CASE STUDY

Revegetation of a Trampled Cliff-Edge Using Three-Toothed Cinquefoil and Poverty Grass: A Case Study at Tettegouche State Park, Minnesota

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ABSTRACT

Cliffs and cliff-edges are often attractive places to humans, and therefore may become damaged through recreational activities. Restoring cliffs and cliff-edges, which can be important sites of biodiversity, is challenging in part because of insufficient knowledge about native plant restoration techniques for these ecologically distinct areas. The cliff-edge at Shovel Point in Tettegouche State Park, Minnesota, has been damaged by heavy visitor use. We propagated 450 three-toothed cinquefoil (*Potentilla tridentata*) and 450 poverty grass (*Danthonia spicata*) plants from locally obtained seed to test revegetation techniques. We seeded plots with cinquefoil and poverty grass seeds for comparison with transplanted plots, we monitored survivorship and seedling recruitment for three seasons, and we counted the number of new shoots produced at 3 and 24 months after transplantation. Visitor access to planted areas was restricted during the study. Overall survival rates at 3, 13, and 24 months were 87.3%, 76.9%, and 68.9% for three-toothed cinquefoil and 98.7%, 96.7%, and 63.8% for poverty grass. The grand mean number of new shoots produced per plant was 0.37 and 2.11 (SE = 0.227, 0.365) at 3 and 24 months respectively for three-toothed cinquefoil and -0.21 and -3.15 (SE = 0.584, 0.295) at 3 and 24 months respectively for poverty grass. Only one seeded plot had a single poverty grass plant by the end of the study. One-way ANOVA tests revealed no statistically significant differences among treatments within species for survival or number of new shoots produced. We conclude that when transplanted, three-toothed cinquefoil and poverty grass are useful species for revegetation of damaged outcrops such as Shovel Point.

Keywords: cliff, *Danthonia*, germination, *Potentilla*, restoration, revegetation

Cliffs are important to humans. Ancient inhabitants of the American Southwest, the Mogao caves in China, and the Mideastern city of Petra valued cliffs for shelter and defense (Serra-Vega 1993, Salopeck 2000, Brown 2003). Today, cliffs serve as hiking, climbing, and sightseeing destinations (Larson et al. 2000b, 254–275; McMillan et al. 2003), and cliff-top real estate is prized. In spite of this popularity, ecologists have historically treated cliffs as minor, indistinct components of larger landscapes (Larson et al. 2000b, 1–18).

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There is, however, increasing awareness that cliffs and their edges are by themselves important systems that are ecologically distinct from their surroundings (Walters and Wyatt 1982, Matheson and Larson 2008). Cliffs and cliff-edges often harbor populations of organisms that are isolated from the main range of their species, making them potential sites of speciation. They increase the biodiversity of a region, provide relatively stable microhabitats, and can function as refugia during climate change and widespread ecological disturbance (Parikesit et al. 1995; Larson et al. 2000b, 87–114; Krebs 2001). Larson and others (2000a) argue that in many cases the vegetation on temperate-zone cliffs should be thought of as ancient forest because tree ring data from their study of mature trees on temperate cliffs regularly revealed stands of trees many hundreds of years old.

The popularity of cliffs as recreational sites is rapidly increasing, often with negative impacts on the vegetation of cliffs and cliff-edges (Müller et al. 2004, Siderilis and Attarian 2004). Hikers trample cliff-edge vegetation and compact soil, altering soil characteristics and making it more prone to erosion (Pounder 1985). Climbers inadvertently abrade plants and lichens from climbing routes on cliff faces and also actively remove them to improve handholds and place hardware (Nuzzo 1995, Kelly and Larson 1996, Camp and Knight 1998, McMillan and Larson 2002). On cliff-edges climbers may stress trees by using them as anchors for safety ropes, and, like hikers, they trample vegetation at the tops of climbs as they rest and congregate before and after climbing (Figure 1).

Figure 1. Climbers preparing safety ropes at Shovel Point near our study site in July 2003. Notice the exposed tree roots and distance from the cliff edge to the nearest suitable anchor trees. There is no evidence of recruitment of saplings with the potential to replace mature trees. Photo by J. Olfelt

Restoration of Damaged Cliff-Edges

The vegetation of northern cliff-edges often resembles that found in alpine areas (Larson et al. 2000b, 254–275), being rich in mosses, lichens, and small-leaved shrubs. Along with their alpine-like flora, northern cliff-edge habitats typically have thin soil with poor moisture retention, which may be more susceptible to trampling damage than most other environments (Bell and Bliss 1973, Liddle 1975). Some studies have shown that heavily trampled alpine or arid areas may require up to one hundred years or more to recover once human foot traffic is halted (Kuss 1986, Parikesit et al. 1995, Forbes and Jefferies 1999). Such long recovery times are probably unacceptable to land managers working under mandates requiring both that public access be maintained and that natural resources such as biodiversity be conserved (Cole and Spildie 2000).

