Low investment revegetation strategies for denuded sites: the effects of surface treatments on native seed recruitment in a low-elevation North Cascades riparian forest

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Introduction

Recreational and construction activity in wilderness areas often result in denudation; the stripping of vegetation and organic soils down to bare mineral soil. Even in an intact wilderness matrix these disturbances can be slow to naturally revegetate due to altered soil conditions predominantly compaction. Compacted soils resist water infiltration and root penetration and lack surface roughness that creates microsites for seed recruitment, retention, and germination. Natural revegetation may also be limited by the ability of primary successional species which tend to be adapted to colonizing disturbed mineral soils to disperse to the denuded site. As well, if the seeds can arrive the light and moisture conditions may not be sufficient to allow for germination and establishment. Many primary successional species are shade intolerant while much localized denudation in wilderness areas often occurs beneath mature canopy.

Active revegetation of denuded sites in wilderness area can involve various strategies with increasing levels of resource investment:

- **High** - De-compaction, planting seedlings and/or mature plants, and mulching
- **High to moderate** - De-compaction, seeding with native early successional herbaceous & grass species followed by planting with native woody species and/or allowing for natural recruitment
- **Moderate** - De-compaction, seeding with sterile nonnative ground covers such as winter wheat (*Triticum aestivum*) followed by planting with native species and/or allowing for natural recruitment
- **Moderate to low** – De-compaction followed by mulch application and allowing for natural recruitment
- **Low** – Either de-compacting soil OR applying mulch and then allowing for natural recruitment

In each of these strategies barriers to natural revegetation are overcome through changing soils conditions (soil de-compaction, cover cropping, mulching) and bringing appropriate species to the site (planting, seeding). Natural recruitment of native species from the surrounding matrix once soil conditions are altered is often perceived in practical application as an unintentional ‘bonus’. Sometimes when the natural recruits are more vigorous and fast-growing than the installed species, for example red alder (*Alnus rubra*) vs. most native conifers, they are treated as a competitor and hence a maintenance problem.

Revegetating denuded sites in backcountry areas can be logistically difficult. Transportation of tools, plants, seeds, mulch, and people needed to perform the work may be limited by safety concerns, budgets, staff availability, and practicality. As a result much localized backcountry disturbance like illicit trails and campsites is left to revegetate naturally. Often this revegetation takes decades as organic matter accumulates gradually and conditions the soil enough to allow for recruitment of appropriate species (if they are available). Denuded backcountry sites also frequently receive continued disturbance since clearings and open paths continue to attract hikers and campers. Wilderness managers have become adept at making these denuded sites ‘unfriendly’ to visitors often in conjunction with active revegetation however it is more common to simply block access and allow for natural revegetation especially in backcountry areas.

Given the extensive dispersed denudation that occurs in wilderness areas there is a need to experiment with and develop multiple revegetation strategies that are ecologically successful while balancing resource availability. At the low investment end of revegetation strategies simply altering surface conditions by applying an organic mulch may be all that is needed to provide the conditions necessary for the successful recruitment of appropriate species from the intact matrix and/or to allow for the successful germination and establishment of intentionally seeded species. This strategy can be employed on relatively small areas of denudation such as trails and campsites by careful ‘borrowing’ of forest litter by hand and covering the denuded area to an appreciable depth (2 cm or more). Such autochthonous inputs bring not only organic matter to the denuded site but also transports the locally adapted, site appropriate organisms needed to decompose organic matter (fungi, macro/microinvertebrates, bacteria, etc.), plant seeds and propagules, and bryophyte spores and fragments. In essence the natural accumulation of forest litter is being accelerated to achieve soil conditioning and plant recruitment in a shorter term. Allochthonous inputs such as Excelsior™ aspen shaving mats, wood chips from brush clearing, decomposed sawdust, and other organic mulches may also serve to overcome limits to natural revegetation. However transportation of such materials over long distances and rough terrain may preclude their use.

Regardless of the method chosen to revegetate a denuded site, any alteration of the soil surface changes the quality and quantity of microsites for seed recruitment and germination. Each plant species has evolved adaptations that allow for successful germination under a certain range of conditions. Moisture, temperature, and light regimes control seed germination. The microsites into which seeds of a certain species are recruited then must provide that particular regime for successful germination. Many co-occurring plant species over evolutionary time have developed unique, non-overlapping microsite preferences while others have developed competing dispersal strategies when microsite preferences are similar. Given knowledge of these microsite preferences for particular species it is possible to favor certain species over others and hence direct plant community development simply by altering soil surface conditions.

