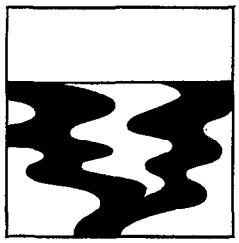

Growth and first sexual maturation size of Gymnotus carapo (Linnaeus, 1758) in the Lobo reservoir (state of São Paulo, Brazil) (pisces, gymnotidae)

Geraldo Barbieri (1) and Marilene Cruz Barbieri (1)

Summary

This work aimed to study the annulus formation on the scales of the Gymnotus carapo *in the Lobo Reservoir. The growth curve was established by the annual ring method, and the growth curve in weight was deducted from the mathematical expressions of the length growth curve and weight/length relation. The first sexual maturation size of the females was determined and related to specimen age.*

Key words : Fish-Growth — Sexual maturation — *Gymnotus carapo* — Brazil.

Résumé

Croissance et taille à la première maturation sexuelle du *Gymnotus carapo* (Linnaeus, 1758) dans l'étang « Represa do Lobo », Estado de São Paulo, Brasil

L'époque de formation des annuli sur les écailles de Gymnotus carapo *a été déterminée dans le réservoir Lobo. La courbe de croissance en longueur a été calculée en se basant sur le caractère annuel des annuli et la courbe de croissance en poids a été déduite de la précédente en utilisant la relation longueur-poids.*

La taille et l'âge à la première maturation des femelles ont été établis.

Mots-clés : Poissons — Croissance — Maturation sexuelle — *Gymnotus carapo* — Brésil.

INTRODUCTION

Gymnotus carapo is widely distributed throughout Central and South America (Ellis, 1913; Föwler, 1915; Ringuelet *et al.*, 1967). The species shows nocturnal habits and their habitat consists of still, muddy waters covered with vegetation, under which the fishes hide. This species is very common in the Lobo Reservoir, a shallow water body located in the center of the State of São Paulo (Southern Brazil), surrounded by a savanna type of vegetation ("cerrado"). The reservoir presents the following general characteristics: Altitude: 760 m, Maximum lenght: 7.5 Km, Maximum depth: 12.0 m, Surface: 6.8 Km^2, Volume: 22.000.000 m^3. The annual water temperature varies from approximately 15 °C at winter (Jun., Jul., Aug.) to 23.8 °C at summer (Jan., Feb., March). The Lobo Reservoir could be considered a model for ecological studies in tropical regions (Tundisi, 1977, 1980).

The reproductive period of *G. carapo* extends from October to December and the spawning is fractioned (Barbieri, 1981). The fish is covered with small scales of the cycloid type (Fig. 1).

The objective of the present investigation was to study the growth of *G. carapo* by the annual ring method and to determine female size at first sexual maturation in relation to age.

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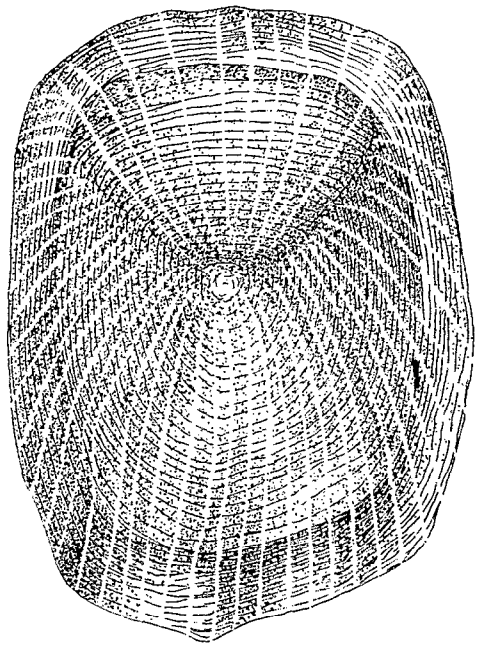

FIG. 1. — Scale of *G. carapo* with one annulus

MATERIAL AND METHODS

A total of 679 specimens (357 males and 322 females) were weekly collected at the Lobo Reservoir during a period of one year. All fish were analyzed for the following parameters: total length (L_t) in *cm*; total weight (W_t) in *g* and gonadal maturation stage (for females).

