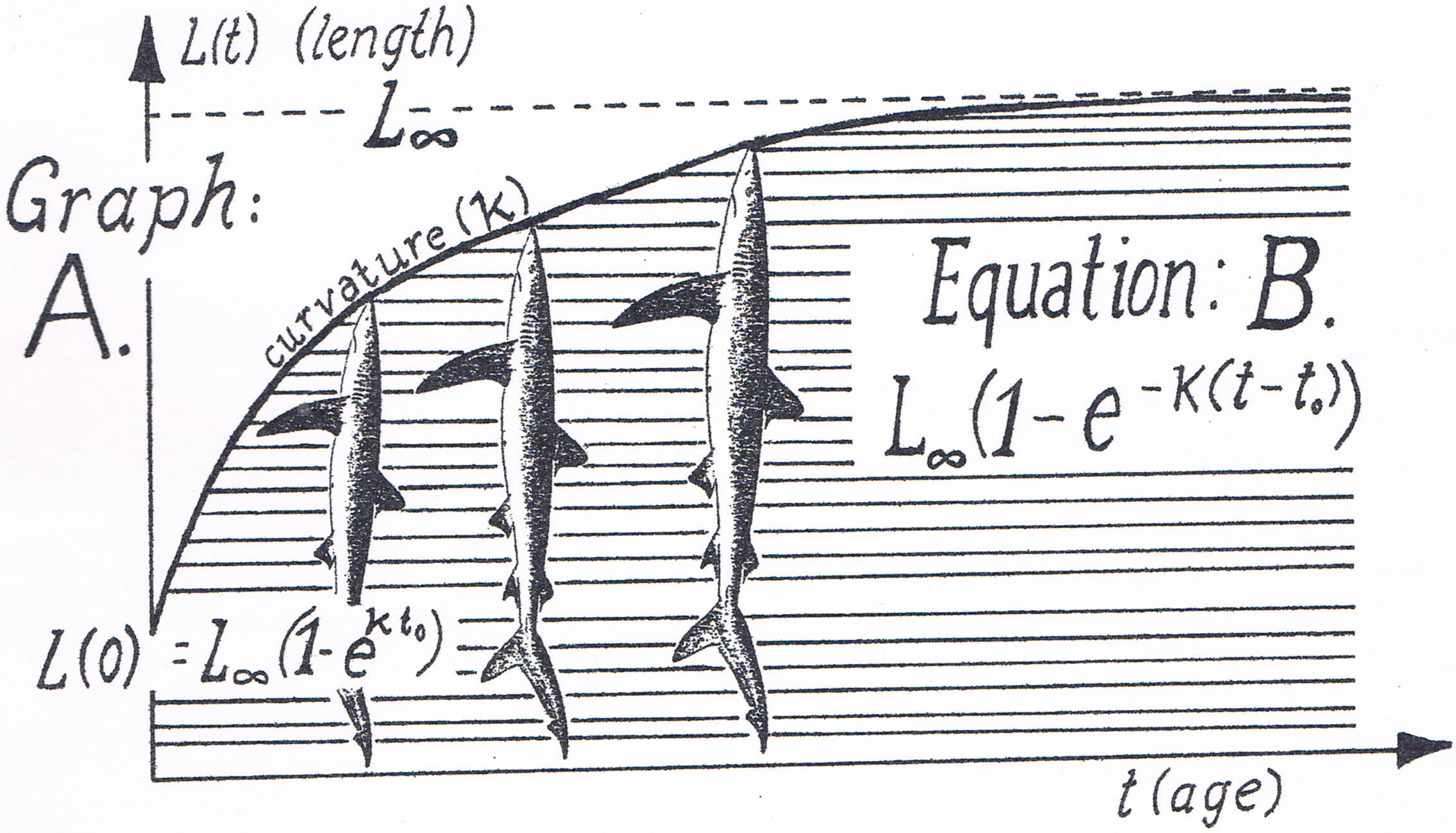
Leeftijd en groei van de blauwe haai, *Prionace glauca*, in zuidelijk Brazilië



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Parte 3

Age and growth of the blue shark, *Prionace glauca,* from southern Brazil

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INTRODUCTION

The aim of this study is, to determine the age of each fish caught, and to use these data to construct the model of body growth to the blue shark, *Prionace glauca*, of southern Brazil. Age of sharks is determined by counting the growth rings of the centrum of the vertebrae. For the blue shark this has been done in the south of Brazil by Amorim (1992) and in the north-east of Brazil by Marques (1998). This method was also adopted in this study.

In order to reach the model of body growth the following steps were taken:

1. The visual appearance of the growth rings at low magnification, the microscopical structure, and the chemical nature of the growth rings were described. Also the terminology referring to the structure of the vertebra was defined.
2. In each specimen the growth rings were counted, and the radius of each growth ring and of the entire centrum were measured.
3. The relationship between centrum radius and total body length (TL) of the fish was established. This relationship was later used for back-calculation of the body size at the first growth ring in order to identify a possible birth mark.
4. The date of birth of the blue shark was established through study of literature.
5. Through study of the seasonal variation of the marginal increment of the vertebra, the periodicity of the formation of the growth rings was determined, for example, it was established how many growth rings are formed per year and in which months of the year they are formed.
6. The ring counts as under (2) were interpreted in terms of age, according to the periodicity of ring formation as under (6). In this way, the age of each specimen, in years and months, was determined.
7. Body size at the age of formation of each growth ring was back-calculated in each specimen.
8. The Von Bertalanffy growth curve was fitted to the length-at-age data obtained under (6) and (7) above.
9. A comparison between the growth curve parameters and the relative annual weight gain was made.