Experimental site description

The experiment is located at the North Cascades Environmental Learning Center (ELC) on the northern shore of Diablo Lake in North Cascades National Park. The ELC was developed on a site formerly occupied by a recreational fishing camp consisting of cabins and associated facilities. Completed in 2004 the ELC post-construction had need to restore historically and construction impacted areas. The opportunity was taken to set aside three areas (blocks A, B, and C; see Figure 1) for an experimental restoration

Each block had historically been the location of a fishing cabin for approximately 80 years. More recently after removal of the cabins they became staging and storage areas for materials during the ELC construction resulting in highly compacted soils. Block A sits above the access road and forms a small gap (< 900 m^2) in the canopy. To the south block B lays aside the access road and forms little or no canopy gap. Block C lies to the west of block A closer to the ELC entrance and has a more open but continuous canopy cover. All three blocks contained very similar compacted silty clay soils with a very high coarse fraction, had slopes of less than 5%, and had a broadly southwestern aspect.

The surrounding canopy is composed of small diameter Douglas-fir (*Pseudotsuga menziesii*), mature big-leaf maple (*Acer macrophyllum*), black cottonwood (*Populus balsamifera*), and red alder (*Alnus rubra*) with paper birch (*Betula papyrifera*) and lodgepole pine (*Pinus contorta* ssp. *latifolia*) present at low densities. The intact understory tends to be dominated in alternating patches by salal (*Gaultheria shallon)* and low Oregon-grape (*Mahonia nervosa)* interspersed with swordfern (*Polystichum munitum*) and a sparse shrub layer of red huckleberry (*Vaccinium parvifolium*), naked hip rose (*Rosa gymnocarpa*) and serviceberry (*Amalanchier alnifolia*). Bryophytes predominantly feather moss (*Hylocomium splendens*), Oregon beaked moss (*Eurhynchium oreganum*) and cat-tail moss (*Rhytidiadelphus* spp.) cover all available surfaces and often reach 100% cover in undisturbed areas.

