Age and Growth of the Blacktip Shark, *Carcharhinus limbatus*, near Tampa Bay, Florida

Kristie A. Killam and Glenn R. Parsons

ABSTRACT: Age and growth of the blacktip shark, *Carcharhinus limbatus*, was investigated in the Tampa Bay area of Florida during May 1985–February 1987. Two hundred and eighteen sharks were captured, and vertebrae were examined from 86 females (52.4–183.0 cm TL) and 54 males (59.8–160.5 cm TL). Minimum and maximum number of translucent winter rings was 0 and 11. Marginal increment analysis on juvenile blacktips with one to three translucent vertebral rings suggested an annual ring deposition during December–January. Length-frequency and length-month analyses suggested three age classes for blacktips <120 cm TL. Growth in length and percentage of size increase of blacktips age 0 and I was 21.0 (29.3%) and 19.0 (20.7%) cm/yr, respectively. Growth in weight and percentage of size increase of age 0 and I blacktips was 3.09 (120.7%) and 3.29 (58.2%) kg/yr, respectively. Age at maturity was 6–7 years (158–162 cm TL) for females and 4–5 years (133–136 cm TL) for males. Maximum age of blacktips captured was 10 years for two females 179.0 and 180.0 cm TL, and 9 years for a 160.5 cm TL male. Growth in weight was fit with a logistic equation. Von Bertalanffy growth parameters for females were estimated at L_∞ = 195.0 cm TL, k = 0.197 and t_0 = −1.154 years and for males, L_∞ = 166.5 cm TL, k = 0.276, and t_0 = −0.884 years.

Blacktip sharks, *Carcharhinus limbatus*, are distributed in all tropical and subtropical continental waters (Compagno 1984) and are very common inhabitants of inshore coastal and estuarine regions in Florida and the Gulf of Mexico (Springer 1940; Clark and von Schmidt 1965; Dodrill 1977; Branstetter 1981; Killam 1987). Recently, blacktip sharks have received commercial interest because of their increased value as a food fish. Commercial shark landings in Florida have risen steadily from 170,740 pounds in 1979 to 1,910,222 pounds in 1986 (Florida Department of Natural Resources 1979–86). In California a similar situation has occurred where landings for the common thresher shark, *Alopias vulpinus*, the blue shark, *Prionace glauca*, and the shortfin mako, *Isurus oxyrinchus*, increased from 800,000 pounds in 1976 to 3,500,000 pounds in 1981 (Cailliet and Bedford 1983).

Elasmobranch populations are thought to be easily overexploited because of their relatively slow growth rates, long gestation periods, and low fecundity (Holden 1974, 1977). As apex predators in complex estuarine and marine ecosystems, blacktip sharks have an important ecological role. Increased exploitation of blacktip shark stocks may effect lower trophic levels in the ecosystem, therefore sound life history information is needed. At present, little information is available concerning the biology of the blacktip shark. Its reproductive biology has been examined in the northern (Branstetter 1981) and east-central (Clark and von Schmidt 1965; Killam 1987) Gulf of Mexico. Killam (1987) provided detailed informaton on the seasonal distribution, reproductive biology, and feeding habits of *C. limbatus* captured near Tampa Bay, FL. Dodrill (1977) provided life history information on blacktip sharks captured along the east coast of Florida. Garrick (1982) reported that distinct populations of *C. limbatus* may exist in different geographic regions, because maximum attainable size and sizes at maturity differ markedly between regions.

At present only a single study has been completed concerning the age and growth of the blacktip shark. Branstetter (1987a) estimated growth parameters of *C. limbatus* in the northwestern Gulf of Mexico. This study provides additional information on the age and growth of *C. limbatus* by 1) providing a detailed examination of early growth rates using length-frequency and length-month analyses, 2) utilizing marginal increment analysis on juvenile *C. limbatus* to determine periodicity of ring deposition, and 3) identifying differences in age and growth rates between female and male *C. limbatus*.

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MATERIALS AND METHODS

Two hundred and eighteen blacktip sharks were collected in Tampa Bay and adjacent offshore areas during May 1985–February 1987. One hundred and forty were utilized for age and growth analyses. Sharks were caught with gill nets, longlines, and rod and reel. Once captured, total length (TL), fork length (FL), and precaudal length (PCL) were measured. Total length of embryos was measured with caudal fin extended horizontally. All lengths reported in this paper refer to total lengths. Sharks were then weighed and sexed. Maturity of males and females was determined using morphological and gonadal characteristics described by Clark and von Schmidt (1965) and Wass (1973).

A section of the vertebral column was removed just anterior to the first dorsal fin, although in a few instances only caudal vertebrae were obtainable. The vertebrae were stored frozen, then cleaned of connective tissue by soaking the individual centra in a solution of 5.25% sodium hypochlorite. Centra were then rinsed and stored in a solution of 70% ethanol. Two techniques were tested to determine optimum enhancement of translucent vertebral rings: the silver nitrate technique (Stevens 1975) was compared with a method described by Parsons (1983) in which the vertebral centrum face is shaded with a No. 1 pencil. The latter method detected differences in microtopography of the centrum face and enhanced the translucent rings. This method proved effective and was used because it took only a fraction of the time of the silver nitrate method. Vertebral centra were read under a dissecting microscope at 10× power using transmitted light. Centrum radius was measured from the focus to the dorsal margin using vernier calipers. Radii measurements were used to determine a relationship with shark TL. Ring radii were measured from the focus to each translucent ring, along the angle of the centrum (Fig. 1). Vertebrae collected from the caudal region were excluded from radius and marginal increment measurements. However, caudal vertebrae were utilized in age determinations since ring counts made on centra from different areas of the vertebral column resulted in similar age estimations. Translucent rings enhanced by the pencil method were counted if they extended continuously around the centrum face. Centra were read independently by the two authors. When discrepancies occurred, the vertebrae were reread until an agreement was reached. Ten centra were unreadable and were discarded from the analysis. Twenty centra of varying size were sectioned with a low speed saw through the focus, along the dorsal-ventral plane, for comparative ring counts with whole centra. Since blacktip sharks are born during late April through early June (Killam 1987), ages and growth rates were estimated based on an arbitrary 1 May birth date.

