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AGE AND GROWTH OF THE BLUE STINGRAY *DASYATIS CHRYSONOTA CHRYSONOTA* FROM THE SOUTH-EASTERN CAPE COAST OF SOUTH AFRICA

*P. D. COWLEY**

The age and growth of blue stingray *Dasyatis chrysonota chrysonota* from the south-east coast of South Africa was investigated by examination of bands on the vertebral centra. The annual nature of band deposition was verified by centrum edge characteristics and supported by growth of known-age individuals kept in captivity. The derived Von Bertalanffy parameters from age and length data were L_∞ = 532 mm (disc width, *DW*), K = 0.175 and t_0 = –3.65 for males and L_∞ = 913 mm *DW*, K = 0.070 and t_0 = –4.48 for females. Growth of three captive specimens showed distinct seasonal differences, with a mean growth rate of 7.3 mm·month^{-1} during summer and 3.8 mm·month^{-1} during winter. The mean rate of growth in captivity for the first year after birth (66.7 mm·year^{-1}) is similar to the value obtained from back-calculations (64.6 mm·year^{-1}), but higher than the calculated value of 45.1 mm·year^{-1}. The estimated age at first maturity is five years for males and seven years for females.

The blue stingray *Dasyatis chrysonota chrysonota* is a medium-sized dasyatid ray which attains a maximum disc width of approximately 750 mm (Compagno *et al*. 1989). Its known distributional range extends from St Lucia on the north-east coast of South Africa to central Angola (Cowley and Compagno 1993). The importance of this species in the surf zone was first noted by Lasiak (1982), who showed that, in terms of biomass of the surf-zone ichthyofauna in Algoa Bay (Eastern Cape), the lesser sandshark *Rhinobatos annulatus* dominated with 22.5%, followed by the blue stingray with 17.4%. During spring and summer (September – February), these stingrays invade sandy beaches, estuary mouths and coastal lagoons and become the popular targets of many recreational rock and surf, and light-tackle skiboat anglers (Cowley 1990). The expansion of this recreational fishery may necessitate the implementation of a management plan for the sustainable use of this and other elasmobranch species. Currently in South African waters, the only catch restrictions placed on elasmobranch species is a limit of 10 in total per day for recreational sport anglers and spearfishermen, with the exception of the great white shark *Carcharodon carcharius,* which has been given full conservation status. A study on the life history of *Dasyatis chrysonota chrysonota* was initiated with the aims of providing information crucial for the development of a future management plan.

Most studies on age and growth in elasmobranchs using vertebrae have reported clear growth zones in their centra, from which age estimates have been made. However, few studies have validated the temporal periodicity of band deposition. Holden and Vince (1973) were the first to validate elasmobranch ageing by establishing annual opaque and translucent zones in the centra of *Raja clavata.* Since then, alternative methods have been used to verify the periodicity of band deposition. These include size frequency analyses, growth model parameters, centrum edge dimensions, histological characteristics, laboratory growth studies, radiometric dating, and electron microprobe analyses of calcium and phosphorous concentrations across sections of vertebral centra (see Cailliet *et al.* 1986 and Cailliet 1990 for reviews).

This paper provides estimates of age and growth rates for the blue stingray by examining the vertebral centra. Verification of annual band deposition is substantiated by centrum edge characteristics and growth characteristics of captive specimens.

MATERIAL AND METHODS

All specimens (105 males and 165 females) used in this study were collected between Mossel Bay (34°11.10′S, 22°09.25′E) and the Fish River mouth (33°31.10′S, 27°06.34′E) from March 1987 to May 1989. Material was collected from fishing competitions and from cruises conducted by the Sea

* Department of Ichthyology and Fisheries Science, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa.
E-mail: p.cowley@mailbox.ru.ac.za

