GETTING THE MOST OUT OF ARTHROPOD BIODIVERSITY SURVEYS: A COMPARISON OF SURVEY TECHNIQUES AND TAXONOMIC GROUPS

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Summary

Due to the high costs and large numbers involved with surveys of terrestrial arthropods, biodiversity surveys of this group typically rely on a select group of taxa sampled using a single technique. These surrogate taxa are often selected on the basis of ease of identification and survey, but there is limited empirical evidence to show how well the diversity of these groups relates to the total number of arthropod morphospecies within a particular region. We surveyed terrestrial arthropods at 14 vegetation remnants within the Murrumbidgee Irrigation Area, in south-western New South Wales (Australia) by pitfall trapping, beating, sweeping and fogging. Our aim was to determine whether there were any taxa and a single sampling technique that best represented the total number of morphospecies in all assemblages at all sites, in order to provide the most efficient survey methods for future monitoring. Taxa included in the analysis were Araneae, Diptera, Coleoptera, Hemiptera and Hymenoptera (excluding Formicidae). No taxa collected using pitfall trapping were significantly correlated with the overall number of morphospecies. However, Coleoptera and Hemiptera from sweep samples were significantly, albeit weakly, correlated with the overall number of morphospecies collected using all sampling methods.

Keywords: terrestrial invertebrates, biodiversity survey methods, surrogate taxa

INTRODUCTION

An increasing number of biodiversity studies now include invertebrates, usually arthropods, as a component (Oliver *et al.* 1999, Sands and New 2003, Andersen *et al.* 2004). These surveys typically aim to provide a baseline of arthropod diversity which can be used to measure the success of conservation and management initiatives and to monitor changes in arthropod biodiversity that may occur with modification of the landscape or, currently, with global warming. Given the high species richness and abundance of arthropods, it is generally impractical to undertake comprehensive inventories (MacNally and Fleishman 2004, Andersen *et al.* 2004). Instead, surveys are usually limited to a few taxa collected using a single sampling technique (New 1998, Buchs 2003). The species richness of these taxa is often used as a proxy for overall arthropod diversity in any selected habitat i.e. they are used as indicator taxa (New 1998). These taxa tend, however, to be selected on the basis of taxonomic and sampling convenience, rather than known sensitivities to particular environmental characteristics or their ability to represent other taxonomic groups. While this approach has the advantages of being cheap and providing detailed information on selected taxa, it is not always clear how well the diversity of the target group represents overall arthropod biodiversity (Lawton *et al.* 1998, New 2000). For example, arthropod assemblages (community units) are likely to change vertically through the vegetation as well as across the landscape (Churchill 1995, New 1998, Oliver *et al.* 1999). Hence, any single sampling method such as pitfall trapping, sweep netting or fogging tends to target different subsets of invertebrates within a whole community (Basset 1991, Churchill 1993, Churchill and Arthur 1999, Moir *et al.* 2005). Choosing suitable indicator taxa as reliable surrogates for all species in any chosen site is difficult and this problem has been the subject of much research (Reyers and van Jaarsveld 2000, Lund and Rahbek 2002).

This paper describes a pilot study undertaken to identify taxonomic groups and sampling techniques that could be used as proxies for the long-term monitoring of changes in arthropod biodiversity in an irrigation landscape.

