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Preference for different prey allows the coexistence of several land planarians in areas of the Atlantic Forest

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ABSTRACT

Land planarians are recognized as important predators, yet studies on their feeding habits are usually restricted to invasive species. Thus, it is difficult to determine the real ecological role of this group in ecosystems and how their communities are structured. In the present study, we analyzed the diet of six co-occurring Neotropical land planarians and their success in capturing prey, based on experiments in the laboratory, in order to determine how they share resources in the same environment. We also calculated indices of food niche breadth and food niche overlap for land planarians for the first time. The diet of *Luteostriata abundans* comprises only woodlice and the diets of *Obama ficki* and *Obama ladislavii* are composed only of gastropods, while *Paraba multicolor* and *Obama anthropophila* feed on both gastropods and other land planarians. An invasive species recently found in Western Europe, *Obama nungara*, showed the highest food niche breadth, feeding on gastropods, earthworms and planarians. We found the highest niche overlap between *O. anthropophila* and *P. multicolor*. The results suggest that land planarians are frequent predators of woodlice and land gastropods in the Neotropical ecozone and thus are important for the maintenance of native ecosystems and for the control of invasive species. The coexistence of several species in the same habitat is possible due to the use of different species as main prey, which reduces interspecific competition.

1. Introduction

Trophic interactions are an important factor affecting the structure of communities (Brännström et al., 2012) and the function of the ecosystem as a whole (Rodríguez-Lozano et al., 2015). Therefore, knowing a predator's life history is essential to understand the dynamics of ecosystems (Schmitz, 2007). Unfortunately, such information is still lacking for many important, yet neglected, predators, such as land planarians (Ogren, 1995; Sluys, 1999).

Land planarians are invertebrate predators having high species richness in the Neotropical Ecozone, especially in areas of the Atlantic Forest in Brazil. They are usually seen as top predators due to the limited number of species known to feed on them (Sluys, 1999). Vertebrates, for example, seem to find them unpalatable (Ducey et al., 1999). Their ecological importance as predators is highlighted by the impact caused by some invasive species on invertebrate populations in areas where they have been introduced (Boag and Yeates, 2001; Sugiura et al., 2006). Most studies on the feeding ecology of land planarians focus on those invasive species, as they may threaten ecosystems as well as human activities such as earthworm culture (Ogren, 1995; Winsor et al., 2004), and aim to understand their life history in order to assist in management programs (Ducey et al., 2007; Sugiura and Yamaura, 2009). Europe is a continent particularly affected by invasive land planarians, with several introduced species, most of them posing a threat to populations of earthworms (Santoro and Jones, 2001; Breugelmans et al., 2012; Murchie and Gordon, 2013; Álvarez-Presas et al., 2014).

Meanwhile, non-invasive species are usually neglected, making it difficult to ascertain their actual ecological role in ecosystems. For example, despite the high diversity of land planarians in the Neotropical region (Sluys, 1999), only two species, *Luteostriata abundans* and *Obama ladislavii*, had their feeding habits consistently examined (Prasniski and Leal-Zanchet, 2009; Boll and Leal-Zanchet, 2015), the first feeding on woodlice and the second on land gastropods. Assumptions on the diet of some other species are based on sporadic observations in the field or in the laboratory (Froehlich, 1955). This lack of knowledge on non-invasive species also limits the understanding of the phenotypic aspects that make invasive species successful, as there are no comparative parameters (Ducey et al., 2005).

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But apart from the diet of an organism, quantitative measures are important to understand the ecological significance of species in their environment. Measurements of food niche breadth and food niche overlap help to clarify the organism's impact on prey populations, its ability to withstand environmental changes and colonize new areas, and the potential competition with similar species (Krebs, 1999).

Competition is, in fact, a factor usually considered important for the structure of communities. Classical ecological theory predicts that species phylogenetically close to each other rarely share the same environment, as they have very similar niches, which leads to competitive exclusion (MacArthur and Levins, 1967). On the other hand, the concept of environmental filtering predicts that similar species will co-occur, as their similarities increase their probability of colonizing the same environments (Mayfield and Levine, 2010).

Land planarian communities in areas of the Atlantic Forest in Brazil contain species closely related to each other, as well as more distantly related ones, all occurring sympatrically (Amaral et al., 2014; Negrete et al., 2014). They almost exclusively inhabit the leaf litter layer, where they remain protected from dehydration, as they do not have water-retaining mechanisms (Sluys, 1998). Since their niche requirements remain almost completely unknown, it is not possible to determine whether interspecific competition is important in structuring their communities.

In the present work, based on experiments in the laboratory, we investigate the diet of six Neotropical land planarians indigenous to areas originally covered by Atlantic Forest, which show habitat overlap. We aimed to identify their prey, analyze their success in capturing different food items, and determine their food niche breadth and food niche overlap. As most land planarians inhabit the leaf litter layer, we predict that they avoid competition by specializing in, or showing preference for, different prey rather than by occupying different spatial layers in the environment.

