AGE AND GROWTH OF THE MARINE CATFISH, *NETUMA BARBA* (SILURIFORMES, ARIIDAE), IN THE ESTUARY OF THE PATOS LAGOON (BRASIL)[1]

ENIR GIRONDI REIS[2]

ABSTRACT

Otolith cross sections from *Netuma barba* were used for age and growth determinations. There is close agreement between average back-calculated lengths and average observed lengths determined from otoliths at capture for each year class. One opaque and one hyaline zone is formed annually. The hyaline zone appears to be formed during the breeding season when the estuarine mature population is scarcely feeding. Von Bertalanffy growth parameters were estimated through Beverton's method which showed the smallest residual variance between observed and calculated lengths for year class. The growth equation (mm) is $Lt = 638 [1 - \exp(-0.1287(t + 0.195))]$. The largest specimen observed was a 980 mm female, 36 years old. The life span of *N. barba* was estimated to be 23.1 years and the natural mortality rate 0.13.

The sea catfish, *Netuma barba* (Lacepède 1803), ranges in the western Atlantic from Bahia (lat. 17°00'S) in Brasil (Günther 1864) to San Blas (lat. 40°32'S) Argentina (López and Bellisio 1965). It is the second most important estuarine fishery resource in the Patos Lagoon and is caught with gill nets (Reis 1982a). The species accounts for about 29% of the total fish landings in the estuary from October to December, a period when it migrates from the sea to spawn. During the remaining months the species is dispersed in low abundance in the ocean (Reis in press). Observations on *Netuma barba* in Brasil have been restricted to taxonomy (Higuchi et al. 1982) and to feeding and reproduction (Ihering 1888, 1896; Nomura and Menezes 1964; Reis in press).

Age determinations in catfishes are usually based on reading vertebrae and pectoral or dorsal spines (Pantulu 1962; Tweddle 1975). Pectoral spines of *Netuma barba* were not used in the present study because they showed inconsistencies in age determination. However, a preliminary investigation revealed the presence of clear and readable zones in otoliths. This paper deals with the interpretation of these zones, the possible causes of zone formation, and the determination of growth of *Netuma barba* in the estuary of the Patos Lagoon.

MATERIALS AND METHODS

Study Area

The Patos Lagoon, the largest lagoon system in southern Brasil (10,360 km²), is connected to the Atlantic Ocean by a narrow access canal (Fig. 1). The estuary of the lagoon serves as a breeding, nursery, and feeding ground for most of the coastal fish which migrate through the canal and represent a significant percentage of the national fishery resource.

Collections of adult *Netuma barba* were made from fish-processing plants located in the estuarine zone of the lagoon, off the coast of Rio Grande to São Lourenço do Sul, a town located 94 km inland (Fig. 1). Juveniles were collected by special research surveys carried out in the estuary. Data were collected from September 1977 to December 1980 on 4,120 specimens. No samples were available from January to March because of a closed fishing season of Ariidae in the area, and few samples were collected from April to July due to the absence of the species in the estuary.