Active revegetation efforts can speed the recovery time of these types of areas (Densmore and Holmes 1987, Forbes and Jefferies 1999). Such efforts may include sowing seeds or planting mature plants (Cargill and Chapin 1987) and should, in general, make use of locally adapted races of native species (Keller and Kollman 1999, Keller et al. 2000). We expect these locally adapted plants to have higher survival rates than varieties adapted to other environments and to integrate well with the local biotic community (Montalvo and Ellstrand 2001, Fridley et al. 2007). The use of native species is also unlikely to disrupt the species composition in an area, which might occur if non-native species are introduced. Even though locally adapted native species are often recommended for revegetation projects (Lesica and Allendorf 1999, Keller et al. 2000, Zabinski and Cole 2000), the practice can be difficult. The germination and cultivation requirements for native species are often poorly known, and few reports of reintroduction techniques are available for most native species (Zabinski and Cole 2000).

Successful recovery of an area with reintroduced plants may depend heavily on soil conditions (Claassen and Hogan 2002, Zabinski et al. 2002, Callaway et al. 2003). In alpine and alpine-like habitats such as northern cliffs, highly disturbed soil may lack microbial activity (Johnson and Ryan 2000, Zabinski et al. 2002), so inoculating planting sites with local soil may aid establishment rates in disturbed areas (Van der Heijden et al. 1998). Highly disturbed alpine areas may lack plant macronutrients and many cliff-edge soils have poor water retention characteristics. Thus the introduction of nutrients and water to a disturbed cliff-edge might enhance the success of revegetation efforts at the site (Parikesit et al. 1995, Farris 1998, Forbes and Jefferies 1999).

Project Objectives and Methods

We tested cliff-edge revegetation techniques at Shovel Point, a popular hiking and climbing destination in Minnesota's Tettegouche State Park. We developed germination, cultivation and transplantation techniques for two native species that are widespread in North America. Our goals were to learn if 1) these species could be propagated in a greenhouse for transplantation; 2) the plants would survive when transplanted to the restoration site; 3) any of several simple soil treatments would enhance the establishment, growth, or survival of the transplants; and 4) simple protection from trampling or protection and sowing seeds would result in successful revegetation. Our study spanned three growing seasons and was one component of a larger effort to manage visitor use of Shovel Point. This larger effort included surveys of park users to determine what changes were likely to be accepted, construction of boardwalks and other well-defined pathways to direct foot traffic, and construction of

Figure 2. Heavily trampled cliff edge at Shovel Point in spring 1999. Plots were established in June 2001 between the exposed roots (foreground) to the cluster of saplings with the mature pine at midslope (left center of the photograph). Photo by D.P. Olfelt

decks on which climbers can rest and congregate before and after climbing.

Study Site

Shovel Point, in Minnesota's Tettegouche State Park (47°20'52" N, 91°10'53" W), is a rocky, sloped peninsula of porphyritic rhyolite that projects about 0.5 km into Lake Superior. Its landward end is most elevated, having 50-m cliffs with vertical drops to water level. Its lakeward tip slopes to water level (Farris 1998). The undisturbed cliff-edge soils have O and A horizons that together are approximately 10 to 20 cm thick; these overlie a gravelly layer of similar thickness. Forest floor vegetation in undisturbed areas includes mosses, lichens such as graygreen reindeer lichen (*Cladonia rangiferina*), and small woody plants such as bearberry (*Arctostaphylos uva-ursi*) and blueberry (*Vaccinium angustifolium*). Canopy species include white pine (*Pinus strobus*), white spruce (*Picea glauca*), and balsam fir (*Abies balsamea*).

The point is a popular destination. The park manager estimated that 50,000 hikers visited the point in 2001 and reported that permits for 3,000 climbers were issued in the same year (P. Leversedge, MN DNR Divn. of Parks & Recreation, pers. comm.). Our study plots were located on an east-facing slope within an approximately 30-m-long stretch less than 10 m from the cliff-edge near the landward end of Shovel Point's west edge. The site was chosen because foot traffic had completely eliminated plants from most parts of the site (Figure 2) and because a survey of park visitors indicated that climbers and hikers were likely to respect the imposition of restricted access to the site (Olfelt et al. 2003). Visitor access to the site was restricted using rope hung from metal posts and signs reading "Restoration research area. Please stay out."

