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Are we selecting appropriate metrics to assess human impacts on biodiversity?

Victor Hugo Fonseca Oliveira[a,b,*], Jos Barlow[b,c], Toby Gardner[d], Julio Louzada[a,b]

[a] *Programa de Pós Graduação em Ecologia Aplicada, Universidade Federal da Lavras, Lavras, Minas Gerais CEP 37200-000, Brazil*
[b] *Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, United Kingdom*
[c] *MCT/Museu Paraense Emílio Goeldi,Campus de Pesquisa, Av. Perimetral, no. 1901, Terra Firme, Belém, Pará CEP 66017-970, Brazil*
[d] *Stockholm Environment Institute. Linnégatan 87D, Box 24218, Stockholm 104 51, Sweden*

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Abstract

Biased and subjective choices of metrics to be used in ecological studies could lead researchers to reach misleading conclusions regarding patterns of biodiversity response to human disturbances. Nevertheless, little attention has been given to the choices of variables in the majority of studies published to date. Here, we used the literature concerning land use change effects on dung beetles to assess the extent to which variables commonly employed in ecological studies correspond to those deemed to be most important by researchers of the same studies. Specifically, we examined both biodiversity (response) and environmental (explanatory) metrics from a comprehensive literature review and compared their use with their relative importance, according to a survey of the authors of the studies. Our results highlight marked disparities between researchers opinion expressed in our survey and their choice of variables in published papers. We suggest that these disparities are due to the high costs of sampling and processing some variables, logistical constraints and different perceptions of importance amongst researchers. We highlight the importance of these issues for our understanding of the biodiversity consequences of land use change, and highlight some recommendations for alleviating this issue.

Keywords: Agricultural expansion; Degradation; Fragmentation; Dung beetles

Introduction

Over the last few hundred years humans have significantly altered the surface and functioning of the biosphere, heralding what is now widely recognised as the start of the Anthropocene (Ellis 2011). Agricultural systems such as croplands and pastures already encompass more than one third of the Earth's land surface (Asner, Elmore, Olander, Martin, & Harris 2004; Ramankutty & Foley 1999) and continue to expand to meet burgeoning human needs. This unprecedented modification of natural landscapes includes habitat loss and fragmentation, land-use intensification, and habitat degradation. The ecological impacts of these changes include biodiversity loss and species extinctions, turnover in species composition, and a loss of the critical ecosystem services provided by biodiversity (Millennium Ecosystem Assessment

*Corresponding author at: Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, United Kingdom.
E-mail address: toru.oliveira@gmail.com (V.H.F. Oliveira).

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2005; Sukhdev, Wittmer, & Miller 2014). These events are particularly important in the tropics, which hold both the highest levels of biodiversity and the highest rates of land-use change (Hansen et al. 2013).

Despite recent advances in our understanding of environmental change and biodiversity responses to human disturbance, there are widespread uncertainties about the quality and reliability of information produced by ecological studies, which can be strongly influenced by (among other things) the choice of variables for sampling and analysis, inadequate sampling methods and biases in data analysis and interpretation (Guisan & Zimmermann 2000; Mac Nally 2004, 2005; Vaughan & Ormerod 2003). In particular, studies may fail to find significant effects if they focus on inappropriate response metrics (Barlow et al. 2007; Su, Debinski, Jakubauskas, & Kindscher 2004), while interpretation of results can be confounded if researchers fail to capture the components of environmental variability that have the strongest influence on the biodiversity of interest. In both cases, such studies could easily reach misleading conclusions about the distribution and dynamics of biodiversity in human-modified landscapes, which in turn may have important consequences for policies and management recommendations aiming to safeguard the availability of ecosystem services and biodiversity.

Here we were interested in investigating researcher's choices of environmental explanatory and biodiversity response variables, using dung beetle research papers and researchers as our study system. Dung beetles have been increasingly used to assess and monitor environmental changes in tropical forest ecosystems (Bicknell et al. 2014; Favila & Halffter 1997; Gardner et al. 2008; Halffter & Favila 1993; Nichols, Gardner, Peres, & Spector 2009) and have been considered good indicators of the severity of ecological disturbance (Barlow et al. 2010; Nichols & Gardner 2011). Their sensitivity to alterations in habitat structure, (micro) climate and natural environmental gradients is well documented in the literature through studies conducted worldwide (Jay-Robert & Marquez-Ferrando 2013; Nichols et al. 2007) and across habitats under several different management regimes (Beiroz et al. 2014; Harvey, Gonzalez, & Somarriba 2006; Korasaki et al. 2013; Neita & Escobar 2012; Spector & Ayzama 2003; Vieira, Louzada, & Spector 2008). Dung beetles also play important ecological roles (Nichols et al. 2008), present different morphological and behavioural traits (Foley et al. 2005) and a relatively stable taxonomy (Philips, Pretorius, & Scholtz 2004).

We examined the choices researchers make by assessing the degree of correspondence between theory and practice in studies of the effects of land-use change on dung beetle communities in the tropics. We restrict our analysis to the forested regions of the tropics, which have suffered some of the most severe land use changes in recent decades (Hansen et al. 2013), are the richest reservoirs of the world's terrestrial biodiversity and hold the highest diversity of dung beetles (Nichols & Gardner 2011), and are where the majority of dung beetle studies have been conducted (Nichols & Gardner 2011). In total, we compiled information from a literature review and a structured survey of the authors of 48 different studies. This allowed us to compare the response and explanatory variables considered by researchers as most appropriate for understanding dung beetles' responses to land use change with those variables actually selected and used by the same researchers in their published work. The choices of variables selected by researchers across the sample of published studies were assessed separately for forested habitats and open agricultural lands because these systems are structurally divergent, host significantly different dung beetle communities and therefore should be driven by different environmental predictor variables. We also assessed justifications given for selecting certain variables and study design choices by researchers. We used this information to address the following questions: (1) to what extent are the response and explanatory variables deemed most appropriate by researchers actually being selected in published studies? (2) To what extent is the choice of variables and study design clearly justified, and, if so, what kind of justification is presented in published work? We use our results to discuss some of the systemic problems in drawing ecological inferences from biodiversity and land use change studies.

Material and methods

We compiled information through a two-stage process. First, we undertook a literature review to identify the variables commonly selected in published studies, and to assess the "level of justification" given by authors for the choices made in their studies (i.e. if authors presented reasons for selecting a specific study design, response variable or explanatory variable, and what kind of reasons were presented). Second, we surveyed the authors of the reviewed studies to identify the relative importance of variables according to researchers' opinions. Because dung beetle communities exhibit marked differences between forested habitats (e.g. primary and secondary forests, *Eucalyptus* sp. plantations and shaded coffee) and open agricultural lands (e.g. soya plantations and pasturelands) and are unlikely to present similar responses to a single factor (Nichols et al. 2007), the information was analysed separately for both land use and cover classes (LUCC).

Literature search and selection criteria

We searched ISI Web of Knowledge and Science Direct (accessed on 15 November 2013) using the following keywords: ((“Tropical Forest” OR “Rainforest” OR “Deciduous Forest” OR “Dry Forest”) AND (“Dung Beetles” OR “Scarab*”)). The search returned a total of 815 studies. From this total; we retained the papers addressing variations in dung beetle community attributes (e.g. richness; abundance; composition and biomass) between two or more land uses.