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Productivity and reproductive characteristics of silver arowana *Osteoglossum bicirrhosum* (Osteoglossiformes: Osteoglossidae) at Grande Lake, Putumayo basin, Peru

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ABSTRACT: Due to the importance of ornamental fishing of silver arowana, as well as, Lago Grande lake as one of the main areas for capturing baby arowanas in Peru, the present study aimed to evaluate the productivity and the biological-reproductive characteristics of the species in the lake, which is located in the lower basin of the Putumayo River and represents an area preferred by fishermen because the important populations of silver arowana inhabiting it. Analysis of population density, biometrics, sexual maturity, spawning, fecundity, sex ratio, water level of the lake and production of baby arowana were made. The study was developed between March and July of 2012 and to implement the activities of the study was important the participation of the Association of Fishermen "Fronteras Vivas". In general, the population density extrapolated to the lake area was 1.29 fish/ha. Of these, the density of progenitors in the lake was 1.19 fish/ha. Also, male animals had total length, standard length and total weight higher than females and it was observed that the spawning period occurred in synchronization with the start of the growing of the hydrological regime. The average number of oocytes produced by females of silver arowana in the study area was 201 and the sex ratio was equilibrated. Furthermore, the study shows the capacity of production of the lake. In order to this the water lever influenced in the production of baby arowanas. It is important to continue studying the species for regulate the fishing and recover populations.

Keywords: baby arowana, production, ornamental trade, length of first sexual maturity, fishing.

Produtividade e características reprodutivas do aruanã, *Osteoglossum bicirrhosum* (Osteoglossiformes: Osteoglossidae), no Lago Grande, bacia do Rio Putumayo, Peru

RESUMO: Devido à importância da pesca ornamental de aruanã, e da lagoa Lago Grande como uma das principais áreas para a captura de alevinos de aruanã no Peru, o presente estudo tive como objetivo avaliar a produtividade e as características reprodutivas na espécie na lagoa, a mesma que está localizada na bacia baixa do Rio Putumayo e representa uma das áreas de pesca preferidas pela importante população de aruanã que a habitam. Foram feitas análises de densidade populacional, biometria, maturidade sexual, desova, fecundidade, proporção sexual, níveis da água na lagoa e sobre a produção de alevinos de aruanã. O estudo foi desenvolvido entre março a julho de 2012 e as atividades foram realizadas em parceria com a Agrupação de Pescadores "Fronteras Vivas". De modo geral, a densidade populacional extrapolada à área da lagoa foi de 1.29 peixes/ha. Daqueles, a densidade de progenitores na lagoa foi de 1.19 peixes/ha. Além disso, os machos tiveram comprimento total e padrão e peso total maior do que as fêmeas, e foi observado que o período de desova ocorreu em sincronia com o início da crescente no nível das águas. A média de oocitos produzidos por fêmeas de aruanã foi de 201 e a proporção sexual foi equilibrada. Assim mesmo, o estudo mostra a capacidade de produção da lago. Nesse sentido, o nível da água influenciou na produção de alevinos de aruanã. É importante continuar os estudos da espécie para regulamentar a pesca e recuperar populações.

Palavras-chave: alevinos de aruanã, produção, comércio ornamental, comprimento de primeira maturidade sexual, pesca.

1. Introduction

The development of new knowledge, as a result of ongoing assessments of the dynamics of fisheries, shows that fisheries resources are limited. Even, their contribution to the nutritional and socio-economic wellbeing of the growing human population could be affected for extractive activities (KVIST et al., 2001). In this sense, the productivity of Amazonian fisheries has been declining for the floodplain deforestation (SMITH, 1985), as well as, uncontrolled fishing. This is observed on silver arowana populations, *Osteoglossum bicirrhosum* (Cuvier, 1829), a relative of pirarucu that enters the aquarium trade, which capture declined significantly in the last years (GARCIA et al., 2009). This species is exploited as an adult for human consumption and as a fingerling for the ornamental trade (BROWN, 1995; CRAMPTOM, 1999; MOREAU; COOMES, 2006; AGUDELO-ZAMORA et al., 2007; ALCANTARA et al., 2007; DUPONCHELLE et al., 2012).

