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Determination of age and its correlation with biometric variables and seasonal reproductive indices of *Leporinus obtusidens*

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ABSTRACT. This study determined the age and its correlation with biometric variables and reproductive indices of piapara *Leporinus obtusidens* caught at the Funil Reservoir. We caught 133 specimens between September 2006 and August 2007. Weight, total length, standard length, depth, height, head length and radius of the scales were measured. The sex was determined by macroscopic examination of gonads. The age of each fish was determined by analyzing the growth rings on the scales. Seasonal differences in biometric variables were tested using the NK test at 5%. The correlation of age and radius of the scales with the biometric variables and reproductive indices were analyzed using the SAEG software. Fish individuals ranging from 3 to 14 years of age were caught. In the spring and summer, smaller fish were captured compared to those caught during the fall and winter. Females tended to have higher weight and morphometric values when compared to males. Age and radius of the scales were correlated with biometric variables in *L. obtusidens*. It can be concluded that the biometric variables of this species can be used as an indicator of age.

Keywords: biometrics, fish, growth, piapara, reproduction.

Determinação da idade e sua correlação com as variáveis biométricas e indíces reprodutivos sazonais de *Leporinus obtusidens*

RESUMO. O trabalho determinou a idade e sua correlação com as variáveis biométricas e os índices reprodutivos de *L. obtusidens* capturados na usina hidrelétrica do Funil. Foram capturados 133 espécimes entre setembro de 2006 e agosto de 2007. Foram medidos o peso, o comprimento total e padrão, a altura, a espessura, o comprimento da cabeça e raio da escama. O sexo foi determinado por exame macroscópico das gônadas. A idade de cada peixe foi determinada pela análise das linhas de crescimento da escama. As diferenças sazonais dos parâmetros biométricos foram determinadas usando o teste de NK a 5%. Foi verificada a correlação da idade e o raio da escama com as variáveis biométricas e índices reprodutivos por meio da correlação de Pearson, usando o programa SAEG. As piaparas capturadas tinham idade que variaram de três a 14 anos de idade. Nas estações de primavera e verão foram capturados peixes menores em relação aos capturados durante o inverno e outono. As fêmeas tendem a ter maior peso e valores morfométricos quando comparados com os machos. A idade e o raio da escama estão correlacionados com as variáveis biométricas de *L. obtusidens*. Concluindo que as variáveis biométricas desta espécie podem ser usadas como um indicador da idade.

Palavras-chave: biometria, peixe, crescimento, piapara, reprodução.

Introduction

River impoundment for hydropower generation is a common practice in large river basins of South America. Currently, almost all of these basins have dams or are affected by the construction of dams. Studies carried out in Brazil estimate that more than 700 large water reservoirs have been built (AGOSTINHO et al., 2007). River regulation by dams is one of the primary causes of reductions in fish diversity and depletion of migratory species (OLDANI et al., 2007). Populations of migratory species may indeed be reduced by interruption of their natural routes (LARINIER; MARMULLA, 2004; OKADA et al., 2005).

Piapara *Leporinus obtusidens* is a large migratory physoclistous fish species that may be negatively impacted by dam construction in its natural habitats in South and Southeast Brazil (GLUSCZAK et al., 2006). It lives in lotic and lentic environments of small streams and migrates upstream once a year to spawn (VAZ et al., 2000). Piaparas are omnivorous and, because of their intermediate position in the food chain, are important for ecosystem balance (ARAYA et al., 2005). These fish can reach 40 cm in length, weigh up to 6 kg and are economically important; indeed, it is one of the most often captured species in South Brazil (GIODA et al., 2007; TAITSON et al., 2008).

The age of a fish population can be verified through growth marks in calcified structures, as otoliths and scales (WEATHERLEY; GILL, 1987), marks that are associated with environmental factors. In some tropical fish species, age determination is difficult, when there are no well-defined environmental changes between seasons, such as winter-spring transitions. During those periods, variables such as temperature, photoperiod and food availability are considered decisive in the formation of annual rings. In scales, there are zones where the grooves are more spaced (rapid growth zones) followed by areas where the flakes are less spaced (slow growth zones) forming a mark on the scale (ring or annulus). Together, these two areas should correspond to an annual growth area (SPARRE et al., 1990). Previous studies have associated ring formation with temperature, water levels, photoperiod, water transparency, water velocity in preferred fish habitats and food (AGOSTINHO et al., 1999; ARAYA et al., 2005).

