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ARTIGO ORIGINAL

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Populacional structure of *Apistogramma agassizii* (Steindachner, 1875) (Perciformes: Cichlidae) in aquatic environments of the Amana Sustainable Development Reserve (Amazonas - Brazil)

Estrutura populacional de *Apistogramma agassizii* (Steindachner, 1875) (Perciformes: Cichlidae) em ambientes aquáticos da Reserva de Desenvolvimento Sustentável Amanã (Amazonas - Brasil)

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Abstract *Apistogramma agassizii* is a dwarf cichlid species endemic of the Amazon basin, about which there is little biological and ecological information in their natural habitat, despite their ornamental importance. This study evaluated the populacional structure *A. agassizii* at Amana Sustainable Development Reserve, Middle Solimões basin, Amazonas, Brazil. Positive sexual dimorphism found is probably related to the reproductive behavior of the species. Some management suggestions are offered to support the sustainable use of the species for the studied sites.

Keywords Amazon, cichlids, reproduction.

Resumo *Apistogramma agassizii* é uma espécie de ciclídeo anão endêmico da bacia amazônica, a qual poucas informações sobre biologia e ecologia são conhecidas para seu habitat natural, apesar de sua importância ornamental. Neste estudo avaliamos a estrutura populacional de *A. agassizii* na Reserva de Desenvolvimento Sustentável Amanã (RDSA), bacia do Médio Solimões, Amazonas, Brasil. O dimorfismo sexual positivo encontrado provavelmente está relacionado ao comportamento reprodutivo da espécie. Algumas sugestões de manejo são oferecidas para dar suporte ao uso sustentável da espécie nos locais estudados.

Palavras-chave Amazônia, ciclídeos, reprodução.

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Introduction

The structure of a population includes several attributes among them are the density and place occupied by individuals in the habitat, number of individuals in each age group or size, sex ratio, and morphological differences between individuals of a generation or population (Nikolsky, 1963; Ricklefs, 2013). Studies on the structure of fish populations with ornamental potential are important as they provide information on the ecology of the species in the natural environment as aspects of life strategy for growth and reproduction. In additional, the relationship length-weight of the fish species can be used to estimate the weight of a certain species through the survey on the length of group of individuals, vice-versa (Lemos *et al*., 2015), collaborating as indirect measure of growth (Gomiero *et al.*, 2010).

The species *Apistogramma agassizii* (Steindachner, 1875), is widely distributed in the Amazon, it is a small cichlid of freshwater occupying lakes and streams in the Amazon environment. *Apistogramma agassizii* can reach up to six centimeters in total length, shows sexual dimorphism in adults. The males are larger, more colorful and more prolonged fins with the compared to females (Hercos *et al*., 2009). The distribution of *A. agassizii* extends across the South American continent from the foot of the Peruvian Andes to the Amazon delta, localities for members of this complex lie not only in the main river itself, but also in the lower to middle courses of numerous tributaries as well as in the entire drainage region of the Negro river (Römer, 2006).

The Amana Sustainable Development Reserve (RDSA) is located in the mid-Solimões basin (35º43 "S / 3º16 '13" W and 62º44' 10 " S/ 65º23 '36" W) between the Negro and Japurá river, characterized by white waters. In addition, in the RDSA we find Amana lake, the largest lake in the reserve, reaching approximately 40 km in length and surface of approximately 100 km^2. Amana lake is an environment of black water, but with strong contribution of the white water of the Japura river (Ayres, 1993). In elevated areas of the RDSA there are several strems (igarape, regional name), which form a dense local network of water bodies (Hercos *et al.*, 2009).

In black water environments are found species of small fish and attractive colors that have been targeted by the ornamental trade. Since 1955, when Herbert R. Axelrod discovered and marketed the cardinal tetra, *Paracheirodon axelrodi* in the middle Rio Negro (Amazonas State), this type of trade has developed considerably (Chao *et al*., 2001). Anjos *et al*., (2009) report that approximately 100 million ornamental fish were exported from the Amazon between 2002 and 2005 and the state of Amazonas accounted for about 93% of Brazilian exports in the period (IBAMA, 2007). The Middle Solimões region stands out for the exploration of ornamental fish exported through the city of Manaus. Export records this region indicate that the discus (*Symphysodon aequifasciatus*) and species of the genus *Apistogramma* are the most commonly traded (Mendonça & Camargo, 2006). The capture and marketing managed ornamental fish has been taking in the Amana Sustainable Development Reserve since late 2008, including *S. aequifasciatus* and species *Apistogramma* genus (Hercos *et al*., 2009).

