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Preferential spawning areas of Neotropical migratory fish species in tributaries of Porto Primavera Reservoir, Upper Paraná River

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Introduction

The Parana River basin is the most regulated river system in South America, with numerous dams built to support the growing demand for energy. The large dams along the Paraná River, particularly in the upper Paraná River, have caused severe impacts on fish communities, especially for long-distance migratory species, with the interception of migration routes, reducing habitats for spawning and nursery grounds beyond the control of the hydrological regime (Agostinho *et al.* 2007).

The blockage of the connection between reproduction, growth and feeding habitats for long-distance migratory species due to river regulation has led to impairment of the life cycle of these species, with a drastic reduction or disappearance in fishing. Survival and life history of migratory fish species are directly related to intact longitudinal pathways, including the possibility of migration into tributaries that are often very important for reproduction and rearing areas for larvae and juveniles (Cowx & Welcomme, 1998). Lateral connections between river and floodplain or backwater habitats are essential in the life history of many migratory fishes that have evolved to take advantage of seasonal floods and utilize the inundated areas for spawning and feeding (Agostinho *et al.*, 2007; Nakatani *et al.*, 2004).

A unique unimpounded reach in the Upper Paraná River is the Upper Paraná River Floodplain. It stretches 230 km from downstream of Porto Primavera Dam to the upper reaches of the Itaipu Reservoir (Pelicie & Agostinho *et al.*, 2008), spans as wide as 20 km, especially on the western margin (Agostinho *et al.*, 2003), and has large tributaries on the eastern margin.

Knowing that studies of fish eggs and larvae can provide evidence that the species has reproduced in a given location, which species, when, and that these information contribute to determine spawning areas, initial development, as well as in making decision of management measures (Nakatani *et al.*, 2001), it becomes necessary to know the role of tributaries in the life cycle of the species. Thus, the aim of this study is to evaluate the importance of the tributaries of Porto Primavera Reservoir for spawning and initial development of fish larvae, especially those long-distance migratory species, the most species impacted by dams, ensuring the assumption that they can be considered critical habitat for the maintenance of the cycle life of these species.

Material and Methods

Assessment of the spatial distribution of fish larvae in the tributaries of the Porto Primavera Reservoir, covering the Aguapeí, Verde, Pardo and Anhanduí rivers, were conducted monthly from October to March (reproductive period for most fish species from Paraná River Basin-Vazzoler, 1996) through 2007 to 2010, comprising three spawning seasons (1=2007/2008, 2=2008/2009, and 3=2009/2010). Ichthyoplankton samplings were conducted using a conical-cylindrical plankton net (0.5mm mesh) equipped with a flow meter for surface collections. Hauls were horizontal (20 cm deep) after nightfall (between 7 and 11 p.m.) during 10 minutes. Sampling included the main channel and marginal lagoons along the tributaries. Ichthyoplankton were anesthetized with benzocaine, fixed in buffered 4% formalin, and identified to the species level based on descriptions in Nakatani *et al.* (2001) and Graça & Pavanelli (2007). Species were also classified according to the reproductive strategies (Suzuki *et al.*, 2004; Agostinho *et al.*, 2003): MIG = long-distance migratory; SSC = sedentary without parental care; SCC = sedentary with parental care; SFIE = sedentary with internal fertilization and external development; and NC = species with unavailable information in literature. The samples were standardized to a volume of 10 m³ of filtered water followed Tanaka (1973) modified by Nakatani *et al.* (2001). The Indicator Species Analysis (IndVal; Dufrene & Legendre, 1997) was used as a tool in determining the preferences of the species by a specific tributary for the spawning through the larval taxa.

Results and Discussion

A total of 63.857 fish larvae were caught during the study period. About 56 fish larvae species were found in the tributaries of Porto Primavera Reservoir, mainly Characiformes (45%) and Siluriformes (43%). The tributaries show differences in species composition indicating greater reproductive activity of these species for a particular tributary. Among the taxa identified the highest densities were found for Anostomidae (17.61 larvae/10m³).