Information obtained on fish age could contribute to an optimal, or at least a rational, exploitation of a fishery. The determination of ages of Brazilian native fish by observing the growth marks on their scales has been performed by several authors such as Cutrim and Batista (2005) for the mapará *Hypophthalmus marginatus*, Araya et al. (2005) for *L. obtusidens*, Araya et al. (2008) in *Leporinus acutidenspelas* and Dei Tos et al. (2009) in *Salminus brasiliensis*.

Age and growth are particularly important for describing the status of a fish population. It also facilitates assessing production, stock size, recruitment to adult stock and mortality (LOWE-MCCONNEL, 1987). Furthermore, studies on fish age comprise an important aspect of their biology and relationship with their environment. However, few studies have related age with biometric parameters and the reproductive index of fish. This study aimed to verify the age of piapara *Leporinus obtusidens* caught at the Funil Hydroelectric Dam and its correlation with biometric variables and seasonal reproductive indices.

Material and methods

Study area

The Rio Grande covers 143,000 km^2 in Southeast Brazil. A number of plants built in this river basin or in its contributing basins are major energy sources in the country. The Funil Hydroelectric station (FHS) is located on the Grande River between the cities of Perdões and Lavras (Minas Gerais State), (21°05'S and 44°55'W). The construction of FHS began in 2000 and operations started in 2003. It uses three Kaplan type turbines in which a flow of 191 m^3 s^{-1} produces an output of 61.5 MW per turbine. The FHS has a fish transposition system of the elevator type designed to allow migration and reproduction processes of the different fish species from downstream to upstream of the dam (FELIZARDO et al., 2010 a, b).

Collection of animals and biometric measurements

We captured 133 piaparas *Leporinus obtusidens* between September 2006 and August 2007 in the Grande River, downstream of the FHS dam, with authorization from Instituto Estadual de Florestas (IEF) through scientific fishing license category D- N. 063-07. The downstream part of the Funil Dam has an average depth of 12 meters.

Fish collection was carried out at 15 day-intervals, in the morning, using rod and reel with cow heart and worms as bait. Mean temperature during the fish collection period was 20.5°C (± 3.2) and the highest rainfall indices were observed from November to February, with a peak of 17.9 mm occurring in January.

The captured fish were anesthetized with benzocaine (80 mg L^{-1}) and transported to the laboratory inside ice-filled coolers. The minimum size for capture was set at 25 cm total length, according to the laws of the State Institute of the Forest of Minas Gerais (VAZ et al., 2000).

The specimens were identified and the total weight (TW - g), total length (TL - cm), standard length (SL – cm; between the end of the head and the lower perimeter of the caudal peduncle, i.e. point of insertion of the caudal fin), depth (cm; measured in the region of the first ray of the dorsal fin), height (cm; at the 1° ray of the dorsal fin) and head length (HL – cm; between the extreme anterior of the head and the caudal portion of the operculum) were measured with the aid of a caliper and a ruler for measuring fish, graduated in millimeters.

Sex determination

A wide ventral incision was made in each animal to observe the internal organs and sex was determined by macroscopic examination of gonads.

Gonads and liver were removed and weighed to calculate the gonadosomatic index [GSI = (Wg/TW) x 100], where Wg is the gonad weight (g) (VAZZOLER, 1996), and the hepatosomatic index [HSI = (Wl/TW) x 100], where Wl (g) is the liver weight (ANDRADE et al., 2006).

Determination of age from scales

Before removing the scales, fish were washed in running water, gently rubbing the surface of the body from head-to-tail, to remove any scales lost from other fish and some dirt residue. The scales were removed without difficulty with the help of forceps. Three scales were taken from each fish collected, from the dorsal lateral area below the dorsal fin and above the lateral line, being careful to collect larger and symmetrical scales.

