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The search for common anthropogenic impacts on biodiversity: a global network

Jari Niemelä,[1]* Johan Kotze,[1] Allan Ashworth,[2] Pietro Brandmayr,[3] Konjev Desender,[4] Tim New,[5] Lyubomir Penev,[6] Michael Samways,[7] and John Spence[8]

[1]Department of Ecology and Systematics, Division of Population Biology, PO Box 17, FIN-00014, University of Helsinki, Finland; [2]Department of Geosciences, North Dakota State University, Fargo, ND 58105–5517, USA; [3]Università della Calabria, Dipartimento di Ecologia, 87036, Rende CS, Italy; [4]Department of Ecology, Royal Belgium Institute of Natural Sciences, Vautierstraat 29, B-1000, Brussels, Belgium; [5]School of Zoology, La Trobe University, Bundoora 3083, Australia; [6]Central Laboratory for General Ecology, 2 Gagarin Street, 1113 Sofia, Bulgaria; [7]Invertebrate Conservation Research Centre, School of Botany and Zoology, University of Natal, P. Bag X01, Scottsville 3209, Pietermaritzburg, South Africa; [8]Department of Biological Sciences, CW405A, Biological Sciences Building, University of Alberta, Edmonton, Alberta, Canada T6G 2E9

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We introduce an initiative to assess and compare landscape changes related to human activities on a global scale, using a single group of invertebrates. The GLOBENET programme uses common field methodology (pitfall trapping), to appraise assemblages of ground beetles (Coleoptera, Carabidae) in visually-similar land-mosaics (urban-rural gradients). Carabids were selected as the focal taxon as they are sufficiently varied (both taxonomically and ecologically), abundant and sensitive to the environment. However, work on other taxa is comparable with the GLOBENET framework. The continuum of decreasing human pressure from city centres into the surrounding countryside was selected to represent human-caused disturbance for this initial stage of GLOBENET because these gradients can be found virtually all over the world. Through the broad-scale assessment envisioned in the GLOBENET programme, we seek to separate general, repeated effects on biodiversity from those that depend on local environments or particular biotic assemblages. Based on this understanding we aim to develop simple tools and protocols for assessing ecological effects of human-caused landscape changes, which could help to sustainably manage landscapes for biodiversity and for human requirements. For instance, the response of different functional groups of carabids to these landscape changes may help guide management practices. Further GLOBENET developments and information are available at our website: http://www.helsinki.fi/science/globenet/

Keywords: global trends; Carabidae; bioindicators; urban-rural gradients; pitfall traps

Introduction

A number of anthropogenic activities, such as farming, forestry and urbanization, create patchworks of modified land types that exhibit similar patterns throughout the world. However, little is known on whether or not these changes affect biodiversity in similar ways across the globe, or depend more on the unique aspects of local conditions (Samways, 1992). Thus, there is an urgent need to develop 'simple' protocols to assess the effects of these activities on native biodiversity, and, where possible, to minimize adverse effects (Andersen, 1999). A multi-regional programme could potentially distinguish globally recurring patterns and convergence from more local phenomena. Such knowledge would foster international collaboration among researchers and managers to find ways to mitigate the adverse effects of human-caused landscape change. Because only a very small proportion of the world's landmass is allocated to nature reserves, approx. four million square kilometres of land (Durrell, 1986; Samways, 1994), understanding and managing changes in biodiversity in altered landscapes is a pressing priority for conservation.

In this paper we report the establishment of a global network for assessing the impacts of landscape change

*To whom correspondence should be addressed at: email: jari.niemela@helsinki.fi

on biodiversity (GLOBENET). We discuss the use of carabids in biodiversity assessment, explain how the network could contribute to development of useful theory, and summarize methods appropriate for such a monitoring network.

