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Short Communication

The surprising "B-side": description of a new foraging tactic for the pearl cichlid, *Geophagus brasiliensis*, in a coastal stream of the Atlantic Forest

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Abstract: A new foraging tactic for the pearl cichlid, *Geophagus brasiliensis*, is described from underwater observations performed in a coastal stream of the Atlantic Forest, Southeastern Brazil. Named "shift picking", the foraging tactic involved the manoeuvering of leaves, wood twigs and tree bark present in the substrate, with fish using its mouth to turn objects and uncover macroinvertebrates adhered to the underside of the object being picked ("B-side"). The object-shifting behaviour is rarely reported for fish and the present description seems to be the first record for a freshwater species of South America.
Keywords: *foraging behaviour; fish ecology; naturalistic studies; Cichlidae; Atlantic Forest.*

O surpreendente "lado-B": descrição de uma nova tática de forrageamento para o acará, *Geophagus brasiliensis*, em um riacho costeiro da Mata Atlântica

Resumo: Uma nova tática de forrageamento do acará, *Geophagus brasiliensis*, é descrita a partir de observações subaquáticas realizadas em um riacho costeiro da Mata Atlântica, Sudeste do Brasil. Chamada de "virar para pegar", a tática de forrageamento envolve o movimento de folhas, galhos e cascas de árvores presentes no substrato, com os peixes usando a boca para virar objetos e expor macroinvertebrados aderidos à parte de baixo dos objetos explorados ("lado B"). O comportamento de mover objetos é raramente relatado e o presente trabalho parece ser o primeiro registro para uma espécie de água doce da América do Sul.
Palavras-chave: *comportamento de forrageamento; ecologia de peixes; estudos naturalísticos; Cichlidae; Mata Atlântica.*

Introduction

The pearl cichlid, *Geophagus brasiliensis* (Quoy & Gaimard, 1824) (Perciformes, Cichlidae), is widely distributed along the coastal drainages of eastern and southern Brazil and Uruguay (Kullander 2003). This species inhabits the lentic habitats and shallow waters of rivers, streams, lakes, reservoirs and even brackish environments (Nunes et al. 2014). Presenting diurnal activity and visual orientation (Sabino & Castro 1990), *G. brasiliensis* feeds on a wide variety of items, preferring benthic resources such as molluscs, vascular plants, crustaceans, fish scales, insects, among others (Nomura & Carvalho 1972, Sabino & Castro 1990, Abelha & Goulart 2004). Its high trophic plasticity and opportunism allow the exploitation of different resources and this species is usually classified as an omnivore (Sabino & Castro 1990, Arcifa & Meschiatti 1993, Dias et al. 2004, Moraes et al. 2004, Gomiero & Braga 2008, Bastos et al. 2011), although differences in prey availability across study sites and conceptual approaches may lead *G. brasiliensis* to a variety of trophic preferences that include detritivory (e.g., Meschiatti 1995), insectivory (e.g., Ribeiro et al. 2014) or even benthivory (e.g., Nunes et al. 2014). However, the diversified foraging behaviour known for *G. brasiliensis* is usually based and inferred from the analysis of stomach contents, thus limiting the understanding of how occurs the ingestion of prey hidden under structures or adhered to objects such as leaves, wood twigs, and tree barks.

Few studies have provided information on the foraging behaviour of *G. brasiliensis* in the wild. Sabino & Castro (1990) observed this species in feeding activity during the day, obtaining food using the foraging tactic named "picking up substrate and sorting prey" (*sensu* Keenleyside

1979), that comprises the combination of the protrusion of the upper jaw with the opening of the operculum to separate the food items from the debris. This foraging behaviour in cichlids has been recently described as "sediment sifting", with several analyses of morphology and evolutionary process related to this strategy for the South American cichlids (see López-Fernández et al. 2012, 2014). Through this tactic, Sabino & Castro (1990) suggested that *G. brasiliensis* was able to excavate the sediment and feed on prey hidden in the substrate. Uieda (1995) also observed the use of this foraging tactic by *G. brasiliensis* and added "picking at relatively small prey" (*sensu* Keenleyside 1979) to the role of foraging tactics displayed by the species. This foraging tactic allowed the species to catch prey on the bottom rocks and classified *G. brasiliensis* as having an intermediate niche amplitude when compared to other two bottom omnivorous fishes which fed on insects (Uieda 1995). After that, no study attempted to refine the knowledge about the feeding behaviour of *G. brasiliensis* through a naturalistic approach, which highlights the need of studies to better understand how prey is selected and captured.

