

Colonization and extinction of land planarians (Platyhelminthes, Tricladida) in a Brazilian Atlantic Forest regrowth remnant

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Abstract Long-term assessments of species assemblages are valuable tools for detecting species ecological preferences and their dispersal tracks, as well as for assessing the possible effects of alien species on native communities. Here we report a 50-year-long study on population dynamics of the four species of land flatworms (Platyhelminthes, Tricladida, Terricola) that have colonized or become extinct in a 70-year-old Atlantic Forest regrowth remnant through the period 1955–2006. On the one hand, the two initially most abundant species, which are native to the study site, *Notogynaphallia ernesti* and *Geoplana multicolor* have declined over decades and at present do not exist in the forest remnant. The extinction of these species is most likely related with their preference for open vegetation areas, which presently do not exist in the forest remnant. On the other hand, the neotropical Geoplaninae 1 and the exotic *Endeavouria septemlineata* were detected in

the forest only very recently. The long-term study allowed us to conclude that Geoplaninae 1 was introduced into the study area, although it is only known from the study site. *Endeavouria septemlineata*, an active predator of the exotic giant African snail, is originally known from Hawaii. This land flatworm species was observed repeatedly in Brazilian anthropogenic areas, and this is the first report of the species in relatively well preserved native forest, which may be evidence of an ongoing adaptive process. Monitoring of its geographic spread and its ecological role would be a good practice for preventing potential damaging effects, since it also feeds on native mollusk fauna, as we observed in lab conditions.

Keywords Free-living terrestrial flatworms · Neotropical · Native · Introduced and exotic species · Invasion · Urban forest

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Introduction

Some invasive species often remain initially unnoticed due to their cryptic habits (Müller and Griebeler 2002) or the lag-time preceding their expansion (Simberloff and Gibbons 2004). Short-term assessments have been shown to possibly be inadequate to describe ecological findings and the roles that exotic species play over time in the areas they invade (Strayer et al. 2006; Hobbie et al. 2003).

The geographical distribution of a few land flatworms (Platyhelminthes, Tricladida, Terricola) has been expanded throughout the globe by human mediation (Ducey et al. 2005). Studies on the introduction and dispersal of a few Australasian flatworm species raised concerns since they seem to affect soil ecosystems and may be responsible for the reduction of the diversity of invertebrate native fauna, where they may become pests (Fiore et al. 2004; Greenslade et al. 2007).

A number of native and a few exotic land planarian species are common in anthropogenic forests and gardens scattered in the city of São Paulo, Brazil. Here we focus on colonization and extinction events undergone by four land planarian species over 50 years in a Brazilian Atlantic forest regrowth remnant.

Material and methods

Study area

The municipality of São Paulo, Brazil has a well defined summer or rainy season and a very dry winter from May to September. The University campus “Armando de Salles Oliveira” belongs to the University of São Paulo, and is located 23°33' S and 46°43' W at 795 m altitude, inside the city. The campus is 417 ha, originally covered by dense Brazilian Atlantic ombrophilous forest. In the century XIX most of its area was occupied by settlement and grass field for cattle grazing, with a remained small valley covered with secondary forest. In the 1950s the area passed to be part of the University of São Paulo, where building and gardening initiatives began. At present, the area is occupied by buildings, gardens, a plant nursery, and a variety of non-native forests, with the exception of the small valley, the so-called Forest Reserve (locally, Reserva do Matão) which is a 70-year-old regrowth forest remnant with about 10 ha.

Field methods

In the period of 1955–1992, field-work was conducted by Froehlich et al. for faunistic inventory purposes. A total of 37 samples were randomly taken by 1–3 people

throughout the total extension of the Forest Reserve, without plotting, lasting from 30 min to 3 h. To assess the present habitat preference and species assemblage, three plots of $\sim 60 \text{ m}^2$ each were selected, two in the most central area of the Forest Reserve, where the oldest vegetation stands (plots 1 and 2) and a third one in the East edge of the Forest Reserve (plot 3). Twenty samples were taken (\sim twice a month) between September 2005 and March 2006. In each sampling session, land planarians were searched for during the day in each plot for 15 min. Animals were searched in situ for in the soil litter, and underneath and inside fallen logs and branches.

Results and discussion

We focus on the four species that have colonized or become extinct in the study site through the period 1955–2006 (Table 1). On the one hand, two species—*Notogynaphallia ernesti* Leal-Zanchet & EM Froehlich, 2006 and *Geoplana multicolor* Graff, 1899—were initially very abundant from 1955 until 1958, whereupon they were clearly in decline, and in 2005–2006 they were not observed in the Forest Reserve. On the other hand, *Geoplaninae 1* and *Endeavouria septemlineata* (Hyman, 1939) were observed only very recently (2005–2006). *Geoplaninae 1* is at present abundant, with most individuals found in the forest border (plot 3). The only sited individual of *E. septemlineata* was found in plot 2.

