

Reproduction of a South American population of pumpkinseed sunfish *Lepomis gibbosus* (Linnaeus) (Osteichthyes, Centrarchidae): a comparison with the European and North American populations

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ABSTRACT. The reproductive biology of the introduced pumpkinseed sunfish *Lepomis gibbosus* (Linnaeus, 1758) in the Custódio's Dam, rio Doce high basin, state of Minas Gerais, Brazil was studied from February/2001 to March/2002 and compared with introduced and native populations. Reproduction occurred almost along the entire period of study with a high frequency of fishes in the advanced ripening/mature and spawned/spent stages. The microscopic analyses indicated that the pumpkinseed sunfish presents multiple spawning. The egg diameter of the Brazilian population is similar to the Spanish, Greek and American ones. The standard length at maturity and the gonadosomatic index of the introduced populations are smaller when compared with native ones. The spawning season of the Brazilian population was the longest among all comparisons made in the present work.

KEY WORDS. Brazil, dam, exotic species, Rio Doce, spawning.

RESUMO. Reprodução de uma população Sul-Americana de percas-sol *Lepomis gibbosus* (Linnaeus) (Osteichthyes, Centrarchidae): uma comparação com populações européias e norte-americanas. Estudou-se de fevereiro/2001 a março/2002 a biologia reprodutiva da exótica perca-sol *Lepomis gibbosus* (Linnaeus, 1758) na represa do Custódio, bacia do alto rio Doce, Brasil, comparando-a à de populações exóticas e nativas. A reprodução ocorreu praticamente ao longo de todo o período de estudo e a análise microscópica de ovários indicou desova do tipo parcelada para a espécie. O diâmetro ovocitário da população brasileira é semelhante à espanhola, grega e americana. O comprimento padrão na maturidade e o índice gonadossomático de populações introduzidas são menores do que as nativas. O período de desova da população brasileira foi o maior dentre todas as populações analisadas no presente trabalho.

PALAVRAS CHAVE. Brasil, desova, espécie exótica, represa, Rio Doce.

Introduced species cause, in whole or in part, the endangerment and extinction of more native species than any other factor except habitat destruction (SIMBERLOFF 2004). On a global level, the United States and Brazil are the countries with the highest number of non-native fishes (WELCOMME 1988, FULLER *et al.* 1999) and the state of Minas Gerais leads the ranking with over 40 species, followed by the states of northeast (N = 39), state of Rio de Janeiro (N = 37), Federal District (N = 15) state of Paraná (N = 13), states of Santa Catarina and Rio Grande do Sul (N = 10) (GURGEL & OLIVEIRA 1987, ORSI & AGOSTINHO 1999, RIBEIRO *et al.* 2000, POLI *et al.* 2000, BIZERRIL & LIMA 2001, MAGALHÃES *et al.* 2002).

Among the exotic species found in Minas Gerais, there is the pumpkinseed sunfish *Lepomis gibbosus* (Linnaeus, 1758), a native centrarchid of North America and introduced in Ouro

Preto County in 1966, during the settlement of Alcan Alumínio do Brasil, a multinational company (A.L.B. de Magalhães, pers. obs.). The species was introduced to serve as a foragefish for the largemouth bass *Micropterus salmoides* (Lacépède, 1802), which is a common procedure in Canada, the United States and Europe (DEUSTCH *et al.* 1992, GARCÍA-BERTHOU & MORENO-AMICH 2000) besides improving the sport fishing in the region (MAGALHÃES & SILVEIRA 2001).