Most larvae species in the tributaries are non-migratory species (short migrators or sedentary species-76%). High importance is the occurrence of larvae of long-distance migratory species (17%-MIG): *Prochilodus lineatus*; *Salminus brasiliensis*; *Brycon orbignyanus*; *Rhaphiodon vulpinus*; *Pimelodus maculatus*; *Sorubim lima*; *Zungaro jahu*; and *Hemisorubim platyrhynchos* / *Pseudoplatystoma corruscans* (they are morphologically similar in the early stages of development).

In general, the long-distance migratory species occurred in all reproductive seasons and tributaries. These species were found in all sampling sites in the Aguapeí River: seven migratory species. The highest density was observed for larvae of *H. platyrhynchos* / *P. corruscans* followed by *P. lineatus* (Figure 1a).

Eight long-distance migratory species were sampled in the Verde River, with higher densities of *H. platyrhynchos* / *P. corruscans* at all sampling sites. Larvae of *Z. jahu*, *B. orbignyanus*, and *S. brasiliensis* also were found occurring in all sampling sites and breeding seasons in this river. These species are threatened and endangered (Figure 1b).

The Pardo River contributed with six long-distance migratory species. Larvae of *H. platyrhynchos* / *P. corruscans* and *P. maculatus* were the most abundant species (Figure 1c). Six long-distance migratory species were recorded in the Anhanduí River. Higher densities were found to larvae of *H. platyrhynchos* / *P. corruscans* and *P. maculatus*. Larvae of *Z. jahu* were captured in RAN1 and RAN2, however, this species was sampled in this river only in the spawning season of 2008/2009 (Figure 1d).

