

**Scale development of *Prochilodus lineatus*  
(Val.) (Pisces, Curimatidae)  
juveniles from the Paraná River**

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ABSTRACT

*Total body length and scale radius as well as the squamation of young Prochilodus lineatus were examined. Fish began to form squamation at 13 mm and were completely scaled at 17 mm total length. The relationship between body length and scale size is curvilinear during the early life of the fish.*

KEYWORDS : Scale — Juveniles — *Prochilodus lineatus* — Curimatidae — Paraná River — Argentina.

RESUMEN

DESARROLLO DE LA ESCAMA EN JUVENILES DE *PROCHILODUS LINEATUS* (VAL.) (PISCES, CURIMATIDAE)  
DEL RÍO PARANÁ

*Se analiza la relación largo total del pez-radio de la escama así como su escamación. Los resultados muestran que esta empieza a los 13 mm, cubriéndose todo el cuerpo a los 17 mm de longitud total. La relación entre la longitud del cuerpo y el tamaño de la escama es curvilínea durante los primeros estadios del pez.*

PALABRAS CLAVES : Escama — Juveniles — *Prochilodus lineatus* — Curimatidae — Río Paraná — Argentina.

RÉSUMÉ

LE DÉVELOPPEMENT DES ÉCAILLES DES JUVÉNILES DE *PROCHILODUS LINEATUS* (VAL.) (PISCES, CURIMATIDAE)  
DU FLEUVE PARANÁ

*La longueur totale, la formation et le rayon des écailles ont été examinés. Les écailles commencent à se former pour une longueur totale de 13 mm, et sont formées pour une longueur du poisson de 17 mm. La relation entre taille du poisson et rayon de l'écaille est curvilinéaire pendant la phase juvénile de P. lineatus.*

MOTS CLÉS : Écaille — Juvéniles — *Prochilodus lineatus* — Curimatidae — Paraná — Argentine.

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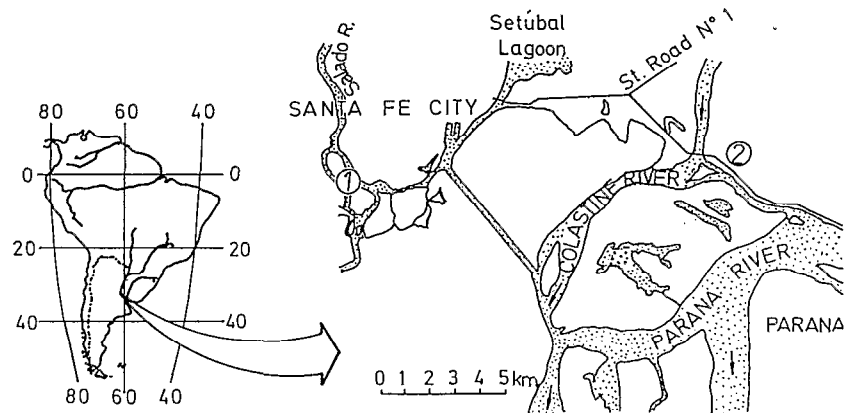


FIG. 1. — Study area. 1: Los Sapos Island and Salado River, and 2: Lagoon of El Espinillar Island.  
 La zone d'étude. 1 : ile Los Sapos et rivière Salado; 2 : lac de l'île El Espinillar.

## INTRODUCTION

The Paraná River is one of the more important rivers in South America. It flows for about 2,000 km through Argentina draining 33,000 km<sup>2</sup> and ending in an important alluvial plain 1,100 km long. It is formed by a very complex system of islands, tributaries, branches and lagoons, all related in different degrees with the principal channel (LOWE-McCONNELL, 1987; CAROZZA and CORDIVIOLA DE YUAN, 1991). In this fluvial macrosystem (NEIFF, 1990) there are more than 300 fish species, being the "sábalo" (*Prochilodus lineatus*) (Val.) dominant both in number and in biomass (BONETTO *et al.*, 1969, 1970 and 1971; CORDIVIOLA DE YUAN, 1974 a and 1992; OLDANI and OLIVEROS, 1984).

The "sábalo" inhabits lentic as well as lotic waters of the system. Adults spawn in the river in summer when water levels are high. Later the larvae and juveniles grow in small lagoons near the lotic environments where they can find shelter and food (CORDIVIOLA DE YUAN, 1974 a).

