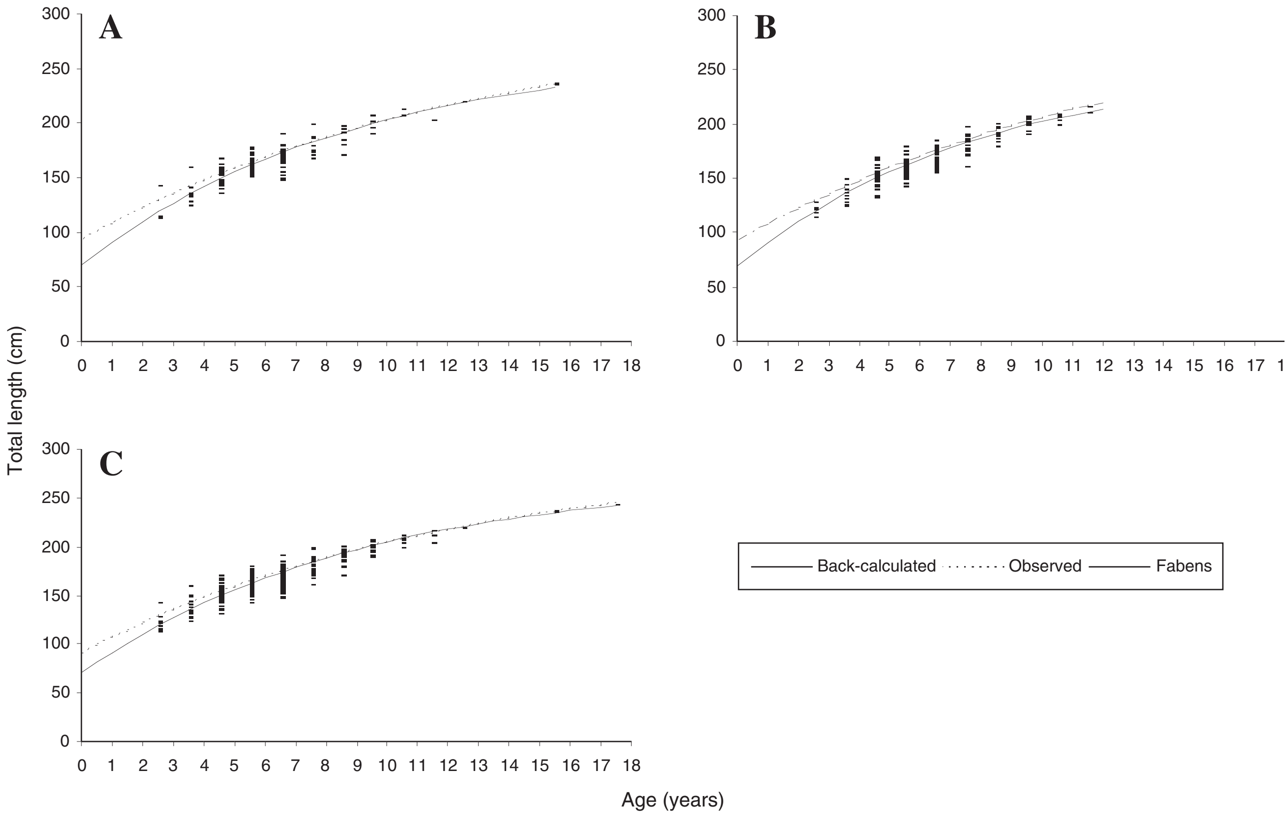

Figure 6

Growth curves generated from (**A**) females, (**B**) males, and (**C**) sexes combined for the night shark (*C. signatus*) off the northeastern Brazil.

Table 2

Von Bertalanffy parameters derived from back-calculated lengths (BC), observed lengths (OL), lengths from the Fabens method, and the length-frequency data analysis (LFDA) package for the pooled database (SE is standard error; CV is coefficient of variation).

