Ecological Indicators 55 (2015) 65–73

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Dung beetle persistence in human-modified landscapes: Combining indicator species with anthropogenic land use and fragmentation-related effects

Bruno K.C. Filgueiras[a,*], Marcelo Tabarelli[b], Inara R. Leal[b], Fernando Z. Vaz-de-Mello[c], Luciana Iannuzzi[d]

[a] Programa de Pós-Graduação em Biologia Animal, Universidade Federal de Pernambuco, Recife, PE 50670-901, Brazil
[b] Departamento de Botânica, Universidade Federal de Pernambuco, Av. Prof. Moraes Rego, s/n, Cidade Universitária, Recife, PE 50670-901, Brazil
[c] Universidade Federal de Mato Grosso, Departamento de Biologia e Zoologia, Cuiabá, MT 78060-900, Brazil
[d] Departamento de Zoologia, Universidade Federal de Pernambuco, Av. Prof. Moraes Rego, s/n, Cidade Universitária, Recife, PE 50670-901, Brazil

ARTICLE INFO

Article history:
Received 11 November 2014
Received in revised form 5 February 2015
Accepted 23 February 2015

Keywords:
Agricultural frontiers
Ecological indicators
Forest-dependent species
Matrix
Scarabaeinae

ABSTRACT

Identifying and making use of ecological indicators becomes an essential task in the conservation of tropical systems, mainly in fragmented landscapes where land use intensification and habitat loss are confounding factors in the detection of species' responses to human-caused disturbance. We aimed to analyze the importance of anthropogenic land use and fragmentation-related effects on dung beetle (Coleoptera: Scarabaeinae) persistence according to the interior–exterior non-linear gradient (forest + matrix) in a fragmented Atlantic Forest landscape used to sugar cane production and cattle ranching/farming. We offer scores for a comprehensive set of community-level attributes, from beetle abundance to taxonomic and ecological composition (i.e. species body size), including a list of indicator species of different forest habitats and adjacent matrix. Dung beetles were surveyed by traps across forest interiors (i.e. core forest areas) and edges of a primary forest, small fragments, sugar cane fields and pastures in a total of 60 sites. Indicator analyses were conducted across the landscape, using two well-established methods (IndVal and SIMPER). Our results suggest that (1) cross-habitat taxonomic distinctness is associated with the presence of indicator species, (2) some species benefit or are dependent of open habitats created by human-disturbances, such as forest edges (e.g. *Canthon nigripennis*) and matrices (e.g. *Canthon* aff. *piluliformis*, *Dichotomius nisus* and *Trichilum externepunctatum*), (3) although landscape habitats exhibit reduced beta diversity, dung beetle assemblages are spatially organized in response to the presence of both forest habitats and matrix and fragment area, (4) forest interior supports beetle assemblages biased toward large-bodied species, (5) accordingly forest interior, forest edges and matrix support taxonomically distinct assemblages, both contributing to the bulk of species richness at landscape level, (6) the response of dung beetles to the interior–exterior non-linear gradient (i.e. forest edge + matrix) reveals a similar pattern regardless of the nature of the matrix, and (7) there is no within-habitat variation in beetle abundance and species richness associated with distance from forest edge. Given that there is a high number of forest-dependent or forest-interior specialist species (e.g. *Aphengium* aff. *sordidum*, *Ateuchus* aff. *alipioi*, *Dichotomius mormon*, *Ontherus* aff. *erosus* and *Onthophagus* aff. *clypeatus*) dung beetle persistence in human-modified landscape is highly dependent on the presence of core areas, although edge-affected and matrix habitats may be complementary. This information is essential to permit a better prospect for dung beetle persistence in human-modified landscapes as they continue to move toward edge-dominated landscapes with intensively managed matrices.

1. Introduction

A myriad of human-associated processes, such as agriculture, forestry and urbanization, has imposed increasing rates of habitat loss and fragmentation on tropical forests, which has threatened native biodiversity across the tropics (Tabarelli et al., 2010). In fact, such an expansion of human-modified landscapes (HMLs) and the consequent reduction of old-growth forests poses a challenge to conservation practitioners devoted to guaranteeing biodiversity persistence (Melo et al., 2013). Understanding the relationship between HML and species persistence

* Corresponding author. Tel.: +55 8198028474.
E-mail address: bkcfilgueiras@gmail.com (B.K.C. Filgueiras).

http://dx.doi.org/10.1016/j.ecolind.2015.02.032
1470-160X/

is a major issue of interest in applied ecology because of its direct relationship with biodiversity conservation (De Angelo et al., 2013).

Studies in HMLs on biodiversity persistence based on data of focal species groups do not exhibit a consistent pattern of response. Generally, forest biodiversity declines along a coarse gradient from old-growth forest patches through agroforestry, plantations, secondary forest stands and small forest remnants or edge-affected habitats (Harvey et al., 2006; Nyafwono et al., 2014). However, other studies support the notion that for certain taxonomic groups small forest patches, secondary forest stands and even some crops are able to retain an important fraction of the original biodiversity (Thornton et al., 2011; Melo et al., 2013).

Tropical biodiversity has been roughly assigned into two mutually excluding groups: forest-dependent species as those with persistence depending on the presence of old-growth forest stands (Melo et al., 2013), and disturbance-adapted species as those able to persist or even proliferate in HMLs dominated by edge-affected habitats (Tabarelli et al., 2010). Particularly in the case of animals, discrepant abilities to persist in HML are related to (1) dispersal ability, particularly the ability to cross non-forested habitats (Schtickzelle and Baguette, 2003), (2) capacity of species to move in the matrix (Uezu et al., 2008), (3) use of edge-affected habitats (Banks-Leite et al., 2010), and (4) lack of collection or hunting by human-populations (Benchimol and Peres, 2013).