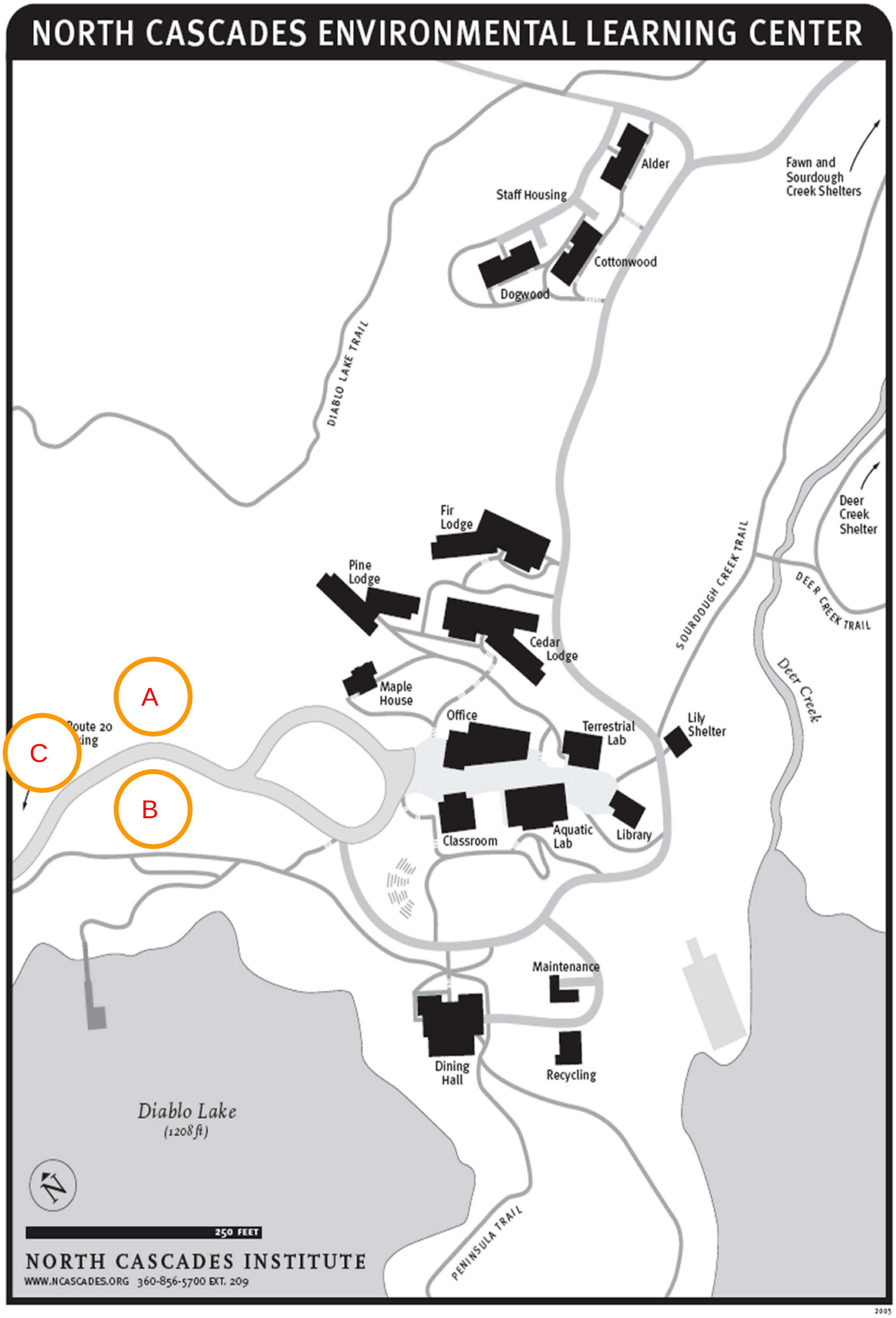


Figure 1: North Cascades Environmental Learning Center experimental site locations

Experimental Design

In this experiment six low-investment soil treatments were evaluated for their ability to recruit local native species from seed rain and to promote the germination and establishment of two intentionally seeded common forest understory species, salal (*Gaultheria shallon)* and low Oregon-grape (*Mahonia nervosa*). The six soil surface treatments consisted of bare mineral soil, woodchips, and collected forest litter either with or without 'inoculum' (see Table 1 below).

CODE	**TREATMENT**
M	mineral soil only (control)
MI	mineral soil + inoculum
ML	mineral soil + forest litter
MLI	mineral soil + forest litter + inoculum
MW	mineral soil + woodchips
MWI	mineral soil + woodchips + inoculum

Table 1: Treatment combinations

Mineral soil refers to the existing compacted site soils. **Inoculum** is highly decomposed, biologically active organic matter harvested from the lower O horizon of the surrounding intact forest. The intent of using inoculum in this experiment was to actively introduce the organisms needed to initiate decomposition and soil nutrient cycling and more directly relevant mycorrhizal spores for germinants. Small trowels were used to collect inoculum from widely dispersed locations yielding one 5 gallon bucketful used for the entire experiment. Care was taken to remove and replace overlying forest litter and bryophytes during harvesting. **Forest litter** consisting mostly of coniferous leaf and twig fall was collected from a local campground using rakes and brooms. The litter also contained cones with seeds, lichens, and mosses. **Woodchips** were derived from trees removed and chipped during the construction of the ELC. Post-construction these chips were spread throughout the denuded areas of the ELC to prevent soil erosion and condition the soil for planting.

In March 2006, 20 replicates of each treatment for a total of 120 were applied in 1 m^2 plots between three locations at the ELC, blocks A, B, and C, resulting in 40 plots/block. Treatments were distributed in a random stratified manner with nearly equal numbers of each treatment being assigned randomly within each block (see Figure 2). Each block had been completely covered in woodchips post construction so the wood chips were raked up as completely as possible before application of treatments. This ensured that the entire site received the same type and level of disturbance before the experiment. For plots receiving a woodchip treatment, the collected woodchips were then reapplied as described below.

Figure 2: Experimental plot installation – Block C facing north

In an effort to mark the plots in a way that kept the ELC landscape aesthetic and uncluttered each plot was planted prior to treatment application with either a mature 2 gallon size *M. nervosa* or G*. shallon*. The installed plants were discretely labeled with aluminum tags that bore the plot number, treatment, and species of the seed installed. Each installed *M. nervosa* or G*. shallon* also indicated which seed had been spread in that plot. Each received seed of its own species. The order of treatment application was as follows; seed→inoculum→woodchip or forest litter. The application rates were as listed below in Table 2.

TREATMENT	RATE
seed	50/plot
inoculum	approx. 200 ml/plot
woodchips	to a depth of 1-2 cm
forest litter	to a depth of 1-2 cm

Table 2: Application rates of treatments

The application of woodchips and forest litter were intentionally light so that installed seed germination would not be suppressed and that seed rain had a chance to penetrate the thatch to the mineral soil (see Figure 3).

Figure 3: Applying experimental litter + inoculum treatment

Hypotheses

H_0: no significant difference between the treatments in (1) number of *M. nervosa* and *G. shallon* seed germinated and (2) the number of each species germinated from seed rain.

H_1: There will be significantly greater germination of *M. nervosa* and *G. shallon* seed with mulched treatments.

M. nervosa and *G. shallon* are evergreen, shade tolerant, dominant understory groundcovers. Their seed is dispersed by birds, mammals, and gravity within the forest understory. It is a fair assumption that they are adapted to germinating in low-light conditions on moist, highly organic substrates. Given this premise the litter + inoculum treatment should most closely mimic microsite conditions for these species.

H_2: Canopy species in the seed rain will preferentially germinate on treatments approximating preferred natural microsite conditions

Deciduous riparian canopy species present in the immediate matrix such as *A. rubra, B. papyrifera,* and *P. balsamifera* germinate preferably on exposed mineral substrates with part to full sun when there is adequate fine soil fraction and moisture. The mineral and mineral + inoculum treatment then should recruit more of these species than the mulched treatments. *A. macrophyllum* can germinate in lower light conditions and leaf litter.