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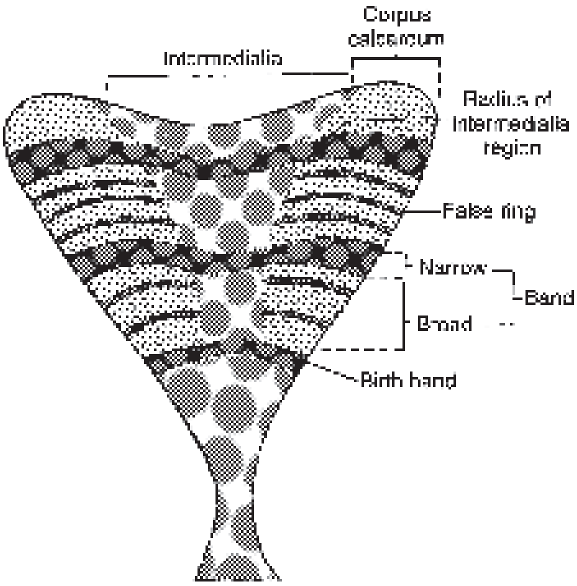

Fig. 1: A diagrammatic representation of a sectioned vertebral centrum of *Dasyatis chrysonota chrysonota*, showing the terminology referred to in the text

Fisheries Research Institute on board the F.R.S. *Africana*.

Preparation and reading of vertebrae

The captured specimens were weighed to the nearest 0.1 kg, measured to the nearest mm for disc width (*DW*), and their sex determined. A section 7 – 10 of the largest monospondylous centra was removed from the vertebral column, labelled and frozen. Three centra were removed from the defrosted vertebral segment, boiled for 3–5 minutes and cleared of both connective tissue and the lateral portions of the neural arch. The centra were then immersed in 100% sodium hypochlorite bleach until all connective tissue had dissolved. Cleaned centra were rinsed in freshwater and stored in 70% propyl alcohol for subsequent analysis.

One vertebral centrum from each sample was embedded in clear casting resin and sectioned through the nucleus using a double-bladed, diamond-edged saw. The result, a thin "hour-glass" section (Fig. 1), was mounted in DPX on a glass slide and viewed under transmitted light using a binocular dissecting microscope. Growth bands were fairly distinct in the corpus calcareum and were occasionally observed in the intermedialia region. The term "band" in this study consists of a narrow dark band of opaque material and a broad translucent band including several "false rings". Bunching of one or more rings within the broad band, to form a false narrow band, often presented problems when interpreting distinct bands. Most consistent results were obtained from readings taken along the radius of the intermedialia region, where the bunching effect of rings appeared less prominent (Fig. 1). To assess the accuracy of the counts, the procedure was performed on three occasions by the same reader at least one week apart.

Growth calculations

Growth parameters were calculated using age-length values and modelled by PC-Yield (Hughes and Punt 1987). The results were computed by means of the absolute error model, which places emphasis on the larger size-classes, and fitted to the equations proposed by Schnute (1981). Back-calculations of length-at-age for both sexes were performed on measurements of the diameters of all observed bands on the vertebral centra. Average length-at-age values were calculated for each age-class and used with back-calculated values to check for Lee's phenomenon of apparent changes in growth rates for a particular age-group (Bagenal and Tesch 1978, Weatherley and Gill 1987), and for consistency in reading vertebral bands in young and old specimens. Sections which did not pass through the centrum focus were discarded for back-calculations, because of the possible differences in centrum band measurements.

Captive specimens

Three specimens (two males and one female) of blue stingray were trawled in Algoa Bay on 20 May 1988. They were successfully transported to the Port Elizabeth Museum and maintained in an indoor circular pool with a capacity of 4 000 ℓ of natural seawater. All three rays began feeding within three days of capture. They were fed to satiation once a day with a variety of foods, including pilchard *Sardinops sagax*, sand prawns *Callianassa kraussi*, sand mussels *Donax serra* and squid *Loligo vulgaris reynaudii*. In November 1988, the rays were transferred to a semi-enclosed pool (c. 4 000 ℓ of filtered seawater) housed at the Rhodes University Laboratory, Port Alfred. There, temperature and salinity readings were taken on a daily basis and compared with ambient sea conditions. The rays were measured and weighed at approximately monthly intervals from August 1988 to October 1989 to monitor growth.