Sampling Procedure

Specimens were measured (total length, mm), weighed (g), and sexed. Lapillus otoliths were removed, sectioned transversally next to the nucleus, polished, and were examined under a 10× binocular microscope. The dorsal, polished half of the otoliths was observed with transmitted light. The
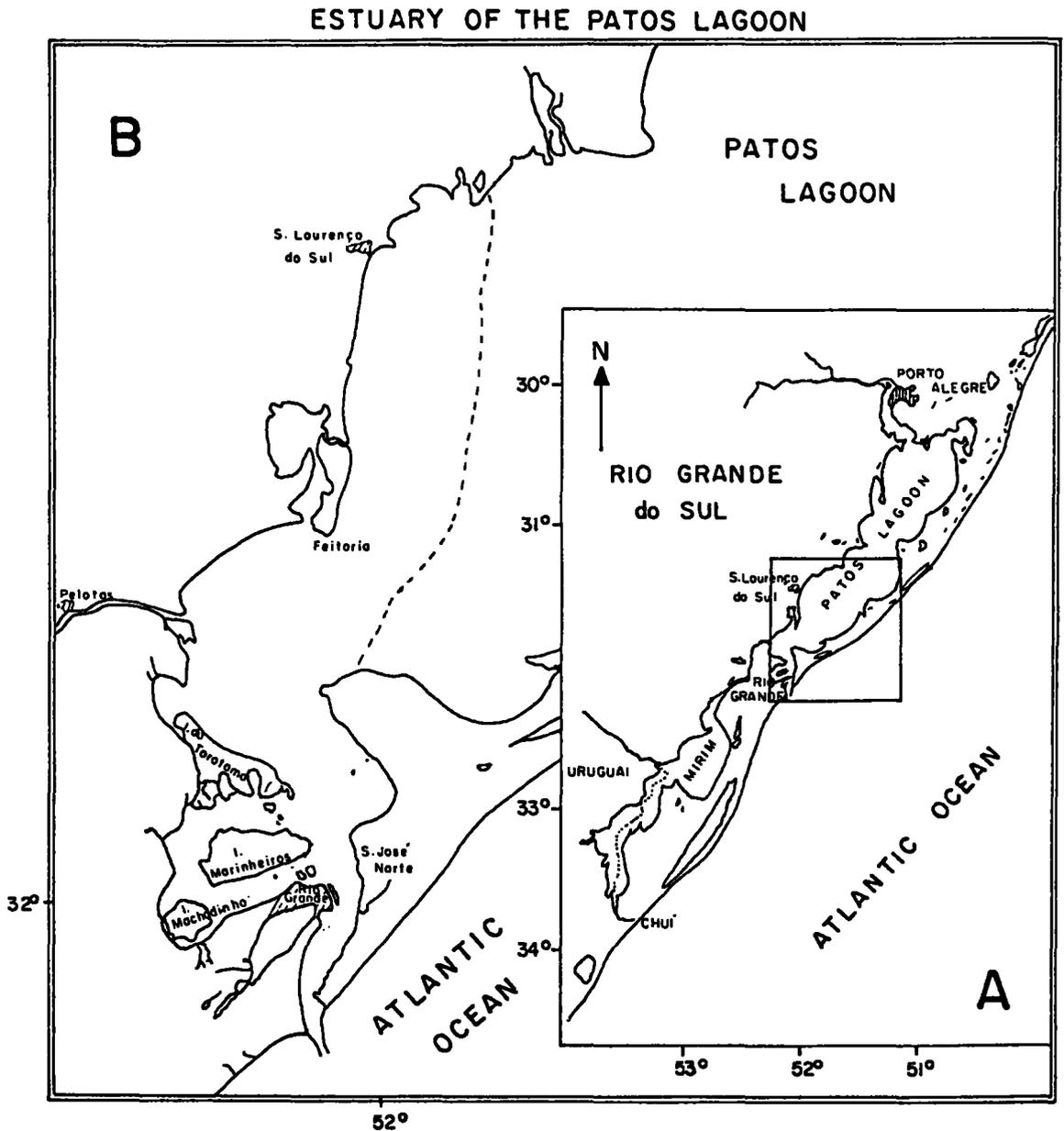
ESTUARY OF THE PATOS LAGOON

FIGURE 1.—Coastal lagoon system of southern Brasil (A) and the study area (B).

type of deposit (opaque or hyaline) on the otolith margin and the number of hyaline zones were recorded for each otolith. Back-calculation was done over the surface, the total length of the otolith (Co) and the length between the nucleus and each hyaline zone (ci) (Fig. 2) were measured with an ocular micrometer. The term nucleus used here refers to the central area of the otolith limited by the first zone (Jearld 1983).

Growth curves for males and females were calculated using the mean lengths for year class. The parameters of the von Bertalanffy growth equation were determined:

$$Lt = L_\infty [1 - e^{-K(t-t_0)}] \qquad (1)$$

where Lt is the total length at time t, L_∞ is the maximum attainable size, K is the growth coeffi-
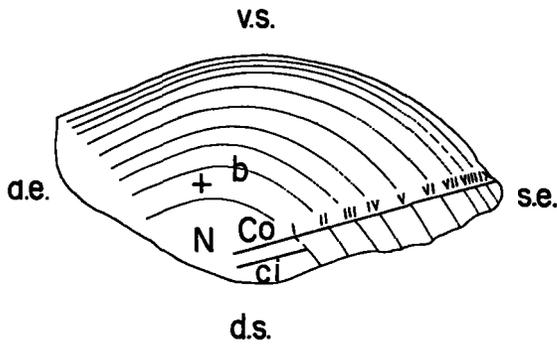
V.S.

d.s.