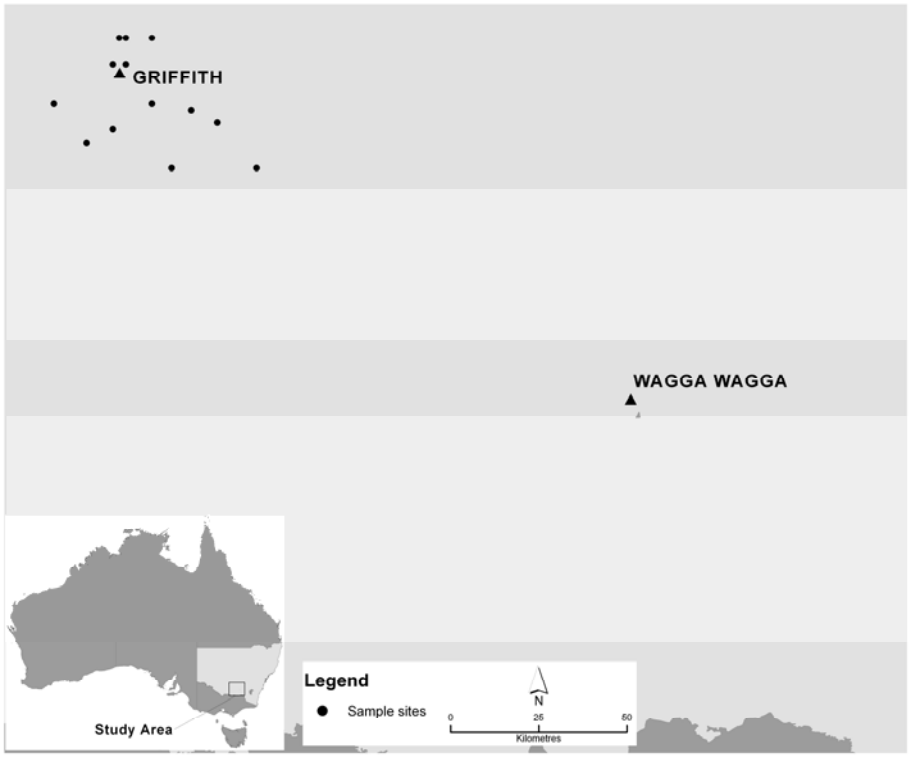
MATERIALS AND METHODS

Site descriptions

Arthropod surveys were conducted in the Murrumbidgee Irrigation Area (MIA) which lies across the northern Riverina and southern Cobar Peneplain biogeographic regions in south-western New South Wales (NSW) (Figure 1). The MIA is a highly modified landscape. Most of the original vegetation has been cleared to make way for irrigated cropping, orchards and livestock grazing. Native vegetation remnant areas are often small, isolated and subject to ongoing disturbances from livestock grazing and feral rabbits (Eldridge 2002). In addition, there are no records of terrestrial invertebrate species before European settlement in the area and, in 2005 only 65 species had been documented within the Australian National Insect Collection and Australian Museum.

A total of 14 remnant vegetation areas were surveyed for arthropods. These areas ranged in size from 3 to 310 ha and represented a range of conditions, from heavily grazed to relatively undisturbed (Eldridge 2002). Because of the highly modified nature of the MIA and because this area was severely drought

Figure 1. The area in south-western New South Wales surveyed in this study.



stricken at the time of the survey, remnant condition and size could not be standardized and few replicates per vegetation remnant community type could be found for surveying.

Four distinct vegetation communities were represented in the 14 survey sites. These were four sites of bimble box *(Eucalyptus populnea)* and cypress pine (*Callitris glaucophylla)*; four sites of black box (*E. largiflorens*); two sites of mallee (*E. socialis*/*E. dumosa*); and four sites of boree (*Acacia pendula*).

Survey techniques

Surveys were conducted within a 1 ha site, approximately 50 m away from the edge of each remnant vegetation area. Four sample techniques were employed at each site: a) pitfall traps were set; the understorey was b) swept or c) beaten; and, d) tree canopies were fogged.

a. Pitfall traps consisted of 2 L plastic containers with a 10 cm x 2 cm oval hole cut into the lids. Each trap was sunk into the ground and filled with 500 mL of ethylene glycol. Two lines of traps, placed as far apart from each other as possible were set for 10 days (25th October - 7th November 2004). Each line was made up of five pitfall traps separated from each other by 10 m.

b. Sweep samples were collected on three different occasions (25-27th October, 6-7th November and 22nd November 2004) at each site. Sweeping was conducted using a triangular net of dimensions 42 cm (height) x 42 cm (base) that was swept back and forth across the top of the understorey vegetation. Within each site two sweep transects of 50 m x 5 m were marked out and sampled systematically. Samples were collected into labelled 'snaplock' plastic bags containing 750 g L^{-1} ethanol.

c. Beating was conducted on only one occasion (25-28th October 2004) at each site, due to the gusty conditions that prevailed during the time allotted for this survey. A wooden truncheon and a nylon 'ripstop' fabric kite (90 x 90 cm) on which to catch falling specimens were used for beating. Individual shrubs within the sample site were selected at random and beaten for between 30 and 60 sec, depending on the size of the shrub. One investigator conducted the beating, another stood ready to collect fast moving specimens by hand or with an aspirator before they could leave the kite.

d. Fogging was conducted once (25-27th October 2004) at each site. Due to height constraints only trees that had foliage within 2 m of the ground could be sampled. In addition, only trees that were in good condition and were representative of the vegetation community were included. Two trees were then selected at random and each fogged with a Mortein® Control Bomb containing 10 g kg^{-1} permethrin applied at a rate of 0.25 L min^{-1}.

