Soil Amendments and Planting Techniques: Campsite Restoration in the Eagle Cap Wilderness, Oregon

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Abstract—Results of the first three years of revegetation research on closed wilderness campsites are described. Experimental treatments involved soil scarification, an organic soil amendment (a mix of locally collected organic materials and peat moss and an inoculation of native undisturbed soil), an organic matter and composted sewage sludge treatment and surface application of commercial mulch (Bionet). Half of the experimental plots received native seed and transplants; the other half did not. Seeding and transplanting were highly successful. The organic and compost soil amendment greatly increased seedling growth and increased transplant growth somewhat. Scarification increased seedling establishment of volunteer seedlings.

On federal lands designated by Congress as Wilderness, management objectives stress protection of natural conditions. Despite this emphasis on protection and preservation, wilderness areas are typically open to recreation use, and resultant impacts can be severe, particularly on campsites. Most campsite impact is accepted as necessary if recreation use is to be allowed. However, in some situations, campsite impacts are deemed to be either excessive or inappropriate in that particular location. In these situations, wilderness managers close sites to camping so they can return to conditions approximating those that existed prior to disturbance. Where recovery rates are slow, managers often employ various restoration treatments in an attempt to accelerate successional processes (for example Lester 1989). These efforts are often costly, in terms of time and money, and frequently are not very successful (for example Moritsch and Muir 1993).

In many wilderness ecosystems, little is known about factors that limit the rate of natural recovery or about the effectiveness of techniques designed to accelerate recovery. Consequently, we designed a study to assess the effectiveness of several common restoration treatments on closed campsites in high subalpine forests in the Eagle Cap Wilderness, in northeastern Oregon. Specific objectives were to assess the influence of (1) amending soils with organic matter, composted sewage sludge and a native soil inoculum, (2) transplanting and seeding with local, native species,

and (3) applying a surface mulch on the establishment, survival and growth of vegetation.

Study Sites

The study is being conducted in the Lakes Basin portion of the Eagle Cap Wilderness, Wallowa-Whitman National Forest, northeastern Oregon. This area, located between 2,170 m and 2,320 m, contains a number of subalpine lakes. Located 12-15 km from the closest trailheads, the Lakes Basin attracts large numbers of wilderness campers. Campsite impacts around these lakes are substantial and numerous (Cole 1981, 1993). Early efforts to close and restore campsites began in the 1970s. These efforts were largely unsuccessful. Campsites that have been closed to use have experienced little recovery over a period of more than a decade (Cole and Hall 1992).

Six campsites were selected for restoration in 1995. All are in a subalpine forest consisting of *Abies lasiocarpa*, *Picea engelmannii*, *Pinus contorta* and *Pinus albicaulis*. The most common groundcover plants, in undisturbed places, are *Vaccinium scoparium*, *Phyllodoce empetriformis* and *Carex rossii*. Soils are derived from a granitic substrate. All are within 70 m of lakes and, therefore, have been illegal campsites for more than 15 years. However, all of these sites received some camping use over this period, had virtually no groundcover vegetation and had not been revegetated in the past. These sites have probably exhibited high levels of impact (soil compaction, lack of vegetation and minimal soil organic horizons) for at least 50 years. Prior to restoration efforts, these campsites were typically about 200 m^2 in size, with about 100 m^2 completely devoid of vegetation.

Methods

Each campsite was divided into two whole plots, one with and one without a surface mulch application. Each whole plot was subdivided into six plots, which received combinations of the two factors: soil amendments (organics/inoculum; organics/inoculum/compost; or nothing) and planting (transplanted/seeded; or nothing). All 12 of these 1.5 m by 1.5 m plots were scarified. An additional plot, the control, received no treatment at all. The six campsites provide six replicates.

