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SHORT COMMUNICATION

Are leaf-litter frogs and lizards affected by edge effects due to forest fragmentation in Brazilian Atlantic forest?

Marianna Dixo* and Marcio Martins

Departamento de Ecologia, Instituto de Biociências, Universidade de São Paulo, Rua do Matão, Travessa 14 no. 321, 05508–090 São Paulo, SP, Brazil

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Edge effects encompass biotic and abiotic changes resulting from the interaction between two different habitat types (Murcia 1995). Edge habitats are ecologically distinct from patch interiors, and understanding how ecological patterns change near edges is important in understanding landscape-level dynamics such as the impacts of fragmentation (Ries *et al.* 2004). Abiotic conditions at the forest edge, such as increased wind and solar radiation, increased fluctuations in temperature, and decreased humidity, may affect forest-adapted organisms (Harper *et al.* 2005, Murcia 1995). So, edges may affect lizards and amphibians due to their physiological needs (Lehtinen *et al.* 2003, Vallan 2000). Anurans are considered sensitive to environmental changes due to their permeable skin, shell-less eggs and use of land as well as freshwater habitats (Vallan 2000). Changes in vegetation structure and microclimate are likely to be the predominant factor affecting amphibian abundances across edges (Jellinek *et al.* 2004, Marsh & Pearman 1997, Schaepfer & Gavin 2001, Urbina-Cardona *et al.* 2006).

Although forest edges have been considered one of the most extensively researched areas in ecology as an important consequence of fragmentation (Harper *et al.* 2005, Ries *et al.* 2004), there is no strong support for the importance of edge effects for amphibians and reptiles (Gardner *et al.* 2007). Here we present the first report on the response of leaf-litter frogs and lizards to edge effects at the Brazilian Atlantic rain forest. Our study was conducted in the Una Biological Reserve and surrounding areas. This region comprises one of the last remnants of Atlantic Forest left in eastern Brazil and it is the habitat of several endemic frogs (Canedo *et al.* 2004, Dixo 2004) and lizards (Rodrigues *et al.* 2002, 2007). It is important to understand how leaf-litter frogs and lizards of Atlantic rain forest respond to edge effects, given that habitat destruction and fragmentation are probably the most important causes of their current decline (Blaustein *et al.* 1994, Young *et al.* 2001).

The forest of Una is classified as tropical lowland rain forest (Oliveira-Filho & Fontes 2000). Mean annual temperature is 24 °C and the rainfall averages 1500 mm y^{-1}, with no marked seasonality, although a rainless period of 1–3 mo may occur from December to March (Mori *et al.* 1981). The studied landscape (14 300 ha) is composed primarily of a mosaic of forests in different successional stages, with nearly 50% of the land cover comprising mature forest fragments and an additional 16% of early secondary forests (Pardini 2004).

We conducted our study in three replicated blocks of 3600 ha (Figure in Pardini 2004) in the Una landscape to reduce the influence of covariates that were not considered (e.g. block-wise variability in soil, relief, etc). In each block, four replicates of edges and four replicates of forest interior were sampled, resulting in a total of 24 sample sites. The interior sites were sampled at least 200 m from the edge with an open area edge (mainly pastures), whereas the edge sites were less than 20 m from the open area, where the edge effects should be more severe.

Leaf-litter frogs and lizards were sampled with pitfall traps with drift fences (Cechin & Martins 2000). At each sample site, pitfall traps containing twelve 35-litre plastic buckets were installed along a transect parallel to forest edge. The buckets were connected by an 8-m long, 50-cm high fence. From October 1999 to February 2000 (rainy season) each sampling transect was sampled twice, for 12 consecutive days each, resulting in an effort of 288 bucket-days per sampling site, and a total sampling effort of 6912 bucket-days considering all 24 sites. Some specimens were collected for identification and vouchers were deposited at the Museu de Zoologia da Universidade

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* Corresponding author. Email: mariannadixo@yahoo.com.br

de São Paulo (MZUSP) and Museu Nacional (MNRJ). Here we follow frog and lizard nomenclature of Amphibian Species of the World, version 5.1 (http://research.amnh.org/herpetology/amphibia/index.php) and Uetz *et al.* (2007), respectively. Except for voucher specimens, frogs and lizards captured in pitfall traps were marked by toe clipping (Donnelly *et al.* 1994) and released.

