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THE USE OF PITFALL TRAPS FOR SAMPLING ANTS — A CRITIQUE

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Abstract

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Invertebrates, especially ants, are increasingly being used in terrestrial surveys and the most commonly used sampling method is pitfall trapping. Pitfall traps may not be effective for species associated with soil, deep litter and vegetation. By drawing on the author's data on ants in a range of ecosystems of increasing complexity, catches obtained by pitfall traps are compared with those obtained by a complementary suite of sampling procedures. The findings indicate that pitfall traps alone undersample the complete ant community and provide a skewed representation of the ant functional groups.. The outcome of this analysis of existing data is that a full sampling protocol, which adequately samples ants and other terrestrial invertebrates, should be used when censusing communities.

Introduction

Now that invertebrates are an accepted part of the conservation agenda, an increasing number of surveys of terrestrial invertebrates are being carried out. Topics for which invertebrates have recently been assessed include the impact of forestry practices (York, 1994), the success of minesite rehabilitation (Andersen, 1993), the comparison of different agricultural management tools (Greenslade and Smith, 1994), the impact of disturbance in conservation areas (Burbidge et al., 1992) and the assessment of biological diversity within regions (Yen et al., 1989).

One group which has received considerable attention in Australia is the ants, so much so that guidelines have been drawn up for their use as bioindicators of the condition of the environment (Majer, 1983; Andersen, 1990). The utility of this taxon is such, that scientists and consultants use it as a bioindicator taxon in all states and territories of Australia. Examples of the use of ants as indicators and in biological surveys have been documented in Beattie (1993).

The most commonly used method for sampling ants in Australia is pitfall trapping and some studies have relied solely on material obtained by this procedure (e.g., Majer, 1977; Yeatman and Greenslade, 1980, Andersen and Yen, 1985; York, 1994). This is reasonable if the study is specifically investigating surface-active ants, but there is a tendency to use this as a surrogate for the entire ant community of the habitat. The ants are generally sorted to species level and analysed in terms of relative abundance of species, species richness, functional group profile and then, using multivariate techniques such as ordination and classification, in terms of species composition.

Pitfall traps have been adopted because they are relatively simple to use, they operate continuously through day and night over extended periods, and they yield high numbers of ants representing a range of species. However, the procedure used affects the results from pitfalls in a variety of ways (Adis, 1979; Luff, 1975). For example, Abensperg-Traun and Steven (1995) evaluated the influence of trap diameter on the number of species caught in eucalypt woodland and found that size affected results. They also found that the number of species caught continued to accumulate up until at least 16 traps. Marsh (1984) found that pitfall trapping did not provide an accurate representation of the epigaeic ant community in the Namib desert and suggested that this was caused by differences in the susceptibility of some species to being trapped. In Venezuela, Romero and Jaffe (1989) compared pitfall trap catches with bait samples and hand collections taken from defined areas or over standardised time periods. Although pitfall trapping was found to be an efficient procedure, it did not collect the full range of species which were present, thus leading the authors to conclude that it should be combined with hand collecting if a more complete community census is required. Andersen (1991) compared catches from pitfall traps with those collected by hand from small quadrats in Australian savannah. He concluded that both procedures provided a similar representation of the epigaeic ant community, although he suggested that pitfall traps might provide an inadequate census in less open habitats where litter impedes surface activity and cryptic species are more important.

The above-mentioned critiques have each addressed specific questions about the efficacy of pitfall trapping. This paper looks at the performance of pitfall traps against a more complete suite of techniques for censusing the entire ant community in habitats of increasing complexity. Three studies of minesite rehabilitation are used for this evaluation as they represent a gradation in habitat complexity from eucalypt forest in North Stradbroke Island, Queensland to dune forest at Richards Bay, South Africa, through to tropical rain forest at Trombetas, Brazil . Within each study, the succession from the newest rehabilitation through to the original vegetation also represents a trend of increasing habitat complexity. Secondly, unpublished data from a Western Australian forest are used to evaluate the efficacy of repeated pitfall trapping at one site as a means of censusing the ant community. It should be noted that the individual studies reported on here were were originally self-contained projects; hence differences exist between the exact method and equipment used.

Study sites

At all three minesites a range of rehabilitated plots, ranging from very recent through to the oldest examples, and three controls, representing the pre-mining situation, were selected.

