

FIRST RECORD OF A NUCLEAR-FOLLOWER ASSOCIATION BETWEEN *Corydoras vittatus* (NIJSSEN, 1971), *Corydoras cf. julii* (CALLICHTHYIDAE) AND *Knodus victoriae* (STEINDACHNER, 1907) (CHARACIDAE)

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RESUMO

A interação nuclear-seguidor é um tipo particular de associação alimentar interespecífica que envolve uma espécie nuclear, que revolve ou vasculha o substrato, e espécies seguidoras, que acessam os itens alimentares disponibilizados pela atividade do nuclear. Este tipo de associação foi observada em um riacho de cabeceira da bacia do rio Itapecuru, no cerrado maranhense, envolvendo os cascudinhos, *Corydoras vittatus*, *Corydoras cf. julii*, como espécies nucleares, e *Knodus victoriae*, como seu seguidor. Indivíduos de *C. vittatus*, *Corydoras cf. julii* revolveram o substrato durante alimentação, promovendo a suspensão de sedimento. Os seguidores, por sua vez, movimentaram-se pela “nuvem” de partículas em suspensão, capturando itens alimentares. As partículas alimentares em suspensão parecem não ser utilizadas pelo cascudinho, mas tornam-se disponíveis para *K. victoriae*. O comportamento de seguidor representa uma tática alimentar alternativa para estas espécies, reforçando a idéia geral de plasticidade comportamental entre as espécies seguidoras.

Palavras-chave: interação interespecífica, comensalismo, dulcícolas, forrageamento, *snorkeling*.

ABSTRACT

Nuclear-follower interactions are a particular type of interspecific foraging association which involves a nuclear species, which revolves or scans through the substrate, and follower species that access the food items made available by the nuclear species' activity. This type of association was observed in a headwater stream at the Itapecuru basin, in the Maranhão cerrado, involving the catfishes *Corydoras vittatus*, *Corydoras cf. julii* as nuclear species and *Knodus victoriae* as its follower. Individuals of *C. vittatus*, *Corydoras cf. julii* revolved the substrate during their foraging, promoting sediment suspension. Their followers, in turn, moved through the “cloud” of particles in suspension, capturing food items. Food particles in suspension do not seem to be used by the catfishes but become available for *K. victoriae*. The follower behavior represents a feeding tactic for these species, reinforcing the general idea of behavioral plasticity between follower species.

Key-words: interspecific interaction, commensalism, freshwater, foraging, *snorkeling*.

INTRODUCTION

Fish activities observations can elucidate a large set of strategies used as feeding tactics and habitat use (Baker & Foster, 1994; Leitão *et al.*, 2007; Teresa & Carvalho, 2008). Feeding associations may include a substantial number and diversity of organisms and foraging tactics, including what it is called nuclear-follower association (Leitão *et al.*, 2007; Teresa & Carvalho, 2008; Garrone Neto & Sazima, 2009; Teresa *et al.*, 2011; Teresa *et al.*, 2014).

This association is characterized by the relationship of an individual or a group of scavenger fish which disturb the substrate when exploring it for food, while one or more opportunistic species feed on small animals and nutrients dislocated in the water column through active foraging (Teresa & Carvalho, 2008; Garrone-Neto & Sazima, 2009; Teresa *et al.*, 2014).

Thus, some species of fish that feed on benthic prey or organic matter deposited in the bottom, often associate with other fish species that actively stir the substrate (Strand, 1988; Lukoschek & McCormick, 2000; Teresa & Carvalho, 2008; Teresa *et al.*, 2014).

This type of association has been broadly described in marine environments (Dubin, 1982; Strand, 1988; Santos & Castro, 2003; Sazima & Grossman, 2005; Bshary *et al.*, 2006; Sazima *et al.*, 2006; Sazima *et al.*, 2007; Gibran, 2007; Luiz *et al.*, 2008; Araújo *et al.*, 2009; Maia-Nogueira *et al.*, 2009; Craig & Erisman, 2010; Pereira *et al.*, 2012; Quimbayo *et al.*, 2014), on a smaller scale in neotropical freshwater environments that provide conditions for subaquatic observations (e.g., Kocher & McKaye, 1983; Sazima, 1986; Baker & Foster, 1994; Casatti & Castro, 1998; Sabino & Zuanon, 1998; Sabino, 1999; Carvalho *et al.*, 2003; Leitão *et al.*, 2007; Teresa & Carvalho, 2008; Garrone Neto & Sazima, 2009; Teresa *et al.*, 2011; Sabino *et al.*, 2017).

This study aimed to describe the nuclear-follower interaction observed between *Corydoras vittatus* Nijssen, 1971, *Corydoras cf. julii* and *Knodus victoriae* (Steindachner, 1907), the first record of ecological interactions between freshwater species in the Mirador State Park, in Maranhão state.