Actually, the silver arowana is increasingly popular on the international aquarium fish market (MOREAU; COOMES, 2006, 2007; ALCANTARA et al., 2007), with considerable economic importance to the communities around the fishing areas (LOWE-MCCONNELL, 1975; KVIST et al., 2001; MOREAU; COOMES, 2006). Precisely, this species is considered one of the most important species to the Peruvian (MOREAU; COOMES, 2006; ALCANTARA et al., 2007) and Colombian (SANCHEZ; ALONSO, 2004)

Amazon aquarium trade, being reported by Moreau and Coomes (2006) over 1 million fingerlings worth USD 560,000 exported in 2001 in Peru. Likewise, according to Direpro-L (2007), the main zone for extraction of fingerlings of the species in Peru, is the lower basin of the Putumayo River, being Lago Grande lake one of the areas with higher production (PEDICP, 2007). The mainly problem with the use of this resource is the routine killing of mouth brooding adults to collect fingerlings for the trade that may threaten wild populations, because the fish are caught from the wild (MOREAU; COOMES, 2007) and cultivation in captivity is a young activity (ARGUMEDO, 2005; COSTA et al., 2009).

This species belongs to the group of the osteoglosids, which are known as the bony fishes (KUMAZAWA; NISHIDA, 2000). It is distributed in the Amazonas, Essequibo and Orinoco basins (WATKINS et al., 2004; MALDONADO-OCAMPO et al., 2008; ESCOBAR et al., 2013), inhabits shallow, black water lakes and the littoral zone of rivers and lakes year-round, as well as invading the flooded forest during high water periods (LOWE-MCCONNEL, 1987; SAINT-PAUL et al., 2000). Furthermore, silver arowana reaches 1 m in total length and three pounds in weight, approximately (LOWE-MCCONNEL, 1987), and is a predator (LOWRY et al., 2005) that prefers fish (AGUDELO-ZAMORA et al., 2007). Something important is that silver arowana has differences in the reproductive-biological characteristics according to the basin that inhabits, showing different patterns in fecundity, sexual maturity (RABELLO-NETO, 1999, 2002; GUTIERREZ et al., 2009), sex ratio, spawning, as well as, growth parameters (DUPONCHELLE et al., 2012). Thus, the biological-reproductive differences would be very important for the management of the species in a determined area.

Due to the importance of ornamental fishing of silver arowana, as well as, Grande lake as one of the main areas for capturing the species, the present study aimed to evaluate the productivity and the biological-reproductive characteristics in the lake during the specific year period of using of the species, contributing to the knowledge of the species.

2. Material and Methods

This study was executed at Grande lake (2°31'10.7"S 70°29'23.5"W), near to Huapapa community, located in the lower basin of the Putumayo River, Peru. This lake has an elongated shape with an area of 289.12 ha and an average depth of 5 m. Also, it belongs to the group of lentic water, which has high organic matter decomposition of the leaves of the forest, as well as low conductivity and a slightly acidic pH. In addition to this, Lago Grande has important populations of silver arowana in good conditions and its proximity to Huapapa, which is the main community in the lower basin of the Putumayo River, represents an area preferred by fishermen, especially for fishing the baby arowanas. The study was developed between March and July of 2012. To implement the activities of the study was important the participation of the Association of Fishermen "Fronteras Vivas" who control the activities in the lake with the help of the specialist of fishing of PEDICP, in order to meet targets of the Manage Program established for the species in the area. During the period of the study, an average monthly rainfall of 251.5 mm and a maximum temperature of 31.9°C and a minimum temperature of 22.2°C were reported. Furthermore, it was reported an average relative humidity of 84.7%, being typical characteristics of a humid-tropical environment.

Population Density

Sampling areas were established with the support of a group of experienced fishermen. For this, journeys around the lake were made, between 8:00 - 9:00am and 15:00 - 16:00pm. In this, were observed and identified areas where groups of silver arowana were active during the day. At dusk, it was observed the areas where those groups of silver arowanas moved. In order to this, three zones were identified in Grande Lake and defined as areas occupied by silver arowana groups during the all day, and these zones were delineated. The delineated areas constituted the sampling areas for population census and were characterized by stand near the bank and with abundant aquatic vegetation. Silver arowana population was estimated through census during the night by journey in the areas delimitated previously. Animals registered in each of the sampling areas were plotted on the Grande Lake total area given the report as fish/ha. With the experience of the fishermen were able to identify progenitors and stage of the offspring that these progenitors incubated.

