Conservation and restoration of peatland fauna requires restoration of landscape heterogeneity

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Summary

Rewetting of degraded bogs generally focuses on *Sphagnum* recovery by means of retaining rain water. Aquatic invertebrate assemblages were compared between degraded and rewetted bog remnants and intact bogs. Invertebrate species respond differently to degradation and restoration, due to differences in their diet, lifecycles, dispersal capabilities and tolerance. Populations of characteristic macroinvertebrates have been able to survive the slow process of degradation, persisting as relict populations in bog remnants, but are unable to cope with rapid, large scale rewetting and the subsequent lower habitat diversity. Therefore, we recommend restoration strategies safeguarding relict populations of characteristic species. Furthermore, retaining rain water generally results in similar changes at large scale, leading to loss of landscape heterogeneity. Restoration of the regional groundwater system may rehabilitate the heterogeneity in both ombrotrophic and minerotrophic parts of bog landscapes, required to rehabilitate invertebrate diversity.

Key index words: fauna, invertebrates, restoration, habitat diversity

Introduction

As *Sphagnum* growth is a necessary prerequisite for the restoration of raised bog ecosystems, restoration measures in degraded bogs focus on creating suitable hydrological conditions for *Sphagnum* growth by blocking drainage ditches and building dams to retain rain water and decrease fluctuations of the water table (e.g. Rochefort *et al.*, 2003; Vasander *et al.*, 2003). Although animals, and especially invertebrates, make up an important part of the total species diversity (Desrochers and Van Duinen, 2006), relatively little attention has been paid to how restoration measures affect the fauna (Longcore, 2003; Van Kleef *et al.*, 2006). To study whether raised bog restoration measures rehabilitate fauna diversity, we compared the aquatic invertebrate assemblages within and between intact Estonian bog landscapes and several degraded bog remnants in the Netherlands. Dutch study sites were divided in two groups: (1) sites in bog remnants that where rewetted 1 to 29 years ago (rewetted sites) and (2) sites in non-rewetted bog remnants (remnant sites). These remnant sites were water bodies in bog remnants that had not been subject to large-scale restoration measures, but remained after ending the former use of bogs before 1950, e.g. abandoned water-filled hand peat cuttings and trenches used in buckwheat culture. This paper combines results of several comparative studies that were published in various papers.

Materials and methods

In Estonia, macroinvertebrates were sampled in 31 water bodies in Nigula bog, Valgeraba and Punaraba. In seven Dutch bog remnants macroinvertebrates were sampled at 47 sampling sites (Van Duinen *et al.*, 2003). Microinvertebrates (Rotifera, Cladocera and Copepoda) were sampled at 20 Dutch sites (Van Duinen *et al.*, 2006). In 2003 macroinvertebrates were sampled in the degraded bog remnant Wierdense Veld (Van Duinen *et al.*, 2004). Verberk *et al.* (2006a) studied the occurrence of aquatic invertebrates in the heterogeneous bog and fen remnant Korenburgerveen before and after rewetting measures took effect. For further details on methods and data analyses we refer to the papers mentioned in the text.

Results and discussion

Effects of rewetting measures and relict populations

The comparison of macroinvertebrate assemblages between the rewetted and non-rewetted Dutch sites showed considerable differences in the macroinvertebrate species assemblage (Van Duinen *et al.*, 2003). The cumulative species richness was lower at rewetted sites than at non-rewetted sites, both for characteristic species and total species richness (Fig. 1). Degraded bog remnants, with little or no botanical value, can still harbour many animal species,

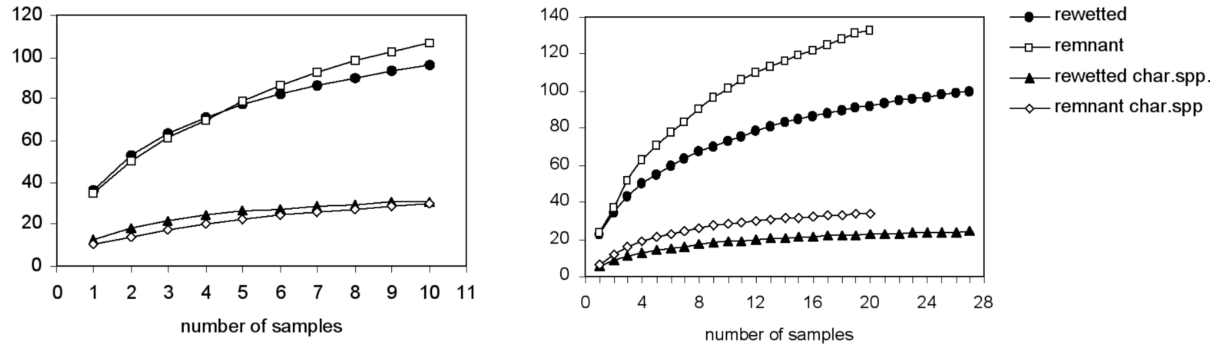

Figure 1. Cumulative species richness curves for all species and for characteristic species of microinvertebrates (left) and macroinvertebrates (right) in rewetted sites and non-rewetted remnant sites in Dutch bog remnants.

