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Fruit-eating fishes of *Banara arguta* (Salicaceae) in the Miranda River floodplain, Pantanal wetland

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Abstract: The role of fish as frugivorous and its ecological consequences are often neglected in ecological studies. However, the importance of the interaction between fish and plants is gaining force in scientific literature, and fish has been considered effective seed dispersers. The fruit-eating fish assemblage of *Banara arguta* (Salicaceae) was evaluated in Southern Pantanal wetlands. Nine species were reported consuming fruits, with different strategies to capture them. The distribution of *B. arguta* associated with the Pantanal floodplain and the presence of several species of fruit-eating fish, suggest that ichthyochory can be an important seed dispersal strategy to *B. arguta*.
Keywords: *Brycon, diet, foraging behavior, frugivory, ichthyochory, Triportheus.*

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Resumo: O papel de peixes como frugívoros e suas conseqüências ecológicas são frequentemente negligenciados em estudos ecológicos. Entretanto, a importância da interação entre peixes e plantas vem ganhando força na literatura científica, e peixes têm sido considerados como efetivos dispersores de sementes. A comunidade de peixes frugívoros de *Banara arguta* (Salicaceae) foi avaliada no Pantanal Sul. Nove espécies foram reportadas consumindo os frutos, com diferentes estratégias para capturá-los. A distribuição de *B. arguta* associada à planície de inundação no Pantanal, além da presença de várias espécies de peixes frugívoros, sugere que a ictiocoria pode ser uma importante estratégia de dispersão de sementes para *B. arguta*.
Palavras-chave: *Brycon, dieta, comportamento de forrageamento, frugivoria, ictiocoria, Triportheus.*

Introduction

Approximately 275 species of fish belonging to 39 families are potentially fruit-eating (Horn et al. 2011). Most of them are Neotropical Characiformes, representing 70% of fish biomass in South America (Harvey & Carolsfield 2003). However, the role of fish as frugivorous and its ecological consequences, including seed dispersion, are often neglected in studies about plant-vertebrates interaction (Correa et al. 2007).

A growing number of studies are beginning to consider the interaction between fishes and plants as an interesting link in the dynamics of Neotropical communities (Horn et al. 2011, Pollux et al. 2011). Indeed, fishes are able to consume large quantity and variety of fruits and seeds (Goulding 1980, Reys et al. 2008, Anderson et al. 2009), keep viable or increase the germination efficiency of seeds (Kubitzki & Ziburski 1994, Horn 1997, Anderson et al. 2009) and disperse seeds for lond distances and in suitable sites (e.g. upstream and floodplains) (Horn 1997, Anderson et al. 2011).

The role of fish as frugivorous is more noticeable in wetlands, mainly floodplains (Goulding 1980, Parolin et al. 2011). Several fish species invade floodplains to feed and breed (Lowe-McConnell 1999). Considering the plants, some species synchronize their fructification with the flood season, which increases the probability of its fruits being consumed by fishes (Goulding 1980, Kubitzki & Ziburski 1994, Anderson et al. 2009). One of the largest wetlands in the world, the Pantanal, still has gaps in knowledge of its fruit-eating fishes, with few studies realized until now (e.g. Galetti et al. 2008, Reys et al. 2008).

Studies on frugivory and seed dispersion by fishes highlights fish-plant species interactions by single fish species (Horn 1997, Banack et al. 2002, Galetti et al. 2008), or more (Kubitzki & Ziburski 1994, Lucas 2008, Anderson et al. 2009). Our aim is to evaluate the fruit-eating fish assemblage of *Banara arguta* Briq. (Salicaceae) in Pantanal wetland. Furthermore, we discuss the ichthyofauna potential role in the seed dispersion of *B. arguta* based on fish foraging behavior.