However, there are still many gaps on the biology and ecology of *A. agassizii* natural environment. Studies on populacional structure are essential for a better understanding of the species life cycle, and to support the management policies of establishing these fishing resources, contributing to the conservation of stocks.

Material and Methods

The collect of *A. agassizii* occurred every two months between January and November 2013, in Amana Lake and Igarapes Cacau and Ubim located in Amana Sustainable Development Reserve (RDSA) (Figure 1). The Amana Reserve is located in the middle Solimões basin (1° 35 '43 "S / 3º 16' 13" W and 62° 44 '10' / 65° 23 '36 "W), between the Negro river, black waters and poor in nutrients and the Japurá river, characterized by white or muddy waters, rich in nutrients. In the higher areas of RDSA occur several streams, characterized by a well-defined streambed, forming a dense mesh of water bodies (Hercos *et al*., 2009).

We used as fishing device the hand net used in the shallow area of the investigated bodies water. The collected samples were dipped in benzocaine hydrochloride solution at a concentration of 250mg / L even the total loss of balance (according to Resolution No. 714 of June 2002 the Federal Council of Veterinary Medicine), subsequently immersed in formalin, then in alcohol 70% and transported to the Laboratório de Ecologia e Biologia de Peixes-ECOBP/IDSM in Tefé-AM, where the sample were measured (standard length, mm) and weighed (total weight, g).

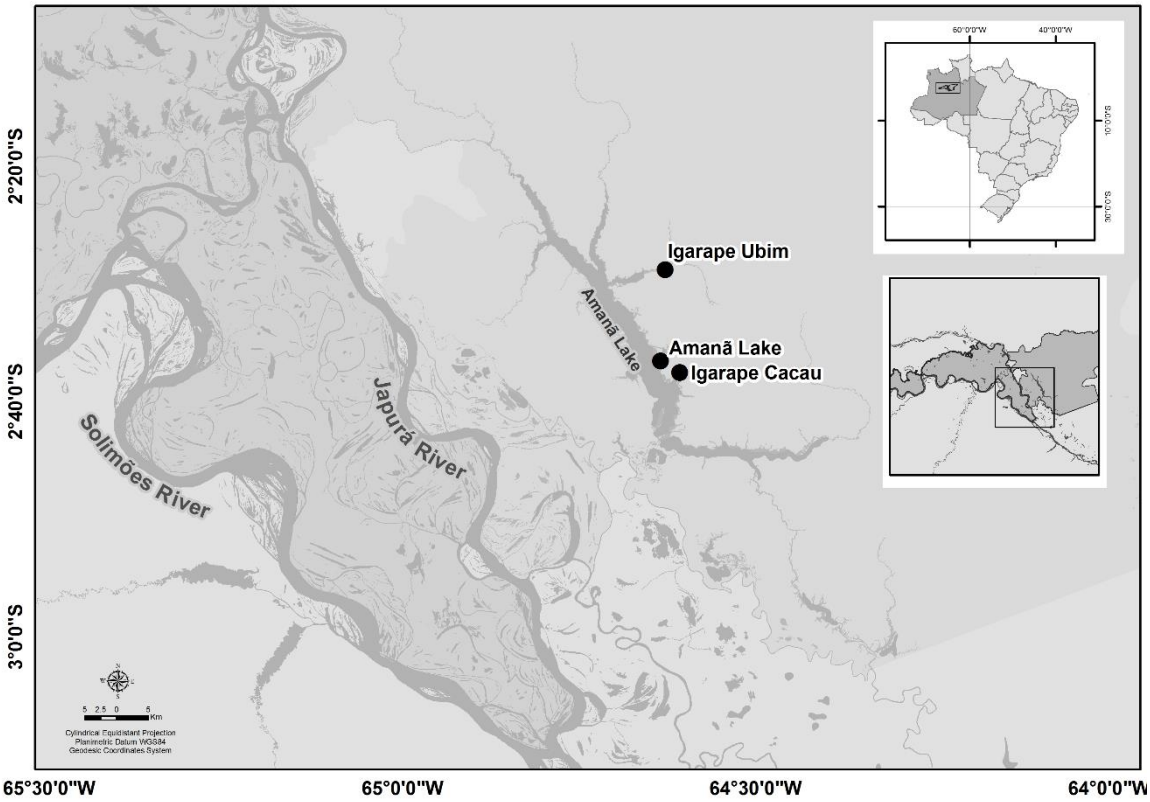

Figure 1. Sites collects of *Apistogramma agassizii* in Amana Reserve.

