Biological Conservation 159 (2013) 119–126

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Creating novel urban grasslands by reintroducing native species in wasteland vegetation

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ARTICLE INFO

Article history:
Received 21 June 2012
Received in revised form 23 November 2012
Accepted 29 November 2012
Available online 21 January 2013

Keywords:
Mycorrhizal inoculation
Novel ecosystems
Regional provenance
Reintroduction
Shrinking cities
Urban restoration

ABSTRACT

In many areas of the world, grassland species have declined due to intensified agriculture and abandonment of unproductive sites. In rural areas, restoration approaches seek to counteract this loss. Additional potential for grassland restoration arises in urban settings, especially on large-scale wastelands isolated from suitable species pools.

We explored the potential of urban wastelands for the development of low-maintenance meadows. We expanded on restoration approaches of rural landscapes by working with altered urban soils and existing wasteland vegetation. We tested if grassland species of regional provenances can be successfully reintroduced by comparing different restoration treatments: (1) transfer of a threshed seed mixture (*Heudrusch*) from local hay meadows, (2) seeding of species of regional provenances, (3) the same seeding combined with mycorrhizal inoculation.

We revealed higher total species richness in all treated plots compared to the control, with similar proportions of grassland species. Both seeding treatments showed increased proportions of target species. The proportion of target species was stable in the seeding/mycorrhiza treatment and increased in the seeding only treatment from the second to the third year of the study to the same level. Urban soil features including stone content were negatively related to target species richness. In contrast, human-mediated impacts (e.g., dog intrusion) showed no significant effect on target species richness.

Our experiment demonstrates that urban wastelands are suitable habitats for grassland species. Including extant soils and resident vegetation results in novel urban meadows with a considerable share of ruderal species but where rare grassland species are able to persist.

1. Introduction

Species-rich grassland communities have developed over centuries due to traditional agricultural use (e.g., in Europe: Poschlod and WallisDeVries, 2002; Veen et al., 2009). Yet intensified agriculture and abandonment of unproductive sites have led to a pronounced decline in grassland species (Poschlod et al., 2005; Wesche et al., 2012). To counteract the loss of grassland habitats, restoration approaches have been successfully conducted in cultural landscapes (Kiehl et al., 2010), mining areas (Baasch et al., 2012; Kirmer et al., 2012) and peri-urban remnants (Joas et al., 2010).

In cities, the potential for grassland species to be present may arise in different context: Lawns are important due to their spatial extent in urban areas and share attributes with semi-natural habitats (Thompson et al., 2004). Usually, these harbour only a limited range of grassland species due to intensive maintenance and recreational pressure but reduced maintenance may allow the persistence of a wider range of grassland species. Furthermore, deindustrialisation, structural and demographic changes lead to a growing extent of open space mainly in developed and transitional countries (Martinez-Fernandez et al., 2012; UN-Habitat, 2008). 54% of the urban regions in the European Union and 13% of the urban regions in the US decreased in their population in the 1990s (Wiechmann and Pallagst, 2012 and references herein). Leipzig/Halle (Germany), Manchester (UK), Osaka (Japan) or Detroit (USA) are examples of such shrinking urban areas (Oswalt and Rieniets, 2006). Here, additional open space arises after the demolition of surplus residential property and infrastructure (Schetke and Haase, 2008), which could improve the urban green infrastructure and may provide substitute habitats for grassland plant species. These, in turn, may increase biodiversity across multitrophic levels as shown in experimental grassland plots (Scherber et al., 2010). However, restoration approaches for these sites have yet to be developed.

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0006-3207/$ - see front matter
http://dx.doi.org/10.1016/j.biocon.2012.11.028

In Europe, current approaches to deal with large-scale wastelands with an urban-industrial past include controlled succession, wilderness (Kowarik and Körner, 2005) and forestation (Burkhardt and Lohmann, 2010). Other schemes involve the enhancement of wasteland vegetation with aesthetically attractive native (Luscombe and Scott, 1994) or non-native forbs, often North American prairie species (Kühn, 2011) that are expected to persist despite low maintenance effort (Hitchmough, 2009).

While these approaches focus on developing woody vegetation or on the aesthetic enhancement of derelict land, we aim here to add the perspective of novel urban ecosystems as potential habitats for grassland species. In keeping with the concept of Hobbs et al. (2006), novel urban ecosystems are characterised by severe human-mediated habitat alterations and by assemblages of native and non-native (ruderal) species, which form novel wasteland vegetation communities (Kowarik, 2011). Given the highly altered soil conditions of urban demolition sites, it cannot be expected that restoration measures induce grasslands with a composition similar to that of grasslands in the traditional cultural landscape. Restoration in this setting could however be based on interventions (Hobbs et al., 2011) that keep elements of the existing wastelands while providing substitute habitats for protected grassland species. Reintroducing native grassland species to urban demolition sites is thus expected to create novel species compositions but may allow native grassland species to colonise urban habitats that are otherwise affected by high dispersal limitation due to fragmentation. To reintroduce native species (sensu Seddon, 2010) to urban habitats would thus merely fill gaps in the species' distributional range that likely developed due to urbanisation.