Disturbed soil from our plots was shallow and compacted, being approximately 10–20 cm deep in most places and on a path between popular climbing sites. The soil was gravelly, with 85% of the mass consisting of particles that would not pass through a 2-mm sieve but which were generally smaller than 2 cm in diameter. A soil sample of particles less than 2 mm in diameter was sent to the University of Minnesota's soil testing laboratory; laboratory results showed that only 11.2% of the sieved matter was organic and that it had high phosphorus concentrations (26 ppm), moderate potassium concentrations (99 ppm), and an acidic pH (4.2 in water). Given the lack of vegetation and the very low level of organic matter in the disturbed soil (1.7% of the unsieved total), we designed our revegetation efforts under the assumption that the study site was in an early successional stage of a rocky outcrop.

Plant Species

We chose *Potentilla tridentata* (Rosaceae) and *Danthonia spicata* (Poaceae) (hereafter cinquefoil and poverty grass, respectively) for our revegetation efforts because they occur naturally on Shovel Point, produce abundant seed each year, and are pioneer species that commonly grow in dry, rocky or sandy, open areas. Based on pilot studies that we conducted on Shovel Point in 1999 and 2000 and literature sources, cinquefoil and poverty grass also seemed likely to be more resistant to trampling than other candidate species (Marchand and Roach 1980, Cole 1995). Both species are perennials with broad ranges in North America. Three-toothed cinquefoil ranges from Greenland west to Mackenzie, British Columbia, in the north, and in the south, from high elevations in Georgia, west to Iowa and North Dakota (Fernald 1950). Cinquefoil produces vegetative shoots each season from a short, branching woody stem (Gleason and Cronquist 1991). Poverty grass ranges from Newfoundland to Florida, west to northeastern Mexico, and north to British Columbia (Hitchcock 1950, Darbyshire 2003). It is a bunchgrass which produces no stolons or rhizomes (Darbyshire and Cayquette, 1989).

Seed Collection, Storage, and Germination

We collected cinquefoil and poverty grass seed heads from plants growing on a rarely visited rocky promontory in Tettegouche State Park about 1 km northeast of Shovel Point in early August 2000 and stored them at ambient temperatures in paper envelopes. Prior to germination treatments, seeds of both species were removed from associated flower parts. Cinquefoil seeds were completely separated from surrounding flower parts, and poverty grass seeds were separated from surrounding glumes and lemmae, but not from their paleae. From these, we chose fully filled seed, discarding any malformed seed as probably nonviable, and monitored the germination of a total of 150 seeds of each species in 10-cm glass petri dishes. Each petri dish was sealed with parafilm to prevent drying and contained 50 seeds, one 90-mm disk of Whatman No. 3 filter paper and 8 ml of distilled water. Petri dishes with cinquefoil seeds were kept at 4°C for two weeks and then incubated at 28–31°C for three weeks under fluorescent lights. Poverty grass seeds were incubated for three weeks at 28–31°C under the fluorescent lights immediately after placement in petri dishes.

Table 1. Number of plots containing one or more poverty grass (*Danthonia spicata*) seedlings (D), unidentified herbaceous seedlings (H), white spruce (*Picea glauca*) seedlings (PG), mosses (M), and lichens (L) during the 2001–2003 growing seasons.

		Plot type (number)			
Year	**Plant Type**	**Untilled, unplanted** (*n* = 3)	**Tilled, seeded** (*n* = 3)	***Potentilla* transplants** (*n* = 18)	***Danthonia* transplants** (*n* = 18)
2001	D	0	2	1	0
	H	0	0	0	0
	PG	0	0	0	0
	M	0	0	0	0
	L	0	0	0	0
2002	D	0	3	9	3
	H	0	0	1	0
	PG	0	0	1	0
	M	0	0	0	0
	L	0	0	0	0
2003	D	0	1	5	4
	H	0	0	1	2
	PG	0	0	1	4
	M	0	0	1	9
	L	0	0	0	4

Propagation and Revegetation Tests

Using the techniques described above, we prepared enough seed to grow 450 plants of each species for reintroduction to Shovel Point. We transferred germinants to Rootrainer containers (Spencer-Lemaire, Edmonton AB) that were filled with Sunshine No. 5 soil mix (J.R. Johnson Supply, Roseville MN). Beginning in January 2001, we placed the germinants on a mist table in the St. Olaf College greenhouse (Northfield MN) for four weeks, then moved them to a bench under sodium lamps that were on a daily 12-hour light, 12-hour dark cycle and began watering the plants daily by hand. We applied fertilizer weekly by misting for the first four weeks of growth and then by soaking using 3.13 mL of all-purpose 20-20-20 fertilizer per liter of water. Temperatures in the greenhouse ranged from 17°C to 36°C during the growing period. In May 2001, the plants were placed outdoors in a cold frame on the south side of the greenhouse to harden off.