Five to six scales were collected near the opercule from each specimen and prepared by the method of OOSTEN (1929).

The stages of female gonadal maturation were defined by the macroscopic (size, colour, presence and egg size) and microscopic aspects of the ovary, according to BARBIERI (1981). The following stages was established:

Stage I — immature or virgin, Stage II — reproducing adult (mature) and Stage III — non reproducing adult (maturing and spent).

The time of annulus formation on the scales was obtained by plotting the distribution of the average length of the specimens with the same number of annuli against collection time.

The growth curve in length was established using the mathematical expression of von Bertalanffy (1938):

$$(1)\ \overline{L}_t = L_\infty\ [1 - e^{-K(t - t_0)}], \text{ where}$$

$\overline{L}_t$ = average fish length at age t

L_∞ = average maximum length attained by the fish, corresponding to the asymptotic value of L_t

K = rate at which length approaches L_∞

t_0 = a parameter related to average fish length at birth

t = fish age.

The value of this mathematic expression to the present study was confirmed by the Ford-Walford transformation (WALFORD, 1946). The K and L_∞ values were determined by linear regression coefficients.

The correction factor of relative age (t_1) was estimated by attributing relative age (t^*) to the individuals with the same number of annuli on the scales. The relative age (L_t^*) values were estimated by the following expression:

$$L_t^* = \ln\left(\frac{L_\infty - L_t}{L_\infty}\right)$$

The t_1 value was estimated from the linear relationship between t^* and L_t^*.

t_0 was estimated by the expressions :

$$t_0 = \frac{1}{K} \ln\left(\frac{L_\infty - \overline{L}^0}{L_\infty}\right), \text{ where}$$

L_0 (average individual length at birth) was estimated at 1.0 cm.

By estimating the average weight ($\overline{W}_t$)/average length ($\overline{L}_t$) ratio, we can describe the relationship between these two variables and individual condition can be determined estimating values of the condition factor (φ) in a single expression. This relationship is one of the basic premises of the deductive method required to obtain the growth curve in weight.

The tendency of the empirical points in the dispersion graphs suggests that the relationship is given by the expression:

$$(2)\ \overline{W}_t = \varphi\ L_t^\theta, \text{ where}$$

φ = condition factor related to individual fatness

θ = constant related to individual growth type.

The empirical data were then transformed logarithmically to ascertain the linear relationship between the two variables, which were transformed by the expression:

$\ln W_t = \ln \varphi + \theta . \ln L_t$, where φ and θ were estimated by the linear regression method. The linear coefficient of correlation of Pearson was estimated.

Once the expressions for the growth curve in length (1) and the weight/length relationship (2)

TABLE I

Average length ($\overline{L}_t$), number of specimens (n) and standard deviation of females and males with the same number of annuli in the scales (0, 1...) in function of trimester (I, II...)

