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Scientific Note

Feeding association between benthic and nektonic Neotropical stream fishes

Fabrício Barreto Teresa[1] and Fernando Rogério Carvalho[2]

Following behaviour among Neotropical stream fishes have been scarcely reported. This type of feeding association was observed in a small stream in the upper rio Paraná system between the catfish, *Aspidoras fuscoguttatus*, acting as a nuclear species, and *Knodus moenkhausii, Poecilia reticulata,* and *Astyanax altiparanae* as follower species. *Aspidoras fuscoguttatus* individuals dug in the bottom during feeding, causing sediment suspension. Their followers picked food items in the "cloud" of suspended particles. Food items of sediment are no longer consumed by the catfish when in suspension, but are still available for *K. moenkhausii, P. reticulata* and *A. altiparanae*. Following behaviour is an alternative feeding tactic for these species, which reinforces the general idea of behavioural plasticity among follower species.

A interação nuclear-seguidor tem sido raramente registrada entre peixes de riachos Neotropicais. Este tipo de associação foi observada em um riacho de cabeceira, no sistema do Alto rio Paraná envolvendo o cascudinho, *Aspidoras fuscoguttatus,* como espécie nuclear, e *Knodus moenkhausii, Poecilia reticulata* e *Astyanax altiparanae* como seus seguidores. Indivíduos de *Aspidoras fuscoguttatus* 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 particulas alimentares em suspensão parecem não ser utilizadas pelo cascudinho, mas tornam-se disponíveis para *K. moenkhausii, P. reticulata* e *A. altiparanae*. O comportamento de seguidor representa uma tática alimentar alternativa para estas espécies, reforçando a idéia geral de plasticidade comportamental entre as espécies seguidoras.

Key words: *Aspidoras fuscoguttatus*, Feeding strategies, Interspecific interaction, Following behaviour, Southeastern Brazil.

Interspecific feeding associations have been widely reported for animal communities (Glander, 1979; Keenleyside, 1979). A peculiar kind of association includes species that dig in or inspect the bottom (nuclear species) usually during foraging activities and follower species, which escort nuclear species in order to pick the food items the latter make available (Strand, 1988). This kind of association has been widely described in marine environments (Dubin, 1982; Strand, 1988; Sazima & Grossman, 2005; Sazima *et al*., 2006), but scarcely reported in freshwater communities (e.g. Kocher & McKaye, 1983; Sazima, 1986; Baker & Foster, 1994; Leitão *et al*., 2007).

In this study, we recorded a feeding association among four fish species in a Neotropical stream, including the catfish *Aspidoras fuscoguttatus* Nijssen & Isbrücker, 1976 as nuclear species, the characins *Astyanax altiparanae* Garutti & Britski, 2000 and *Knodus moenkhausii* (Eigenmann & Kennedy, 1903) and the guppy *Poecilia reticulata* Peters, 1859 as follower species.

Observations were made during the daytime, in October 2006 and February 2007, in a first order stream stretch (5 m long, 2 m wide, 0.25 m mean depth, and sandy bottom). The stretch is located in Vitória Brasil municipality, 20º10'5.7''S, 50º29'49.9''W, Northwestern São Paulo State, upper rio Paraná system, Brazil. The stream runs in a pasture matrix, with banks covered by herbaceous vegetation (Poaceae and Cyperaceae). Its clear waters enable fish observation from stream margins, and therefore underwater observations were unnecessary.