Although Brazil posses a high number of introduced fishes from other external river basins and countries, studies related to their reproductive biology are still incipient, being restricted to a few oviparous species such as Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) in Orós Reservoir, state of Ceará (GURGEL & OLIVEIRA 1987), peacock bass *Cichla ocellaris* Bloch &

Schneider, 1801 in Três Marias Reservoir, state of Minas Gerais (MAGALHÃES *et al.* 1996), South American silver croaker *Plagioscion squamosissimus* (Heckel, 1840) in Itaipu, Volta Grande and Barra Bonita Reservoirs, states of Paraná, Minas Gerais and São Paulo (FUEM/ITAIPU BINACIONAL 1990, GODINHO *et al.* 1997, CASTRO & PIORSKI 2000), bluegill sunfish *Lepomis macrochirus* Rafinesque, 1819 in Paranoá Lake, Federal District (RIBEIRO *et al.* 2000) and peacock bass *Cichla monoculus* Spix & Agassiz, 1831 in Campo Grande Dam, state of Rio Grande do Norte (CHELLAPPA *et al.* 2003).

In this context, the aims of the present work are: (1) study the reproduction of *L. gibbosus* introduced in Brazil; (2) compare its reproductive aspects with introduced populations from Europe and native populations from North America; and (3) discuss the possible potential ecological impact of pumpkinseed sunfish.

MATERIAL AND METHODS

Sampling

The specimens (188 females and 264 males), were collected bimonthly between February/2001 and March/2002 by using a rod and line in the shallow (0.5-2 m depth) littoral zone of the dam, where pumpkinseeds are most commonly found in native and introduced environments (GARCÍA-BERTHOU & MORENO-AMICH 2000).

Study site

Custódio's Dam, is situated at 20°23'45"S, 43°31'15"W in Itacolomi State Park (Ouro Preto County), a region which belongs to rio Doce headwaters, state of Minas Gerais, Brazil (Fig. 1). It consists of a lake of 2,5 km in length lake whose maximum depth reaches 17 m and it was built in the 50's by the damming of Prazeres stream. The dam is inhabited mostly by the exotics redbreast tilapia *Tilapia rendalli* (Boulenger, 1897), pumpkinseed sunfish *L. gibbosus*, largemouth bass *M. salmoides* and the natives camaleon cichlid *Cichlasoma facetum* (Jenyns, 1842) and the lambari *Astyanax scabripinnis* (Jenyns, 1842).

Histological methods

For histological determination of the stages of the reproductive cycle and type of spawning, fragments of gonads from each specimen were fixed in Bouin's liquid for 10 to 12 hours and subjected to histological routine techniques such as embedding in paraffin, sectioning at 3-5 mm and staining with haematoxylin-eosin and Gomeri's trichrome. Microscopically, the stages of the reproductive cycle were confirmed by the distribution of oocytes and spermatogenic cells. To determine the type of spawning, the bimonthly frequency distribution of the stages of the reproductive cycle were analysed, as well as the histological characteristics of the spawned ovaries (BURNS 1976).

The latitudes of places were associated to egg diameter of introduced and native populations. To measure the egg diameter, mature ovaries were immediately stored in 4% formaldehyde. To correct the effect of formaldehyde preservation on

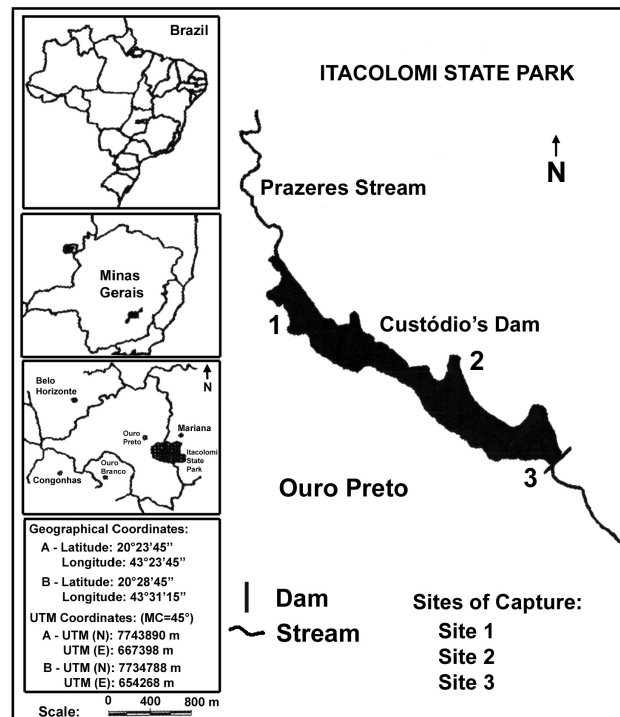


Figure 1. Map showing sites of capture of *L. gibbosus* in the Custódio's dam, Rio Doce headwaters, state of Minas Gerais, Brazil.