Back-calculated size at age was determined by a direct proportion method (Everhart and Youngs 1981):

$$(TL)_n = (TL)_c \times (VR)_n/(VR)_c$$

where TL_n = calculated length at ring n, TL_c = total length at capture, VR_c = the centrum radius at capture, and VR_n = centrum radius to ring n. Back-calculations were made on blacktip sharks of all sizes.

Marginal increment analysis examines the distance from the most recently deposited ring to the centrum margin and was utilized to determine the time of year that rings are deposited. The centrum margin becomes difficult to resolve in older fish and, therefore, only sharks with one, two, or three rings were utilized in this analysis. Marginal increments were measured from the distal most translucent ring to the edge of the centrum (Fig. 1). Measurements were made with vernier calipers along the angle of the centrum face.

Age and weight relationships were determined by fitting a logistic growth curve to observed data, as described by Kappenman (1981).

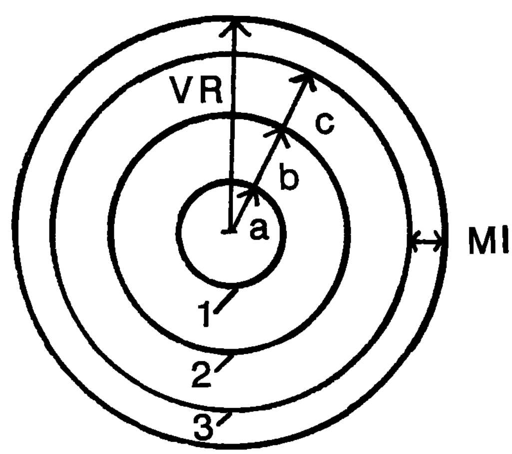

FIGURE 1.—Diagram of typical vertebral centrum of *Carcharhinus limbatus*. Measurements taken include: VR = vertebral radius; MI = marginal increment; a, b, and c = ring radii of translucent rings 1, 2, and 3. Measurements were taken along the dorsal-ventral plane.

The equation is

$$W = a/1 + \exp^{(-(b*r)+c)},$$

where W = weight in kg, a = asymptotic weight in kg, r = number of vertebral rings, and b and c are constants.

The von Bertalanffy (1938) growth equation was used to predict a growth curve for male and female blacktip sharks (Ricker 1975). The equation is

$$L_t = L_\infty(1 - \exp^{-K(t - t_0)}),$$

where L_t = length at age t in years, L_∞ = maximum theoretical length, K = the rate at which the asymptote is reached, and t_0 = the theoretical age at zero length. The von Bertalanffy growth equation was fit to observed data using a nonlinear, Statistical Analysis System method (SAS Institute, Inc. 1982).

RESULTS

Centrum Analysis

A total of 140 vertebral centra were read from 86 female and 54 male *C. limbatus*. These sharks ranged in size from 52.4 to 183.0 cm. The minimum and maximum numbers of translucent rings counted were 0 and 11. Centrum radii ranged from 2.8 to 10.6 mm. Initially, exact agreement of ring counts was reached on 83% of the readings, 15% differed by one ring, and 2% by two rings. Translucent ring counts made on sectioned centra were very similar to those of the corresponding whole centra. The number of translucent rings counted ranged from 1 through 10. When comparisons between whole and sectioned centra were made, exact agreement was reached on 15 centra, 3 centra differed by one ring and 2 centra differed by two rings. In addition, the ring structures counted on the sectioned centra were coincidental with those enhanced by the pencil method. Subjectivity is involved in both methods and sometimes resulted in slightly different counts.

The relationship between blacktip shark total length and centrum radius was linear for both sexes. Analysis of covariance (ANCOVA) indicated no significant difference in the regression lines between sexes, so data were combined into the relationship (Fig. 2)

$$TL = 63.2 + (16.7)R \qquad (r = 0.9797, N = 130)$$

where TL = total length in mm and R = centrum radius in mm.

Initial vertebral ring deposition appeared to occur at or shortly after parturition. Examination of 15 centra from embryonic *C. limbatus*, which ranged in size from 48.4 to 61.8 cm, had no observable translucent ring formation. These sharks were collected between April and June 1986. If a ring had been deposited prior to birth, it should have been visible in the near-term embryos. Free-swimming juveniles captured in late May and early June had a translucent ring deposited on the edge of the centrum. With subsequent growth, this "birth" ring became more apparent as opaque tissue was deposited distally to it.

Marginal increment data on juvenile blacktip sharks (52.4–116.0 cm) of both sexes were combined, because at this age there were no significant differences in sizes (Student's t-test, $P > 0.10$). Fish captured in early February were approximately 9 months old and had very small marginal increments (0.1–0.2 mm), indicating recent ring deposition. Analysis of juveniles taken later in the spring and summer showed that marginal increments increased in width (Fig. 3) to as much as 1.4 mm until December when the next ring formed. This analysis suggests ring deposition occurs during the months of December–January and, in the juvenile blacktip shark, is an annual event.

Early Growth Rates

The relatively large numbers of juvenile and subadult blacktip sharks examined in this study allowed the estimation of early growth rates. A length-frequency distribution of sharks <120 cm TL captured during the months of May–August suggests three separate size classes at approximately 68, 93, and 111 cm (Fig. 4). A length-month distribution (Fig. 5) indicated three distinct size classes for juvenile blacktip sharks <120 cm, and these fish appeared to represent three separate cohorts. Rapid growth of the young sharks produced distinct separations in length and weight between these age classes (Table 1) and each of the sharks examined from these three age classes had one, two, or three translucent rings, respectively. This further supports the annual nature of vertebral ring deposition in juvenile blacktip sharks.