Shade tolerant conifers such as western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla)* tend to germinate under forest canopy on decaying wood and in forest litter and therefore should prefer mulched treatments especially the litter + inoculum treatment. This hypothesis is confounded by the transport of seed in the litter treatment, primarily T*. heterophylla* and *T. plicata* which are lacking in the local seed rain. It would be expected that the litter treatments would have higher numbers of these species germinating since they were introduced. Shade intolerant conifers such as *P. contorta* and *P. menzeisii* are found in the surrounding canopy and tend to germinate on exposed mineral soil and in light needle litter.

There are a few untested assumptions with this hypothesis.

Assumption 1: The seed of all the species present in the immediate matrix surrounding the experimental sites have more or less equal opportunity to reach all the experimental plots.

This is closer to being realistic with *A. rubra, B. papyrifera,* and *P. balsamifera* who's seeds are small, light, and adapted to wide dispersal in air currents. This is a less realistic assumption with winged but heavier seed of *A. macrophyllum, P. contorta* and *P. menzeisii*.

Assumption 2: The experimental treatments are the primary influence on seed germination for all species.

The interaction between light, moisture, and temperature regimes triggers seed germination. Each species has its own preferred regime. In this experiment the treatments are assumed to provide microsites that differ substantially from each other in these factors. It is assumed that average canopy cover, precipitation, and temperature do not vary significantly from plot to plot, and block to block since they are all in very close proximity. It was also assumed that certain species requiring cold stratification for germination were satisfied over the winter of 2006-7.

Data Collection

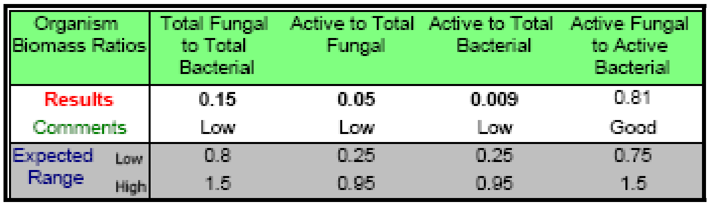
The experimental plots were assessed for species and numbers of germinants once in June 2006 and once again in October 2007. Only the October 2007 data are presented in this report since the majority of first season germinants were unidentifiable to species. All germinants were counted in each 1 m^2 plot and identified to species if possible. 21 of the 40 plots in block B were lost due to windthrow of a mature *P. menziesii* during the winter 2006-7 and are not included in data collection or analysis. Samples of the pre-treatment site soils and inoculum were sent to Soil FoodWeb laboratories for bacterial/fungal analysis (see Tables 3 and 4). Post treatment soils have yet to be collected and analyzed and will be in March 2008 as funding is available. Pre-treatment approximately 500 ml samples of the site soils, forest litter, woodchips, and inoculum were also taken to the University of Washington Botanic Gardens Center for Urban Horticulture (CUH) for seed bank analysis. Samples were spread onto standard growing media and maintained in moist, moderately warm, and well lit environs to force germination. Germinants were identified and counted as they emerged (See Table 5).

Data Analysis

Seed germination data gathered in October 2007 was analyzed using univariate analysis of variance (ANOVA) with SPSS 11.5. Individual treatments were compared for significant difference at $p<0.05$ using a post hoc Tukey's HSD test. Both individual species and groups of species were assessed for their germination/recruitment response to the individual treatments. Greater than 90% of the germinants counted were *A. rubra* therefore a pooled analysis of all species counted was not performed. Six sets of analyses were chosen for relevance to be discussed; *M. nervosa, A. rubra, P. balsamifera, B. papyrifera*, shade-intolerant conifers (*P. menziesii*+*P. contorta*), and shade –tolerant conifers (*T. plicata*+*T. heterophylla*).

