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Sehome Hill Arboretum Trail Decommissioning Follow Up

Calvin Heslop
Western Washington University

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WWU Honors Senior Project
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Introduction

Maintaining accessible trail networks for recreation and travel is an important part of management in the Sehome Hill Arboretum in Bellingham Washington. Trails aid in bringing people into the arboretum so they can appreciate and enjoy what it has to offer. Additionally trails serve the purpose of limiting human impact to known and maintained areas. Unofficial "social" trails can be detrimental to both the accessibility and ecological function of the Arboretum. By adding to the existing trail network, these social trails can confuse park visitors as well as decrease the aesthetic value of the arboretum. Additionally, repeated traffic by hikers can compact soil, trample plants, and disturb wildlife (Sun and Liddle, 1993, Wilson and Seney, 1994). Due to these impacts, the Sehome Hill Arboretum Board, which manages the park, has attempted to limit the existence and impacts of social trails.

The process of closing, removing, and/or restoring a trail is known as trail decommissioning. Through trail decommissioning, the negative consequences of a trail system can be reduced. Foot traffic can be directed to maintained areas that can be monitored effectively by land managers. Trail decommissioning can reduce harmful trampling of plant life as well as reduce soil compaction and erosion by hikers. Additionally, the general aesthetic value of an area can be improved by creating a less trafficked look, as well as preventing the confusion of hikers. The Sehome Hill Arboretum has both an extensive official and social trail network. Decommissioning and restoring a problem social trail in this area would help to alleviate its negative impacts.

Unfortunately follow up studies for restoration work rarely take place. Agencies and managers like to see their money go towards executing restoration projects themselves rather than determining if the project in fact met it's goals. Some studies have found that much more rigorous post assessment is needed in order to determine if some restoration projects are in fact making a positive contribution (Roni et al. 2003). Additionally, post assessment may need to be specifically designed around the target organisms and their life histories (Reeves et al. 1991). In many cases funding can not even be provided for post assessment of a restoration project (SRFB, 2014). In the case of student restoration projects completed by students in ESCI 470, their projects are often left without subsequent evaluation of success due to limited time and financial resources available. The opportunity to do follow up work on one of these restoration projects will give insight into the effectiveness of restoration methods as well as help to determine an appropriate temporal scale for post assessment of this type of project.

During September of 2015 four classmates and I planned and executed a decommissioning and restoration project of a social trail in the Sehome Hill Arboretum. The social trail we decommissioned is immediately adjacent to the north Fairhaven entrance to the Hontoon Trail (Figure 1). The trail connects the Hontoon Trail to another social trail that then connects to the Douglas Fir Trail. The social trail's entrance is partially obscured where it connects to the Hontoon Trail but very obvious where it meets the upper social trail. We suspected that many users enter from the top before realizing the trail is unofficial. The trail is approximately 90 meters long and about a meter wide. The trail has a maximum slope of about 39° with evident erosion on the steep portions (Allen et al. 2015).

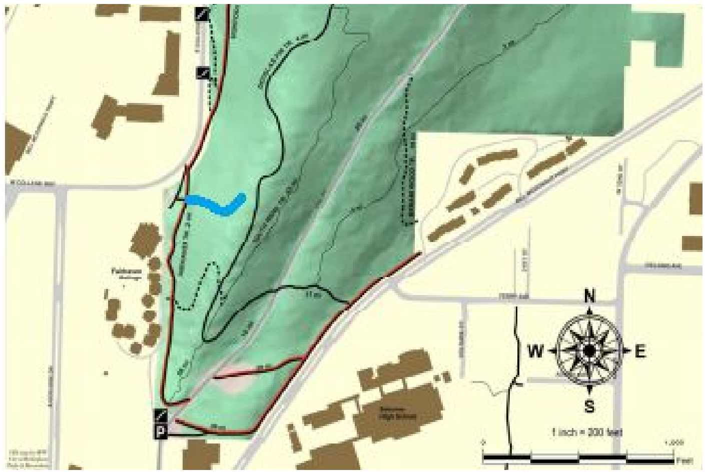

Figure 1. The southern portion of Sehome Arboretum in Bellingham, WA. The blue line represents the approximate location of the social trail.

