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Are disturbance gradients in neotropical ecosystems detected using rove beetles? A case study in the Brazilian Amazon

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ABSTRACT

In the Neotropics, Rove Beetles (Staphylinidae) are known to be especially diverse and abundant, but studies in this region are still incipient and the information is dispersed in the scientific literature. In this work the responses of the Rove Beetles to gradients of disturbance in representative ecosystems of the Brazilian Amazon were evaluated. Specifically, we assessed the possibility of using patterns in richness, abundance and taxonomic diversity of Rove Beetles as anthropogenic disturbance indicators. The obtained results show that the Rove Beetles richness was sensitive to the structural changes induced by increasing anthropogenic disturbance. Additionally an increasing trend in community complexity from more to less disturbed ecosystems was observed. Differences in responses can be explained by differences in the intensity and extent of the change from pristine systems. Overall, the composition of Rove Beetles communities is ecosystems' specific and sensitive to anthropogenic induced structural changes and management actions and, therefore, should be considered a valuable ecological indicator for assessing the extent ecosystems' disruption in the Neotropics.

1. Introduction

Neotropical forests are biologically diverse ecosystems, representing some of the richest areas of the planet (Lindenmayer et al., 2002). Species from these forests are threatened by deforestation, fragmentation, conversion to forest monocultures, climate change and other stressors like fire and even fire suppression (Carnus et al., 2006; Loskotová and Horák, 2016). There is an enormous concern and speculation about the effects of human disturbances in the biodiversity of neotropical ecosystems, namely the impacts on species composition and the modifications in the ecological services provided (e.g. Morris, 2010; Aerts and Honnay, 2011; Cajaiba et al., 2017). Deforestation in the Brazilian Amazon (Amazonia), has been causing a sharp erosion of biodiversity and the disruption of complex global climate cycles (e.g. Morris, 2010; Cajaiba et al., 2017). The most significant landscape changes identified for the Amazonia are forest logging, the establishment of extensive livestock operations and intensive farming, but also the expansion of road nets and urban areas (Mertens et al., 2002; Tabarelli et al., 2004), power generation, and mining (Soares-Filho et al., 2005). These anthropogenic activities are considered strong environmental stresses whose impacts were not fully anticipated (Cajaiba et al., 2017). In fact, these landscape changes promote ecosystems' substitution and might isolate taxa and even cause extinctions due to interactions in which species are engaged (Aizen et al., 2012; Valiente-Banuet et al., 2015). Understanding the impacts of ecosystem transitions in the Amazonia will ultimately support the best conservation strategies for the region, considered fundamental for sustaining earth's functioning and ultimately humankind (Cajaiba et al., 2017).

In a conservation perspective, the condition of an ecosystem might be evaluated using the "difference" from reference situations, i.e. the disparity of a specific ecosystem from pristine ecosystems (Costanza, 2012). Considering the unfeasibility of measuring all aspects in a specific ecosystem, several scientists advocate the use of surrogates, usually termed ecological indicators (Costanza, 2012; Heath, 2013). Species, populations and communities might prove useful as indicators if sensitive to ecosystem changes, anticipative and easily monitored (Gardner et al., 2008; Rapport and Hildén, 2013). Besides the universal need for developing ways to assess status and trends in environmental

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condition of ecosystems (Niemi and McDonald, 2004), selecting organisms as indicators of anthropogenic disturbance to help conservation decisions is still a challenge in most biodiverse countries, where taxonomic and natural history knowledge is deficient (Kim and Byrne, 2006). This task is considered particularly urgent in megadiverse neotropical countries, since their natural systems are being eroded at unprecedented speeds and scales (Uehara-Prado et al., 2009). Even though a steady stream of scientists and a large number of publications and projects have been investigating the ecosystem changes versus disturbance, they provide a very fragmented picture concerning the environmental changes and its ecological consequences. Additionally and considering its vastness, most of the Amazonia' ecosystems were still marginally studied (Cajaiba et al., 2017).

Terrestrial invertebrates and especially insects play a crucial role in most ecological processes and are key components of ecosystems' structure and functioning (Bicknell et al., 2014; Cajaiba and Silva, 2015; Cajaiba et al., 2015; Campos and Hernández, 2015). In this context, insects' abundance, composition and richness are related with other taxa, climate and soil characteristics, thus representing potential target indicators of environmental changes (e.g. Nichols et al., 2008; Cajaiba et al., 2017). Understanding the ecological relevance of insects' communities in the humid neotropics could even support decision-making and robust management/recovery of imperiled ecosystems in the scope of the need for rapid, standardized and cost-saving assessment methodologies (Cajaiba et al., 2017). Among insects, Rove beetles (RB) of the family Staphylinidae (Insecta: Coleoptera) have been proposed as disturbance indicators (Anderson and Ashe, 2000; Pohl et al., 2007) given their abundance and diversity (Vásquez-Vélez et al., 2010) and variety of ecosystems used. Additionally they are easy to collect because the majority of species are found among leaf litter and fallen trunks. RB are sensitive and respond rapidly to abiotic, biotic and anthropogenic disturbances (Magura et al., 2013) and are considered ecological significant, particularly of the soil-related fauna (Vásquez-Vélez et al., 2010). Moreover most are predators, sensitive to prey densities – although, parasitoids, saprophytes, omnivores, and opportunists can be found (Caballero et al., 2009).