Dung beetles (Coleoptera: Scarabaeinae) are well-represented insects in tropical regions and have been used in biodiversity monitoring studies (Nichols et al., 2007, 2013; Audino et al., 2014; Campos and Hernández, 2015). These beetles are very sensitive to habitat alterations and have distinct organization patterns when studied in tropical forest fragments (Klein, 1989; Filgueiras et al., 2011) or in areas that have deteriorated due to human activities (Gardner et al., 2008; Barlow et al., 2010a; Korasaki et al., 2013). Such characteristics make dung beetles indicators of natural or anthropogenic environmental disturbances in tropical forests (Halffter and Favila, 1993). However, dung beetle persistence in such altered landscapes remains controversial (Nichols et al., 2007; Gardner et al., 2008); it is particularly unclear how much, and for how long, tropical dung beetles can persist in HMLs under current land uses, mainly in fragmented landscapes where anthropogenic land use and fragmentation-related effects are confounding factors in the detection of species' responses to human-caused disturbance. In this way, dung beetle responses across edge gradients effectively integrate many facets of habitat degradation, providing a generalized indication of the role played by HMLs on species persistence (Barnes et al., 2014).

In the Brazilian Atlantic Forest, more than 80% of the fragments are <50 ha, almost half the remaining forest is <100 m from its edge (Ribeiro et al., 2009). This is one of the most diverse ecosystems in the world, presenting high rates of endemism but also experiencing huge habitat loss (Tabarelli et al., 2010). Seventy percent of the Brazilian population lives in the Brazilian Atlantic Forest region where there are unprecedented levels of habitat loss and other human disturbances going back to the 16th century (Silva and Casteleti, 2003). Approximately 88% of the natural vegetation in this ecosystem/biome/region has been modified or replaced by anthropogenic environments (Ribeiro et al., 2009). The historical and current land-use trajectory of Brazilian Atlantic Forest offers an excellent opportunity to examine the role played by HMLs in terms of forest species persistence (Melo et al., 2013).

Here, we discuss the uncovered patterns of dung beetle assemblage organization in core areas and edges of a large tract of primary forest, small fragments, sugar-cane fields, and cattle pastures in a human-modified Atlantic Forest landscape of northeastern Brazil. We aimed to analyze the importance of anthropogenic land use and fragmentation-related effects on dung beetle persistence according to the interior–exterior non-linear gradient (forest + matrix). This issue was addressed by a set of predictions: (1) habitats largely differ in terms of species richness and taxonomic and ecological composition, with each habitat supporting exclusive and indicator species; (2) edge-affected habitats (i.e. edges of primary forest and small fragments) are able to retain less species of dung beetles than core primary forest patches independently of fragment characteristics (i.e. fragment area, isolation, soil type and vegetation type) and matrix type; and (3) although both factors (i.e., land use and habitat fragmentation) negatively affect dung beetle persistence, land use exerts a stronger effect with matrix habitats harbor a set of species consisting of anthropogenic-specialists.

2. Materials and methods

2.1. Study sites

The Serra Grande landscape is located within the Pernambuco Centre of Endemism (Fig. 1), the most threatened bioregion of the Brazilian Atlantic Forest (Silva and Casteleti, 2003). Annual precipitation is 2000 mm with a dry season (<60 mm/month) occurring from November to January (Santos et al., 2008) and with the wettest period between April and August (Pimentel and Tabarelli, 2004). This hyper-fragmented landscape (667 km^2) contains approximately 9000 ha of forest (9.2% forest cover) distributed in a total of 109 forest remnants, ranging from 1.67 to 3500 ha, which are almost all completely surrounded by sugar-cane fields (Santos et al., 2008). The presence of Coimbra forest (3500 ha), the largest remnant of Atlantic Forest in northeast Brazil, makes Serra Grande landscape an excellent scenario for understanding the long-term effects of habitat fragmentation on plant (Santos et al., 2008) and animal (Filgueiras et al., 2011; Leal et al., 2012) communities. We are aware, however, that Coimbra forest does not fully represent a 'continuous forest', limiting our study design. But it is the single, unreplicated tract of primary forest has several large-seeded tree species and medium-sized frugivorous vertebrates at the landscape and regional scales (Pimentel and Tabarelli, 2004). In addition Coimbra forest is surrounded by different types of matrix besides the predominant sugar cane fields, such as pastures and plantations maintained for subsistence by local human communities.

2.2. Habitats and dung beetle surveys

Beetles were surveyed using equal sampling effort across six habitats arranged in two spatially independent setups: (A) 10 sampling units in the Coimbra forest interior (control), 10 in Coimbra forest edges, 10 in the sugar-cane plantation and 10 in pastures surrounding Coimbra forest. Forest interior referred to forest stands >200 m from the nearest edge (Santos et al., 2008). (B) 10 units in the edges of 10 small forest fragments (range in size = 8.25–91 ha), and 10 in the surrounding sugar-cane matrix (Fig. 1). We therefore sampled a total of 60 sites. Sampling units across surrounding matrix and small forest fragments were randomly selected considering fragments with little (<1 ha) or no forest interior habitat.

Dung beetle surveys were carried out between October 2011 and February 2012. To avoid the effects of seasonality on dung beetle communities, trapping was carried out under generally similar climatic conditions, avoiding rainy days (Estrada et al., 1999), and was conducted once at each site. In the interior of Coimbra forest, sampling units were located randomly with a minimum distance of 300 m. Each sampling unit consisted of four pairs of pitfall traps, each pair 50 m apart and set along a linear transect.