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Importance of landscape heterogeneity for the conservation of aquatic macroinvertebrate diversity in bog landscapes

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Summary

Heterogeneous landscapes are biodiversity 'hotspots'. Degradation resulting from acidification, desiccation and eutrophication not only decreases habitat quality, but also causes heterogeneity to decline. While restoration measures aim at restoring habitat quality, they can further reduce heterogeneity when they affect large parts of an area (large scale) or cause disturbance (high intensity). Successful restoration of biological diversity therefore requires knowledge of the mechanisms underlying the relation between landscape heterogeneity and species diversity. This paper addresses two questions:

(1) Do bog pools in a heterogeneous landscape harbour more aquatic macroinvertebrate species than those located in more homogeneous landscapes?
(2) Is distance between water bodies an important factor determining species composition?

To answer the first question, aquatic macroinvertebrate assemblages in bog pools with a similar water chemistry range were studied in bog remnants differing in landscape heterogeneity. The most heterogeneous remnant (Korenburgerveen) had

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the highest scores on all diversity indices, indicating that bog pools situated in a heterogeneous landscape have a higher diversity than those located in more homogeneous landscapes.

To answer the second question, the most heterogeneous remnant was studied in greater detail. Adjacent water bodies were more similar in species composition than expected on the basis of differences in local environmental conditions. This indicates that not only environmental conditions, but also spatial configuration determines the species composition.

In conclusion, species diversity in heterogeneous landscapes (i.e. those with a combination of different parts) is greater than the total number of species that would be present if the individual parts were separated. Conservation and restoration strategies should not only focus on enlarging habitat areas and restoring a single habitat type, but also on conserving and strengthening landscape heterogeneity. We present some guidelines for improving habitat quality without causing heterogeneity to decline.

Introduction

A high environmental heterogeneity generally leads to a high species diversity. This relation has been described for various groups, such as birds (e.g. Cody, 1968; MacArthur & MacArthur, 1961), diatoms (e.g. Patrick, 1963) and aquatic macroinvertebrates (e.g. Harper, Mekotova, Hulme, White, & Hall, 1997; Heino, 2000; Ranta, 1985). The number of species is also known to increase with the size of the area (MacArthur & Wilson, 1967). However, when sampling a larger area, one inevitably samples greater heterogeneity, making it difficult to differentiate between effects of area size and heterogeneity. Knowledge of the factors controlling species diversity is important as macroinvertebrate species diversity is declining in Western Europe, due to habitat deterioration by acidification, desiccation and eutrophication (Heywood & Watson, 1995).

Unlike area size, landscape heterogeneity is difficult to quantify. A landscape is best described as a continuum without borders, but for practical reasons it is easier to distinguish individual patches (i.e. spatially explicit areas). Different patches can provide different functions for a particular species (reproduction, hibernation, foraging, etc.). A habitat is best defined, in relation to an organism, as the full complement of patches in a landscape that the organism needs to complete its life cycle. Landscape heterogeneity combines variations in patch quality (*habitat diversity*) and variations in size and distance between patches (*habitat configuration*). Because of their mobility, animals in particular are expected to be able to make use of the spatial heterogeneity of a landscape. Heterogeneous landscapes may therefore be characterised by high fauna diversity, including species not found in more homogeneous landscapes.

Environmental heterogeneity in natural landscapes is declining due to chronic large-scale processes of acidification, desiccation and eutrophication, resulting in reduced complexity (loss of habitat diversity and of gradual transitions between habitats) and fragmentation (deterioration of habitat configuration). Restoration and conservation measures based on a single discipline (e.g. hydrology, vegetation) do not make allowance for habitat diversity and habitat configuration at the scale level relevant to many animal species. These measures can result in a decline in landscape heterogeneity when they affect large parts of an area (large-scale measures) or cause disturbance (high-intensity measures). An example is the large-scale rewetting of peat bogs (Van Duinen et al., 2003). Therefore, successful restoration of biological diversity requires knowledge of the mechanisms underlying the relation between landscape heterogeneity and species diversity (Verberk & Esselink, 2003).

To investigate the effect of landscape heterogeneity on macroinvertebrate diversity, aquatic macroinvertebrate assemblages were compared between water bodies with similar environmental conditions (bog pools) but located in various Dutch bog remnants differing in landscape heterogeneity. We chose to study aquatic macroinvertebrates for several reasons. Restoration measures in bog remnants focus on restoring the hydrology by raising the surface water level and improving water quality. Water bodies can be regarded as individual habitat islands, which, like true islands, offer excellent opportunities to study fundamental ecological patterns and processes (Whittaker, 1998).