The relationship between weight and standard length was established using a linear regression represented by mathematical expression $TW = a \times SL^b$, the total weight data and standard length were logaritmizados and adjusted by the least-squares method for calculating the linear regression where we obtain the values of b (angular coefficient) and the (linear coefficient). The t test was used to verify the existence of significant differences among the *b* values, when close to isometrics (*b*=3), respecting the confidence interval of 95% (α=0.05) (Giarrizzo *et al*., 2015). The correlation between W and L was verified by Pearson analysis through r-squared (r^2) (Schmidt *et al*., 2015).

The sex ratio was compared by frequency of occurrence for males and females for each studied area and sampling month. The G test was applied in order to verify possible differences in the expected ratio of 1: 1. Significant differences were considered when the calculated value of G was higher 3.84.

All statistical analyzes were carried out using statistical software BioStat 5.0 (Ayres *et al.*, 2007). Samples of *A. agassizii* used in this study were collected in the project "Reproductive Biology Apistogramma" whose procedures were approved by the Ethics Committee on Animal Use and Plants for Sustainable Development Mamirauá Institute, with the protocol number CEUAP IDSM-003 / 2013.

Results

During the study period 900 specimens were captured, 300 of these were from Amana lake, 300 Igarape Ubim and 300 Igarape Cacau. Males and females of the Amana lake and igarape Ubim showed significant difference between the relationship of weight and length, as evidenced by the values of the intercepts (a), indicating sexual differentiation in the increase in length or weight (Table 1). When compared the relationship of weight and length of the specimens with different sites, we observed significant differences in all sites. The males were always greater in length and weight than females, featuring one of the most important aspects of sexual dimorphism of *A. agassizii*.

Table 1. Parameters of the linear regressions of standard length (SL) and total weight (TW) of females and males of *Apistogramma agassizii*. N = number of samples; a = numerical value of the intercept; b = coefficient of regression; T_a = t test between the intercepts; T_b = t test between the regression coefficients; r^2 = coefficient of determination; r = correlation coefficient. t test, 5%.

Parameters of the equation $TW = a \times SL^b$							
Amana lake	N	a	T_a	b	T_b	R^2	R
Female	151	-5.1742	0.0125	3.3828	0.1143	0.955	0.9773
Male	149	-5.0324		3.2649		0.9754	0.9876
Igarape Cacau	N	a	T_a	b	T_b	R^2	R
Female	152	-4.8723	0.6923	3.1556	0.2198	0.9794	0.9897
Male	148	-4.9712		3.2321		0.972	0.9859
Igarape Ubim	N	a	T_a	b	T_b	R^2	R
Female	167	-4.9093	0.0367	3.1873	0.5682	0.9185	0.9584
Male	133	-4.8547		3.1365		0.967	0.9834

The sex ratio, considering the total number of specimens was 1 male:1 female. However, we observed some significant differences in sex ratio when the data were analyzed throughout the study period, when there was a predominance of females relative to males for a few months of collection (Figure 2, Table 2,)

