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PROSPECTS FOR THE RAPID ASSESSMENT OF TERRESTRIAL INVERTEBRATE BIODIVERSITY

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Abstract

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Calls for rapid biodiversity assessment (RBA) have not always been explicit about what is meant by Rapid or by Biodiversity Assessment. Rapid can imply (i) a need for immediate results, (ii) speedy field survey, (iii) the use of diversity measures based on taxonomic identification to categories above the species level, or (iv) fast (?) post-field techniques such as the use of recognisable taxonomic units (RTU) in place of species-level identification. Some policy documents confound more than one meaning in a single statement.

Biodiversity, in invertebrate survey work, has been taken to mean species richness, though the significance of such a measure for conservation evaluation purposes has not been established.

This paper reports on a rapid (fast), rapid (short sampling time) comparison ofrapid (higher taxon and morpho-species) versus non-rapid (species level) approaches to species-richness assay at five disparate sites in north-east Tasmania. The study has implications for Rapid Biodiversity Assessment in several of its meanings.

Introduction

The term Rapid Biodiversity Assessment (RBA) has become associated with at least four different meanings of rapid:

1. that answers to biodiversity questions are needed quickly;
2. that field surveys should be done speedily using multidisciplinary teams to cover many taxa simultaneously;
3. that diversity measures may be based on traditional taxonomic categories above the species level; and
4. that species richness measures may be based on Recognisable Taxonomic Units (RTU) in place of conventional specimen identification.

Rapid *sensu* fast is the meaning commonly found in government policy documents and the like. For example, the Rio Convention (UN Convention on Biological Diversity) calls for signatory countries to undertake comprehensive biodiversity assessments within two years. Rapid *sensu* quick survey using a multidisciplinary team has been popularised by Conservation International, Inc., which sends such teams to remote, previously unstudied sites to provide a detailed inventory of the flora and fauna to be found there (see, e.g., Conservation International, 1991). Rapid *sensu* the use of higher taxonomic categories and of RTU correspond to the "Ordinal RBA" and "Basic RBA" of Beattie et al. (1993), and are Australian meanings not in current use elsewhere.

The current draft National Strategy for the Conservation of Australia's Biological Diversity (DEST, 1995) conflates three of the four meanings of Rapid. Section 4.1.2 of that document calls for action to

> . . . establish a joint Commonwealth and State and Territory program to carry out rapid assessment of Australia's biological diversity. (From the context, rapid in sense 1.)

but characterises "rapid biological diversity assessment" as

> a range of methods that facilitate rapid field survey work and classification. The fieldwork normally involves a multidisciplinary team, including experienced field scientists and people with local knowledge, in surveying component groups representative of biological diversity. (rapid: sense 2)

which leads the survey team to

> quantify the variety of organisms collected by classifying them into recognisable taxonomic units. (rapid: sense 4)

The document asserts that RTU techniques will "overcome the large time requirements of formal classification", but this claim currently is unproven. RTU methods may well be as slow or

slower than conventional identification using published keys when many taxa are compared across many samples simultaneously.

In the literature on Rapid Biodiversity Assessment as it applies to invertebrate taxa and to rapid in senses 3 and 4, "Biodiversity" has come to be equated with site species richness. Given that many species remain undescribed and that the biology of most others is poorly known, neither intra-species variation (genetic diversity) nor species interactions (ecosystem diversity) are measurable for most invertebrate taxa. Species diversity thus is, arguably, the one aspect of biodiversity which can be reliably surveyed. However, the usefulness of the resulting site species richness measures, especially in the context of conservation decisions, is questionable.

Differences in site species richness clearly are relevant in comparative studies in ecology and evolution. Their significance in any other context has yet to be established. Rapid Biodiversity Assessment is concerned almost entirely with conservation and land management decisions, and in this context species number as a measure of site diversity would appear to be of minor importance. Representativeness and complementarity amongst conserved areas, the 'keystone' attributes of species or ecosystems, the ecological products of species and areas, ecosystem fragility, current or forecast threat and the likely results of possible management interventions appear to be of greater significance than any count or comparison of species number across sites.

Site-based study

We set out to examine several issues in RBA as it applies to terrestrial invertebrates, using literature review supplemented by a small site-based study. Amongst the questions to be addressed were

1. the prospects for establishing the relative species richness of sites using fast field survey;
2. the prospects for obtaining site biodiversity rankings from higher-taxon counts;
3. the prospects for obtaining species number estimates using RTU;
4. the relative time budgets, information content and practicality of RTU-based versus conventional post-field procedures; and
5. the prospects for identifying predictor sets: taxa which predict site species richness.

Details of the field survey were reported in Trueman and Cranston (1994) (copies available from the authors). Findings re item 5 are discussed in an accompanying paper (Cranston and Trueman, this volume). In the current paper we summarise our observations and field-survey findings as they relate to items 1–4.