In June 2001, we initiated tests of field survival and growth rates in six different soil treatments: 1) tilled plot substrate; 2) a 1:1 mix of substrate dug from plots to sterile soil (Sunshine #5); 3) a 2:1:1 mix of plot substrate to sterile soil to local soil that was obtained from the root zone of an undisturbed site approximately 100 m northeast of the study site; 4) 18.9 L of plot substrate mixed with approximately 85 g of fertilizer (Nutricote Total 13-13-13 Type 180, J.R. Johnson Supply, Roseville MN), which is gradually released from its pellets over the course of one year or more (Broschat and Moore 2007); 5) 18.9 L of plot substrate mixed with approximately 50 mL of the hygroscopic polymer Terra*sorb hydrogel (Forestry Suppliers, Jackson MS) to increase the availability of water to plants; and 6) 2–5 cm of woodchips on top of the tilled plot substrate. These treatments were chosen based on our assessment that the availability of organic material, soil symbionts, soil nutrients, or water might limit revegetation success. We rejected the use of unsterilized soil from off Shovel Point to avoid introducing non-native species, and we chose simple treatments because of the budgetary constraints typical of revegetation efforts and because all experimental materials had to be carried in by foot or by helicopter.

We stratified the study site into three sections based on slope steepness and randomly assigned twelve 0.5 m × 0.5 m treatment plots in each section. Each plot had one of the soil treatments and contained 25 plants of cinquefoil or poverty grass. Plots were dug with trowels to a depth of 10 cm or to bedrock. The plants were randomly assigned to plots and were placed 10 cm apart, 5 cm from plot edges. Each section of our study site also contained two additional randomly assigned plots, one tilled and planted with 140 cinquefoil seeds and 70 poverty grass seeds, and one untilled and unplanted. These were established to test whether plots could be revegetated by active seeding or by natural seed rain or seed banks, and led to a total of 42 plots in our revegetation tests. Plot corners were marked with 16d nails driven through numbered metal tags.