*P. lineatus* adults transforms organic matter since its diet is composed more of detritus than microorganisms (BOWEN *et al.*, 1984). A series of morphological transformations of the digestive tract occurs during the post-larval and juvenile stages which correspond with changes in their diet: from zooplankton to phytoplankton to detritus (WELCOMME, 1985; ROSSI, 1992). BAYO and CORDIVIOLA DE YUAN (1992 a and b) who studied the fatty acids as indicators of the species assimilation obtained similar results.

Previous investigation on *P. lineatus* age and

growth were conducted in fishes from different environments of the Paraná River (CORDIVIOLA DE YUAN, 1971 and 1974 b; CAROZZA and CORDIVIOLA DE YUAN, *op. cit.*). Most of these studies were concerned with fish older than 2 years old, in which the age was determined by lepidological method. Very little is known about larvae and juvenile growth and squamation.

The present study has been undertaken in order to investigate the early scale development of *P. lineatus* by analyzing the relationship between total length and scale radius as well as early squamation of juvenile fish.

## RESEARCH SITES

Fish were caught in two areas: a) Near the mouth of the Salado River in the Coronda River (tributary of the Paraná) in the alluvial plain of the Paraná. They were obtained in the Salado River as well as in the lagoons of the Los Sapos Island (31° 40' S; 60° 43' W) the later environments are shallow and small, and b) in a permanent lagoon (31° 42' S; 60° 37' W) located in El Espinillar Island in the alluvial plain near the Colastiné River and the principal channel of the Paraná (fig. 1).

It was not possible to obtain fish of a wide range of sizes in all the environments of the alluvial plain at the same time. For this reason samples were taken during 1988 in February, March, April, October, and December, and along 1989 in March, April, and August.

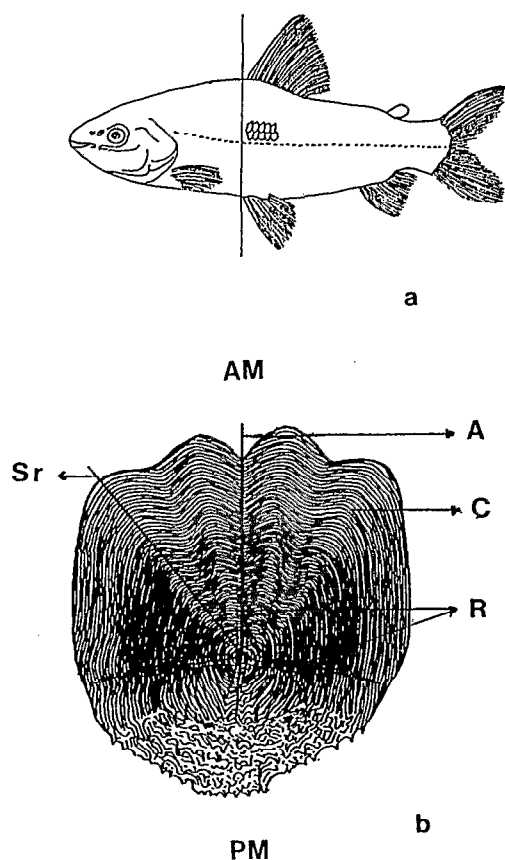


FIG. 2. — a) Scale sampling area on the fish. b) *Prochilodus lineatus* scale indicating the radius Sr ( $38^\circ$  to the anterior-posterior axis A) where measurements were taken; C: circuli;

AM: anterior margin; PM: posterior margin; R: radius (adapted from CORDIVIOLA DE YUAN, 1971).

a) Zone de prélèvement d'écaillies; b) Écaille de *Prochilodus lineatus* avec l'axe Sr (à  $38^\circ$  de l'axe antéro-postérieur) sur lequel les mesures ont été faites. Les autres symboles indiquent les circuli (C), les faces antérieure (AM) et postérieure (PM) et les rayons (R) (d'après CORDIVIOLA DE YUAN, 1971).

## MATERIAL AND METHODS

The total length of 329 fishes ranged from 8.0 (post-larvae) to 235 mm and weight from 0.01 to 212 g, 86 fishes were subsampled for the squamation study.

Standard, fork and total lengths, weight, and scale samples were obtained from the remaining 243 fish prior to preservation in 10 % formalin. Scales ( $N = 10$ ) were taken from the left side of the body 5 from the row immediately above the lateral line and behind a vertical that passes through the origin

of the dorsal fin and the other five scales from the second row (CORDIVIOLA DE YUAN, 1971) (fig. 2a).

