Biological Conservation 142 (2009) 1220–1228

Contents lists available at ScienceDirect

Biological Conservation

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

Selecting terrestrial arthropods as indicators of small-scale disturbance: A first approach in the Brazilian Atlantic Forest

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ARTICLE INFO

Article history:
Received 15 September 2008
Received in revised form 15 December 2008
Accepted 5 January 2009
Available online 14 March 2009

Keywords:
Anthropogenic disturbance
Ecological indicator
Multi-taxa
Surrogacy
Species composition

ABSTRACT

The growing pressure placed by human development on natural resources creates a need for quick and precise answers about the state of conservation of different areas. Thus, identifying and making use of ecological indicators becomes an essential task in the conservation of tropical systems. Here we assess the effects of small-scale disturbance on terrestrial arthropods and select groups that could be used as ecological indicators in the Brazilian Atlantic Forest. Arthropods were sampled within a continuous forest in the Serra do Mar State Park, southeastern Brazil, both in disturbed and undisturbed areas of the reserve. The abundance of exotic species was higher in the disturbed site, and this pattern seems to be an adequate indicator of anthropogenic disturbance. Species richness of Araneae, Carabidae, Scarabaeidae, Staphylinidae, and epigaeic Coleoptera (pooled) was higher in the undisturbed site, while that of fruit-feeding butterflies was higher in the disturbed site. Species richness was not significantly correlated between any pair of taxa. In contrast, species composition was significantly correlated among most groups, and clearly discriminates the disturbed from the undisturbed site. Moreover, fruit-feeding butterflies and epigaeic Coleoptera composition discriminated disturbed and undisturbed sites even when species were grouped into higher taxonomic levels, which may be a way of overcoming the difficulty of identifying arthropod species from poorly studied, species-rich ecosystems. Potential applications for these indicators include the choice and evaluation of sites for the establishment of natural reserves, elaboration of management plans, and the assessment of ecological impacts due to human activities, either for the purposes of licensing or legal compensation.

1. Introduction

Practical approaches concerning the assessment of the ecological integrity of natural systems require the selection of organisms or groups of organisms that work as ‘shortcuts’, i.e., surrogates of the other elements of the system and of the ecological processes in which they are involved (Kremen et al., 1993; McGeoch, 1998; Feinsinger, 2001; Niemi and McDonald, 2004). These organisms may act as indices of environmental conditions or biological phenomena that are difficult, inconvenient or expensive to be directly measured (Landres et al., 1988), comprising an attempt to synthesize information and recognize key aspects that at length should guide reliable conservation decisions (Niemeijer, 2002; Niemi and McDonald, 2004).

Biological indication may take place in several ways, such as changes in species richness and abundance, shifts in biological attributes (such as body size or symmetry) or, in a more general way, by some change in species composition from an undisturbed state (New, 1995; Hodkinson and Jackson, 2005). Besides the universal need for developing ways to assess status and trends in environmental state (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 greatly deficient (Kim and Byrne, 2006). This task is especially urgent in the

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doi:10.1016/j.biocon.2009.01.008

megadiverse countries, since their natural systems are being continually destroyed by human activities (e.g., Bawa et al., 2004; Hong and Lee, 2006; Miles et al., 2006).

The Brazilian Atlantic Forest is considered a 'hotspot' (sensu Myers et al., 2000) due to its high species diversity associated with high rates of endemism and elevated level of disturbance, attaining highest conservation priority (MMA, 2000; Myers et al., 2000). Having once covered 1.5 million km^2 of the Brazilian territory, the Atlantic Forest is now reduced to ca. 12% of its original condition, with its remnants occurring mostly in small fragments (Ribeiro et al., 2009). Besides habitat loss, Atlantic Forest suffers from wood harvesting, plant collecting, hunting, invasion by exotic species, among other anthropogenic pressures (see Tabarelli et al., 2005). Due to its shattered state, the development and testing of indicators to assess and monitor the state of Atlantic Forest remnants should be a priority (Tabarelli et al., 2005).

Terrestrial arthropods share a number of qualities that make them highly adequate as biological indicators. These include their sensitivity to habitat change, rapid responses to disturbance, and easy and cost-effective sampling (e.g., Brown, 1996; McGeoch, 1998; Basset et al., 2004, 2008; Hodkinson and Jackson, 2005; Lawes et al., 2005; Lewinsohn et al., 2005; Pearce and Venier, 2006; Bouyer et al., 2007; Gardner et al., 2008). However, their usefulness has been systematically neglected in conservation planning in Brazil, which focuses their attention on more "charismatic", but sometimes less informative groups (Landres et al., 1988; Lewinsohn et al., 2005). Even when arthropods were used in the assessment of anthropogenic disturbances in Brazil (see Lewinsohn et al., 2005), multi-taxonomic approaches have rarely been applied for this purpose (for exceptions see Barlow et al., 2007; Fonseca et al., 2009; Pardini et al., 2009), making it difficult to extrapolate the results from one taxon to another.