[1]UNESP - Universidade Estadual Paulista, IBILCE - Instituto de Biociências, Letras e Ciências Exatas, Laboratório de Ictiologia, Departamento de Zoologia e Botânica. Rua Cristóvão Colombo, 2265, 15054-000 São José do Rio Preto, São Paulo, Brazil. fabricioteresa@yahoo.com.br
[2]UFRGS - Universidade Federal do Rio Grande do Sul, IB - Instituto de Biociências, Laboratório de Ictiologia, Departamento de Zoologia. Avenida Bento Gonçalves, 9500, bloco IV, prédio 43435, 91501-970 Porto Alegre, Rio Grande do Sul, Brazil. frcarvalho2004@yahoo.com.br

In order to describe qualitatively the general pattern of the interaction a total of 240 minutes of ad libitum observations (Lehner, 1996) was performed. For obtaining quantitative data of the catfish activity pattern and for further details on the interaction, the behaviour of *A. fuscoguttatus* was video-recorded continuously and analyzed later according to the focal animal observation method (Lehner, 1996), with four minutes per replicate, n = 5, size of individuals approximately 26 mm TL. We compared the catfish proportion of time being followed (considering just period spent digging the bottom) by each follower species by using Kruskal Wallis Test complemented by Dunn. Moreover, to evaluate the relationship between catfish feeding activities and follower behaviour, time spent by *A. fuscoguttatus* when disturbing the bottom and total time spent by follower species following catfish, was analyzed by using Spearman correlation test. Voucher specimens of all species were deposited in the fish collection of Departamento de Zoologia e Botânica, IBILCE/UNESP (DZSJRP): DZSJRP 4877 - *Aspidoras fuscoguttatus*; DZSJRP 5023 - *Astyanax altiparanae*; DZSJRP 5025 - *Knodus moenkhausii*; DZSJRP 4879 - *Poecilia reticulata*.

Aspidoras fuscoguttatus dug in the bottom for 42.58 ± 24.12% of the total time of observation sessions. During this period, individuals moved in an oblique position (30 degree angle from the bottom) digging with its snout and therefore causing sediment suspension. *Knodus moenkhausii*, *P. reticulata*, and *A. altiparanae* followed *A. fuscoguttatus* during its foraging activity and picked particles amidst the sediment "cloud" (Fig. 1). The follower species moved away from *A. fuscoguttatus* as soon as it stopped digging in the stream bottom.

Aspidoras fuscoguttatus was followed by *K. moenkhausii* and *P. reticulata* for 30.32 ± 25.61% and 19.41 ± 10.43%, respectively, of the time the former spent in digging. *Astyanax altiparanae* behaved as a follower in only two of the five replicates and for a shorter period of time, or 1.11 ± 2.19% ($p < 0.05$). Moreover, a positive correlation was obtained between *A. fuscoguttatus* time involved in foraging activities and the following time of *K. moenkhausii* and *P. reticulata* (Spearman Correlation, $p = 0.05$ and $r = 0.87$; $p = 0.04$ and $r = 0.9$, respectively).

Similar to the feeding pattern of other Callichthyidae species (Sazima, 1986; Aranha *et al.*, 1998), *A. fuscoguttatus* is a "grubber" (*sensu* Keenleyside, 1979; Sazima, 1986) whose foraging activity involves inspecting the bottom with tactile barbels. The diet of *A. fuscoguttatus* consists primarily of benthic larvae of Chironomidae and Simuliidae (Veronezi-Jr, pers. comm.). Other items abundantly found in the bottom are debris and plant fragments. While digging in the stream bottom, individuals of *A. fuscoguttatus* probably make these food items available for other species. The followers diet also include food items often found in the bottom, mainly insect larvae (Dussault & Kramer, 1981; Castro & Casatti, 1997; Ceneviva-Bastos & Casatti, 2007), and these species can benefit from their association with *A. fuscoguttatus* which may facilitate their access to these food items. In spite of similarities between the diets of follower and nuclear species (i.e. benthic items), they differ in their ways to obtain food. Food items of sediment are no longer consumed by the catfish when in suspension but they are still available for these follower species.