Number of annuli (scales)	I				II				III				IV			
	♀		♂		♀		♂		♀		♂		♀		♂	
	$\overline{L}_t \pm s$	n	$\overline{L}_t \pm s$	n	$\overline{L}_t \pm s$	n	$\overline{L}_t \pm s$	n	$\overline{L}_t \pm s$	n	$\overline{L}_t \pm s$	n	$\overline{L}_t \pm s$	n	$\overline{L}_t \pm s$	n
0	3.6±0.851	16	3.5±1.52	6	8.5±2.03	10	8.8±1.64	17	11.4±1.56	16	12.6±1.98	16	2.2±0.376	7	2.1±0.967	6
0	19.9±1.03	14	19.1±2.05	9	20.5±1.96	8	21.3±1.98	19	23.5±2.58	13	22.0±2.12	14	18.3±2.38	14	18.2±2.23	18
1	27.6±1.48	19	27.5±1.98	13	30.1±1.73	13	30.6±3.02	18	31.3±1.87	18	30.8±1.79	8	26.6±1.98	15	25.1±1.61	19
2	33.9±1.62	11	32.5±2.80	20	34.2±3.36	14	34.4±2.16	10	35.2±1.31	12	33.6±1.27	8	32.5±1.80	14	32.0±1.88	15
3	35.3±2.36	18	35.2±2.11	13	37.5±2.42	13	36.3±1.14	21	37.6±1.82	9	39.2±2.10	14	36.2±0.929	11	36.3±1.15	11
4	39.7±1.85	8	39.2±2.42	19	41.7±1.18	9	41.1±1.38	16	40.9±1.36	3	42.3±1.18		38.0±2.40	10	40.1±2.17	19
5	40.7±1.89	6	44.5±1.66	3	43.7±1.69	4	45.3±1.11	5	45.1±0.00	1	46.4±1.00	2	41.3±2.96	5	43.5±1.94	7
6	45.0±0.998	3	48.0±0.00	1	46.2±1.10	3	48.6±2.74	2	46.0±1.36	4	48.8±0.00	1	46.1±0.00	1	46.5±2.08	2
TOTAL	95		84		74		108		76		68		77		97	

were known, the growth curve in weight was determined by the deductive method:

$$\overline{W}_t = W_\infty\ (1 - e^{-Kt})\theta, \text{ where}$$

W_∞ = average maximum weight reached by the individuals.

The first sexual maturation size (Lpm) was estimated by the relative frequency of females in the samples. The methodology used has been described by WALFORD (1946), BEVERTON & HOLT (1957), GULLAND (1977) and SANTOS (1978).

RESULTS

The average lengths ($\overline{L}_t$) of males and females with the same number of annuli in the scales, were distributed in function of the quartely sampling times. The results for males and females are given in Table I, Figure 2 and Table I, Figure 3, respectively.

The empirical points were not randomly distributed, but showed growth in relation to time, thus confirming that natural "age classes", i.e., periodic spawns, occur.

Figure 2 and 3 show the appearance of a new mode during the third quater of the year.

Mean $\overline{L}_t$ and $\overline{L}_{t+\Delta t}$ values (Δt = 3 months) were plotted graphically for the Ford-Walford transformation (Walford, 1946). The results for males and females are shown in Figure 4 and Figure 5, respectively.

Once the validity of the Bertalanffy expression (BERTALANFFY, 1938) was confirmed by the Ford-Walford transformation, K, L_∞ and t_0 were estimated. The growth curve in total length was expressed as follows:

$$\overline{L}_t = 52.6\,[1 - e^{-0.307\,(t+0.0625)}] \text{ for males and}$$
$$\overline{L}_t = 50.0\,[1 - e^{-0.311\,(t+0.0650)}] \text{ for females}$$

The theoretical curves (Fig. 6A) obtained with these expressions were in agreement with the empirical data.

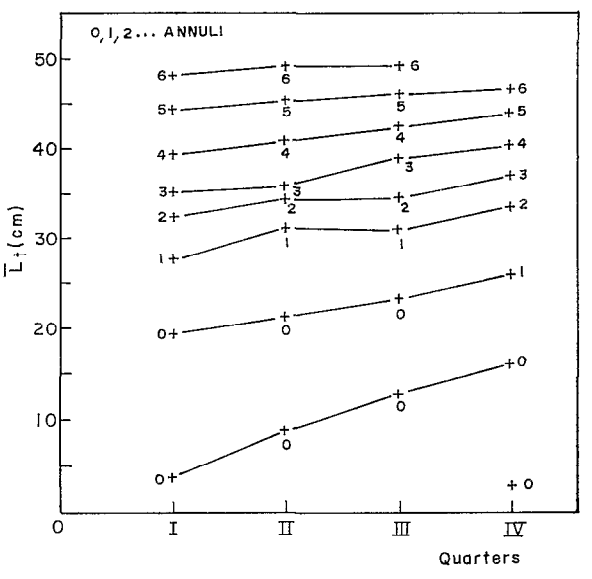

FIG. 2. — Average length of males with the same number of annuli on the scale in function of trimester

