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A novel approach to assess livestock management effects on biodiversity of drylands

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ABSTRACT

In drylands livestock grazing is the main production activity, but overgrazing due to mismanagement is a major cause of biodiversity loss. Continuous grazing around water sources generates a radial gradient of grazing intensity called the piosphere. The ecological sustainability of this system is questionable and alternative management needs to be evaluated. We apply simple indicators of species response to grazing gradients, and we propose a novel methodological approach to compare community response to grazing gradients (double reciprocal analysis). We assessed degradation gradients of biodiversity under different management strategies in semiarid rangelands of the Monte desert (Argentina) by analyzing changes in vegetation, ants and small mammal richness and diversity, and variation due to seasonality. At the species level, we determined the trend in abundance of each species along the gradient, and the potential cross-taxa surrogacy. At the community level, the new methodological consists of assessing the magnitude of biodiversity degradation along different piospheres by comparing the slopes of linear functions obtained by the double reciprocal analysis. We found that most species showed a decreasing trend along the gradient under continuous grazing; while under rotational grazing fewer species showed a decreasing trend, and a neutral trend (no change in the abundance along the gradient of grazing intensity) was the most common. We found that vegetation cannot be used as a surrogacy taxon of animal response. Moreover, weak cross-taxa surrogacy was found only for animal assemblages during the wet season. The double reciprocal analysis allowed for comparison of multi-taxa response under different seasons and management types. By its application, we found that constrains in precipitation interacted with disturbance by increasing the negative effect of grazing on vegetation, but not on animal assemblages. Continuous grazing causes biodiversity loss in all situations. Rotational grazing prevents the occurrence of vegetation degradation and maintains higher levels of animal diversity, acting as an opportunity for biodiversity conservation under current scenarios of land use extensification. Our approach highlights the importance of considering multi-taxa and intrinsic variability in the analysis, and should be of value to managers concerned with biodiversity conservation.

1. Introduction

Drylands occupy around 41% of world's land surface and are home to over two billion people who depend on the natural resources of these systems for their livelihoods (MEA, 2005; Reynolds et al., 2007). One of most common mode of livelihood is livestock production, which supports over 600 million smallholder farmers in the developing world (Thornton, 2010). As a major component of food security, livestock production – which is one of the fastest-growing agricultural subsectors in developing countries (Thornton, 2010) – is also one of the key drivers of land degradation (Pelletier and Tyedmers, 2010). Biodiversity loss associated with land degradation deserves special attention as it is widely recognized that this can decrease ecosystem functioning and services (Hooper et al., 2012; Maestre et al., 2012). Thus, rangeland management strategies that promote biodiversity conservation are urgently needed.

There is a strong dependence between livestock production and water availability. Hence, providing point water sources, e.g., water trough at a borehole, is a widespread practice in drylands. This

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practice generates a piosphere or pattern of grazing-induced changes in biotic and abiotic factors that radiate outward from the concentrator or watering point (Lange, 1969). Piosphere analysis is a quantitative measure of the degree of radial attenuation that exposure to livestock has on ecosystem structure and function (Landsberg et al., 2003; Washington-Allen et al., 2004; Sasaki et al., 2011 Wesuls et al., 2013). A variety of vegetation patterns associated with piospheres in arid and semiarid rangelands have been reported, the nature of which are a function of numerous ecological factors, including competitive relationships, soil types, species life history (Landsberg et al., 2003; Sasaki et al., 2009), as well as stocking rates and other management strategies (Pringle and Landsberg, 2004). With increasing distance from water points, researchers have found increases in species diversity (Sasaki et al., 2009), plant cover (Brooks et al., 2006), plant vertical structure (Macchi and Grau, 2012), abundance of perennial grasses and forbs (Gonnet et al., 2003), palatable grasses and non-tolerant species (Landsberg et al., 2003), but a decrease in the cover of annual forbs (Sasaki et al., 2011). Although such changes in vegetation undoubtedly affect animal communities by modifications of habitat structure and food availability (James et al., 1999), surprisingly few studies have examined non-livestock animal responses. Saba et al. (1995) found that the piosphere effect on mammals depended mainly on changes in vegetation structure, while Hoffmann and James (2011) reported that ants were sensitive to natural variability in soil and vegetation structure (although some grazing effects were also present). Macchi and Grau (2012) found an inverse relationship between the abundance of several bird guilds and distance from the water hole, which they suggest may be due to higher resource availability (water, insects, open space, etc.) nearest the water source, although restricted species showed an opposite response.