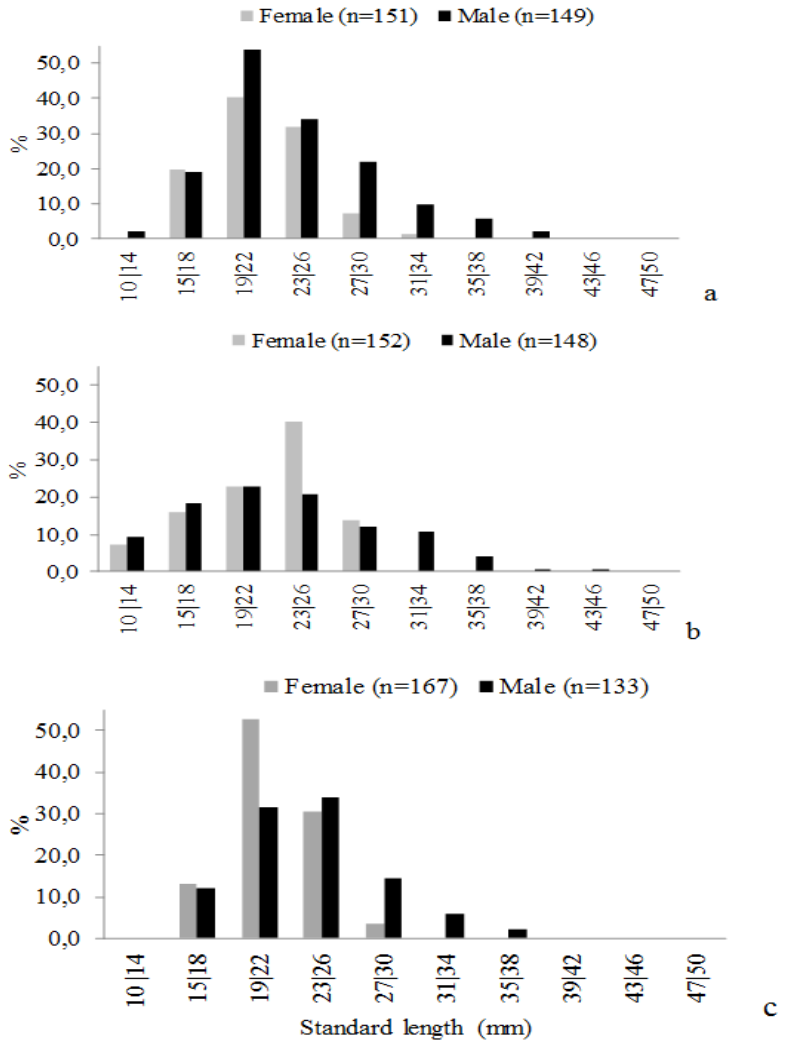

Figure 2. Size distribution by standard length classes of females and males of *Apistogramma agassizii* (a) Amana lake (b) igarape Cacau and (c) igarape Ubim.

Table 2. Sex ratio of *Apistogramma agassizii* for each collect site. *G test, significant G> 3.84, p <0.05.

Months samples	Amana lake				Igarape Cacau				Igarape Ubim			
	Female	Male	Proportion F:M	G test	Female	Male	Proportion F:M	G test	Female	Male	Proportion F:M	G test
January/13	30	20	1.50	10.54*	26	24	1.08	1.35	39	11	3.55	26.31*
March/13	30	20	1.50	10.54*	23	27	0.85	-4.44*	19	31	0.61	-14.50*
May/13	18	32	0.56	-12.07*	20	30	0.67	-9.45*	27	23	1.17	-1.64
June/13	26	24	1.08	1.69	24	26	0.92	-2.60	30	20	1.50	4.49*
September/13	26	24	1.08	1.69	36	14	2.57	25.3*	27	23	1.17	-1.64
November/13	21	29	0.72	-7.60*	23	27	0.85	-4.44*	25	25	1.00	-5.36*
Total	151	149	1.01	2.43	152	148	1.03	2.74	167	133	1.26	3.82

Discussion

The presence of males larger than females in all environments studied, is the highest expression of sexual dimorphism by *A. agassizii* (Nikolsky, 1963), as well as other differences already described, such as the morphology of the fins and body color (Chellappa *et al*., 2005; Ismiño & Padilla, 2005). These characteristics can be decisive in courtship processes and mating, particularly during the breeding season, since larger males tend to win aggressive encounters with other males, keeping territories of better quality and more access food (Cacho *et al*., 2006).

The length-weight relationship describes the ways of growth in the different stages of the life cycle of the fish species, which becomes a good indicative of the food and reproductive activities (Silva Júnior *et al*, 2007). Le Cren (1951) indicate out that the b values for fish may range from 2.5 to 4.0, but they usually show an isometric growth around 3.0. Therefore, when b = 3, the species has an isometric growth, where the weight increases proportionally with the length. However, when b < 3, the growth is negative allometric which indicates that the increment occurs due to the weight, and when b > 3, the growth is positive allometric, and the increment in the length is higher than the weight. These differences which occur around the allometric coefficient may be related to the biological aspects which characterize the specie, as the different environmental and food variation of the enviromental where they reside (Silva *et al*., 2005), since they were collected from different places and environments (lake and igarape/stream), consequently differences in growth was be observed.

The sex ratio vary along the life cycle due to successive events that act differently on the individuals of each sex, as the mortality be her caused by natural factors or fishing events, determine the predominance of individuals from one of the sex or different stages of development. (Vazzoler, 1996; Nascimento *et al*., 2012). During the study we observed the sexual ratio of 1: 1, but in detailed analyzes changes were observed in this proportion, indicating the predominance of females in different length classes or at different times of the study.

Therefore, the significant proportion of females observed during the study for the collect sites, can probably be related to the fact that these sites in the years prior to this study, there was the ornamental fishing *A. agassizii*. During the ornamental fishing had preference for male individuals, because morphologically are larger and more colorful than females, showing greater interest in the ornamental market. Consequently, this selection by males may have contributed to the higher proportion of female *A. agassizii*.

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