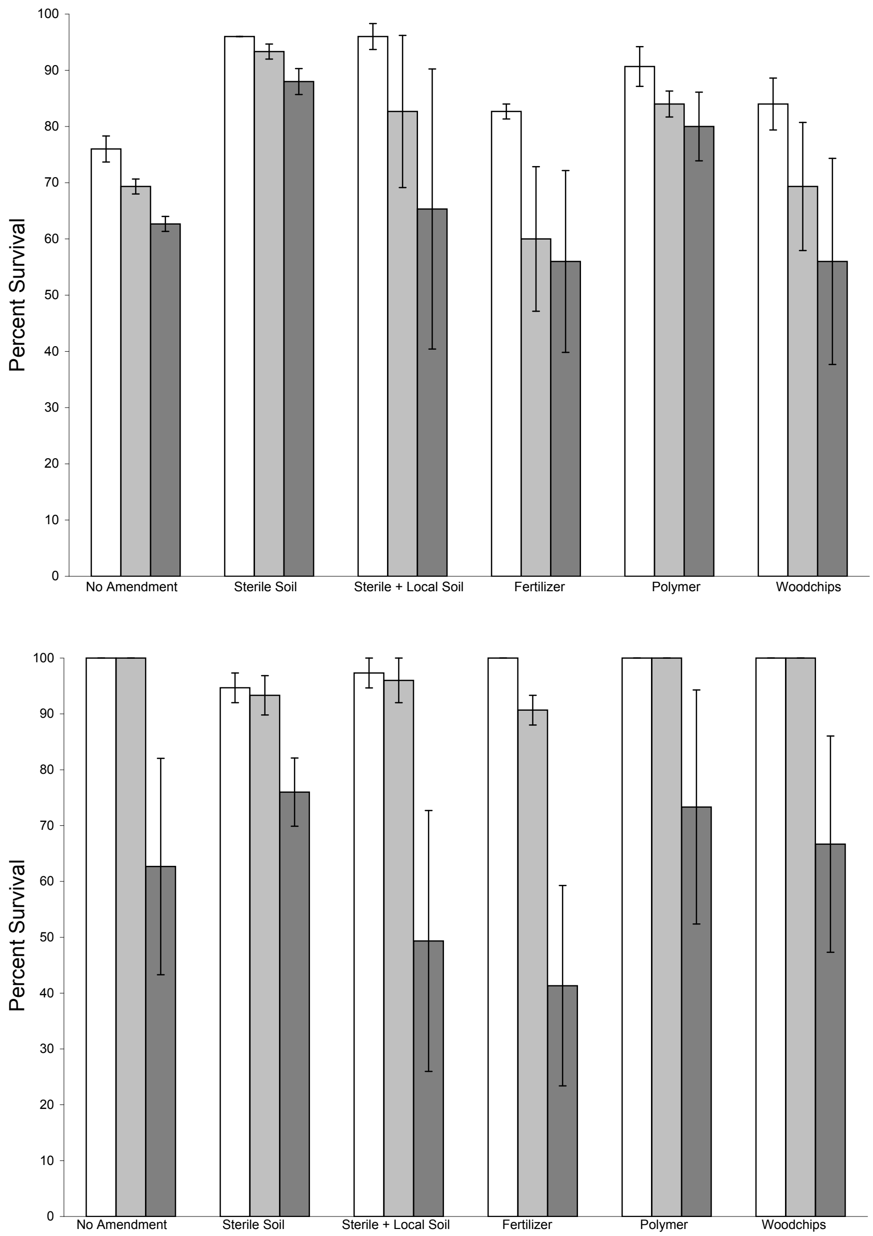

Figure 3. Mean percent survival (± SE) at 13 weeks (white bars), 13 months (light gray bars), and 2 years (dark gray bars) after planting for (top) three-toothed cinquefoil (*Potentilla tridentata*); and (bottom) poverty grass (*Danthonia spicata*).

We recorded the survival and number of shoots above soil level for each plant of each species at 2 and at 13 weeks after planting in 2001, and again at the end of June 2003. In June 2002, we recorded the survival rates in all plots, but not the number of shoots above soil level. Only shoots with at least one green, fully expanded leaf were counted for cinquefoil plants; for poverty grass, only shoots longer than 2 cm were counted. In each of the three growing seasons from 2001 through 2003, we recorded the presence and number in each plot of cinquefoil, poverty grass, and white spruce or unidentified herbaceous plant seedlings and the presence of mosses or lichens (Table 1).

Data Analysis

In order to ask whether there were statistically significant differences in the growth of cinquefoil or poverty grass plants among the soil treatments, we tested for differences in the average number of new shoots produced by living plants in each plot between weeks 2 and 13 after planting [$\sum(S_2 - S_1)$] using one-way ANOVA (SPSS, vers. 11.0, Upper Saddle River NJ). Plant growth data were square-root transformed to better fit ANOVA assumptions. Average survival rates for each season (untransformed) were also analyzed using the one-way ANOVA option of SPSS. The average numbers of new shoots produced by living plants per plot between 2001 and 2003 [$\sum (S_3 - S_1)$] were square-root transformed and analyzed using the one-way ANOVA option of GraphPad Prism (vers. 5.00 for Windows, GraphPad Software, San Diego CA).

Results

Germination, Survival, and Growth

The germination rates for cinquefoil were 44%, 51%, and 67% by the end of weeks 1, 2, and 3, respectively. For poverty grass, the germination rates were 55%, 88%, and 91% by the end of weeks 1, 2, and 3, respectively.

Visitors appeared to respect the boundaries of the study site; we found no evidence of trampling within the restricted study area during any of our visits. Survivorship was 87.3%, 76.9%, and 68.9% for cinquefoil at 13 weeks, 13 months, and 24 months, respectively. There were no statistically significant within-species differences in survival among the treatments over the time periods (F = 0.904, 1.724, 0.745; all df = 5, 17; p = 0.509, 0.204, 0.605, respectively, Figure 3). For poverty grass, the survivorship was 98.7%, 96.7%, and 63.8% at 13 weeks, 13 months, and 24 months, respectively. There were no statistically significant within-species differences in survival among the poverty grass treatments (F = 1.554, 2.730, 0.855, all df = 5, 17, p = 0.246, 0.072, 0.537, respectively, Figure 3). Though not statistically significant, the average survival for cinquefoil tended to be highest in plots augmented with sterile soil and was lowest at 24 months for the fertilizer- and woodchip-treated plots.

Though not statistically significant, the average survival for poverty grass was highest (100%) at 13 weeks and 13 months in the no-amendment, polymer, and woodchip treatments; at 24 months, survival for poverty grass was lowest in the fertilizer-treated plots.

Three-toothed cinquefoil plants had an average of 3.4, 3.8, and 5.7 shoots per plant overall (SE 0.07, 0.1, 0.2) at weeks 2 and 13 and after 24 months, respectively. Overall, poverty grass plants had more shoots per plant, averaging 9.5, 9.3, and 6.9 (SE 0.2, 0.1, 0.3) shoots each at 2, 13, and 24 months, respectively. The average number of shoots produced was positive for most of the cinquefoil plots between weeks 2 and 13 and was positive for all plots after 24 months (Figure 4); none of the differences among treatments were significant (F = 0.87, 0.745; all df = 5, 17; p = 0.53, 0.605, respectively). In contrast, the average number of new shoots produced was negative for most of the poverty grass plots between weeks 2 and 13 and negative for all plots after 24 months (Figure 5). None of the differences among treatments within poverty grass were significantly different (F = 1.53, 0.855; all df = 5, 17; p = 0.25, 0.573).