The main goal of this study was to select a set of arthropod taxa as small-scale ecological indicators (sensu McGeoch, 1998) of disturbance in the Brazilian Atlantic Forest. The specific objective was to answer the following questions: (a) How does forest disturbance affect arthropod groups in their abundance, species richness, and diversity? (b) Does disturbance change species composition of different arthropod groups? (c) Does a higher taxon approach affect the discriminatory ability of the arthropod groups? (d) Can some arthropod groups be established as efficient surrogates for others? Based on the responses of each group, we then propose which arthropod groups should be employed and/or deserve to be further investigated as indicators of small-scale rainforest disturbance.

2. Methods

2.1. Study area

The study was carried out in the Santa Virgínia nucleus of Serra do Mar State Park (23°17′–23°24′S, 45°03′–45°11′W), located on the Paraitinga-Paraibuna plateau, in the eastern region of the state of São Paulo, southeastern Brazil (Fig. 1a). The region is located on mountainous relief, with altitudes ranging from 870 to 1100 m (Ururahy et al., 1987). The regional climate is humid, without a dry season, with mean annual rainfall of 2180 mm, and no monthly rainfall below 65 mm (DNMet, 1992). The region was originally covered with Atlantic Forest vegetation, classified as montane rainforest (Ururahy et al., 1987).

The Santa Virgínia nucleus has an area of ca. 18 000 ha (J.P. Villani, pers. comm.) and is located inside a well-preserved vegetation continuum of 1,109,546 ha along the Serra do Mar (Ribeiro et al., 2009), a large mountain range near the Atlantic Ocean in southeastern Brazil (Fig. 1b). The Brazilian Ministry of the Environment considers the region where Serra do Mar State Park is located as an "area of extreme biological importance", of highest priority toward conservation of the Atlantic Forest (MMA, 2000).

In the 1960s, part of the forest that currently belongs to the Santa Virgínia nucleus suffered slash-and-burn management, and was subsequently replaced by pasture. Nowadays, this part of the reserve is a forest mosaic composed of old-growth forest, abandoned pastures occupied by woody vegetation, abandoned *Eucalyptus* plantations, and secondary forest at different regeneration stages (see Tabarelli and Mantovani, 1999 and references therein). Another section of the reserve (~8 km distant from the former) was severely logged for hardwood before the establishment of the Serra do Mar State Park in 1977 (J.P. Villani, pers. comm.), and now is a fairly well-preserved old-growth forest, with some nearby remnants of primary forest. Hereafter, these sites with different disturbance degrees will be referred to as "disturbed" and "undisturbed", respectively. It is worth emphasizing that both sites are embedded within a continuous, well-preserved forest context in the Serra do Mar region (see Ribeiro et al., 2009).

By comparing sites within a vegetation continuum, we seek to minimize noise due to fragmentation effects. We also hypothesize that if responses by arthropods are found in such apparently low-contrast sites, meaningful responses should also be achieved under higher-contrast conditions.

2.2. Sampling design and procedures

Twelve replicated sampling stations were set in the Santa Virgínia nucleus, six in the disturbed site and six in the undisturbed site, so that disturbance degree was homogeneous within sites (Fig. 1c). Replicates were set within structurally similar vegetation in both sites, but within spots with different history of disturbance. A pitfall trap sampling unit plus a bait trap sampling unit (each composed of five traps) set in the same location comprised a sampling station. Sampling stations were at least 100 m apart from each other (median: disturbed = 136.6 m; undisturbed = 141.1 m).

The bait traps were cylinders of netting, with an internal funnel, baited with a mixture of mashed banana and sugar cane juice, fermented for at least 48 h. Bait traps were disposed along pre-existing trails in the understory of each site, suspended at a height of 1.5–2.0 m above the ground with a distance of at least 23 m between adjacent traps. The average distance between traps did not differ among sampling stations (ANOVA $F = 0.213$, $P = 0.996$). The traps were checked every 48 h, and the baits replaced at each visit (see Uehara-Prado et al., 2007 for details on the sampling scheme).

The pitfall traps consisted in 500 ml clear plastic cups, 85 mm wide at the opening and 120 mm in depth, flush with ground level, with a polystyrene cover suspended above the cup by wooden sticks. Each trap contained ca. 50 ml of a mixture of 69.9% water, 30.0% propylene glycol, 0.1% formaldehyde, and a few drops of detergent. Pitfall traps were placed in lines parallel to the bait traps lines, inside the forest understory, at 2 m intervals, and at least 20 m from the trails.

Pitfall and bait traps were kept simultaneously in the field for 6 and 8 days/month, respectively. Sampling was done monthly from November 2004 to May 2005, including the most favorable season for the capture of arthropods in southeastern Brazil (butterflies: Brown, 1972; Scarabaeidae: Hernández and Vaz-de-Mello, in press; Opiliones: Almeida-Neto et al., 2006). Sampling effort was 60,840 trap-hours for pitfall traps; the effective effort for butterflies was 33,600 trap-hours (considering 10 h of sampling/day).

Most fruit-feeding butterfly species captured in the bait traps could be identified in the field and were released after marking. The few specimens that could not be recognized even with a field guide (Uehara-Prado et al., 2004) were collected for later identification. The remaining arthropods collected in bait and pitfall traps