Treatments

Scarification utilized shovels, picks, pitchforks, hoes and hand kneading to break up compaction and clods to a depth

of about 15 cm. We tried to avoid turning over the soil, but substantial mixing of soil horizons was unavoidable in our resolve to develop a crumb texture. On several sites, numerous tree roots were cut and removed during scarification. This intensity of scarification exceeds that commonly undertaken. Treatments that received the organics/inoculum treatment were covered with a mix of peat moss and well-decomposed, locally collected organic matter to a depth of about 2.5 cm. The dry peat moss was mixed with water before application. This material was then mixed with mineral soil to a depth of 7.5 cm. Inoculum came from the rooting zone of local transplants that were being transplanted onto the site. About 1.2 liters of soil were mixed with about 20 liters of water to make a slurry. Three liters of this slurry were sprinkled over each plot and raked into the soil. Compost treatments had organic matter and inoculum added in an identical manner. In addition, we added 2.5 cm of composted sewage sludge (Ekocompost from Missoula, Montana), lightly watered and raked into the top 10 cm of organic and mineral soil.

Half of the plots were seeded and transplanted. Seeding involved (1) collecting seed locally from several species with mature seed, (2) division of available seed into equal quantities for each seeded plot, (3) pinch-broadcasting seed over the plot, and (4) raking seed into the upper 2.5 cm of soil. Seeded species varied between campsites and included *Antennaria lanata*, *Aster alpigenus*, *Danthonia intermedia*, *Juncus parryi*, *Penstemon parryi*, *Phleum alpinum*, *Sitanion hystrix* and *Sibbaldia procumbens*. Locally available seed was unusually limited due to the unusually short growing season in 1995. One of the campsites (at Crescent Lake) was not seeded due to a lack of mature seed in the vicinity.

Transplanting involved (1) digging up enough transplants in the vicinity to plant equal numbers of each species in each plot, (2) digging a hole and placing transplants in the hole, along with Vita-start (vitamin B-1) to reduce transplant shock, and (3) giving each transplant 0.6 liters of water. Plots that were not planted were given an equivalent amount of water. Most transplant plugs were between 5 and 25 cm in diameter, and most plots received five to six plugs. Although most plugs contained only one species, some contained more than one. Transplanted species varied between campsites and included *Abies lasiocarpa*, *Achillea millefolium*, *Antennaria alpina*, *Antennaria lanata*, *Aster alpigenus*, *Calamagrostis canadensis*, *Carex rossii*, *Danthonia intermedia*, *Gaultheria humifusa*, *Hypericum formosum*, *Juncus parryi*, *Luzula hitchcockii*, *Oryzopsis exigua*, *Phyllodoce empetriformis*, *Pinus contorta*, *Polemonium pulcherrimum*, *Sibbaldia procumbens*, *Spiraea betulifolia* and *Vaccinium scoparium*. All seeding and transplanting occurred in the central 1 m^2 of each plot. Measurements were also confined to this central area, leaving a 1 m buffer between the measured portion of each treated plot.

Half of the plots were covered with a biodegradable erosion control blanket made of straw interwoven with cotton string and jute (Bionet). The blanket was held in place with rocks. Where there were transplants, string was cut to allow the transplants to penetrate the strands of straw. Each campsite was closed to use by blocking main access points with string and an obvious sign. No evidence of camping use has been observed since campsites were closed to use.

In 1996, when it appeared that soils were extremely dry, plots were watered several times. When this was done, all plots were given an equal amount of water. No supplemental watering was done in later years. In all four years of the study, the late snowpack was unusually deep, suggesting that early season conditions were much less droughty than normal. In 1996, the first growing season after restoration, when plots were occasionally irrigated, the summer was dry but cool. In 1997, the summer was cool and wet. In 1998, the summer was hot and dry, and plants were not given supplemental water. In 1998, at Aneroid Lake, located at a similar elevation in an adjacent drainage, the mean maximum temperatures in July were 5-7 degrees Celsius higher than in 1996 or 1997. At Mt. Howard, the closest site with precipitation data, July-August precipitation was 18 cm in 1997, compared with 7 cm or less in 1996 and 1998.

Measurements

For each transplant, we measured areal extent of canopy cover (using a 1-m square PVC frame with a 5-cm by 5-cm grid) and maximum height. Measurements were taken immediately after transplanting (September 1995) and in September of 1996, 1997 and 1998.