Seedling Recruitment

None of the untilled, unplanted plots had any living vegetation in them when we monitored them in the 2001, 2002, and 2003 seasons, and we found no cinquefoil seedlings (Table 1). At the end of the 2001 growing season, two of the three tilled, seeded plots contained a total of 16 poverty grass seedlings, and one contained no seedlings. In July 2002, three of the tilled, seeded plots contained a total of 8 poverty grass seedlings, and by July 2003 only one of the tilled plots had one single poverty grass seedling and one seedling of an unidentified herbaceous species. Apparently none of the seedlings from 2001 or 2002 had survived the winters. Plots transplanted with cinquefoil recruited seedlings of other species in each year of our study;

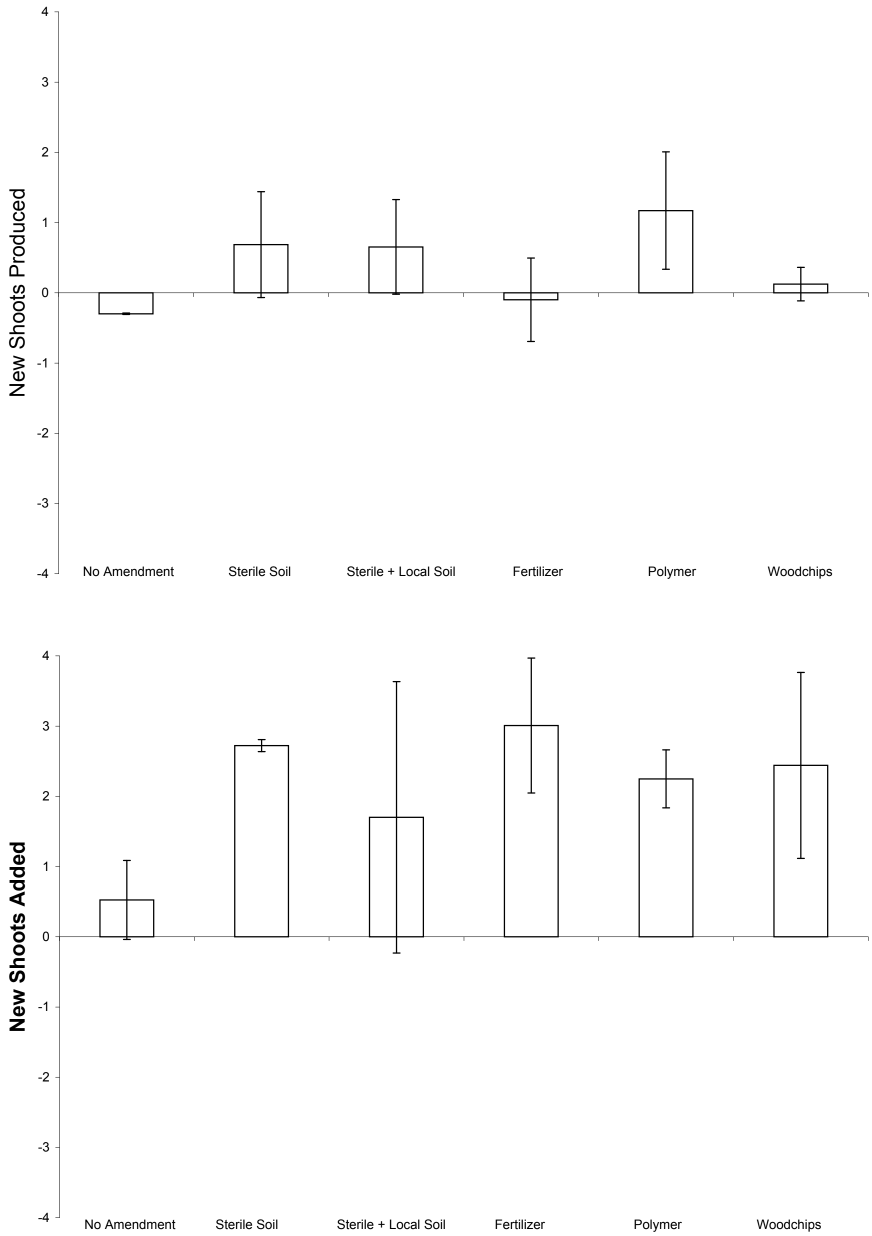

Figure 4. Average number (± SE) of new shoots produced by three-toothed cinquefoil (*Potentilla tridentata*) plants in each treatment: (top) between weeks 2 and 13 in 2001; and (bottom) after 24 months in 2003.

plots transplanted with poverty grass first recruited seedlings in 2002; and mosses and lichens were present in planted plots in 2003.