Growth of neonatal sharks was found to be rapid. Mean size of free-swimming juveniles captured during June was 60.5 cm (SD = 3.9, N =

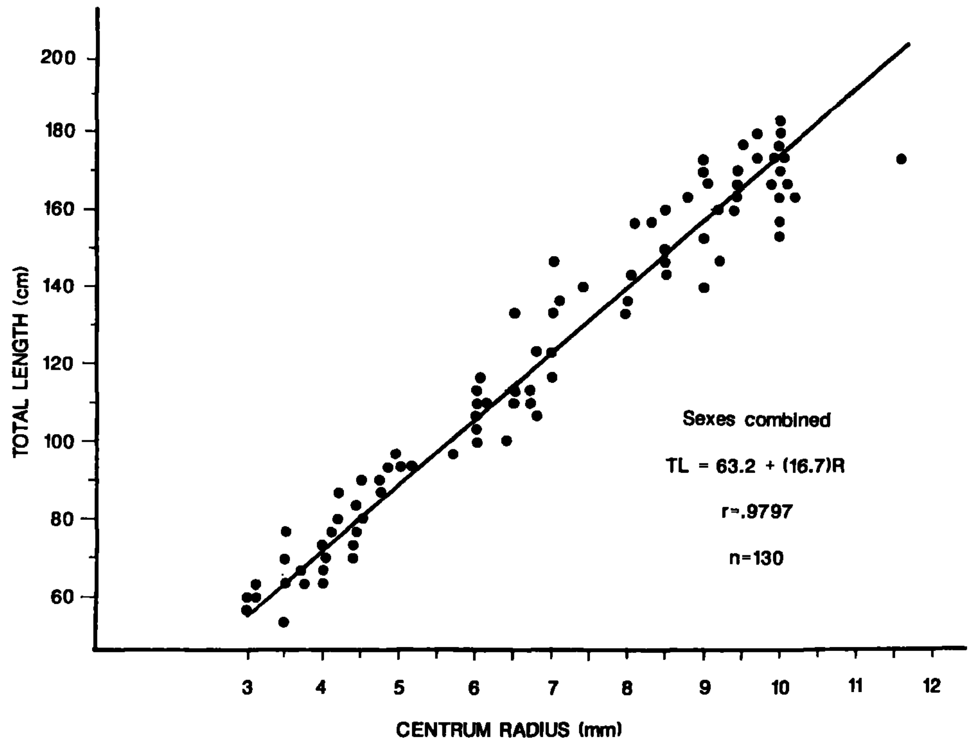

FIGURE 2.—Relationship between vertebral centrum radius and total length (sexes combined) for blacktip sharks captured in the Tampa Bay area of Florida.

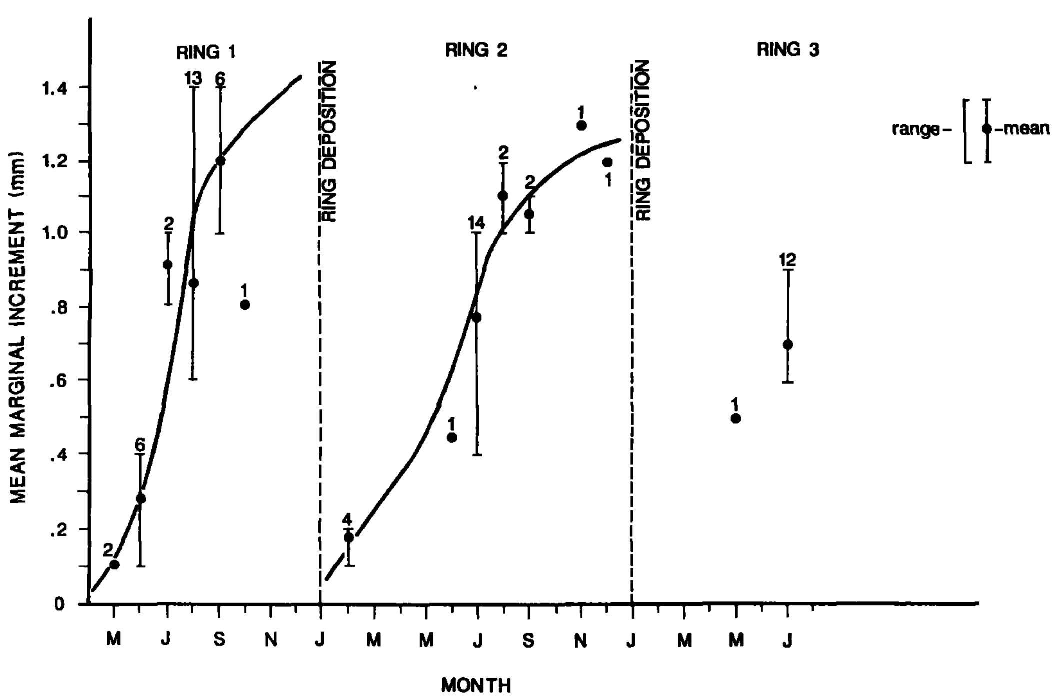

FIGURE 3.—Mean monthly marginal increment correlated with month of capture for blacktip sharks with 1, 2, or 3 vertebral rings. Curves were fit by eye to best approximate the seasonal increase in marginal increment. Translucent ring deposition appears to occur during December or January.

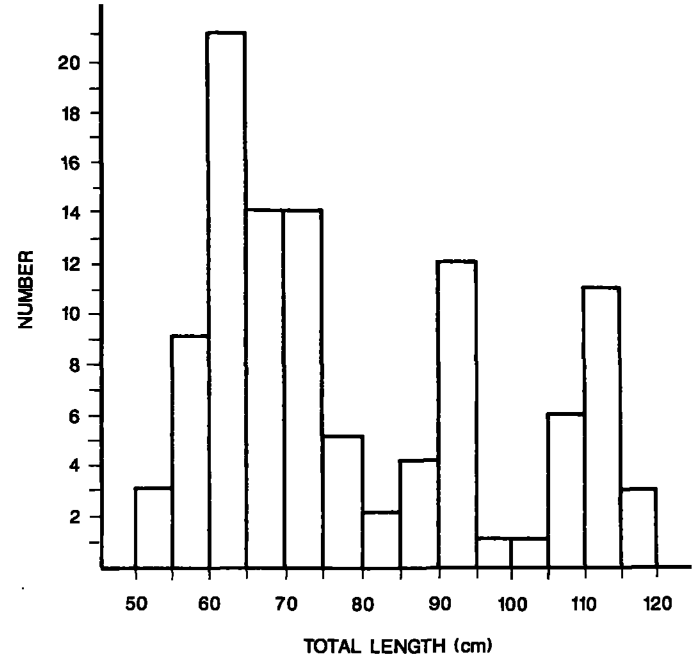

FIGURE 4.—Length-frequency distribution of juvenile blacktip sharks <120 cm TL. Three peaks in abundance are apparent and probably indicative of separate age classes.