In the rangelands of the Central Monte desert (Argentina), there are two main livestock management strategies: (i) the dominant one involves continuous, year-long grazing (hereafter, continuous), and (ii) a rest-rotation approach that invokes the use of recovery periods for paddocks depending upon range conditions (hereafter, rotational). Guevara et al. (2009) describe an experimental adaptive management approach (AMA) that involves 12 months of rest and 4 months of intense grazing and argue that it has economic advantages with regard to cattle production. However, the long-term sustainability of this AMA is under debate due to the potential negative effects that short-term periods of intense grazing pressure has on the semiarid rangelands of the Monte. Similar results have been reported in rangeland assessment in general, where the effectiveness of AMA-type strategies remain equivocal (Teague et al., 2011).

To better understand and predict dryland ecosystem response to livestock disturbance, a variety of piosphere analyses of degradation have been proposed. For example, Landsberg et al. (2003) classified species response curves based on changes in their abundance, Sasaki et al. (2011) posited plant functional groups could be indicators of ecological thresholds, Washington-Allen et al. (2004) developed a GIS-remote sensing technique to help decipher short- from long-term disturbances, and Wesuls et al. (2013) used hierarchical response curves of increasing complexity to analyze changes in plant growth form and life cycles. Another widely used methodology is the identification of surrogate groups (Caro and O'Doherty, 1999), which is based on the assumption of a concordance in the response of species across different taxonomic groups such that some taxa may be correlated with the diversity of other taxa. For example, as vascular plants are a key component of ecosystem structure and function, they may serve as surrogates of non-vascular plants and some animal groups (Kati et al., 2004; Anand et al., 2005). These indicators are useful tools for the analysis of species response but the results are not easy to compare between piospheres, as differences such as higher or lower species richness due to site condition (i.e., different land use history) may cause non-valid statistical comparisons. In this paper we propose and evaluate with a case study a statistical approach which allows for simple but effective comparison of different piospheres with regards of community level richness and diversity. Our analysis involves a simple transformation of the data in order to fit a linear regression and compare the parameters between piospheres (see Section 2).

Thus, the aim of this study was to develop and test a new piosphere analytical approach that allows for valid comparison of different piospheres, and thus useful for rangeland monitoring and management. In our case study we assess how different livestock management strategies (continuous vs. rotational) affect the diversity of vegetation, ants and small mammals in the semiarid rangelands of the temperate Central Monte desert of Argentina. Because of the importance of rainfall, our analysis also considered the role of seasonality in precipitation as a contributing factor that can impact biodiversity. Our piosphere analysis involved the use of two ecological indicators of species level response: (i) trends in species abundance along grazing gradients (e.g., Landsberg et al., 2003) and (ii) the identification of potential surrogate taxa for grazing disturbance assessment. Moreover, we used a novel statistical approach to compare piospheres at the community level. Our analysis is novel in that it takes into account several taxa and the complex dynamics of drylands, where intrinsic factors (seasonality of precipitation) interact with extrinsic factors (grazing intensity as dictated by either continuous or rotational management).

2. Methods

2.1. Study sites

The study was conducted approximately 200 km southeast of Mendoza province, Argentina (33°46′ S, 67°47′ W), between December 2008 and September 2010. The climate is semiarid and markedly seasonal, with cold dry winters and hot wet summers. The mean annual temperature is 12 °C and mean annual precipitation is 342.5 mm (data from the Ñacuñán Reserve weather station; www.cricyt.edu.ar/ladyot/red_iadiza/index.htm). All study sites (of both management strategies) were placed within sand dunes habitat type. The vegetation is an open xerophytic savanna and shrubland where grasses dominate the herbaceous layer.

For continuous management treatments, we selected seven piospheres in different private rangelands ($n = 7$ replicates), where stocking rates varied between 18 and 26 ha/AU, and the areas ranged from 3000 to 6000 ha. Since rotational management is not common, the few sites we found were located in different habitat types and had a wide variety of stocking and resting regimes. Therefore, we selected a single 25-year old experimental rangeland ("El Divisadero") of 5000 ha for our rotation AMA treatment, with a mean stocking rate of 20–25 ha/AU (Guevara et al., 2009). The spatial design involved four paddocks ($n = 4$ replicates) radiating from a central water source. Appendix S1 shows the spatial location of all replicates. In this system, as cattle are rotated each paddock is exposed to four months of intense grazing followed by twelve months of recovery (or rest). The minimum distance of the closest site between piospheres was 300 m, a distance found within the limits of the recommended range to consider sites as different replicates for small mammals (minimum distance suggested between 300 and 500 m; Ojeda *pers. obs.*). Thus, we considered the potential occurrence of spatial autocorrelation for the piosphere analysis selection (see Section 2.3.3 and Appendix S2). It is important to highlight that, due to the wide