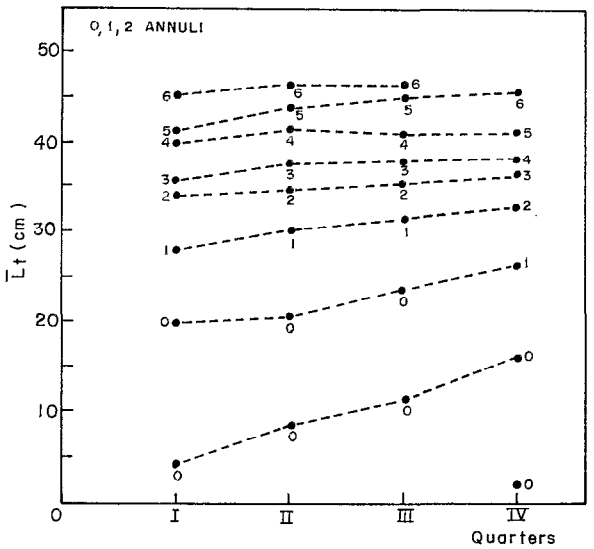

FIG. 3. — Average length of females with the same number of annuli on the scales in function of trimester

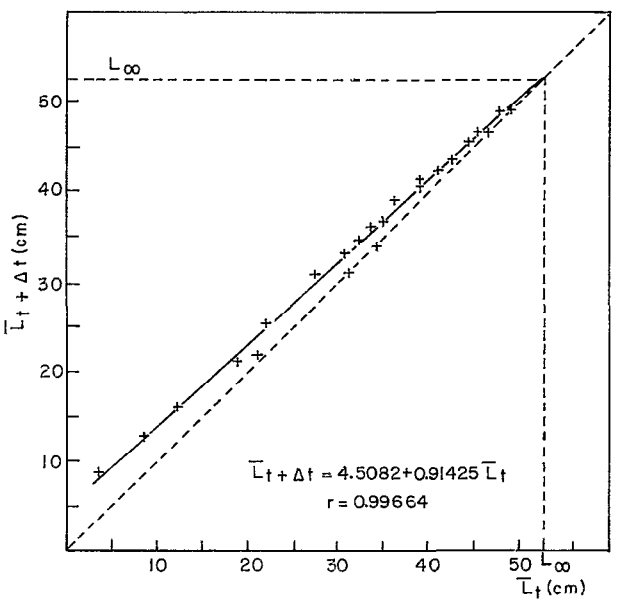

FIG. 4. — Linear relationship between $\overline{L}_t$ and $\overline{L}_t+\Delta t$ for males

The weight ($\overline{W}_t$) was plotted in relation to length ($\overline{L}_t$) for males and females (Tab. II). The mathematical expressions obtained were:

$$\overline{W}_t = 0.005214\ \overline{L}_t^{2.7813} \text{ for males and}$$
$$\overline{W}_t = 0.0050756\ \overline{L}_t^{2.7955} \text{ for females,}$$