As typical seed mixtures usually contain cultivars or introduced provenances of native species (Kiehl et al., 2010), sowing native grassland species may still alter the genetic structure of local populations (Aavik et al., 2012) and promote invasions below the species level. To avoid this situation, grassland restoration today aims at using the regional species pool, e.g., by hay transfer from nearby donor sites (Baasch et al., 2012; Donath et al., 2007). Using regional provenances of native species thus helps to conserve genetic diversity and reduces invasion risks at the sub-species level (Hufford and Mazer, 2003).

Approaches to reintroducing grassland species to urban demolition sites could take inspiration from methods tested in mining areas (Baasch et al., 2012; Kirmer et al., 2012) as both settings are characterised by the lack of organic matter and by wind erosion. Additional challenges in urban areas include disturbances by residents, high contents of stony material from demolition processes and competition with existing wasteland vegetation.

To our knowledge, established methods of ecological restoration have not yet been tested systematically within this new urban context. It is therefore unclear if reintroduced species will succeed under strong urban pressure, at sites with strongly altered soils and wasteland vegetation. To experimentally test if grassland species can be established on urban demolition sites, we applied treatments known from mining sites to urban demolition sites in a randomized block design. We aimed to achieve nature conservation objectives while creating attractive but low-maintenance green spaces. To keep costs low, we supported germination chance of reintroduced grassland species only by deep tilling prior to treatments. We anticipated that some existing species will regenerate by vegetative means or from the soil seed bank and co-exist with the added grassland species. We hypothesised that (1) urban wastelands offer potential habitats for dispersal-limited grassland species, (2) the proportion of target species and total species richness as measures of treatment success increase in the treatments compared to an untreated control and (3) competition of resident vegetation and environmental variables such as soil variables or human intrusion of sites limit the establishment of target species.

2. Materials and methods

2.1. Study area

Hellersdorf is a large-scale housing area constructed in the 1980s in the former East Berlin, Germany, where demographic changes caused an oversupply of infrastructure and housing. Through demolition processes, additional free space with undetermined future use has rapidly emerged amidst the remaining buildings. Here, ruderalised young lawns or wasteland successions develop. In addition to typical lawn species such as *Lolium perenne*, the native ruderals *Artemisia vulgaris* and *Tanacetum vulgare* and the non-natives *Conyza canadensis* and *Solidago canadensis* frequently appear.

2.2. Treatments

We tested three treatments to reintroduce grassland species: (a) the *Heudrusch* method of transferring components of hay, taken in this case from species-rich grassland communities of the nearby Nature Protection Area Rahnsdorf, (b) application of a seed mixture of regional provenances of grassland species provided by commercial producers and (c) the same seed mixture as (b) combined with a mycorrhizal inoculation. In fall 2008 we applied the treatments in a randomized block design on eleven wasteland sites (each about 1 ha or more) that were scattered across the district of Hellersdorf (30 km^2). Distance between study sites was at least 500 m, with one exception. Within each study site we randomly located a block of 4 m $\times$ 4 m plots with an untreated control containing the extant spontaneous vegetation and one plot of each of the treatments. Before treatment, plots were mown and tilled to about 30 cm. Exposure of sites was even. Plots were located in full sun, with scattered trees at some study sites. We did not fence the plots, as we wanted residents to use the sites as usual, but already existing fences allowed us to study varying human impacts on the treatments. Regularly over the following years, a buffer of 2 m was mown between plots and a band of 30 cm around the plots was tilled to reduce root runners. The plots themselves were mown each fall.

The *Heudrusch* method is inspired by traditional hay transfer (Engelhardt, 2001), but rather than transferring the hay in its entirety, it is first threshed by a specialised producer (Engelhardt, Gangkofen, Germany). The final product applied on-site includes seeds, stems and glumes. Our source, the Nature Protection Area Rahnsdorf was mown in August 2004 and the dry hay was collected and threshed under standard conditions. According to the producer, the donor site included 16 target species (see Table A1 in Supporting Information). We tested the germination rate of the *Heudrusch* under standard conditions in a greenhouse, adjusted the amount to 20 g m^{-2} dry weight and applied the material to the sites in combination with diaspore-free grass clippings (500 g dry - weight/plot) to prevent seeds from being blown away.

For both seeding treatments, we created an identical mixture of seeds of 27 species from regional provenances provided by commercial producers (Rieger-Hofman, Blaufelden-Raboldshausen; Saaten-Zeller, Riedern, Germany). After germination tests, we adjusted the species' seed numbers to yield 1000 potentially germinating diaspores/m^2, equally distributed among species. The species number was oriented on other grassland restoration experiments (e.g., Kiehl et al., 2010). The mixture contained target species of dry and mesic grassland types to account for the varying soil conditions of the wasteland sites. Most of these are locally rare species with limited or no source populations in the study area to test if their occurrence in urban wastelands is dispersal limited. We did not consider very rare and strongly endangered species, as a