Summary and Discussion

We successfully germinated, cultured, and transplanted greenhouse-grown cinquefoil and poverty grass plants to the cliff-edge of Shovel Point using locally obtained seed. We found no significant within-species differences among treatments in survival or growth and found that transplantation was necessary for successful revegetation within the three seasons of this study.

The overall survival rates after the first, second, and third seasons (87.3%, 76.9%, and 68.9% for cinquefoil; 98.7%, 96.7%, and 63.8% for poverty grass) compare favorably with the first season survival rate (94%) reported by Densmore and Holmes (1987) for ten successional species tested at subalpine sites in Denali National Park, Alaska. The survival rates at Tettegouche

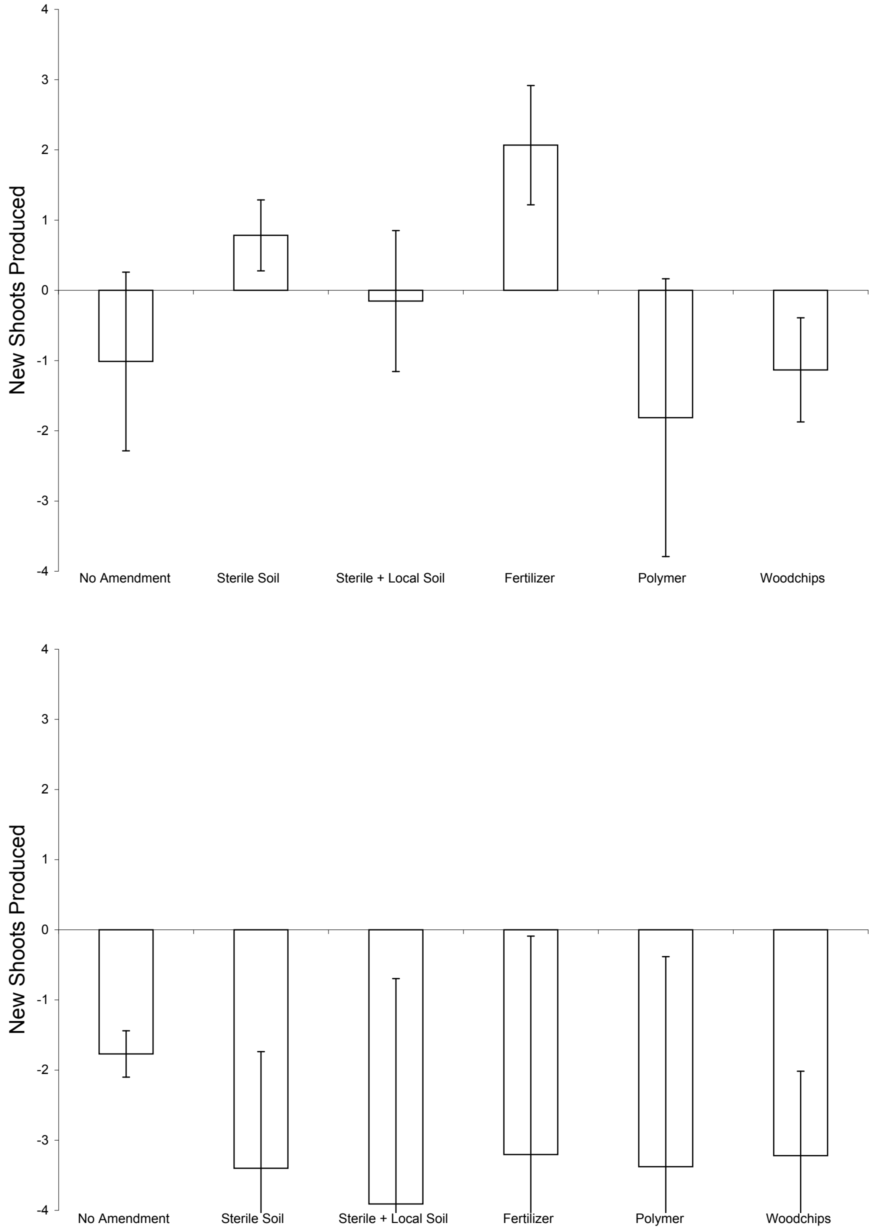

Figure 5. Average number (± SE) of new shoots produced by poverty grass (*Danthonia spicata*) plants in each treatment: (top) between weeks 2 and 13 in 2001; and (bottom) after 24 months in 2003.

greatly exceed the first, second, and third year survival rates (64.4%, 44.4%, and 39.4%) reported by Matthes and others (2003) for arborvitae (*Thuja occidentalis*) in Bruce Peninsula National Park, Ontario. The high survival at Tettegouche suggests that the use of early successional species, such as poverty grass and cinquefoil, is useful for revegetating cliff-edges and rocky outcrops.

