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Morphometric characteristics of *Prochilodus lineatus* (Valenciennes 1847), of the migratory and resident stocks of the river Mogi-Guaçu, São Paulo State, Brazil

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ABSTRACT. The species *Prochilodus lineatus*, with great commercial relevance in the rivers Grande, Pardo and Mogi-Guaçu, is characterized by the formation of great shoals which are capable of developing wide migratory displacements. Current assay evaluates, by means of the morphometric characteristics and age, whether the curimatás (*P. lineatus*) of different migratory and resident stocks form a single population, with interactivities among the sub-populations during the 'piracema' period (reproduction migration). A completely randomized plot with a 4 x 2 factorial scheme, with four stocks (one resident and three migratory) as factors and two genders (male and female), with thirty replicates, was employed, with each fish taken as an experimental unit. An 80.19% variation for the first principal component and an 8.09% variation for the second principal component were reported as provided by the ten morphometric variables of resident and migratory stocks. The resident stock had the highest rate for the whole morphometric variables. There was superposition of individual scores of the same characteristics among the migratory stocks. Significant predominance of males was observed among resident stocks and migratory stocks I and II. Morphometric similarity verified among the migratory stocks showed a single population, with small inter-population variations.

Keywords: fish age, reproductive migration, analysis of main components.

Características morfológicas do curimatá (*Prochilodus lineatus*) dos estoques migradores e residentes do rio Mogi-Guaçu, Estado de São Paulo, Brasil

RESUMO. A espécie *Prochilodus lineatus* é de grande importância comercial na região dos rios Grande, Pardo e Mogi-Guaçu e tem como característica a formação de grandes cardumes, apta a desenvolver amplos deslocamentos migratórios. O presente trabalho objetivou avaliar, por meio das características morfológicas e etária, se os curimatás (*P. lineatus*) dos diferentes estoques migradores e residentes constituem uma única população, havendo interação entre as sub-populações no período de piracema (migração reprodutiva). Utilizou-se um delineamento inteiramente casualizado em esquema fatorial 4 x 2, com quatro tipos de estoques (um residente e três migradores) e dois sexos (macho e fêmea) com trinta repetições, considerando cada peixe como unidade experimental. Foi observada variação de 80,19% para o primeiro componente principal e 8,09% do segundo componente principal fornecida pelas dez variáveis morfológicas dos estoques residentes e migradores. O estoque residente correspondeu aos maiores valores para todas as variáveis morfológicas. Houve sobreposição dos escores individuais das mesmas características entre os estoques migradores. Observou-se predominância de machos entre os estoques residentes e migrador I e II. As semelhanças morfológicas verificadas entre os estoques migradores indicam tratar-se de uma única população, com pequenas variações interpopulacional.

Palavras-chave: idade dos peixes, migração reprodutiva, análise dos componentes principais.

Introduction

Reproduction of the rheophile species *Prochilodus lineatus* (Valenciennes, 1836) occurs in river channels and its initial development takes place in marginal lakes close to floodplains. The species, which is capable of wide migratory displacements, has high commercial importance in the basin of the rivers Grande, Pardo

and Mogi-Guaçu. Fish stocks for commerce or sports normally reveal high impaired size and age distributions with no bigger and/or older specimens. This is not only due to the fact that fishermen retrieve the biggest specimens but also to fishing regulations that, as a rule, impose a single minimum fish size or fishing tackle that ensure a selective harvesting of the

biggest fish. These collection practices provide genotypes with a slower growth, low maturity age and other changes that decrease the population's productivity (CONOVER; MUNCH, 2002).

The weight-length relationship is a relevant tool in fish biology and ecology since it provides information on weight and biomass that compares the growth of different species (MENDES et al., 2004; OSCOZ et al., 2005) or of different populations of the same species (SOUZA et al., 2000) within the natural environment and in captivity. Current analysis has the following aims: description of development related to the species's life stages; indication of population stock levels; indication of feed and reproduction activities. According to Domingues and Hayashi (1998), age and growth of fish are relevant factors in the evaluation of stocks and fishing resources normally undertaken by production models that would diagnose changes and furnish projects on stocks. Studies may also provide basic information on life strategies, population structure and growth changes, with the formation of a basis for population dynamics models.