Scale samples were cleaned and mounted between two slides. They were viewed in a Shadowgraph Nikon with 50 and 20 X magnification. For each fish the scale radius was measured on a straight line that forms an angle of  $38^\circ$  with its anterior-posterior axis taking as its vertex the scale center (CORDIVIOLA DE YUAN, *op. cit.*) (fig. 2b).

The relationship between total length (Tl) and scale radius (Sr) was estimated as follows:

$$Sr = d + e Tl + f (Tl)^2$$

where: Tl = total length in mm, Sr = scale radius in mm;

$d$ ,  $e$  and  $f$  are constants estimated by a least squares adjustment.

To provide a simple and continuous way of quantifying the relative growth of the scale at any body size it was calculated the relationship lg-lg and from it the first derivative (CASSELMAN, 1990).

In some fish the caudal fin was damaged, and it was impossible to obtain accurate measurements of total length. In such cases, the total length was estimated based on a regression relationship between total and standard length, as follow:

$$Tl = 0.29 + 1.21 Sl \quad R^2 = 0.99$$

The length-weight relationship calculated from the data registered was:

$$W = 0.01 Tl^{3.16} \quad R^2 = 0.99$$

To examine early squamation fishes were washed with distilled water, placed in a solution of 1 % KOH, treated with alizarin red to stain the scales, and finally examined with an Olympus stereoscopic binocular microscope. Drawings were made showing the distribution of scales on the body at different sizes.

## RESULTS

The scale-body relationship calculated was (fig. 3, and table I):

$$Sr = 0.103 + 0.039 Tl + 0.0001 Tl^2 \quad R^2 = 0.98$$

The estimated regression log-log, was:

$$\text{Log Sr} = -0.618 - 0.800 \text{Log Tl} + 0.586 (\text{Log Tl})^2 \quad R^2 = 0.97$$

From this equation was calculated the first derivative (fig. 3).

For *P. lineatus* juveniles of the Paraná River the scale grew at a slower rate than the body up to

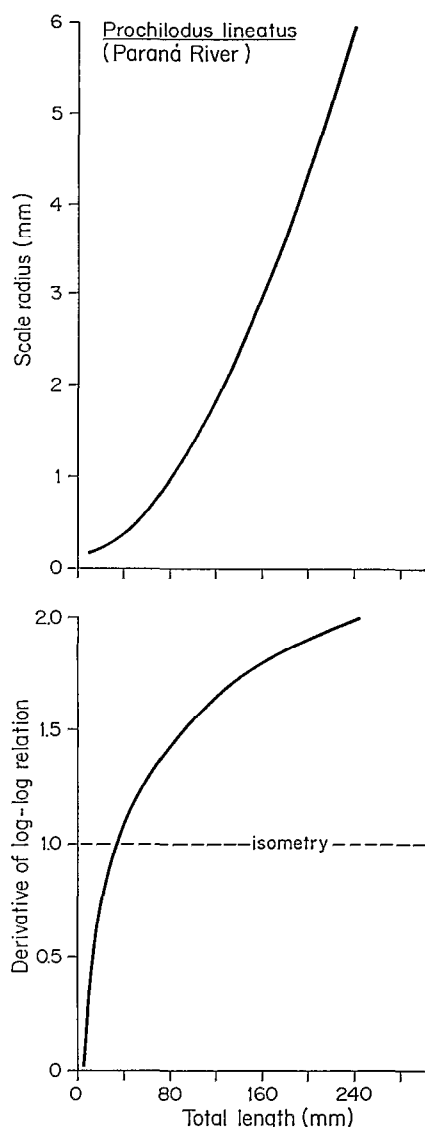


FIG. 3. — **Upper panel:** scale radius-body length relationship for 243 "sábalo" *Prochilodus lineatus* (8-235 mm T1) from several water bodies of the alluvial plain of the Paraná River. Coefficients and statistics for the arithmetic relationship are given in table I. **Lower panel:** relative growth is indicated by the relation between the first derivative of the Log-log relation (base 10) and body length. Coefficients of the first derivative and statistics for the Log-log relation are given in table I. *Relation entre la longueur totale de Prochilodus lineatus (243 spécimens de taille comprise entre 8 et 235 mm) provenant de divers plans d'eau de la plaine alluviale du Paraná avec en haut le rayon de l'écaïlle, en bas la croissance relative calculée par la dérivée de la relation Log-log (base 10). Voir le tableau I pour les données numériques.*

TABLE I

Model fitting results for the relationship between total length and scale radius of *Prochilodus lineatus* juveniles from Paraná River

*Détermination des coefficients des relations entre longueur totale et rayon de l'écaïlle pour les juvéniles de P. lineatus du fleuve Paraná*