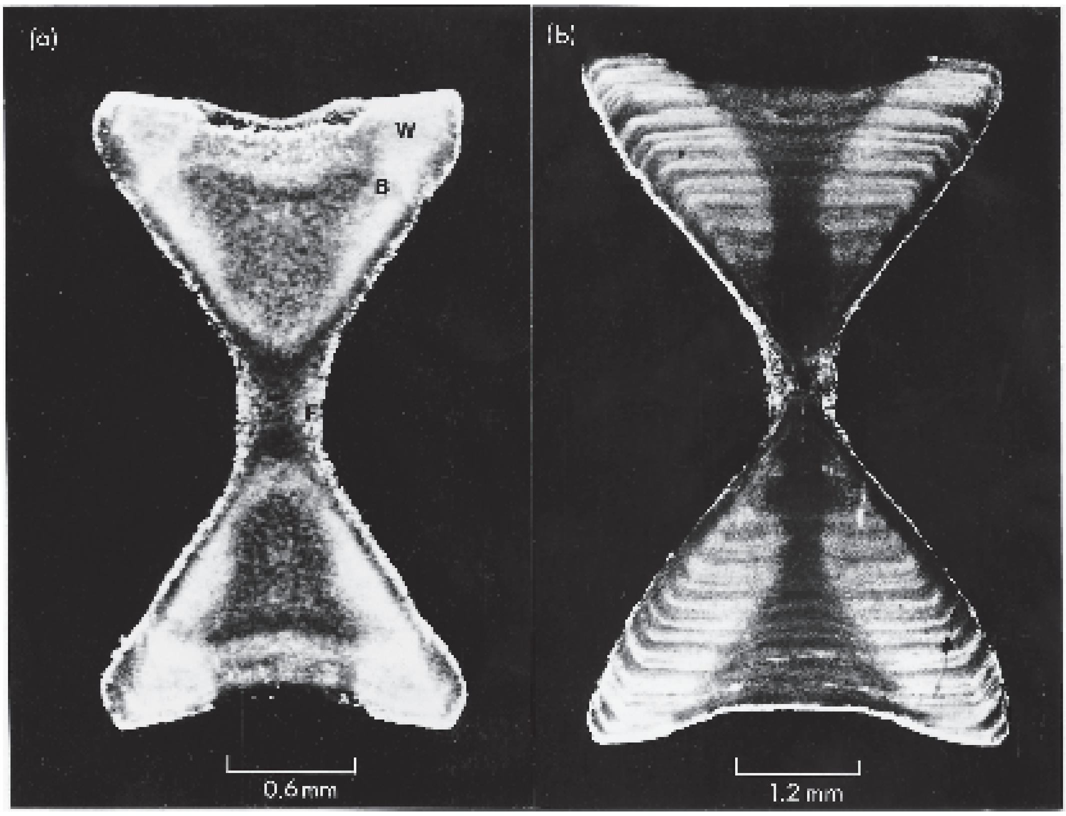

Fig. 2: The sectioned vertebral centrum of (a) a 10-month-old *Dasyatis chrysonota chrysonota*, 253 mm *DW* (F = centrum focus, B = birth band, W = winter band) and (b) a 10-year-old female, 583 mm *DW*

RESULTS

Centrum analysis

Regression analyses between disc width and centrum diameter for various age-classes were carried out for both sexes to obtain best-fit linear relationships. Poor linear relationships were obtained for several age-classes for both sexes, because of the small sample size per age-class. Stronger relationships were achieved by combining all age-classes for each sex. The relationship between disc width (y) and centrum diameter (x) was $y = 53.46 + 74.04\ x$ ($r^2 = 89.56$, $n = 94$) for males and $y = 68.47 + 72.67\ x$ ($r^2 = 92.24$, $n = 151$) for females.