The proportion between the sexes also constitutes relevant information for the characterization of species or population structure and also provides support for the investigation of such aspects as the evaluation of reproduction potential and estimates of stock size (VAZZOLER, 1996).

Owing to the increase in the importance of *P. lineatus* in commercial fishing in the river Mogi-Guaçu, studies on the dynamics of this population should be endeavored. Current assay evaluates, through morphometric and age characteristics, whether the *P. lineatus* of the river Mogi-Guaçu, from different migratory and resident stocks, form one population, with interactivities among the sub-population during the 'piracema' (reproduction migration) period.

Material and methods

Current assay was conducted at the Universidade Estadual Paulista (UNESP), in the Laboratory of Technology of Animal-originated Products of the Department of Agro-industry Management and Technology of the Faculty of Agronomic Sciences, campus Botucatu, São Paulo State, Brazil. Thirty specimens of *Prochilodus lineatus* (Valenciennes, 1836), were captured in September 2006 from the resident stock (feed phase), or rather, the stock which remained during the whole year, in the river Mogi-Guaçu (Alto Paraná basin), in the Cachoeira de Emas Dam, municipality of Pirassununga, São Paulo State, Brazil.

Collection was undertaken by the technical and logistical help of the National Center for Research and Preservation of Continental Fish/Chico Mendes Institute (CEPTA/ ICMBio) team. 30 *P. lineatus* specimens were also collected from the migratory stock (reproduction phase) originating from shoals that reach the Cachoeira de Emas during the 'piracema' period, collected in December (28 specimens), January (30 specimens) and March (30 specimens) 2007. The migratory fish were kept in earth tanks at the National Center for Research and Preservation of Continental Fish/Chico Mendes Institute (CEPTA/ICMBio), Pirassununga São Paulo State, Brazil, up to data collection. Nets with different mesh sizes were used for capture.

All specimens of *P. lineatus* (males and females) were measured morphometrically (Figure 1), following techniques by Souza Júnior et al. (2002). The following variables were analyzed: total length (Lt) – measured from the tip of the snout to the furthest extreme tip of the tail fin; standard length (Ls) – measured from the tip of the snout to the start of the tail fin; furcal length (Lf) – measured from the tip of the snout to the furcal vertrix of the tail fin; length of head (Lh) – measured from the tip of the snout to the most external projection of the operculum; length of upper jaw (Lma) – measurement from the start of the maxilla up to its most external projection; maximum height (Hb) – vertical measurement of the insertion of the first spike of the dorsal fin up to the ventral region; length of the dorsal fin base (Ld) – measurement obtained from the insertion of the first spike of the dorsal fin up to the insertion of its last ray; length of the anal fin base (Lan) – measurement obtained from the insertion of the first spike of the anal fin up to the insertion of the last ray; length of breast fin base (Lpe) – measurement obtained from the insertion of the foremost ray up to the extremity of the longest ray. Measurements were obtained with a centimeter-graded ichthyometer and with a pachymeter, with the animal stretched on a plane surface. Specimens' sex determination was performed by direct observation of gonads, with or without oocytes.

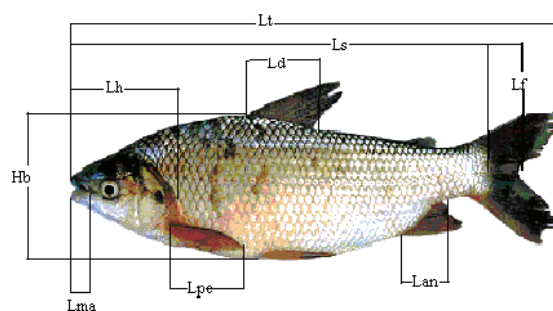


Figure 1. A specimen of curimatá, *Prochilodus lineatus*, with variables related to analyzed morphometric characteristics.

Scales over the breast fin were retrieved from each specimen. They were conditioned in labeled envelopes and an average of 15 scales per specimen was collected. Cleansing, preparation and mounting of scales on glass laminas were undertaken according to Vazzoler (1981). Considering yearly periodicity, two readings with an optic microscope (magnifications 100 and 400 X) were performed on the selected scales.