Arithmetic relation			
	estimate	std. error	ratio
Coeff. 1	0.103	0.039	2.658
Coeff. 2	$3.86 \times 10^{-3}$	$9.32 \times 10^{-4}$	4.143
Coeff. 3	$8.84 \times 10^{-5}$	$4.04 \times 10^{-6}$	21.889
Log-log relation			
	estimate	std. error	ratio
Coeff. 1	-0.618	0.204	-3.034
Coeff. 2	-0.800	0.224	-3.570
Coeff. 3	0.586	0.061	9.611

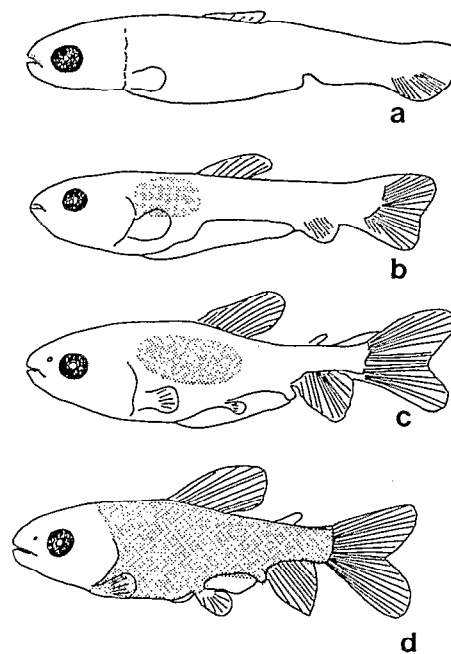


FIG. 4. — Development of squamation on *P. lineatus* from the Paraná River. a) 8-11 mm: body naked, b) 12-13 mm: the first scales appear, c) 14-15 mm: the scales are extended toward the posterior region, and d) 16-17 mm: body completely scaled. *Apparition des écaïlles chez P. lineatus du Paraná. a) 8-11 mm, le corps est nu; b) 12-13 mm, les premières écaïlles apparaissent; c) 14-15 mm, les écaïlles se développent dans la partie postérieure; d) 16-17 mm, le corps est recouvert d'écaïlles.*

35 mm TL, the range over which scale was isometric (fig. 3, lower panel). On larger fish the scale grew at a faster rate than the body (up to reach  $K = 2.0$  at 240 mm TL), changing from negative to positive allometry.

The body is completely naked at 11 mm. At 12-13 mm scales start to appear in the anterior region of the body near the lateral line. The squamation spreads from this primary site in the middle region of the body at 14-15 mm. The scales extend finally over the posterior region completely covering the body at 17 mm (fig. 4).

## DISCUSSION AND CONCLUSIONS

In this work it is proved that the relationship between body length and scale is not linear during the early life of the fish. CAROZZA and CORDIVIOLA DE YUAN (*op. cit.*), grossly overestimated (in a linear regression) the time of scale formation of the fish (155 and 222 mm for females and males, respectively). The present study provides a more accurate estimation of early growth of *P. lineatus*. Combining these data (i.e., from old and young fish) would provide a better estimation of overall growth.

Fish squamation has been studied for more than 80 species all over the world, most of them freshwater ones species of the orders Anguiliformes, Clupeiformes, Cypriniformes, Siluriformes, Salmoniformes, Gasteroteiformes, Cyprinodontiformes, Scorpaeniformes, Perciformes, and Pleuronectiformes (SIRE and ARNULF, 1990). The squamation research aims have ranged, from age and growth stu-

dies to systematic analysis, and, others to determine the factors that might initiate and organize the process in fishes. Among teleosts, seven different regions of first scale appearance have been delimited on the body. Some species have only one site, whereas others have two or more. *P. lineatus* is in the first group, with the localization in the anterior region of the body near the lateral line.

Squamation data for South American fishes are scarce: ARAUJO-LIMA (1985) studied larval development of the amazonian *Semaprochilodus insignis* and analyzed scale appearance. GERVY (1977) considers this genus to be only a subgenus of *Prochilodus*.

Observations made on *P. lineatus* have demonstrated that there is no evidence of scales in samples smaller than 12 mm total length. The first scales appear in fish of 13 mm total length, coinciding with the values obtained in a species of a similar genus: *Semaprochilodus insignis*, where scales appeared at 13 mm (ARAUJO-LIMA, *op. cit.*).

The scale grows at a slower rate than the total length of the fish up to 35 mm, the size in which is isometric. From this point the scale grows at a faster rate than the total length.

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