FIGURE 2.—A lapillus otolith of *Netuma barba* showing opaque (+) and hyaline (b) zones, the nucleus (N), the axes where back-calculation was made (Co = distance between the nucleus and the otolith's edge; ci = distance from the nucleus to "i" hyaline zone) and the position of otolith on fish head (a.e. = antisulcal end; s.e. = sulcal end; d.s. = dorsal surface; v.s. = ventral surface; and hyaline zones = I-IX).

cient, and t_0 a correction on the time axis. The parameters of Equation (1) were estimated by determining the predictive regression of $\ln(L_\infty - Lt)$ against t (Beverton 1954):

$$\ln(L_\infty - Lt) = \ln L_\infty + K(t_0 - t) \qquad (2)$$

where K is the slope of the regression line and the y-intercept of Equation (2) can be equated to $\ln L_\infty + Kt_0$ providing the value of t_0 (Ricker 1975). Trial plots, including values of L_∞ first derived by the methods of Walford (1946) and Gulland (1964), yielded the L_∞ which gives the straightest line. The agreement between observed and calculated lengths for year class was determined by residual variance (S^2y) expressed by

$$S^2y = \frac{\Sigma \ (\text{observed } Lt - \text{calculated } Lt)^2}{N - 1} \qquad (3)$$

where N is the number of age classes.

Length-weight relationship was determined for males and females

$$Wt = \mu Lt^v \qquad (4)$$

where Wt is the weight at time t, and μ and v the coefficients of the functional regression between Wt and Lt (Ricker 1973). The condition factor was calculated for each sex as follows:

$$K = \frac{Wt}{Lt^v} \qquad (5)$$

and

$$Wt = W_\infty \ [1 - e^{-K(t-t_0)}]^v \qquad (6)$$

expressed growth in weight, where W_∞ is the maximum attainable weight obtained by solving for L_∞ in Equation (4).

The life span was estimated:

$$A_{0.95} = t_0 - \frac{\ln(1 - P)}{K} \qquad \text{(Taylor 1960)} \quad (7)$$

where $A_{0.95}$ is the time required to attain 95% of L_∞, $P = 0.95$ and t_0 and K are derived from the growth equation. The natural mortality coefficient (M) was estimated according to Taylor (1960)

$$M = \frac{\ln(1 - P)}{A_{0.95}} \qquad (8)$$

Statistical analyses were done when necessary (Snedecor and Cochran 1970; Sokal and Rohlf 1981).

RESULTS AND DISCUSSION

Age Determination

The lapillus otolith used for the determination of age of *Netuma barba* is the most developed ear bone in the Ariidae (Stinton 1975), its length attaining 3% of fish fork length (Reis 1982b). Growth zones can be observed on a sectioned otolith from the sulcal to the antisulcal end and from the nucleus on the dorsal face to the ventral one (Fig. 2). The hyaline and opaque zones are clearly evident even in otoliths of old specimens. Under transmitted light the opaque zones, or fast-growth zones, are white (broad) and hyaline zones, or slow-growth zones, are dark (narrow) (Fig. 2). Warburton (1978) counted growth checks on whole otoliths of *Galeichthys caerulescens* (Günther), and Dmitrenko (1975) studied *Arius thalassinus* (Rüppel) by viewing the otoliths the same way as in the present paper. The number of hyaline zones on sectioned otoliths and of growth checks observed on whole otoliths (Warburton 1978) were compared. A smaller number of growth checks was encountered in all cases when using whole otoliths.

In the present study only 2.4% of the otoliths were considered illegible. About 60% agreement was obtained when otoliths were read on two different occasions separated by a month. Disagreement was due to the inability to distinguish the first hyaline zone and those near the otolith's edge. When the same otoliths were analyzed for the third time, the

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agreement between observations increased to 79.9%.

