

MEASURING INVERTEBRATE BIODIVERSITY: SURROGATES OF ANT SPECIES RICHNESS IN THE AUSTRALIAN SEASONAL TROPICS

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Abstract

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The search for surrogate measures of total species richness has taken two paths, one considering the number of higher-level taxa such as genera or families, and the other considering species richness within particular target taxa. A previous analysis of Australian ant faunas indicated that genus richness was often an unreliable predictor of species richness, and that the richness of particular target genera might be a better surrogate. The data presented here from the Kakadu region of the Northern Territory support this analysis. Correlations between site species and genus richness gave r-squared values of 0.37 at natural sites ($n = 22$) and 0.66 at disturbed sites ($n = 17$). In both cases, correlations with the richness of individual target genera (the eight richest genera, contributing 110 of the 163 species recorded) gave equivalent or higher r-squared values — up to 0.46 for *Melophorus* at natural sites, and 0.66 for *Melophorus* at disturbed sites. Stepwise linear regression using all target genera gave r-squared values of 0.92 at natural sites (with six of the eight genera contributing to the model), and 0.89 at disturbed sites (with only *Melophorus* and *Polyrhachis* contributing to the model). The effort required to obtain data on the richness of target genera is likely to be similar to that required for genus richness, making target genera a more attractive option for biodiversity surrogacy. The choice of target genera varies with the spatial scale (regional or national) of analysis, and diversity relationships among sites representing variation between habitats are not the same as those among sites representing variation in disturbance.

Introduction

There is an increasing demand for robust ecological indicators (McKenzie et al., 1995) for use in environmental assessment and monitoring programs. Such indicators are most commonly required in the context of monitoring for ecological change following habitat disturbance (Noss, 1990; Spellerberg 1993), and invertebrates have often been targeted for such use (James and Evison, 1979; Greenslade and Greenslade, 1984; Disney, 1986; Rosenberg et al., 1986; Majer, 1989; Andersen, 1990; Williams, 1993).

More recent attention has focussed on the development of indicators of biodiversity *per se*, particularly in relation to estimates of species richness in highly diverse groups, such as invertebrates, where comprehensive species-level surveys are usually not an option (Hammond, 1994; Oliver and Beattie, 1996). The search for surrogates of total species richness has taken two paths, one considering the number of higher-level taxa (genera, families, etc.; Gaston and Williams, 1993; Prance, 1994; Williams and Gaston, 1994), and the other considering species

richness within particular target taxa (Kremen, 1994; Pearson, 1994; Oliver and Beattie, 1996).

In a previous analysis of Australian ant faunas (Andersen, 1995a), I showed that genus richness has limited reliability as a surrogate of species richness. Genus and species richness were closely related within a particular region, but the relationship showed large biogeographic variation, and was confounded by sampling area and sampling intensity. On a continental scale, the richness of particular target genera was more highly correlated with total species richness than was genus richness.

Here, I further explore indicators of species richness in Australian ant faunas by comparing higher-taxon richness with the richness of target genera as surrogates within a particular region. When searching for indicator taxa in the context of ecological change, it is important to differentiate between change across habitats or other aspects of the biophysical environment on the one hand, and ecological change within a particular environment due to disturbance on the other. Taxa providing a good indication of vari-

ation between habitats do not necessarily provide a good indication of the effects of disturbance within a habitat, and *vice versa*. Similarly, the best surrogate of between-habitat variation in diversity may not be the best surrogate for indicating changes within a particular habitat due to disturbance. This paper also explores the effects of disturbance on diversity patterns and the reliability of surrogates.

Methods

Study Sites

The study was conducted in and around Kakadu National Park, approximately 250 km E of Darwin in the seasonal tropics of northern Australia. Mean annual rainfall in the region is approximately 1400 mm, almost all of which falls between November and April (see Taylor and Dunlop, 1985). Temperatures are constantly high, ranging from overnight minima of about 15°C during July to daytime maxima of about 40°C during October. Soils are predominantly infertile, sandy clay loams, supporting savanna woodlands and open forests dominated by species of *Eucalyptus* (Mott et al., 1985; Taylor and Dunlop, 1985). The study was restricted to these savanna vegetation types, and did not include other regional habitats such as floodplains and monsoon rainforest.