Methods	Sex	L_∞ (cm)	SE	CV	K(/year)	SE	CV	t_0(year)	SE	CV	r^2
BC	Males	256.5	5.56	0.022	0.124	0.007	0.055	–2.538	0.119	0.047	0.999
	Females	265.4	4.15	0.016	0.114	0.005	0.045	–2.695	0.127	0.047	0.999
	Both	270	2.78	0.01	0.112	0.003	0.031	–2.705	0.099	0.037	0.999
OL	Males	306.1	37.71	0.117	0.076	0.02	0.267	–4.663	0.882	0.189	0.995
	Females	297.1	26.71	0.09	0.077	0.018	0.235	–4.853	0.977	0.201	0.99
	Both	289.9	7.6	0.026	0.085	0.006	0.077	–4.395	0.348	0.079	0.998
Fabens	Both	285.3	15.69	0.055	0.08	0.016	0.2	—	—	—	—
LFDA	Both	270.9	—	—	0.106	—	—	—	—	—	—

fourth trimesters (new bands begin to form in this period) in juveniles. Results were inconclusive for adults. For *C. obscurus* (Natanson et al., 1995), *C. plumbeus* (Sminkey and Musick 1995), *C. porosus* (Batista and Silva, 1995; Lessa and Santana, 1998), *C. acronotus* (Carlson et al., 1999), and *I. oxyrhynchus* (Lessa et al., 2000), inconclusive results for MI analysis were obtained. The inability to demonstrate the periodicity of band deposition in adult sharks in the present study is similar to the outcome for *C. limbatus* older than four years (Wintner and Cliff, 1996). For the last mentioned species, the problem was circumvented by restricting MI analysis to juveniles (Killam and Parsons, 1989).

Age was assigned by assuming an annual pattern of deposition, as commonly occurs for most carcharhinids like *C. brevipinna* and *C. limbatus*, *Rhizoprionodon terraenovae* (Branstetter et al., 1987; Branstetter and Stiles, 1987), *Negaprion brevirostris* (Gruber and Stout, 1983), and *C. longimanus* (Seki et al., 1998; Lessa et al., 1999c). Three sources of bias generally occur with MI analysis: 1) sample sizes are small for any particular month or for any age class (Cailliet, 1990); 2) data are collected over a too long a period causing variability on account of annual marks that are not formed at the same time (Brothers, 1983) and 3) births occur over a long period (Brothers, 1983). All these may have biased MI analysis in the present study.

Research carried out in the study area by Hazin et al. (2000) indicated that copulation takes places throughout the austral summer. Embryos measuring 10 to 40 cm were collected in February, whereas 31.8 to 37.2 cm embryos were found in June. This remarkable variability in embryo size during the gestation period suggests that birth period lasts several months. Furthermore, with an estimated back-calculated birth length of 66.8 cm, individuals measuring ~40 cm in February will be born long before individuals that measured 37.2 cm in June. Such a protracted parturition period could lead to differences in MI of the same cohort. Thus, after an assumed ~12 months gestation period, individuals are born with birth dates varying by several months. Moreover, no significant differences in MI analysis was found for *C. porosus* and *I. oxyrhynchus*, which also have a protracted birth seasons (Lessa et al., 1999a, 1999b).

A comparison of growth model parameters by using known size information, such as size-at-birth and maximum observed size, can be

Table 3

Back-calculated and observed length-at-age data (cm) for combined sexes of the night shark (*C. signatus*) caught off northeastern Brazil. Numbers in parentheses are the number of individuals examined for each category of band count.