Seedling establishment was assessed beginning in early July 1996. Every two weeks from early July to early September (four times), all established seedlings were mapped. Each seedling was identified by species, and a colored toothpick was placed next to it to denote date of establishment. This made it possible to assess period of establishment and death, if mortality occurred. In 1997, seedlings that germinated in 1996 were identified on the basis of their size, location and species. New seedlings (the 1997 cohort) were identified in the surveys conducted every two weeks. In some plots, seedlings were so numerous that they were assessed in subplots. In 1998, seedling assessment occurred twice, in mid-July and early September. Again, we attempted to differentiate between new seedlings (the 1998 cohort) and older plants.

Ten individuals of a seeded species were randomly selected on each plot, and their height was measured in September of 1996, 1997, and 1998. In 1996 and 1997, another four individuals of the same species were carefully excavated. Their root and shoot biomass was measured, following cleaning and drying. In 1998, we measured the height of the tallest individual of the seeded species, which we had found to be well-correlated with biomass. This avoided the need for further destructive sampling. In 1997 and 1998, height and biomass measurements were taken only on seedlings that germinated and established in 1996.

Transplant areal extent and seedling locations were digitized to allow spatial analysis. Treatment effects were analyzed using standard statistical techniques, primarily t-tests and analyses of variance, with post-hoc Duncan's multiple comparisons.

Results

In September 1995, a total of 206 plugs were transplanted onto 36 of the 78 plots. These plugs contained 280 individual

transplants (either separate species, separate individuals or separate vertical stems that might be separate individuals). By September 1996, 96% of these plugs and 92% of the individual transplants were still at least partially alive. By September 1997, 96% of the original plugs were still living, and the number of live individual transplants (382) exceeded the number apparent at the time of planting. Transplant mortality was greater during the hot, dry summer of 1998. Nevertheless, by September 1998, 90% of the original plugs and 86% of the original transplants were still living (table 1). In 1998, the number of live individual transplants (318) still exceeded the number of individuals apparent at the time of planting.

The mean canopy cover of surviving transplants (areal extent) decreased 5 cm^2 (5%) between September 1995 and September 1996. By September 1997, mean canopy cover was 113 cm^2; by September 1998, mean canopy cover was 151 cm^2. In three years since transplanting, then, the mean cover of surviving transplants increased 52 cm^2 (55%). The total cover provided by all transplants was 33% greater in 1998 than in 1995, when transplanting occurred. Mean transplant height declined 4% (from 7.6 cm to 7.3 cm) during the first year following transplanting. By September 1997, mean transplant height was 10.2 cm. By September 1998, mean transplant height was 12.6 cm. After three years, mean transplant height was 66% greater than at the time of transplanting. In 1997, 12% of the transplants flowered. Forty percent of transplants flowered in 1998.

During the summer of 1996, almost 20,000 seedlings germinated and established on the 78 1 m^2 plots. Most of these seedlings (>70%) germinated from the seed we had broadcast. However, volunteers germinated from seed that reached the site through natural dispersal processes or, perhaps, from the soil seedbank. In 1996, most of the volunteers were perennial species; in 1997 and 1998, most volunteers were annual species. Germination and establishment continued throughout the two-month assessment period (early July to early September). However, about two-thirds of the seedlings established (cotyledons were well-developed) in the early August period—about one month after snow had left most plots. Germinants were probably emerging from the soil about two weeks prior to the point at which we considered them established.

In 1997, the 1996 seedling cohort generally emerged early, by mid- to late July. The 1997 seedling cohort established throughout the season, but primarily in early August. The 1997 cohort of seeded species was about one-third as abundant as the 1996 cohort (fig. 1). The 1997 cohort of volunteer perennials was about one-half as abundant as the 1996 cohort. However, annuals were about four times more abundant in 1997 than in 1996. In 1997, the total number of seedlings that either re-emerged (the 1996 cohort) or became established (the 1997 cohort) on the 78 1 m^2 plots exceeded 25,000.