The main goals of the project were to reduce foot traffic and increase native plant cover. We developed four quantifiable and two qualitative objectives. Our first objective was to reduce human trail use by at least 75 percent. Any restoration action taken on the trail will quickly become useless if people are continuing to use it. We assumed it would be unlikely to eliminate all traffic, but did expect to make a significant impact through our restoration actions. Our second objective was to reduce bare ground by 80 percent. Reducing bare ground serves as a form of camouflage that can aid in preventing trail use as well as increase the natural aesthetic of the site. It was also our goal to increase native plant cover by 50 percent. We expected this to be the most important objective, as it could contribute the most to the positive feedback of restoration through natural ecosystem processes. Increased cover keeps the people off which in turn helps the plants recover. Our final quantifiable objective was to reduce surface water runoff by at least 75 percent. Given that our site is very steep and the soil compacted, the social trail can become like a stream under heavy rainfall events. This had several adverse impacts. The increased frequency of disturbance events could inhibit the growth of native plants, which then increases bare ground, thus limiting the benefits of restoration (Allen et al. 2015).

We expected to improve the conditions overall by making the site better habitat for native plants and enhancing the natural aesthetic. We hoped that over time this degraded section of the forest can become a part of the Sehome Hill Arboretum's healthy ecosystem.

As part of our restoration work, we placed check dams on all the trail's steepest slopes at intervals of 1-3 meters. We installed a total of 9 check dams on the bottom half of the trail (Figure 2). Exact locations were chosen based on a visual assessment of erosional damage and slope steepness. The check dams were made from small logs ranging from 0.4-0.6 meters in length held in place with two wooden stakes. The purpose of the check dams was help to anchor soil on steep slopes by acting as catches for loose soil falling down the hill (PCTA, 2011). They were also intended to help divert the flow of water onto the sides of the trail and and slow the flow velocity (PCTA, 2011 and Metropolitan, 2000). By reducing surface runoff and erosion, we hoped to create a stable sloped habitat that is more suitable for native plants (Allen et al. 2015).

We also planted sword ferns (*Polystichum munitum*) along the trail with a density of approximately 1 fern every 1-3 meters (except in the upper section) for a combined total of 17 ferns (Figure 2). The ferns were intended to help anchor soil, contribute to soil decompaction, and camouflage the trail. We transplanted *P. munitum* from secluded and non-degraded areas of the Sehome Arboretum. We planted a single Western Red Cedar (*Thuja plicata)* sapling in the midsection of the trail. We also planted six Nootka roses (*Rosa nutkana)* were transplanted along the top 20 meters of the trail (Figure 2)(Allen et al. 2015).

Lastly, we covered the entire trail with leaf litter, needles, and woody debris in order to reduce bare ground, increase water retention, and to further conceal the trail. We brought in large fallen branches and several small moss-covered logs from elsewhere in the arboretum. We completed restoration in two days over the course of a week (Allen et al. 2015).

We used a $1m^2$ Daubenmire frame to estimate ground cover along the trail (Bureau of Land Management, 1996). We divided the trail into nine 10 meter sections and then used a random number generator to determine the placement of the frame within each of those sections. This gave us a total of 9 sampling locations that were randomly generated but fairly evenly spaced along the trail. We estimated ground cover before and after we implemented our restoration actions (Allen et al. 2015).

To assess surface water runoff volume we recreated a natural level of precipitation on one section of our trail and measured the volume of runoff one meter downslope. We selected this one meter section due to the steepness of the slope and the high level of erosion on that part of our trail. The sampling area was 20 meters from the bottom of the trail and was the area that we expected runoff to present the greatest threat. The average slope at this spot was 37°. We only measured runoff after a rain event. At the end of the one meter section we used a 34 cm by 24 cm metal pan as a catch basin to collect the runoff. We poured one liter of water at the top of the one meter section for 17 seconds, then waited another 30 seconds for the runoff to collect. We then removed the catch basin and measured the volume of water it had collected. We measured runoff both before and after we implemented our restoration actions (Allen et al. 2015).

