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SPECIAL FEATURE

Restoring plant communities

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The 19 papers presented in this Special Feature result from the Conference on Restoration Ecology, held from 25-31 August 2002 in Budapest, Hungary

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Restoring plant communities – Introduction

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Introduction

The present volume contains 19 papers presented at the Conference on Restoration Ecology, held from 25-31 August 2002 in Budapest, Hungary. This conference was organized under the auspices of the Society for Ecological Restoration (SER), the Institute of Botany of the Hungarian Academy of Sciences, under the title 'Challenges of the new millennium – Our joint responsibility'. This was the third International Conference on Restoration Ecology in Europe after Zürich, Switzerland (Urbanska et al. 1997) and Groningen (van Diggelen et al. 2001; Bakker et al. 2000; Verhoeven 2001).The conference resulted in a total of 24 papers, to be published in the journals *Applied Vegetation Science* (19 papers in this issue) and *The Journal of Nature Conservation* (five papers).

The conference fits in a world-wide trend to stop and reverse the ever increasing degradation of the natural environment. This increased pressure on the world's biodiversity affects ecosystems in two ways, either they are destroyed as a result of man's action (e.g. through industrial use, quarrying and mining) or through poor management of the resources where the biodiversity loss is one of quality. As these increased biodiversity losses have been identified at the international level at the Rio Earth Summit and its successor in Johannesburg, there has been increasing policy development to redress these impacts. Within Europe action plans have been formulated and constituent member countries have had to devise their own subsidiary strategies to conserve those high-quality communities that remain, as well as attempting a recovery plan for biotopes that have either been destroyed or damaged. Such Biodiversity Action Plans prioritise action for each country and they aim to protect both endangered biotopes and species. The plans often describe in detail what such habitats should look like and which species should be protected (http://europa.eu.int/comm/environment/nature/natura.htm; Anon. 1995a, b). Restoration ecology is a key player in achieving these wider conservation goals.

Restoration ecology can be considered a recent, applied development of conservation biology. Within these two disciplines most practitioners think along the same lines; they are concerned with the restoration of the above-mentioned endangered communities or habitats as refugia for endangered species. In this introduction we will explore whether it is possible to go back to a historical situation and to restore past communities that have developed upon a template that is much different from the present one.

Steps in vegetation restoration

We believe that breaking up the restoration process into several smaller steps will make it easier to judge its feasibility. We distinguish a series of conditions that have to be satisfied all for a restoration attempt to be succesful.

1. The first constraint at all sites is the set of *abiotic conditions*. Essentially, the abiotic conditions have to fall within the tolerance limits of the target communities and species.

2. However, restoring the correct abiotic conditions on its own is in most situations not enough to re-establish the desired target, especially if the aim is to do this quickly. There must also be available sufficient viable *propagules* of the target species on the target site. This is not an absolute constraint as there are many instances of natural colonization of sites and the subsequent development of biotopes with a high conservation value. However, this natural approach usually takes a longer time than managed approaches, there is sometime a high variability and there is a much greater risk of failure.

In some cases some species may have viable propagules already present within propagule banks at the site.

Where this occurs it is essential to know if they are present, and whether they are likely to contribute to the restoration process. It is also worth knowing which other species are present in propagule banks as some weed species may be present which will outcompete target species, and reduce success.

3. Once present at the restored site, propagules have to either germinate (seeds and spores) or sprout (vegetative parts) so that the species can *establish* itself.

4. Finally, once the target vegetation has established on the site, there will almost certainly be a need for an appropriate *management* regime to be implemented; this may involve disturbance (or the absence of it!) but is needed to guarantee that conditions remain suitable for the persistence of newly-established species and communities.

Abiotic conditions

Vegetation changes have occurred at an unprecedented rate during the last decades, particularly in densely populated areas. Changes in land use are considered to be the most important cause of species endangerment in the USA (Wilcove et al. 1998). Apart from direct changes such as habitat destruction by urbanization and mining (Oleksyn & Reich 1994; *Novák & Prach* this issue) most changes are caused as by-product of other processes, especially changes in the agricultural system. Agricultural intensification has increased local soil fertility but also exported large amounts of nutrients to areas outside the agricultural fields, such as woodlands or other nature reserves. A second major process has occurred especially in lowland areas, where the hydrology has been changed completely to suit agricultural needs. Drainage has not only resulted in the loss of large areas of wetlands (http://pasture.ecn.-purdue.edu/AGEN521/epadir/wetlands/status.html) but also in the release of nutrients stored in the soil (Hefting et al. in press). At a landscape scale these processes have resulted in a large increase in the surface covered by nutrient-rich and/or drained habitats, at the expense of infertile and wet biotopes. It is therefore not surprising that many threatened communities and Red List species are typically from these biotopes.

