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# Small fishes follow large mammals suspending sediment

## Pequeños peces siguen a grandes mamíferos que suspenden sedimento

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Foraging interaction is one of the most interesting issues in trophic ecology. Species with different evolutionary histories interact to explore resources with vantages to both, one, or none. Trophic interactions provide examples of ecological and evolutionary adaptations between species to explore resources efficiently (Arditi & Ginzburg 2012). These interactions act not only in the populations of the interacting species, but may also affect the community and ecosystem functioning (Montoya et al. 2006).

The nuclear-follower interaction involves a nuclear species, that dig in or disturb the substrate bottom, and a follower species that capture food items that became available by the activity of the former (Strand 1988). In marine environments, nuclear-follower interactions are largely reported and are considered strongly associated with community assembly (Strand 1988, Lukoschek & McCormick 2000, Sazima et al. 2007). In freshwater environments foraging interactions are poorly known. Most studies have focused in describing the behavioral and natural history of interacting species, an important step to future ecological approaches (Ricklefs 2012). The number of nuclear-follower interaction records has grown in the last decades, especially those reporting the interaction between fish species (Baker & Foster 1994, Leitão et al. 2007, Teresa & Carvalho 2008, Garrone-Neto & Sazima 2009, Garrone-Neto & Carvalho 2011, Teresa et al. 2011). Here I report the first case of how two large mammals, the tapir *Tapirus terrestris* (Linnaeus, 1758) and the giant otter *Pteronura brasiliensis* (Gmelin, 1788), act as nuclear species to follower fishes in a clear-water Brazilian stream.

The Rio Sucuri (21º15'58.3" S, 56º33'30.6" W) is a clear-water stream in the Bodoquena Plateau, Bonito city, Brazil. The water transparence allows up to 20 m of underwater visibility, and touristic activities explore this potential by observing the high underwater biodiversity. This stream is around 1800 m of extent, with 5-20 m of width and 0.5 to 2 m of depth. A rich diversity and abundance of aquatic vegetation can be observed along the stream extension. Some of the plant species, as *Gomphrena elegans* Mart., *Ludwigia peruviana* (L.) H.Hara and *Helanthium bolivianum* (Rusby) Lehtonen & Myllys, are an important source of microhabitats and food for fishes. Floating macrophytes (especially *G. elegans*) occur on the margins of Rio Sucuri in most of its extension. The substrate is mainly composed of sand, but clay, rocks, trunks and mollusk shells are also representative.

The observations occurred during the monitoring of the ichthyofauna of Sucuri River. Monthly in 2011 and in January, March and June, 2012, I performed the subaquatic observations using a snorkel and a dive mask. I observed along 1600 m of the Rio Sucuri in the morning (7:30-9:00) and afternoon (15:00-16:30), totaling 45 hours of sampling. This transect includes the longitudinal gradient of depths and substrate composition of Rio Sucuri. During the record of subaquatic activity of a large mammal, I followed the Ad libitum rules throughout the observation sessions of mammal and fish behavior (Martin & Bateson 1986). Fishes were identified in situ or through the recorded pictures (Fujifilm XP30). Additionally, I performed observation sessions of the behavior of fishes when large mammals were not present.

I observed a total of six nuclear-follower interactions. The nuclear species were tapirs (*Tapirus terrestres*) and giant otters (*Pteronura brasiliensis*).

In two different occasions, March and June of 2012, I observed a female tapir (*Tapirus terrestres*) leaving the riparian vegetation and crossing the river (Figure 1A). Both observations were early in the afternoon and in the same site. Certainly, the same individual was recorded in two occasions, once this female has a scar on the back. In one of the occasions, the female was accompanied by a young tapir. The tapirs sank about 1.5 m and walked on the bottom of Rio Sucuri stream for approximately 15 m for about one minute, and emerged out of the water, going to the other side of riparian vegetation. The life area of this tapir probably includes the riparian vegetation of Rio Sucuri stream, once local habitants frequently observe this female crossing the River. During this underwater walk, the tapir suspends a cloud of sediment (Fig. 1A).

Giant otters (*Pteronura brasiliensis*) were observed foraging on the bottom of stream for four times. The individuals were foraging alone in all occasions. The giant others were foraging three different strategies could be observed: i) turning rocks (Fig. 1B, observed in August 2011 around 9:00 AM), ii) scraping submerged wood (observed in September 2011 around 10:00 AM), and iii) digging in the substrate bottom (Fig. 1C, observed in November 2011 and March 2012 around 1:00 PM). These microhabitats (fissures on rocks and wood, and holes in the clay) are usually explored by catfishes *Hypostomus* spp., which are potential prey items to giant otters. Giant otters swim quickly, stopping on rocks, logs or specific points on the substrate of the river looking for food for few seconds. In all observations the otters were unsuccessful to find food, but the physical action of foraging suspended sediment from the river bottom.