The 1998 cohort of seeded species was small, only about 2% as abundant as the original 1996 cohort. The 1998 cohort of volunteer species was similar in quantity to the 1997 cohort, about one-half of the 1996 cohort. Annual species
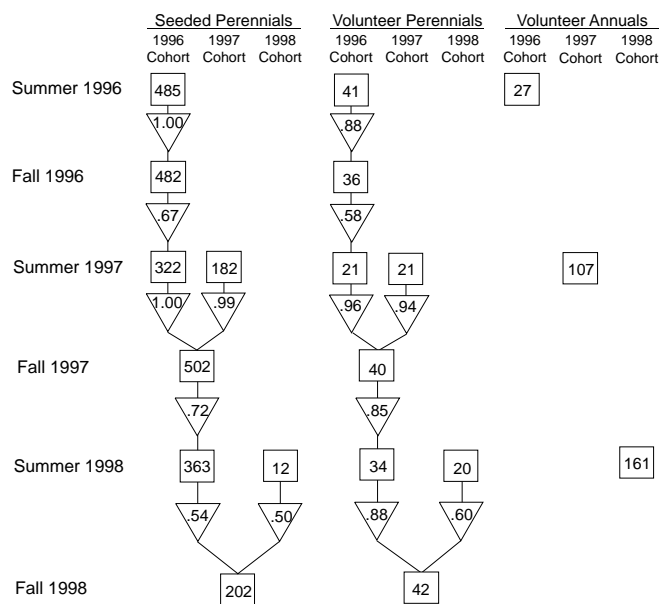

Figure 1—Seedling density (#/m^2—in squares) and survival rates (in triangles) of seeded species and volunteers from cohorts of seedlings that established in 1996, 1997, and 1998.

Table 1— Mean (standard error) plug and transplant survival, growth and flowering, 1995–1998.[a]

Treatment	Plug survival	Transplant survival	Change in transplant area	Change in transplant height	Transplant flowering
	- - - - - - - - *Percent* [b] - - - - - - -			(*cm*^{2})[c]	(*cm*)[c]	*Percent*
Soil amendment					
None	88(4)	84(4)	30(12)a	4.4(0.8)a	42(4)
Organics	89(4)	87(4)	49(25)ab	5.7(0.7)ab	76(32)
Organic/compost	92(4)	89(4)	76(12)b	7.6(1.2)b	35(4)
Mulch treatment					
None	90(3)	85(3)	36(15)	6.0(0.7)	60(22)
Mulched	89(3)	89(3)	67(19)	5.8(0.8)	42(4)
Total	90(2)	86(2)	52(12)	6.0(0.5)	51(11)

[a]Means with different letters are significantly different ($\propto$= 0.05).
[b]Plugs and transplants (individual species within a plug) planted in 1995 still alive in 1998.
[c]Change between time of planting in 1995 and 1998.

were extremely abundant. In 1998, the total number of seedlings that either re-emerged or became established on the 78 1 m^2 plots was about 16,000, 36% less than in 1997. Seedling density varied greatly between the six campsites.

Seedling survival varied between years and seasons, as well as between seeded species and volunteers (fig. 1). We could not assess mortality prior to seedling establishment (the emergence of well-developed cotyledons). However, once established, there was virtually no mortality (< 1%) of seeded species during the summer of 1996, when plots were occasionally watered, and the summer of 1997, which was wet. For volunteer perennial species, mortality rates were slightly higher, 12% in the summer of 1996 and about 5% in 1997. For both seeded and volunteer species, mortality during the winter of 1996-1997 was about 35-40%. Overall, about 65% of the seedlings that established in 1996 were still alive in fall of 1997. Mortality within the 1996 cohort was more than offset by germination and establishment of additional seedlings in 1997. About 17,000 perennial seedlings were alive on the 78 1 m^2 plots in September 1996; about 18,000 perennial seedlings were alive in September 1997.

Winter mortality rates were lower during the winter of 1997-1998—28% for seeded species and 15% for volunteer perennials. However, mortality rates during the hot, dry summer of 1998 were high, particularly for seeded species and for the small 1998 cohort. Close to one-half of the seedlings that re-emerged or established in 1998 had died by September 1998. About 10,000 perennial seedlings were alive on the 78 1 m^2 plots in September 1998. The proportion of perennial seedlings that were volunteers increased from 16% in 1996 to 35% in 1998.

