

Revegetation after Disturbance in High-Altitude Meadow Ecosystems

Helen Beeson
Independent Study 2006
Mentor: Jennie Reithel

Abstract:

Restoration Ecology is the science of techniques in which environmental degradation can be reversed and the previously existing ecosystems can be reestablished. Revegetation is a common restoration technique and I chose to investigate whether it could be applied to disturbed areas in high-altitude meadow ecosystems in Gothic, Colorado. I transplanted 100 plants, 20 of each of five native species: *Potentilla gracilis*, *Linum lewisii*, *Fragaria virginiana*, *Erigeron speciosus*, and *Achillea millefolium* and tested the effect of varying amounts of sunlight, plant size prior to transplant, and species on the development of new growth and reproductive success. I found that the best species for future revegetation projects are *Erigeron speciosus* and *Fragaria virginiana* and that, although *Achillea* and *Potentilla* were fairly successful at developing new growth and flowers, they might benefit more from reseeding as a restoration technique. I also surveyed plant communities in previously disturbed areas and found no relationship between plant diversity and time since disturbance and a marginally significant positive relationship between invasive plant cover and time since disturbance.

Introduction:

Environmental disturbance can be reversed through restoration, the process of mimicking and accelerating primary succession to overcome the natural limitations, such as seed dispersal, that make succession a generally slow process (Dobson et al. 1997). The general goal of restoration is to restore the biodiversity to its original level with a similar plant community, enabling it to support the same or similar organisms. This would constitute “rehabilitation”, or the reestablishment of the ecosystem that existed prior to disturbance; whereas “replacement” would mean the establishment of a different ecosystem.

Invasive species cause concern because of their ability to alter ecosystems and lower biodiversity. Invasive species will outcompete native plants, excluding them from the area and resulting in a loss of not only the native plants but all organisms affiliated with them directly or through a trophic cascade. Invasive species can also negatively affect the native plants around them by lowering their visitation rate by pollinators, resulting in less fertilization and seed production (Traveset. 2006). Disturbed areas are generally more vulnerable to the initial colonization and spread of invasive plants (Floyd et al. 2005, Johnson et al. 2006). Therefore, to avoid expediting the spread of invasive species we should try to minimize the area of disturbed land by applying restoration techniques such as revegetation. If rehabilitation of an ecosystem is not attempted the ecosystem could go down a road of replacement, most likely becoming a community dominated by invasive species (Jordan et al. 1987).

The threats to natural habitats and the processes with which to restore them are as diverse as the ecosystems themselves. For this reason, it can be difficult to generalize restoration techniques across varying habitats. The most appropriate treatment for a disturbed piece of land is not always immediately apparent so it is usually necessary to do a pilot study in every place. With more research some general guidelines can be formed for each type of ecosystem. Already forming are international databases for information on restoration projects with lists of case studies from which one can draw techniques for other restoration projects and the effectiveness of restoration on a larger scale can be documented (Jenkinson et al. 2006). When conducting restoration projects it is necessary to have a perspective that takes into account the entire ecosystem and to identify specifically what problems the disturbed area has (Ehrenfeld, J.G. 1997). This includes testing how degraded the land is and the boundaries of the disturbed land (distance to undisturbed land) to determine what the appropriate restoration treatment is. This gradient of severity in disturbance creates a gradient in appropriate restoration strategies that range from minor, such as reseeded or revegetation, to more challenging projects, such as the use of bioremediation to clean up environmental toxins, the extermination of invasive species, or the reintroduction of animals.

A considerable amount of land has been disturbed since the beginning of Gothic, Colorado as a mining town at the turn of the century. Construction of new cabins or renovation of cabins has been the main cause of disturbance within the Gothic townsite. The Gothic townsite contains a lot of *Linaria vulgaris* and *Bromus inermis*, two very invasive exotic species. *Bromus inermis* was brought here by ranchers for cattle to graze around the 1940's and *Linaria vulgaris* was brought to the United States as an ornamental

flower. Given the premise that disturbed lands are more easily invaded, it seems imperative in Gothic that restoration of disturbed land is attempted. Surveying the natural succession that has occurred around cabins built or renovated through many years (from 1935 to 2004) would help us understand whether rehabilitation or replacement is the usual fate of disturbed land in Gothic and whether it is necessary to do restoration. Knowing how these disturbances affect the plant community diversity and invasive species cover even many years since the disturbance might help reveal how important it is to conduct revegetation projects following construction or renovation of cabins.