Material and Methods

The Pantanal is one of the largest continuous floodplain in the world, located in the upper Paraguay River basin (Junk et al. 2006). Its flood pulse follows a uni-modal annual cycle whose amplitude varies between two and five meters and last three to six months, usually between January to May (Harris et al. 2005). This ecosystem can be divided into 10 different sub-regions due edaphic, hydrological and biogeographical variations (Lourival et al. 2000). This work was conducted in the Miranda-Abobral sub-region.

Our data were collected in the daytime during four days in the flood season on the Pantanal, May 2011, on the Miranda River floodplain, near the Universidade Federal de Mato Grosso do Sul Pantanal Studies Base (19° 34' 36'' S and 57° 01' 06'' W). Four trees of Salicaceae *Banara arguta* with ripe fruits falling in the water were selected. This species is common on flooded areas, fruiting during the flood season in Pantanal (Lorenzi 2002). Primates, birds and bats were already registered in literature consuming *B. arguta* fruits (Bravo & Sallenave 2003, Ragusa-Netto & Fecchio 2006, Gonçalves et al. 2007, Teixeira et al. 2009).

We collected 50 mature fruits of *Banara arguta* to quantify the number of seeds and the fruit´s size with a precision caliper. To capture the fishes, we used four fishing rods/tree with barbless hooks baited with fruits of *B. arguta* around the four selected trees (sampling effort of 16 hours). Captured individuals were quantified and mostly returned to the water. Fishes were identified according to Britski et al. (2007). For taxonomic identification of species of the genus *Triportheus* (Malabarba 2004) is necessary to count gill rakers, so we captured three individuals and deposited in the zoological collection of the Federal University of Mato Grosso do Sul (ZUFMS-accession number: 3089). Additionally, we offered ripe fruits of *B. arguta* to fishes and observed the feeding behavior with a snorkel and a dive mask. All species which consumed fruits were recorded. Feeding behavior was recorded in situ following Sazima (1986).

Results

The fruits of *B. arguta* presented an average weight of 0.59 g (sd = 0.29), average length of 86 mm (sd = 18) and average width of 98 mm (sd = 18). The seeds were small and numerous, reaching up to 53 seeds in one fruit, with an average of 17.68 seeds per fruit (sd = 19.23).

We recorded nine species of fish consuming fruits of *B. arguta*. Most of individuals captured were *Triportheus pantanensis* (Kner, 1858), followed by *Brycon hilarii* (Valenciennes, 1850). Three species were not captured with the rods, but only observed during the snorkeling (Table 1). The only species captured by the rods that was not observed during snorkeling was *Markianna nigripinnis*.

The consumption of fruits occurred in different ways among species (Table 1). *Brycon hilarii* formed small shoals of three to nine individuals, swimming constantly around the *B. arguta* trees. They captured the fruit at the surface or in the water column, mostly entire. *Triportheus pantanensis* and *Astyanax asuncionensis* Géry, 1972 (Figure 1a) adopt a similar foraging strategy, but only larger individuals captured entire fruits. Juveniles of these species bite the fruit on the surface or in the water column, and pluck large pieces. Another species with ontogenetic differences in foraging strategy was *Leporinus friderici* (Bloch, 1794): adults manipulate

Table 1. Fish species that consumed *Banara arguta* in the Miranda River floodplain.

Species	Position	n	Strategy
Astyanax asuncionensis	S,C	1	Plucks fruit fragments or take advantage of fragments left by the larger species
Brycon hilarii	S,C	15	Captures the entire fruit or large pieces
Triportheus pantanensis		74	
*Leporinus striatus**	B	-	Nibbles fruit on the bottom, ingesting small pieces
Leporinus friderici	B	1	Adults manipulate the fruit in the mouth and ingest the entire fruit, while young individuals manipulate the fruit tearing small fragments
Tetragonopterus argenteus	C	1	Tears fruit fragments or take advantage of fragments left by the larger species, nibbling on those pieces while it fall into the water column
Markiana nigripinnis		1	
*Brachychalcinus retrospina**		-	
Mylossoma duriventre	B	-	Swallows the entire fruit that was being contested by smaller fish

Position on water column: S = surface, C = water column and B = bottom; number of individuals captured (n) and strategy to capture the fruits. *Species that were recorded consuming fruits of *B. arguta* only during the subaquatic observation sessions.