MATERIAL AND METHODS

The subaquatic record of the interaction nuclear-follower interaction was conducted in the Itapecuru river, in a stretch that runs through the Mirador State Park, located in the mid-southern region of the Maranhão state (Figure 1). This state park is a domain of the Cerrado biome, with geographic formations of plateaus and chapadas, corresponding to the largest conservation unit in the state (Conceição & Castro, 2009).

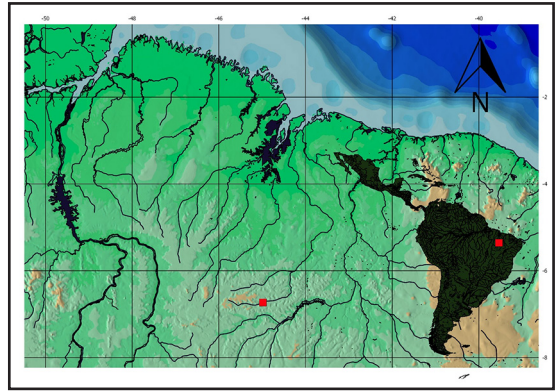


Figure 1. The study site in the Itapecuru river - Maranhão state, northeastern Brazil marked in red.

Our study area exhibit typical characteristics of a headwater region, with rapids, a deep-narrowed bed, sandy bottom, crystalline waters and banks with preserved ciliary forest. Information on the nuclear-follower behavior was obtained through subaquatic photographs and videos using the method *ad libitum*. Free dives was conducted in December of 2011, during the afternoon, in a location that was up to 1.5 m deep and close to the shore for a period of three hours for two consecutive days.

RESULTS

Photographs and videos recorded the nuclear-follower behavior for *Corydoras vittatus* and *Corydoras cf. julii* which were observed foraging by themselves or in groups of up to three individuals. The behavior was characterized by animals revolving the substrate with (a) their pectoral fins in rapid beats, (b) their bodies close to the bottom and (c) digging with their snouts, leading to sediment suspension and the formation of a “cloud” of particles. During this set of behaviors, the animals were closely followed by individuals or groups of up to ten fishes *Knodus victoriae*, that took advantage of the fragments and food remains suspended in the water column by the foraging activity of the catfishes (Figure 2).

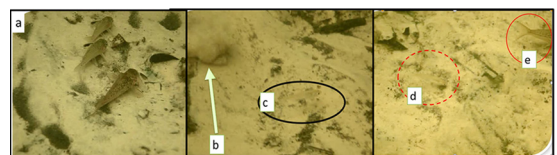


Figure 2. Records of nuclear-follower association. A) *Corydoras vittatus* and *Corydoras cf. julii* on feeding activity. B) sediment suspension. C) *Knodus victoriae* a follower. D) *Corydoras vittatus*.

DISCUSSION

The ability to disturb the substrate is one of the main indicators of a nuclear species (Strand, 1988; Sazima *et al.*, 2007). On the other hand, according to these authors, there are not, apparently, any other behavioral components that could predict the chances of a species to act as a follower (Sazima *et al.*, 2007), but a common trait in species that act as followers is the ability of immediately being able to respond to perturbations in the bottom.

Characidae are known for exhibiting opportunistic foraging behavior (Sazima, 1986, Teresa & Carvalho, 2008), with even minor substrate movements (stones rolling, fruits and branches falling or divers) attracting their attention (pers obs. Guimarães, E. C.).

Regarding nuclear-follower interactions between Callichthyidae (nuclear) and Characidae (follower), this type of association was already reported by Sazima, 1986 between *Corydoras polystictus* (Regan 1912) and *Astyanax bimaculatus* (Linnaeus 1758) in a foraging activity at a lagoon in the Pantanal, as well as by Teresa & Carvalho (2008) in a record between *Aspidoras fuscoguttatus* (Nijssen & Isbrücker, 1976), as a nuclear species, and *Knodus moenkhausii* (Eigenmann & Kennedy 1903), *Poecilia reticulata* (Peters 1859) and *Astyanax altiparanae* (Garutti & Britski 2000) as followers in a headwater stream, in the high portion of Paraná River. Both studies corroborates our findings, where Callichthyidae individuals disturbing the substrate during foraging, promoting sediment suspension while followers move through the “cloud” of particles in suspension, capturing food items. Particles in suspension do not seem to be used by Callichthyidae but are made available to Characidae.

It seems that the follower behavior presents an alternative feeding strategy for these species, reinforcing the general idea of behavioral plasticity of Characidae species (Sazima, 1986, Teresa & Carvalho, 2008) as well as species from other families (Baker & Foster, 1994; Casatti & Castro, 1998; Sabino & Zuanon, 1998; Sabino, 1999; Carvalho *et al.*, 2003; Leitão *et al.*, 2007; Teresa & Carvalho, 2008; Garrone Neto & Sazima, 2009; Teresa *et al.*, 2011).

This is the first report of such behavior being performed by *Knodus victoriae* following *Corydoras vittatus* and *Corydoras cf. julii*. Such discovery is an important addition to our knowledge on the behavior of this particular species and, in a larger scale, on the feeding dynamics on freshwater environments, mainly on the Maranhão state.

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