egg size for mature ovaries, 500 fresh eggs from six ripe ovary were stored in 4% formaldehyde in individual vials and the measurements (using an ocular micrometer) of diameter were taken from fresh eggs.

For maturity study, each female was measured for standard length in mm to permit comparisons with other studies. Respectively, the gonadosomatic index ($GSI = GW \times 100/BW$; GW = weight of the gonads, BW = weight of the body) and the spawning season (number of months) were calculated and determined for females only and compared with introduced and native populations.

Statistics

We performed a one-way analysis of variance, followed by Duncan's test ($p < 0.05$) to compare the biological indices (ED = egg diameter, LaM = standard length at maturity, GSI = gonadosomatic index) of the introduced and native populations. We used a Student's t-test ($p < 0.05$) to compare the mean values between populations.

RESULTS

Based on the microscopics characteristics of the gonads, the following stages of the reproductive cycle were determined: 1) rest, 2) advanced ripening/mature, 3) spawned for females,

spent for males (Figs 2-7), similar to the pumpkinseed sunfish reproductive cycle in its native range (BURNS 1976).

Female and male pumpkinseed in reproduction (stages 2 and 3) were found almost during the entire period of study (Fig. 8). The high frequency of female in stage 2 and 3 was associated with the histological characteristics of the spawned ovaries containing post-ovulatory follicles, as well as young (O1), previtellogenic (O2); cortical alveoli (O3) and vitellogenic (O4) oocytes, indicating that the spawn of pumpkinseed sunfish is one of the multiple type.

According with the table I, despite the different latitudes, the egg diameter (ED) of the Brazilian population is similar to the Spanish, Greek and American ones. As for the standard length at maturity (LaM), the Brazilian population is similar to the Spanish and French populations and smaller than the Canadian natives. The gonadosomatic index (GSI) of the introduced populations was smaller than the native ones. The spawning season (SS) in the present work indicated that the Brazilian population reproduces all year long, a longer period than the European and the North American populations.

long and has multiple spawning, characteristics which may have contributed to the establishment of the species. An example of this statement was given by MARTINEZ *et al.* (1994) for the green sunfish *Lepomis cyanellus* Rafinesque, 1819, bluegill sunfish *L. macrochirus*, black crappie *Pomoxis nigromaculatus* (Lesueur, 1829) and largemouth bass *M. salmoides* introduced in White River before the damming and afterwards when those species were well-succeeded in the colonization of Kenney Reservoir, state of Colorado, U.S.A., due to the extended reproductive period and the spawning of those species be a multiple or fractioned type.

SCOTT & CROSSMAN (1973) showed that the latitude (°Lat.) is related to egg diameter (ED) in fishes. In high latitudes, where the climate and temperature are colder, was determined the largest egg diameter. According to the authors, the Rumanian and English pumpkinseed populations are similar to the Canadian native population. Otherwise, in low latitudes, where the climate and temperature are less cold, were characterized smaller egg diameters as found in the Brazilian, American, Greek and Spanish populations. Those results have been confirmed by HEINS & BAKER (1987) who described that oviparous fishes of

Table I. Comparison of the reproductive characteristics of *L. gibbosus* among introduced and native populations. (ED) Egg diameter (mm), (LaM) standard length at maturity (mm, only females), (GSI) gonadosomatic index (peak months of spawning, only females), (SS) spawning season (number of months, only females). In the same column, different superscript letters indicate statistically significant differences ($p < 0.05$).