Time of Zone Formation

The percentage of hyaline and opaque edged otoliths was plotted for each month (Fig. 3). Otoliths showing hyaline edge are more abundant in December when they comprise 63.7% of the total; opaque edged otoliths are fewer in this month (33.9%). Student's *t*-test (Snedecor and Cochran 1970) showed that proportions between hyaline and opaque edged otoliths differ significantly ($P < 0.05$) for most months (Fig. 3). Also, the mean width of the opaque

zone on the otolith edge decreased towards the end of the year (Fig. 4), indicating a recent hyaline zone formation. The period of zone formation is not the same for all individuals, the result of individual growth differences. It is evident, however, that only one hyaline and one opaque zone is formed each year. Formation of slow-growth zones during warm months in *Netuma barba* coincides with the spawning period and the cessation of feeding activity (Reis in press). Both events suggest a decrease or a pause in growth when hyaline zones are formed. Menon (1953) observed that decreased feeding and gonad maturation may cause a periodic formation of the growth marks in skeletal parts of fish. During the
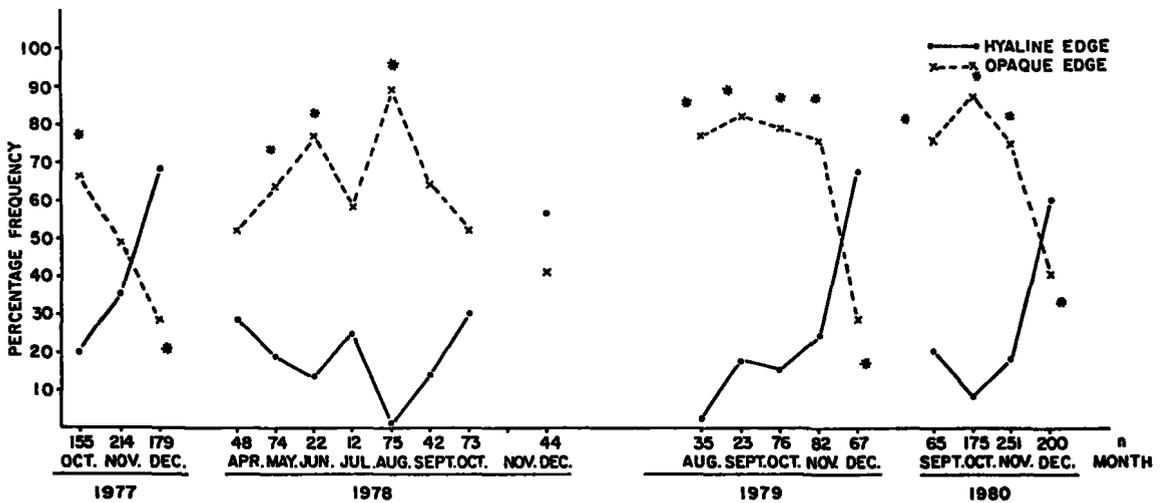

FIGURE 3.—Percentage of hyaline and opaque edge on otoliths of *Netuma barba* related to the months of four years (* $P < 0.05$; n = number of specimens).
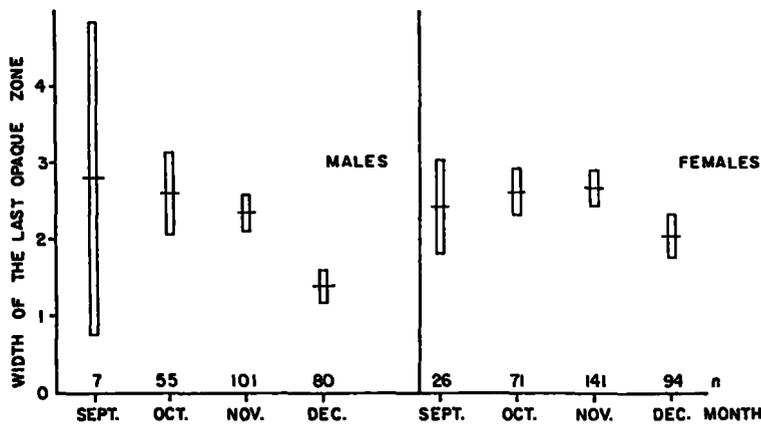

FIGURE 4.—Mean width and confidence limits at $P < 0.05$ level of the last opaque zone on otolith's edge for males and females of *Netuma barba* (n = number of specimens).

remaining months, when *Netuma barba* is at sea actively feeding and the gonads are resting (Reis in press), the opaque zones appear to be laid down due to fast somatic growth. According to Pannella (1974), fishes of temperate environments tend to form opaque zones or fast-growth zones during warm months but the synonymity of the terms summer and opaque, winter and hyaline has to be demonstrated in each instance rather than accepted as a general fact. For *Netuma barba* slow-growth zones are formed during warm months and may be related to the maturation of the gonads and a pause in feeding activity. Gonad maturation may be one of the causative factors of hyaline formation in adults; however, a plausible cause still needs to be established for immature specimens.