Biometrics

Direct and indirect samples were taken. Direct samplings were performed twice a month with the participation of fishermen by using of gillnets of 4.5" and 5" of mesh size, put between 30 to 40min per set, and located in three places suggested by a group of fishermen. Also, direct samplings were performed by using arrows and the specimens were captured by journeys around the lake. The assessment of indirect sampling consisted of the fish captured from the study area and landed in Huapapa. Total length, standard length and total weight were considered. For determining the relationship between weight and length of the studied specimens was performed a linear correlation analysis of Pearson.

Degree of sexual maturity

The degree of sexual maturity was recorded of females and males captured based on the scale of gonadal maturity proposed by Ruiz (2011). Subsequently, the length of first maturity was calculated by comparing the percentage of sexually mature individuals plotted versus length.

Spawning

The gonadosomatic index (GSI) was determined, so that allowed to estimate the spawning season. The formula described for the determination of GSI was: fish weight (g)/weight of gutted fish (g). GSI and the water level in the study area were compared, to see if these variables were related.

Fecundity

This parameter was determined by direct count of the oocytes of females sacrificed. Relations between fertility, length and weight, were made to determine if the production of oocytes in the species was influenced by fish size.

Sex ratio

The sex ratio was determined by using the x^2 test (Chi-square). For this, fish were sacrificed to recognize the sex.

Water level of the lake

The initial value was measured with the Garmin GPS, Etrex10 model, by recording the height provided by the equipment to the water level in the lake. From that value recorded was placed a measuring rod and it was checked daily at 06:00am for measuring the increase or decrease of the water level. Furthermore, quality water of the lake was determined by analyzing monthly water temperature (°C), water transparency (cm), pH, dissolved oxygen (mg/L), free carbon dioxide (mg/L), ammonia (mg/L), alkalinity (mg/L) and total hardness (mg/L).

Production of baby arowana

Extraction values of baby arowanas from the lake during the 2012 campaign were recorded. Likewise, the stage and the number of larvae per parent were recorded based on the next characteristic: The larvae 1 (stage I) are called "lying" with yolk sac, initially are transparent and have no proper movement, with a weight of about 1 g and diameter of 10 mm. The larvae 2 (stage II) are called "swimmer" and reaches sizes greater than 35 mm long, the yolk sac represents approximately 20% of their body weight with a tendency to disappear, has proper movements for swim and float. The length and weight of the progenitors (at least for 50%) were recorded. Also, was made an analysis of mortalities of larvae and fingerlings taken from the lake during the fishing period. The linear correlation analysis of Pearson between the standard length and the number of oocytes showed no association with α=0,05.

3. Results

Population Density

In this study, 373 individuals of silver arowana were counted in the lake, of which 92.49% were adult parents. Of these adult parents, 20.64% were parents with egg into the mouth and 71.85% were parents with larvae into the mouth. Only a small percentage of individuals observed (7.51%) were juveniles. Furthermore, were observed that the larvae hatched by parents were in the stage I. The population density extrapolated to the lake area was 1.29 fish/ha. Of these, the density of progenitors in the lake was 1.19 fish/ha, of which a density of parents with egg into the mouth was 0.27 fish/ha and 0.93 fish/ha for progenitors with larvae. Furthermore, the study showed a density of 0.10 juvenile/ha.

Biometrics

For biological-reproductive characteristics of silver arowana were collected 140 individuals among juvenile (27) and adults (113), being 72 females and 68 males. Biometrics male fish were 69.61 cm (±10.18) in total length, 66.71 cm (±9.75) in standard length and 1952.79 g (±614.39) in total weight. Biometrics female fish were 63.93 cm (±7.87) in total length, 61.19 cm (±7.62) in standard length and 1635.14 g (±489.87) in total weight. Male animals had total length, standard length and total weight higher than females ($p<0.05$ in all three cases).

The linear correlation analysis of Pearson between standard length and weight of silver arowana indicated that it was a strong positive correlation between the both variables analyzed (r=0.85, $p<0.05$, R^2=0.72) (Graphic 1). This result showed that as the fish grew in length so did in weight too. As the correlation analysis made included gravid females, which could influence the erroneous result since had greater weight for the ovaries filled, linear correlation analysis of Pearson was made, excluding gravid females, existing a strong positive correlation between standard length and weight (r=0.852, $p<0.05$, R^2=0.726).