including relict populations of characteristic and rare species. Aquatic macroinvertebrate species which are characteristic for raised bogs usually have slow growth and high tolerances to drought and acidity. Due to their high tolerance they have been able to persist in the degraded bog remnants by surviving the slow process of degradation.

This comparative research provides a strong indication that there may be risks involved in the restoration of remnants where rare and characteristic species are still present. This indication was confirmed in a study were aquatic invertebrates were studied in the *same* area before and after measures took effect (Verberk *et al.*, 2006a). These risks are twofold: (1) *rapid* changes causing a disturbance (shock effects) species cannot cope with, and (2) *similar* changes over a large scale leading to a loss of variation between patches (loss of heterogeneity) and consequently to a loss of species. In a subsequent study, we showed habitat heterogeneity to be a driver of bog biodiversity (Verberk *et al.*, 2006b). These risks are enhanced for characteristic species as they generally occur either in low densities, or very locally, or both (thus contributing to the need to take restoration measures) and because characteristic species usually depend on specific patches.

Recolonisation

In order to inhabit restored areas, species either have to persist in the area during the process of degradation and restoration, or they have to recolonise the restored area from source populations. Mazerolle *et al.* (2006) concluded that some aquatic invertebrate species, including bog-associated species, readily colonise man-made bog pools created in a Canadian raised bog that had been mined for peat and where no aquatic invertebrates could have persisted. This conclusion is apparently valid for vagile aquatic beetle species, but probably not for more sedentary aquatic invertebrates, such as smaller water beetles, caddisflies, damselflies and aquatic oligochaetes (Van Duinen *et al.*, 2007).

Recolonisation is thought to be low, as many characteristic species are incapable or not inclined to disperse over long distances. For example some beetles have reduced flight muscles or non-functional wings, having established their current distribution in historic times when more marshland existed (Jackson, 1955). The distance between remaining bog habitats has increased. This may have reduced colonisation rates of bog-associated macroinvertebrates even further. In our comparative study, many rare and characteristic species were still absent in rewetted sites after 30 years (Van Duinen *et al.*, 2003), even though source populations were present nearby, sometimes even in the same bog remnant. This may be attributed to the above mentioned low dispersal capacity of characteristic species, or -more alarming- to an incomplete restoration of the conditions needed by these species.

In contrast to macroinvertebrates, species assemblage and species richness of micro-crustaceans and rotifers (including bog-associated species) did not differ between rewetted and non-rewetted sites in Dutch bog remnants (Fig. 1; Van Duinen *et al.*, 2006). As microinvertebrates have less complex lifecycles, they may have less strict demands on their environment (regarding e.g. vegetation structure, combination of habitat elements). In addition, high (passive) dispersal rate of micro-crustaceans and rotifers (easy dispersal by wind and animal vectors), may explain this difference in the response of macroinvertebrates and microinvertebrates.

Importance of landscape heterogeneity

Intact bog landscapes have an high landscape heterogeneity with transitional mire and lagg zones (Schouten, 2002). Even within the raised bog centre much variation was found between bog pools in terms of size and depth, vegetation structure, water flow and nutrient availability (Smits *et al.*, 2002). Characteristic bog species did not occur just anywhere in the bog, but showed distinct distribution patterns. Certain characteristic species preferred locations with either lower or higher nutrient concentrations (Smits *et al.*, 2002). Minerotrophic, hydrologically stable transitions supported many characteristic species. A study in a Dutch degraded bog remnant showed that several characteristic species selectively reproduced in temporary pools and others in permanent pools (Fig. 2; Van Duinen *et al.*, 2004). Regarding rewetting measures aiming at raising the water table and minimizing its fluctuations, especially small populations of characteristic species might be sensitive to sudden changes in water table fluctuations. Even though the average number of species per water body was lower in Estonia than in the Dutch bog remnants, the Estonian