The first narrow band present in all sectioned centra at a diameter of 1.9 – 2.2 mm was also observed on the outer edge of the centrum of a full-term embryo prior to birth. Martin and Cailliet (1988) suggested that this band is possibly formed in response to the changes in nutrient source during embryonic development. No other pre-birth marks were visible on the sectioned centra.

The formation of narrow and broad bands correlated well with season in young individuals (<4 years old). The narrow dark or optically dense bands form in winter and the broad translucent bands in summer. The first narrow band that forms just prior to birth (October – November) is followed by a broad band (December – April). These centra characteristics were observed in several 0+ age-class specimens collected in May 1988 (approximately six months old). The centra of specimens of the same age-class collected in September 1987 (approximately 10 months old) contained an additional narrow band, which represented the winter period (May – August, Fig. 2a).

Centra of older specimens were more variable in

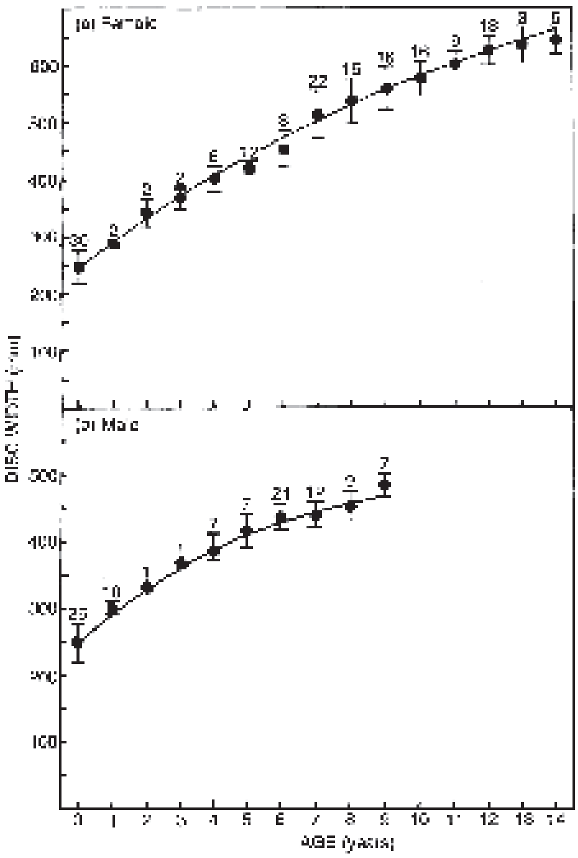

Fig. 3: Calculated Von Bertalanffy growth curve for (a) female and (b) male *Dasyatis chrysonota chrysonota*, derived from vertebral age-length data. The standard deviations and number of measurements are indicated

appearance and often presented problems in interpretation of age bands (Fig. 2b). A total of 8.5% of the 165 female centra and 10.5% of the 105 male centra examined were discarded because of obscure centrum-edge characteristics.

Age and growth estimates

The derived Von Bertalanffy growth equations were:

$$L_t = 531.8\ [1\text{-}e^{-0.17(t+3.65)}] \text{ for males,}$$

$$L_t = 913.4\ (1\text{-}e^{-0.07(t+4.48)}) \text{ for females.}$$

The growth curves for male and female blue stingrays are shown in Figure 3. Size at birth and growth for the first three years is similar for both sexes. However, with the onset of adolescence (4+ years old), distinct sexual differences are noticeable. The K value of 0.17 for males and 0.07 for females confirms a faster growth rate in males, with the growth approaching an asymptote earlier in males. The L_∞ values of 531.8 mm for males and 913.4 mm for females are greater than the largest sizes aged in the present study (507 mm *DW* for males and 674 mm *DW* for females). These values are 95.3 and 73.8% of the asymptotic *DW* for males and females respectively. The largest female recorded by Cowley (1990) was 719 mm *DW*. Unfortunately, this specimen was captured off Swakopmund (Namibia) and was not used for ageing purposes. The largest male, from which no vertebrae were obtained, was captured in Algoa Bay and measured 531 mm *DW*. The observed minimum size of sexual maturity for males (408 mm *DW*) and females (500 mm *DW*) indicates a minimum age-at-maturity of five and seven years for males and females respectively (Cowley 1990).