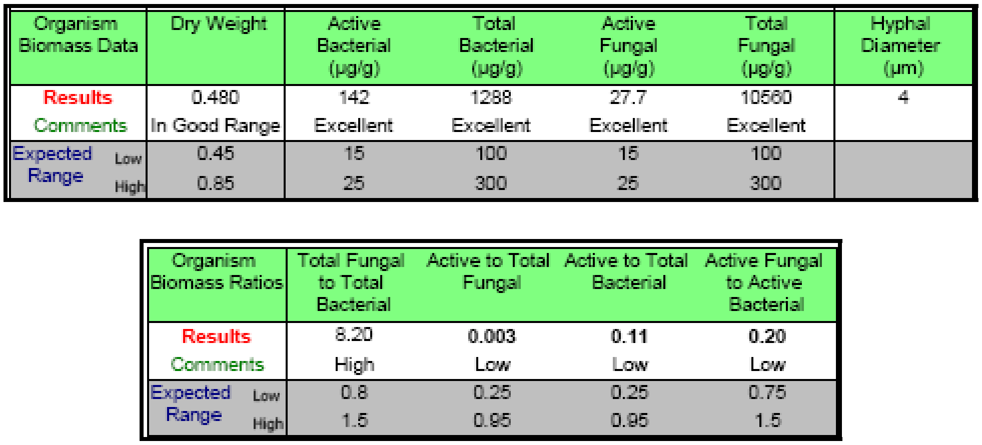
Pre-experimental Analyses

Site soils and experimental treatments were analyzed for relevant baseline information regarding soil biota and seed bank. The bacterial and fungal biomass analysis performed by Soil FoodWeb laboratories showed that the pre-treatment mineral site soils tended to be dominated by bacterial biomass and lack fungi (indicating lack of organic matter accumulation) while the 'inoculum' was highly fungal as well as bacterial (see Tables 3 and 4) and had nearly 20X the microbial biomass. This would seem to confirm that the 'inoculum' could possibly serve to introduce decomposer propagules to the plots. Mycorrhizal spore analyses were not performed due to budgetary constraints.



Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial
Results		0.15	0.05	0.009	0.81
Comments		Low	Low	Low	Good
Expected Range	Low	0.8	0.25	0.25	0.75
	High	1.5	0.95	0.95	1.5

Table 3: Pre-treatment site soils – bacterial and fungal analysis



Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		0.480	142	1288	27.7	10560	4
Comments		In Good Range	Excellent	Excellent	Excellent	Excellent	
Expected Range	Low	0.45	15	100	15	100	
	High	0.85	25	300	25	300	

Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial
Results		8.20	0.003	0.11	0.20
Comments		High	Low	Low	Low
Expected Range	Low	0.8	0.25	0.25	0.75
	High	1.5	0.95	0.95	1.5

Table 4: Forest lower O horizon "inoculum" - bacterial and fungal analysis

The seed bank analysis of the pre-treatment site soils and each treatment were performed to assess what species each may introduce to the experiment. Not unexpectedly *T. heterophylla* was only found in the litter treatment while interestingly *B. papyrifera* was found exclusively in the inoculum treatment and in relatively high numbers. *A. rubra* was found in all treatments which is not surprising since it is a highly common species whose seed is widely dispersed in the fall and winter. The species in red are common contaminants of growing media and except for *M. muralis* (a common naturalized nonnative in the Pacific Northwest) were not found in the experimental plots (see Table 5). Comparing the potential contribution from the site soil and treatment seed bank to germinants recruited over two growing season it is clear that the majority of germinants were recruited from seed rain.

	ALNRUB	**CHAMAC**	**POLAVI**	**BETPAP**	**OXACOR**	**RUBSPP**	**MYCMUR**	**TSUHET**	**ACEMAC**
INOCULUM	4	3		31	3	1	1		
WOODCHIP	9		1		5				
SITE SOILS	4		2		4				
LITTER	7	1	2		2			5	1

CODE	**SPECIES NAME**	**COMMON NAME**	**STATUS**
ALNRUB	*Alnus rubra*	red alder	native
CHAMAC	*Chamaesyce maculata*	spotted spurge	introduced
POLAVI	*Polygonum aviculare*	prostrate knotweed	introduced
BETPAP	*Betula papyrifera*	paper birch	native
OXACOR	*Oxalis corniculata*	creeping wood-sorrel	introduced
RUBSPP	*Rubus* spp. (most likely *R. ursinus*)	trailing blackberry	native
MYCSPP	*Mycelis (Lactuca) muralis*	wall lettuce	introduced
TSUHET	*Tsuga heterophylla*	western hemlock	native

Table 5: Experimental treatment seed bank – May 2006

Results

As of October 2007, the end of the second growing season since planting *G. shallon* has yet to be identified in the experimental plots. *G. shallon* seed is rather small (approx. 11,000/g) as are the seedlings so they may have been easily overlooked. 47 *M. nervosa* seedlings total were identified out of 120 plots, representing less than 1% of the seed applied to the plots (50/plot; 6000 seed total). Even with the paucity of germination there was significantly greater germination with the litter+inoculum treatment than the control. While other differences were not statistically significant, trend-wise more *M. nervosa* germinants were found with mulched treatments on average than unmulched treatments (see Figure 4)