The control bomb was strapped to the end of a 2 m pole so that it could be held in the canopy until all the permethrin had been released (approx 4 min). As arthropods fell to ground, they were collected in upturned open umbrellas spiked into the ground beneath the trees (Richardson *et al*. 1999). Specimens were then removed from the umbrellas and stored in 750 g L^{-1} ethanol.

Laboratory techniques

All taxa were sorted to Order (CSIRO 1991) and then into recognisable taxonomic units (morphospecies) as recommended by Oliver and Beattie (1993). Only Lepidoptera had appreciable numbers of larvae that could not be identified with the adults in the same morphospecies but as overall numbers of Lepidoptera were small compared with those of other Orders, they were not included in the data analysis. Very few larvae of other groups were collected and were, therefore, not matched to adults, but excluded.

Data analysis

The main aim of this study was to identify taxa that could be used as surrogates for overall numbers of arthropod morphospecies (morphospecies richness) across a range of different remnant community types and conditions. Only arthropod taxa that occurred across all sites and had a number of morphospecies greater than 30 were considered in the analysis. These included the Orders Diptera, Coleoptera, Hemiptera, Araneae and Hymenoptera (separated into Formicidae and other Hymenoptera). The Formicidae were separated from the other Hymenoptera because Formicidae are considered to be useful indicator species (Andersen *et al.* 2004).

Significant differences in arthropod communities within the four remnant vegetation types were tested using separate one-way crossed Analysis of Similarities (ANOSIM) tests (PRIMER 5 for Windows Version 5.2.2, Primer E Ltd. 2001) (Clarke and Warwick 1994). ANOSIM tests were also used to test for significant differences in arthropod assemblages collected using the four sample techniques. All multivariate analyses were performed using PRIMER Version 5.

Univariate general linear models and Tukey Post Hoc tests were used to test for significant differences in the overall morphospecies richness collected using each of the four sampling techniques. Linear regression models were used to test the relationship between the morphospecies richness of major taxonomic groups collected using a single sampling technique and the overall morphospecies richness of all taxa collected firstly using the same sampling technique and secondly using the taxa collected with all four techniques combined. These analyses were preformed using the statistical package SPSS Version 11.5 (2002).

RESULTS

A total of 70490 individuals from 25 different Orders, represented by 594 morphospecies was collected. Four Orders made up almost three-quarters of the overall species diversity: Hymenoptera (23.9%), Coleoptera (17.8%), Araneae (17.3%) and Diptera (15%).

Arthropod community composition differed significantly between remnant type (ANOSIM Global R = 0.515 p=0.001) and sample method (Table 1).

The number of morphospecies collected also differed significantly with sample method (F_3 = 80.515, $p<0.001$), but not remnant type (F_3 = 0.58, p = 0.626). There were no significant differences in the morphospecies richness of sweeping (mean morphospecies richness (MMR) 98.9) and pitfall trapping (MMR 102.7)(Post Hoc p=0.947). Results for fogging (27.5 MMR) and beating (22.5 MMR) were similar to one another, but both were significantly lower than sweeping (Post Hoc, $p<0.001$) and pitfall trapping (Post Hoc, $p<0.001$).

Relationship with other taxa

The relatively small numbers of morphospecies collected using beating and fogging meant that no significant relationships between specific taxa and morphospecies richness were detected using these collecting techniques.

The number of morphospecies of Diptera, Hymenoptera (excluding Formicidae), Coleoptera and Hemiptera were all significantly related to overall morphospecies richness (OMR), but this relationship varied depending on sampling technique. For sweep net samples, the number of morphospecies of Hymenoptera (excluding Formicidae) (r^2 = 0.83, $p<0.001$), Diptera (r^2 = 0.80, $p<0.001$) and Coleoptera (r^2 = 0.78, $p<0.001$) collected by sweeping were all significantly correlated with the OMR collected using the same sampling technique (Figure 2). For pitfall trap samples collected Diptera (r^2 =0.490, p=0.005) and Hymenoptera (r^2 = 0.549, p=0.004) showed the strongest relationships with the OMR of taxa collected (Figure 3).

When comparing the morphospecies richness of taxa collected using a single sampling technique with the OMR estimated using all four techniques combined, the relationships were relatively weak. None of the taxa collected using pitfall trapping was significantly related to the OMR estimated using all four techniques. Of the taxa collected in sweep samples, Coleoptera (r^2= 0.369, p=0.021) and Hemiptera (r^2 = 0.346, p=0.027) were significantly correlated with the OMR estimate at

Table 1.ANOSIM pair–wise tests of the differences between arthropod communities collected using each of four sampling techniques.

	beating	fogging	sweeping	pitfall trapping
beating		R=0.171; p=0.002	R=0.589; p=0.001	R=0.739; p=0.001
fogging			R=0.653; p=0.001	R=0.819; p=0.001
sweeping				R=0.954; p=0.001

each site, but these relationships were relatively weak.