GLOBENET: aims and structure

To assess changes in anthropogenic landscapes we are developing a global programme that uses a common field methodology (pitfall trapping), the same taxonomic group (carabid beetles, which form definable assemblages) in visually-similar land-mosaics, in different parts of the world. Carabids are sufficiently varied taxonomically and ecologically, abundant, are sensitive to human-caused disturbances to be a reliable monitoring group, and they have been widely studied in relation to land use throughout the world (Niemelä, 1996). Recent studies, spanning several countries, showed that although species identities differed, the general patterns of community response to anthropogenic disturbance were surprisingly similar (Niemelä *et al.*, 1994; Jaganyi, unpub. data). Such results illustrate the possible significance of a multi-regional approach, and foster confidence in the feasibility of general theory for landscape planning and design.

Urban landscapes typically consist of densely built and highly developed cores surrounded by areas of decreasing intensity of development and increasing 'naturalness'. Urban-rural gradients have this appearance all over the world, although the exact type of ecosystems involved differs. Thus, these gradients provide a framework in which ecologists can examine human-induced landscape changes and compare the findings across the world to unravel generalities in community structure in relation to urbanization. Through consistent monitoring efforts, these landscapes can be treated as field experiments for addressing basic ecological questions and issues related to the impact of humans on their environment (McDonnell and Pickett, 1990; Niemelä 1999). This is not to say that other types of land-uses are insignificant, but with increasing urban sprawl and concentration of human populations worldwide, these changes potentially affect the lives and attitudes of a majority of human beings. Those with little exposure to biodiversity may develop little basis to value it and thereby contribute to the cycle of a growing biodiversity crisis. Initiatives that provide information about familiar biotic assemblages could help reverse this cycle.

Urban-rural gradients are complex with a number of potential cause and effect relationships between physical and chemical features (McDonnell *et al.*, 1997). For instance, it may at first appear surprising that urban forests are characterized by high rates of litter decomposition and N mineralization when compared to suburban and rural forests (Pouyat *et al.*, 1997). However, two anthropogenic causes – increased temperatures due to the heat island effect of the city, and the introduction of earthworms in the North American urban forests – should contribute to the existence of such patterns (McDonnell *et al.*, 1997). On the other hand, along the same gradient, urbanization negatively affected nematode, micro-arthropod and fungal densities, a possible consequence of increased heavy metal concentrations at the urban end of the gradient (Pouyat *et al.*, 1994).

Carabid beetle distribution patterns across these gradients should provide a useful measure of the impact of urbanization on biota. For instance, Davis (1978) noted that the best predictor of species richness of ground arthropods, mainly carabids, in London gardens, was the proportion of green areas within a 1 km radius of the sampling site. Furthermore, the number of ground arthropod species increased with distance from the city centre. These findings indicate that fragmentation of green space poses problems for the survival of arthropod taxa. In particular, less mobile species, such as non-flying ground-dwelling arthropods, have difficulties in dispersing among increasingly isolated patches. Only a global programme can reveal the extent to which these are general patterns applicable in various parts of the world.

Specific hypotheses that will be tested by GLOBENET are as follows:

1. Does the intermediate-disturbance hypothesis (Connell, 1978) apply to urban-rural gradients, i.e. is species richness highest in suburban sites?;
2. Does habitat homogenisation through urbanisation always lead to faunal similarities, and if so, which aspects of the functional group ('life-form') classification are most useful?;
3. What are the effects of species introductions on the diversity of indigenous carabid assemblages?;
4. Is there a temporal dimension, i.e. do older cities show more faunal effects?; and
5. Is there a spatial dimension, i.e. do cities with more and connected green areas show less faunal effects?

GLOBENET was launched at a workshop in Helsinki in April 1998 and at present, GLOBENET studies are in progress in Canada, England, Finland and Bulgaria. A workshop to discuss the first results was organized in

Bulgaria in April 1999, and a joint paper dealing with the results is in preparation.

Use of carabids in biodiversity assessment: why and how

At present, use of total biota is simply impossible for assessing impact of human activities over large areas, for reasons such as high species richness and insufficient taxonomy (New, 1993; Wheeler and Cracraft, 1997). Frequently, reduced sets of taxonomic groups are used instead as bioindicators (McGeoch, 1998; Niemelä and Baur, 1999). This approach has been advocated for studies of 'hyperdiverse' terrestrial invertebrate assemblages (Colwell and Coddington, 1995) because the 'taxonomic impediment' and their high species richness make it difficult to sample the entire fauna adequately (Kremen *et al*., 1993; Samways, 1994).

