Ecological Restoration in Parks and Protected Areas: Using Protected Areas for Testing Methods of Restoring Forest Communities

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Abstract

*Severe disturbances usually denude an ecological community of its structure (based on its species composition) and function. Restoration requires that the community be re-assembled, but the question is what key aspects need attention and in what order or priority? Parks and protected areas offer some challenges but the opportunities offered by the existence of good, protected 'reference states' for comparison to degraded areas and restored areas are attractive to researchers. To begin to test methods of ecological restoration of forest communities, I compared four sites within a medium-sized municipality (Region of Waterloo, Ontario, Canada). Two sites were relatively undisturbed forest communities in protected areas; the other sites were disturbed by construction of housing developments. I compared the relative success of restoration on the disturbed sites by combinations of treatments: transplanting three different densities of two guilds of forest understory herbs – early spring guild of dog's-tooth-violet (*Erythronium americanum*), acute-lobed hepatica (*Hepatica acutiloba*), May-apple (*Podophyllum peltatum*), bloodroot (*Sanguinaria canadensis*), barren strawberry (*Waldsteinia fragarioides*); late spring/summer guild of red baneberry (*Actea rubra*), strawberry (*Fragaria virginiana*), avens (*Geum canadense*), pale touch-me-not (*Impatiens pallida*), American germander (*Teucrium canadense*); a guild of tree seedlings – sugar maple (*Acer saccharum*), white oak (*Quercus alba*), common elder (*Sambucus canadensis*); and adding soil harvested intact before housing developments began. After six years, analyses of variance with repeated measures have indicated that transplanting five plants m^{-2} of the early spring guild plus the pre-development* *soil, followed by transplanting tree species and the late spring/summer guild gave the best survivorship. The populations of herbs and tree seedlings that resulted produced an understorey comparable to the reference states of relatively undisturbed communities. The reasons for this are the ability of native species to outcompete invasive species, protection of transplants from desiccation, and increased presence of mycorrhizae and invertebrates.*

Introduction

In parks and protected areas, restoration ecology poses a challenge because of high visibility (fear of failure or waiting long periods for success), potential conflicts between conservation and recreation, and the scale of restoration, i.e. it transcends boundaries of parks and protected areas. However, these areas offer opportunities for experiments in restoration ecology because of the presence and support of experts committed to environmental issues, an ability to implement relative secure and long-term studies, and the availability of protected 'reference states' needed for experimental testing of the relative degradation of other sites versus the ecological restoration methods used to reverse this degradation. Probably the greatest impact in parks and protected areas in Ontario is the historical problem of habitat fragmentation making forest communities vulnerable to edge effects and further 'runaway' fragmentation.

Given that a key issue in restoration is how to reassemble communities or ecosystems, the challenge to restoration ecologists is to determine which critical structures or functions should be given attention and in what priority (Palmer *et al*., 1995; Pywell *et al*., 2002)? There tend to be recommendations on how to do this on a theoretical basis but there are few tests or applied examples, especially in the context of restoration ecology (e.g., Keddy and Drummond , 1996; Pyšek *et al*., 2001; Vallauri *et al*., 2002). One limitation is that there are so many structures and functions in an ecosystem, that it is difficult even to decide on where to begin. Since urbanization is a major reason why ecosystems have been disturbed (e.g., Pickett *et al*., 2001) and in need of restoration and, in the Great Lakes region, urbanization has been particularly destructive to mixed-woods forests, I chose to test the impact of restoring structural losses to see if this translates into restoration of both structure and function. I tested how best to restore different densities of two phenological guilds of understorey herbs, a guild of locally dominant tree species, and the soils that existed before housing developments began.

Methods

I chose four sites in Waterloo Region, Ontario, Canada (43.48 [N], -80.54 [W]). Of these sites, two were relatively undisturbed upland forests dominated by sugar maple (*Acer saccharum)*, white oak (*Quercus alba)*, and common elder (*Sambucus canadensis*) and two were similar forests that were denuded of most of the vegetation during housing development, leaving remnant edges. Plants and soils were rescued in autumn before development began near forest edges in winter 1996; the experiment began in spring 1998 as houses were now being built but earth-moving near the remnant edges of the forests had ceased. Potential (individual) treatments to be applied to a split-plot design (four replicates per site) were as follows:

- Transplanting three different densities (5, 7, or 9 plants m^{-2}) of an early spring guild of forest understory herbs: dog's tooth violet (*Erythronium americanum)*, acute-lobed hepatica (*Hepatica acutiloba)*, May-apple (*Podophyllum peltatum)*, bloodroot (*Sanguinaria canadensis)*, and barren strawberry (*Waldsteinia fragarioides*).