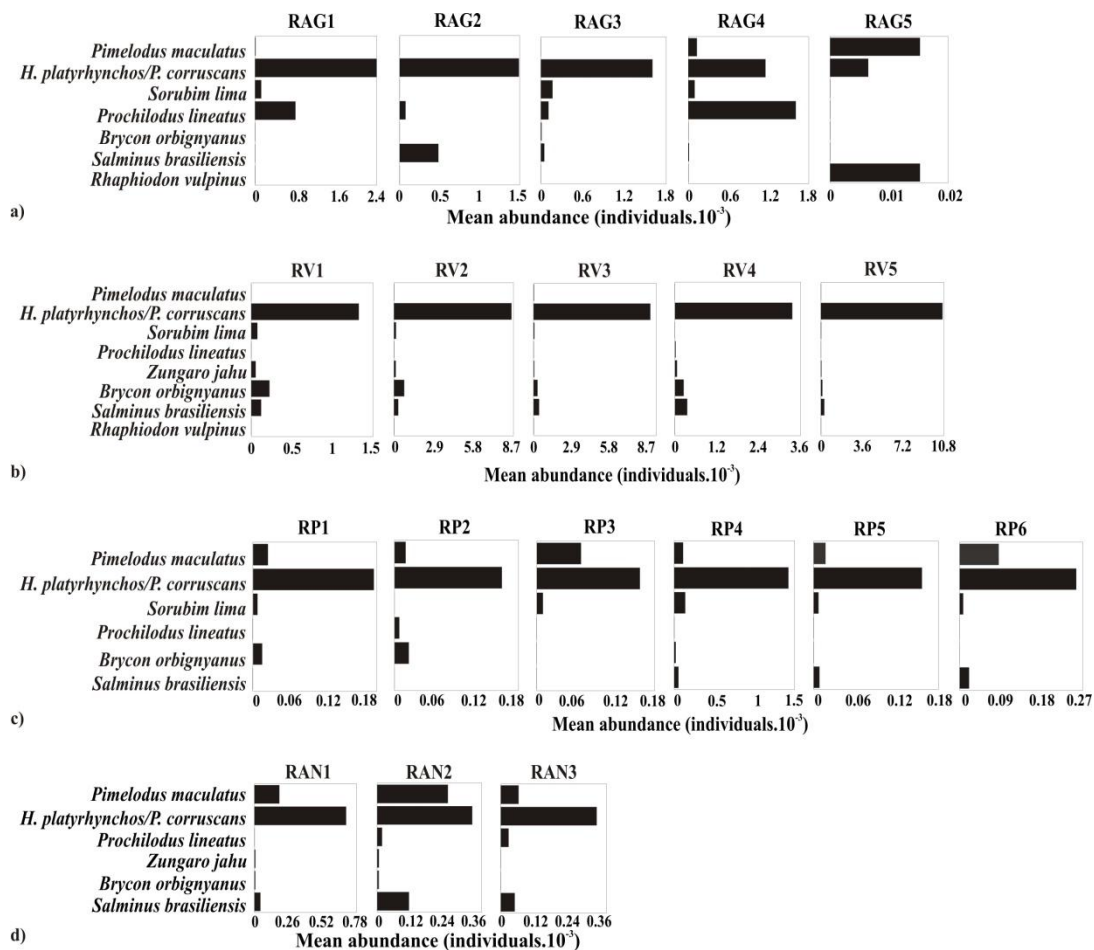


Figure 1. Larvae mean density of long-distance migratory species in the different sampling sites: **(a)** Aguapeí, **(b)** Verde **(c)** Pardo, and **(d)** Anhanduí River.

The Indicator Species Analysis demonstrated differences among tributaries in the indicator larvae species. The Aguapeí River was characterized by larvae of *Hoplias* spp., *Ageneiosus inermis*, *Roeboides descavadensis*, and especially *P. lineatus*, a long-distance migratory species (Figure 2). The highest number of indicator taxa (8 taxa) was registered to Verde River, as follows: Anostomidae, Characiformes, Heptapteridae, Siluriformes, emphasizing 5 indicator long-distance migratory species: *B. orbignyanus*, *H. platyrhynchos / P. corruscans*, *Z. jahu*, and *S. brasiliensis*. *Auchenipterus oestemystax*, *Serrasalmus* spp., *Bryconamericus* spp., *Apareiodon* spp., and *Tatia neivai* exhibited a greater preference for the Pardo River, however no long-distance migratory species was an indicator of this river. Only *P. maculatus* larvae, a long-distance migratory species, *Iheringichthys labrosus* and Pimelodidae were typical of the Anhanduí River.

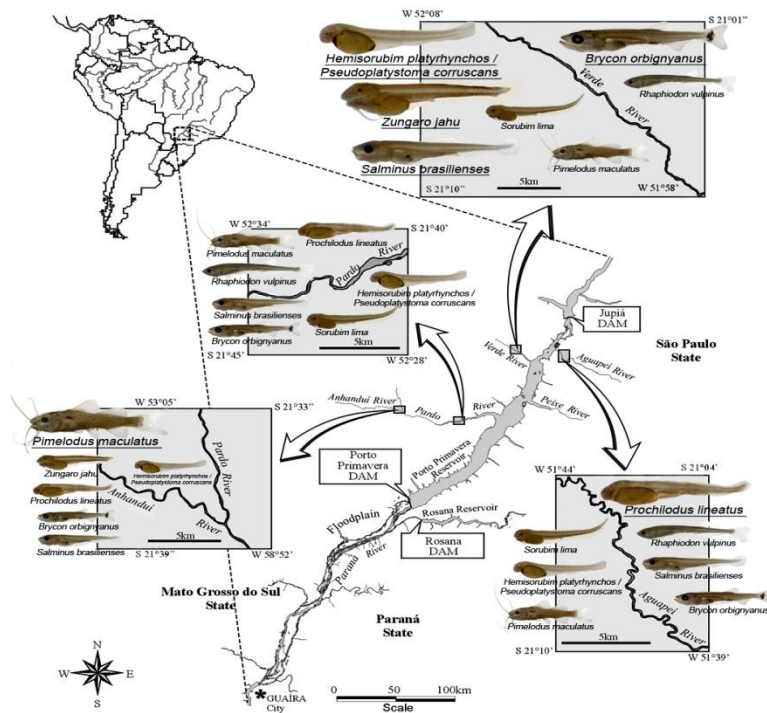


Figure 2. Distribution of the migratory fish species larvae in the tributaries of Porto Primavera Reservoir, Upper Paraná River, Brazil. Indicator species are underlined.