This study consists of two parts: an experimental manipulation and an observational component. In the experimental manipulation I am testing five native plants in Gothic, Colorado for their use in revegetation and restoration projects, examining their survival, new growth, and reproductive success following transplanting into a disturbed site. I chose five of the most common plants in the meadows in this area and transplanted them from the proposed building site for maroon cabin. I am examining whether it is possible to conduct revegetation projects in high-altitude meadow ecosystems without the use of common restoration treatments such as fertilizer or mulch, and whether size of plants prior to transplant affects whether the plant makes new growth and produces flowers. I am also examining whether side of cabin affects growth and reproductive success, because the North side of the cabin gets considerably less sun than the South.

In the observational component I am surveying plant communities surrounding cabins that had no active revegetation around them to observe the natural succession that has occurred and see if there is a correlation between plant community diversity and time

since disturbance. The goal of this part of the experiment is to see how plant communities respond to disturbance and how diversity relates to time since disturbance. I hypothesized that newer cabins will have a lower total percent cover and lower plant community diversity. The purpose of the experimental manipulation is to recommend for future restoration projects whether revegetation is a practical means of restoration and, if so, what species have reproductive success and which have the highest survival rates after transplant. I predicted that all species will not have the same rate of survival and reproductive success possibly because of differences in their root structure or sensitivity to shock.

Materials and Methods:

Part 1: The Transplanting of Native Plants

I transplanted five native species: *Potentilla gracilis*, *Erigeron spp.*, *Achillea millefolium*, *Fragaria spp.*, and *Linum lewisii* from the proposed building site for Maroon cabin to an area around Mammal Lab cabin that was disturbed by renovation in 2005 and is now almost completely bare. I selected 20 plants of each species, for a total of 100 plants. I selected the plants haphazardly so they were a variety of sizes. None of the plants had any invasive weeds growing near them. Half of the samples of each species were planted on the South side of the cabin and half on the North side. I dug the holes ahead of time and then plants were moved in groups of ten, with 5 (one of each species) planted on the South and 5 planted on the North, to avoid having plants out of the ground for too long. I transplanted them during the morning and the late afternoon, avoiding the heat of the day. Each plant in each group of five was randomly assigned one of five

adjacent holes so that overall the plants were evenly scattered but randomized within each group.

I recorded the height, and width of the leaves of each plant and the number of flowering stalks before I transplanted it. I measured the height from the ground to the tallest leaf and I measured width as the greatest lateral distance from leaf to leaf. At the end of the summer, I recorded whether or not there was new growth or not. During the first three days after the transplant I watered the plants in the morning and again in the afternoon if it did not rain. During the following week I watered them in the afternoon only if it did not rain. It rained almost every day for the three weeks after the plants were transplanted.

I have a randomized block design since my sample of plants is divided between both sides of the building. I first tested to see if there was a significant difference in the results from each side of the cabin with a contingency test. The difference was not significant so I pooled the data between new growth and species, and growth of flowers and species, both of which I analyzed with a chi square test. I then analyzed whether or not initial plant size affected whether or not there was new growth and reproductive success with survival/reliability tests. All data were analyzed in JMP 5.1.

Part 2: Natural Succession after Disturbance

I surveyed 13 different cabins around the Gothic townsite and compared the vegetation occurring in the different areas. Building and renovating old cabins disturbs the soil and vegetation in the immediate area. I examined how time since the cabin was disturbed affected the vegetation naturally occurring there. I chose cabins in similar open

habitats that had roofs that sloped to the South, to avoid a difference in the effects snowfall has on the vegetation. I surveyed 1 square meter on the South side of each cabin and I chose cabins that were built or renovated between 1933 and 2004.