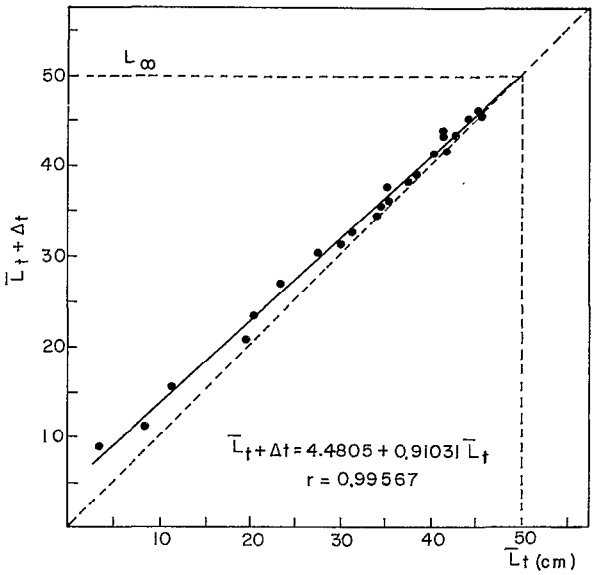

FIG. 5. — Linear relationship between $\overline{L}_t$ and $\overline{L}_t+\Delta t$ for females

which were corroborated by the linear relationship expressions:

$$\ln \overline{W}_t = -5.27288+2.7813 \ln \overline{L}_t \text{ for males and } r = 0.999$$
$$\ln \overline{W}_t = -5.28329+2.7955 \ln \overline{L}_t \text{ for females } r = 0.999$$

Based on these expressions, the growth curves in weight (Fig. 6B) were established by the deductive method that permits calculating total fish weight in function of age. The following expressions were obtained:

$$\overline{W}_t = 318.97[1 - e^{-0.397\,(t+0.0625)}]^{2.7818} \text{ for males and}$$
$$\overline{W}_t = 285.07\ [1 - e^{-0.3111\,(t+0.0650)}]^{2.7955} \text{ for females}$$

Table II shows the relative frequencies of adult females by total length class, which, when plotted graphically (Fig. 7A), yielded the curve described by the expression:

$$fr = 1 - e^{(-3.91^{-14}\,.\,L_t^{10.2})}$$ which was corroborated by the linearity (Fig. 7B) of the logarithmic form of these variables:

$$y = -33.176+10.2177x$$

The size of *G. carapo* females at first sexual maturation (Lpm) was calculated to be 24.8 cm (Fig. 7A).