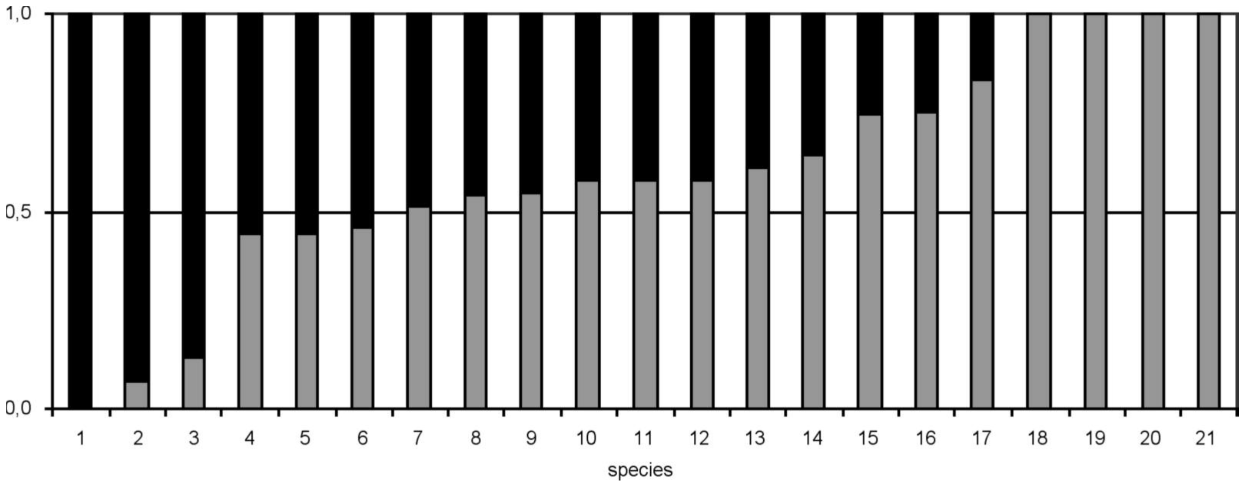

Figure 2. Figure 2. Preference of the 21 characteristic water beetle species found in the Wierdense Veld reserve for permanent (black) or temporary (grey) sites . The numbers of sampling sites in which the species were found are given between brackets. 1. *Dytiscus lapponicus* (4); 2. *Hydroporus scalesianus* (7); 3. *Graphoderus zonatus* (11); 4. *Hygrotus decoratus* (22); 5. *Acilius canaliculatus* (12); 6. *Hydroporus umbrosus* (29); 7. *Bidessus* spec. (10); 8. *Enochrus affinis* (18); 9. *Enochrus ochropterus* (11); 10. *Berosus luridus* (4); 11. *Hydroporus obscurus* (8); 12. *Hydroporus melanarius* (4); 13. *Hydroporus tristis* (18); 14. *Agabus melanocornis* (5); 15. *Hydroporus pubescens* (15); 16. *Hydroporus gyllenhalii* (23); 17. *Agabus labiatus* (12); 18. *Rhantus suturellus* (7); 19. *Hydroporus neglectus* (3); 20. *Agabus congener* (3); 21. *Ilybius aenescens* (1).

species accumulation curve was more steep than the curve for rewetted sites, indicating a higher -diversity (heterogeneity) in intact raised bog systems (Van Duinen *et al.*, 2002).

Implications for conservation and restoration

In nature reserves of high ecological value, a first priority of restoration management is the conservation of relict populations of characteristic species and the landscape heterogeneity. A second priority is strengthening the landscape heterogeneity by improving the quality of the various parts of the landscape (raised bog centre, lagg zone, transitional mire) and their transitions. Improving growing conditions for *Sphagnum* species is but a single goal, albeit important on the *long term* for restoring the acrotelm layer and thereby the internal hydrology. On the *short term*, conservation of the present nature values and improving their situation is important, which is further emphasized by the low recolonisation observed.

Because influence of calcareous groundwater can also stimulate *Sphagnum* growth (Lamers *et al.*, 1999), these goals can be reconciled when measures aim at improving the regional hydrology. These management goals can by achieved by taking measures outside the reserve, for example reducing drainage (filling in ditches) and increasing infiltration (by logging trees). Should internal measures still be necessary, changes resulting from restoration measures should be slow and reversible, allowing species to gradually redistribute in response to the changes (Van Duinen *et al.*, 2004). In addition, phased implementation of the measures, changing only small parts at a time may allow local populations to recover from disturbance or recolonise from adjacent unchanged locations. In conclusion, restoration measures should therefore aim at a *gradual* improvement of growth conditions for *Sphagnum* and increasing the heterogeneity of the landscape. This requires more attention to the landscape scale in bog restoration projects.

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