Field methods

Surveys were conducted at five sites in north-eastern Tasmania. Sites were established in wet sclerophyll forest (3 km NE of Weldborough: 41°10′S, 147°54′E), dry eucalypt forest (20 km E of above site: 41°09′S, 148°08′E), coastal heathland (Eddystone Point, Mount William National Park: 41°00′S, 148°19′E), periodically inundated heath (Mount William National Park: 41°02′S, 148°15′E) and buttongrass swamp (18 km N of St Helens: 41°12′S, 148°10′E.) We refer to these as sites A-E respectively.

The sites were selected to be visually and vegetatively different from each other. We reasoned that if very disparate sites such as these are not consistently given the same rank ordering on some measure of biodiversity, that measure will not be suitable for comparing more closely similar sites.

Sites were sampled three times at three-monthly intervals. Ten pitfall traps and two yellow-pan traps of standard design were set at each site in each of February, May and August, 1993. (Trap design details are given in the accompanying paper.) The pitfalls were opened for 1 week and the yellow-pans for 24 hours on each sampling occasion. In February only, ten small pitfall traps of a different design (McCartney bottles part filled with 75–80% ethanol, Greenslade and Greenslade, 1971) were set and equal-effort vacuum samples were taken. Yellow-pan traps on a black background were set in August for comparison against conventional traps. Leaf litter samples were taken at the two forested sites on each sampling occasion, and arthropods extracted from the samples over a 1 week period in Tullgren funnels.

All animals from each sample were picked and sorted to ordinal level (insects) or to phylum or other appropriate category (other arthropods). Specimens were counted, identified to RTU by project personnel not expert in the relevant taxonomic group, prepared and mounted (as necessary) for formal identification, and identified by expert taxonomists where available. Records were kept of the times taken at each stage of each

process. All comparisons of species richness, etc, are based on comparable sampling procedures

Field survey results

Table 1 compares fieldwork times and post-field times for our modest sample survey. We recovered 41137 specimens of which 47% were mites, 29% Collembola, 18% insects and 6% other taxa. The ratio of post-field time to field time was approximately 3.5:1 for an incomplete identification of the taxa present in the samples. This is comparable with times recorded in previous partial invertebrate surveys (e.g., Coddington et al., 1991). It emphasises the scope for fast post-field procedures in producing rapid (sense 1) results.

Table 1. Overall time allocation (person-hours)

Fieldwork (elapsed)	390
Sorting	590
Counting/recording	200
Specimen preparation*	250
Taxonomic Identification**	332
	1762

* Not all taxa were prepared for identification, and then not all by project personnel as distinct from expert consultant taxonomists. The figure of 250 hours includes partial preparation of all samples but full preparation only of adult Coleoptera and adult Diptera.

** Not all taxa were identified by taxonomists, as for some groups no taxonomist was available within the time frame of the project. The figure of 332 hours covers myriapods, spiders, collembolans, thrips, adult beetles, adult flies (to family), ants, and non-ant hymenopterans. For Collembola and non-ant Hymenoptera only the February samples were processed.

Table 2 compares our sites based on identified species (including in litter samples from the two sites where litter was present). The figures given are rank order of sites from 1 (most speciose) to 5 (least speciose). It is immediately apparent that relative species richness varies according to which taxa are being sampled.

We found clear evidence that the spectrum of arthropods captured is sensitive to choice of trapping method. For example, 65% of non-ant Hymenoptera specimens and 41% of adult Diptera specimens were taken in yellow-pan traps while 98% of pseudoscorpions occurred in the leaf litter samples. Such gross differences in catch are to be expected for these taxa. Less expected were major differences based on trap design. We found large and consistent differences in species composition between samples from small and standard pitfall traps and from yellow-pan traps with and without a black background sheet. Amphipods, spiders, opilionines, scorpions, centipedes, millipedes, grasshoppers and adult moths were taken almost exclusively in large pitfall traps not in small, while isopods, earwigs and larval lepidopterans were taken in small traps not in large. At site B five times as many Diptera were taken in yellow-pans with black background as in the standard design trap while at site E, with a different faunal composition, these proportions were reversed.

Table 2. Site ranking by species richness.

	Site*				
	A	B	C	D	E
Diplopoda	1	2	3	4	4
Chilopoda	2	1	2	4	4
Spiders	2	1	3	4	5
Collembola (Feb)	1	2	3	5	4
Thysanoptera	5	1	2	3	3
Coleoptera	1	2	3	4	5
Diptera (fams)	5	3	1	3	2
Ants	5	2	1	3	4
Non-ant Hymenoptera (Feb)	2	1	3	5	3
All taxa	2	1	3	5	4

* Sites: A, wet sclerophyll; B, dry sclerophyll, C, coastal heath; D, wet heath; E, buttongrass.