The vegetation structure of all sampling sites was described by the RestaUna project using physical and biological environmental variables related to vegetation cover (R.G. Montigelli, unpubl. data). This analysis showed that the frequency of pioneer species, grasses and trees with diameter at breast height (dbh) between 5–10 cm were the variables that define edge areas, while forest interiors had a greater canopy cover and a greater basal area.

We calculated richness (number of species), abundance (number of individuals) and diversity (Shannon's diversity index) for each sampling unit. Two-way analysis of variance (two-way ANOVA) was used to investigate whether species richness, total abundance, diversity and abundance of selected species of leaf-litter herpetofauna differed between the two combinations of habitats (forest interiors vs. edges) and the landscape blocks (block 1, block 2 and block 3), and to search for possible interactions between these two factors (habitats vs. blocks). Data were tested for homogeneity of variance (Levene test). Differences were considered to be statistically significant at $P < 0.05$.

Overall, we captured 2229 individuals of 28 species, 302 lizards (13 species) and 1927 frogs (15 species). The richness (R), total abundance (A) and diversity (H') of leaf-litter lizards (R: $F_{(1, 18)} = 1.37$, $P = 0.256$; A: $F_{(1, 18)} = 0.67$, $P = 0.425$; H': $F_{(1, 18)} = 0.05$, $P = 0.819$), and frogs (R: $F_{(1, 18)} = 0.04$, $P = 0.849$; A: $F_{(1, 18)} = 0.55$, $P = 0.466$; H': $F_{(1, 18)} = 0.02$, $P = 0.885$), did not vary significantly either between forest habitats (interior vs. edge) or among blocks. There was no interaction between these variables (blocks and habitats). The abundance of frog species (*Rhinella hoogmoedi*, *R. granulosa*, *Proceratophrys laticeps*, *Physalaemus crombiei*, *Chiasmocleis carvalhoi*, *C. gnoma*, *C.* cf. *schubarti*, *Hyophryne histrio* and *Stereocyclops incrassatus*) did not vary significantly between forest interior and edge. Among the analysed lizard species (*Coleodactylus meridionalis*, *Gymnodactylus darwinii*, *Alexandresaurus camacan*, *Leposoma annectans*, *L. scincoides*, *Ameiva ameiva*, *Kentropyx calcarata*, *Enyalius catenatus*, *Tropidurus torquatus*), only the abundance of the lizard *T. torquatus* was greater at in edges than forest interiors ($F_{(1, 18)} = 20.5$, $P < 0.001$)

Despite the variation in forest structure between forest interiors and edges, we failed to find differences in total abundance, diversity and richness of leaf-litter lizards and frogs between these habitats. The absence of edge effects on leaf-litter lizards and frogs was unexpected since the response of these organisms to edge effects is expected to be strong due to physiological needs (Lehtinen *et al.* 2003). Frogs and lizards are considered by many authors as sensitive to overall and specific changes in vegetation structure and microclimate (Lehtinen *et al.* 2003, Marsh & Pearman 1997, Vallan 2000). However, frogs showed no response to microclimatic changes within the forest associated with abrupt edge in an Amazon forest (Gascon 1993), in a cloud forest in Ecuador (Toral *et al.* 2002) and in an Andean montane forest (Marsh & Pearman 1997). Similarly, the abundance of lizards did not vary significantly in response to distance to the forest edge in Australia (Jellinek *et al.* 2004). On the other hand, some lizard species are common in forest clearings and seem to benefit from forest fragmentation, being more abundant at edges (Lehtinen *et al.* 2003).