The scales were stored in envelopes duly identified for future reading of age. Scales are hydrophilic structures and, therefore, dry preservation causes distortion of their original form (with a tendency to curl). Thus, after storage for a period of one year at room temperature, the scales went through a hydration treatment by immersion in distilled water before analysis.

The scales (n = 3) of each specimen were placed on slides and their readings were taken with a binocular microscope, using the smallest magnification (4 x) to allow full view of the whole scale. The reading was performed by visualizing areas where stretch marks were more widely spaced (areas of rapid growth - which usually occur in summer) followed by areas where the scales were less widely spaced (areas of slow growth - which occur in winter) forming a mark on the scale (ring or annulus). This set of two zones corresponds to an annual growth area. These marks of growth should be observed throughout the surface of the scale (ARAYA et al., 2005).

In addition to the reading of age, the ray (in mm) of the scales from the focus (center of the scale) until the edge was also measured.

Statistical analysis

To test the effects of sex and season on the biometric variables of the collected fish, data were subjected to analysis of variance using a statistical model with two cross-classification criteria that included the effects of sex, season of the year and the interaction between these factors. Means were compared using the Student Newman Keuls test (SNK) at 5% probability. The Pearson correlation coefficient was used to check for significant correlation of the age and radius of the scales with the variables related to biometric data and reproductive indices. The computer software SAEG (2007, version 9.1) was used to run this analysis.

Results

The growth rings (age rings) of the scales analyzed were well-defined and easy to identify and count, although for about 15% of the scales, it was not possible to identify their age, because of irregularities in the rings.

It was captured a total of 81 females and 52 males (Table 1). The number of animals taken in each season is presented in Table 1

Piaparas ranging from 3 to 14 years of age were caught during the collection period (Table 2).

The greatest number of animals was collected at 9 years of age; this number then declined with either increasing or decreasing age (Table 2). The biometric data and reproductive indices according to the age of the specimens captured also are summarized in Table 2.

The age and radius of scales of *L. obtusidens* are highly correlated with biometric variables of this species. The age and radius of scales of *L. obtusidens* does not influence the GSI. However, it was found that the HSI has a negative correlation with age (Table 3).

There was no significant interaction ($p > 0.05$) between sex and season for the biometric variables, so the season data and sex were independent. It was further observed that smaller fish were caught in the spring and summer in relation to those caught during the winter and autumn. Females of *L. obtusidens* tended to have higher weight and morphometric values compared to males (Table 4).

Table 1. Specimens of *L. obtusidens* caught by season and sex.

Season	Sex		Total
	Male	Female	
Winter	13	31	44
Spring	14	18	32
Summer	11	14	25
Fall	14	18	32
Total	52	81	133

The seasonal GSI of females was higher ($p < 0.05$) than that of males, except in the summer, when males and females showed similar GSI values ($p > 0.05$) (Figure 1).

The GSI of females decreased significantly in the summer compared to spring, demonstrating that the reproductive period of this species preferentially occur in the spring, when we verified a higher ($p < 0.05$) value of GSI (Figure 1).

Table 2. Biometric data and reproductive indices according to the age of *L. obtusidens* caught downstream of the Funil Reservoir (n = 114).