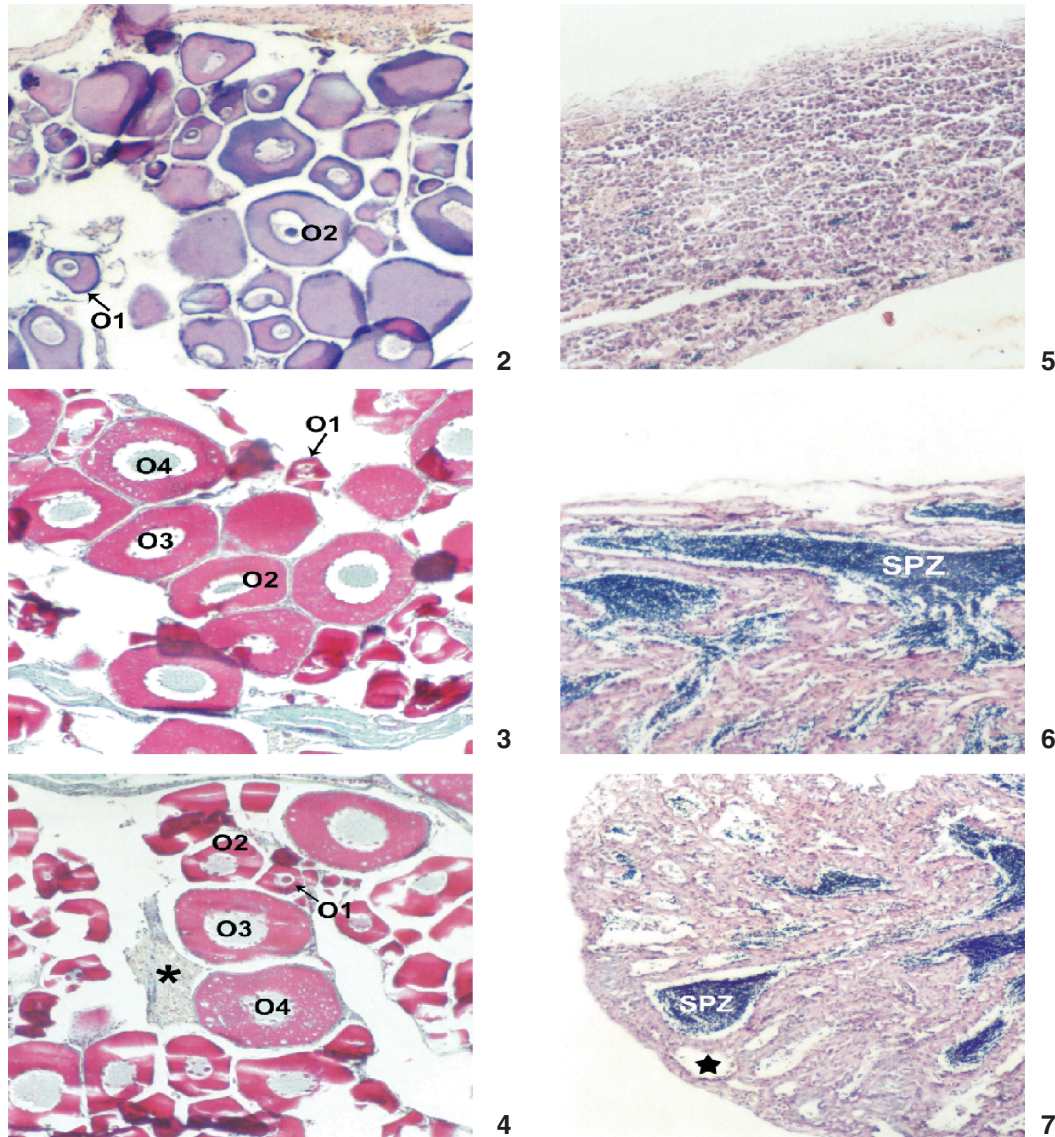
Country and place	Latitude (°)	ED	LaM	GSI	SS	Source
Introduced populations						
England (Cottesmore Pond)	51	1.06a	61.1 a	6.1 a	2	COPP <i>et al.</i> (2002)
Romania (Danube Delta)	44	1.10a	75.0 a	9.0 b	3	PAPADOPOULOS & IGNAT (1967)
France (Fumemorte Wetlands)	43	–	54.6 b	6.5 a	2	FOX & CRIVELLI (2001)
France (Sollac Wetlands)	43	–	59.2 a,b	6.9 a,b	3	FOX & CRIVELLI (1998)
France (Ligagneau Wetlands)	43	–	51.6 b	5.4 a	3	FOX & CRIVELLI (2001)
Spain (Banyoles Lake)	42	0.76b	47.6 b	6.5 a,b	4	VILA-GISPERT & MORENO-AMICH (1998)
Greece (Kerkini Lake)	41	0.80b	–	9.0 b	4	NEOPHYTOU & GIAPIS (1994)
Brazil (Custódio's Dam)	20	0.79b	50.0 b	6.4 a	12	PRESENT STUDY
Native populations						
Canada (lakes of east region)	51	1.00a	–	–	3	SCOTT & CROSSMAN (1973)
Canada (Opinicon Lake)	51	–	108.0 a	7.7 b	3	GARVEY <i>et al.</i> (2002)
Canada (Little Round Lake)	44	–	65.0 a,b	7.7 b	2	BERTSCHY & FOX (1999)
Canada (Warrens Lake)	44	–	74.0 a	9.3 b	2	BERTSCHY & FOX (1999)
Canada (Belopordine Lake)	44	–	89.0 a	7.4 b	2	BERTSCHY & FOX (1999)
Canada (Black Lake)	44	–	84.0 a	6.9 a,b	1	BERTSCHY & FOX (1999)
Canada (Vance Lake)	44	–	95.0 a	7.5 b	1	BERTSCHY & FOX (1999)
U.S.A. (Amherst Pond)	42	–	–	7.0 b	3	BURNS (1976)
U.S.A. (Rhode Island ponds)	41	0.80b	–	–	3	TRACY (1910)