When trying to restore these types of threatened communities the first aim must be to restore the abiotic conditions found in the past, especially to lower fertility. Several techniques have been used in restoration ecology: (1) hay-making or grazing without fertilizer application, although this takes a long time because relatively few nutrients are removed, especially with grazing (Bakker 1989); (2) top soil removal, which is much faster (Verhagen et al. 2001; *van den Berg et al.* this issue; *Hölzel & Otte* this issue). However, just removing the top soil does not necessarily result in the same conditions as a previous nutrient-poor situation developed over a long period of time. *Van den Berg et al.* (this issue) show that sod-cutting also results in greater concentrations of free aluminium. The aluminium is highly toxic, and has been produced because buffering mechanisms (e.g. base cations or humic acids) have been reduced in effectiveness.

Restoration of hydrological conditions is often very complex. Not only should a previous water regime be restored, but water chemistry must also resemble its previous composition (*Tomassen et al.* this volume). In practice this is often very difficult. The hydrochemical conditions at a site are the result of complex interactions between soil chemistry within the site, neighbouring land and ground water flows. Changes in landscape hydrology are often at such a large scale that it is more or less impossible to return to a previous situation and hence to former chemical conditions. In such situations it might be wise to try to translocate threatened communities to sites with suitable conditions (*Beyen et al.* this issue) instead of trying to restore them in sites where the hydrological basis has been changed and suitable conditions are doomed to disappear.

Propagules

After changes in the abiotic conditions, there are generally shifts in the relative abundance of existing species, as new species start to invade the site. Shortly after the beginning of the restoration process, the majority of the newly-arrived species originate from the immediate surroundings and consists mainly of species with rapid vegetative spread and species from the soil seed bank. The large differences in seed longevity between species (Thompson et al. 1996) imply that restoration prospects of degraded communities also depend on the degradation period. After a longer degradation phase (> 10 yr) only species with very persistent seeds will have survived in the seed bank and other species are likely to be absent when such sites are being restored. The fraction of species with long-persistent seeds differs highly between different communities (Bekker et al. 1998) and this suggests that the 'restorability' differs in a similar way. Indeed, there are large differences between different communities (*Matějková et al.* this issue; *Matus et al.* this issue; *Blomqvist et al.* this issue) and different vegetation treatments (*Ghorbani et al.* this issue). In general, however, re-establishment of species out of the soil seed bank is considered to be poor if the degradation phase is longer than a few decades.

If species have disappeared locally but are still present in the regional species pool (cf. Zobel et al. 1998) they will have to disperse from their present locale to the restored site. Again, there are large differences between species (Verheyen et al. 2003) and communities, but in the absence of a database on dispersal traits, it is impossible at present to compare communities on the basis of constituent species. There are also large differences between dispersal vectors. Wind dispersal seems to be relevant mainly for very short distances (Bakker et al. 1996), except for a small number of species and possibly in very windy climates. Animal dispersal is potentially capable of transporting seeds over much larger distances (Poschlod & Bonn 1998) but is probably mainly important in unfragmented landscapes and much less effective in the fragmented landscapes found in many parts of modern Europe. Water dispersal has been shown to be very effective (Middleton 1999; Johansson et al. 1996) but is, due to its very nature, limited to flooded areas only. Although the lack of detailed information prevents a formal assessment of dispersal probability it is obvious that the probability of arrival is inversely related with distance (MacArthur & Wilson 1967). The best chances to restore degraded communities are, therefore, found in sites that lie in the close vicinity of areas that can act as propagule sources (*Novák & Prach* this issue; *Khater et al*. this issue). Nevertheless, there are some sites where species have arrived from some distance (Ash et al. 1994), but this is unpredictable.