Age (N)*	Parameters								
	Weight(g)	TL(cm)	SL(cm)	Ray(mm)	DP(cm)	Height(cm)	HL(cm)	GSI(%)	HSI(%)
3 (1)	200.0 ± 0.0	29.5 ± 0.0	35.0 ± 0.0	4.5 ± 0.0	4.0 ± 0.0	7.9 ± 0.0	7.5 ± 0.0	0.4 ± 0.0	1.1 ± 0.0
4 (5)	250.0 ± 50.0	25.9 ± 4.0	29.9 ± 5.1	4.6 ± 0.8	3.7 ± 0.4	6.9 ± 1.0	5.7 ± 1.0	0.5 ± 0.7	0.7 ± 0.3
5 (11)	366.3 ± 122.6	27.2 ± 3.6	32.7 ± 4.7	5.6 ± 0.5	4.1 ± 0.6	7.7 ± 1.1	6.1 ± 1.1	0.3 ± 0.3	0.6 ± 0.2
6 (14)	457.1 ± 199.8	29.8 ± 3.5	35.5 ± 4.7	5.9 ± 0.6	4.4 ± 0.5	8.3 ± 1.2	6.8 ± 1.1	0.4 ± 0.3	0.7 ± 0.3
7 (19)	727.8 ± 305.5	33.1 ± 4.2	39.2 ± 4.9	7.1 ± 0.6	5.0 ± 0.7	9.5 ± 1.3	7.7 ± 1.3	1.0 ± 1.4	0.7 ± 0.2
8 (19)	1115.7 ± 184.1	37.1 ± 1.8	43.9 ± 1.9	8.1 ± 0.6	5.3 ± 0.4	10.5 ± 0.9	8.1 ± 0.9	1.1 ± 1.6	0.5 ± 0.2
9 (23)	1226.9 ± 217.3	37.7 ± 3.4	44.4 ± 3.9	9.0 ± 0.4	5.5 ± 0.4	11.0 ± 0.9	8.4 ± 1.2	0.9 ± 1.5	0.5 ± 0.1
10 (12)	1387.5 ± 194.3	40.6 ± 2.4	46.8 ± 2.2	9.5 ± 0.6	5.7 ± 0.6	11.3 ± 0.6	8.9 ± 0.8	0.5 ± 0.3	0.6 ± 0.2
11(6)	1373.6 ± 319.1	39.5 ± 3.7	46.7 ± 4.5	9.6 ± 0.8	5.8 ± 0.5	11.2 ± 0.9	8.8 ± 1.1	1.4 ± 1.9	0.5 ± 0.1
12 (9)	1750.0 ± 463.6	43.2 ± 3.6	49.7 ± 4.0	10.0 ± 1.0	6.1 ± 0.4	12.3 ± 1.7	9.6 ± 1.2	0.5 ± 0.3	0.5 ± 0.1
13 (4)	1972.5 ± 559.4	44.3 ± 3.6	52.6 ± 3.2	10.5 ± 0.5	6.4 ± 0.5	13.5 ± 2.3	10.1 ± 1.2	0.7 ± 0.5	0.6 ± 0.1
14 (1)	3500.0 ± 0.0	59.0 ± 0.0	62.0 ± 0.0	11.0 ± 0.0	6.9 ± 0.0	15.4 ± 0.0	13.0 ± 0.0	0.03 ± 0.0	0.7 ± 0.0

*N – number of specimens caught; TL - Total length; SL - Standard length; DP - Depth; HL - Head length; GSI - Gonadosomatic index; HSI - Hepatosomatic index.

Table 3. Pearson correlations of age and radius of scales with biometric variables of male and females of *L. obtusidens*.

Variable	Variable	Correlations (R^2)	
		Male	Female
Age	Weight	0.83	0.88
	Ray	0.89	0.90
	Depth	0.79	0.76
	Height	0.79	0.80
	Head length	0.62	0.75
	Total length	0.79	0.82
	Standard length	0.80	0.83
	GSI	-0.18*	0.03*
	HSI	-0.26	-0.22
Ray	Weight	0.78	0.89
	Depth	0.83	0.82
	Height	0.82	0.85
	Head length	0.63	0.79
	Total length	0.83	0.86
	Standard length	0.81	0.87
	GSI	-0.11*	0.11*
	HSI	-0.23	-0.22

*Non-significant correlation by Pearson correlation at 5% probability. GSI -Gonadosomatic index; HSI - Hepatosomatic index.

Table 4. Seasonal biometrics of *L. obtusidens* caught downstream of the Funil Reservoir.