A total of 39 sites were selected for study, comprising 22 'natural' sites that had been relatively undisturbed by human activity, and 17 disturbed sites. The natural sites were widely dispersed (separated by up to 100 km from each other), and chosen to represent the full range of savanna types in the region. The 17 disturbed sites were all located within approximately 25 km², inside the Ranger Uranium Mine lease near Jabiru, and were selected to represent a range of disturbance levels within a relatively small area. Ten of these were located adjacent to the immediate minesite, and represented a range of disturbance histories indirectly associated with mining activity. The level of disturbance ranged from slight (e.g., a roadside strip with intact vegetation, but subject to edge effects) to severe (vegetation completely cleared, with unmanaged regrowth). The remaining seven sites were located on the mine's northern waste rock stockpile (Unger and Milnes, 1992), and represented a range of stages of revegetation.

Sampling

Local ant diversity is exceptionally high in the region, with up to 100 or more species occurring per hectare (Andersen, 1992; Andersen and

Patel, 1994). Most of these are uncommon, such that a comprehensive census of species at a single site requires a prolonged period of high sampling intensity. This is obviously not a feasible option within the context of normal biological survey programmes. The sampling intensity used here was designed to be achievable within the resources of normal survey programmes, with the aim of providing comparative, rather than comprehensive, data on site species richness.

Ants were sampled primarily using pitfall traps (4 cm diameter plastic specimen jars, partly filled with ethanol as a preservative), which have been widely used in quantitative studies of Australian ant communities (Andersen, 1995b), and have been shown to provide a reliable estimate of species composition in the Kakadu region (Andersen, 1991). A 5 by 3 trapping grid with 10 m spacing was established at each site, and traps were operated for a 48 hr period at each site during July and November 1992, and November 1993. Trapping was supplemented by opportunistic, daytime handcollections.

Analysis

Ants were sorted to species, and samples from different time periods were combined to produce a single species list for each site, from which numbers of species and genera were counted. The eight richest of the 32 genera recorded were selected for target taxa analysis: *Monomorium* (21 species), *Pheidole* (16), *Melophorus* (15), *Iridomyrmex* (14), *Rhytidoponera* (13), *Meranoplus* (13), *Camponotus* (11) and *Polyrhachis* (7). Together these genera contributed 110 (67%) of the total of 163 species (see Andersen et al., 1996 for details of species composition).

Pearson correlation coefficients were calculated for the relationships between total ant species richness and (a) genus richness, and (b) richness of each of the selected target genera, considering natural and disturbed sites separately. The relationship between total species richness and combinations of the richnesses of target genera was then analysed by stepwise linear regression, using STATISTIX 4.1, again considering natural and disturbed sites separately.

Results

Diversity patterns varied markedly between natural and disturbed sites. At natural sites, genus richness was rather poorly correlated ($r^2 = 0.37$; Fig. 1) with species richness, and was

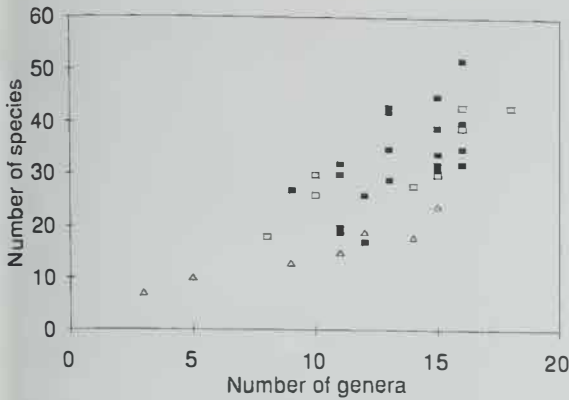


Figure 1 Relationship between number of ant species and number of ant genera at natural sites (closed squares; $r^2 = 0.366$, $p < 0.001$, $n = 22$) and disturbed sites (open triangles (waste-rock sites) and open squares (other disturbed sites); $r^2 = 0.655$, $p < 0.001$, $n = 17$) in the Kakadu region.