In order to estimate the number of trail users, we hung a voluntary survey in the middle of our trail using a clip board with an attached pencil. We used an arbitrary question, unrelated to our restoration work, to encourage random and unbiased counts, and we marked a few tallies in each column to encourage others to make their mark (these preliminary marks were not later counted). We hung survey sheet approximately 15 meters from the bottom of the trail, on a tree facing up the trail so that the survey was not clearly visible from the top or the bottom of the trail. After posting the survey we returned every few days to check the tally results. We posted a survey before and after restoration. Each survey was in place for a period of 11 days (Allen et al. 2015).

In order to assess whether our actions had the desired impacts, we used the same methods for measuring percent cover and surface water runoff at an undegraded reference site both before and after restoration. The reference site was 3 meters north (left, if facing up the slope) of our trail. The site was comparable to the trail site in sunlight, precipitation, aspect, and slope. The site was also visually representative of the contiguous forest surrounding the trail. Sampling points on the reference site were paired with the randomly generated sampling points on the trail. For surface runoff, the reference site location for data collection was also paired with the location of the surface runoff site on our trail (20 meters from the bottom). The average slope at this location was 32°, which was slightly less than the trail at 37°. Trail use was only measured on the trail and not at the reference site (Allen et al. 2015).

The purpose of this report is to act as a follow up to that study to determine the effectiveness and condition of the restoration after 5 months have passed. In this report I will use data from the previous study as well as new data collected the spring after restoration. I will refer to data collected during the previous study as “before” and “after”. “Before” refers to baseline data taken before restoration took place. “After” refers to data collected immediately following the implementation of the restoration actions. Data described as “spring” is data that I collected for this post assessment report. All spring data was collected in late April and early May 2016. Approximately five months passed since the project started and the “spring” data was collected. These five months were the winter season which in Western Washington is cool and very wet.

Methods

I collected measurements of ground cover following the same methods as described above. In our previous study, there was some inconsistency about what counted as bare ground versus organic matter, so for this study I lumped those into the same category. I also went back and combined these two categories in the previous two sampling periods in order to make all of the data directly comparable. Ground cover data were compared using a split plot multiples measures ANOVA for each ground cover type. Pairwise comparisons were done by comparing calculated 95% confidence intervals for each mean to determine if they overlap. We cannot say with confidence that means with overlapping confidence intervals are statistically different. Means with non overlapping intervals were considered to be different.

I conducted runoff measurements in the same area and using the same methods as the before and after data was collected. Due to the drier weather in the spring, the soil was visually less saturated than in the fall, despite conducting the measurements after a rain event and moistening the slope prior to measuring. Because of this I had to be moisten the soil with three liters of water before I began to record consistent measurements. Runoff data was compared using a multiple measures one-way ANOVA and subsequent Bonferroni corrected pairwise comparison.

To measure the numbers of trail users I repeated the voluntary tally method that we had employed previously. I placed a clipboard with a survey question in the same location and waited the same 11 day interval. In addition to the repeated measurements from the previous study, I also did a visual survey to assess survivorship and vigor of the transplanted plants as well as the effectiveness of the check dams. Using the map of the trail (Figure 2) I located each transplanted plant and visually assessed if it was alive and how well it appeared to be doing. I also visually assessed each of the check dams and noted any damage.

