Observation of an invasion of the piranha *Serrasalmus marginatus* Valenciennes, 1847 (Osteichthyes, Serrasalmidae) into the Upper Paraná River, Brazil

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ABSTRACT. The building of Itaipu Dam, 150 km downstream from Sete Quedas Falls, resulted in the natural geographical barrier drowning, with subsequent mixing of the fish faunas. *Serrasalmus marginatus* (Osteichthyes, Serrasalmidae), a species that had been restricted to the river segment downstream from Sete Quedas, invaded the Upper Paraná River. The catching of *Serrasalmus spilopleura*, a resident species, decreased drastically after the invasion, contrary to *S. marginatus*, which increased in abundance. In the Piquiri River, where the latter species does not occur, the abundance of *S. spilopleura* remained high, due to the presence of Nhá Bárbara and Apertado Falls.

Key words: colonization, reservoir, geographical barrier, Paraná River.

RESUMO. Invasão da piranha *Serrasalmus marginatus* Valenciennes, 1847 no alto rio Paraná, Brasil (Osteichthyes, Serrasalmidae). A construção da barragem de Itaipu, 150 km a jusante do salto de Sete Quedas, resultou no afogamento da barreira geográfica natural, com conseqüente mistura das ictiofaunas. *Serrasalmus marginatus* (Osteichthyes, Serrasalmidae), uma espécie que apresentava distribuição restrita ao segmento a jusante de Sete Quedas, invadiu o alto rio Paraná. A captura de *Serrasalmus spilopleura*, uma espécie residente, diminuiu drasticamente após a invasão, ao contrário de *S. marginatus* que aumentou em abundância. No rio Piquiri, onde a espécie invasora não ocorreu, a abundância de *S. spilopleura* permaneceu alta por causa das quedas de Nhá Bárbara e Apertado.

Palavras-chave: colonização, reservatório, barreira geográfica, rio Paraná.

Introduction

The introduction of species into freshwater ecosystems has often resulted in considerable changes in the natural communities (Vooren 1972; Barel *et al*., 1985; Balon and Bruton 1986). Introduced species may alter habitats, indirectly affecting natural species, or may exercise a direct biological effect via predation, competition, aggression, or interfere in the natural species reproduction, through hybridization, or change the parental behavior of such species (Taylor *et al*., 1984; Crowl *et al*., 1992). Species introduction may cause more harm than benefic effects, from the genetic as well as the demographic points of view (Drake *et al*., 1996). Thus, from the conservationist perspective, the organisms artificial movement ought to be avoided whenever possible (Agostinho and Júlio Jr, 1996).

The upstream dispersal of fish after natural barriers flooding by impoundment, can be considered a sort of species introduction that has not been investigated in tropical and subtropical regions. Sete Quedas Falls was a natural geographic barrier, setting the limits of the Upper and Middle Paraná fish provinces. The building of the Itaipu Dam, 150 km downstream this fall, and the consequent impoundment of this natural obstacle, allowed the mixing of these regions fish faunas. Agostinho *et al.* (1994) recorded at least 17 species, formerly exclusive to the Lower Paraná River, that successfully colonized the new habitat, among them the piranha *Serrasalmus marginatus* (Osteichthyes, Serrasalmidae). The present study describes the consequences of this species invasion into the Upper Paraná River.

Material and methods

The Itaipu Reservoir (22°00' - 25°21'S; 54°19' - 54°31'W) was impounded in November 1982. It comprises an area of 1,460 km^2 at its maximum level and an extension of 150 km. Average depth is

21,5 m with a maximum of 170 m. The Paraná River segment, now occupied by the Itaipu Reservoir, formerly flowed through a canyon, and its tributaries waters spilled over falls of various heights. Reservoir building submerged the Sete Quedas Falls, and transferred this natural barrier to fish dispersal 150 km downstream.

Twenty-one sampling sites were established along a 380-km stretch of the Paraná River, including the Itaipu Reservoir (150 km) and the floodplain upstream (230 km) (Figure 1).