- Transplanting three different densities (5, 7, or 9 plants m^{-2}) of a late spring/summer guild of forest understory herbs: red baneberry (*Actea rubra)*, strawberry (*Fragaria virginiana)*, avens (*Geum canadense)*, pale touch-me-not (*Impatiens pallida)*, and American germander (*Teucrium canadense*).

- One density (one sapling [about 1 m high] of each species within a 10 m^2 area) of a guild of tree seedlings (sugar maple, white oak, common elder). The presence or absence of this tree guild was the split-factor.

- Adding soil harvested intact before housing developments began. This soil was removed with shovels, reflecting the typical working pace. The soil was dug to 20 cm with shovels (preserving the depth profile), preserved in 60 cm deep 'flats', transported to a growth room, watered with amounts mimicking local precipitation patterns, and planted with native herbs from the above guilds (random selection of species planted at 7 plants m^{-2}) in an attempt to allow key soil flora and fauna to remain intact.

- All plants used were rescued from the original sites before development began and allowed to grow in individual 10-50 cm diameter pots with 'promix'. Pots were watered with amounts mimicking local precipitation patterns. Photoperiod conditions also mimicked the local patterns from autumn 1998 through summer 2000.

- All possible combinations of the number and order of treatments (planting densities of the two guilds and 'pre-development' soil) were used. This meant that treatments ranged from control (no intervention) through to a treatment with 9 plants m^{-2} of both guilds and addition of pre-development soil in varying implementation orders. I transplanted mature individuals.

- The experiment has continued since 1998. Population and communities of plants in each replicate are monitored monthly and during critical phenological stages to measure leaf areas at flower bolting and seed production. Key responses are numbers of visible stems during the midpoint of the growing season, end-of-season population, and (where relevant) % survivorship of original transplants. Analyses of variance with repeated measures have been used to report on the first six years of results (Mauchly's tests for sphericity indicate no violations). When comparing individual combinations or orders of treatment, contrasts were used to test for differences.

Results

For this presentation to PRFO 2004, I focused on how well the guilds have done based on changes to the population demographics of species and whether any new species (native or exotic) have colonized the sites. In the longer term (once more data are collected), community analyses will be used to assess the progress of the various restoration treatments. Between-subjects, the significant factors are the sites ($F = 19.81$, $P < 0.01$), the treatments ($F = 22.31$, $P < 0.01$), and a site-treatment interaction ($F = 9.87$, $P < 0.05$). Within-subjects, time, treatment-time, and site-time all are significant (respectively: $F = 14.32$, $P < 0.01$; $F = 11.76$, $P < 0.01$; $F = 8.96$, $P < 0.05$). Despite the interaction effects, it was possible to generalize the ranking of success of treatments and their orders by using the contrasts from the analyses. Given the number of possible combinations, an abbreviated version is presented:

- The best combination and order was: trees with pre-development soil, then 5 plants m^{-2} of the early spring guild (with the pre-development soil), and finally late spring/summer guild at 7 plants m^{-2} (with pre-development soil). This resulted in populations that were not significantly different than the relatively undisturbed reference sites.

- Densities were critical for the late spring/early summer guild. When these were planted after early spring guilds or trees, higher densities were better (e.g., 7 and 9 plants m^{-2}; Figure 1).

- The order of assembly was critical: the best results were obtained by first planting the trees, then the early spring guild, and then the late spring guild (Figure 2).

- Use of pre-development soil was critical as treatments without it consistently fared worse (Figure 3).

- Failing to plant the early or late spring/early summer guilds encouraged invasions by exotic species (Figure 4).