Although in part such differences may reflect small sampling effects, the observed distribution of lower level taxa (families, genera) across trap type suggests that trap design has a real influence on the spectrum of arthropods captured. Clearly, any biodiversity survey which seeks to sample the entire range of species at a site must employ a range of collecting methods, and intersite comparison will require that a common set of methods be employed across sites.

We found evidence that a short time frame, generalist trapping program of the type we employed gives a sufficient sample for the estimation of species richness in some taxa but not others. Species accumulation curves suggested that small ground-dwelling animals such as Colembola and small beetles were sampled sufficiently to estimate actual species presence (as

opposed to species collected) using extrapolative techniques such as those described in Heltsche and Forrester (1983) and employed by Coddington et al (1991). Larger animals (eg carabid beetles), animals with naturally clumped distributions within eaeh site (eg, ants), or taxa comprising many species each represented by few individuals (eg, spiders) were insufficiently represented for accurate species number estimation. The implication is that a field survey several times more intensive than ours, or else special sampling techniques directed at individual taxa, would be necessary to adequately sample some parts of the fauna for site species richness.

Table 3 shows the results of a site ranking exercise based on "Ordinal RBA" (rapid assessment in the third sense of "rapid"). Many ordinal measures are possible. We chose to use taxonomic categories to which we could allocate specimens with minimal error. For us this corresponded to the family/ order/ higher-level groupings used in our initial sort. Persons with greater knowledge of some taxa would, no doubt, be able to define and use a different set of categories.

Table 3. Site ranking by the numbers of specimens in each "order"; large pitfall samples only

	Site*				
	A	B	C	D	E
Amphipoda	1	2	3	5	4
Acari	3	2	1	4	5
Spiders	3	1	2	4	5
Opilionida	2	3	1	4	5
Chilopoda	3	2	1	4	4
Diplopoda	3	2	1	4	4
Collembola	2	1	3	5	4
Orthoptera	3	5	3	1	2
Hemiptera	1	5	2	4	3
Thysanoptera	4	5	1	3	2
Coleoptera	1	2	3	4	5
Diptera	3	2	1	4	5
Non-ant Hymenoptera	3	1	1	4	5
Ants	5	3	1	2	4
All groups*	3	2	1	4	5

*ie, an average across "orders" when each is given equal weight. Collembola and Acari would dominate the result if equal weight were given to each specimen.

A comparison of sites on the basis of which "orders" are present was uninformative because all orders were minimally present at all sites on all sampling occasions. Instead we examined the pattern of specimen abundance by "order". Table 3 shows site rankings based on the catch from large pitfall traps. As with the previous table the site ranking varies depending which taxon is surveyed. The average of the rankings, 3–2–1–4–5 for sites A–E respectively, matches that of Acari and Diptera. This pattern applies only to the large pitfall trap samples and it is unstable over time. For example, the site ranking for Diptera in pitfalls was 5–1–2–3–4 in May and 1–4–5–3–2 in August. Whether such changes represent true seasonal effects or erratic non-seasonal natural fluctuations, or are an artifact of a sampling process which clearly does not suffice for making accurate site species richness estimates in every taxon (and was not designed for that purpose), is unknown. Whatever the cause, findings such as these suggest that this particular form of ordinal RBA measure will not be useful for making comparisons across sites.

Table 4 compares site species richness as estimated from conventionally identified specimens against the corresponding estimates based on RTU. There is some correspondence in rankings despite, for some taxa, large discrepancies between taxonomist's species number estimates and the RTU numbers estimated by project personnel. For example, Collembola from the February samples were placed to 40 RTU but to 78

Table 4. Site rankings by RTU ("Basic" RBA) and by taxonomists' estimates of species number.

Site	RTU RANK ABCDE	SPECIES RANK ABCDE
Spiders (Feb)	13245	21345
Spiders (May)	31245	21245
Chilopoda	31244	21244
Diplopoda	13244	12344
Colembola (Feb)*	12345	12345
Thrips	51341	51332
Beetles*	12345	12345
Ants	42135	52134
Non-ant Hymenoptera (Feb)	12335	21353

* Taxa giving the same site ranking by RTU as by species count.

species. Non-ant Hymenoptera were placed to 65 RTU but to 113 species. Cranston and Hillman (1992) have previously shown that such errors are both taxon- and operative-sensitive, and hence are unstable.