Statistical analysis

In an attempt to find general patterns in the use of environmental resources on the basis of morphometric characteristics of *P. lineatus* was made a principal component analysis (PCA), evaluated the populations' morphometric characteristics which identified general standards in the use of resources, or rather, whether selected phenotypic characteristics correspond to differences in the use of resources among stocks. Analyses of variance for all variables were undertaken to compare means of groups, sex and interactivities group – sex and Pearson's correlation coefficients for all variables were also calculated. The proportion between the sexes in the areas under analysis was verified by χ^2 test at 5% significance level SAS (2001).

Results and discussion

Analyzed populations of *P. lineatus* showed important morphometric variations for their identification. Analysis of Principal Components was undertaken to verify general standards in the use of environmental resources based on the body shape of *P. lineatus*. The first principal component (PC 1) triggered most variance data, with 80.19% variation, whereas the second principal component (PC 2) exhibited 8.09% of data variation provided by the ten morphometric variables for resident and migratory stocks (Table 1). All coefficients of PC 1 presented positive rates, interpreted as a multivariate analysis with regard to size. In the case of PC 2, positive and negative rates informing on the characteristics of body shape were reported.

Table 1. Coefficients of the first (CP 1) and second (CP 2) principal components of variables studied in resident and migratory stocks of *Prochilodus lineatus*.

Variables	Size of fish (CP 1)	Shape of fish (CP2)
Total weight (Wt)	0.3264	-0.1534
Total length (Lt)	0.3472	-0.0339
Standard length (Ls)	0.3471	-0.0462
Furcal length (Lf)	0.3475	-0.0512
Head length (Lh)	0.3105	-0.0548
Maxilla length (Lma)	0.2965	-0.1433
Length dorsal fin (Ld)	0.3329	0.0557
Length anal fin (Lan)	0.1712	0.9693
Length breast fin (Lpe)	0.3154	-0.0349
Maximum height (Hb)	0.3280	-0.0558
% variation	80.19	8.09

Analyzed variables with highest rates comprised total (Lt), standard (Ls) and furcal (Lf) length for PC 1, with the exception of the length of anal fin (Lan), characterized by low rates. Locomotion relevance for eco-morphological studies lay in the type of swimming with direct implications on habitat use (WAINWRIGHT et al., 2002), biotic interactions (WERNER, 1977) and foraging (WEBB, 1984).

Figure 2 shows the distribution of the morphometric characteristic rates evaluated for each fish in different stocks, with the overlapping of individual scores of the characteristics among the migratory stocks (EM I, EM II, EM III) analyzed within the space defined by the two principal components. Residence stock (ES) comprised the highest rates for all morphometric variables, positively correlated with PC 1. Consequently, residence stock differentiates itself from the other groups due to the fact that these fish are stocked in a single place, also called 'feeding home' and may be considered a place for adults' growth and recovery (AGOSTINHO et al., 1993), including 'piracema' fish (VAZZOLER et al., 1997), feed availability and a haven protection area for these fish. Since no difference in form and size existed among stocks, different fish shoals (migratory stocks) under analysis failed to show any significant morphological differences.

Nikolsky (1963) found that specimens of the same species, albeit living in several environments, with different available feed and temperatures, may have distinct growth rates, as Table 1 and Figures 2, 3 and 4 show.

With regard to PC 1, resident stock was different from the others although migratory stocks I, II and III were similar (Figure 3). No difference among groups was registered in the case of PC 2 (Figure 4). Since *P. lineatus* is a species characterized by wide feed and reproduction migrations, the morphometric differences above may be due to environmental variations. Domingues and Hayashi (1998) reported that high size variations in *P. lineatus* populations kept in tanks have been attributed to chromosome numerical amplitude and, when in natural environments, to natural pressures.

Pearson's correlation analysis demonstrated that almost all variables were highly correlated. Only the anal fin length (Lan) had a lower correlation when compared to the other variables (Table 2). Since correlation among the morphometric measures was significant and positive, all morphometric measures were directly proportional to standard length (Lt).