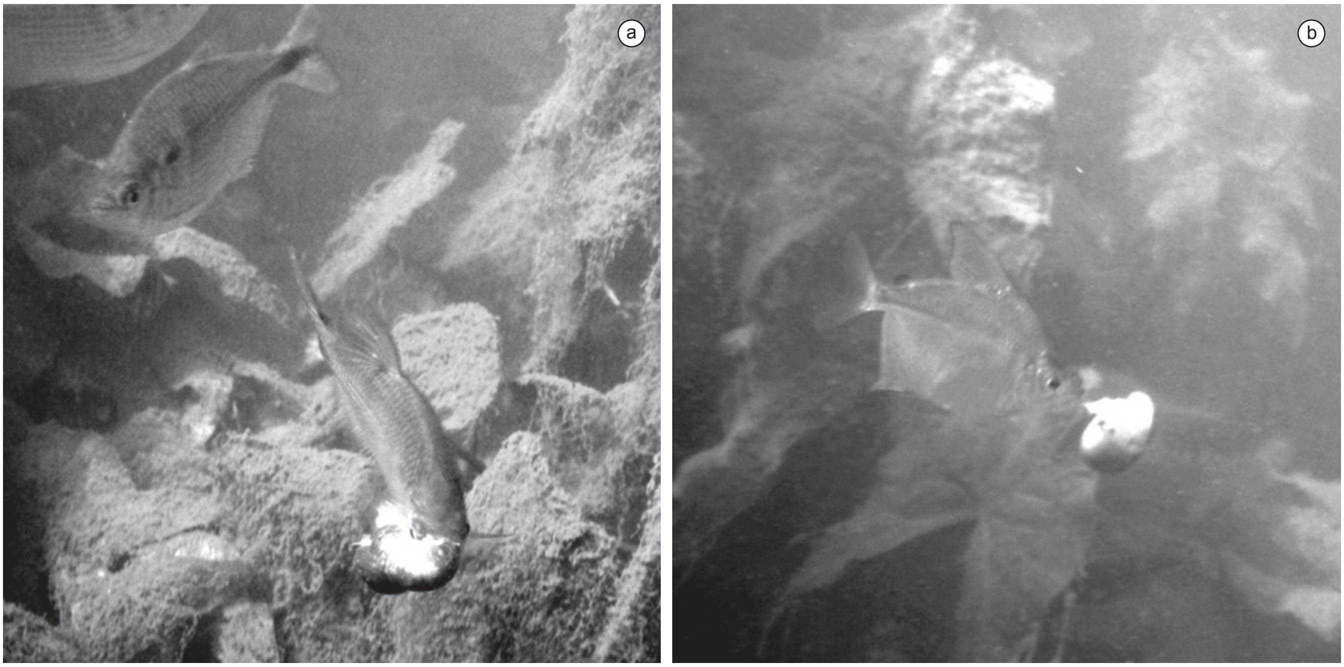

Figure 1. a) *Astyanax asuncionensis* tearing a peace of fruit of *Banara arguta*; and b) *Brachychalcinus retrospina* consuming small fragments of fruits of *Banara arguta*.

the fruit in the mouth before eating it entirely, while young nibble fruit tearing small pieces, but both capture fruits deposited on the floodplain bottom. *Leporinus striatus* (Kner, 1858) nibble fruits in the bottom of the floodplain, eating small pieces.