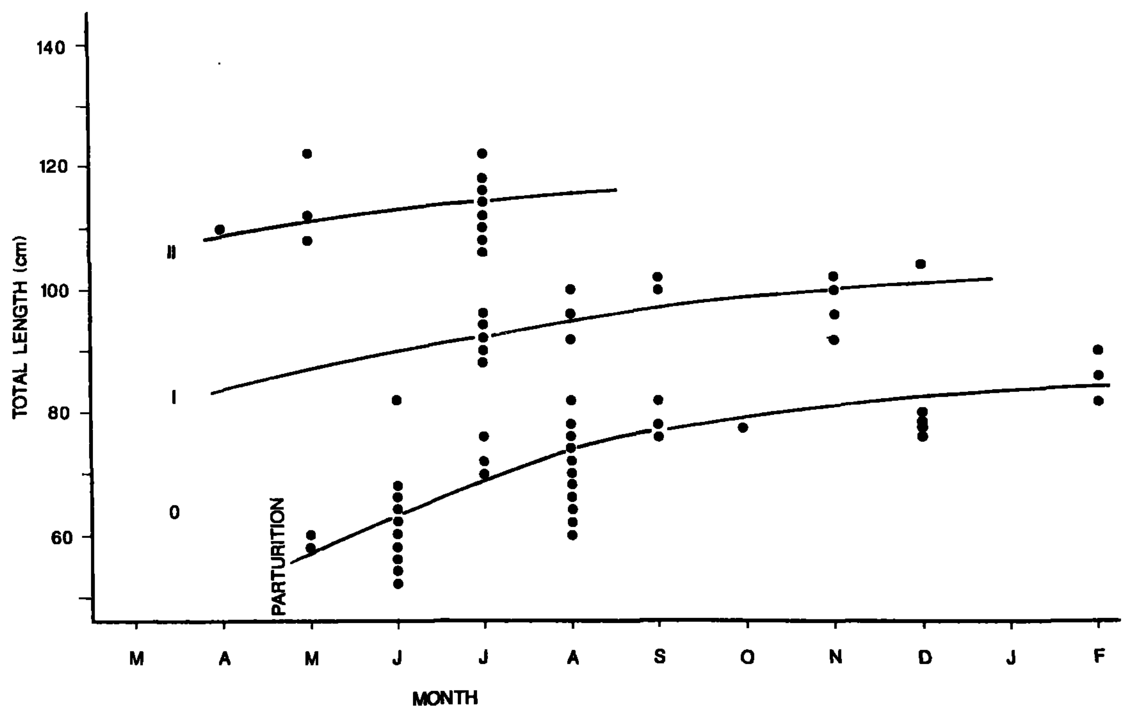

FIGURE 5.—A length-month distribution for juvenile blacktip sharks in age classes 0–II. Curve was fit by eye to best approximate the seasonal increase in total length for each age class.

TABLE 1.—Size differences among juvenile blacktip sharks with 1, 2, or 3 vertebral rings, captured during July and August 1986.

No. rings	No. fish	Mean TL (cm) ± SD	Mean weight (kg) ± SD
1	14	68.7 ± 1.2	2.3 ± 1.2
2	15	93.2 ± 7.3	5.8 ± 1.6
3	15	111.4 ± 8.5	8.9 ± 2.3

33) and mean weight was 1.47 kg (SD = 0.28, N = 29). These fish had prominent umbilical scars which indicated recent parturition. Sharks of this size possessed a birth ring on their vertebral centra and were assigned to age class 0. By mid-August, age 0 sharks had increased 11.1 cm (mean TL = 71.6 cm, SD = 4.74, N = 28), and 1.09 kg (mean weight = 2.56 kg, SD = 0.46, N = 28). This is an increase in length of 18.3% and an increase in weight of 74.0% from mid-June to mid-August. Growth during the first two months was 5.56 cm and 0.55 kg/mo. Four age class 0 *C. limbatus* captured in early February possessed two vertebral rings on their centra and had a mean TL of 85.5 cm (SD = 2.3, N = 4). Compared with the lengths of age 0 fish in mid-August, these fish had grown an additional 13.9 cm or approximately 2.5 cm/mo. This indicates a decline in growth rates over the winter months, and is depicted as a leveling off of the growth curves on the length-month distribution (Fig. 5).

Blacktip sharks captured after May 1 that possessed two vertebral rings (a birth ring and a first winter ring) were assigned to age class I. In late July, these fish had a mean length of 92.6 cm (SD = 2.36, N = 13) and mean weight of 5.65 kg (SD = 0.84, N = 14) representing growth in one year of approximately 21.0 cm (29.3%) and 3.09 kg (120.7%). Age class II sharks (3 vertebral rings) captured in late July had a mean length of 111.8 cm (SD = 3.51, N = 15) and a mean weight of 8.94 kg (SD = 0.80, N = 13) representing an increase of 19.2 cm (20.7%) and 3.29 kg (58.2%) in their second year of growth.

