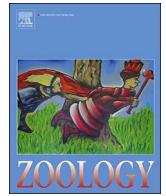




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Diversity out of simplicity: interaction behavior of land planarians with co-occurring invertebrates

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ABSTRACT

Land planarians have a simple anatomy and simple behavioral repertoire in relation to most bilaterian animals, which makes them adequate for the study of biological processes. In this study, we investigate the behavior of land planarians during interaction events with other invertebrates found in the same environment. We observed 16 different behavioral units, including seven different capture behaviors and three different prey ingestion behaviors. The capture behavior varied from very simple, such as simply covering the prey with the body, to more complex ones, including two forms of tube formation that are described for the first time. In general, the capture behaviors were similar among different predators but different for different prey. Similarly, prey ingestion type was more related to prey type than to predator species, with small soft prey being swallowed without fragmentation, large prey being crushed, and prey with a hard skeleton being perforated. Considering that land planarians face limitations due to their lack of efficient ways to retain water, thus being highly dependent on a moist environment, the set of behaviors shown by them in this study was considerably rich, especially concerning strategies to capture prey.

1. Introduction

In animals with simple anatomy and without social organization, behavioral strategies to obtain food and avoid predation are usually the most diversified and are strongly related to the organism's evolutionary history and anatomy, as well as to the ecological context in which it is found (Alcock, 2001; Whelan and Schmidt, 2007). Flatworms are considered simple animals and, just like their anatomy, their behavior is much simpler than that of other animals, such as mollusks, arthropods and vertebrates (Corning and Kelly, 1973; Sheiman and Tiras, 1996).

Various comments on the behavior and diet of land planarians as observed during collection and maintenance are presented in many publications focused on the description of new species since the group was discovered (Darwin, 1844; Moseley, 1877; Goetsch, 1933). Among the works on the behavior of land planarians, most are observations on their behavior in face of different stimuli (Lehnert, 1891; Kawaguti, 1932; Ogren, 1956) or, when directed to their predatory behavior, are focused on species that are invasive in the Northern hemisphere due to the threat they may present to ecosystems (Dindal, 1970; Zaborski, 2002; Fiore et al., 2004; Ducey et al., 2007; Sugiura, 2010).

Concerning the Neotropical region, Froehlich (1955) briefly described the predatory behavior of several native planarians. Later

studies gathered more detailed information on the predatory behavior of six native species (Hauser and Maurmann, 1959; Prasniski and Leal-Zanchet, 2009; Boll and Leal-Zanchet, 2015, 2016; Cseh et al., 2017) and one exotic species (Boll et al., 2015) common to human-disturbed areas. These works showed that these species feed on different invertebrates and presented data regarding the strategies used by those planarians to capture prey.

In order to increase the knowledge on predatory behaviors presented by land planarians and how they relate to co-occurring invertebrate species, we investigated the behavior of six species of Neotropical land planarians that have different diets during interaction events with other invertebrates found in the same environment. We aimed to verify whether the behaviors presented by these planarians are similar for different prey consumed by the same predator or similar for the same prey consumed by different predators.

2. Materials and methods

2.1. Capture and maintenance

We captured specimens of land planarians in the field in human-disturbed areas (HDA), as well as in different forest formations

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Fig. 1. The six land planarian species used in the experiments: (a) *Obama anthropophila*; (b) *Obama ficki*; (c) *Obama ladislavii*; (d) *Obama nungara*; (e) *Paraba multicolor*; (f) *Luteostriata abundans*. Anterior end of the planarians to the left. Scale bars = 10 mm.

belonging to the Atlantic Forest biome, viz. Araucaria Moist Forest (AMF), Subtropical Atlantic Forest (SAF), Deciduous Seasonal Forest (DSF) and Semi-Deciduous Seasonal Forest (SSF).

We selected the following six species (with their respective number of individuals (N) and areas of capture) according to their availability (Fig. 1): *Luteostriata abundans* (Graff, 1899) ($N = 30$; HDA, DSF, SSF); *Obama anthropophila* Amaral, Leal-Zanchet & Carbayo, 2015 ($N = 41$; HDA, AMF, DSF, SSF); *Obama ficki* (Amaral and Leal-Zanchet, 2012) ($N = 12$; SSF, DSF, AMF, SAF); *Obama ladislavii* (Graff, 1899) ($N = 27$; HDA, AMF, SAF, DSF); *Obama nungara* Carbayo, Álvarez-Presas, Jones & Riutort, 2016 ($N = 10$; HDA); and *Paraba multicolor* (Graff, 1899) ($N = 20$; HDA).

In the same localities, we captured other invertebrates in order to observe how the planarians interact with them (asterisks indicate exotic species): land gastropods – snails *Bradybaena similaris* (Férussac, 1821)* and *Helix aspersa* (O.F. Müller, 1774)*; slugs *Deroceras laeve* (O.F. Müller, 1774)*, *Meghimatium pictum* (Stolitzka, 1873)*, *Sarasinula plebeia* (P. Fischer, 1868) and *Belocaulis* sp.); earthworms *Eisenia andrei* Bouché, 1972*, *Metaphire schmardae* (Horst, 1883)* and *Amyntas gracilis* (Kinberg, 1867)*; land planarians – *Endeavouria septemlineata* (Hyman, 1939)* and *Dolichoplana carvalhoi* Corrêa, 1947*; woodlice – *Atlantoscia floridana* (van Name, 1940), *Balloniscus glaber* Araujo & Zardo, 1995, *Benthana cairensis* Skolowicz, Araujo & Boelter, 2008, *Porcellio scaber* Latreille, 1804* and *Armadillidium vulgare* Latreille, 1804*; harvestmen – *Discocyrtus* cf. *dilatatus* Sørensen, 1884, Gonyleptidae 1 and Gonyleptidae 2; termites – *Nasutitermes* sp., ants – *Camponotus* sp. and *Solenopsis* sp.; millipedes – *Rhinocricus* sp. 1,

Rhinocricus sp. 2. and *Obiricodesmus* sp.; and unidentified species of Hirudinea, Entomobryidae, Hypogastruridae, Blattodea, Dermaptera and larvae of Elateridae, Passalidae and Mycetophilidae.

In the laboratory, we maintained the specimens in small plastic terraria containing moist soil, leaves, and log fragments to simulate their natural environment. The terraria remained in the dark at a temperature ranging between 18 °C and 20 °C and a relative air humidity of about 90%.

We also tested the interaction of the four planarians of the genus *Obama* with each other and of *Luteostriata abundans* with the other five species. Interactions of *Paraba multicolor* with species of *Obama* were not included in the study because not enough specimens of *P. multicolor* were simultaneously available in the laboratory.

We made the observations reported herein simultaneously with the experiments reported in Boll and Leal-Zanchet (2016), where we presented the results related to the diet identified for each species.

2.2. Investigation of interactive behaviors

To record the behavior of the planarians when interacting with other invertebrates, we put one land planarian in a moistened Petri dish together with a specimen of another invertebrate species. We performed 15 repetitions with each invertebrate species for each planarian species, in random sequence, with intervals of three or four days between the experiments.

After recording the planarian's movements and postures in an empirical manner, we characterized the behavior in a functional manner

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