The mean back-calculated, mean observed and calculated disc widths at successive ages for male and female blue stingrays are presented in Table I. Marked variation in mean size for each age-class indicates the presence of "Lee's phenomenon", when comparing mean observed and mean back-calculated values. The mean observed values of the 0+ age-class are overestimated, because such specimens were collected only in May and September, approximately 6 and 10 months old respectively. However, the mean back-calculated value for this age-class corresponds with the actual size at birth (true Age 0) of between 170 and 200 mm *DW* (Cowley 1990).

Captive growth rates

The observed growth of the three captive specimens is given in Figure 4. Considering that parturition occurs in November at a size of 170 – 200 mm *DW* (Cowley 1990), extrapolation from observed growth rates indicates that all three specimens were approximately six months old when collected in May 1988. The captive growth rates for each sex were combined, because growth rates were similar for both sexes for the first three years. The mean annual growth rate for the first year after birth (1 November – 31 October) was estimated to be 66.7 mm·year^{-1}. Growth over the same one-year period from 1 September to 31 August was 69.0 mm·year^{-1}. These growth rates are comparable to the value obtained from back-calculations for

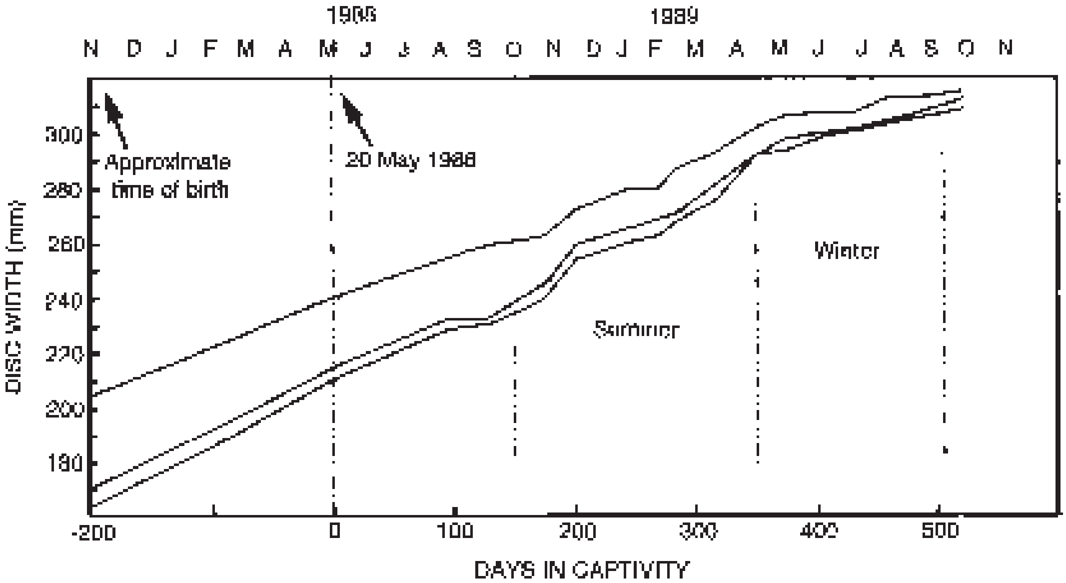

Fig. 4: Observed growth increments (*DW*) of three *Dasyatis chrysonota chrysonota* specimens kept in captivity between May 1988 and October 1989

females (64.6 mm·year^{-1}), but are higher than the calculated value of 45.1 mm·year^{-1}. Branstetter (1987) noted that seasonal fluctuations in temperature and light may be important controlling factors in growth and band formation. The mean monthly temperatures recorded in the pool were comparable to the ambient sea surface temperatures, with the exception of slightly higher than ambient during summer (Fig. 5).