Age-Length

Growth in length was described using the von

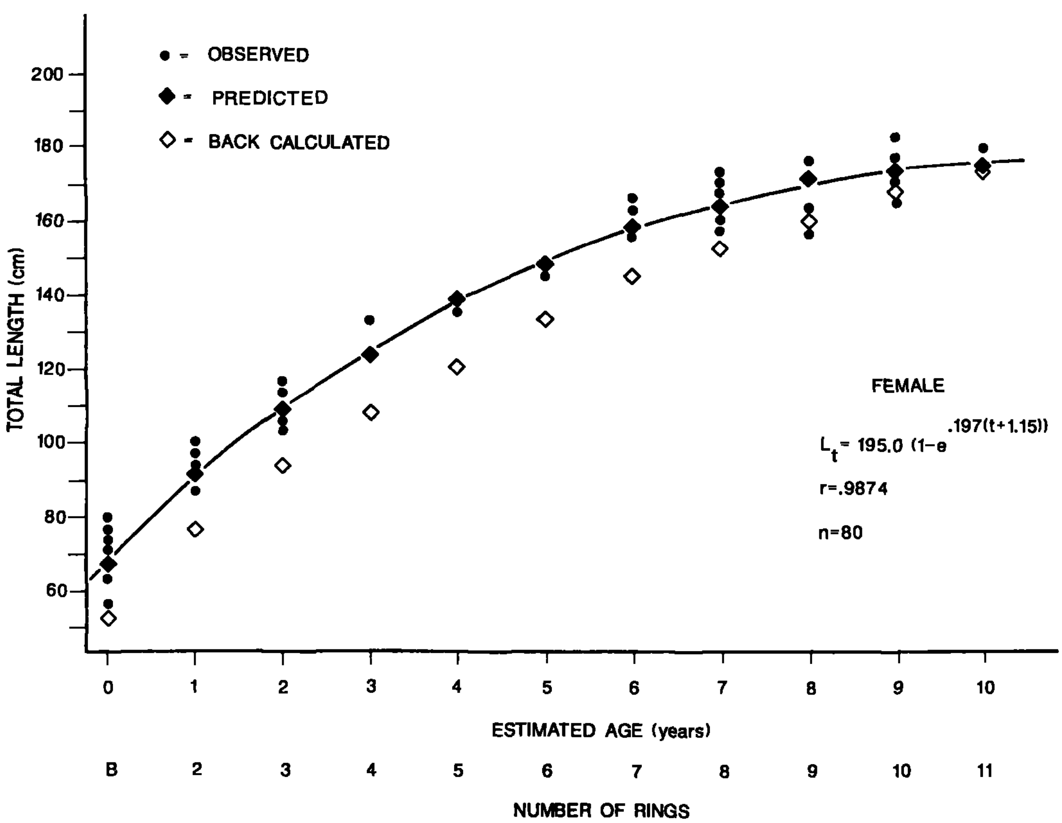

FIGURE 6.—Von Bertalanffy growth curve for female blacktip sharks fit from observed data. Distance between ring B and ring 1 is only 7–8 months but is represented as a 1-yr interval to prevent overestimation of early growth rates.

Bertalanffy growth equation fit with observed data. Growth curves for both sexes were significant at $P < 0.05$. Growth equations produced for female and male *C. limbatus* were

$$\text{Female: } L_t = 195.0\,(1 - \exp^{0.197(t+1.15)}) \quad r = 0.987,\ N = 80$$

$$\text{Male: } L_t = 166.5\,(1 - \exp^{0.276(t+0.88)}) \quad r = 0.979,\ N = 53.$$

Estimated maximum total length of females was significantly different from males as indicated by the separation of the calculated 95% confidence intervals. K values, although larger for males, were not significantly different from females (Table 2); however, females were significantly larger than males after age seven (Student's t-test, $P < 0.05$).

Growth rates for juvenile, adolescent, and mature blacktip sharks were approximately 19–21, 9–10, and 3–4 cm/yr, respectively. Females matured at 158–162 cm at 6–7 years; males matured at 133–136 cm at 4–5 years (Killam 1987, Figs. 6, 7). The smallest gravid female captured was six years old. Maximum age obtained by female *C. limbatus* was 10 years for two fish which measured 179.0 and 180.0 cm. Maximum age of male *C. limbatus* was nine years for a fish which measured 160.5 cm.

TABLE 2.—Estimated parameters of the von Bertalanffy growth equation derived using SAS nonlinear method, including 95% confidence intervals.

Parameter	Estimate	Asymptotic 95% confidence interval Lower	Upper
Females			
L_∞(cm)	195.0	183.0	206.9
K	0.1967	0.1546	0.2393
t_0(yr)	−1.154	−1.555	−0.753
Males			
L_∞(cm)	166.5	155.0	177.9
K	0.2758	0.2066	0.3450
t_0(yr)	−0.8836	−1.3006	−0.4665