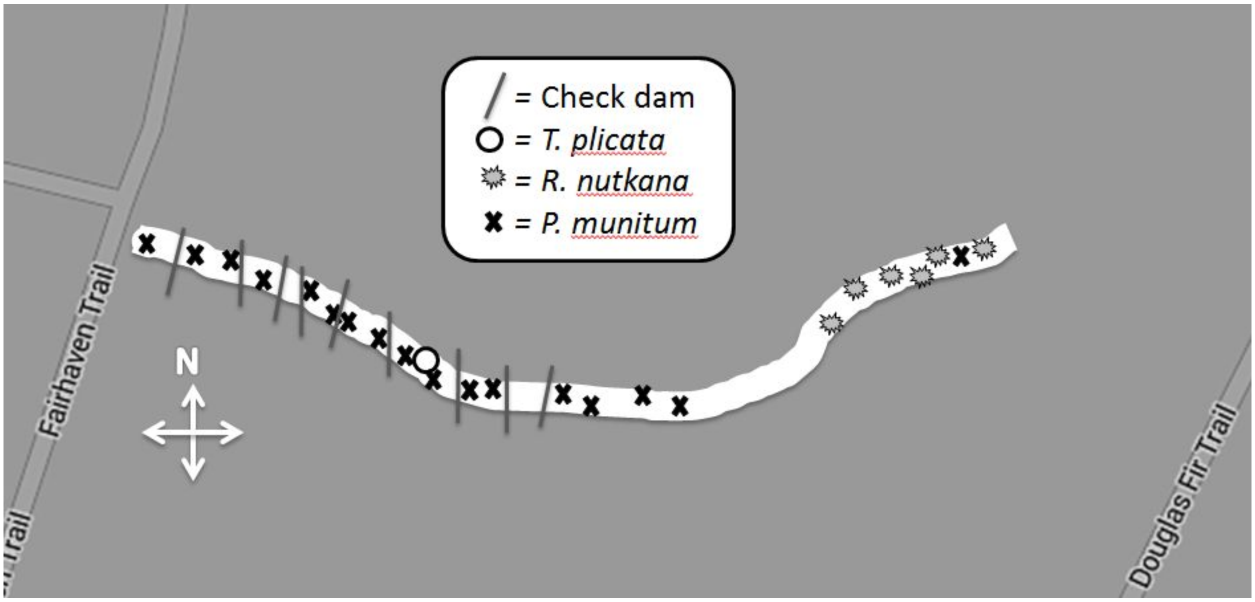

Figure 2. A map identifying the general placement of the check dams, *Thuja plicata, Rosa nutkana,* and *Polystichum munitum* at the restoration site.

Results

I found native plant cover changed from 21.1% before restoration to 32.9% after and to 36.1% in the spring. Over the entire time period this represents a net gain of 15% native cover. Before restoration no non-native plants were found. After restoration 2.4% of the cover was found to be non-native which changed to 0.2% in the spring. This represents a net increase of 0.2% non-native cover over the course of the whole study. Bare/organic cover changed from 78.9% before to 64.7% after and then to 63.7% in the spring. This represents a decrease in mean bare/organic cover of 15.6% over the course of the study. (Table 1).

Table 1. Mean and change values for each ground cover type. Reference site values are not included. Change values listed on top are change between before and after followed by after and spring. Change values listed in the bottom row are changes between before and spring.

<table>
<tr><th></th><th colspan="6">Native (%)</th><th colspan="6">Non-Native (%)</th><th colspan="6">Bare/Organic (%)</th></tr>
<tr><th></th><th colspan="2">Before</th><th colspan="2">After</th><th colspan="2">Spring</th><th colspan="2">Before</th><th colspan="2">After</th><th colspan="2">Spring</th><th colspan="2">Before</th><th colspan="2">After</th><th colspan="2">Spring</th></tr>
<tr><th>Mean</th><td colspan="2">21.1</td><td colspan="2">32.9</td><td colspan="2">36.1</td><td colspan="2">0.0</td><td colspan="2">2.4</td><td colspan="2">0.2</td><td colspan="2">78.9</td><td colspan="2">64.7</td><td colspan="2">63.7</td></tr>
<tr><th rowspan="2">Change</th><td colspan="3">11.8</td><td colspan="3">3.2</td><td colspan="3">2.4</td><td colspan="3">-2.2</td><td colspan="3">-14.2</td><td colspan="3">-1.0</td></tr>
<tr><td colspan="6">15</td><td colspan="6">0.2</td><td colspan="6">-15.2</td></tr>
</table>

Native plant cover on both the trail and the reference site increased the spring after restoration. The trail and the reference site were statistically different before and not statistically different after restoration. In the spring, the trail differed significantly from the reference site (split plot ANOVA, $p<0.05$). The difference in non-native cover between the trail and reference site was indistinguishable at all time periods and remained very low with a wide confidence interval (split plot ANOVA, $p>0.1$). Bare ground/organic was higher on the trail than at the reference site before restoration but indistinguishable after restoration. The spring after restoration, the reference site lost more bare ground with native plant cover than the trail, resulting in the trail having more bare ground (split plot ANOVA, $p<0.05$; Figure 3).