I put each quadrat one meter out from the center of the southern wall of the cabin unless there was something obstructing surveying there, such as a path, in which case I went farther away from the cabin. In each quadrat I counted the number of plants of each species and the percent cover of each species. I calculated Simpson's Diversity for each sample and then used regression analyses to test the relationship between the diversity of vegetation and the time since disturbance and the relationship between percent cover of invasive species and time since disturbance. All data were analyzed with JMP version 5.1.

Results:

In the revegetation component of the project I found that plant species had a significant effect on the likelihood that a plant had new growth (Pearson Chi square (4, 95) = 40.154, $p < 0.001$; Figure 1). Ninety percent of the *Achillea* plants showed new growth, 80 % of the *Erigeron* and *Fragaria* plants showed new growth, 60% of *Potentilla* showed new growth, and only 5 % of *Linum* showed new growth. Side of cabin (the amount of sunlight) had no significant effect on the development of new growth (Pearson Chi square (1, 18) = 0.00- 1.25; $0.2636 < p < 1.00$). Size of plant prior to transplant also had no effect on the development of new growth for any of the five species (Wilcoxon test Chi square(1) = 0.0186-2.1961; $0.1384 < p < 0.8914$).

I found that species had a significant effect on the production of flowers (Pearson Chi square (4, 95) = 33.604, $p < 0.0001$; Figure 2). Of the *Erigeron spp.* Plants, 60% produced flowers, compared to 20% of *Potentilla gracilis*, 10% of *Achillea millefolium*, and zero *Fragaria spp.* and *Linum lewissii*. I also found that side of cabin (varying in amount of sunlight, temperature, moisture retention, and other abiotic factors) had no significant effect on the production of flowers of any species (Pearson Chi square (1, 18) = 0.00- 1.25; $0.2636 < p < 1.00$). Size of plant prior to transplant had a significant effect on the production of flowers by *Erigeron spp.* (Wilcoxon Chi square (1) = 12.6984; $p = 0.0004$; Figure 3 and 4) and by *Potentilla gracilis* (Wilcoxon Chi square (1) = 6.1164; $p = 0.0134$; Figure 5 and 6). In both cases it was the larger plants that produced flowers. Since neither *Linum lewesii* nor *Fragaria spp.* produced any flowers, no effect of size prior to transplant was measured, and the effect of size prior to transplant on the production of flowers by *Achillea millefolium* was not significant (Wilcoxon Chi square (1) = 3.3878; $p = 0.0657$).

During the observational component I found that plant community diversity was not affected by time since disturbance ($R_{(1,11)} = 0.055$; $p = 0.44$; Figure 7). I also found that percent cover of invasive species decreased with time since a cabin was built, but the relationship was only marginally significant ($R_{(1, 11)} = 0.29$; $p = 0.056$; Figure 8). In short, plant diversity was not correlated to the time since disturbance but percent cover was pretty well correlated to the time since disturbance

Discussion:

In the experimental manipulation component of my project I found that the development of new growth depended only on the species and not on the side of cabin to

which it was transplanted (i.e. the amount of sunlight and other abiotic factors). I also found that the size of the plant prior to transplant did not affect the development of new growth. I found that species had a significant effect on reproductive success but that side of cabin to which it was transplanted had no significant effect. I also found that plants of *Erigeron speciosus* and *Potentilla gracilis* that were larger prior to transplant had were more likely to flower but that size prior to transplant had no significant effect on the other species.

My results suggest that, if plants of the right species are chosen, most sizes will survive and develop new growth in varying levels of sun, moisture retention, temperature, and other abiotic variables. Also, if *Erigeron* and *Potentilla* are being transplanted, larger plants should be chosen because they are more likely to have reproductive success and equally likely to produce new growth with varying sunlight, temperature, and other abiotic factors that differed between the North and South sides of the cabin. Few *Potentilla spp.* plants flowered because many were already flowering when I transplanted them. If they had been transplanted prior to their flowering time, we might see a higher rate of reproductive success, a stronger effect of size, and possibly an effect of amount of sunlight. Although not all plants that developed new growth had reproductive success this summer, it is likely that they will survive the winter and produce flowers next year. Also, it seemed like some plants (definitely *Fragaria*) may have reproduced asexually by stolons or rhizomatously. Future work could look at asexual reproduction as well as sexual reproduction.

