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Recent perspectives on ants as bioindicators: A review

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Abstract
Intensive exploitation of natural resources and the resulting impacts on pristine habitats have led to calls from the scientific community and the general public to measure or monitor the level of these environmental impacts. The indicator qualities of terrestrial invertebrates are widely recognized in the context of detecting ecological change associated with human land-use. However, the use of terrestrial invertebrates as bioindicators remains more a topic of scientific discourse than a part of land-management practice, largely because their inordinate numbers, taxonomic challenges and general unfamiliarity make invertebrates too intimidating for most land-management agencies. Terrestrial invertebrates will not be widely adopted as bioindicators in land management until simple and efficient protocols have been developed that meet the needs of land managers. There are several characteristics that an indicator species must have, the most notable being ease of measurement, sensitivity to environmental stress, and predictable responses to environmental stress. Ants are increasingly being recognized as useful tools as bioindicators for land managers to monitor ecosystem health conditions. This group has useful characteristics for successful indication and monitoring of environmental impacts, including widespread distribution, high abundance, importance in ecosystem functioning, ease of sampling, and latively well-known taxonomy and ecology. Therefore, in the current narrative review of literature we aimed describe and delineate current perspectives on use of ants as bioindicators.

Keywords: Ants, species, bioindicators, land management, ecosystem health

1. Introduction

Habitat disturbances and transformation affect ant communities in many ways, either by changing habitat structure, microclimate and resource availability or by altering the balance of competitive interactions [1]. Ants are widely used to assess landscape disturbance, ecological functioning and species diversity of habitats [2, 3]. These insects constitute an important fraction of the animal biomass in terrestrial ecosystems and respond to stress on a much finer scale compared to vertebrates [2]. Ants perform major ecological functions such as predation, scavenging, soil turnover, nutrient cycling and pollination, and are also responsible for dispersal of numerous plant species [4, 5]. Moreover, ants are present at almost all the trophic levels of the food web [6], making them indispensable for the proper functioning of most terrestrial ecosystems and the resulting eco- system services [7].

The majority of environmental problems are related to anthropic action, with habitat loss and fragmentation being a major threat to biodiversity [8-10]. This affects the richness, species abundance, distribution and biodiversity in general. [11-17]. Fragmentation is more threatening than habitat loss, depending on the existence of ecological effects that be attributed to changes in the spatial pattern of habitat regardless of their quantity [18]. The effects of area loss and fragmentation are complex, since both spatial phenomena exhibit a strong correlation [19]. However, as a result, we always have the change of the configuration, with the replacement of the original vegetation by another type of habitat and, consequently, connectivity becomes disrupted [20]. Defining the factors and effects of these changes on the remaining environments and their implications for species richness and composition is part of the management practice of degraded areas, which include the effect of size, isolation and vegetation type within the spots to ensure biological viability in this area [18].

Intensive exploitation of natural resources and the resulting impacts on pristine habitats have led to calls from the scientific community and the general public to measure or monitor the level of these environmental impacts [21-23].

Bioindicators are a useful way to evaluate such impacts, since changes in their population dynamics or community parameters can indicate an environmental state more easily, quickly, and safely and with lower financial and labour inputs than direct measurements [24-26]. McGeoch divided the general use of the term bioindication into three categories according to the three main applications: (i) environmental indicators: used to detect or monitor changes in the environmental state, (ii) ecological indicators: used to demonstrate the impact of an environmental stress on the biota or monitor longer-term stress-induced changes in the biota, and (iii) biodiversity indicators: used to identify the diversity of a taxa in a specified area or to monitor changes in biodiversity [27].

Therefore, there are several characteristics that an indicator species must have, the most notable being ease of measurement, sensitivity to environmental stress, and predictable responses to environmental stress [24, 28]. The use of certain species or groups of species as indicators of successful rehabilitation practices or for environmental monitoring has been commended in recent years [25, 26, 29]. Ants have been used as a powerful tool in several ecological studies [30, 31]. This group has useful characteristics for successful indication and monitoring of environmental impacts, including widespread distribution, high abundance, importance in ecosystem functioning, ease of sampling, and latively well-known taxonomy and ecology [32]. Hence, in the present narrative review of literature we aimed describe and delineate current perspectives on use of ants as bioindicators.

2. Using Ants as Bioindicators

Many authors have discussed the ideal attributes of an indicator group for assessing ecological change, and ants routinely perform well against these criteria [33-35]. Many of the attributes directly address a taxon's ability to reflect general ecological change, and relate to their abundance, diversity, functional importance and sensitivity to disturbance. Ants clearly meet these criteria, especially in Australia. However, it is also recognized that costs and logistic constraints are important variables in the design of monitoring programmes [36]. Ants also perform relatively well in this context. For example, Brown scored 21 potential insect indicator taxa in the neotropics according to a variety of attributes relating primarily to their practicality of use, and ants rated equal highest, scoring 19 out of a possible 20 points. Nevertheless, ants still pose formidable challenges for workers who are inexperienced with insect surveys [35].