The spatial pattern of the initial cohort of seedlings was analyzed with GIS. The 1996 cohort of seedlings was neither regularly nor randomly distributed. They were aggregated to a significant degree. Seeded species were more aggregated than volunteers. This suggests that aggregation resulted from both the seeding process and the availability of "safe sites." Seedling density was greater outside transplant plugs than within, but seedlings were attracted to the transplants (that is, they were located closer to transplants than expected). Seeded and volunteer species did not differ in the extent to which they were less abundant under transplants or more abundant close to transplants. This suggests that conditions close to transplants favor seedling establishment, while conditions underneath transplants discourages establishment. It is unclear whether these spatial patterns result from transplant effects on seed dispersal-entrapment patterns, soil conditions, microclimatic conditions or competitive interactions.

Treatment Effects

Survival of transplants was high (about 86%) regardless of treatment (table 1). Between 1995 and 1998, increase in canopy cover (areal extent) of transplants was significantly greater on plots with the organic and compost soil amendments than on scarified plots that received no soil amendments (fig. 2). Increase in height was also significantly greater on organic and compost plots (table 1). Compared to plots without a surface application of mulch, mulched plots experienced a greater increase in canopy cover but a smaller increase in height. Neither of these differences was
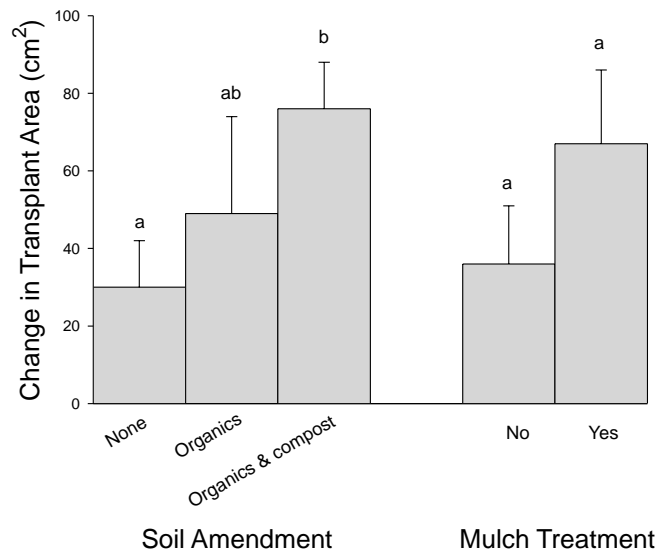
Figure 2—Effect of soil amendments and mulch on increase in canopy cover of transplants, 1995 to 1998. Vertical bars indicate one standard error; different letters indicate significantly different means (α = 0.05).

statistically significant, however. Transplant flowering was highest on plots that received organic soil amendments but no compost, as well as on plots without a mulch treatment. This response was highly variable within treatments, however, and differences are not statistically significant.

The effect of scarification on seedling density was assessed by comparing the nonscarified control plot with plots that were scarified but received no other treatment. On these two sets of plots, all established seedlings are volunteers. In 1998, scarified plots had a significantly greater seedling density (mean of 31 seedlings/m^2) than control plots (7 seedlings/m^2) (fig. 3). Seeding had a tremendous influence on seedling density, with seeded plots having over five times as many seedlings as unseeded plots, three years after seeding. Volunteers were equally abundant on seeded and nonseeded plots. Plots that were amended with organic matter and compost had significantly more seedlings than unamended plots. However, the surface mulch treatment did not have a significant effect on total seedling density, the density of seeded species or the density of volunteers.

Explanations for differences in seedling density varied between the treatments. Scarification was advantageous to seedling establishment. The scarified plots included in the analysis were not seeded, and their mortality rate was not significantly lower than that on controls. Seeding was advantageous because it provided a more abundant source of propagules. Despite higher mortality rates on seeded plots (table 2), seedling density remains higher on seeded plots. The organic/compost amendment was advantageous because mortality rates during the hot, dry summer of 1998 were lower than on other plots (table 2). Propagule availability and establishment rates were no greater on organic/ compost plots. After the moist 1996 and 1997 summers, seedling density was not greater on the organic/compost plots.