After each time interval, runoff decreased by a statistically significant margin. Runoff from the trail was decreased by 76.5% after restoration (multiple measures ANOVA $p<0.01$, Tukey HSD $p<0.01$; Table 2). The spring after restoration, trail runoff was 87.7% lower than the baseline value (Tukey HSD, $p<0.01$) and 47.4% lower than after restoration (Tukey HSD, $p<0.01$; Figure 4; Table 2).

In the spring, the number of trail users declined by 100% from pre-restoration levels (from 11 to 0). After restoration the number of trail users had declined by 73% from before restoration (from 11 to 3 users; Table 2). No trail users were recorded during the spring sampling period. Due to the qualitative nature of the method used to record trail use, no formal statistical testing could be performed on these measurements.

Visual inspection in the spring showed that all of the transplanted plants had survived. All of the sword ferns (*Polystichum munitum*) had survived transplanting and the winter. Fourteen (82%) of the sword ferns appeared to be quite healthy (>80% green) and had produced new growth. All six of the Nootka roses (*Rosa nutkana)* were found alive and had produced new growth. The single western red cedar (*Thuja plicata)* was alive but did not show signs of new growth and did not appear healthy. I did not observe natural colonization of plants on the trail, but I did see a number of trailing blackberry (*Rubus ursinus*) vines crossing the trail. Also, adjacent sword ferns had begun to grow over the margins of the trail. All of the check dams were still in place, but one showed signs of deterioration, likely from preexisting rot or possibly from trail traffic.

Table 2. Mean and percent change values for runoff and the number of trail users. Reference site values are not included. Change values listed on top are change between before and after followed by after and spring. Change values listed underneath are change between before and spring. Values marked with an * were found to be statistically different.

	Runoff (L)			Number of Users		
	Before	After	Spring	Before	After	Spring
Mean	0.81	0.19	0.10	11	3	0
Percent Change	-76.5%*	-47.4%*		-72.7%	-100%	
	-87.7%*			-100%		