Low population density of *A. altiparanae* in the study site (pers. obs.) may partially explain why it was not often recorded as a follower as the other species were. Additionally, the shorter time that *A. altiparanae* behaved as a follower, when compared to the other follower species, can be explained by the fact that whenever *A. altiparanae* approached *A. fuscoguttatus* the latter immediately moved away, suggesting that this interaction is avoided by the nuclear species. *Astyanax altiparanae* is the largest follower species observed in this study site (approximately twice the *A. fuscoguttatus* size). When it approaches the catfish it can be misinterpreted as a predator and therefore, elicit an escape response by the nuclear species. Considering that the catfish's sight can be little developed as in some siluriform species (Todd *et al.,* 1967), the immediate differentiation be-

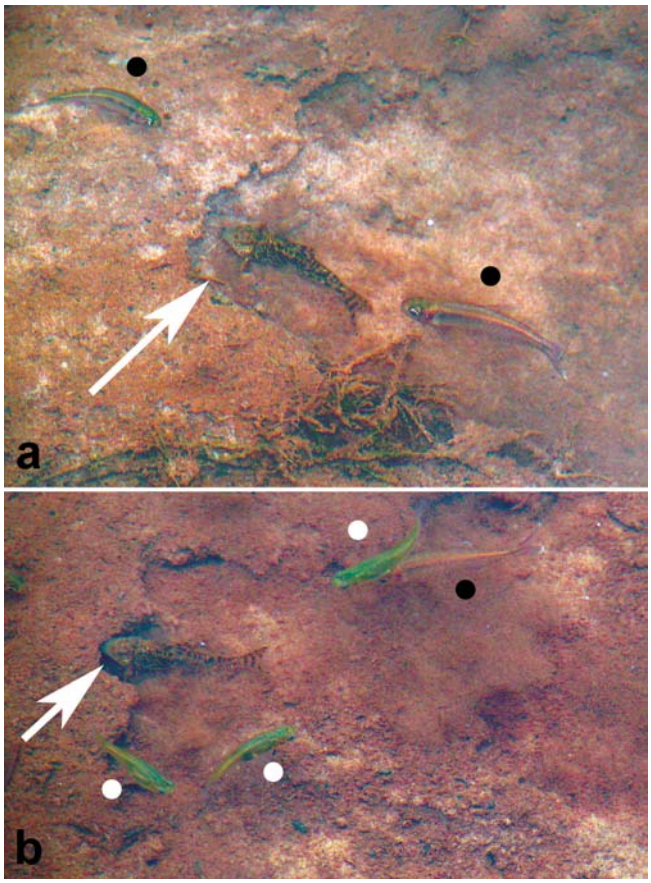

Fig. 1. *Aspidoras fuscoguttatus* (arrows) disturbing the bottom while followed by (a) two specimens of *Knodus moenkhausii* (black spots) and (b) one specimen of *Knodus moenkhausii* (black spot) and three *Poecilia reticulata* individuals (white spots).

tween predator and non-predator by the nuclear species could be difficult. Therefore, escape due to stimulus caused by the presence of a larger animal can be a general response that ultimately diminishes the role of large animals as followers when associating with some catfishes or other poorly sighted species.

Bottom disturbance during feeding or moving is one of the most important indicators to characterize a nuclear species (Strand, 1988; Sazima *et al*., 2006). According to these authors, followers immediately respond to bottom disturbances. It was also found in this study for *Knodus moenkhausii* and *Poecilia reticulata*, as can be observed for the correlation results. Soft bottoms, largely available in silted streams of the Northwestern São Paulo state, upper rio Paraná system, favour sediment suspension, which in turn, instigates following behaviour.

Capacity in using available resources may be essential in order to guarantee survival in degraded environments, such as study site, mainly when usual resources are scarce (Baker & Foster, 1994). *Poecilia reticulata*, *K. moenkhausii* and *A. altiparanae,* are the most abundant species in this region (Castro *et al.,* 2005; Casatti *et al.,* 2006) which is possibly related to their phenotypic plasticity and opportunism (Dussault & Kramer, 1981; Casatti *et al.,* 2006; Ceneviva-Bastos & Casatti, 2007). In this context, following behaviour is an alternative feeding tactic for these species, which reinforces the general idea of behavioural plasticity among follower species (Baker & Foster, 1994; Leitão *et al.,* 2007).

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