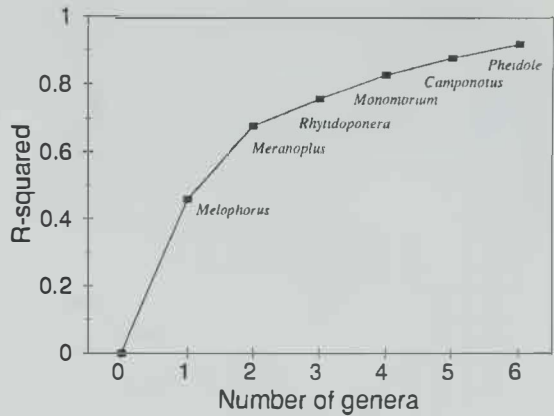


Figure 2 Relationship between number of ant species and numbers of species of selected ant genera, based on results of stepwise linear regression. The curve shows the increase in the correlation coefficient (r-squared) as additional genera are introduced into the regression.

therefore not a reliable surrogate. The richness of the best target genus (*Melophorus*, $r^2 = 0.46$; Table 1) provided a better indication of total species richness. The inclusion of a second genus (*Meranoplus*) improved the relationship substantially ($r^2 = 0.68$), with the final step-wise linear regression model (including six of the eight richest genera) accounting for 92% of the variation in total species richness (Fig. 2).

At disturbed sites, species richness showed continuous variation from the least revegetated waste-rock sites to the least impacted sites (Fig. 1). Overall, genus richness provided a good indication ($r^2 = 0.66$) of total species richness, with the relationship being particularly strong

($r^2 = 0.91$) at waste-rock sites. The richness of the best target genus (again *Melophorus*, $r^2 = 0.66$; Table 1) also provided a good indication of total species richness at disturbed sites. The final step-wise linear regression model included only *Melophorus* and *Polyrhachis*, and accounted for 89% of the variation in total species richness.

Discussion

Comparisons between potential surrogates obviously need to take into account the effort required to measure them. The effort required to sample and discriminate species from a site varies markedly with genus. The task is obviously far easier for genera containing large and conspicuous species (e.g., *Camponotus*, *Rhytidoponera* and *Polyrhachis*) than it is for genera containing numerous small, inconspicuous and morphologically similar species (e.g., *Monomorium*). The effort required to sample a genus like *Melophorus* lies somewhere inbetween, and is probably comparable to the effort required to measure genus richness.

Given these observations on sampling effort, the richness of target genera appears to be more useful than genus richness as a surrogate of total species richness in Australian ant faunas. This is especially true when considering different habitats, but less so for disturbance-related changes within a particular habitat.

The choice of target genera will vary substantially. When considering different habitats, an appropriate target genus for continental-scale comparisons may not be appropriate for analy-

Table 1. Correlations between total number of ant species and number of species of selected ant genera. Data are r-squared values, with statistical significance indicated as follows: ns not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	Natural sites	Disturbed sites
<i>Rhytidoponera</i>	0.382***	0.620***
<i>Meranoplus</i>	0.401***	0.391**
<i>Monomorium</i>	0.339**	0.606***
<i>Pheidole</i>	0.260**	0.455**
<i>Iridomyrmex</i>	0.169*	0.337**
<i>Camponotus</i>	0.073 ^{ns}	0.339**
<i>Melophorus</i>	0.464***	0.661***
<i>Polyrhachis</i>	0.134*	0.419**

ses confined to a particular region. For example, *Camponotus* appears to be an excellent target genus for comparing sites distributed throughout Australia ($r^2 = 0.83$, $n = 10$; Andersen, 1995a), but was ineffective at the natural sites described here ($r^2 = 0.07$). Further, just as genus-species relationships varied between natural and disturbed sites, so did both the reliability and composition of the optimum set of genera for target-taxa analysis.

In addition to identifying potential surrogates of ant species richness, this study has shown that disturbance and biophysical variation have different effects on species packing. This points to the need for distinguishing between different types of ecological change when searching for ecological indicators.

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