More than one-third (36%) of the seedlings that re-emerged or established during the hot, dry summer of 1998 died,
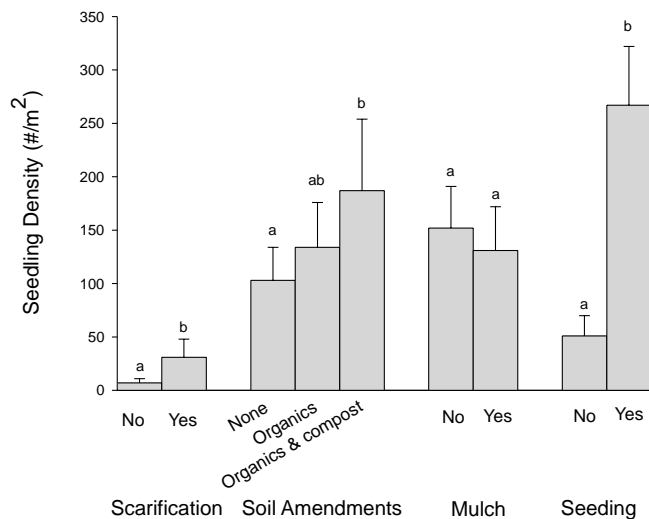
Figure 3—Effect of scarification, soil amendments, mulch and seeding on seedling density, September 1998. The scarification treatment reported received no soil amendment, mulch or seeding. Vertical bars indicate one standard error; different letters indicate significantly different means (α = 0.05).
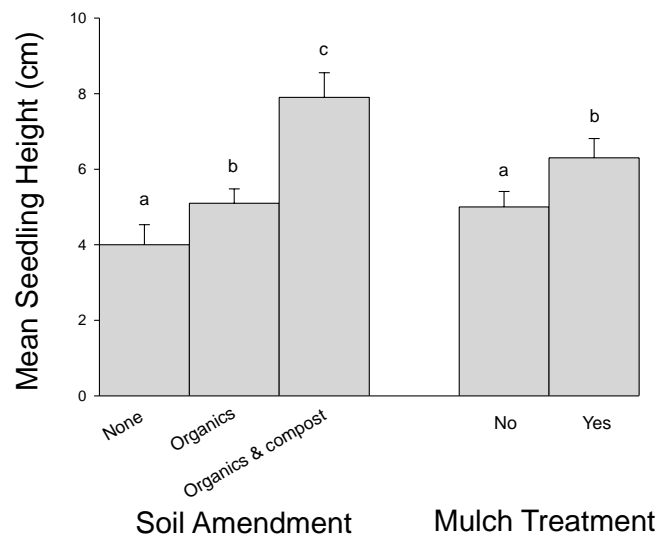

Figure 4—Effect of soil amendments and mulch on increase in mean height of 3-year-old seedlings, September 1998. Vertical bars indicate one standard error; different letters indicate significantly different means (α = 0.05).

Table 2—Seedling density in September 1998 and seedling mortality and flowering during 1998.[a]

	Seedling density	Seedling mortality	Seedling flowering
	(#/m^2)	- - - - - Percent - - - - -	
Soil amendment			
None	103(31)a	33(7)a	7(4)a
Organics	134(42)ab	23(4)ab	5(2)a
Organics/compost	187(67)b	13(3)b	15(4)b
Mulch treatment			
None	152(39)	24(4)	9(3)
Mulched	131(28)	21(4)	9(3)
Seeding treatment			
None	51(19)a	17(3)a	9(3)
Seeded	267(55)b	32(6)b	9(2)
Scarification treatment			
None	7(4)	36(18)	0(0)
Scarified[b]	31(17)b	23(4)	20(16)
Total	141(28)	23(3)	9(2)

[a]Means with different letters are significantly different (∝ = 0.05).
[b]Scarified treatment received no soil amendment, mulch or seed.

although the mean seedling mortality rate for the plots was just 23%. Nine percent of surviving seedlings flowered in 1998. Flowering rates were significantly higher on the plots that were amended with organic matter and compost than on unamended plots or plots amended with just organic matter and soil inoculum (table 2).