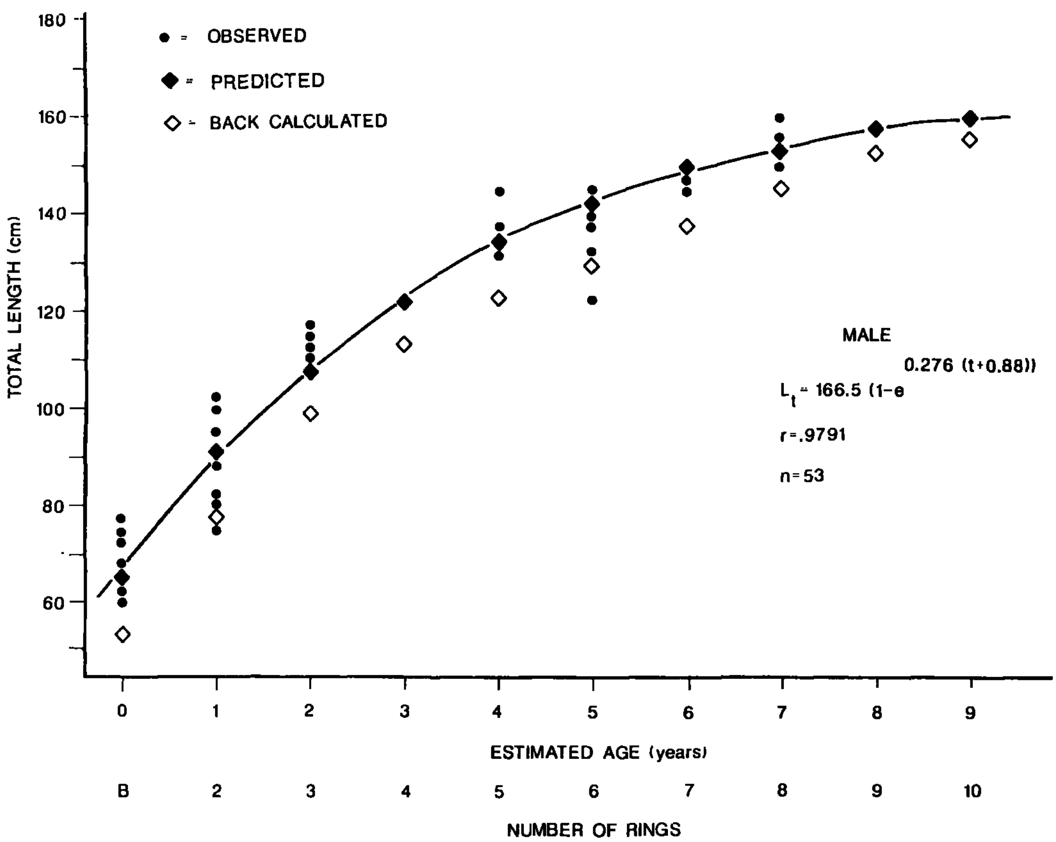

FIGURE 7.—Von Bertalanffy growth curve for male blacktip sharks fit from observed data. Distance between ring B and ring 1 is only 7–8 months but is represented as a 1-yr interval to prevent overestimation of early growth rates.

Back-Calculation

Back-calculated size at time of first ring deposition was 52.1 and 53.2 cm for females and males, respectively. These values correspond closely to observed sizes of *C. limbatus* at birth, further supporting the first translucent ring being a birth ring. Back-calculated size was inspected for "Lee's Phenomenon," which appeared to occur at some ages; however, no consistent trend was identified (Table 3). Mean back-calculated size at age was consistently lower than observed and predicted data (Figs. 6, 7).

Growth curves for both sexes were derived using observed data from sharks with 1–11 vertebral rings. As shown in Figures 6 and 7, ring 1 (birth ring) and ring 2 are shown to be one year apart. In actuality, the second translucent ring is deposited approximately 7–8 months after the formation of the birth ring. However, because 83.4% of these sharks were captured during the summer months of May–September, sharks with two translucent rings are more likely to be at least one year older than those with only the birth ring.

Age-Weight

The nonlinear relationship between shark age and weight was significantly fit with a logistic growth equation ($P < 0.05$). The relationship for females $(W)_f$ and males $(W)_m$ was

$$(W)_f = 42.68/1 + \exp^{-(0.540*r)-3.14}$$
$$r = 0.962, N = 69$$

$$(W)_m = 27.83/1 + \exp^{-(0.550*r)-2.58}$$
$$r = 0.974, N = 48$$

where W = weight in kg, and r = number of translucent rings (Figs. 8, 9). Growth in length and weight of *C. limbatus* appears to reach an asymptote, and blacktips greater than 10 years old probably grow very little each year.

TABLE 3.—Mean back-calculated total lengths (cm) at age, for female and male blacktip sharks captured in the Tampa Bay area of Florida.

Rings	Number	Mean	±	SE	B	1	2	3	4	5	6	7	8	9	10
Females															
B	19	68.1	±	8.0	54.3										
2	16	88.7	±	7.5	54.6	79.6									
3	5	109.7	±	4.1	49.2	77.6	101.0								
4	1	132.0	±		57.2	88.0	114.4	125.9							
5	1	136.4	±		49.9	68.2	96.5	113.1	126.4						
6	2	142.0	±	7.2	51.5	70.2	87.9	104.8	119.8	133.0					
7	2	157.0	±	10.1	50.9	69.9	88.0	103.6	119.2	133.9	144.2				
8	12	165.8	±	6.2	48.7	72.6	96.1	111.9	126.9	138.2	149.9	159.5			
9	6	166.4	±	8.0	48.5	66.8	85.4	100.7	114.1	127.0	137.9	138.8	158.6		
10	3	172.3	±	4.9	48.9	68.7	86.9	102.2	116.0	128.6	139.1	150.6	162.7	168.8	
11	2	179.1	±	7.6	51.0	69.9	87.9	103.1	119.3	131.0	140.8	149.8	157.9	170.3	176.5
Weighted mean					52.0	74.3	93.2	107.4	121.4	133.5	144.5	154.7	159.6	169.4	176.5
Number of back-calculations					69	50	34	29	28	27	25	23	11	5	2
Growth increment					22.6	18.9	14.2	14.0	12.1	11.0	10.2	4.9	9.8	7.1	
Males															
B	16	68.0	±	6.9	55.5										
2	12	89.4	±	8.7	53.0	79.7									
3	9	112.3	±	3.5	50.5	76.9	101.1								
4	1	122.0	±		56.1	79.4	103.6	125.6							
5	3	138.3	±	5.4	52.9	75.8	97.3	117.3	130.4						
6	3	135.7	±	8.8	51.1	75.5	95.3	109.0	120.3	132.8					
7	2	145.8	±	10.6	53.7	76.7	96.6	111.2	119.5	128.7	140.2				
8	1	155.1	±	5.4	51.7	72.4	93.1	110.3	120.7	132.8	141.4	148.3			
9	2	155.8	±	3.9	52.2	75.7	89.6	103.6	118.4	127.1	137.5	144.4	151.4		
10	1	160.5	±		46.7	63.8	95.0	110.6	118.4	126.2	134.0	140.0	148.0	154.3	
Weighted mean					53.2	77.2	97.8	112.0	122.3	129.9	138.4	144.2	150.3	154.3	
Number of back-calculations					50	34	22	13	12	9	6	4	3	1	
Growth increment					24.0	20.6	14.2	9.4	7.6	8.5	5.8	6.1	4.5		