		Vertebral band count																	
Age (yr)	*n*	0 (317)	1 (317)	2 (317)	3 (307)	4 (285)	5 (236)	6 (146)	7 (80)	8 (54)	9 (31)	10 (16)	11 (7)	12 (4)	13 (3)	14 (3)	15 (3)	16 (1)	17 (1)
Back calculated																			
2	10	65.1	90	112.1															
3	22	65.7	90.9	112.8	127.1														
4	49	57.8	93.5	115.4	130.9	144.2													
5	90	67.6	92.5	113.8	128.9	142.1	154												
6	66	67.6	91.6	112.1	126.7	139.7	151.6	162.3											
7	26	68.2	92.2	113.2	128.2	141.3	153.4	164.6	174.7										
8	23	68.5	92.6	113.4	128.2	141.9	153.9	165.3	175.9	185.1									
9	15	67.8	93.3	114.4	130.1	143.9	156	167.5	178.1	187.7	196.3								
10	9	67.1	93.2	112.9	127.9	141.5	153.6	165	175.7	185.6	194.3	201.6							
11	3	66.9	93	112.4	128.5	143.4	157.3	169	178.4	187	194.2	201.4	206.7						
12	1	64.3	90.8	110.7	129.2	143.8	155.7	167.7	178.3	187.5	195.5	202.1	208.7	214					
15	2	66.3	91.5	115.3	131	145.9	159.6	171.8	182.1	190.2	197.7	205.2	211.3	217.4	222.2	226.9	231.7		
17	1	65.5	93.3	119.7	133.6	146.1	157.2	168.3	179.4	189.2	198.9	207.2	214.2	219.8	225.3	229.5	233.7	237.8	240.6
Mean		66.8	92.2	113.7	129.2	143.1	155.2	166.8	177.8	187.5	196.1	203.5	210.2	217.1	223.8	228.2	232.7	237.8	240.6
SD		1.316	1.127	2.224	1.924	1.978	2.358	2.833	2.362	1.83	1.896	2.603	3.229	2.882	2.213	1.796	1.376	—	—
Observed																			
Mean		—	—	120.9	133.9	150.7	159	167.4	177.8	188.3	199	205.2	209	218	—	—	234.4	—	242
SD		—	—	8.765	9.185	8.803	7.688	9.003	9.354	7.556	5.641	3.509	6.557	0	—	—	0.629	—	0

Table 4

Likelihood ratio tests comparing estimates of von Bertalanffy parameters for males (noted as 1) and females (noted as 2) for *C. signatus* in the linear constraints.

Hypothesis	Linear constraints	Residual SS	χ^2_r	df	P
HΩ	none	60536.4			
Hω1	$L_{\infty 1} = L_{\infty 2}$	10511	0.049	1	0.996
Hω2	$K_1 = K_2$	10524.3	0.047	1	0.996
Hω3	$t_{01} = t_{02}$	10205.6	0.122	1	0.999
Hω4	Same L_∞, K, and t_0	24301.2	0.164	3	0.973

useful as a method of verification (Cailliet et al., 1983). Although no specimens younger than 2-years-old were caught (perhaps due to the gear selection bias), the presumed size at birth was about 60–65 cm (Compagno, 1984), which is similar to the estimated size in the present study (66.8 cm). Also, the estimated L_∞ value (270 cm), derived from the back-calculated or observed VBGF is close to the maximum size of 276 cm mentioned by Bigelow and Schroeder (1948), 280 cm off Cuba (Compagno, 1984), and 275 cm by Garrick (1985).

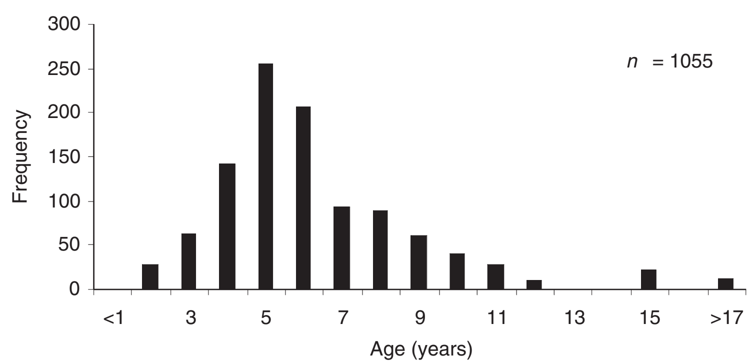

Figure 7

Age composition for the night shark (*C. signatus*) collected off northeastern Brazil.

Mean observed length-at-age is generally higher than back-calculated mean length-at-age (Bonfil et al., 1993; Lessa and Santana, 1998), leading to lower values of L_∞ and higher values of K. However, in the present study, although mean observed length-at-age is higher than mean back-calculated lengths, parameters derived from back-calculation provided a lower L_∞ and a higher K value. Inconsistency of the observed length-at-age set is attributed to the missing values in for ages 0, 1, 13, 14, and 16. This led to a VBGF which provided an unrealistic birth size of 90 cm and which present a flatter shape than the back-calculated curve.

Von Bertalanffy growth parameters generated from both back-calculation and by the Fabens method were all considered suitable and were of the same magnitude. However, taking into account 1) parameters close to those derived for length-frequency analysis, and 2) the best statistical fit, the back-calculated VBGF was chosen as best representing growth in the species.