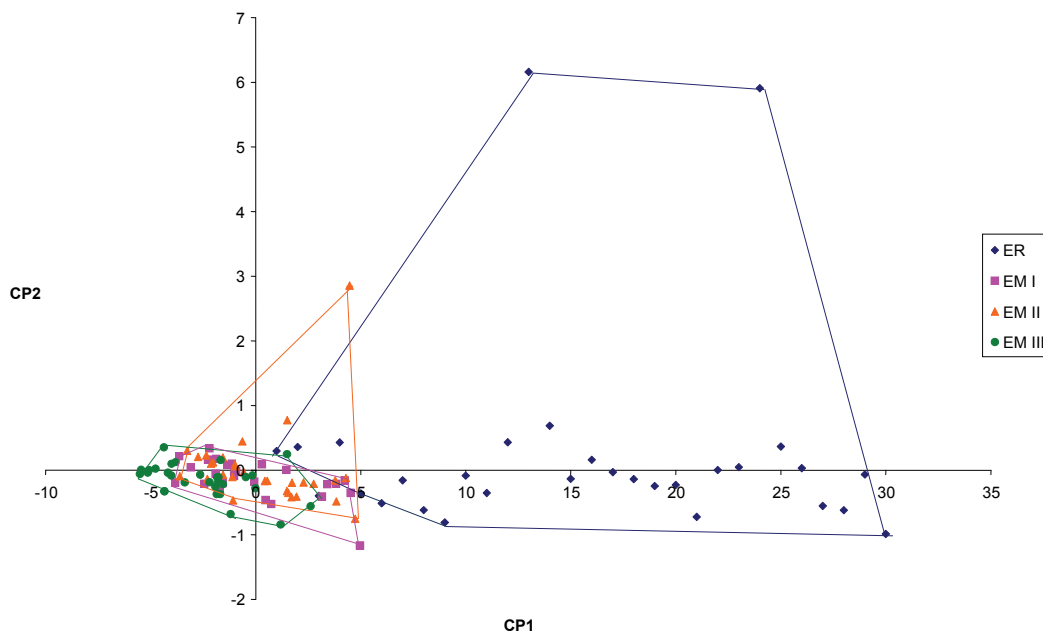


Figure 2. Diagram showing the individual score dispersion of migratory and resident stocks of *Prochilodus lineatus* analyzed in spaces defined by PC 1 and PC2. (ER) resident stocks; (EM I) migratory stock I; (EM II) migratory stock II and (EM III) migratory stock III.

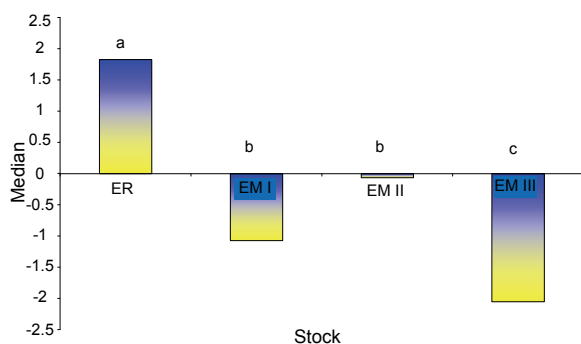


Figure 3. Median of scores of PC 1 of *Prochilodus lineatus*. Resident stocks (ER); migratory stock I (EM I); migratory stock II (EM II) and migratory stock III (EM III).

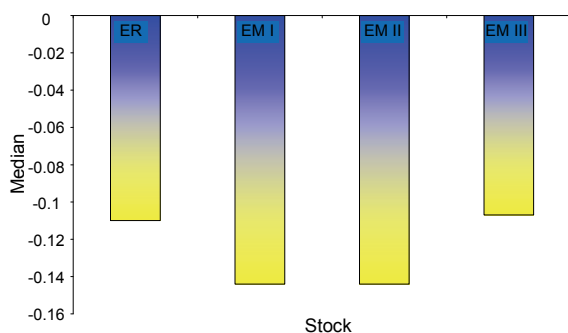


Figure 4. Median of scores of PC 2 of *Prochilodus lineatus*. Resident stocks (ER); migratory stock I (EM I); migratory stock II (EM II) and migratory stock III (EM III).

Table 2. Pearson's correlation among the morphometric measures under analysis in resident and migratory stocks of *Prochilodus lineatus*.