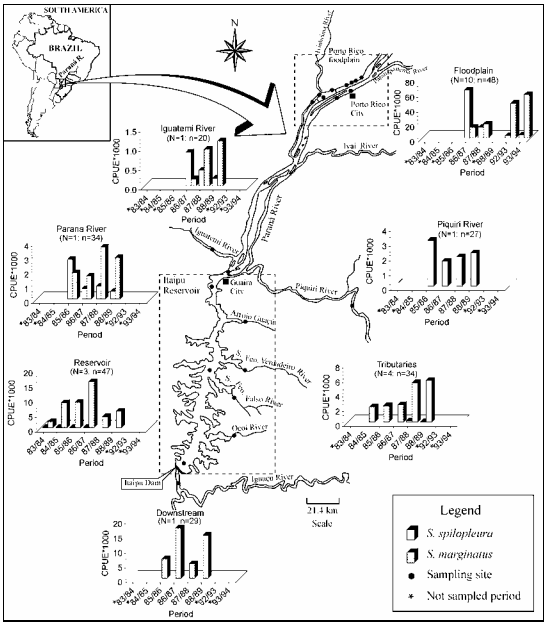

Figure 1. Numbers (CPUE) of *Serrasalmus spilopleura* and *S. marginatus* per sampling period in the section of the Paraná River between the Porto Rico floodplain and downstream from the Itaipu Reservoir (N = number of sampling sites and n = number of sampling)

Eleven sampling sites were established in a stretch of Itaipu Reservoir and Paraná River: three stations in the main water body of Itaipu Reservoir, four stations in tributaries on the left margin, two stations in the Paraná River (upstream and downstream of Itaipu Reservoir) and two stations in Paraná River tributaries. Sampling was carried out from 1983 to 1989, in the Itaipu Reservoir, and from 1985 to 1989 in the Paraná River and tributaries. Collections were taken monthly and only bimonthly during 1986-1988 autumn-winter periods (Figure 1).

Collections were monthly made during the periods of 1986-88 and 1992-94 on the floodplain of the Upper Paraná River (22°40' - 22°50'S; 53°10' - 53°40'W). In this stretch, the Paraná River has a complex channels system and numerous temporary and permanent lagoons, forming a 20-km-wide floodplain and complex drainage system. Sampling floodplain includes numerous temporary and permanent lagoons. Collections were carried out in ten stations, grouped in three types of habitats: lagoons (Fechada, Guaraná, Patos and Pousada das Garças), river channels and arms (Curutuba Channel, Baía I and Baía II), and rivers (Paraná, Ipoitã and Ivinheima).

Nylon gill nets, 1.7 m tall X 20.0 m long, with meshes of 3, 4, 5, 6, 7, 8, 10, 12, 14, and 16 cm (stretched measure), were exposed for 24 hours at each site. Each piranha in the sample was measured (standard length to the nearest millimeter). Data were expressed as number of individuals per 1,000 m^2 of gillnet 24 h^{-1} (CPUE).

Results

Abundance (CPUE) analysis for piranhas in the river segment, including the Porto Rico floodplain and the first kilometers downstream from Itaipu Dam (Figure 1), indicates a stratified distribution of *Serrasalmus spilopleura*. This species was caught almost exclusively at the sampling sites above Guaíra. The catch of *S. spilopleura* decreased after the Itaipu Reservoir was impounded, contrary to *S. marginatus*, which increased in abundance. In the Piquiri River, where the latter species does not occur, the abundance of *S. spilopleura* remained high. *Serrasalmus nattereri* was caught exclusively downstream from Itaipu Dam and represented only 0,4% of the whole catch (44 individuals).

Analysis of piranhas CPUE by habitat category shows that the greatest abundance of *S. spilopleura* and *S. marginatus* occurred in lentic habitats (lagoons and channels). In lotic waters (rivers), *S. spilopleura* was virtually absent, while *S. marginatus*, though less abundant than in the other habitats, had increased catch values (Figure 2).