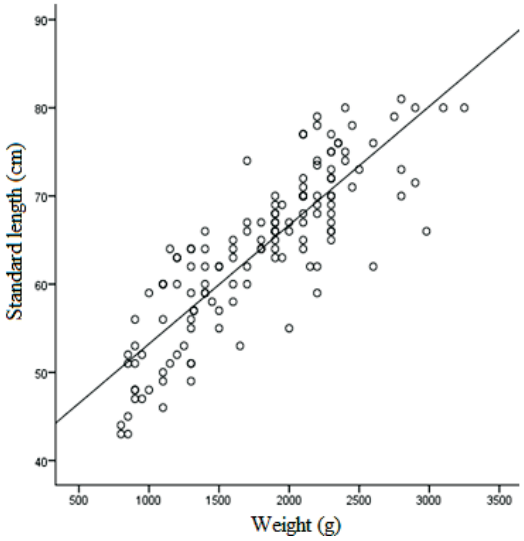

Figure 1. Degree of association between standard length (cm) and weight (g) of silver arowana, *Osteoglossum bicirrhosum*, Lago Grande lake.

Degree of sexual maturity

The size of silver arowanas observed with sexual maturity ranged 53-78 cm in total length and 51-74 cm in standard length for females and for males between 59-84 cm and 56-80 cm in total length and standard length,

respectively. The length of first maturity for silver arowana population in the study area, occurred at about 58 and 62 cm in standard length for females and males, respectively (Graphic 2); size in which 50% of the individuals observed were sexually mature.

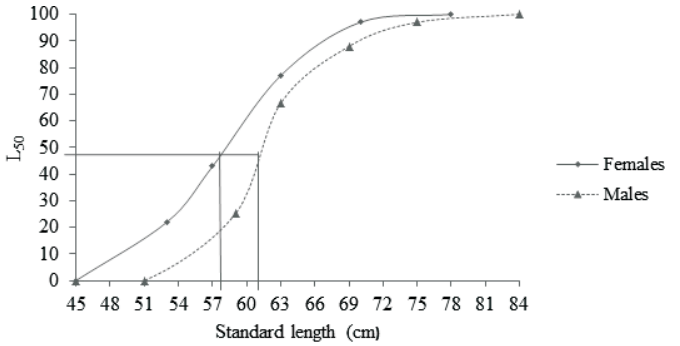

Figure 2. Length of first sexual maturation established for the population of silver arowana, *Osteoglossum bicirrhosum*, based on the standard length, Lago Grande lake.

Spawning

Females with an average total length of 50.92 cm (±3.75), an average standard length of 48.58 cm (±3.45) and an average total weight of 1045.83 g (±172.49) were immature and presented low GSI (0.23±0.08). Females with total length of 67.29 cm (±4.75), an average standard length of 64.41cm (±4.35) and an average total weight of 1945.88 g (±458.98) were mature and had high GSI (5.14±1.30) due to the presence of oocytes in the ovary. Post-spawning females showed low values of GSI (0.51±0.20) and an average total length of 66.23 cm (±5.82), an average standard length of 63.44 cm (±5.75) and an average total weight of 1676.74 g (±421.36), indicating that they had traces of oocytes. The ANOVA indicated that there was no significant difference between the values of total length and standard length of mature and post-spawning females ($p>0.05$). With regard to the monthly variation of GSI in relation to the hydrological regime, we observed that the decline of the spawning period was between April and May. Also, it was observed that the spawning period occurred in synchronization with the start of the growing of the hydrological regime (Graphic 3).

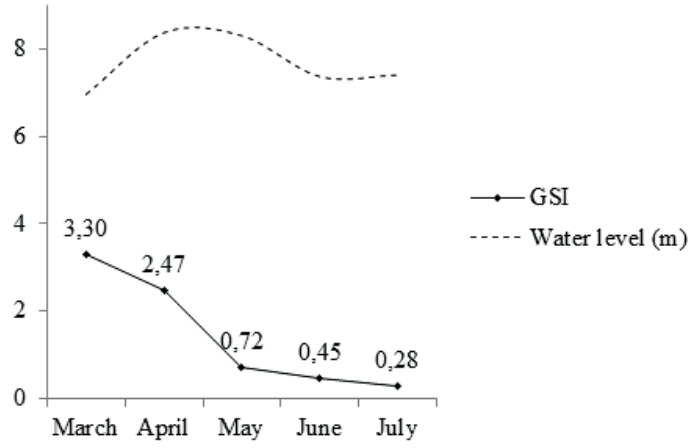

Figure 3. Monthly variation of gonadosomatic index of females of silver arowana, *Osteoglossum bicirrhosum*, and the water level of Lago Grande lake during the study period.