In this study we report a new foraging tactic for *G. brasiliensis*, presumably focusing on macroinvertebrates hidden under objects. We confronted our findings with the literature on the diet of the species, discussing how its morphological and behavioural characteristics can influence the capture of prey. Additionally, we searched for information about the behaviour of moving objects among freshwater fish, since this tactic seems to be rarely described or even uncommon worldwide.

Material and Methods

The study was performed in the Rio das Minas, a coastal stream located in Cananeia, a municipality of Southeastern Brazil that comprises a biodiversity hotspot with the largest remaining fragment of the Atlantic Forest ecosystem in the country (about 24°59'35"S, 48°07'31"W).

The underwater observations were made at day hours (10h00min-14h00min) while snorkelling (*cf.* Sabino 1999), during the dry season between April to August 2018. "Ad libitum" and "behaviour" sampling rules (Martin & Bateson 1986) were used throughout the observational sessions, mostly recorded on a plastic slate. Additionally, digital photographs and video records were taken to check visual observations, based on the methods presented by Sazima (1986) and Sabino (1999). Size estimates (total length in cm, TL) for *G. brasiliensis* were calibrated against objects of known size. Fish identification was done *in situ* during the underwater observations (following Oyakawa et al. 2006 and Oyakawa & Menezes 2011), without the need to capture the animals.

Results

During approximately ten hours of underwater observations, mostly at depths of 0.8 to 2.5 m, 19 individuals of *G. brasiliensis* (8-25 cm TL) were observed moving leaves, wood twigs and fragments of tree bark to uncover prey adhered to the underside ("B-side") of the object being picked (see Supplementary Material - Video). Named here as "shift picking", this foraging tactic started when fish were swimming under organic substrate until they encountered some object (mainly leaves). To turn it, the fish approach the object horizontally, pushing it forward with the mouth while performing movements with the caudal and pectoral fins (Figure 1a). Such movements were apparently stronger when objects were larger in relation to fish size, with fish moving the caudal fin faster than was observed while moving smallest objects. Once turned, the object had the "B-side" explored by the fish; in this case, with fish biting items sighted at the surface of the object, with the body horizontally positioned in relation to the substrate or slightly inclined forward (Figure 1b). Between a bite and another, the fish moved away from the object, swimming backwards and moving the head to the side, in an apparent attempt to spot other prey. The number of bites ranged from one to three per object, with fish performing buccal and opercular movements as described by Sabino & Castro (1990) and Drucker & Jensen (1991) while consuming the prey. The time spent by the fish to turn and examine on each object was about 30 seconds. There was no relationship between the use of "shift picking" and the current flow; however, the foraging tactic was only observed in fish present in lentic environments, such as mesohabitats formed by pools. Although sighted during the observation sessions in the shallower areas of the pools, individuals smaller than 8 cm TL were not observed using this foraging tactic.

Figure 1. *Geophagus brasiliensis* performing "shift picking". The individual on the right side approaches the object (tree bark), turning it with the mouth (a) to pick up a hidden prey (white arrow) (b).

Discussion

Neotropical communities of freshwater fish are characteristically rich in species and present complex interrelationships between its components (Lowe-McConnell 1987). Among these relationships, feeding strategies are known to involve morphological and behavioural specializations, such as cleaning, mimicry and social foraging associations and seem to involve several species of fish and invertebrates (see Sazima 1986 and Sabino et al. 2016 for overviews). However, the manoeuvering of object by freshwater fish (named as "object-shifting behaviour") seems to be uncommon and is poorly documented in the literature.