		Weight	Age	Ray	TL	SL	DP	Height	HL
Season*	Winter	1421.1 ± 446.0^{a}	9.5 ± 1.6^{a}	9.1 ± 1.0^{a}	46.9 ± 4.4^{a}	39.0 ± 4.3^{a}	5.7 ± 0.6^{a}	11.5 ± 1.2^{a}	9.0 ± 1.4^{a}
	Spring	794.6 ± 391.7^{b}	7.4 ± 1.8^{b}	7.5 ± 1.3^{b}	40.0 ± 5.9^{a}	33.5 ± 5.1^{a}	5.1 ± 0.7^{ab}	9.9 ± 1.5^{ab}	7.8 ± 1.3^{ab}
	Summer	364.0 ± 173.5^{c}	5.4 ± 1.1^{c}	5.6 ± 0.9^{c}	32.8 ± 4.9^{b}	27.7 ± 3.9^{b}	4.1 ± 0.6^{b}	7.5 ± 1.1^{b}	6.3 ± 1.2^{b}
	Autumn	1276.0 ± 481.2^{a}	9.3 ± 2.1^{a}	8.6 ± 1.4^{a}	45.4 ± 4.6^{a}	38.5 ± 4.3^{a}	5.4 ± 0.6^{a}	10.9 ± 1.7^{a}	8.5 ± 1.1^{a}
Sex	Male	857.3 ± 552.6	7.7 ± 2.3	7.5 ± 1.5	39.7 ± 6.3	33.8 ± 6.0	4.8 ± 0.7	9.51.7	7.3 ± 1.3
	Females	1152.2 ± 552.7	8.4 ± 2.3	8.2 ± 1.8	43.8 ± 7.3	37.0 ± 6.2	5.4 ± 0.9	10.62.0	8.6 ± 1.5

* Different superscript letters in the same column indicate significant differences at 5% probability level. TL - Total length; SL - Standard length; DP - Depth; HL - Head length.

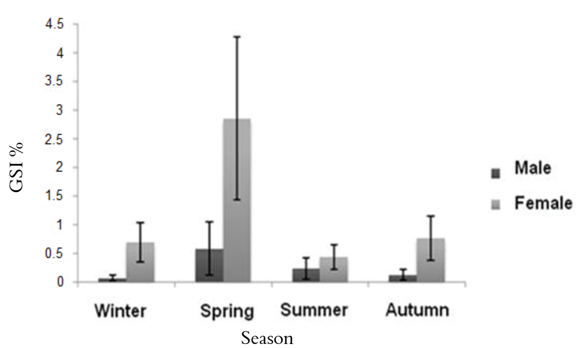

Figure 1. Gonadosomatic index (%) of *L. obtusidens* males and females according to seasons.

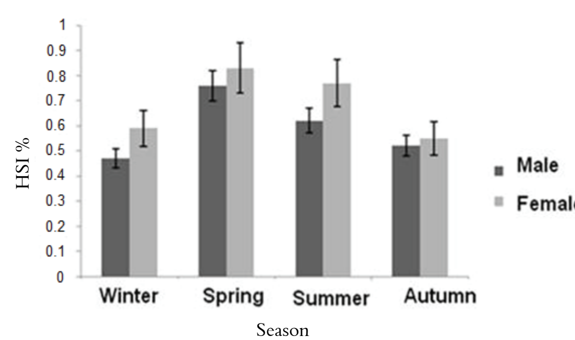

Figure 2. Hepatosomatic index (%) of *L. obtusidens* males and females according to seasons.

The highest ($p < 0.05$) percentage of hepasomatic index of females and males was found in the spring and summer (Figure 2).

Discussion

Determining the ages of fish populations behind hydroelectric plants is extremely important to understand the impacts of reservoirs, and thus may contribute to perform control measurements to maintain sustainable use of the species (FERREIRA; RUSS, 1994). The technique used allowed to easily check the age of the animals, thereby demonstrating that the animals probably went through stations with their distinctive characteristics.

This work enabled to identify the age in approximately 85% of the scales. Irregularities in growth rings are a common problem due to lost of scales and consequent regeneration of new ones, which make them unsuitable for age determination. Regenerated scales can be easily identified by the confused (irregular) pattern of the streaks and the absence of concentric grooves near the center of the scale. Araya et al. (2008), analyzing the age of *Leporinus acutidens*, discarded 45% of the scales because of irregularities in the growth rings. The formation of growth marks on calcified structures is associated with environmental variables such as temperature, photoperiod (ARAYA et al., 2008) and food availability (SPARRE et al., 1990). It is also related to seasonal changes, i.e., rainy and dry periods (BOUJARD et al., 1991).