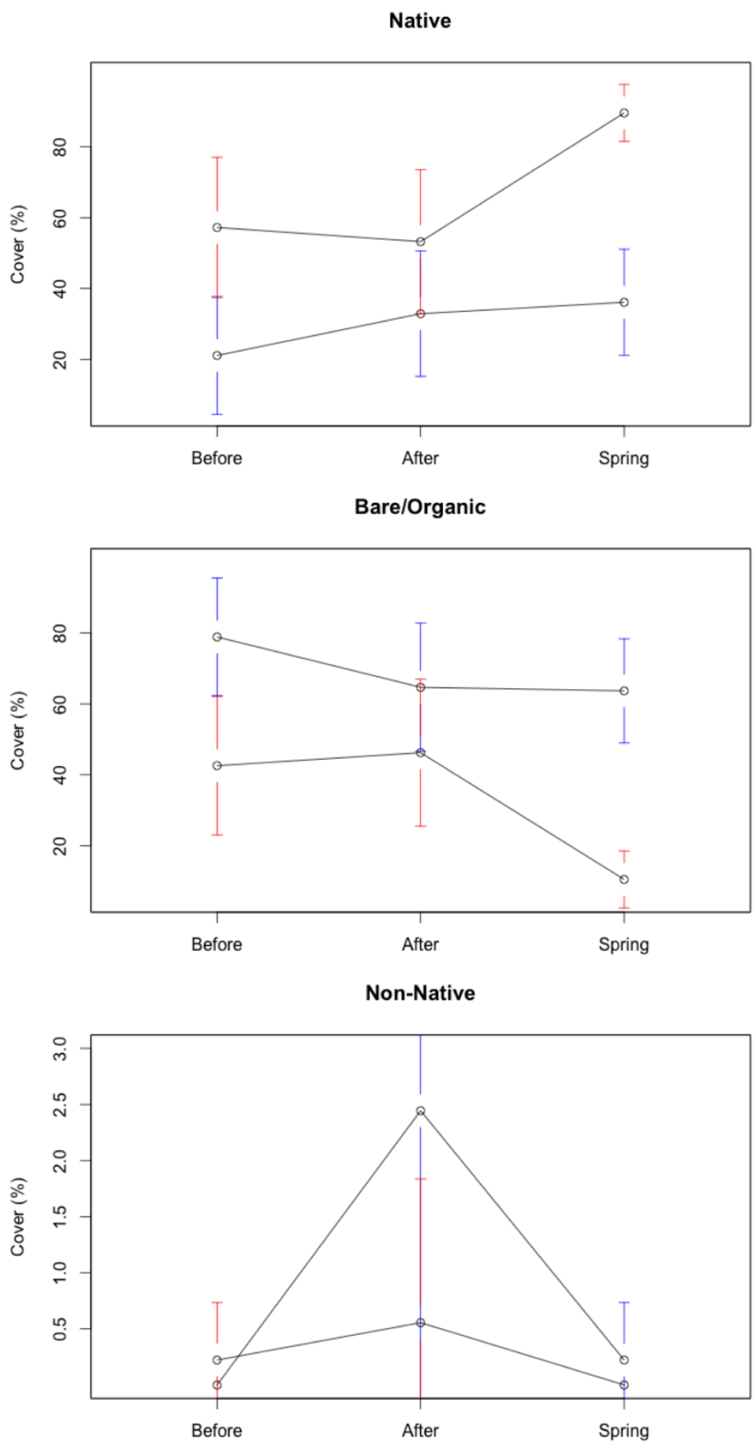

Figure 3. Interaction plots showing the relationship between the trail (blue) and reference site (red) over time for each ground cover type (native, bare/organic, and non-native). Whiskers represent 95% confidence intervals. Values with overlapping confidence intervals are likely not significantly different. Note the change in scale for the non-native plot.

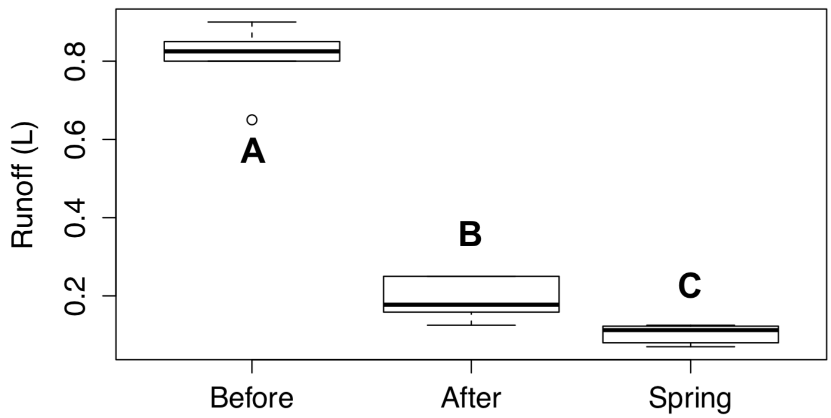

Figure 4. Box plots of trail runoff in liters before, immediately after, and the spring following restoration. Different bolded letters represent statistically significant differences ($p<0.05$) (single factor multiple measures ANOVA, Tukey HS

Discussion

After five months, our goal of increasing mean native plant cover by 50% has in a sense been met. Given our restoration actions and visual observation, it is obvious that native plant cover has increased compared to baseline measurements. However, as we did not transplant plants over the entire course of the trail, these plant free areas are likely creating the wide variation in native plant measurements. This high level of variation, in conjunction with limited statistical power is likely the reason our results were not statistically significant, despite an apparent increase in native plant cover.

When comparing native plant cover on the trail to the reference site we observed that the trail had statistically less native plant cover before restoration. The confidence intervals for these means do not overlap which makes us confident they are different. Immediately after restoration the two sites were no longer different from one another. As we concluded in the previous paper, this suggested that we had succeeded in making the trail more similar to undisturbed forest understory. However, measurements the spring following restoration once again showed the trail to have significantly less native plant cover than the reference site. This result suggests that the site may in fact be much more different than the reference site than we previously concluded, despite restoration efforts. Native plant cover at the reference site increased dramatically in the spring. A modest but non-significant increase also occurred on the trail. The larger increase observed at the reference site suggests that the increase on the trail was due to a mechanism other than our restoration actions (Figure 3). This mechanism is likely new growth associated with the transition to spring conditions. The higher native plant cover in the spring is likely due to spring growth rather than an increase in the number of plants. Visual observation confirmed that natural colonization by native plants has not occurred to a large extent but new spring growth is the main contributor to increased coverage. The fact that such a small increase occurred on the trail may actually suggest the trail is stunted and growing less vigorously than the rest of the understory. The decreased vigor could be due to stress from being transplanted, competition for adjacent naturally growing plants, and/or the compacted soil on the trail site. In order to account for the increased seasonal growth, data would have to be collected over the entire year and likely for multiple years. With a longer time frame, fluctuations in cover due to seasonal variability could be differentiated from changes due to restoration.