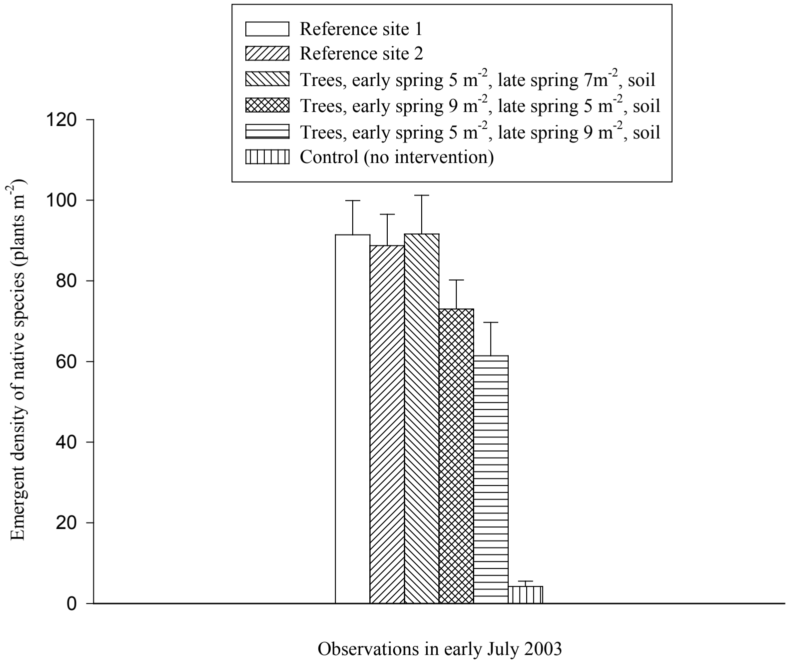

Figure 1. *Effect of selected densities of two understorey guilds on success of ecological restoration.*

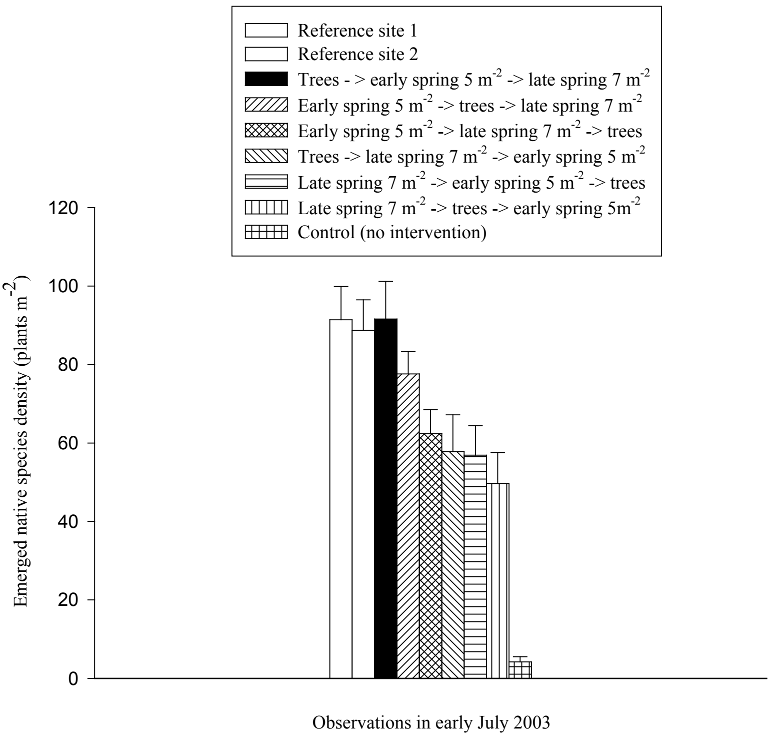

Figure 2. *Effect of assembly order on success of ecological restoration.*

- Transplanting trees was important – their presence significantly improved success (Figure 5).

- Control plots (no intervention) were significantly worse than all other combinations.

To provide relatively concise evidence for this summary, Figures 1-5 offer selected comparisons; the selection was based on clarity and represent results that were consistent with those from similar analyses.