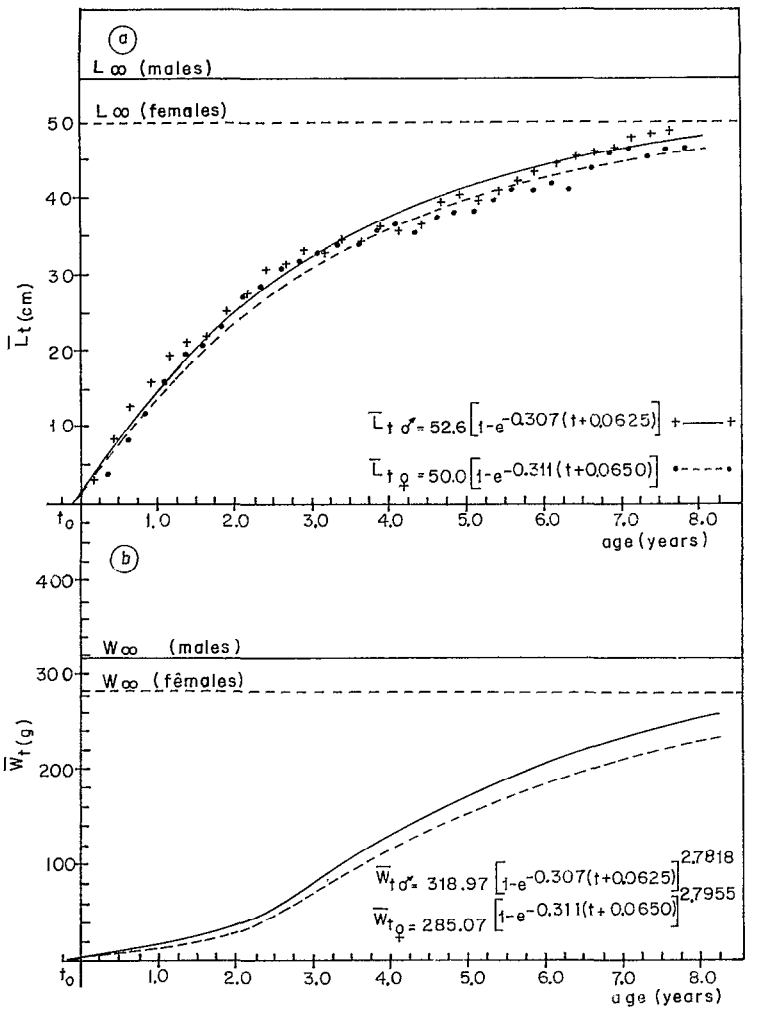

FIG. 6. — Length growth curves (a) adjusted by the Bertalanffy expression, and weight growth curves (b)

DISCUSSION

Several studies on the fish age and growth by the annual ring method have been reported in the literature. The validity of this method for tropical fishes, however, is still a matter of controversy.

MENON (1953) reported that determination of age and growth is difficult in tropical regions because the scales may show rings that are not necessarily annual. In contrast, NEKRASOV (1979) reported that annulus formation occurs once a year in tropical fishes and is linked to spawning.

In our study on *G. carapo* we found that ring formation occurs during the last quarter of the year and coincides with the spawning season in the Lobo Reservoir. Formation of the first annulus occurs during the second year of life and corresponds to the first sexual maturation size (Lpm). BARBIERI *et al.* (1980), using the same method for *Geophagus brasiliensis* of the same reservoir, determined the ring formation during the winter (June and July) and confirmed a number of 6 and 5 rings on the scales of males and females, respectively.

Rapid growth in length occurs during the first year of life of *G. carapo*, before the fish can reach first sexual maturation size. However, the opposite occurs for the growth in weight. The asymptotic length (L_∞) of males is greater than of females, suggesting greater female wear during the spawning season.

The weight/length relationship has been used to estimated the growth curve in weight and to define fish condition.

According to Le CREN (1951), the condition

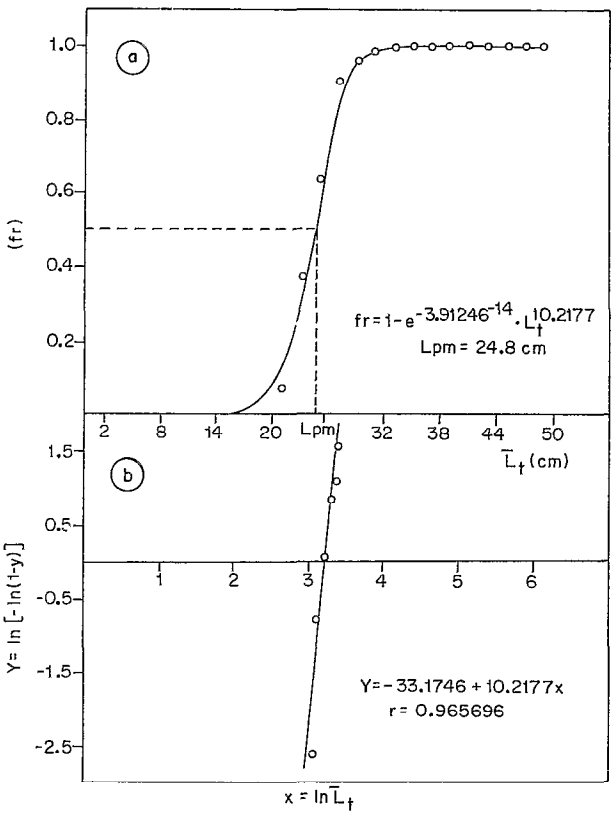

Fig. 7. — Relative frequency (a) of adult females (fr) by total length (L_t) class and logarithmic transformation (b) (Lpm — first sexual maturation size)

TABLE II

Average weight ($\bar{W}_t$) average length ($\bar{L}_t$) ratio for males and females and relative frequency (fr) of adult reproducing females by total length class