GROWTH

Growth in Length

Sectioned otolith lengths (measured as shown in Figure 2), and fish lengths were best fitted to the power curve:

$$Lt = 1.89 \, Co^{1.047} \qquad r = 0.960; \qquad n = 689,$$

and the equation for back-calculation was

$$Lt\,i = Lt \left(\frac{ci}{Co} \right)^{1.047}$$

where $Lt\,i$ is the length of fish when zone "i" was formed. Observed and back-calculated mean lengths for year class for each sex increase as one opaque and one hyaline zones are formed in the otolith each year (Table 1). Up to age 11, the mean lengths are similar; older females had mean lengths greater than males. The same was true for mean weight although a small number of specimens were analyzed from age 11 onward. Observed lengths are usually higher than back-calculated lengths except in ages that few specimens were analyzed.

Lengths corresponding to ages 8 to 12 are most frequent in the samples since they are most affected by the mesh size of the fishing gear used in the estuary. Mean observed lengths at these ages agree closely with mean back-calculated lengths (Fig. 5) for both sexes. Gill nets are highly size selective and retain fish at lengths of 370–520 mm (Reis 1982a). The analysis of variance (Sokal and Rohlf 1981) showed that observed lengths at ages 5, 6, and 7 are significantly higher than back-calculated lengths ($P < 0.05$) which could be due to the capture of the largest specimens of these ages since the minimum size of fish held by gill nets depends on the maximum body girth (opercle). Mean back-calculated lengths showed no definitive tendencies for any age class (Fig. 6) indicating no growth changes. Fur-

TABLE 1.—Mean observed and back-calculated lengths of males and females of *Netuma barba* for each age class (sample size in parentheses).

Estimated age	Mean observed length		Mean back-calculated length	
	Male	Female	Male	Female
1	84 (10)	96 (4)	65 (310)	63 (370)
2	145 (31)	152 (21)	140 (303)	137 (371)
3	203 (40)	197 (50)	193 (295)	192 (362)
4	228 (7)	261 (2)	244 (291)	245 (359)
5	348 (16)	146 (1)	300 (286)	299 (357)
6	378 (28)	365 (11)	347 (281)	347 (349)
7	403 (59)	394 (56)	386 (263)	385 (336)
8	415 (144)	416 (111)	413 (241)	412 (313)
9	433 (291)	431 (281)	430 (140)	433 (193)
10	452 (94)	463 (120)	444 (79)	446 (129)
11	476 (73)	493 (138)	455 (31)	462 (54)
12	490 (57)	526 (51)	460 (8)	507 (8)
13	464 (15)	602 (23)	508 (4)	612 (3)
14	551 (10)	667 (21)	480 (3)	637 (2)
15	522 (13)	622 (5)	520 (2)	578 (1)
16	533 (10)	620 (3)	528 (1)	608 (1)
17	494 (2)	647 (2)	546 (1)	637 (1)
18	620 (1)	714 (1)	564 (1)	657 (1)
19	588 (4)	554 (3)	—	666 (1)
20	550 (1)	860 (1)	—	696 (1)
21	520 (2)	520 (2)	—	706 (1)
22	490 (1)	649 (1)	—	—
23	— —	736 (1)	—	—
24	680 (1)	— —	—	—
36	930 (1)	980 (1)	—	—