2. Materials and methods

2.1. Capture and maintenance

We captured specimens of land planarians in the field and took them to the laboratory, where we kept them 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 and 20 °C and a relative air humidity of about 90%. We used terraria of four different sizes according to the size of the planarian maintained in each one: (1) 9 cm × 5.5 cm × 2.6 cm, for specimens less than 20 mm in length; (2) 13 cm × 6.6 cm × 3.5 cm or (3) 11.2 cm × 7.2 cm × 4 cm, for specimens between 20 and 100 mm in length; and (4) 15.5 cm × 10.7 cm × 6 cm for specimens more than 100 mm in length.

Planarians were captured in the state of Rio Grande do Sul, southern Brazil, in areas of different forest formations which belong to the Atlantic Forest biome, viz. Araucaria moist forest (AMF), subtropical Atlantic Forest (SAF), deciduous seasonal forest (DSF) and semi-deciduous seasonal forest (SSF), as well as human-disturbed areas (HDA).

We selected the following six species (N = number of individuals; areas of capture) according to their availability: *Luteostriata abundans* (N = 35; HDA, DSF, SSF); *Obama anthropophila* (N = 41; HDA, AMF, DSF, SSF); *Obama ficki* (N = 12; SSF, DSF, AMF, SAF); *Obama ladislavii* (N = 27; HDA, AMF, SAF, DSF); *Obama nungara* (N = 13; HDA); *Paraba multicolor* (N = 22; HDA). Fig. 1 shows a schematic overview of how the species co-occur.

We captured several other invertebrate species in the same areas in order to test them as potential prey. The following list presents the selected invertebrate prey species (asterisk indicates exotic species):

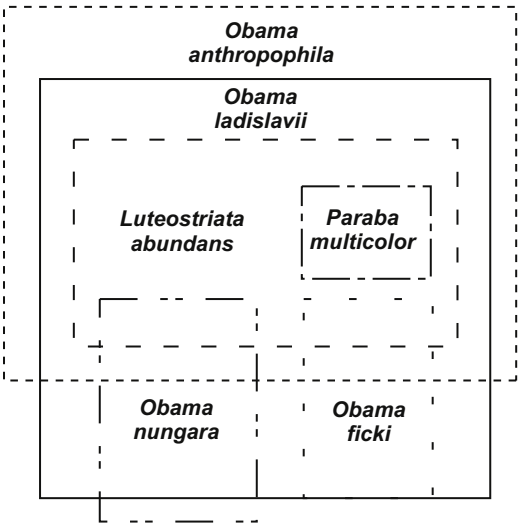

Fig. 1. Co-occurrence of six species of land planarians. Each rectangle represents one species. Overlapping rectangles indicate that the species may co-occur.

- land gastropods: snails *Bradybaena similaris** and *Helix aspersa**; slugs *Deroceras laeve**, *Sarasinula plebeia* and *Belocaulus* sp.;
- earthworms: *Eisenia andrei**, *Metaphire schmardae**, *Amynthas gracilis**;
- land planarians: *Endeavouria septemlineata**, *Dolichoplana carvalhoi**;
- woodlice: *Atlantoscia floridana*, *Balloniscus glaber*, *Benthana cairensis*, *Porcellio scaber**, *Armadillidium vulgare**;
- harvestmen: *Discocyrtus* cf. *dilatatus*, Gonyleptidae sp. 1, Gonyleptidae sp. 2;
- termites: *Nasutitermes* sp.;
- ants: *Camponotus* sp., *Solenopsis* sp.;
- millipedes: *Rhinocricus* sp. 1; *Rhinocricus* sp. 2., *Obiricodesmus* sp.;
- unidentified species of Hirudinea, Entomobryidae, Hypogastruridae, Blattaria, Dermaptera and larvae of Elateridae, Passalidae and Mycetophilidae;

We also offered the four planarian species of the genus *Obama* to each other, and *Luteostriata abundans* to the other five species.

2.2. Prey preference identification and capture success

For the identification of each planarian species' prey, we put one planarian and one other invertebrate together in a Petri dish under low diffuse daylight entering through a window. We covered the dish with its lid and let both the planarian and the other invertebrate move around freely until they contacted each other. If both specimens entered in a resting state in different places in the dish before contacting each other, we induced them to resume moving through the dish by slight touches with a soft brush. While left undisturbed, we observed the specimens continually from a distance of ca. 30 cm. We considered prey those species that the planarian captured and consumed. If the planarian did not capture and ingest the invertebrate inside the Petri dish, we left one individual of that invertebrate species in the terrarium with the planarian for three or four days in order to determine whether or not the planarian had rejected the invertebrate due to the artificial conditions of substrate and luminosity in the Petri dish.

We offered a different invertebrate to each planarian every three or four days. If the planarian consumed the invertebrate,