A very similar result was obtained for bare ground/organic matter measurements. Immediately after restoration a significant difference in bare ground cover in the trail, compared to the baseline, was not observed. No significant difference was observed the spring following restoration either (Figure 3). Although the mean values have been continuously decreasing with time the large overlap in confidence intervals does not give us confidence to suggest they are significantly different (Table 1, Figure 3). Before restoration, the trail had significantly more bare ground and organic matter than the reference site. Immediately following restoration the two sites do not appear to be significantly different as they have large overlap in their 95% confidence intervals. The spring following restoration, the trail returns to having significantly higher levels of bare and organic matter than the reference site (Figure 3). Due to the extremely low values for non-native cover, what is not native therefore must be bare or organic matter. As a result these two measurements behave as inverses of the other. As native cover increases due to spring growth, so must bar and organic matter decreases proportionally. The reference site experienced a larger decline in organic matter than the trail suggesting that any small change at the trail is due to increased spring growth rather than restoration actions. Due to the small and insignificant change in bare ground cover for each time interval, we did not meet our objective of reducing bare ground by 80%.

I did not measure any change in non-native plant cover for neither the trail nor reference site. For all time periods and sites the percent cover of non-native plants we very low. In most measurements no non-native plants were found at all. Because of this I was not able to determine any statistical difference between groups. The visual observation indicated that there are very few non-native plants at either site. During the course of conducting the study I did observe a number of non-native English holly (*Ilex aquifolium*) plants spread in the area. While their density was too low to be detected in this study, non-native plants are present in the area. The removal of non-native species was not part of this restoration effort but given that many non-natives are known to colonize disturbed and recently restored areas, this site should continue to be monitored to ensure colonization of non-native plants does not occur.

The 100% survival rate of the transplanted plants greatly exceeded our expectations. Nearly all of the sword ferns were growing vigorously and had produced new growth. If trail traffic stays at its current low levels this new growth will be able to expand and increase cover as well as cover up the trail. The Nootka roses were also healthy and growing. These had been placed at the entrances to one end of the trail in order to discourage traffic. Once they grow wider and taller they will fulfill this purpose excellently. Based on these results it appears sword fern and Nootka rose are both robust to transplanting and would be recommended for this purpose in western Washington. The single western red cedar while still alive seems unlikely to survive to maturity without assistance, perhaps with watering. In general, the high survivorship and vigor suggest that our transplanting was successful. With time I predict these species will grow larger and continue to naturally restore the trail without further human intervention.

Since restoration, I have measured a continuous decline in runoff levels. Immediately after restoration we had achieved our goal of reducing runoff by 75%. The following spring this goal was exceeded with a reduction in runoff of 87.7% of the pre-restoration level. While the runoff levels are still declining it appears that the rate of decline has been decreasing. This result indicates that our restoration actions had a significant effect in decreasing runoff. The continued but slow decline after restoration is likely due to the slow accumulation of detritus. There was noticeable accumulation of sticks and fallen leaves throughout the length of the trail. I predict that this will continue as a natural humus layer forms over the old compacted trail surface. The accumulation of fallen plant material has the added benefit of aiding in the camouflage of the trail so people are not tempted to walk over the restored area.