The cloud of suspended sediment caused by the activity of the two large mammals makes food items available to small-sized fishes, which come out from their microhabitats in clusters of macrophytes to capture food. Both the tapir and giant otter acted as nuclear species, and in all the six nuclear-follower interactions I observed seven follower species of fish: *Astyanax asuncionensis* Géry, 1972,


*Fig. 1:* (A) The tapir *Tapirus terrestris* suspending a cloud of sediments while cross the Rio Sucuri stream; (B) The giant otter *Pteronura brasiliensis* wambling rocks on the substrate bottom; (C) The giant otter *P. brasiliensis* digging the stream bottom.

(A) El tapir *Tapirus terrestris* suspendiendo una nube de sedimentos cuando cruza el Río Sucuri; (B) El arirai *Pteronura brasiliensis* rodando piedras em el lecho del río; (C) El arirai *P. brasiliensis* cavando el fondo del río.

*Astyanax* sp., *Bryconops* cf. *melanurus* (Bloch, 1794), *Hyphessobrycon eques* (Steindachner, 1882), *Jupiaba acanthogaster* (Eigenmann, 1911), *Moenkhausia bonita* Benine, Castro & Sabino, 2004 and *Serrapinnus calliurus* (Boulenger, 1900). All these species are small Characiformes abundant in Rio Sucuri, with maximum body size up 4.4 cm (*S. calliurus*) to 15 cm (*A. asuncionensis*) (Froese & Pauly 2012). Before dispersing the cloud of sediment, the fishes returned to the clusters of macrophytes.

All seven fish species do not depend exclusively on nuclear-following behavior to forage. Individuals of *B.* cf. *melanurus* forage chiefly on allochthonous items on water surface, but also capture food items carried by the water. *Astyanax asuncionensis* use the substrate bottom, the water column and surface as well, capturing invertebrates and plant fragments. Individuals of *H. eques* forage on the sand bottom or in submerged plants. The other four species (*J. acanthogaster*, *M. bonita*, *S. calliurus* and *Astyanax* sp.) are strongly associated with macrophytes, foraging on roots and submerged leaves. Thus, the following-nuclear behavior seems to be occasional for all seven species, and associated with the generalist and opportunistic feeding habits of fish follower species (Lowe-McConnel 1987, Baker & Foster 1994).

The benthic fauna of Rio Sucuri and other streams from the Bodoquena Plateau exhibit a great diversity of invertebrates, mainly Gastropoda; Diptera, Odonata, Trichoptera larvaes; and Amphipod (Maia 2005). Besides, the riparian vegetation provides a source of organic matter, so that plant fragments and debris are deposited on streams bottom. The stream bottom resources are potential food items to small-sized fishes, however they might be difficult to capture for being usually associated with grains of sand. Furthermore, benthic invertebrates and plant debis are not available in macrophyte clusters or open water. The occasional physical activity of large mammals makes these additional food resources available. The clear-water, with high transparency, allows visually oriented fishes to find these resources more easily, even in the middle of sediment cloud.

Massive trampling on streams bottom, such as those caused by the cattle ranching, might lead to changes in the abiotic conditions, microhabitats simplification and decrease of resources availability to fishes (Kauffman & Krueger 1984, Strand & Merritt 1999, Gregory & Gamett 2009). However, occasional trampling or bottom digging may promote a temporary food source, by suspending small invertebrates, plant and algae that are often unavailable to small fish species. Additionally, the input of resources associated with occasional disturbs in streams may increase local diversity through a release in competition (Resh et al. 1988). Other potential advantage associated with the occasional disturb related to tapir and giant otter activities, is the appearance of new microhabitat sites. Sporadic wambling of rocks and trunks on river bottoms may promote new microhabitats to fishes and invertebrates. As such, underwater activities of tapirs and giant otters seem to be an important trophic event to several species of small fishes.

The subaquatic activities of large mammals are rare and fishes apparently do not depend exclusively on the released resources. Thus, this trophic interaction might be weak and purely occasional. However, the ecological role of large mammals as nuclear species to small follower fishes should be studied further, once a high diversity of small fish takes advantage of the resources available occasionally.

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