Seedling growth was influenced by both soil amendments and mulching (fig. 4). In September 1996, the mean height of seedlings of a selected seeded species was 1.7 cm. Seedling height was significantly greater on plots that received either the organics amendment (mean of 1.8 cm) or the organics and compost amendment (1.9 cm) than on plots without

amendments (1.5 cm). Seedling height was also significantly greater on mulched plots (2.0 cm) than on plots without mulch (1.5 cm). By September 1997, the mean height of seedlings established in 1996 had increased to 3.5 cm, and it was possible to confidently guess a plot's soil treatment simply by observing seedling robustness. Mean height increased to 5.7 cm in 1998. In 1997 and 1998, seedling height on the plots with the organics and compost amendment was significantly greater than on plots receiving organics or no soil amendments at all. Plots amended with organics had taller seedlings than unamended plots (fig.4). Seedling height was also significantly greater on the mulched plots than those without mulch, in both 1997 and 1998.

For the selected seeded species, the mean biomass of seedlings that established in 1996 increased from 12 mg in 1996 to 190 mg in 1997. Their root:shoot ratio increased from 0.34 in 1996 to 0.52 in 1997. In both 1996 and 1997, seedlings on plots amended with organics and compost had significantly more biomass than seedlings on other plots. Root:shoot ratios did not differ significantly with soil treatment, although they were higher on the organics (0.65) and organics and compost plots (0.55) than on plots without soil amendments (0.37). Greater biomass of individual seedlings might partially explain the lower seedling mortality rates on the plots with organic and compost amendments. Mulching had no effect on biomass in either year.

Vegetation cover was negligible before restoration. Immediately after transplanting and seeding, mean total cover was 3.7%. Mean cover increased to 9.0% in 1996, 10.6% in 1997 and 13.2% in 1998 (table 3). Most cover was initially provided by the transplants. By 1997 and 1998, however, more cover was provided by plants that germinated from seed. Although initially most of the plants that germinated from seed were seeded species, the proportion of volunteers has increased every year. Planting was the treatment that had the most dramatic effect on cover. Mean cover exceeded

Table 3—Canopy cover of transplanted, seeded, and total vegetation, September 1998.[a]

| | Canopy cover | | |
	Transplanted	Seeded	Total
	- - - - - - - - - - - - *Percent* - - - - - - - - - - - -		
Soil amendment			
None	5.0(1.2)	5.1(2.5)a	9.2(2.8)a
Organics	6.0(1.7)	6.8(1.5)a	12.4(2.6)ab
Organics/compost	7.4(2.0)	11.8(2.6)b	18.1(3.6)b
Mulch treatment			
None	5.7(1.2)	6.9(1.7)	11.8(2.3)
Mulched	6.6(1.5)	8.9(2.1)	14.6(2.7)
Planting treatment			
None	0(0)a	4.8(1.1)a	4.5(1.1)a
Planted	12.3(1.3)b	11.0(2.3)b	21.9(2.7)b
Scarification treatment			
None	0(0)	<0.1(0)	<0.1(0)
Scarified	0(0)	1.2(0.6)	0.8(0.5)
Total	6.2(0)	7.9(1.3)	13.2(1.7)

[a]Means with different letters are significantly different ($\propto$ = 0.05).

20% on planted plots but was less than 5% on plots that were not planted. The plots amended with organic matter and compost had twice the mean cover of plots that were not amended. Plots that were mulched and scarified also had more cover than plots that were not treated, but differences were not statistically significant.

Discussion and Conclusions

Overall, the restoration techniques we employed were highly effective. Virtually all of the transplants survived the procedure. Most were growing vigorously and many were flowering three years after planting. Soil amendments (organic matter, soil inoculum and composted sewage sludge) contributed greatly to the vigor of transplant growth. The surface mulch had no clear effect, either positive or negative.

Although seedling density varied greatly between camp-sites, the mean seedling density of perennial species on seeded plots was 267 seedlings/m^2 three years after seeding. Seedlings were growing vigorously. Mean seedling biomass increased more than ten fold during the second growing season, and mean seedling height increased 68% during the third growing season. Scarification, seeding and the organic and compost soil amendment were all effective in increasing seedling density. Scarification and seeding had more effect on seedling establishment, while the soil amendment had more effect on seedling survival during the hot, dry summer of 1998. The organics and compost treatment was most effective in enhancing seedling growth. This effect of soil amendments only became apparent in the second growing season. The surface mulch and organics treatments had less pronounced positive effects on seedling growth, which only became apparent in the third growing season.