Analysis of the abundance of *S. spilopleura* per length class demonstrates a drastic reduction in the number of adults, as well as low recruitment in the first 2 years of collection, and almost no adults or recruitment during the last 2 years. The juveniles of *S. marginatus* abundance, in turn, increased markedly from the first 2 collection years to the last 2 (Figure 3).

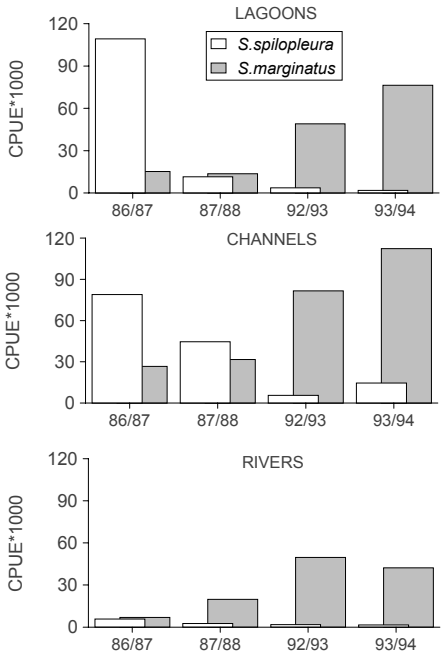

Figure 2. Numbers (CPUE) of *Serrasalmus spilopleura* and *S. marginatus* by sampling period and habitat on the Porto Rico floodplain

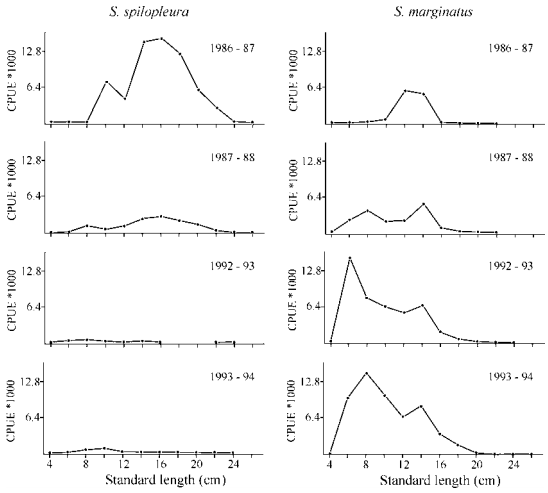

Figure 3. Numbers (CPUE) of *Serrasalmus spilopleura* and *S. marginatus* by length class on the Porto Rico floodplain

Discussion

Prior to Itaipu Reservoir building, *S. spilopleura* was the only species of the genus recorded in the Upper Paraná River (Castro and Arcifa 1987; Garutti, 1988). In the Lower Paraná River and the Pantanal of Mato-Grosso, however, this species occurs together with *S. marginatus* and *S. nattereri* (Sazima and Machado 1990; Bistoni and Haro, 1995). With the elimination of the natural barrier formed by Sete Quedas in November 1982, it became possible for both *S. marginatus* and *S. nattereri* to invade the Upper Paraná; however, only the former species has successfully colonized the new habitat.

The low abundance of *S. nattereri* at the beginning of the colonization process, as observed in the low catch rates downstream from the Itaipu Dam, may have been a factor in the failure of this species to colonize the Upper Paraná. Taylor *et al*. (1984) emphasized the importance of the individuals initial number for the process of colonizing a new habitat.

Serrasalmus spilopleura was more abundant in the first collecting years in the Paraná and Iguatemi rivers and on the Porto Rico floodplain; however, in succeeding years, the abundance of this species decreased and *S. marginatus* became the most abundant species in this river stretch. In the first years following the drowning of Sete Quedas, *S. marginatus* had already spread into all the sampled habitats, except the Piquiri River, demonstrating its high capacity for dispersal and new habitats occupation. Its absence from the Piquiri can be explained by the presence of the Nhá Bárbara and Apertado Falls, which worked as barriers to its further dispersal.