The North Stradbroke Island study was of a mineral sand mine. Twelve areas of rehabilitation, ranging from 0.1 to 15 years, were studied and the controls consisted of two open forest and one high closed scrub plot. A full description of the plots appears in Majer (1985).

The Richards Bay study was also of a mineral sand mine. Here eight rehabilitated plots, ranging from 0.3 to 13 years, and three premining controls of dune forest were studied. Full details of the plots are given in Majer and de Kock (1992).

The Trombetas study was of a bauxite mine in the Brazilian Amazon. It included nine rehabilitated plots, ranging from 0.3 to 11 years, and three pre-mining rain forest plots. One of the control plots was an annually inundated plot (C_3) where ant species richness was lower than upland forest (Majer and Delabie, 1994). Full details of the plots are given in Majer (1995)

Although this was never actually quantified in a manner where comparisons could be directly made, it should be emphasised that the vegetation in the control plots of the Australian, South African and Brazilian rehabilitation studies represents a trend of increasing structural complexity (see data in original publications). Secondly, the succession from recent rehabilitation to the oldest examples within all three localities also represents a gradient of increasing complexity (see data in primary references). Finally, the rehabilitation attains a complex structure more rapidly in the Brazilian and, to a lesser extent in the South African, mines which were studied.

The Western Australian forest site was situated near Dwellingup, where it formed the control plot for the ongoing study of ant succession in rehabilitated bauxite mines (Majer, 1981).

Ant survey procedures

Similar, but not identical, sampling procedures were utilised in the minesite succession studies. First a 100 m transect was marked out in the centre of each plot and ant collecting was performed along, and within 20 m of this line.

Ten pitfall traps (43, 25 and 20 mm internal diameter at North Stradbroke, Richards Bay and Trombetas respectively) containing ethanol/glycerol preservative were established at equal distances along the transect and run for 7 days. Day collections were performed for two person hours per transect and consisted of visual searching of soil, litter and vegetation as well as sweeping of undergrowth and beating of trees. At Trombetas, sweeping and beating were each carried out for 2 person hours so day collecting was more intensive than at the other two sites. Night collecting was carried out by visual searching for 1–1.5 person hours. Litter was collected from along the transects of all plots at North Stradbroke, the 13-year old rehabilitation and one control at Richards Bay and from the 5- and 11- year old rehabilitation and all controls at Trombetas. Litter ants were extracted by Tullgren funnels at North Stradbroke and Richards Bay and by Winkler sacks at Trombetas. Finally, at Richards Bay and Trombetas, the surface-active ants were respectively sampled by fish/honey and fish/honey/biscuit baits. Baiting was only carried out on those plots where litter samples were taken. The plots sampled by pitfall trapping plus day and night collecting were censused by what I refer to as the 'standard' sampling regime, whereas those also sampled by litter extraction or by litter extraction plus baiting were censused by the 'extended' sampling regime.

The Western Australian forest site was sampled by a grid of 6 x 6 18 mm internal diameter pitfall traps spaced at 3 m intervals. Traps were run monthly for 7 day periods from March 1976 to December 1977.

In all four studies ants were sorted to species level and assigned species code numbers within each genus.

Results and discussion

The full results of these studies are described in the references listed above. Here I concentrate on the efficacy of pitfall trapping in providing a census of the ant species present within these areas.

Figures 1a, b, and c show the numbers of ant species caught per plot by pitfall trapping and the additional number of species caught by day collecting, night collecting, litter sampling and baiting. Note that, with the exception of litter sampling at North Stradbroke, litter sampling and baiting were only performed in selected plots. Thus, the combination of pitfall trapping plus day and night collecting is generally the measure of species richness that may be universally compared between plots.

The pattern of build up in the ant fauna was not linear at any of the sites. At North Stradbroke and Richards Bay ant richness built up and then declined for a period when *Pheidole megacephala* reached high densities (Majer, 1985; Majer and de Kock, 1992), before increasing once again. Species richness peaked at around 5 years at Trombetas and exhibited some oscillations thereafter (Majer, 1995).

The pitfall trap catch showed broadly similar trends to those shown by pitfall trapping plus day and night collecting, although the number of species trapped was considerably less than the cumulative richness. Furthermore, although the number of species in pitfall traps was correlated with the number of species obtained by the standard sampling regime at all three sites, the percentage variance explained declined with increasing habitat complexity (73%, 59% and 47% at North Stradbroke, Richards Bay and Trombetas respectively). Thus the ability for the pitfall trap catch to act as a surrogate for overall species richness lessens as the complexity of the habitat increases.