MATERIAL & METHODS AND RESULTS

202 Blue sharks were caught (150 males, 52 females) during the ARGO journeys in 1996-1997-1998, they were most abundant in the winter (figure 1, 2). Of all sharks morphometric measurements were taken and of 172 blue sharks (136 males, 36 females) a sample of the vertebral column was taken under the first dorsal fin. The samples were stored in alcohol.

1. Vertebrae and sections made in the horizontal plane of the centrum were coloured with alizarine red S, which binds calcium and therefore colours calcium rich areas dark red, and silvernitrate, which replaces calcium and therefore colours calcium rich areas dark brown. One section was coloured with haematoxyline for histological examination.

Comparisons between unstained and stained vertebrae and sections were made using transmitted and reflected light under a dissecting microscope.
The haematoxyline coloration revealed that the section contains chondroïd tissue and has a homogene cellstructure. Comparison between vertebrae and sections resulted in the conclusion that sections show the growth structures better. Examination under transmitted and reflected light showed a section is constructed of a zone that gradually increases in opacity followed by a transparent zone. Coloration with alizarine red S and silvernitrate resulted in a gradual increase in coloration of the opaque structure, this structure therefore shows an increase in calcification, and a transparent zone which remained colourless. Regarding terminology the transparent zone was called hyaline ring, the opaque structure was called opaque zone and one hyaline ring + one opaque zone was called a growth zone.
Overall it could be concluded the unstained sections could be used best for counting growth rings (figure 3).

2. All 172 samples were cleaned of excessive muscle tissue. Per sample four vertebrae were separated. Of one of the vertebrae three sections, one before one including and one after the notochordal remnant, in the horizontal plane were made. The thickness was approximately 0,3 mm. The radius of each growth ring was measured in the intermedialia, at the border of the opaque zone and hyaline ring (figure 4). The remnant of the notochord was taken as focus for the measurements.

3. The relationship between centrum radius (mm) and TL (cm) revealed the growth of the vertebrae is isometric (figure 5). That is when the TL increases the centrum radius increases proportionally without changing its shape. The regression formula:
TL (cm) =34,356 + 17,249 * Radius (mm)
determined that for the blue shark the first growth ring found in the section is the ring deposited at birth.

4. A collection on the total body length of embryos found in Brazilian waters resulted in a graph (figure 6) from which could be concluded that the month of birth for the blue shark in southern Brazil is January.

5. The marginal increment was calculated using the formula:
$M.I. = (R-r_n)/(r_n-r_{n-1}) * 100\%$
in which
R = radius of intermedialium in oculair micrometers
r_n = distance of focus till the last growth ring in oculair micrometers
r_{n-1} = distance of focus till previous last growth ring in oculair micrometers
Based on the marginal increment-frequency diagramms (figure 7) it could be concluded the formation of the growth rings was annual and formation of a hyaline ring started in July.

6. Based on the results described as under (3), (4) and (5) tables for interpretation of the growth rings in terms of age were made for each season (table 1). This way the age for each specimen was determined.

7. The mean TL of each growth ring was back-calculated using the formula of Campana:

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

in which:

L_0 = length at birth in centimeters

L_c = length of the fish at the moment of capture in centimeters

O_0 = radius of the corpus calcareum at birth in millimeters

O_a = distance of the focus till ring a in millimeters

O_c = radius of the corpus calcareum at the moment of capture in millimeters

Putting the back-calculated mean TL of each growth ring per age class in a table (table 2), it could be seen that within this collection Lee´s phenomenon had to be taken into account. Lee´s phenomenon means that when the TL for growth ring x is back-calculated older animals have a smaller back-calculated TL than younger animals. This can be a result of natural selection of fast growing individuals, in this sample mainly slow growing individuals were caught.

8. The observed length-at-age and the back-calculated length-at-age data were both used in the Von Bertalanffy growth formula:

$L_t = L_\infty * (1 - \exp(-K * (t - t_0)))$

L_t = length at age t

L_∞ = theoretical maximal (asymptotic) length the fish would reach if it lived infinitive

K = growth slope of the curve which shows with which rate the maximum length would be reached

t_0 = theoretical age at which the fish would have a TL of zero

First all the graphs were made for male and female separately, afterwards it was tested if there was a significant difference in the growth curves for both sexes. For the observed length-at-age there was no significant difference, the growth curve (figure 8) shows

L_∞ = 596,64 cm

K = 0,047 cm/year

t_0 = -4,310 year

For the back-calculated length-at-age a significant difference between males and females was found, the two growth curves (figure 9, 10) show

L_∞ = 458,83 cm

K = 0,087 cm/year

t_0 = -1,88 year

for male blue sharks and

L_∞ = 526,55 cm

K = 0,065 cm/year

t_0 = -2,19 year

for female blue sharks.

9. The regression formula determined using the relationship between gutted weight and TL was used to transform the Von Bertalanffy growth formula to a weight-at-age formula. The back-calculated length-at-age data for male and female blue sharks were used separately to obtain the relative annual weight gain per sex. The formula with results per sex can be found in table 3. For both male and female blue sharks the weight gain in the first two years is high.

OVERALL CONCLUSIONS

Comparing our results with previous research (table 4) it can be seen that our K is smaller and L_∞ and t_0 are larger. Since our sample composition is representative it can be believed that our values of these parameters describe the growth curve of the blue sharks of this study.

Compared with teleosts the K-value is small indicating that the blue shark is a slow growing species. Taking the annual weigth gain into account it can be concluded the blue shark is a fast growing species under the elasmobranchs.