Some terrestrial invertebrate taxa have been successfully used as bioindicators (Brown, 1997). For instance, ants are used by the Australian mining industry as indicators of restoration success (Andersen, 1997). Also carabid beetles appear to be well-suited as indicators as they have several advantages in signalling the relative qualities of the land mosaic:

1. Carabids are speciose and varied (morphologically, taxonomically, behaviourally and ecologically), abundant, and measurable in many parts of the world (Lövei and Sunderland, 1996). Also, most species can be relied upon to provide consistent habitat-related information (Thiele, 1977; Niemelä *et al*., 1994; Samways *et al*., 1996).
2. Pitfall trapping, a method that can be standardized with respect to several kinds of variation (Spence and Niemelä, 1994), can easily collect carabids. Pitfall trapping has been shown to reliably reflect variation in carabid assemblages and their habitat associations (Eyre and Luff, 1990; Dufrêne and Legendre, 1997).
3. Carabids have a Pleistocene and archaeological fossil record which indicates that they respond to climatic and non-climatically caused changes of paleo-landscapes (Buckland, 1993; Coope, 1994; Ervynck *et al*., 1994; Ashworth, 1996).
4. These beetles are well-known indicators of ecological change at different spatial scales (Stork, 1990; Desender *et al*., 1991; 1994; Desender, 1996; Luff, 1996; Niemelä, 1996; Dufrêne and Legendre, 1997), and several parameters of carabid populations and assemblages have been studied with respect to their response to environmental change (Thiele, 1977). Knowledge about suites of co-adapted traits in carabids is available (Desender, 1986), and carabids tend to respond to climate change by shifting distribution rather than by physiological adaptation, indicating that they can be successfully used as indicators of environmental change (Butterfield, 1996).
5. There is a long history of success using carabids to signal environmental change (Lindroth, 1949; Stork, 1990; Desender *et al*., 1994; Niemelä, 1996). Furthermore, effects of landscape changes such as fragmentation (den Boer, 1977; Brandmayr, 1980), recreational use (Emetz, 1985), urbanization (Czechowski, 1982; Klausnitzer, 1983), forest management (Niemelä *et al*., 1994; Spence *et al*., 1996), and fire (Potapova, 1983) on carabids, have been studied. Also, carabids have been used as indicators of large-scale environmental changes (Penev, 1996), and predictors of future landscape changes (Müller-Moetzfeld, 1989).

In addition to these qualities, a useful bioindicator should provide more general information about the ecosystem in which they occur (Andersen, 1999). The above studies and some rigorous tests (Dufrêne and Legendre, 1997; McGeoch, 1998) indicate that carabids can be considered as useful ecological indicators as defined by McGeoch (1998): '. . . a characteristic taxon or assemblage that is sensitive to identified environmental stress factors, that demonstrates the effect of these stress factors on biota, and whose response is representative of the response of at least a subset of other taxa present in the habitat'.

Measures of carabid response to disturbance and sampling design

We propose both community-level and species-level measures for examining changes in carabid assemblages along the urban-to-rural gradient and across countries. Community-level measures will include species richness, abundance, similarity of samples along the gradient, assemblage-specific body size (Blake *et al*., 1994), and comparison of functional groups. As species composition varies greatly among geographical regions, direct cross-country comparisons of species lists are of little value (Andersen, 1997). To facilitate such comparisons the aim of GLOBENET is to develop a standardized functional group scheme for carabids. Sharova (1981) provided a starting point for such a scheme by introducing a classification of carabid functional groups, or 'life forms', based on morphological and ecological criteria (e.g. feeding type, body size, body shape and habitat preference). As taxonomic relations are not considered in this scheme, species from phylogenetically distant taxa can be grouped into the same 'life-form' group. A number of studies show that the 'life-form spectrum' of carabid assemblages can vary in a meaningful way in relation to several environmental factors, both natural and anthropogenic (Dushenkov, 1984; Sharova and Dushenkov, 1986; Šustek, 1992). Hypotheses derived from these studies can be tested within the GLOBENET framework. For instance, Šustek (1992) found several changes in carabid functional groups along an urban-rural gradient.