FIGURE 5.—Mean observed and back-calculated lengths for year class of *Netuma barba* (* *P* < 0.05).
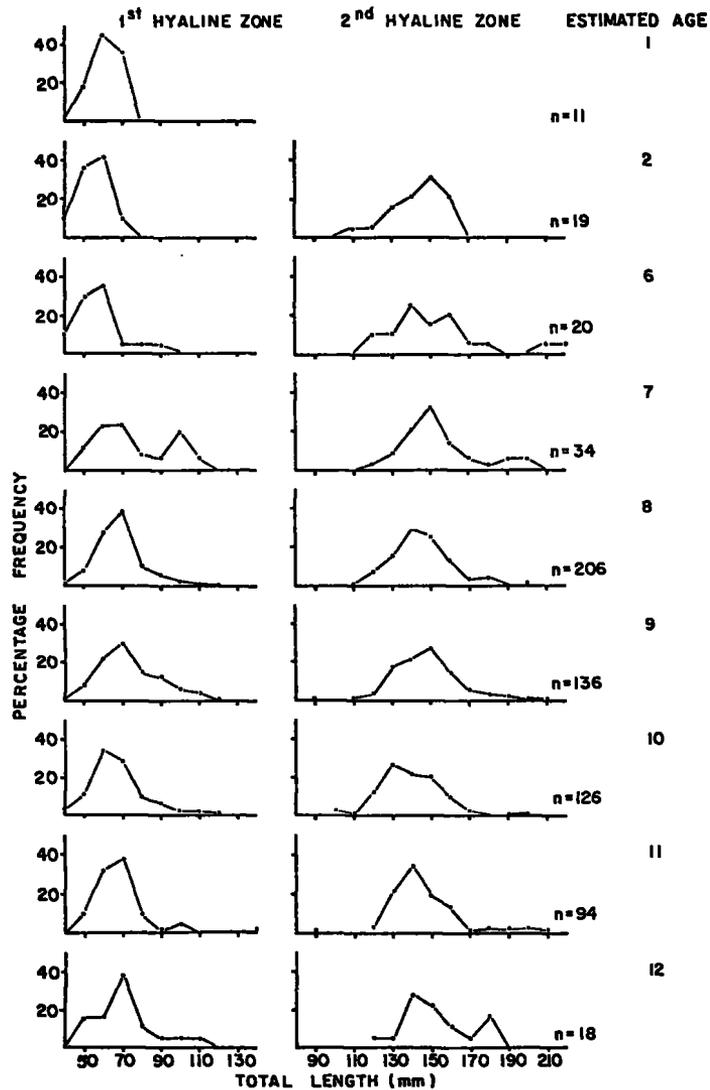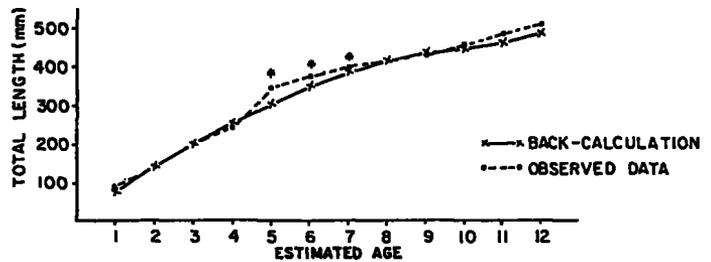

FIGURE 6.—Back-calculated lengths frequencies at first and second hyaline zones for year class of *Netuma barba* (n = number of specimens).

thermore, as the modes for each year class are similar, age determination can be considered consistent.

Validation of Age

Validation of the otolith method for aging *Netuma*

barba is supported by the following: 1) one opaque and one hyaline zone is formed annually (Figs. 3, 4); 2) a gradual decrease of length increments with age (Table 1); 3) observed lengths generally agree with back-calculated lengths (Fig. 5); and 4) distribution of back-calculated lengths for previous ages shows similar modes for each year class (Fig. 6).