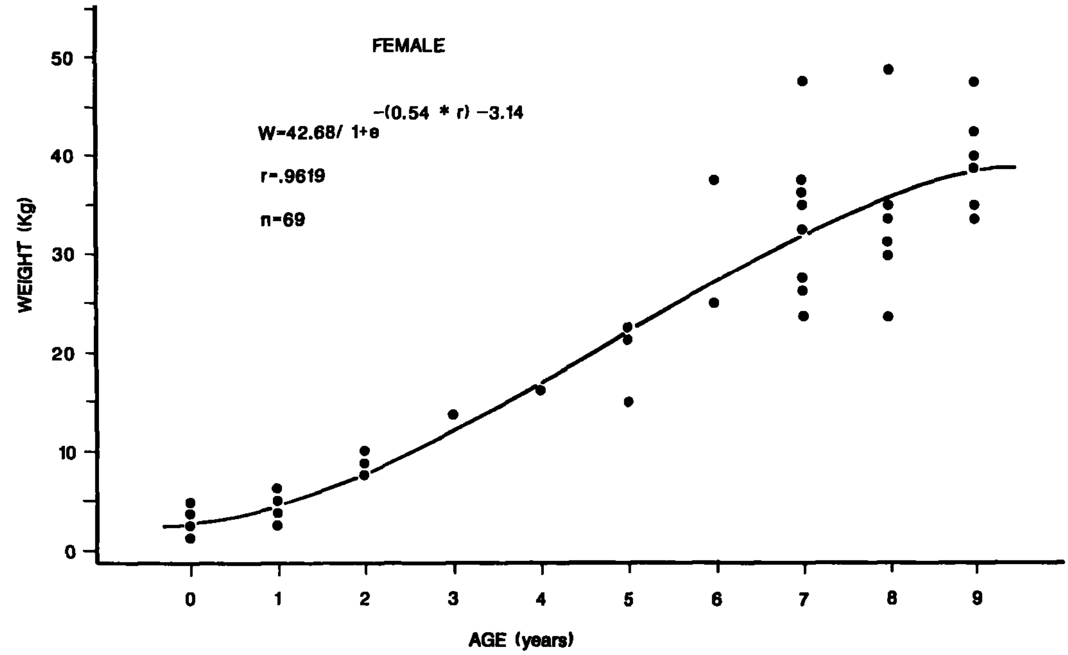

FIGURE 8.—Age-weight relationship for female blacktip sharks; logistic growth equation provided a significant fit to the data ($P < 0.05$).

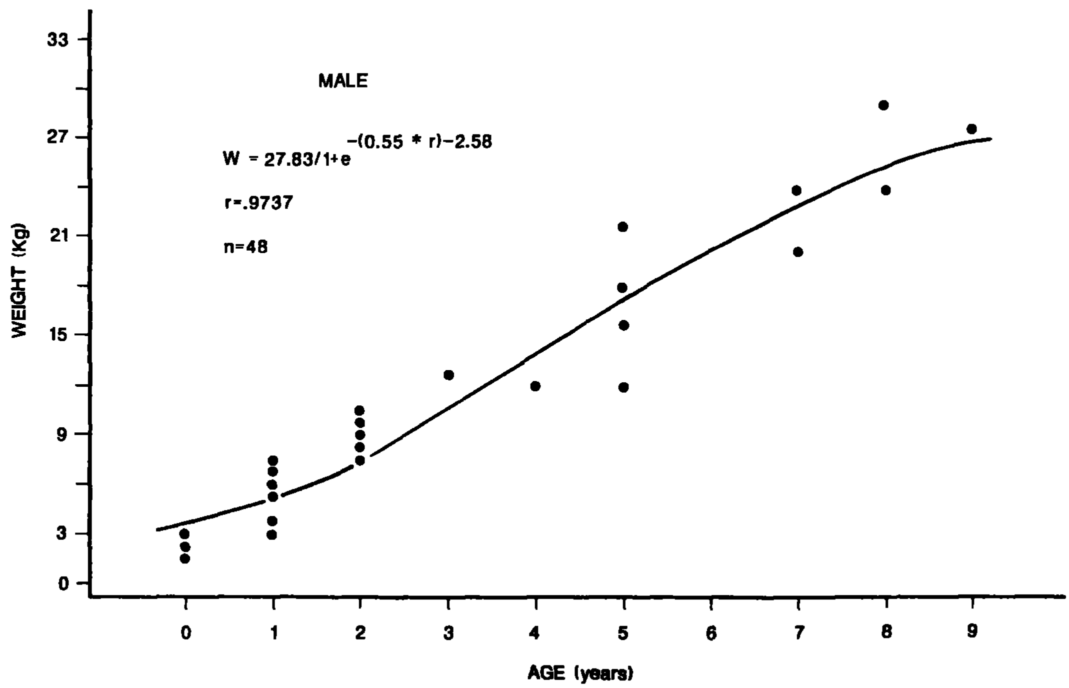

FIGURE 9.—Age-weight relationship for male blacktip sharks; logistic growth equation provided a significant fit to the data ($P < 0.05$).

DISCUSSION

Centrum analysis

Perhaps the most common limiting factor in many studies concerning shark species is the acquisition of sufficient specimens over the entire size range of the species. The relatively large sample size reported here made annulus verification and subsequent growth estimation possible. Marginal increment, length-frequency, and length-month analysis suggest that ring periodicity in juvenile *C. limbatus* is annual. Annual ring deposition in sharks has been verified or validated for several species, including *Prionace glauca* (Stevens 1975), *Rhizoprionodon terraenovae* (Parsons 1983), *Negaprion brevirostris* (Gruber and Stout 1983), *C. amblyrhynchos* (Radtke and Cailliet 1984), *Triakis semifasciata* (Smith 1984), *C. plumbeus* (Casey et al. 1985), *C. leucas* (Branstetter and Stiles 1987), *C. falciformis* and *Sphyrna lewini* (Branstetter 1987b), *Galeocerdo cuvieri* Branstetter et al. 1987), and *S. tiburo* (Parsons 1987). Cailliet et al. (1986) provided an extensive review of elasmobranch species for which age and growth rates have been estimated. In some lamnoid species such as *I. oxyrinchus* (Pratt and Casey 1983) and *Cetorhinus maximus* (Parker and Stott 1965), deposition of two rings per year has been suggested. Therefore, it appears that for each species being examined, periodicity of ring deposition must be verified or validated before proper age and growth estimates can be attained.

Early Growth

Because Tampa Bay is a nursery area for *Carcharhinus limbatus* (Killam 1987) the capture of numerous juvenile specimens was fairly easy. Rapid early growth rates of these young sharks made determination of periodicity of ring deposition possible. Marginal increment analysis suggested that one translucent ring is deposited during the winter months of December–January, and that opaque tissue is deposited distally to these rings, during periods of rapid growth in warmer months. A similar pattern of ring deposition has been identified in *C. amblyrhynchos* (Radtke and Cailliet 1984; Cailliet et al. 1986). The opaque areas have been found to contain higher amounts of calcium and phosphorus than the adjacent translucent rings.