It was noted that *Achillea millefolium*, which had the highest percentage of plants that developed new growth (90%), already had new shoots visible around the transplants.

Some new seedlings are also scattered in other areas so it is not clear whether it is growing rhizomatically or if the other plants are from seeds that had remained in the soil. This means that although it is successful in producing new growth when transplanted it may not be necessary to transplant it because it might come up by itself fairly rapidly after disturbance. In contrast, *Erigeron speciosus*., of which 80% of the plants had new growth, showed no seedlings, only new shoots coming up from the base of the transplants. Some new *Fragaria spp* plants were also noted in the plots, but not enough that transplanting would seem unnecessary. Non-transplanted *Fragaria* plants only grew underneath a much larger weedy plant that came up by itself. However, within the plots are many *Potentilla gracilis* plants that are much larger, look much healthier, and appear to have produced many more flowers. Therefore, this species is naturally ruderal or it may be coming up from underground roots because the disturbance in Gothic mostly causes soil compaction. Either way, although this species did fairly well (60% developed new growth, 20% flowered), I think that it is unnecessary to transplant this species in this area because if it was there it should come back and if it wasn't it might come in naturally.

Percent cover of invasive species tended to increase with time since disturbance (Fig. 8). One possible explanation for this is that the building of a cabin causes increased human traffic which carries seeds of invasive plants to the area and causes continued disturbance. Therefore, areas near older cabins may actually experience more disturbance over a longer period of time than newer cabins. A second possible explanation is that the percent cover of invasive species is actually correlated to the proximity of the county road through Gothic. This would make sense because that is

where there have been the most disturbances over the years and that is where seeds for *Bromus inermis* and *Linaria vulgaris* were originally distributed. The newer cabins are all farther away from the main road in areas that have remained mostly undisturbed. Another possible explanation is that the initial effects of disturbance never completely go away and make the ecosystem more easily invaded.

Revegetation begins the process of rehabilitation and keeps the soil from eroding or drying out too much. However, since most of the plants will not produce seeds until next year, future projects might include reseedling along with revegetation. These results are applicable to future restoration projects in the Gothic townsite and probably to projects in other high-altitude meadow ecosystems. Ideally revegetation would help keep invasive species from spreading rapidly into the area. However, there are many confounding variables which make it difficult to tell if disturbance increases the spread of invasive species. Further research on the long-term effects of restoration techniques would establish whether revegetation would stop, or at least slow, the spread of invasive species.

Literature Cited:

Dobson A.P., Bradshaw A.D., Baker A.J.M.. (1997). Hopes for the future: Restoration Ecology and Conservation Biology. *Science* 277: 515-522.

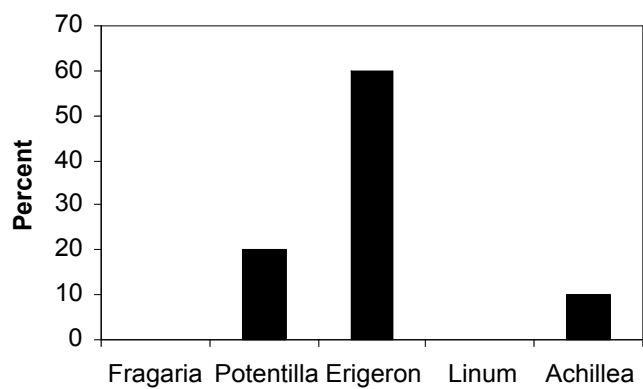
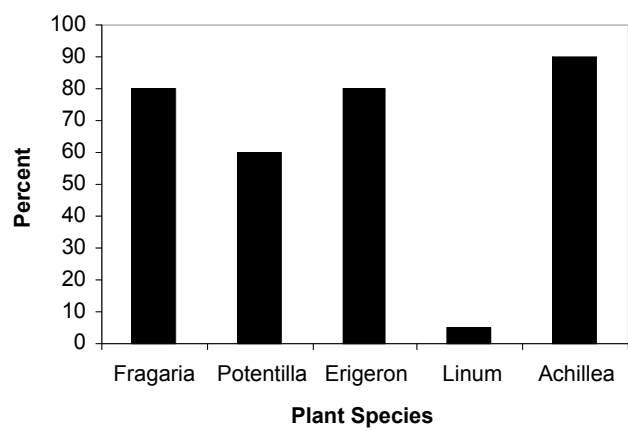
Ehrenfeld, Joan G. & Toth, Louis A. (1997) Restoration Ecology and the Ecosystem Perspective. *Restoration Ecology* 5 (4), 307-317.