Differences in seasonal growth were evident in the captive specimens. Mean growth rate was

Table I: The calculated, mean observed and mean back-calculated size-at-age for male and female *Dasyatis chrysonata chrysonata*

Estimated age (years)	Size-at-age (mm disc width)					
	Calculated		Mean observed		Mean back-calculated	
	Male	Female	Male	Female	Male	Female
0	245.86	245.87	249.12	248.20	184.29	193.26
1	290.57	291.01	301.30	288.50	242.83	257.83
2	328.28	333.08	330.00	343.50	281.61	294.73
3	360.09	372.32	368.00	367.50	307.02	330.87
4	386.94	408.89	384.86	403.17	338.93	370.62
5	409.59	443.00	417.14	421.83	367.54	401.95
6	428.69	474.81	437.52	455.38	386.43	435.56
7	444.81	504.46	441.25	516.14	414.58	467.29
8	458.41	532.10	454.44	538.94	443.36	492.26
9	469.88	557.88	485.14	560.38	472.25	517.23
10		570.59		576.56		541.30
11		604.33		601.78		569.11
12		625.22		627.08		598.02
13		644.71		635.67		614.28
14		662.87		643.40		591.76

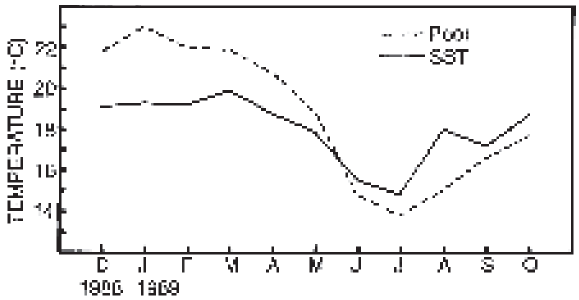

Fig. 5: Mean monthly pool and sea surface temperatures (SST) at Port Alfred between December 1988 and October 1989

7.3 mm·month^{-1} during the warmer October – April period, whereas a slower growth rate of 3.8 mm·month^{-1} was estimated for the colder May – September period (Fig. 4). It is noteworthy that the feeding rate and general activity of the captive specimens decreased considerably during winter. The broad summer band and narrow winter band characteristics, clearly observed on the centra of the 0+ fish, could be a direct result of this differential growth rate.

DISCUSSION

The use of vertebral-centra-band deposition in ageing studies in elasmobranchs has been widely documented in the literature (Cailliet *et al.* 1986, Cailliet 1990). In *Dasyatis chrysonota chrysonota*, the growth of the calcified centra provides a continuous record of body growth, as indicated by the direct relationship between disc width and centrum diameter. However, variation in band periodicity on the centra is the most important feature when attempting to age an animal. Results from most studies report the annual formation of one calcified opaque and one less calcified hyaline band in the centra (Yudin and Cailliet 1990). However, Pratt and Casey (1983) showed that the shortfin mako *Isurus oxyrhinchus* produces two band pairs annually and Natanson and Cailliet (1990) found that band formation in *Squatina californica* was related to somatic growth and were not deposited annually.

The annual formation of one distinct opaque and one hyaline zone in the centra of the blue stingray may be explained as follows. First, the observed differential growth rate of captive specimens between summer and winter suggests changes in the mineralization pattern in the centra as a result of varying environmental conditions, such as temperature and feeding activity. Second, the vertebral centra of free-swimming young-of-the-year captured in May (approximately six months old) exhibited both a birth band, formed *in utero*, and a clear broad band, but specimens collected in September (approximately 10 months old) contained an additional dark narrow band. Therefore, one clear broad band and one narrow dark band represent the annual band characteristics in *Dasyatis chrysonota chrysonota*. These results indicate that the clear broad band is formed in summer, between October and April, and the narrow dark band associated with slower growth is formed in winter, between May and September. The narrow false rings occasionally observed in the broad summer band are thought to result from changes in environmental conditions, such as cold-water upwelling events.