Local extinctions

Why did *Notogynaphallia ernesti* and *Geoplana multicolor* become extinct? The known records of *N. ernesti* date from the late 1940s. The species were observed mainly in open vegetation areas and gardens in the São Paulo town and other cities of the states of São Paulo and Paraná (Southern Brazil), where the species is still common, including the University campus. These registers suggest that it prefers open vegetation, as previously reported (Carbayo et al. 2002), and that its decline in the Forest Reserve could be caused by the progressive thickening of the forest.

Geoplana multicolor was also not observed recently in the Forest Reserve. However, differently from *N. ernesti*, it almost has disappeared from the University campus, where until the 1960s it was

Table 1 Number of samplings per year and abundance of the four species of land planarians (Platyhelminthes, Tricladida) studied in the forest reserve

Year	Number of samplings	<i>Notogynaphallia ernesti</i>	<i>Geoplana multicolor</i>	Geoplaninae 1	<i>Endeavouria septemlineata</i>	Number of individuals
1955	5	53	23	–	–	81
1956	3	12	10	–	–	25
1958	2	10	22	–	–	34
1961	1	–	–	–	–	1
1962	1	3	–	–	–	4
1963	1	1	1	–	–	3
1965	1	–	9	–	–	10
1969	1	1	–	–	–	2
1971	1	1	–	–	–	2
1972	1	–	–	–	–	1
1976	2	–	1	–	–	3
1977	11	1	–	–	–	12
1980	1	–	–	–	–	1
1985	2	1	–	–	–	3
1986	1	3	–	–	–	4
1987	1	–	–	–	–	1
1989	1	–	–	–	–	1
1992	1	1	1	–	–	3
2005–2006 (plot 1)	20	–	–	1	–	21
2005–2006 (plot 2)	20	–	–	2	1	23
2005–2006 (plot 3)	20	–	–	11	–	31
Number of individuals	–	87	67	14	1	169

abundant (up to 30 individuals were to be found in one day) in areas covered with bushes (EMF, pers. obs.). The causes for the extinction of *G. multicolor* in the Forest Reserve, and rarefaction in the University campus, could be related with its apparent preference for closed bushy environments, but it is not able to easily survive in gardened areas, nor inside mature and dense forests.

Local colonizations

Man-mediated dispersion of land planarians was related to transport of hardy plants or building materials (Hyman 1940; Christensen and Mather 1998). Geoplaninae 1 (Geoplanidae) and *Endeavouria septemlineata* (Geoplanidae, Caenoplaninae) were only observed in the Forest Reserve after 50 years of sampling. Both species have been introduced into the Forest Reserve, with man being their most likely vector.

Geoplaninae 1 belongs to the neotropical fauna and is only known to be present in the University campus. It was first seen in the plant nursery (1965, EMF, pers. obs.), where the species probably arrived to the campus through plant exchange. Since 1969, it has been repeatedly located in gardens around buildings in the campus. The species was found in the Forest Reserve very recently (in 2005–2006), and could be acclimating to the Forest Reserve after recent man-mediated introduction from the plant nursery located in the University campus. Although there is no track of its origin, this long-term study allowed us to detect the neotropical Geoplaninae 1 as an introduced species to the study site.

Endeavouria septemlineata is an exotic species, first described from Hawaii and also reported for Australia. In the University campus, it was recorded for the first time in 1986 in gardens around buildings with dense populations. In the existing plant nursery in the University campus it was first collected in

1989. It has been continuously present from the 1980s in the city of São Paulo (EMF, per. obs.), and it is found frequently in some parks and city waste lands of other Brazilian towns, Campo Grande (MS), Florianópolis (SC), Maquiné (RS), São Lourenço do Sul (RS) (EMF; FC, pers. obs.). The species is an active predator of the giant African snail *Achatina fulica* Bowdich in Hawaii (Mead 1963), and accordingly it accepted snails and smashed native slugs in laboratory conditions (FC and R. Araújo, per. obs.).

This is the first record of *E. septemlineata* inhabiting the Brazilian Atlantic ombrophilous forest, which may be evidence of an ongoing adaptive process. It raises concerns of its potential damaging effects on the local fauna on which it feeds, as reported for other land planarians elsewhere (Schrader and Unger 2003; Ducey et al. 2007).

Motivation to study invasions usually only arises after they have spread extensively, and only in species that already seem to be having an impact (Parker et al. 1999). It would be a good preventive practice to trace the evolution of the population of *E. septemlineata* in the Forest Reserve and to study potential interferences with the native fauna, especially its preys and species competitors for food resources.

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