The rapid early growth of juvenile *C. limbatus* produced distinct separations in length-frequency modes for sharks <120 cm TL. Modes are more difficult to resolve in larger *C. limbatus* because fish of similar sizes may represent a variety of age classes owing to differences in individual growth rates and the decrease in growth rate as age increases. Ketchen (1975) utilized length-frequency analysis to estimate early age classes of *Squalus acanthias*, 44–70 cm TL. It appears that only early age classes of sharks undergoing rapid growth can be estimated by analyzing length-frequency distributions. Casey et al. (1985) found that in 3–8 year old *C. plumbeus*, several age classes may be represented at any one length.

A length-month distribution subjectively assigned *C. limbatus* to age classes and provided estimates of growth rates. Modes identified by this method were subjectively assigned to age classes. Three age classes were apparent for blacktips 62–118 cm. As with the length-frequency distributions, the length-month distribution becomes increasingly difficult to resolve in older sharks. Pratt and Casey (1983) utilized this method to estimate three age classes of juvenile *I. oxyrinchus*, 54–175 cm TL. Parsons (1985) used this procedure to estimate age and growth through maturity for the rapidly growing *R. terraenovae* whose males mature as early as 2.0–2.4 years and females mature at 2.4–2.8 years.

Early growth rates have been examined in only a few species of sharks. Juvenile *C. leucas* grew at 18 and 16 cm/yr during the first 2 years, respectively, decreasing to 11 cm/yr in larger sharks (Thorson and Lacy 1982). *Rhizoprionodon terraenovae* growth rates for age classes 0 and I were 30 and 10 cm, respectively, which corresponded to a 100% increase in length for age 0 individuals and a 15% increase at age I (Parsons 1983). Young *N. brevirostris* growth rates did not exceed 25 cm/yr and probably averaged 10–20 cm/yr (Gruber and Stout 1983). *Galeocerdo cuvieri* appeared to grow > 20 cm/yr until near maturity (Branstetter et al. 1987). *Carcharhinus limbatus* had growth rates of 21.0 and 19.2 cm/yr for age classes 0 and I. A very similar growth rate was determined for juvenile *C. limbatus* in the northern Gulf of Mexico (Branstetter 1987a).

It appears that early growth in more pelagic species may differ. Young *I. oxyrinchus* showed rapid first year growth rates of 49.0 cm/yr and second year rates of 32.0 cm/yr (Pratt and Casey 1983). They found that growth of *I. oxyrinchus* was more similar to other species of pelagic fish such as the blue shark, dolphin, and tuna.

Age-Weight

While growth in length was fit with the von Bertalanffy growth equation, a logistic equation provided a significant fit to age-weight data. In a similar manner, Parsons (1987) reported that *Sphyrna tiburo* age-weight data were best fit with a logistic equation. Both the von Bertalanffy and logistic growth equation imply that the increase in length and weight of *C. limbatus* is asymptotic. Ricker (1979) cited contrasting opinions on the feasibility of asymptotic growth for fishes, and stated that usually a few older individuals in a fish population may be considerably larger than the asymptote, particularly in terms of weight. *Carcharhinus limbatus* >10 years old probably grow very little in length each year. The results of this study suggest that *C. limbatus* tends toward a W_∞, and appear to grow very little in weight at older ages.

Age and Growth Estimates

The von Bertalanffy growth equation closely described the growth of *C. limbatus*. Estimated size at birth was approximately 53.0 cm which corresponds closely to that of observed data. Maximum theoretical length from the von Bertalanffy growth equation was 195.0 cm for females and 166.5 cm for males, similar to the maximum length of females and males collected during this study, 183.3 and 165.0 cm, respectively. Maximum lengths reported for *C. limbatus* in the Gulf of Mexico were 191.0 and 175.0 cm for females and males, respectively (Clark and von Schmidt 1965); within the 95% confidence intervals predicted for L_∞ (Table 2). Branstetter (1987) estimated L_∞ at 176.0 cm for blacktip sharks captured in the northwestern Gulf of Mexico although his estimates were with sexes combined (34 females, 13 males). Because growth curves differ between males and females, this underestimates L_∞ for females and overestimates L_∞ for males. This may also influence estimated ages of maturity for the sexes; for example, males included in the growth curve would slow the rate at which the curve approaches a particular size and thus result in an older estimated age at maturity for females.

A positive linear relationship between shark length and centrum radius has been established in many shark species. In *I. oxyrinchus* (Pratt and Casey 1983) and *G. cuvieri* (Branstetter et al. 1987), a curvilinear relationship may be more applicable to the data. In either situation, this allows back-calculation of length at time of ring deposition. Back-calculated sizes were smaller at each age class than sizes from observed and predicted data (Table 3, Figs. 6, 7). Ring deposition occurs during the winter months of December–January; however, 83.4% of the blacktips were captured during May–September; thus the increase in size between time of ring deposition and time of capture produced the above disparity. This situation is less evident in older *C. limbatus* with decreased annual growth rates.

Growth rates estimated for adolescent and mature *C. limbatus* were 9–10 and 3–4 cm TL/yr, respectively. These rates were similar to those found by Branstetter (1987a) in the northwestern Gulf of Mexico, although he reported that lengths at age for female and male *C. limbatus* were similar. This study found a significantly larger total length of females at age 7 or greater. Age at maturity for blacktips captured in the Tampa Bay area and in the northwestern Gulf of Mexico were similar for males (4–5 years) but differed among females. Females reach maturity in 6–7 years near Tampa Bay, and 7–8 years in the northwest Gulf of Mexico. Similarity of life history parameters for *C. limbatus* captured in the Tampa Bay area (Killam 1987), in the east central Gulf of Mexico (Springer 1940; Clark and von Schmidt 1965), and in the northern Gulf (Branstetter 1981, 1987a) suggest a continuous population of this species in the Gulf of Mexico.

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