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Review

Using ants for rangeland monitoring: Global patterns in the responses of ant communities to grazing

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ABSTRACT

Ants are a prominent invertebrate group used to assess ecological change in response to disturbance. Their application as a bioindicator group has been particularly widespread in Australia, and a recent comprehensive review of their responses to environmental disturbance identified a range of consistent and predictable patterns. Here I conduct a literature review of the responses of ants to grazing globally, and specifically test whether key patterns identified in the review of ant responses to disturbance in Australia apply globally. The patterns tested were (1) soil and vegetation type are primary determinants of ant community composition, and often have a far greater effect on ant community composition than disturbance, (2) disturbance induces species compositional change, but does not necessarily affect overall species richness or abundance, (3) a species' response is not necessarily consistent across habitats because of variation in inherent habitat suitability, and (4) approximately one quarter to one half of species that are common enough for statistical analysis have significant responses to disturbance. All these patterns were found to hold true for grazing studies worldwide. All but three studies sampling multiple soils/vegetation types found the influence of these variables to override grazing effects. Community composition changed consistently, yet the responses of total ant abundance and species richness were highly inconsistent. All studies that analysed species-level data on multiple soils/vegetation types, showed mixed responses to grazing across habitats. On average, 33% of tested species had statistically significant differences across treatments. This is the first such formulation of global patterns for any terrestrial invertebrate group for their use in bioindication, and provides valuable support to the use of ants as indicators of ecological disturbance. The challenge now is to provide a predictive understanding of this context dependency, as well as to improve the precision of the predictive responses. The confirmation of global patterns to grazing presented here represents a first step in developing the valuable contribution that ants can provide to rangeland monitoring systems.

Contents

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1. Introduction

Ants are a particularly prominent invertebrate group used in assessing ecological responses to disturbance (Rosenberg et al., 1986; Andersen, 1999; Taylor and Doran, 2001; Andersen et al., 2004; Underwood and Fisher, 2006). Ants have been targeted because they are ubiquitously abundant and important in terrestrial ecosystems, are easily sampled, and have community dynamics that vary predictably in relation to environmental stress and disturbance (Majer, 1983; Greenslade and Greenslade, 1984; Andersen, 1990). The available evidence also suggests that ant responses to disturbance reflect those of other ecosystem processes and biota (Majer et al., 1984; Andersen et al., 1996; Andersen and Sparling, 1997; Landsberg et al., 1997a, 1999; Hoffmann, 2003).

Ants have had a particularly long history of use as bioindicators in Australia (Andersen and Majer, 2004), and the responses of ants to environmental disturbance on this continent have been comprehensively reviewed (Hoffmann and Andersen, 2003). This Australian review identified a range of consistent and ecologically interpretable response patterns. Specifically, it was found that (1) soil and vegetation type are primary determinants of ant community composition, and will often have a far greater effect on ant community composition than does disturbance, (2) disturbance induces species composition changes, but does not necessarily affect overall species richness or abundance, (3) a species' response is not necessarily consistent across habitats, due to variation in inherent habitat suitability, and (4) approximately one quarter to one half of species that are common enough for statistical analysis have statistically significant responses ($\alpha = 0.05$) to disturbance. The question arises—to what extent do these patterns apply worldwide?

Throughout the world, rangeland grazing is a prominent land-use where the responses of ants have been widely studied. Ant community dynamics have been measured in relation to indirect measures of grazing intensity such as density of sheep dung (Abensperg-Traun et al., 1996) and distance from water (Hoffmann, 2000; Nash et al., 2004), as well as to numerous environmental characteristics that reflect rangeland condition (Kirkham and Fisser, 1972; Abensperg-Traun et al., 1996; Seymour and Dean, 1999; Hoffmann, 2000; Nash et al., 2001, 2004). Similarly, the respective responses of ants and other rangeland biota have been compared (Hutchinson and King, 1980; Putman et al., 1989; Landsberg et al., 1997a, 1999; Fabricius et al., 2003), or combined within multivariate analysis to identify broad faunal response patterns (Abensperg-Traun et al., 1996; Seymour and Dean, 1999; Kramer et al., 2007). However, there has been no attempt at synthesising these studies to identify common patterns and therefore better understand the consequences of grazing rangeland ecosystems.