We found much higher germination rates with simpler treatments than have been previously reported for cinquefoil and poverty grass (Toole 1939, Kelley 1953). This is probably because of genetic or environmental differences between the Tettegouche populations and those tested by Toole and Kelley (Yang et al. 1999, Schrader and Graves 2000). Seed collected for restoration projects at other times or places may have differing germination rates. Plant growth in the standard commercial potting mix was very good, suggesting that experimentation with other growing media is unnecessary.

The very high first season survival and growth of poverty grass in all of our treatments, compared with the lower survival and growth rates for cinquefoil, might suggest that the grass species should be used alone to stabilize damaged areas. Our longer-term data, however, show that poverty grass had a higher mortality rate than cinquefoil between the second and third seasons, possibly because some of the poverty grass plants could not support their relatively high aboveground biomass in the droughty conditions of 2003. The different responses to environmental conditions between the second and third seasons and the demonstrated idea that communities with higher diversity are more stable (Tilman et al. 2006, Fridley et al. 2007) suggest that restoration efforts using multiple species are likely to be more robust.

Since transplants of both species survived at relatively high rates in all of our treatments, this work reveals no compelling argument for time-consuming soil treatments for cinquefoil and poverty grass. We recognize, however, that an experiment with greater statistical power might detect significant differences. Cole and Spildie (2006) found significant improvements in growth after three seasons in their tests of soil amendments in six sets of alpine campsite plots, but they report little effect on survival and show that the effects on growth diminished by the eighth season.

In this study, both species had generally lower survival in fertilized plots than with other treatments by the third season. Though the differences are not statistically significant, the results are consistent with Ratliff and Westfall's (1992) study on revegetating gravel areas in Sequoia National Park, California, and contrast somewhat with results from Klokk and Rønning (1987) at Ny-Ålesund, Norway. Klokk and Rønning found higher survival and vegetative production over five years for several arctic species in fertilized plots than for the same species in unfertilized plots. However, they also noted that one species showed little or no response to fertilization and that the number of plant species was lower in fertilized plots than in unfertilized plots after five years. We suggest caution in the use of inorganic fertilizers, especially because the larger-scale damaging effects of inorganic nutrient deposition are well documented (Cornell et al. 1995, Wedin and Tilman 1996, Fenn et al. 2003).

The persistence of the transplants in our study area, the recruitment of new seedlings, the growth of cinquefoil plants, and the increasing presence of mosses, lichens, and spruce seedlings in the planted plots (Table 1) all suggest that our revegetation efforts at the Shovel Point study site are successful. The presence of poverty grass germinants in the tilled, seeded plots in 2001 suggests that planted seeds can germinate, but their subsequent reduction in numbers shows that transplantation of cinquefoil and poverty grass was required to accelerate the pace of revegetation. The transplants apparently enhanced conditions for the germination of seeds either from seed rain or seed banks within plots by the second and third seasons of growth.

We have shown that germination, cultivation, transplantation, and establishment of cinquefoil and poverty grass are feasible using basic techniques. Our approach to the damaged cliff-edge at Tettegouche State Park as a rocky outcrop in an early successional stage was successful in the first three seasons of growth. Larger scale and longer term revegetation studies with a similar approach are warranted to further develop our ability to restore heavily damaged cliff-edges.

Given the broad ranges of cinquefoil and poverty grass across North America (Fernald 1950, Hitchcock 1950, Darbyshire 2003), managers of other degraded cliffs and rocky outcrops in North America should consider revegetation efforts using transplants grown from locally obtained cinquefoil and poverty grass seeds. We believe that visitor respect for the restricted area at Tettegouche was important to the success of this project because unrestricted plants in our 1999 and 2000 pilot efforts were heavily damaged and because Matthes and others (2003) show that destructive visitor behavior can significantly hamper revegetation efforts. We believe that the efforts by park managers to communicate with park users through public planning processes, surveys, interpretive signs, and the provision of well-marked trails and platforms were important in the acceptance of the restrictions. We recommend that designers of cliff-edge revegetation efforts consider the use of early successional species and that they consider visitor restrictions to revegetated areas until the areas no longer appear to be legitimate paths to sites of interest.

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