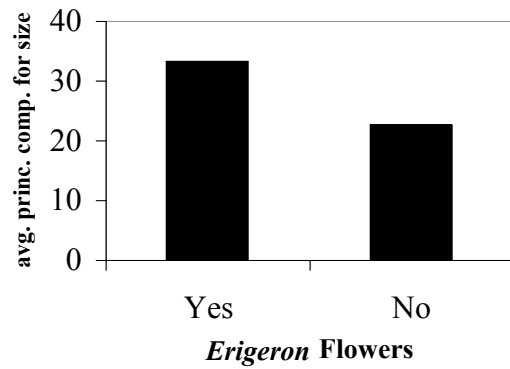
Jenkinson, Robin G., Barnas, Katie A., Braatne, Jeffrey H., Bernhardt, Emily S., Palmer, Margaret A. & Allan, J. David (2006). Stream Restoration Databases and Case Studies: A Guide to Information Resources and Their Utility in Advancing the Science and Practice of Restoration. *Restoration Ecology* 14 (2): 177-186.

Johnson, V.S., John, A.L., Lee, T.D., Frey, S.D. (2006). The role of spatial and temporal scale in colonization and spread of invasive shrubs in early successional habitats. *Forest Ecology and Management* 228 (1-3): 124-134.

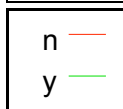
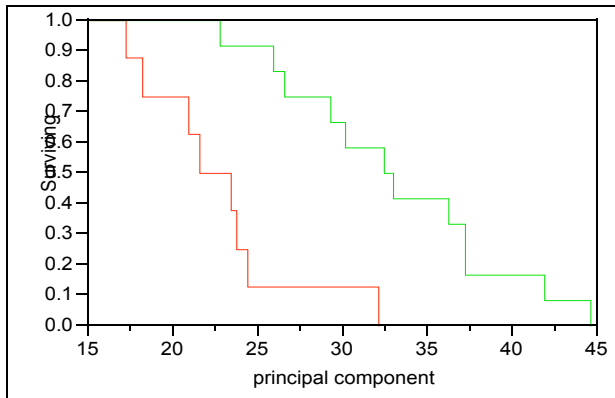
Jordan, Gilpin, Aber. 1987. *Restoration Ecology: A Synthetic Approach to Ecological Research*. Publisher: Press Syndicate of the University of Cambridge.

Traveset, A., Richardson, D.M. (2006). Biological invasions as disruptors of plant reproductive mutualisms. *Trends in Ecology and Evolution* 21 (4): 208-216.





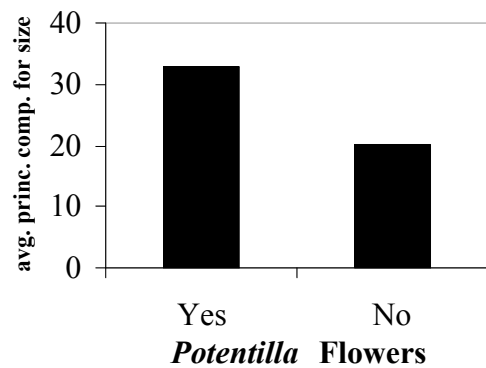
species=Erigeron
Product-Limit Survival Fit
Survival Plot