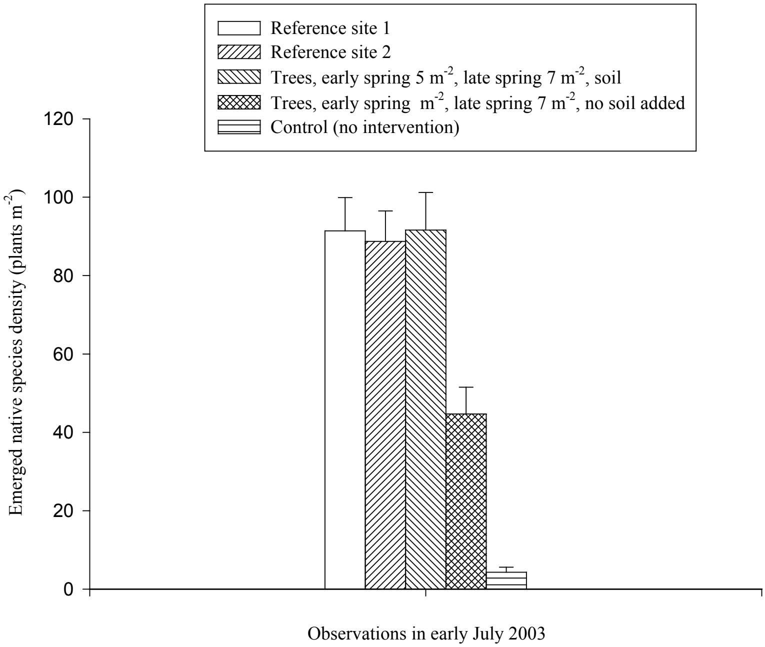

Figure 3. *Effect of addition of pre-development soil on success of ecological restoration.*

Discussion

The use of different densities (Figure 1), assembly order (Figure 2), and pre-development soil (Figure 3) contributed greatly to the success of the restoration efforts. In particular, Figure 3 indicates that the experiment is succeeding in preserving at least some of the key soil flora and fauna, e.g. mycorrhizae and invertebrates (see Kourtev *et al*., 2002; Richter and Stutz, 2002; De Deyn *et al*., 2003; Wardle *et al*., 2004). Focus on soils should be a priority for ecological restoration of the understorey community of upland mixed-woods/deciduous forests. The assembly order implies that planting saplings first in early spring has the effect of minimizing disturbance since other guilds were not yet planted, maximizing survivorship by reducing sapling root shock and related factors and offering increased shading (especially to suppress invasives – see Figure 4) and possibly 'nursing' guilds planted later, e.g., protect them from desiccation. The assembly order also indicates that planting early spring guilds probably reduces disturbance or competition between this guild and

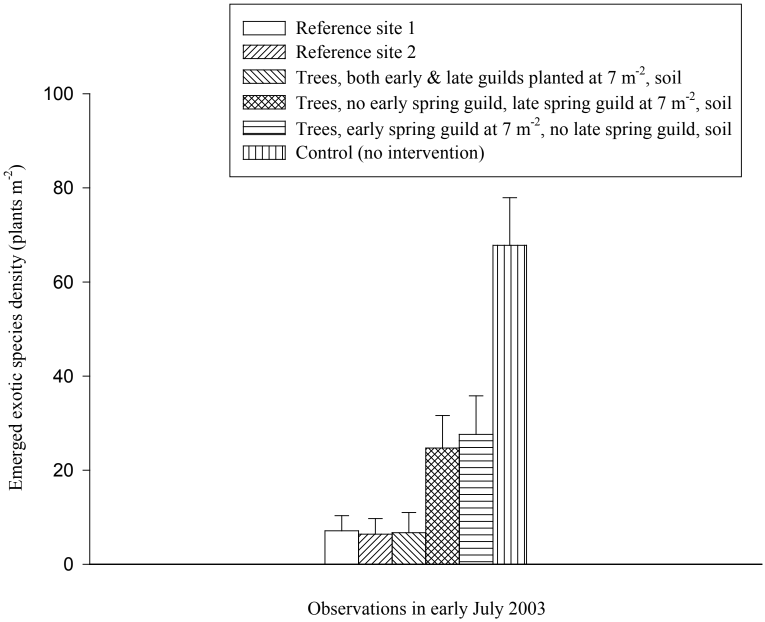

Figure 4. *Effect of planting early and late spring guilds on density of exotic species.*