Establishment

Once new species have arrived in restored sites they face the same problems as invasive species and therefore it is likely that there is selection for the same traits. The present state of knowledge is clearly not sufficient to predict which species will be succesfull (Crawley 1987) but successful species appear to have some features in common. A broad survey of the Czech alien flora by Pyšek et al. (1995) showed that successful invasion of semi-natural habitats was favoured by C-strategists (i.e. competitors), height (i.e. better competition for light) and perennials (i.e. because they skip the dangerous establishment phase every spring). At the same time there are also large differences in the invasibility of existing communities (Crawley et al. 1999). In spite of much effort, there is surprisingly poor understanding of the mechanisms that control invasion resistance. In a recent review article Levine & D'Antonio (1999) suggest that – contrary to what most people believe – there is some evidence for a positive correlation between species richness and invasibility. Moreover, invasibility is almost certainly not constant over time. *Bartha et al*. (this issue) found that after extreme weather events, total species cover decreased and colonization rates increased significantly, suggesting that interspecific competition is a major bottle-neck for the establishment of new species (*Rey Benayas et al*. this issue) and is thus an important constituent of invasion resistance. If this relationship is generally true this would relate invasibility directly to competition for resources, especially light (i.e. site productivity). It suggests that communities on infertile sites are less resistant to invasion and might be easier to restore, of course under the premise that ample propagules are available. At the same time, such habitats will also act as a selection sieve for certain plant characteristics and the concept of plant functional types is, therefore, a potentially very useful tool for assessing species composition during regeneration trajectories (*Gondard et al*. this issue).

Management

Once the restoration has proceeded to a certain stage the management regime that was applied in the past is generally re-installed. All over Europe the large majority of the surface was used intensively for low-intensity agricultural purposes in the past and this means that old agricultural practices such as mowing without fertilization or grazing with ancient cattle races are re-installed in restored sites. Nowadays these practices have no economic purpose anymore but act essentially to remove nutrient and create regeneration gaps.

Increased nutrient input by air and water flows causes mowing and especially grazing to be much less effective in nutrient removal than in the past (Bakker & Olff 1995). The creation of recruitment gaps by temporarily reducing light competition is, therefore, assumed to be the main effect of grazing and mowing .

Both grazing and cutting lead to a creation of recruitment gaps but there are also differences (*Hayes & Holl* this volume). Mowing leads to a spatially homogeneous but highly heterogeneous situation in time where species have to time their germination and establishment exactly to avoid competition for light. Moderate grazing on the other hand leads very often to the development of so-called grazing lawns where the herbivores visit the same spots repeatedly. The result is a spatially, highly heterogeneous environment with spots with high standing crop adjacent to spots with a very low vegetation, but with a pattern that is stable in the short- to medium-term. In the longer term, successional cycles maybe developed with change this pattern (Bokdam & Gleichman 2000; *Castro et al*. this issue; *Smith et al*. this issue). However, where a heterogeneous vegetation is produced by grazing the timing of arrival of invading species is not as critical compared to a mowing regime.

Species that do not tolerate low light intensities may be able to colonize grazed sites with low standing crop, whereas species that do tolerate low light intensities will find suitable sites as well. This suggests that biodiversity will increase faster and to a greater asymptote in grazed sites than in mown areas, but in reality the opposite may occur (*Stammel et al.* this issue). One possible reason might be that heterogeneous grazing leads locally to such a high grazing pressure that establishment is not possible there (*Matějkova et al.* this issue).

Can we restore threatened plant communities?

Technically it is possible to restore many communities at least to some degree of success. They can be achieved very simply in some situations, relying on spontaneous succession (Kirmer & Mahn 2001; *Prach* this issue), although this can be a very variable and stochastic approach (Wiegleb & Felinks 2001). Alternative species can be added in a variety of ways, for example through the use of hay transfer, (*Hölzel & Otte* this issue) or soil translocation (*Vécrin & Muller* this issue). However, even if the abiotic conditions can be completely restored – and this is often only partly possible – it is very likely that natural selection will favour similar plant traits but not necessarily the same species as in the past. This implies that similar community types will develop, but their species composition might be entirely different from the past and possibly even include exotic species. We realize that many people do not like this idea but we see replacement of some native species by some exotic ones as a natural process in a dynamic environment. After all, if we enlarge our temporal horizon to the whole period since the last ice age most of the temperate zones was an arctic desert without any vegetation. This has been colonised over time and all species, now considered native, would have been considered exotic at that time.

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