	Wt	Lt	Lf	Ls	Lh	Lma	Ld	Lan	Lpe	Hb
Wt	1.00	0.92	0.93	0.93	0.76	0.72	0.85	0.33	0.79	0.87
Lt		1.00	0.98	0.98	0.84	0.79	0.92	0.45	0.87	0.91
Lf			1.00	0.99	0.84	0.79	0.92	0.43	0.86	0.91
Ls				1.00	0.84	0.79	0.92	0.44	0.85	0.91
Lh					1.00	0.76	0.80	0.38	0.76	0.77
Lma						1.00	0.75	0.32	0.74	0.76
Ld							1.00	0.48	0.83	0.86
Lan								1.00	0.40	0.41
Lpe									1.00	0.78
Hb										1.00

$p < 0.05$ for all correlations among variables.

It has been reported that, with regard to arithmetical means of morphometric characteristics, growth in females is higher than that in males and reach a higher body size. According to Vazzoler and Menezes (1992), the above characteristic is related to the female's reproduction dynamics. In fact, females invest more in reproduction than males. In other words, they have larger gonads and have higher energetic expenditure for reproduction, requiring higher body proportions to hold big ovaries.

Population morphometric analyses may be not only useful in the investigation of biological diversity within a determined region but they reveal morphometric similarities among the stocks under analysis. According to Souza Júnior et al. (2002), morphological differences among stocks may be associated to different environmental and biological pressures. Morphometric similarities among the

migratory stocks reveal a single population with slight interpopulation variations. Differences may have been due to environmental variations and to population polymorphisms, similar to other populations of the same species in other places.

In the case of morphometric characteristics of analyzed stocks, mean resident stock for most variables exceeded the other averages and revealed a mean age of 5 years. Migratory stock III had the lowest average, with a mean age of 2 years. In his investigation on *P. scrofa* of the river Mogi-Guaçu, Castagnolli (1971) found specimens up to 6 years old with standard length of 48 cm. On the other hand, Toledo-Filho et al. (1986) stated that species growth depended on the environment in which the species was found since the environment may provide the species with different migratory standards and thus different growth standards. A similar situation may have occurred in resident stock and migratory stock III investigated in current assay. Lizama (2000) reported that juvenile specimens of *P. lineatus*, slightly more than one year old, were living in the lakes of the high Paraná river floodplain during March and April. This is similar to what has been registered for migratory stock III (during March), two years old, collected in the Mogi-Guaçu river. Capeleti and Petrere Jr. (2006) studied the migration of *P. lineatus* in the Mogi-Guaçu river and verified that the last fish, migrating during March and April, had lower length measurements and were not in the reproduction phase, as reported in current analysis.

According to Nikolsky (1969), proportion between the sexes may provide important data on the relationship between specimens and the environment and on the population situation of a specific species. The application of the χ^2 test to the proportions of males and females (Table 3) shows a significant predomination of males among the resident stock and the migratory stocks I and II. Resende (1992) provided similar results when investigating the bioecologia of *Prochilodus lineatus* in the Pantanal at Miranda-Aquidauana, Mato Grosso do Sul State, Brazil. Current investigation shows lower female rates among resident stock and migratory stocks I and II, perhaps due to the mortality caused by reproduction effort-caused stress. A high number of females in migratory stock III may have been one of the strategies adopted by the species for population replenishment. However, the possibility of changes in the sex proportions in the populations under analysis when the number of analyzed specimens increase, should not be discarded.

Table 3. Proportions between males and females of *Prochilodus lineatus* and results of χ^2 test in resident and migratory stocks.

Stock	Females		Males		Total	χ^2
	N	%	N	%		
Resident	11	36.67	19	63.33	30	1.60
Migratory I	10	35.71	18	64.29	28	1.75
Migratory II	13	43.33	17	56.67	30	0.17
Migratory III	21	70.50	9	30.00	30	8.84
Total	55	46.61	63	53.39	118	9.25*

N = number of captured specimens; * significant difference $p < 0.05$.

Conclusion

Morphometric similarities among migratory stocks demonstrate a single population with slight interpopulation variations. They differ significantly from the variables provided by morphometric data of the resident stock. Results indicate two different stocks of *P. lineatus* in the environment investigated – one comprises the resident population and the other the species's set of migratory population.

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