Length class (L_t) in cm	FEMALES				MALES			
	$\bar{L}_t$(cm)	$\bar{w}_t$(g)	n	fr (adults)	$\bar{L}_t$(cm)	$\bar{w}_t$(g)	n	N
0 ⊢ 2	1.7	0.03	5	0.00	1.7	0.03	4	9
2 ⊢ 4	3.1	0.12	9	0.00	3.1	0.13	8	17
4 ⊢ 6	5.1	0.45	8	0.00	5.1	0.40	11	19
6 ⊢ 8	7.2	1.20	11	0.00	6.3	1.10	14	25
8 ⊢ 10	8.9	2.07	12	0.00	8.9	1.90	16	28
10 ⊢ 12	10.9	3.38	8	0.00	10.8	3.26	11	19
12 ⊢ 14	12.8	5.41	9	0.00	12.9	6.00	13	22
14 ⊢ 16	15.2	9.01	14	0.00	15.1	8.25	18	32
16 ⊢ 18	16.9	12.61	10	0.00	16.8	12.72	15	25
18 ⊢ 20	19.0	17.32	7	0.00	19.1	18.36	16	23
20 ⊢ 22	20.9	23.83	12	0.07	21.0	25.26	9	21
22 ⊢ 24	22.9	32.60	16	0.37	23.0	34.07	10	26
24 ⊢ 26	25.0	40.31	16	0.64	25.1	40.32	13	29
26 ⊢ 28	27.0	56.11	21	0.90	27.0	54.90	19	40
28 ⊢ 30	28.9	68.85	30	0.96	28.9	70.08	27	57
30 ⊢ 32	30.9	83.58	24	0.93	30.9	80.09	18	42
32 ⊢ 34	33.0	97.18	22	1.00	32.7	91.08	20	42
34 ⊢ 36	34.9	119.29	13	1.00	34.9	116.45	16	34
36 ⊢ 38	37.0	136.16	23	1.00	36.9	131.78	27	50
38 ⊢ 40	38.9	146.90	15	1.00	38.9	145.09	24	39
40 ⊢ 42	41.0	161.83	11	1.00	41.0	157.68	26	37
42 ⊢ 44	42.8	184.27	8	1.00	42.9	180.92	7	15
44 ⊢ 46	45.2	221.37	5	1.00	44.9	196.42	6	11
46 ⊢ 48	46.9	236.60	2	1.00	47.0	215.28	3	5
48 ⊢ 50	49.1	251.00	4	1.00	48.7	243.69	3	7
50 ⊢ 52	-	-	-	-	51.1	285.27	2	2
52 ⊢ 54	-	-	-	-	52.1	315.00	1	1
N	-	-	322	-	-	-	357	679

factor (φ) is related to the physiological condition of fishes and may vary according to fatness, suitability of environment or gonad development. On the other hand, the θ parameter, which is a constant for the species, defines the kind of growth peculiar to this species. *G. carapo* has a θ value of about 2.8, which characterizes an allometric type of growth.

According to SANTOS (1978), there is no fixed size at which individuals begin to reproduce, but frequency increases gradually with fish length. Thus, the first sexual maturation size is defined as the size that corresponds to the 50 % frequency.

The first sexual maturation size for *G. carapo* females (Lpm = 24.8 cm) correspond to almost half the asymptotic length the females can reach (L_∞ = 50.0 cm). Based on the growth curve in length, this is the size of individuals in the second year of life.

No adult females with sizes inferior to 19.0 cm were sampled. Hundred percent of the adult females occurred from 33.0 cm on (Tabl. II).

CONCLUSIONS

Basis on the results obtained, it can be concluded that the annuli encountered in the scales of *G. carapo* from Lobo Reservoir are formed during the last quarter of the year, corresponding to the spawning period, which starts during the second year of life when the fish attains first sexual maturation size (Lpm).

Males reach higher asymptotic values (L_∞) than females.

The estimated θ value suggests allometric growth.

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