Available records show that some North American species of the genus *Percina* (family Percinidae) use their conical snout to flip gravel and feed on exposed invertebrates that may be unavailable to other benthic fish (Rosenberger & Angermeier 2003). According to Burkhead (1983) and Jenkins & Burkhead (1993), this behaviour seems to be associated with environments where the substrate is loosely embedded and should not be displayed by young individuals of *Percina* spp. (which live in shallower areas, over sandy substrate). Other records describe the "object-shifting behaviour" for cichlids in Central America (Wisenden et al. 1995 and references therein) and for the coal grunter, *Hephaestus carbo* (Ogilby & McCulloch, 1916) (Terapontidae), in northern Queensland, Australia (Ebner et al. 2018).

In the first case, the cichlids *Amatitlania nigrofasciata* (Günther, 1867), *Cribroheros alfari* (Meek, 1907) and *Cryptoheros panamensis* (Meek & Hildebrand, 1913) were considered as occasional users of two foraging tactics, "fin digging" and "leaf lifting", in an attempt to increase the availability of food for their fry (Wisenden et al. 1995). Sometimes non-breeding individuals of these species occasionally fin dig and leaf lift while foraging for themselves, but both acts appear to be performed more often by breeding pairs, especially when their young are free-swimming fry (Wisenden et al. 1995). In the second case, small (< 5 cm TL) to medium-sized individuals (5-15 cm TL) of *H. carbo* were observed using the mouth, snout and even the nape to lift, flip and roll benthic objects to feed on benthic macroinvertebrates (Ebner et al. 2018). Larger individuals (15-20 cm TL) of *H. carbo* were not observed performing "object-shifting behaviour", which may reflect the ontogenetic changes in the diet of the species, from the ingestion of benthic macroinvertebrates by juveniles to crustaceans, fishes and insects caught in the surface by adults, and/or be related to an effect of data collection (e.g., observer effect) (Ebner et al. 2018).

For *G. brasiliensis*, even though it has been described as an omnivore which consumes a wide range of food items, an analysis of the trophic interactions between the species and the community of benthic macroinvertebrates showed an important contribution of Chironomidae larvae (Diptera) in its diet when compared to other items, especially to debris (Nunes et al. 2014). These findings also suggested that the ingestion of debris and organic matter by *G. brasiliensis* seems to be more related to the selection of macroinvertebrates present in the substrate than to the intentional consumption of this type of item as cited by several studies (Nunes et al. 2014). Our observations of "object-shift behaviour" for *G. brasiliensis* agree with these findings and can help explain the high selectivity of macroinvertebrates (presumably insect larvae such as Chironomidae) by the species.

The non-observation of "shift picking" among individuals of smaller size (< 8 cm TL) may reflect ontogenetic changes in the diet and habitat utilization of *G. brasiliensis*. In the study area, individuals of smaller size preferentially inhabit shallower areas (0.5-0.8 m depth) with predominantly sandy and muddy bottoms, while medium and large-sized individuals (8-25 cm TL) prefer the deeper areas (0.8 to 2.5 m depth) where the foliage covers the bottom (G. R. S. Souza pers. obs.). Thus, the accumulation of allochthonous material allows the concentration of detritivorous invertebrates and may help predict the adoption of "shift picking" by *G. brasiliensis* in coastal streams. The description of this new foraging tactic highlights the importance of naturalistic studies for a better understanding of the way of life of fish in nature and reinforces the importance of the connection between fish and riparian forests in tropical environments. The "object-shifting behaviour" is still rarely reported in the literature for fish and the present description seems to be the first record for a freshwater species in South America.

Supplementary Material

The following online material is available for this article:
Video

Acknowledgments

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Author Contributions

Gabriel Raposo Silva de Souza: Substantial contributions to the conception and design of the work, contribution to data collection, contribution in the analysis and interpretation of data and contribution in the writing of the work.

José Sabino: Contribution in the analysis and interpretation of data, contribution in the writing of the work and contribution in critical review adding intellectual content.

Domingos Garrone-Neto: Substantial contribution to the idea and design of the work, contribution in analysis and interpretation of data, contribution in the writing of the work and contribution in critical review adding intellectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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