Table 4 suffices to demonstrate that the site rankings may vary, even amongst disparate sites, when RTU is used in place of (presumably more accurate) taxonomists' counts of species. One question which this raises is whether the counts of RTU could be made more like counts of species by a more careful assignment of specimens to RTU. In other words, what is the most-appropriate protocol for RTU "identification"? A related question is whether steps can or should be taken to minimise systematic errors in RTU. In our data the clearest example of such errors occurred in the ants, for which RTU number was systematically underestimated by one of us (JT) through a failure to distinguish congeneric species when present, but systematically overestimated through the assignment of different castes to different RTU. The net effect on RTU number was small for all sites except site A, but such a result clearly is sample-specific and not generalisable. These two sources of error would not have been eliminated by a slower or more careful asignment of specimens to RTU.

Discussion

For the most part our field study repeats or reinforces themes which are common in invertebrate field survey work, such as that different taxa occur in different relative or absolute abundances at different sites and that different trapping procedures address different subsets of the fauna. The following have direct implications for the design of methods in conservation assessment:

1. natural seasonal or erratic fluctuations place a lower limit on the absolute time necessary for reliable survey of invertebrate biodiversity;
2. any site survey sufficient to provide an accurate estimate of species number over a wide range of taxa would likely be extremely costly and time consuming and also destructive of the site, therefore the goal of an accurate overall species number estimate for a wide range of taxa generally is not attainable;
3. as regards invertebrate survey, the relationship between fieldwork and post-fieldwork is such that there is far greater potential for time and cost savings in post-fieldwork than in fieldwork;
4. the taxon composition of samples is highly dependent on sampling procedures, making it difficult to standardise results across surveys;
5. site species richness rankings vary widely amongst taxa, and therefore are largely determined by sampling protocol or by the choice of which taxonomic groups to assess;
6. a naive "Ordinal RBA" signal based on a mix of insect orders and families, with class or phylum-level identification of other arthropods, is uninformative of site diversity for sites such as those we surveyed;
7. "Basic RBA" may produce site richness rankings inconsistent with the underlying species counts.

In addition, our observations on the meanings of "Rapid" and on the usefulness of species richness data in a conservation decision context suggest the need for a reappraisal of Rapid Biodiversity Assessment as that term currently is understood. Progress toward a meaningful set of biodiversity assessment protocols is unlikely unless (a) the present conflict over meanings of "Rapid" is resolved, and (b) the concept of "Biodiversity" is widened to include more than a mere species count.

It is significant that by its very nature an RTU count can never indicate which taxa deserve or require more conservation action than others. RTU-based methods cannot discriminate between common and rare taxa, between introduced and endemic taxa, or between those taxa which are threatened and those which are not. Taxon-based methods, in contrast, do preserve access to this type of information when it is available. The species-level identification phase of our study enabled us to make observations such as

1. The apparently greater species richness of Collembola at site A compared with site B all but vanishes if introduced species are ignored.
2. Species new to science were taken at a greater rate at sites A and B than at the other sites. (Site A yielded three new species of beetle and one collembolan; site B one beetle, one thrips and two wasps; site C one spider; site E one dipteran.)
3. Sites A, C and E produced significant range extensions to known genera or species. (Site A, a beetle of a genus known from New Zealand and an IUCN listed snail; Site C, ants of a genus known from mainland Australia; Site E, an IUCN listed, Australian endemic dragonfly known from only five sites.)

Information such as this is relevant to site management and conservation decisions. Such data always will be incomplete but it would be perverse to ignore that which can be obtained. RTU-based methods fail to retain the possibility of accessing this type of data, while a species count as an assay for biodiversity assigns it no value. Taxon-based identification facilitates the use of information other than the raw species number.

Conclusions

The term "Rapid Biodiversity Assessment", as currently used in, e.g., the draft National Strategy for the Conservation of Australia's Biological Diversity (DEST, 1995), blends several meanings of Rapid and a restricted meaning of Diversity into a hybrid concept. Evaluation of this hybrid requires that the parts be separated and individually assessed. We have addressed a few issues in RBA, some more adequately than others, and have sufficient evidence to demonstrate that a thorough reappraisal of RBA in invertebrate conservation decision making would be in order.

One major aspect which our study failed to examine but which warrants a detailed evaluation, is the potential of conventional identification using existing keys as an alternative to the RTU stage in a rapid (sense 1) assessment. Conventional identification by non-taxonomists likely would be slower than RTU assignment and less accurate than identification by experts. However, it would eliminate the need for separate voucher-specimen systems (essential when allocating large numbers of specimens to RTU) and avoid the systematic bias which comes from inappropriate definition of RTU units while also eliminating the resource bottleneck involved in identification by expert taxonomists. While this method might yield species number estimates no more accurate than those obtainable from RTU counts, the possibility of recovering information on the rarity, endemicity, etc. of species also would be conserved.

Key-based conventional identification could well outperform both (i) RTU with calibration and confirmation by experts, and (ii) the direct expert identification of samples to species level, if evaluated on either an information-per-unit-time or information-per-unit-cost basis.

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