In the Neotropics, RB are considered to be diverse and abundant, although supported mostly by incipient works (Gutiérrez-Chacon et al., 2009), dispersed within scientific and grey literature (Newton et al., 2005). The purpose of this study was to evaluate the responses of RB communities to increasing levels of stress in the Amazonia, in the scope of its usefulness as ecological indicators of anthropogenic disturbance. For that several ecosystems with increasing levels of anthropogenic stress were monitored, such as: primary forest, our reference condition, secondary forests within different stages of recovery, farmland and pasture for extensive livestock. We were particularly interested in assessing the RB communities' sensitivity to anthropogenic induced structural changes, i.e. how does richness, abundance and taxonomic composition change? Is the response of these indexes correlated with increasing trends in disturbance? In addressing these questions we attempt to build a framework of reference, gauging its effectiveness as ecological indicators of disturbance. New insights in RB diversity responses to ecosystem degradation and/or recovery could also provide standards guiding the most efficient conservation management actions in the Neotropics (Kotze et al., 2003).

2. Material and methods

2.1. Study sites

The study area was located in the municipality of Uruará, state of Pará, northern Brazil (Fig. 1). Primary forest (69% of the area) is the dominant land use/land cover while deforestation is concentrated mainly in the south-central part of territory and near the main roads. Extensive livestock production and the exploitation of timber (mostly illegal) are currently considered the most negative environmental pressures (Cajaiba et al., 2015). The studied areas contain the most representative ecosystems of the region, in terms of biophysical and ecological characteristics, for understanding the response of RB communities, such as Native Vegetation (NV), Early Secondary succession (ES – secondary vegetation with five years of regeneration), Maturing Secondary succession (MS – secondary vegetation with 15 years of regeneration), Agriculture (Ag – cocoa plantations, *Theobroma cacao* L.) and Pasture for extensive livestock (Pa) (Fig. 1, For generic characteristics of the ecosystems sampled, see Table S1). The climate of the study area is classified as Aw (Köppen), hot and humid with an average annual rainfall of 2000 mm.

2.2. Staphylinidae sampling

Sampling was carried out during the year 2015, in the months of February/March (rainy season), June (final of rainy season and early dry season) and September/October (dry season), allowing the integration of annual seasonal differences in the activity of RB. The sample points were placed at a minimum distance of 100 m from ecotones, to ensure that most beetles captured were associated to the ecosystem in study (Cajaiba et al., 2017). Pitfall traps with 75 mm diameter and 110 mm deep were filled with preservative liquid consisting of formalin, alcohol, water and a few drops of detergent to break the surface tension. A roof was attached to each trap to prevent rainwater from entering the trap, remaining installed for 48 h prior to collection. Sampling survey period and intensity, although apparently inadequate for definitive inventory, served the purpose of comparing RB general sensitivity to ongoing changes in the scope of their application as ecological indicators of disturbance (Dale and Beyler, 2001; Santos and Cabral, 2004).

Each pitfall was associated to a different treatment in order to attract RB in accordance with to their feeding ecology: non-baited, human faeces, meat and banana. In each studied site four sample points were placed 100 m apart. Each sample point contained the four pitfall treatments, separated by 5 m. The distance between pitfall traps by location was determined in order to select individuals according to their favoured food resources, as suggested by related studies (Almeida and Louzada, 2009; Silva et al., 2012; Campos and Hernández, 2015; Qodri et al., 2016). This protocol was applied to all ecosystems and periods of collections, totalizing a sampling effort of 480 traps. The identification was based on the taxonomical keys proposed by Navarrete-Heredia et al. (2002) and by comparison of material deposited in the DZUP (Entomological Collection Pe Jesus Santiago Moure of the Department of Zoology of the Federal University of Paraná).

2.3. Environmental variables

Fourteen microclimate and ecosystem variables were measured by location: Temperature, Humidity, Precipitation, Circumference at Breast Height, Circumference at ankle height, Canopy cover, Number of plant species, Number of plants, Number of species of shrubs, Number of shrubs, Percentage of exposed soil, Percentage of green (vegetation) cover, Percentages of leaf litter cover, Height of leaf litter. The Temperature, Humidity and Precipitation of each point were measured during the traps installation and removal with a portable weather station (model Oregon Scientific WMR200A). To assess the environmental complexity of each sampling site, the quadrat-section method was adopted (Campos and Hernández, 2015). Using a cross as a reference, four quadrants (northeast, northwest, southeast, southwest) were marked and, in each quadrant the following variables were measured: the distances to the centre of the cross, height, crown diameter and trunk diameter of all trees with Circumference at breast height greater than 15 cm and all shrubs with Circumference at ankle height less than 15 cm and height greater than 1 m. Trunk diameter was taken at breast height (1.3 m) for the trees and ankle height (Circumference at ankle height = 0.1 m) for the shrubs. In each quadrant, the Height of leaf