Here I review approximately 40 studies documenting the responses of ants to grazing worldwide to examine the extent to which they follow consistent patterns. The few number of studies coupled with a high level of ant species diversity globally preclude any meaningful species-level analysis, thus investigations of patterns are purposefully limited to the community-level. Specifically, I test whether the four key patterns of ant community response to disturbance identified in Australia apply to ant responses to grazing globally.

2. Methods

2.1. Literature review

I summarised the results of all studies found in a formal literature search in which data are provided or described ($n = 35$) on the responses of ants to varied grazing pressure. The definition of grazing was not restricted to commercial grazing, however, all studies found involve livestock (cows, sheep, horses) rather than native ungulates. Searches were conducted within Cambridge Scientific Abstracts, Web of Science and CAB abstracts, using the keywords ants, ant community, cattle, effect, grazing and impact, as well as the reference list of each paper. Research results were categorised relative to the four key patterns described above. I sought to be comprehensive rather than selective in the inclusion of studies, thus there is high variation in experimental integrity, data quality, and analyses conducted. This approach maximised the number of studies available for analysis so that the conclusions could not be determined by isolated results.

Where data were presented in multiple papers, only the paper containing the most comprehensive data was used. Where multiple sampling techniques were used, only the data from pitfall traps were considered because (1) pitfall traps are the predominant method for studying ant communities in rangelands, and (2) the key patterns identified by Hoffmann and Andersen (2003) were from pitfall trap data. Papers that utilised non-pitfall trap data were listed in a separate table and summarised where possible against the four key patterns (e.g. mound density measurements were considered to be indicative of total abundance). Five papers were excluded as grazing effects could not be differentiated from those of other disturbances (Kondoh, 1978; King et al., 1998; Foster and Kettle, 1999; Nakamura et al., 2007; Fergnani et al., 2008).

Many studies reported responses in the absence of statistical tests or lacked replication. Among studies there was also great variation in sampling intensity, as well as the form of data used (i.e. raw vs transformed). Re-analysis of all studies using a consistent method and data form was not an option due to the lack of data, thus my assessments are necessarily qualitative, similar to that of Hoffmann and Andersen (2003). For example, summaries of whether species composition changed with grazing are predominantly "yes" or "no". Only the number of species/genera that were statistically responsive is quantitative. Such qualitative generalisation rather than quantitative precision is currently a dominant syndrome of ecological theory for conservation management that will only allow the development of general guiding principles (Andersen, 2002).

For patterns 1 and 3 which rely on sampling of multiple soil, vegetation, habitats, or landscape locations, the distinction of these classes is determined by their separate descriptions within each papers' methodology and/or described differences within analyses. For example, Beever et al. (2003) stratified plots as being of high or low elevation, as well as referring to plots belonging to distinct mountain ranges within analyses. Likewise, Boulton et al. (2005) described plots as being sampled from either serpentine or non-serpentine grasslands.

Grazing history and pressure varied greatly among papers, so for clarity, ant responses are discussed only in the context of a gradient of increasing grazing pressure, such that species whose abundance was greater in areas of greater grazing pressure are termed "increasers", and conversely "decreasers". As such, relative stocking rates are not quantified or compared among papers. For simplicity, the terms *change*, *response*, and *difference* are used interchangeably as studies that do or do not contain pre-treatment data are not differentiated. Ant community *composition* refers to the presence/absence matrix of species, whereas ant community *structure* refers to the relative abundance of species or ecologically defined species groups.

3. Results

I found 35 papers that measured ant responses to varied grazing regimes, of which 22 utilised pitfall traps (Table 1) and 13 used