Length-weight Relationship and Condition Factor

A total of 685 specimens captured during 1980 was used to compute the length-weight relationship for each sex:

Male $Wt = 4.70 \times 10^{-6} Lt^{3.14}$ $r = 0.992$ $n = 332$
Female $Wt = 2.19 \times 10^{-6} Lt^{3.26}$ $r = 0.952$ $n = 363$
Total $Wt = 4.41 \times 10^{-6} Lt^{3.15}$ $r = 0.987$ $n = 685$
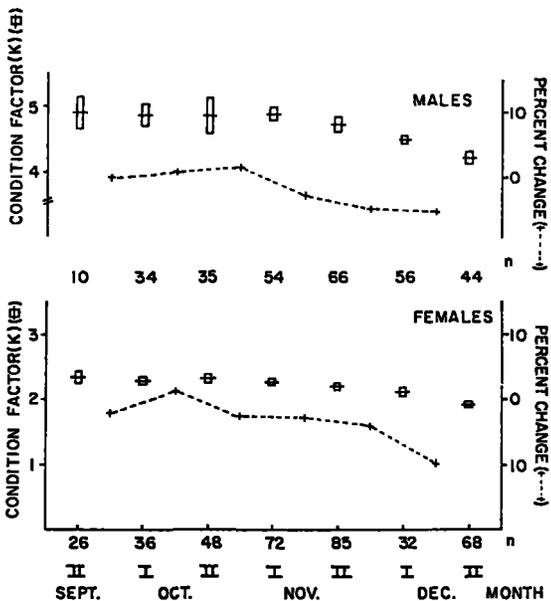

FIGURE 7.—K condition factor and percent change for males and females of *Netuma barba* related to time (n = number of specimens; I = first half of the month; II = second half of the month)

The analysis of covariance (Snedecor and Cochran 1970) at $P < 0.05$ level showed significant difference only for the μ value, and for that reason condition factor (K) was determined for each sex. There is a decrease of mean K values towards the end of the year (Fig. 7). The condition factor for males is always higher probably due to a more intense feeding prior to reproduction. Low K values reveal the stress the fish suffers when it is scarcely feeding and fat reserves are being diverted to gonad maturation (Reis in press), thereby causing a cessation of growth. I proposed that K values for males will sharply decrease after spawning due to an oral incubation period that lasts 1 to 2 mo and prevents males from feeding (Reis in press).

Calculation of Growth Parameters

Von Bertalanffy growth parameters were estimated by Beverton's (1954) method which presented the smallest residual variance between observed and calculated lengths for year class on the ages that are most affected by gear selectivity (8-12 yr old). For fish populations captured from a certain age onward, the smallest residual variance should be sought for all year classes from age at first capture. For *Netuma barba* the smallest residual variance could not be ascertained by this method because the true length distribution is unknown due to the use of gillnets as fishing gear. Growth equation for age 1 to 12 for both sexes in represented by

$$Lt = 638 \left[1 - e^{-0.1287(t+0.195)}\right].$$

Figure 8 shows both calculated and observed lengths for each year class.

Growth in weight for each sex resulted in

Male $Wt = 2981.89 \left[1 - e^{-0.1287(t+0.195)}\right]^{3.14}$
Female $Wt = 3035.70 \left[1 - e^{-0.1287(t+0.195)}\right]^{3.26}.$
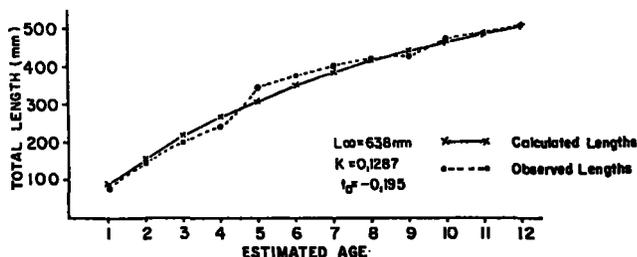

FIGURE 8.—Growth curve of *Netuma barba*.

Maximum Size and Age, Life Span, and Mortality Rate

Netuma barba is a long lived, slow growing species with a low mortality rate. Specimens as long as the theoretical mean length (638 mm) are frequently captured. The largest catfish observed was a 980 mm female 36 yr old. *Netuma barba* life span was estimated to be 23.1 yr and its mortality rate was 0.13. I assumed that the estimate of M (natural mortality) is accurate, since *Netuma barba* reveals a long life span, a capacity to avoid predation through the defense represented by its hard dorsal and pectoral spines and a parent-juvenile care behavior (Reis in press). Pauly (1980) suggested that species with low mortality rates are related to high L_∞ values and to low growth coefficients. These characteristics combined with the fact that *Netuma barba* has a low fecundity (Reis in press) define the species as *K*-strategistic (Gunderson 1980).

ACKNOWLEDGMENTS

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