The simplified ant assessment protocol we have tested here overcomes many of these challenges. First, it is readily incorporated into routine wildlife surveys, such that ants can be reliably assessed without specifically sampling for them. Alternatively, if vertebrate trapping is not being conducted, it is simple to install pitfall traps specifically for ants, as this takes only a few minutes per trap. Secondly, by considering only a subset of species it greatly reduces laboratory time required for the processing and sorting of specimens. Most ant species are relatively small [< 4 mm], so most species were ignored by our protocol. Thirdly, large species are far easier to sort into morphospecies than are small species. Throughout the world, small-sized taxa [such as the myrmicine genera Pheidole, Crematogaster, Monomorium, Leptothorax and Strumigenys] are typically the most demanding ants taxonomically, and require considerable experience for them to be reliably sorted to species level. Most large species can be successfully sorted with only limited experience, such that a focus on large species makes ants accessible to a wide range of users. Finally, these efficiencies mean that a greater number of sites can be surveyed. Despite taking only about 10% of the effort, in this study our protocol was able to sample 65 sites compared with 40 for the intensive survey. Our sampling protocol has parallels with the concept of 'taxonomic sufficiency' [37], which addresses the level of taxonomic resolution at which samples are most efficiently sorted and analyzed. Both approaches focus on the resolution required to satisfy the objectives of the monitoring or assessment programme, as opposed to what is required for a comprehensive description of the taxa under investigation. Given that they comprise a single taxonomic family, the question of taxonomic sufficiency for ants is one of genus-level analysis. Analysis of ant community data at genus level can often reproduce species-level patterns [38, 39], but the reliability of genus as a surrogate for species in ants can vary widely between regions [40]. Our protocol has the advantages of species-level precision, and achieves efficiency through 'sampling sufficiency'.

3. Antis as Bioindicators in Land Management

For 20 years scientists have been promoting the use of terrestrial invertebrates as bioindicators, but such use still largely remains a topic discussed by scientists rather than a practice embraced by land managers. In the scientific arena, attention has focused on identifying the most reliable indicator taxon. However, the actual use of invertebrates by land managers is not limited by scientific uncertainty over which taxon might give the most precise results. Rather, it is limited by general unfamiliarity and inexperience with dealing with insects. The truth is that a number of functionally important invertebrate groups can provide valuable information on ecological change associated with land use. Hence, it was suggested that research directed at making these groups accessible to land managers deserves higher priority than does further assessment of the relative merits of different candidate taxa. Once invertebrate bioindicators become engrained in land-management culture, then it would be appropriate to focus attention on what might be the 'best' indicator taxon [41].

Comprehensive sampling was not required to reveal complex ant community responses to land use. Our study has shown that a relatively few taxonomically tractable ants can say a lot about the environment in which they occur, and considerably more than could traditional wildlife [vertebrate] surveys. This is not to decry the need for detailed studies of ants or other invertebrate groups as part of research into ecological responses to land use. However, the requirements of such research should not be confused with those of routine monitoring programmes, where the focus is not on the target groups *per se*, but on using them to provide

Information on the broader environment. The main issue in environmental monitoring is not whether or not samples are comprehensive, but whether they are reliable, and simplified ant sampling can provide reliable results [41].

4. Ants as Bioindicators of Ecosystem Health

The Northern-Indian Shivalik mountain range recently come under strong anthropogenic pressure. Ants were used as bioindicators to assess ecosystem health of the area through measurement of diversity, community patterns, species composition and the influence of invasive species of Formicidae by collecting at 75 sites from 44 locations in three habitats: primary forest (PF), secondary forest (SF), and non-forest areas (NF) using six collection techniques. Obtained the most comprehensive dataset compiled for Indian ants to date (sample coverage 94% to 97%) and sampled 31,487 ant specimens, representing 181 species from 59 genera and 9 ant families. Thirty of the 59 genera were represented by a single species, 12 genera by more than five species and 26 species were new to science. Species richness differed significantly between habitats with 151 in SF, 120 in PF and 110 in NF. Species richness rose with altitude and was influenced by precipitation, northern latitude and eastern longitude. As demonstrated by redundancy analysis and beta diversity, habitats also differed in species composition. Nineteen invasive/tramp species, comprising ca. 13% of total abundance, were distributed among the three habitats including PF [42].

Taken together, differences in composition of species communities and functional diversity among habitats have been eroded; the distribution of invasive species even in PF indicates a threat to the natural habitats in the Shivalik area. While the hypotheses are based on the assumption that mainly non-forest habitats would be impacted by human activities, the current distribution of invasive species of ants show clearly that the ecological status of the Shivalik Mountains as a whole is highly degraded, with many areas already showing clear symptoms of ecosystem distress syndrome. Climate change and increasing population density will doubtlessly further increase the threats to the unique Shivalik landscape. These findings depicted a disrupted, degraded ecosystem with high anthropogenic impact and reduced ecosystem health, even in the primary and protected forest areas. Invasive species pose a serious threat to the native species of Himalaya. For these reasons, enhanced protection and habitat rehabilitation of the Shivalik Mountains is urgently needed to conserve the fragile ecosystem, prevent further loss of biodiversity and curb the encroachment of invasive species [42].

5. Conclusions

Ants provide a valuable component to any monitoring framework. Ants are ubiquitous, abundant, and ecologically important, and also easy to collect. Evaluating ant responses at the species level has become increasingly feasible and can help pinpoint geographic variations in
morphology. However, in most cases an ant specialist is required to establish a successful monitoring program.

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