Fecundity

The average number of oocytes produced by females of silver arowana in the study area was 201. The minimum number of oocytes recorded was 115, belonging to a female of 58 cm total length, 56 cm standard length and total weight of 1100 g. The maximum number of oocytes was 265 registered for a female of 61 cm total length, 58 cm standard length and total weight of 1450 g. The linear correlation analysis of Pearson between the standard length and the number of oocytes showed no association ($r=0.207$, $p>0.05$) (Graphic 4). This meant that the number of oocytes produced per female of silver arowana was not related to length. Likewise, the linear correlation analysis of Pearson made between the total weight of the fish and the number of oocytes, indicated that there was a weak positive correlation between the variables ($r=0.465$, $p<0.05$) (Graphic 5).

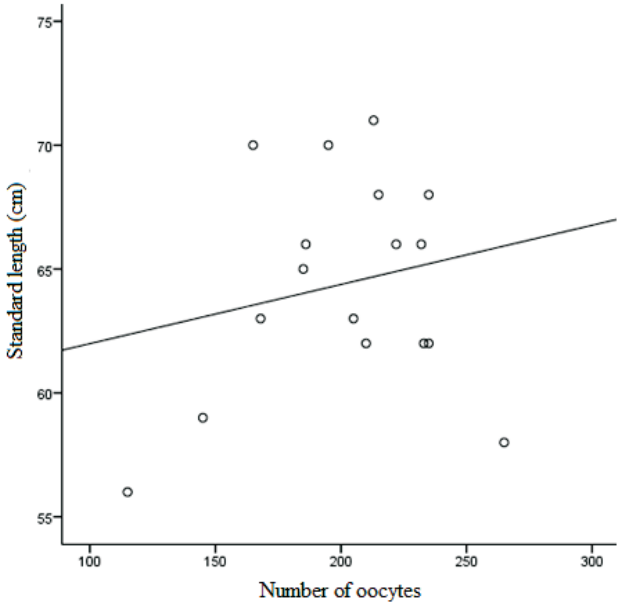

Figure 4. Degree of association between standard length (cm) and number of oocytes for silver arowana females, *Osteoglossum bicirrhosum*, Lago Grande lake.

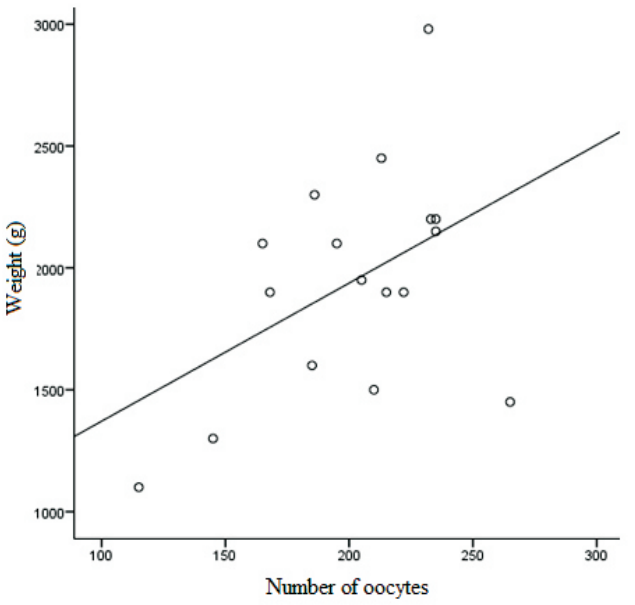

Figure 5. Degree of association between weight (g) and number of oocytes for silver arowana females, *Osteoglossum bicirrhosum*, Lago Grande lake.

Sex ratio

The 48.57% of the fish caught were males and 51.43% were females (n=140). That is because there was a tendency of effort concentration on silver arowana males, because they are captured for removal the baby arowanas. Otherwise, to submit the results to the chi-square test, it was observed that there was no significant difference between the proportions of both sexes, being the sex ratio 1:1 (p>0,05).

Measuring the water level

The minimum value was recorded in March with an average of 6.96 m and the maximum value in April with 8.38 m on average. Likewise, a decrease in water level was observed in May and June, and then the level water increased again in July. That fact did not allow the use of the resource by the fishermen, because the increased water level influenced to the dispersion of parents with larvae into the mouth to the flooded areas in the lake (Graphic 6). All parameters analyzed were within the appropriate range for the development of the species in the wild (Table 1).

Table 1. Physical and chemical water parameters in Lago Grande lake, 2012.