I observed a large decline in trail users over the course of the study. Our original goal was to reduce the number of trail users by 75%. While we did not achieve this goal immediately after restoration, it appears that we now have exceeded that goal. While no users were recorded that does not mean there was no traffic on the restored trail. There was evidence of depressed organic matter that appeared to be from foot traffic, though there is no way to confirm this. Also, over the course of completing this follow-up study myself and those assisting me had to walk along the trail. While we tried to do as little damage as possible, we certainly had at least a small impact. Additionally, in our efforts to not walk in the restoration site, we attempted to access the site from the sides. This had the unintended effect of creating faint paths adjacent to the trail that could attract people to walk up the slope and thus create a new trail. Continued monitoring is needed to prevent the creation of new social trail in the vicinity of the restoration site.

Increased growth by plant matter, accumulation of detritus, and the reduction in foot traffic can generate a positive feedback loop that can aid in restoration. A reduction in foot traffic can allow for plants to grow more vigorously which can in turn more discourage foot traffic. Increased plant growth will also allow for accelerated accumulation of detritus and coarse woody debris. This material can disguise the trail and once again discourage use. This positive feedback could in theory make trail decommissioning rather easy. The issue is if people can actually be kept off. Human traffic reduces growth and makes a clearer path which encourages more traffic. In order to be successful at restoring a trail foot traffic must be limited enough to allow the recovery feedback to take over.

Despite few instances of statistically significant change, I believe our restoration project was a success. We were able to definitively accomplish two of our four quantitative goals. We reduced trail use by over 75% and we decreased runoff by over 75% as well. In a sense we met the goal of increasing native plant cover by 50% but we lack the statistical power to know for sure. We did not even come close to reducing bare ground by 80%. I predict that without additional restoration, this goal will not be met for a number of years. Our two qualitative goals were to make the trial better habitat for native plants and to enhance the natural aesthetic of the area. In terms of plant habitat the restoration site is much better than a trail. Plants at the site are now largely protected from trampling and the site is more similar to contiguous understory. However the soil remains compacted and a humus layer is a long way from developing. Much more time is needed for the soil to recover and for plant roots to break up the hardened soil. In term of aesthetic I believe that we accomplished our goal. The former trail is well hidden even months after restoration. The site is hardly different, visually, from the understory around it. If a passerby did not know there was once a trail there, they would be hard pressed to discover it .

While we were able to accomplish most of the original project goals after five months, there is still quite a bit of change that must occur before the site could be considered fully restored. If the site was fully restored I would expect it to be indistinguishable from the reference site. A complete year of data is needed in order to distinguish any seasonal effects on plant growth. *P. munitum* can regenerate each spring even if its fronds have been killed (Zouhar. 2015). With this in mind I would predict that spring regeneration at the trail should be similar to the reference site only after another year or two, if trampling can be prevented. However, natural reproduction of firms may take more time at this site. The gametophyte stage of *P. munitum* requires moist soils in order to germinate from spores (Zouhar. 2015). Given that much of the trail surface is still compacted mineral soil, it is unlikely ferns will naturally colonize the area immediately. Studies of *P. munitum* recolonization following logging disturbances have found populations to experience most growth 4 to 5 years after disturbance depending on shade and moisture availability (Zouhar. 2015). Given that our site is much less disturbed and has comparatively favorable conditions I would predict recolonization of ferns to occur within a shorter period of time. During the study I observed bare ground to slowly decline but is not yet comparable to the reference site. As ferns and other plants grow and recolonize over the next couple of years, I expect to see a proportional decline in bare ground. I expect similar results with runoff levels. With a few seasons of growth more organic matter should cover the trail and continue to decrease runoff. Continued monitoring is needed in order to determine the time frame for monitoring this type of restoration. Continued monitoring would allow us to determine how growth responds with the seasons as well as track the progress of the site until complete restoration.

Given the different rates of response for each variable it appears no one sampling regime is appropriate in every case. Trail use may decline rapidly while runoff experiences a slow decline, as was the case here. In the case of plant cover, seasonal effects may be an important factor and growth could vary from year to year. Additionally project goals may appear to have not been met at one time of the year but accomplished in others. With this in mind, the post assessment regime for any given project must be tailored to the specific project goals and measured responses. In the case of this study, continued monitoring and of plant cover is needed in order to determine if restoration goals have been accomplished, while monitoring of the other variables will shed light on the duration of recovery. With a more complete picture of the entire restoration process, we can better evaluate success and improve restoration methods in future projects.

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