The composition of the fish larvae species in this study reflects the viability of the tributaries of the Porto Primavera Reservoir as spawning areas for many fish species, since covered species with different reproductive strategies and in particular several long-distance migrators (*Prochilodus lineatus*, *Salminus brasiliensis*, *Brycon orbignyanus*, *Rhabdiodon vulpinus*, *Pimelodus maculatus*, *Sorubim lima*, *Zungaro jahu*, and *Hemisorubim platyrhynchos / Pseudoplatystoma corruscans*).

The occurrence of migratory species larvae in all sampling sites in the Aguapeí, Verde, Pardo, and Anhanduí rivers demonstrates that the reproduction of these species has occurred throughout the sampled stretch. Larvae of long-distance migratory species (*Leporinus elongatus*, *Pterodoras granulatus*, *Pimelodus maculatus*, and *Salminus maxillosus* - now named *S. brasiliensis*) were found downstream from Porto Primavera, in Amambaí, Parana and Ivaí Rivers (Baumgartner *et al.*, 2004). Larvae of long-distance migratory species were also observed in Ivinhema River, Upper Paraná River Floodplain, by Tataje *et al.* (2011), with similar larvae densities, however the number of taxa identified were lower than those observed in this study.

The preference exhibited by adults for a particular tributary evidenced by IndVal may be related to the characteristics of the site, where the species could find ideal conditions for reproduction and initial development. Most of tributaries showed long-distance migrator as indicator species: *B. orbignyanus*, *H. platyrhynchos / P. corruscans*, *S. brasiliensis*, and *Z. jahu* – Verde River; *P. lineatus* – Aguapeí River; *P. maculatus* – Anhanduí River (Figure 2). The fact of the Pardo River does not make any long-distance migratory species as an indicator does not indicate that these species do not occur in it (08 migratory species were recorded in this river), but the occurrence of them was lower than other tributaries. Verde River exhibited the greatest number of indicator taxa, probably consequence of the wetlands available in this tributary, which benefit during the floods, making it natural nurseries for many fish species

The species spawning with diverse reproductive strategies occurring in the tributaries of Porto Primavera Reservoir, particularly the long-distance migrators, denotes critical

habitats for maintenance of the life cycle of these species: 9 of 19 migratory species spawning in the Porto Primavera tributaries, including two threatened (*Salminus brasiliensis* and *Zungaro jahu*), and one endangered (high risk of extinction) (*Brycon orbignyanus*), according to Abilhoa & Duboc (2004). The importance of reservoir tributaries for fish species life cycle was also emphasized by Makrakis *et al.* (2012) because the intense lateral migrations (to and from tributaries) exhibited by a diversity of migratory species.

Considering that the Paraná River is highly impounded, special attention must be given to the few remaining low-impacted habitats as they continue to be targets of hydropower development that will likely intensify impacts on migratory fish stocks (Makrakis *et al.*, 2012). An essential responsibility is to encourage reservoir managers and environment agencies to preserve these tributaries and avoid actions that potentially can condemn some fish species to decline.

Conclusions

This scenario shows the existence of large tributaries used for spawning and development initial by long-distance migratory species upstream of the Porto Primavera Dam. Studies on recruitment have been carried out in order to certificate the existence of recruitment conditions in these areas. Associated to this, upstream movements of migratory species passing through Porto Primavera fish ladder, identified by mark-recapture studies (Makrakis *et al.*, 2012) may indicates an existence of genetic flow between downstream and upstream populations. This information is essential for a better understanding of the role of fish ladder at Porto Primavera Dam for fish species conservation.

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