The high level of seedling establishment and survival on all seeded plots during the first two growing seasons and the relative ineffectiveness of the mulch treatment were two

surprising results. Both results might be explained by the unusual climatic conditions that persisted over the first three summers of fieldwork. In all three years, late snow combined with frequent summer rainfall meant that soil moisture levels were probably relatively high. With abundant soil moisture, seedling germination, establishment and survival might have been unusually high, even without some of the microclimatic amelioration that a surface mulch can provide.

The third growing season was hot and dry, and seedling survival declined dramatically. Seedling mortality was much lower where soils were amended with organic matter and compost, perhaps a result of increased soil water-holding capacity and seedlings with better developed root systems. This suggests that supplemental watering may be critical to effective restoration during years with hot, dry summer weather. Supplemental watering may be needed for several years, particularly where soils have not been amended with organic matter.

It is quite possible that much of our success with seeding was the result of the supplemental watering done when seedlings were germinating during the initial growing season following seeding. The unusually high intensity of scarification we employed may also partially account for our success.

Projected recovery rates vary greatly between treatments. Mean vegetation cover on undisturbed stands close to campsites is about 55% (Cole 1982). Plots with the organic and compost amendment that were scarified, planted and mulched had a mean cover of 35% in 1998. This amounts to more than 60% recovery in just three years. Projecting past recovery rates into the future, plots receiving this most beneficial treatment would experience complete recovery of cover in about five years. On planted plots without soil amendments, recovery would require about 10 years. On plots that are scarified but neither amended nor planted, recovery would require more than 100 years. Without scarification, recovery would take even longer.

Although more than 60% recovery of plant cover in three years seems successful, composition has not recovered as rapidly as cover. On restored sites, graminoids constitute more than 50% of the vegetation cover compared to about 25% on undisturbed sites (Cole 1982). On undisturbed sites, the two low shrubs, *Vaccinium scoparium* and *Phyllodoce empetriformis,* account for 28% and 11% of the vegetation cover, respectively. On restored sites, they account for 7% and 4% of the cover, respectively. Compositional recovery will require many decades unless transplanting, particularly of shrubs, is done at densities that mimic undisturbed conditions.

We recommend that closed sites remain signed and roped off at least until vegetation cover on restored sites approximates pre-disturbance conditions. Even with effective restoration techniques, it will likely require hundreds of years to eliminate the undesirable and unnecessary campsite impacts in the Lakes Basin and confine impacts to the levels and places deemed acceptable. This suggests the importance of avoiding damage in the first place, by implementing effective management programs wherever regular recreation use occurs.

Acknowledgments

References

Cole, D. N. 1981. Vegetational changes associated with recreational use and fire suppression in the Eagle Cap Wilderness, Oregon: some management implications. Biological Conservation. 20: 247-270.

Cole, D. N. 1982. Wilderness campsite impacts: effect of amount of use. Resarch Paper INT-284. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 34 p.

Cole, D. N. 1993. Campsites in three western wildernesses: proliferation and changes in condition over 12 to 16 years. Research Paper. INT-463. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

Cole, D. N. and T. Hall. 1992. Trends in campsite condition: Eagle Cap Wilderness, Bob Marshall Wilderness, and Grand Canyon National Park. Research Paper INT-453. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 40 p.

Lester, W. J. 1989. Revegetation efforts at North Cascades National Park Service Complex. In: Hughes, H. G.; Bonnicksen, T. M. (eds.). Restoration '89: the new management challenge. Proc. First Annual Meeting of the Society for Ecological Restoration; 1989 January 16-20; Oakland, CA. Madison WI: Society for Ecological Restoration: 261-270.

Moritsch, B. J. and P. S. Muir. 1993. Subalpine revegetation in Yosemite National Park, California: changes in vegetation after three years. Natural Areas Journal. 13:155-163.