The smaller species *Markiana nigripinnis* (Perugia, 1891), *Tetragonopterus argenteus* Curvier, 1916 and *Brachychalcinus retrospina* Boulenger, 1892 (Figure 1b), take advantage of fruit fragments left by larger species, nibbling on those pieces while they fall into the water column. Moreover, when the entire fruit that fell in the water are not attacked by the larger species, smaller species also nibble on the fruit into the water column or bottom. *Mylossoma orbignyanum* (Valenciennes, 1849) was seen moving from bottom to the fruit, and swallowing whole the fruit that was being contested by smaller fish.

Discussion

No other study reported the occurrence of *B. arguta* fruits in the stomach contents of fish as food item, so far. The feeding of fish is strongly dependent on the availability of food resources and, considering that fruits are available seasonally due to plant phenology, frugivory is also seasonal (Correa et al. 2007). Except in studies that capture fish in floodplains or monitor the diet of the species throughout the year in flooded areas (Mérona & Rankin-de-Mérona 2004, Lucas 2008), frugivory by fish is underestimated (Correa et al. 2007). Another source of underestimation is the aggregation of fruits, seeds, flowers, leaves and macrophytes in major food categories, such as plant material. This partly explains the only recent consideration of ichthyochory as an important part of life history for many species of plants and fish (Anderson et al. 2009, 2011, Horn et al. 2011).

The frugivory of *B. arguta* by *Triportheus* spp. is well known in riverine communities (Morais & Silva 2010). In literature, Goulding (1980) points out that the *Triportheus* genus possesses behavioral and morphological adaptations for the consumption of fruits. By testing the germination of seeds recovered from the digestive tract of *T. angulatus* in a lake in the Amazon, Maia et al. (2007) found that the species is one of the dispersal agents of the Rubiaceae *Bothriospora corymbosa*. The high abundance of *T. pantanensis* in floodplains of the Miranda River, and the high number of individuals caught by baits of *B. arguta*, suggests this species as a major consumer of fruits of *B. arguta*.

The genus *Brycon* comprises omnivorous – frugivorous species (Goulding 1980, Kubitzki & Ziburski 1994, Horn 1997, Gomiero et al. 2008), with morphological and biochemical evidence of specialization to herbivory and frugivory as adults (Drewe et al. 2004). Reys et al. (2008) observed 12 fruit species in the diet of *B. hilarii* and discussed that half of all plant species of riparian vegetation in Formoso River, Central Brazil, can be dispersed by this species. Horn (1997) showed that the seeds of *Ficus glabrata* remained viable for germination after their passage through the tract of *B. guatemalensis*, and that the species dispersed seeds upstream. The larger body size and high mobility of *B. hilarii* suggests this species as potential seed disperser of *B. arguta* in the Pantanal floodplains.

We found some evidences of *B. arguta* dispersal by fish, related to its fruits and seeds characteristics, and also its phenology and distribution in the floodplain. Their small size and conspicuous color of the fruit, numerous and small seeds, the distribution along floodplains and the fruiting during the rainy season of *B. arguta* are characteristics that allows the dispersal by ichthyofauna. Moreover, the fruits of *B. arguta* do not float which is a disadvantage to hydrochory, especially in lentic environments such as floodplains, and highlights the potential role of ichthyochory as a dispersal strategy of the *B. arguta*.

As for the ichthyofauna foraging behavior, the ingestion of whole fruit or large pieces by some of the species, such as *B. hilarii*, and adults of *T. pantanensis*, *A. asuncionensis* and *L. friderici*, decreases the probability of seed predation by the bite of the Characidae (Correa et al. 2007). On the other hand, the small seeds of *B. arguta* can be ingested even by small fish species that nibble the fruits, such as *B. retrospina*. In this context, we suggest future studies to evaluate the seed dispersal potential of the fruit-eating fish assemblages, mainly *T. pantanensis* and *B. hilarii*. Aspects such as dispersal distance, seed viability and the efficiency of seed germination involving experimental analysis are important to defining the real role of fish in the recruitment of *B. arguta*.

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