DISCUSSION

The present study documents the reproduction characteristics of the introduced pumpkinseed sunfish *L. gibbosus* in a tropical country, compared with introduced and native populations in the temperate regions. The species in Brazil reproduces all year

the same species but native from distinct geographic regions (temperate, sub-tropical, tropical or semi-arid), may produce eggs whose diameters varies in size.

The standard length at maturity (LaM) indicated that the pumpkinseed sunfish of the present work, *L. macrochirus* and



Figures 2-7. Histological sections of *L. gibbosus* ovaries (left column) and testes (right column) in different stages of reproductive cycle, haematoxylin-eosin (2, 5, 6, 7) and Gomeri's trichrome (3, 4). (2) Rest: only young (O1) and pre-vitellogenic (O2) oocytes are present; (3) advanced ripening/mature: young (O1), pre-vitellogenic (O2), cortical alveoli (O3) and various vitellogenic (O4) oocytes are present; (4) spawned: young (O1), pre-vitellogenic (O2), cortical alveoli (O3), vitellogenic (O4) oocytes and post-ovulatory follicle (asterisk); (5) rest: the lumen of seminiferous tubules is closed; (6) advanced ripening/mature: lumen of seminiferous tubules is filled with spermatozoa (SPZ); (7) spent: seminiferous tubules partially empty, few cysts of spermatocytes and spermatozoa (SPZ) associated with seminiferous tubules containing spermatogonia and empty lumen (star).