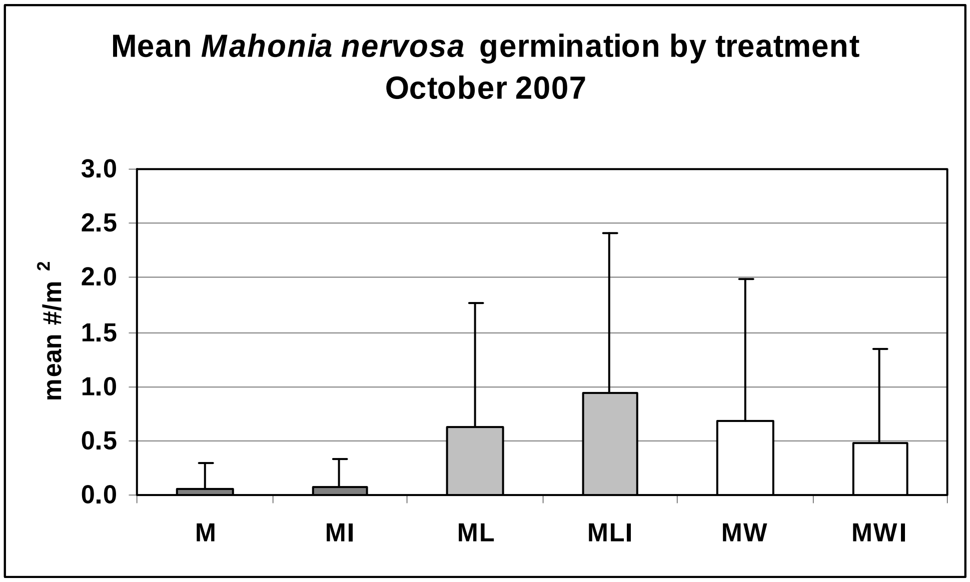


Figure 4: Mean *M. nervosa* germination October 2007 by treatment MLI>M; p=0.035; error bars = standard deviation

Over 90% of all germinants recruited from seed rain were *A. rubra* which commonly dominates early succession plant communities in low-elevation riparian zones where bare mineral substrate lies above high water during seasonal flooding. Given the profusion of *A. rubra* in the experimental plots (2657 total) it would be expected that mean recruitment between treatments would be significant, if found. However due to high variability in the data there were no significant differences between treatments even though unmulched treatments recruited 2X more *A. rubra* on average than either of the mulched treatments (see Figure 5). Anecdotally this may be due to the exposure of patches of bare soil in mulched treatment plots after snow and rain events. Indeed, *A. rubra* seedlings, when found in the mulched treatments, almost exclusively were found in these exposed patches.

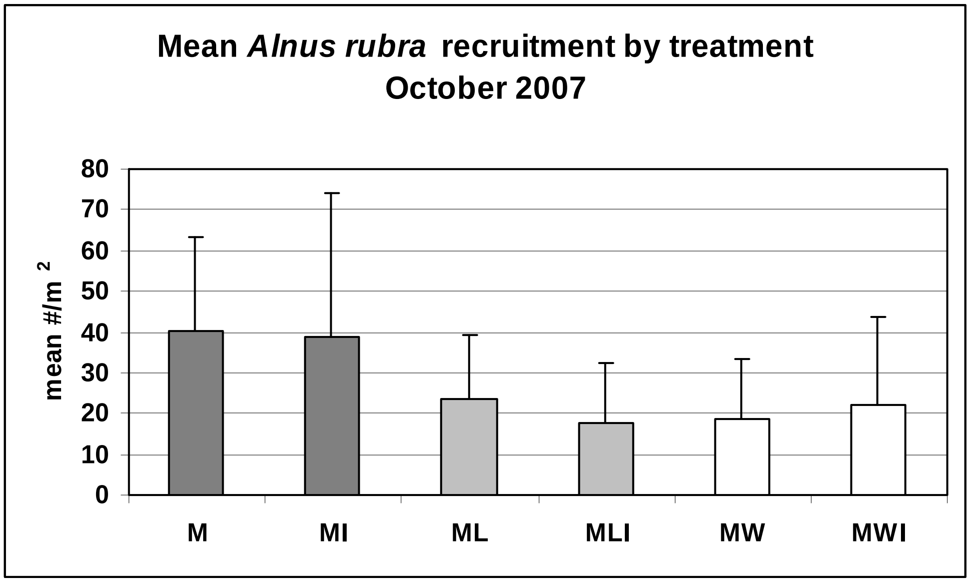


Figure 5: Mean A. rubra recruitment October 2007 by treatment No significant difference between treatments; error bars = standard deviation

After *A. rubra*, *P. balsamifera* and *B. papyrifera* were, however distantly, the most prevalent deciduous riparian canopy species recruited (26 and 39 total, respectively). While there were no substantive differences in recruitment between treatments for either species the control treatment on average had more germinants for both species than other treatments. For *B. papyrifera* there was also a greater germination response for both litter treatments than for inoculum alone and the woodchip treatments (see Figure 6).