In some studies, frog richness in a fragment (or at its edges) increases significantly after isolation due to invasion by matrix species (Gascon *et al.* 1999, Tocher *et al.* 1997). This had not happened yet in our study region, probably because of the high percentage of forest cover and the presence of forested matrix. However, some generalist and non-forest species of frogs can already be found at forest edges in the region (e.g. *P. cuvieri*, *L. ocellatus*), indicating that this may happen with the increasing deforestation rate and the increase in the size of open areas around forest fragments. The only species that was affected by edge effects was a lizard, *T. torquatus* (South American fence lizard). This is a common lizard that occurs in various habitats, more frequently in open habitats and edges, and can be found even in urban environments. So, this species benefits from forest fragmentation and the consequent increase in the occurrence of forest edges in the region.

Our results may be influenced by some additional factors not dealt with here, such as the sampling period, sampling method, the surrounding matrix and the synergism between area and edge effects. As our samples were carried out only during the rainy season, the microclimate of edge may not suffer drastic alterations compared with dry seasons. Some studies showed that the impact of edge effects (or edge proximity) differed greatly between dry and wet seasons (Lehtinen *et al.* 2003, Schlaepfer & Gavin 2001). Perhaps the absence of a marked dry season (Mori *et al.* 1981) in southern Bahia makes the climate of the forest edges more similar to that of forest interiors than in areas with a more seasonal rainfall regime.

The matrix of the studied landscape may also be responsible for the absence of edge effects. Edge effects depend on the quality of the matrix, which may function as an alternative habitat for the original species (Gascon 1993, Pardini 2004) or as a source of exotic species that may invade remnants (Dixo 2005, Tocher *et al.* 1997). The studied site is characterized by having a complex matrix in which the forest fragments are surrounded not only by non-forest habitats like pastures, but also by secondary forests and shaded plantations such as cocoa and rubber trees. Although considered disturbed habitats, secondary forests and shaded cocoa plantations represent a permeable matrix that allow the existence of a local herpetofauna (Argôlo 2004, Faria *et al.* 2007), maintaining local and regional diversity. This permeable matrix and the high percentage of forest cover in the landscape may prevent the occurrence of edge effects on lizard and frog richness and abundance, despite of changes at forest structure.

Forest amphibians showing different life histories, reproductive modes and habitat preferences are certainly influenced in distinct ways by habitat change, but our understanding of these influences is still very poor (Gardner *et al.* 2007). Pearman (1997) showed that some amphibian taxa are particularly sensitive to forest structure variation in a lowland Amazonian forest and suggested that eleutherodactyline frogs (of the genus *Pristimantis*, Hedges *et al.* 2008) are especially sensitive to forest disturbance. Since eleutherodactylines show a terrestrial mode of reproduction, they do not depend on standing water. On the other hand, they seem to be sensitive to changes in forest humidity (Pearman 1997) and thus would probably be more sensitive to forest disturbance than pond-breeding species. However, a recent study in the Brazilian Atlantic forest showed that species that depend on aquatic habitats, which may be absent in some fragments, are particularly threatened (Becker *et al.* 2007). Unfortunately our methods failed to capture eleutherodactylines because they were able to climb and escape the traps. Thus most frogs captured in our study breed in aquatic habitats which precludes any attempt to test for these differences.

In the present study we used only one method to sample the herpetofauna (pitfall-traps with drift fence) and we focused our study on leaf-litter species only, not considering arboreal frogs and lizards. This precludes comparisons between terrestrial and arboreal species. Arboreal species may be differently affected by edge characteristics. Thus, differences in microhabitat use may influence the responses to fragmentation and changes in forest structure, as observed for two lizard species in Atlantic Forest (Dixo & Metzger, in press). Arboreal species may be more sensitive to edge effects, once they use more than one stratum that may suffer stronger influences due to changes in forest structure after fragmentation (Dixo & Metzger, in press; Vallan 2000). Despite some limitations of our study (not considering seasonal patterns, arboreal species, proximity to edge and area effect), we believe that our results can contribute to the understanding of edge effects on leaf-litter herpetofauna. For instance, our results indicate that permeable forested matrix and the absence of rainfall seasonality may both alleviate edge effects.

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