Parameter	March	April	May	June	July
Water temperature (°C)	27.30	26.00	26.00	27.30	27.80
Water transparency (cm)	94.67	103.17	102.17	101.67	99.00
pH	6.00	5.83	6.00	5.92	6.00
Dissolved oxygen (mg/L)	3.13	2.87	3.17	2.67	5.20
Free carbon dioxide (mg/L)	15.33	16.67	15.17	15.83	11.00
Alkalinity (mg/L)	16.00	11.33	8.67	10.00	10.67
Total hardness (mg/L).	37.33	8.33	8.67	11.33	4.00
Ammonia (mg/L)	0.52	0.65	0.52	0.52	0.52

Production of baby arowana

A total of 14595 baby arowanas were extracted from the lake, with a mortality level of 2.30% in the extraction-gathering process, remain viable and sold to aquariums in Iquitos a total of 14260 baby arowanas. In this regard, management fishermen and gatherers made on the appeal did not cause significant losses in the number of offspring marketed. The use of this species was conducted in the months of March and April. In March was reported an extraction of 12541 larvae with a mortality of 2.62%, remain viable and sold 12 213 larvae. In April, 2054 larvae were extracted with a mortality rate of 0.34%, remain viable and sold 2047 larvae to aquariums in Iquitos. It should be noted that the existence of relation between the Putumayo regime and the fishing of the species, which high water level contributed well in reducing harvest levels in April (14.073%). It was also observed that the offspring in stage I had a higher mortality rate (3.49%) in comparison to offspring in stage II (2.11%).

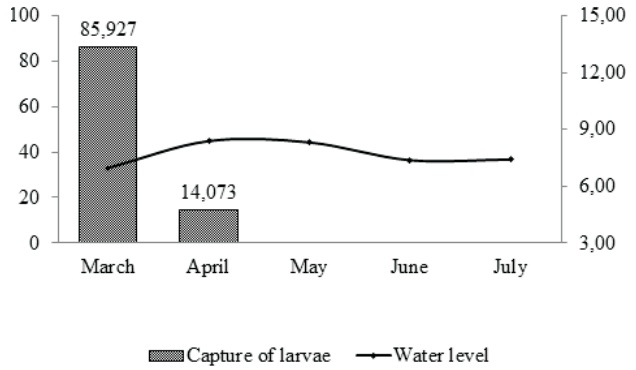

Figure 6. Percentage of extraction for baby arowana, *Osteoglossum bicirrhosum*, per month, in relation to the water level (m), Lago Grande lake.

4. Discussion

There is no reliable scientific information reporting population density of silver arowana in water bodies, being this study the first. In this regard, Tresierra and Culquichicon (1993) mentioned that it is difficult to estimate fish densities in natural systems; however, this species inhabits identifiable areas within the lake allowing a reliable report. Also, the maximum length reported in this study for both females and males was lower than that reported in other studies (CALA, 1973; LOWE-MCCONNELL, 1987; ARGUMEDO, 2005) which were recorded specimens with lengths greater than 1 m. On average, the silver arowana in the lake has length and weight higher than in other basins in Peru, except in the Amazon basin, as reported by Duponchelle et al. (2012). In other sense, the length of first sexual maturity in silver arowana was determined in Peru as 62 cm for females, being the base for regional regulations of minimum capture size (TANG; GOMEZ, 2005). In another study, the length of first sexual maturity in the Ucayali basin was 65.9 cm and 73.9 cm for females and males, respectively (AYALA, 2001), and in the river Caucaya-Colombia, it was determined 75 cm and 72 cm for females and males, respectively (SANCHEZ et al., 2007). The differences may be due to the different conditions of aquatic ecosystems and the fishing pressure, what is happening with the fertility too. It is important to consider these results in the establishment of rules for fishing in the area. Concerning to the spawning, it occurred in synchrony with the rising of water level (AYALA, 2001; TANG; GOMEZ, 2005; RUIZ, 2011), except the reported by SANCHEZ et al. (2007), where spawning occurred at low water levels. Related to the sex ratio, the proportion determined as 1:1 show that the Manage Program established in the area is, possibly, retrieving the population (PRADA-PREDREROS; AGUILAR-GALINDO, 1997) and it is an indicator that the fishing has not destabilized the sex ratio (TRESIERRA; CULQUICHICON, 1993). Finally, this is the first report that shows number of fingerlings extracted by fishing in one of the main areas for capturing the species for ornamental trade, being this activity very important for economic sustainability of the communities around the areas of extraction (MOREAU; COOMES, 2006, 2007).

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