Most species of piranhas inhabit mainly lentic habitats. Although some species live in riverine habitats, none is limited only to main river channels (Goulding, 1980). Analyses of *S. spilopleura* and *S. marginatus* abundance indicate these species preference for lentic waters. However, *S. marginatus*, in contrast to *S. spilopleura*, is also caught in great abundance in the lotic habitats of the floodplain. *S. marginatus* adaptation to lotic waters was probably an important factor in the river segment occupation upstream from Sete Quedas, in the probable abundance of this species individuals at the invasion process beginning, and in its easy overcoming of the rapid currents during its dispersal.

The *S. spilopleura* mortality rate is not known. However, it is unlikely that there was massive mortality in adults of this species from the first to the second collecting year. The adults catch decrease most probable cause is a limitation in this species distribution and movement patterns in the region, imposed by *S. marginatus*. Svardson (1976) mentioned that a species may have a greater ecological amplitude when living in allopatry, rather than sympatry, with a dominant species. Burrough and Bregazzi (1979) attributed the *Scardinius erythropthalmus* catch reduction to this species

displacement to areas with higher shelter availability, where it lived sympatrically with *Rutilus rutilus.*

The drastic reduction occurred in the *S. spilopleura* population after the invasion of *S. marginatus*, as shown by the variations in CPUE over time, suggests, as a preliminary analysis, that the former species is being excluded from the latter distributional area. However, these two species occur sympatrically in other parts of the basin. In the Middle Paraná floodplain near Yaciretá, *S. spilopleura* and *S. marginatus* occur together in a proportion of 1:4.5 (CIDET, 1996). This appears to indicate the possibility that these species can coexist in the Upper Paraná. If this is confirmed, *S. spilopleura* will remain much less abundant than *S. marginatus*.

An hypothesis advanced by Hutchinson (1953, *apud* Cleveland 1994) to explain the potentially competing species coexistence was that one or more of these species persist in the habitat as fugitive species, using a resource less valued by the dominant species. In this model, the resource does not need to be shared; the fugitive species needs only to avoid interaction with the superior competitor. If the habitat is sufficiently heterogeneous, a fugitive species must be capable of obtaining some of the limited resources (Hixon, 1980; Larson, 1980). *Gasterosteus wheatlandi* is capable of coexisting with the competitively dominant *G. aculeatus*, because *G. wheatlandi* is a generalist and a fugitive competitor (Cleveland, 1994). The coexistence of *S. spilopleura* and *S. marginatus*, into the Upper Paraná River, will depend on the possibility of *S. spilopleura* behaving as a fugitive competitor until the establishment of different models for resource use, as it probably happened in the Middle Paraná River.

Implications for future reservoirs

The drowning of the natural geographical barrier allowed the invasion of the Upper Paraná River by at least 17 species, formerly exclusive to the Lower Paraná River (Agostinho *et al*., 1994), and the mixing of populations. In addition to changes in genetic diversity, barrier removal resulted in damage to fisheries and leisure. *Serrasalmus marginatus*, like other species of piranhas, attack fishes caught in fishing gear and eliminate, or reduce, their commercial value (Agostinho *et al*., 1997). Beyond this, *S. marginatus* is particularly aggressive to humans when it is caring for offspring (Agostinho *et al*., 2000). The stingray, *Potamotrygon* sp, is an additional species, among those that dispersed, considered undesirable to fisheries and leisure, because it represents a hazard to swimmers and fishermen that use seine nets.

The fish fauna elements dispersal to upstream locations within a hydrographic basin, following the flooding of natural barriers by impoundment and invasion of fish species into areas outside their native ranges, has not been much researched in tropical and subtropical regions. In addition, loss evaluation in ecological and genetic diversity, as a result of drowning natural barriers by reservoirs, is difficult, when complete ichthyofauna surveys are lacking. Therefore, analysis of possible biological, fisheries and leisure impacts, resultant of drowning natural geographical barriers, should be adopted by the environmental agencies, as a requisite in feasibility studies for future hydroelectric projects.

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