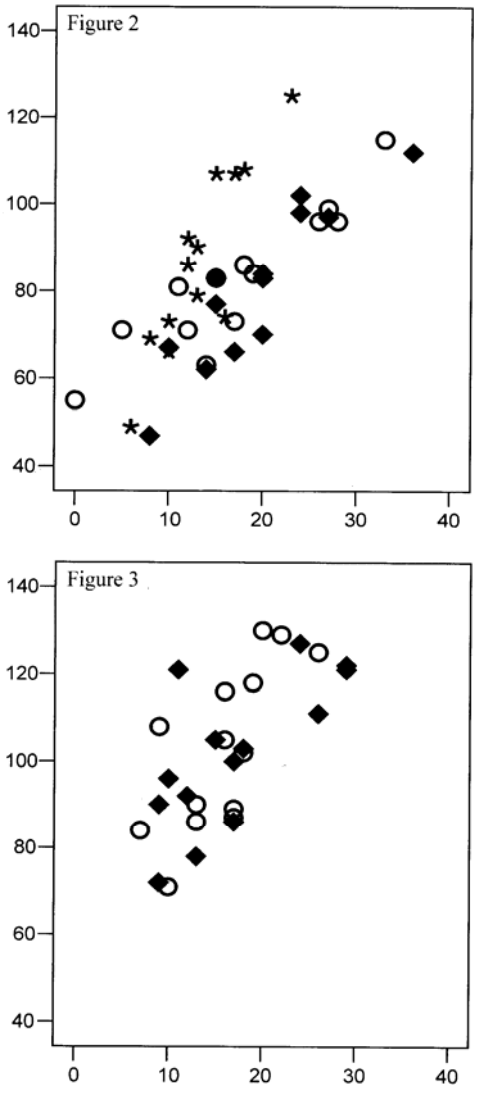
DISCUSSION

The taxa that showed promise as indicators or surrogate taxa were Hymenoptera (excluding Formicidae), Coleoptera, Diptera and Hemiptera. These relationships were however, specific to particular sample methods: e.g. Coleoptera collected in sweep samples showed the strongest relationships with the total number of morphospecies, but, conversely, ground dwelling Coleoptera collected in pitfall traps in this study showed little promise as surrogate taxa. The poor relationship between the number of Coleoptera morphospecies collected in pitfall traps and other taxa has been shown elsewhere e.g. (Gill *et al*. 1999) but it is not clear why this is the case. Formicidae and Araneae did not appear to be useful indicators of the total number of morphospecies regardless of the sample technique employed.

One of the main problems with the use of surrogate taxa is that different taxa may respond differently to disturbances (Lawton *et al.* 1998). For example, arboreal invertebrate assemblages may show little response to habitat fragmentation (Major *et al.* 2003) while ground-dwelling assemblages may undergo significant changes due to habitat fragmentation (Gibb and Hochuli 2002, Driscoll and Weir 2005). Given that many ground dwelling species have poor dispersal capabilities, recolonisation after disturbances may also be slow (Driscoll and Weir 2005). This may explain the differences in the relationships between taxa collected in pitfall traps and sweep samples and the OMR measured using all four techniques.

While the relationships between morphospecies of specific taxa and OMR were relatively strong across the range of vegetation communities and habitat conditions in this study, these relationships may not hold in different community types or at different times of year (Tovar-Sanchez *et al.* 2004). There is the added complication that species richness of particular taxonomic groups within remnant vegetation areas may actually increase as a result of species substitution and increases in exotic species (Burel *et al*. 1998, Bromham *et al*.

Figures 2 and 3. Plots of the relationships between specific taxa and overall morphospecies richness in sweep samples (Figure 2) and pitfall trap samples (Figure 3).



★ number of morphospecies of Coleoptera against total number of morphospecies (excluding Coleoptera).
♦ number of morphospecies of Diptera against total number of morphospecies (excluding Diptera).
○ number of morphospecies of Hymenoptera against total number of morphospecies (excluding Hymenoptera).

1999, Woinarski *et al*. 2002). Ideally, pilot studies using a range of the survey methods and taxa should be conducted prior to the commencement of biodiversity surveys. Alternatively, single taxa sampled using multiple techniques may yield more useful information about the characteristics of arthropod communities within a particular site, than single-, or multiple-taxa collected using a single technique.

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