Comparisions of biological features such as maturity size and maximum sizes have been used for inferences in growth and to explain differences between sexes (Natanson et al., 1995; Natanson and Kohler, 1996; Lessa et al., 2000). The studied species shows a disparity of ~15 cm in maturity sizes between sexes (Hazin, et al., 2000), corresponding to ~2 years. In addition, the largest specimen, for which sex was determined, was a 252-cm female and the largest male was 248 cm. These disparities, however, did not bring about differences in growth between sexes, as indicated by results of both tests used. Such a result can be explained by the number of juveniles used for age determination (~83%). Thus, the number of adults was not high enough to bring about any differences in the growth equation although differences frequently occur after maturity, caused by different growth rates between sexes (Natanson et al., 1995; Sminkey and Musick, 1995).

Assuming that the time elapsed between birth and the band corresponding to age 1 is one year, the species grows 38% of its birth length during the first year. This growth rate is close to that (50%) generally assumed (Branstetter 1990; Cortés, 2000). Furthermore, the estimated K value falls within the range suggested by the first author, and according to him, the night shark is a relatively fast growing species, presenting a life strategy similar to that of *C. falciformis,* and apparently depending on rapid growth for adequate neonate survival due to vulnerability to predation from large sharks.

In summary, considering the increasing fishing effort on the night shark as a targeted species and that catches are mainly composed by juveniles (representing 74.7% of specimens in landings), we believe that the K-selected characteristics of the species (including late maturity, long gestation period, and low fertility) should be taken into account in determining the management of this resource. Demographic analyses will be required for the examination of consequences of current levels of exploi-

Table 5

Age-length key (in percentages) for the night shark (*C. signatus*) caught off northeastern Brazil. Numbers in parentheses are the number of individuals examined in each age class.

		Age (years)															
TL (cm)	*n*	2 (10)	3 (22)	4 (49)	5 (90)	6 (66)	7 (26)	8 (23)	9 (15)	10 (9)	11 (3)	12 (1)	13 —	14 —	15 (2)	16 —	17 (1)
112.5	3	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
117.5	1	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
122.5	6	66.7	33.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
127.5	8	12.5	87.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
132.5	9	—	66.7	33.3	—	—	—	—	—	—	—	—	—	—	—	—	—
137.5	5	—	60	40	—	—	—	—	—	—	—	—	—	—	—	—	—
142.5	11	9.1	9.1	63.6	18.2	—	—	—	—	—	—	—	—	—	—	—	—
147.5	16	—	12.5	62.5	12.5	12.5	—	—	—	—	—	—	—	—	—	—	—
152.5	42	—	—	28.6	61.9	9.5	—	—	—	—	—	—	—	—	—	—	—
157.5	39	—	2.6	20.5	56.4	20.5	—	—	—	—	—	—	—	—	—	—	—
162.5	37	—	—	8.1	51.4	37.8	2.7	—	—	—	—	—	—	—	—	—	—
167.5	26	—	—	15.4	34.6	34.6	11.5	3.8	—	—	—	—	—	—	—	—	—
172.5	29	—	—	—	20.7	48.3	31	—	—	—	—	—	—	—	—	—	—
177.5	21	—	—	—	19	52.4	14.3	14.3	—	—	—	—	—	—	—	—	—
182.5	9	—	—	—	—	33.3	33.3	33.3	—	—	—	—	—	—	—	—	—
187.5	12	—	—	—	—	8.3	41.7	41.7	8.3	—	—	—	—	—	—	—	—
192.5	8	—	—	—	—	—	—	62.5	37.5	—	—	—	—	—	—	—	—
197.5	12	—	—	—	—	—	16.7	50	25	8.3	—	—	—	—	—	—	—
202.5	7	—	—	—	—	—	—	—	71.4	14.3	14.3	—	—	—	—	—	—
207.5	9	—	—	—	—	—	—	—	33.3	66.7	—	—	—	—	—	—	—
212.5	2	—	—	—	—	—	—	—	—	50	50	—	—	—	—	—	—
217.5	2	—	—	—	—	—	—	—	—	—	50	50	—	—	—	—	—
222.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
227.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
232.5	2	—	—	—	—	—	—	—	—	—	—	—	—	—	100	—	—
237.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
>242.5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100

tation to ensure the sustainability of the night shark in northeastern Brazil.

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