The correlation between fish size and age was also reported by Abowei (2009) in *Parailia pellucida*.

Most fish was 9 years of age, and the number of animals collected at a given age decreased in accordance with approaching either the lowest or highest verified age. Araya et al. (2005) evaluated age population through the scales of *L. obtusidens* at the Yacyretá Dam, located on the upper Paraná River, and observed that the age of this species ranged from 1 to 13 years, with the most frequently caught specimens being 4 or 5 years of age. These same authors also noted that the number of captured animals decreased as the maximum verified age of the fish was approached. Probably, animals younger than 3 years were not found in this work because we determined a minimum size for capture of 25 cm total length, in accordance with the laws of the of State Institute of the Forest of Minas Gerais (VAZ et al., 2000). According to Dei Tos et al. (2010), freshwater fish from South America are not long-lived, reaching a maximum of 15 years of age.

Considering that age determination based on detailed observation of the scales depends on equipment not available in the collection field, biometric variables may be helpful for this determination, especially weight, radius of scales and standard length, which are correlated over 80% with age in both sexes. Abáñez and Higgins (2011) observed that the size of fish has a high correlation with the size of fish scales. On the other hand, Haimovici and Reis (1984) observed that the radius of the scales of *Umbrina canosai* increases in direct proportion to length, and further reported that the length of this fish can be used as an indicator of age.

It was also found that the age of *L. obtusidens* does not influence the GSI, suggesting that age does not affect the reproductive performance of this species; however, the quality of the gametes has to be checked, and these characteristics were not evaluated. Nevertheless, it was determined that the HSI has a negative correlation with age. The hepatosomatic index is a way to quantify the stock of energy, that is, the stock of glycogen, one of the many energy reserves consumed by fish, which may decrease with age of the animal (NAVARRO et al., 2006).

According to fishermen, the fact that smaller fish were caught in the spring and summer seasons compared to the winter and fall is related to floods and river currents. These usually drove the hook that was released in the middle of the river to the edge, this place where smaller fish are to not become easy prey in places more funds, in view also that the water of the river became cloudy at this time, making it difficult to capture this species.

On the other hand, the flow of the river may also stimulate fish to seek the margins. This river current was usually caused by water release from drains opened in times of flooding to control the level of the dam upstream, since the FHS is a hydroelectric that does not store water.

The observation that females tend to have higher weight and morphometric values than males is also reported by Felizardo et al. (2010a) who found, when evaluating abnormalities in the swim bladder of piapara collected at the same reservoir, that females were longer than males, even though both were of the same age. Araya et al. (2005) also observed this trend in this same species collected in the Paraná River. This fact is also observed in *Salminus brasiliensis* (DEI TOS et al., 2009) and *Lycengraulis grossidens* (GOULART et al., 2007). This is because females have a higher growth rate than males and, consequently, reach longer lengths in the same age.

The reproductive period of fish species may be related to climate change, but not all years have uniform climatic conditions. Late or early rainfall events in different years can alter the biological processes of reproduction; Romagosa et al. (2000) suggest that there is the influence of increased rainfall on the spawning. Considering that, after spawning, the female gonads are empty, and the GSI of males does not change seasonally justifies the observation of the similar GSI between the sexes in the summer. Males reach GSI values relatively lower compared to females during the breeding season.

The highest percentage of the hepatosomatic index of females and males was found in the spring and summer, coinciding with the reproductive period of the species. During the gonadal maturation, there is a possible participation of the liver in the synthesis and secretion of substances for the formation of vitellogenin in the process of oocyte maturation. Andrade et al. (2006) suggests that, during testicular maturation and Spermiation, it can also occur the participation of the liver as an energy supplier to the process of resorption and reorganization of the testis, and also in the transfer of substances in the liver for the metabolism involved in the production of gametes in the testes.

Conclusion

Based on this work, it can be concluded that piaparas caught downstream of the Funil Reservoir ranged from 3 to 14 years in age; the age and radius of the scales of *L. obtusidens* are highly correlated with biometric variables, so these variables can be used as an indicator of age in this species.

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