Table 1 shows the mean number of ant species caught by pitfall trapping expressed as a percentage of those caught by the standard and extended samples in rehabilitation and native vegetation at the three localities. A number of trends are clearly evident.

Firstly, pitfall trapping never obtained more than 60 % of the ant species obtained from the more complete sample sets. Secondly, looking at the standard sampling set data first, the percentage of ants trapped by pitfall trapping in the control plots was always considerably lower than in the rehabilitated plots. Thus, pitfall trapping does not sample a constant proportion of the fauna if widely divergent habitats such as rehabilitation and native vegetation are considered. Thirdly, the shortfall in pitfall trap catch increased in both rehabilitation and controls with the increasing habitat complexity

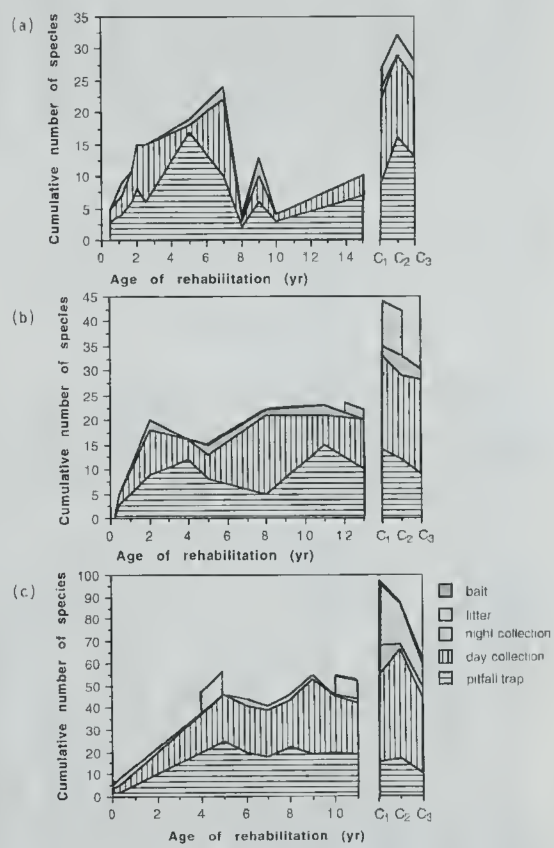

Figure 1. Number of ant species caught in rehabilitated and native vegetated control plots (C1–3) by pitfall trapping and with the addition of day collecting, night collecting, litter sampling and baiting. Data are for (a) North Stradbroke Island, Australia, (b) Richards Bay, South Africa and (c) Trombetas, Brazil. Note that baiting was not performed at North Stradbroke and baiting plus litter sampling were only performed in selected plots at Richards Bay and Trombetas.

from North Stradbroke, through Richards Bay to Trombetas. In the forest at Trombetas the pitfall traps only sampled an average of 22.3 % of the species obtained by the standard sampling regime.

If the data from the extended sampling regime are used for the calculation of percentage catch by pitfall traps, the trends are further exaggerated (Table 1), although direct comparison of the standard and extended sample percentages is complicated by the fact that the extended sample averages are only calculated from a subset of plots.

Which ants are not sampled by the pitfall traps? Inspection of the species lists indicates that cryptic, hypogaeic ants and arboreal nesting species are the groups which are most likely to be undersampled. The increasing tendency for arboreal nesting and the increased litter layer in the more tropical environments in part accounts for the decreased efficiency of pitfall traps. A further category which is undersampled is the rare ants; those which are only likely to be sampled occasionally as a result of their sparse distribution and/or low numbers (Abensperg-Traun and Steven, 1995). Although there is a high chance of missing them in the row of pitfall traps, a diligent search over a less restricted area tends to reveal them.

The conclusion from this comparative analysis is that pitfall trapping provides an inadequate census of the ant community of an area and this problem becomes more pronounced as the structural complexity of the habitat increases.

A procedure which is commonly used when conducting ant surveys is the examination of the functional group profile of the fauna. This is a procedure which was originally developed by Greenslade and Thompson (1981) and refined by Andersen (e.g., 1990). How useful is this procedure, if the full community has not been sampled? This can only be investigated at North Stradbroke Island, since the scheme was specifically designed for Australian ants.