Indices based on the 'rarity' and relative size of species are another promising approach for global application, as they are independent of species identity (Eyre *et al.*, 1996). Assemblage-specific carabid body size also appears to be a useful measure of the effect of disturbance. For instance, small-sized carabid species survive frequent disturbances better than large-sized species (Blake *et al.*, 1996).

If our comparisons show similar responses of carabid assemblages to disturbance along urban-to-rural gradients across the world, similar management and conservation practices could be applicable in various parts of the world. Of course, general prescriptions for conserving features of assemblages would not automatically conserve particular species on any continent. However, initiatives like GLOBENET can determine the extent to which classifications may be effectively substituted for complete information about the species involved. The ultimate goal would be to determine whether it is possible to manage for specified assemblage structures, e.g. by using the functional group approach, without having to know the relevant natural histories of all the species present in the area to be managed. To test this proposition we will compare community level patterns with species-specific measures of taxonomic affinities (species to genus ratio), sex ratio, wing development, and habitat requirements of the species along the gradients.

An effective programme for monitoring field populations and assemblages must be related to a 'baseline' or pre-defined standard, usually measured by establishing distributional patterns and ecological needs of focal taxa through survey, surveillance and monitoring (Karr, 1987; Kremen *et al.*, 1994; McGeoch, 1998). For many regions, especially in western Europe and North America, part of these baseline data are already available for carabids (Thiele, 1977), but for many other parts of the world this information is lacking (New, 1998). Establishing the baseline for these parts of the world is one of the important initial outcomes of GLOBENET. Understanding the baseline structure of carabid communities will enable us to make predictions on how carabid communities should respond to human-caused environmental changes.

We have developed a standardized sampling protocol for capturing carabid beetles across urban-rural gradients that is both cheap and easy to implement. We propose the following procedure:

1. Select three disturbance regimes: highly disturbed urban, less disturbed suburban, and undisturbed rural.
2. Within each disturbance regime select four replicate sites.
3. Within each site place 10 pitfall traps in a random arrangement, at least 10 m apart, to ensure independent sampling (Digweed *et al.*, 1995).
4. In summary, 120 traps are installed across an urban-rural gradient, 40 traps per disturbance regime, 10 traps per site.
5. Traps are plastic collecting cups, 65 mm in diameter, with an alcohol-glycerol mixture as collecting fluid.
6. Trapping period covering the whole growing season is recommended.

Currently we are considering only forest systems (natural forests in urban, suburban and rural areas) and a single taxon, carabid beetles. However, cities are not all situated in forest systems, and we envisage incorporating other habitat types, and eventually other invertebrate taxa. Follow our website for further developments (http://www.helsinki.fi/science/globenet/).

Conclusions: GLOBENET in action

The initial GLOBENET programme will focus on providing consistent inventory and description of biological communities in an attempt to better understand biological diversity at landscape or larger scales (Dennis and Ruggiero, 1996). Researchers interested in contributing to GLOBENET are advised to follow the Internet website http://www.helsinki.fi/science/globenet/ for instructions and results.

In the future we hope to be able to expand the network and include as many countries in the world as possible. The results and comparisons which flow from this enterprise differ markedly from simply elaborating species richness and diversity for a growing set of assemblages studied in isolation and for a brief moment in time. In essence, we add the dimension of change along environmental gradients as a chronosequence to provide a dynamic comparison of assemblages in many parts of the world. The goal is to elucidate the general aspects of human impact on biodiversity in situations where human impact flows simply from human presence, and not from specific point effects like pollution and deforestation. For managers and planners GLOBENET will provide information about how carabid beetles as bioindicators respond to human-induced habitat changes along the urban-rural gradient. Understanding of the responses should help to design and manage landscapes for high biodiversity.

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