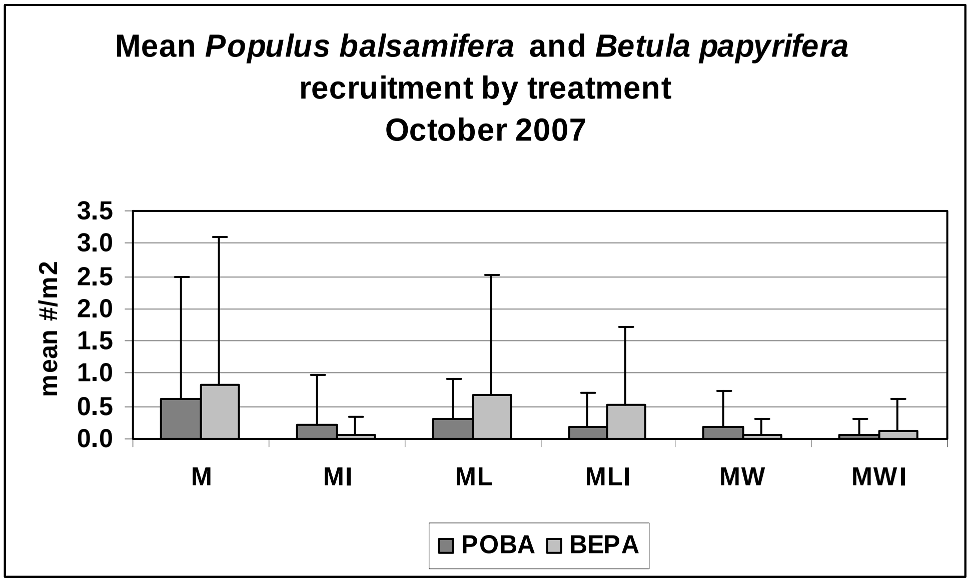


Figure 6: Mean P. balsamifera and B. papyrifera recruitment October 2007 by treatment - No significant difference between treatments; error bars = standard deviation

As previously noted, the litter treatment introduced *T. plicata* and *T. heterophylla* seed cones to the site while the immediately surrounding canopy lacks these species. These species were grouped for analysis for this reason and that they are shade tolerant confiers who can germinate successfully under partial canopy. It should be noted that almost 90% of these were *T. heterophylla. P. menziesii* is the dominant conifer found on site with *P. contorta* frequently interspersed especially upslope of the experimental site. These two species are also generally shade intolerant and were also grouped together for these reasons. In both cases the assumption behind the grouping is that the treatment preferences, if any, would be similar.

T. plicata and *T. heterophylla* recruitment, no surprise, was the strongest in the litter treatments. While this says nothing about how these would have responded to the other treatments it does offer evidence that forest litterfall collected and distributed on a denuded site can also successfully introduce these species. *P. menziesii* and *P. contorta* interestingly displayed a more or less equal preference for all the treatments though the total numbers recruited were low; 19 and 16 respectively (see Figure 7). These species germinate preferentially on exposed or thinly littered mineral substrate. *P. contorta* especially is adapted to germinating on post-fire exposed substrates.

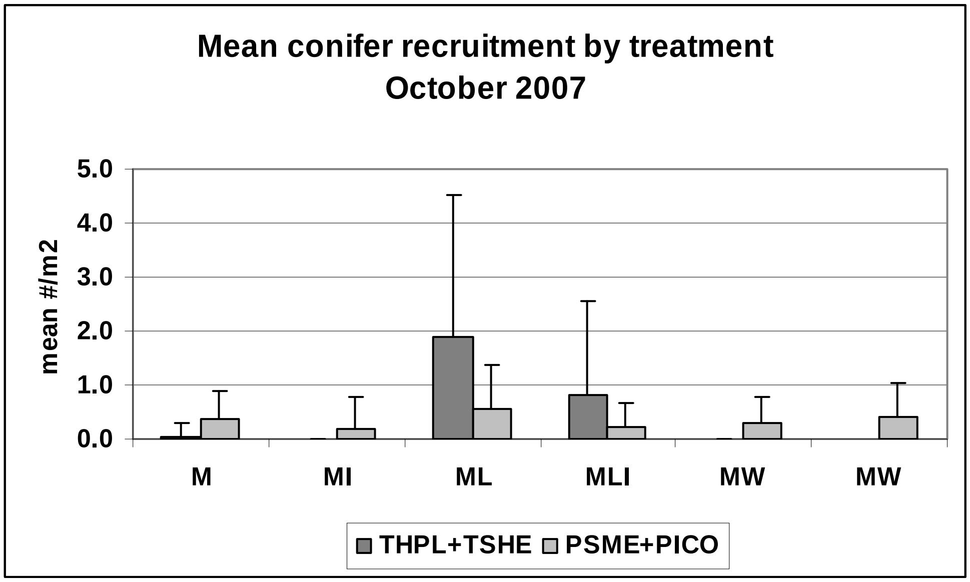


Figure 7: Mean conifer recruitment October 2007 by treatment THPL+TSHE; ML>M, MI, MW, MWI; p=0.001 error bars = standard deviation

Discussion and Conclusions

This experiment explored simple low investment techniques for promoting revegetation of denuded sites in wilderness areas by asking two questions:

Does applying mulch promote recruitment of native groundcover species over bare mineral soil (H_1)?