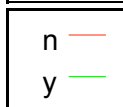
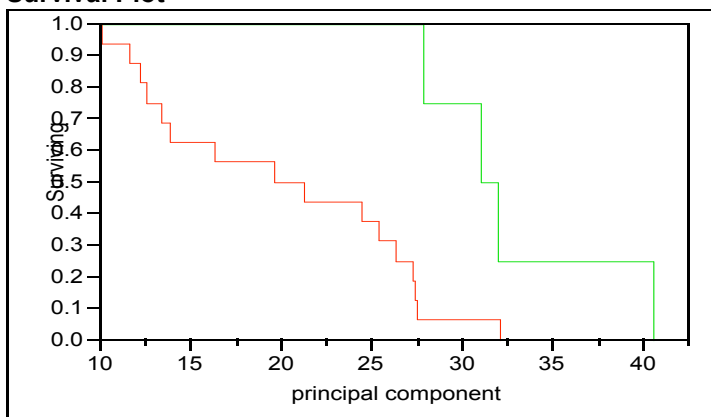
Time to event:
principal component
Grouped by
flowers

Tests Between Groups

Test	ChiSquare	DF	Prob>ChiSq
Log-Rank	13.2923	1	0.0003
Wilcoxon	12.6984	1	0.0004



species=Potentilla
Product-Limit Survival Fit
Survival Plot



Time to event:
principal component
Grouped by
flowers

Tests Between Groups

Test	ChiSquare	DF	Prob>ChiSq
Log-Rank	6.2539	1	0.0124
Wilcoxon	6.1164	1	0.0134

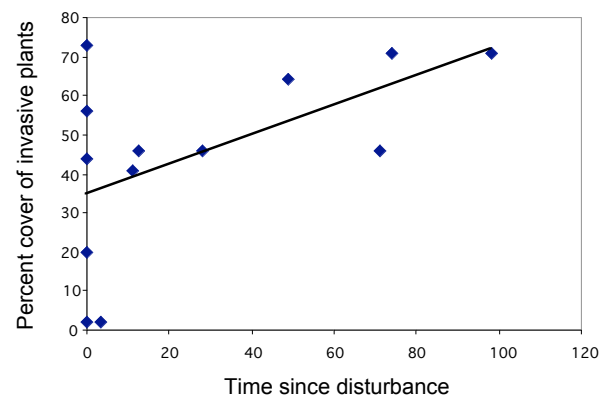
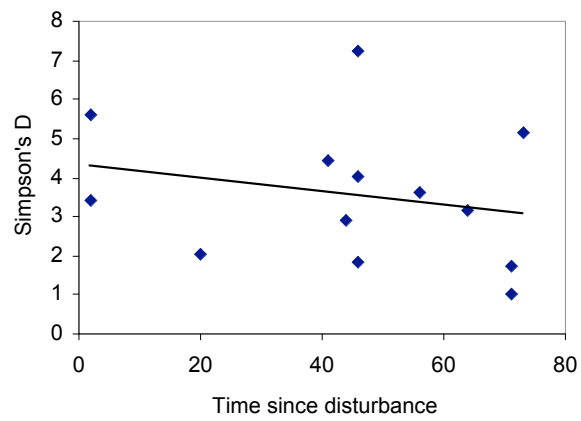


Figure 1: The percents of five native plant species that developed flowers after being transplanted to a disturbed area in Gothic, Colorado.

Figure 2: New growth of five native plant species transplanted into a disturbed area around a renovated cabin in Gothic, Colorado.

Figure 3: The effect of size prior to transplant (by average principal components) on production of flowers by *Erigeron speciosus* after being transplanted to a disturbed area.

Figure 4: The results of a survival/reliability test on the effect of size prior to transport (in principal components) on production of flowers by *Erigeron speciosus* after transplant to a disturbed area.

Figure 5: The effect of size prior to transplant (by average principal component) on the production of flowers by *Potentilla gracilis* after being transplanted to a disturbed area.

Figure 6: The results of a survival/reliability test on the effect of size (in principal components) on production of flowers by *Potentilla gracilis* after being transplanted to a disturbed area.

Figure 7: The relationship between Simpson's Diversity measure around 13 different cabins in open-meadow habitat in Gothic, Colorado and time since disturbance.

Figure 8: The relationship between percent cover of invasive plants around 13 different cabins in Gothic, Colorado and time since disturbance.