Several studies on elasmobranchs have indicated faster growth rates for captive animals than those caught in the wild. For example, an eight-fold increase in the growth rate was reported for lemon sharks *Negaprion brevirostris* (Gruber and Stout 1983) and a ten-fold increase was found for grey reef sharks *Carcharhinus amblyrhynchos* (Wass 1971, as cited by Gruber and Stout 1983). In contrast, the present study showed similar growth rates between wild and captive animals. Branstetter (1987) noted that differ-

Table II: Comparisons of Von Bertalanffy growth parameters of batoid fish with an aplacental viviparous mode of reproduction

Species	Source	Parameter					
		L_∞ (mm *DW*)		t_0		K	
		Male	Female	Male	Female	Male	Female
Urolophus paucimaculatus	Edwards (1980)	428	573	–0.57	–1.78	0.450	0.210
Rhinoptera bonasus	Smith and Merriner (1987)	119	125	–3.69	–3.76	0.126	0.119
Myliobatus californica	Martin and Cailliet (1988)	1 004	1 587	–1.58	–2.06	0.229	0.099
Dasyatis chrysonota chrysonota	Present study	532	913	–3.65	–4.48	0.175	0.070

ences in the growth rate between captive and wild-caught animals could be attributed to changes in temperature regimes, photoperiod (daylength), diet, feeding activity and/or stress-related activities. In the present study, temperatures and day length period were similar to the natural environment. Furthermore, all possible forms of stress, such as excessive handling, were kept to a minimum.

The three parameters of the Von Bertalanffy model (L_∞, K and t_0) for several myliobatoid species (stingrays, eagle and manta rays) with a viviparous mode of reproduction are listed in Table II. Holden (1974) reported that the calculated t_0 values should predict the gestation period (in years) for elasmobranchs. However, t_0 values of species displaying aplacental viviparity are overexaggerated because of the much greater pre-parturition growth rate (Smith and Merriner 1987). Therefore, calculated t_0 values for species with this reproductive mode do not provide estimates for gestation period. Calculated t_0 values of –3.646 and –4.481 for male and female *Dasyatis chrysonota chrysonota* respectively were obtained in the present study. A known gestation period of approximately nine months, of which only five is attributed to embryonic somatic growth, was observed for this species (Cowley 1990).

Holden (1974) indicated that batoids typically have K values ranging between 0.2 and 0.3. However, those values were based on growth data for rajoid skates, which exhibit an oviparous reproductive mode, and are therefore not comparable with aplacental viviparous batoids. Literature values of K for viviparous batoids range between 0.07 and 0.45 (Table II).

Differences in K and L_∞ values between males and females show a similar trend in myliobatoid rays. K values for *Urolophus paucimaculatus* (Edwards 1980), *Myliobatis californica* (Martin and Cailliet 1988), *Rhinoptera bonasus* (Smith and Merriner 1987) and *Dasyatis chrysonota chrysonota* (present study) are higher in males than in females. This illustrates a faster growth rate in males, which attain their asymptotic length at an earlier age than females. In the present study, size frequency analyses indicated that females attain a larger size than males, a finding substantiated by the observed L_∞ values. This feature appears to hold for other myliobatoid rays (Edwards 1980, Smith and Merriner 1987, Martin and Cailliet 1988). It is hypothesized that natural selection for a larger female size is an adaptation to satisfy their reproductive needs. Therefore, larger female size can be considered as a sexual dimorphic characteristic for myliobatoid rays. This phenomenon emphasizes the need to treat sexes independently when conducting age and growth studies on species belonging to this order of elasmobranchs.

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