Yes, for one of the two understory groundcover species evaluated, *M. nervosa*, which showed a clear preference for litter+inoculum treatment over bare mineral soil. This indicates that in denuded areas where appropriate that *M. nervosa* can be seeded and covered in litter to accelerate groundcover recovery under mature canopy. This technique may be a more attractive option where transport of potted *M. nervosa* is impractical. While not studied here other understory shrub species common in the riparian zones of North Cascades National Park such as *R. gymnocarpa*, *A. alnifolia*, *V. parvifolium*, Douglas maple (*Acer glabrum*), vine maple (*Acer circinatum*), and other *Vaccinium* spp. may also successfully recruit from seed with improved microsite conditions via mulching and de-compaction.

Do canopy species available in the matrix show preferences for the treatment substrates (H_2)?

Yes, this experiment demonstrated certain riparian forest canopy species have differential germination response to the treatments offered. However these differences in germination were largely unsubstantiated statistically. With over 90% of germinants recruited being *A. rubra* it is inappropriate to make generalizations regarding recruitment overall however it was shown that *A. rubra* tends to prefer bare mineral sustrate as do the deciduous riparian canopy species *P. balsamifera* and *B. papyrifera*. Of the conifer species recruited *T. plicata* and *T. heterophylla* were introduced via the litter treatment and not recruited from the local seed rain. Both species, primarily *T. heterophylla*, were successfully recruited in the litter treatments which demonstrate that using collected forest litterfall on denuded soils can be an effective method of introducing and promoting forest canopy regeneration. The other two conifer species recruited, P. menziesii and P. contorta, were components of the local seed rain. Neither species showed a clear preference for any of the treatments though the number of germinants recruited was quite low.

Beyond the individual species preferences for the experimental treatments offered, is there any indication from the results that plant community composition can be selected or directed through manipulation of substrate? While not conclusive, it would seem that coniferous species may be recruited preferentially using forest litter simply through seed introduction while deciduous riparian species can be favored via leaving exposed mineral soil bare.

Post-recruitment however the selective dynamic shifts towards level of available light. While certain species such as *A. rubra* germinate preferentially on bare mineral substrates if this occurs under partial or full canopy the likelihood is that shade intolerant species such as *A. rubra* will not reach maturity. It would also be the case that shade tolerant species such as *T. heterophylla* which is also shade dependent in the seedling stage may germinate under full sun but not survive beyond germination and early seedling stage. Surface treatments therefore should be used strategically to favor species adapted to ambient light and moisture conditions in their seedling establishment phase.

Management Recommendations for Experimental Site

The three blocks that comprised the experimental site are in highly visible areas of the ELC. They stand out from the rest of the ELC landscape that was restored with dense plantings of native understory shrubs and trees. The experiment as it was designed can not be continued now that forest litter from the surrounding matrix is accumulating on the experimental plots. With experiment concluded it is recommended these sites be revegetated with site appropriate species. Three potential strategies for revegetating these sites are:

(1) There is educational potential in allowing the sites to revegetate through recruitment demonstrating how ecosystem self-repair moves through successional stages and varies with site conditions. While stressed by compacted soil conditions and deer grazing the installed *G. shallon* and *M. nervosa* will over time fill in spaces among the recruited species. Bryophytes will also undoubtedly gain a stronger presence as spores disperse and litterfall creates more favorable conditions. However during this mostly unassisted recovery the sites will look bare compared to the adjacent restoration and intact forest.

(2) The experimental sites could also be planted in a manner similar to the restored areas of the ELC. The soils however are rocky and very compacted. Planting would be challenging but not impossible however the installed plants may establish slowly. The mixture of understory shrubs and trees utilized throughout the ELC restoration would be appropriate for these sites.

(3) Assist natural recruitment by augmenting and visually ‘softening’ the sites with additional litterfall, downed woody debris such as branches and limbs, and large rocks.

These would serve to ‘anneal’ the sites into the surrounding matrix both aesthetically and ecologically, creating more structural complexity and hence more microsites for recruitment. These sites would still serve an educational purpose distinct from the surrounding forest matrix and restored landscape area by demonstrating that restoration encompasses a continuum of approaches that include the introduction of structural complexity as well as plant installation.

If possible a hybrid of all three approaches would likely achieve desirable results. Installing structural features with selective planting to augment natural recruitment would create an ‘instantaneous’ aesthetically pleasing naturalistic appearance that would also accelerate desired ecological functions such as habitat, primary productivity, and soil retention. Regardless of the strategy chosen, a detailed revegetation plan will be created and be implemented using volunteers recruited by the primary investigator, if desired by North Cascades National Park.