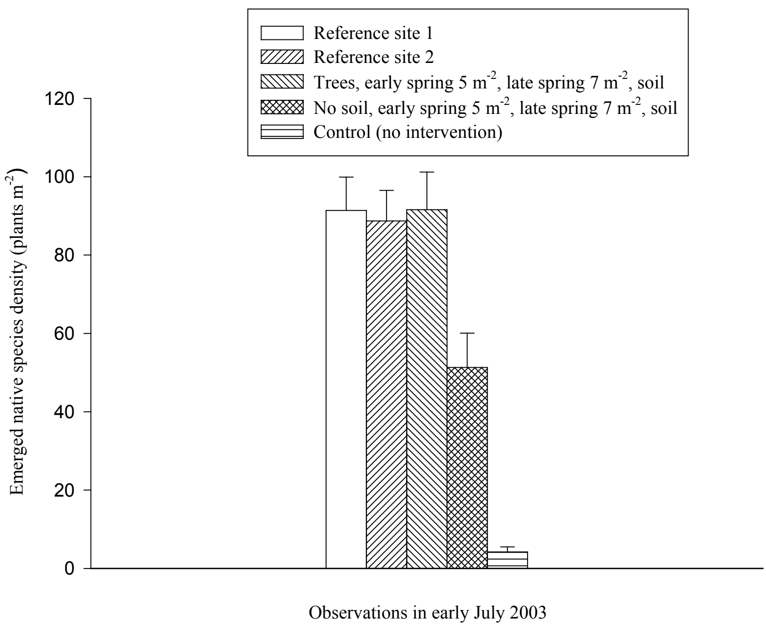

Figure 5. *Effect of planting trees on success of ecological restoration.*

the later spring/early summer guild. Density effects specifically indicate that the 5 plants m^{-2} for early spring guilds allows them to outcompete immediate invaders, e.g., garlic mustard (*Alliaria petiolata*), without promoting too much competition between guild members. When planted after the early spring guild and saplings, the later spring/early summer guild needed to be transplanted at higher densities, probably to compensate for lingering effects of competition. Most likely, competition was for light but it could exist for other resources, e.g., nutrients or water, and could occur amongst the understorey guilds, saplings, and any invasives (Booth *et al*., 2003; Meloche and Murphy, in press). There were some interaction effects involving the sites chosen, but this was that some of the marginal orders or combinations (e.g., no understorey guild and/or no pre-development soil) were significantly worse at one site and this was exacerbated over time.

The main implication is that for ecological restoration to work best (at least after six years under my sites' conditions), the assembly order and specific treatments are critical. Locally, it means that developers, municipal staff, and restoration ecologists should ensure that soil disturbance is minimized or repaired (often, soils are compacted or dug, inverted, carted, covered and replaced – in an effectively 'dead' condition). Trees and early spring understorey plant guilds should be transplanted first – perhaps this is expected given that this reflects the typical phenology of communities in the Waterloo area. In concurrent studies in my own research, it appears that the use of understorey species (especially bloodroot and May-apple) to outcompete early spring invasives for light and plantings with species of different heights are very useful (Murphy, accepted). In the latter case, the plantings act as 'structural buffers' by deflecting wind, conserving moisture, raising relative humidity and providing 'nursing' for other plants, animals, and (particularly) mycorrhizae and soil fungi. There are, of course, other scales, structures and processes that should be examined (e.g., spatially explicit processes, Robinson and Handel, 2000; herbivory, Ruhren and Handel, 2003). Relative new exotic threats to forests like emerald ash borer (*Agrilus planipennis*) and Asian longhorn beetle (*Anoplophora glabripennis*) will divert attention to other pest management strategies and cause restoration ecologists to re-think their species plantings lest they be destroyed but coming threats. The human dimension of planning and management of protected areas (vs. other land-uses) must be more collaborative at a landscape scale if ecological restoration is to succeed long-term at more than just local scales. Ultimately, my study indicates that restoration ecologists should test assembly order and the often-neglected soil community (even at a broad scale) rather than just the structure of the species composition being restored. This has particular relevance to parks and protected areas and their environs where there is more latitude and opportunity to test this and to truly restore ecological integrity in its functional sense.

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