Figure 2 shows the functional group profiles for the rehabilitated and forest control plots at North Stradbroke Island. The data have been expressed as percentages of the total ants caught by each sampling regime in order to make the two graphs visually comparable. It is immediately obvious that the pitfall traps generally sampled ants from a smaller number of functional groups than did the standard sampling regime. Also, the proportions of species in the various functional groups tends to deviate considerably between the two sets of data. Thus, any study which categorises ants into functional groups on the basis of pitfall trap data alone is in danger of producing findings which differ from those which would be obtained by a more complete census of the fauna.

The data presented here indicate that there are severe limitations in relying on pitfall trap data alone for censusing ant communities although, in part, the efficacy of the traps may be improved by using more and larger diameter traps (Abensperg-Traun and Steven, 1995). Another possibility is to trap over an extended period. Figure 3 shows the cumulative number of species obtained by 22 months of pitfall trapping of an 18 x 18 m plot at Dwellingup, Western Australia. Numbers plateaued at 36 species after the first year of sampling, a figure which fell only slightly short of the richness which is known to exist in this area of habitat (Majer, unpublished data).

Table 1. Number of ant species caught by pitfall trapping expressed as a percentage of those caught by the 'standard' and 'extended' sampling regimes in rehabilitation and native vegetation controls at North Stradbroke, Richards Bay and Trombetas.

Number of ant species in pitfall traps as a percentage of:	North Stradbroke		Richards Bay		Trombetas	
	Rehab.	Control	Rehab.	Control	Rehab.	Control
Standard samples	59.5	47.3	46.4	35.3	41.9	22.3
Extended * samples	56.0	44.0	45.0	32.0	40.0	17.7

*Note that the percentages for the 'extended' samples at Richards Bay and Trombetas are not totally comparable with those from the 'standard' samples since they represent a more limited range of plots.

Figure 2. Ant functional group profiles obtained by (a) pitfall trapping and (b) the standard sampling regime in rehabilitation and controls at North Stradbroke Island. Key to ant functional groups: 1= dominant Dolichoderinae; 2= subordinate Camponotinae; 3= climate specialists; 4= cryptic species; 5= opportunists; 6= generalised Myrmicinae; and 7= large, solitary foragers and/or specialist predators

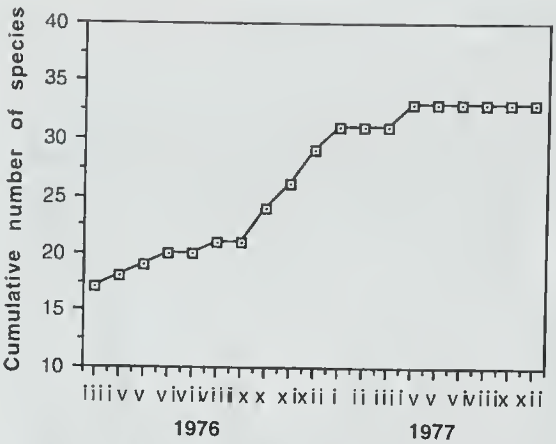

Figure 3. Cumulative number of ant species trapped by 7-day pitfall trapping at monthly intervals in forest at Dwellingup, Western Australia.

Conclusion

In part, the discrepancy between pitfall and standard or extended sample catches is related to the low number of pitfall traps used in the minesite studies; pitfall trapping was never intended to be the main sampling tool. An adequate number of suitably sized pitfall traps are indeed a suitable means of sampling the surface-active ant community in open habitats, although authors who use this approach should specify that the study pertains to the epigaeic ant community. However, traps generally undersample the entire ant community in more closed formations. The more structurally complex the habitat, the more serious becomes the problem, with cryptic, hypogaeic, arboreal and rare species being particularly prone to undersampling. Unless the study is specifically of the surface-active ant community, it is not appropriate to rely upon pitfall traps alone.

The purpose of this paper has not been to elucidate the best possible combination of sampling techniques for sampling ant communities. However, in line with the conclusion of Disney et al. (1982) it is recommended that a combination of sampling procedures must be employed if a reasonably complete census of the ant community is to be obtained. A suitable sampling protocol, which involves pitfall trapping, vegetation sweeping and also day and night hand collection has been described in Allen (1989) and Majer (1993). Also, although ants have been used to illustrate the points in this paper, the conclusions and recommendations may well apply to other invertebrate taxa as well.

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