L. cyanellus introduced respectively in Cuba and in the state of California, U.S.A., have smaller lengths in relation to those natives (HOLCIK 1970, MOYLE 1976). The gonadosomatic index (GSI) of introduced populations were also smaller than those native, probably due to the natives' largest body size. In fact, according to COURTENAY & STAUFFER (1984), introduced fish popu-

lations show a smaller body development in the new habitat than the old one.

The spawning season (SS) of the introduced populations is longer than the native ones, specially in mild climate countries like Spain and Greece and tropical climate like Brazil (NEOPHYTOU & GIAPIS 1994, VILA-GISPERS & MORENO-AMICH 1998).

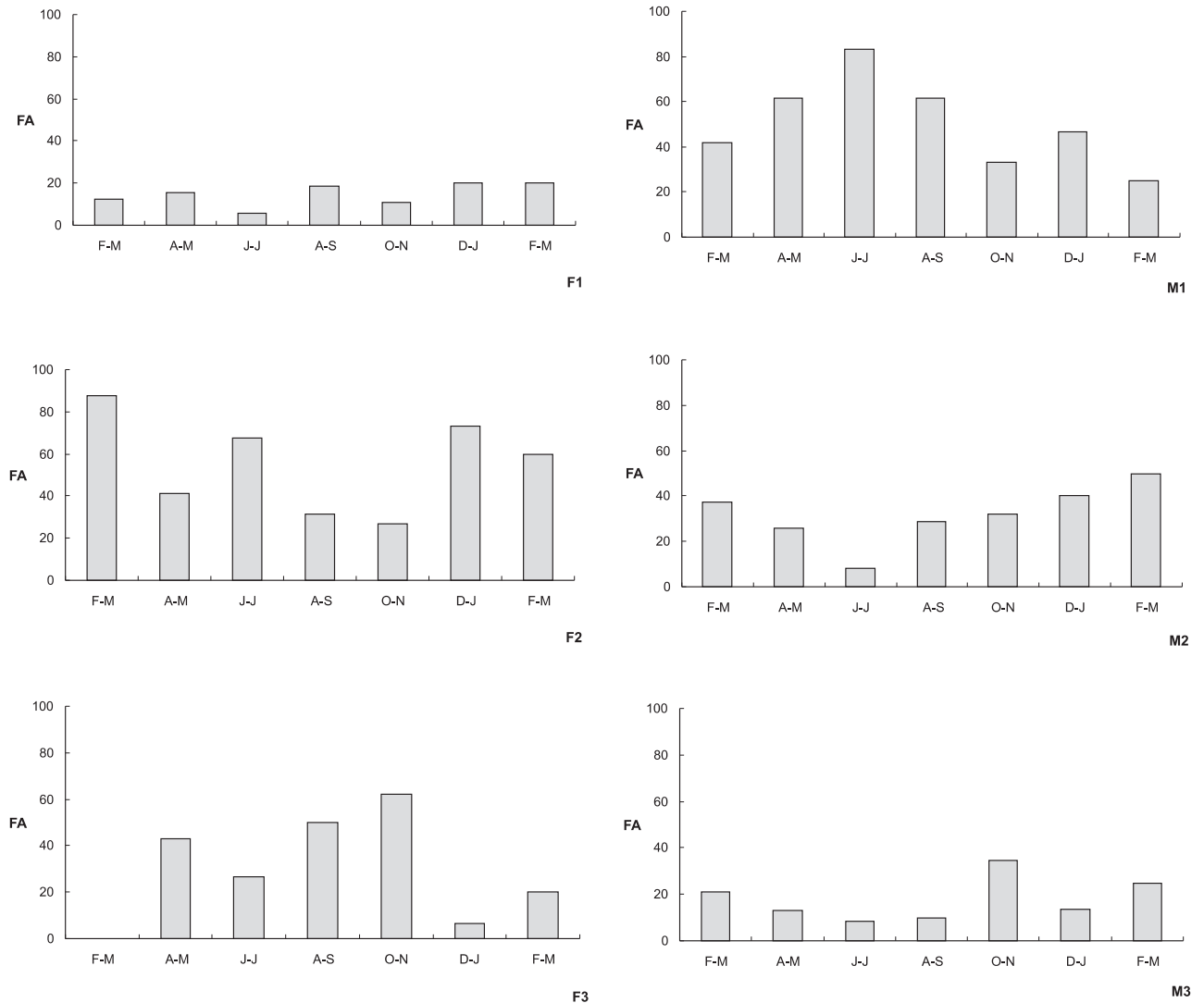


Figure 8. Absolute frequency by stage of reproductive cycle of *L. gibbosus* females and males captured in the Custódio's Dam, between February/2001 and March/2002. (AF) Absolute frequency, (F1) female in stage of rest, (F2) female in advance ripening/mature stage, (F3) spawned female, (M1) male in stage of rest, (M2) male in advance ripening/mature stage, (M3) spent male.

This is corroborated by BURNS (1976) who showed that the native *L. gibbosus* had a short reproductive period in the state of Massachusetts, U.S.A., due to the eastern cold climate in America. WANG (1986) and RIBEIRO *et al.* (2000), indicated that the introduced warmouth sunfish *Lepomis gulosus* (Cuvier, 1829) in state of Texas, U.S.A. and *L. macrochirus* in Paranoá Lake, central Brazil, had long reproductive period due to the typical warm climate in those areas.

Our study showed that the Brazilian population of *L. gibbosus* displayed traits of a successfully invading r-strategist or opportunistic species, such as: (1) precocial maturity (the smallest female: 50.0 mm and the smallest male: 47.0 mm); (2) year-

round reproduction; and (3) multiple spawning suggesting a rapid populational expansion, typical characteristics of introduced species of the genus *Alburnus* (Linnaeus, 1758), *Carassius* (Linnaeus, 1758), *Lepomis* (Rafinesque, 1819), *Oreochromis* (Linnaeus, 1758), *Tilapia* (Boulenger, 1897) and *Perca* Linnaeus, 1758 (COURTENAY & STAUFFER 1984). Possible consequences of this phenomena are: (1) dwarfing or "stunting" as a result of the rapid expansion of the pumpkinseed sunfish population producing large numbers of individuals which mature and breed at a much reduced size; (2) interspecific competition due to the egg predation of native fishes specially *A. scabripinnis*; and (3) progressive diminution of *A. scabripinnis* population in the dam,

which according to the old habitants in the area, occurred along the 38 years of introduction of this centrarchid. Similar observation was noticed by VOOREN (1972) who related that stunted populations of the introduced redbreast sunfish *Lepomis auritus* (Linnaeus, 1758) in Italian mountain lakes, has supplanted the native *Alburnus alburnus* (Linnaeus, 1758) due to the intensive predation on eggs and alevins.

The impact magnitude of the introduced species in natural and artificial environments is dependent upon local environmental characteristics (MOONEY & DRAKE 1989). Thus, systems with few native species tend to present higher vulnerability to the invasion by introduced fishes (NICO & FULLER 1999). Therefore, the presence and adaptation of the pumpkinseed sunfish in Custódio's Dam is reason to concern because it's a delicate ecosystem which define the area as potentially threatened. Thus, it's necessary to have protection strategies on the native ichthyofauna in Itacolomi State Park due to the fact of this exotic fish be considered pest (as well as *T. rendalli* and *M. salmoides*) and its presence has changed the structure of the native invertebrates and fish communities in many countries after its introduction (COURTENAY & STAUFFER 1984, WELCOMME 1988, GARCÍA-BERTHOU & MORENO-AMICH 2000).

The ability of adaptation of *L. gibbosus* to different and harsh environments by modifying its reproductive life history, has allowed the species to become one of the most successful vertebrate on Earth. Further studies are planned, especially in light of attempts to introduce additional species such as the *T. rendalli* and *M. salmoides* into Custódio's Dam.

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