Rocky Mountain Field Institute Citizen Science Report

Niobrara Trail Restoration in the Garden of the Gods

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The Rocky Mountain Field Institute (RMFI) Citizen Science Program (herein referred to as the "Program") provides a sustainable system for monitoring land stewardship and restoration activities by engaging adult volunteers and college students in the measurement of ecological parameters in RMFI project sites over time. RMFI is the first non-profit organization in the Colorado Springs area to train and engage citizen scientists. The educational model for the Program provides an innovative case study for other organizations and agencies interested in monitoring natural lands. In the 2017 field season, RMFI citizen scientists were recruited and trained. They collected data on four trails in the Garden of the Gods, Colorado Springs, CO, USA. These measurements are ongoing and this report presents one component of the Program, involving the restoration of the Niobrara trail in the Garden of the Gods park in Colorado Springs, CO.

Niobrara Trail Monitoring Statistics

- 1 monitoring protocol implemented
- 6 days in the field conducting measurements on the Niobrara trail
- 4 trails measured
- 3 adult volunteer citizen scientists trained and monitoring at regular intervals, 2 of whom are UCCS geography students
- 2 partnering entities- Friends of the Garden of the Gods, City of Colorado Springs

Program Development

Review of the Garden of the Gods Community Restoration Program (Byers, Ebersole, & Hesse, 2000a, 2000b) and consultation with the RMFI Board and staff informed the development of the Program objectives. Two main objectives for monitoring arose as central themes. RMFI staff and Board are particularly concerned with 1) subsurface structure implementation and its effect over time, and with 2) the efficacy of social trail closure efforts. This report addresses the efficacy of subsurface structure implementation.

Restoration Monitoring Research Questions

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- How does the trail change over time?
- How do slope and aspect relate to trail tread depth and width?
- Do structures slow the rate of change on a trail?
- Is this correlated with slope and aspect?
- Do trail improvements redirect traffic onto the designated trail, thereby reducing vegetation impacts on social trails?

Research Goals

- Create a long-term monitoring data set that records trail depth and width over time in RMFI project areas
- Compare trail depth and width measurements before and after structures are implemented in RMFI restoration projects
- Analyze the effect of slope and aspect on trail dynamics
- Investigate plant recovery on closed social trails

Data Collection Objectives

- Measure the trail tread depth and width over time
- Measure the slope and aspect of trail
- Collect photo point data over time
- Measure vegetative cover and richness on social trails

The subsurface structures implemented by RMFI restoration crews are proprietary structures with no measurement or reporting in the peer-reviewed or grey literature to support their use. Despite their anecdotal success, measurement of trails where this restoration technique is applied are a primary Program objective.

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Figure 1. Andrew and Larry toil over the complex trail measurements. Their insights contributed to the final revisions of the measurements collected. Co-created citizen science increases science literacy outcomes and retention for participants.

Citizen Science Program Training

The Program objectives informed the research questions and goals, and data collection parameters. These, in turn, informed the learning objectives for the citizen scientists. From these learning objectives, pre- and post-training assessments were developed, followed by the instructional materials.

Learning Objectives for Citizen Science Training Initiative

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After completing the RMFI citizen science training, volunteers will be able to:

- Explain how recreational impacts affect trails and their environs
- Define ecology and identify biotic and abiotic factors in a field setting
- Describe the effects of erosion
- Identify erosion on the landscape
- Define slope and aspect and know how to measure it
- Characterize the trail profile using longitudinal, cross-section, and thalweg measurements

- Discuss the ecological differences between native and non-native plant species in an ecosystem
- Identify native and non-native plant species in our project areas
- Collect vegetation data including percent cover and richness using a quadrat method
- Monitor sites with consistent photo documentation using photo points

11 instructional videos address the ecological framework and data collection protocols. Potential citizen scientists take the pre-test (https://goo.gl/forms/yyjmLyJalBNWunni2), watch the videos, and then take the post-test. When they pass the post-test with a score of 80% or higher, volunteers participate in field mentoring until they are ready to collect data on their own. The videos and the powerpoint presentations that support the videos are always available for potential volunteers and future live trainings. The instructional videos are openly published on the RMFI Citizen Science Training playlist at (https://youtu.be/uINdhpwzcIA). As new opportunities arise, seasoned volunteers will promote to leadership and mentor roles, to facilitate the field mentoring of new citizen scientists.

The pre- and post-training components are valuable in reporting the impacts of the training program on “foster[ing] community awareness about the ecology and natural history of the Garden of the Gods Park,” and “educat[ing] the community about the current threats to the park.” These are two of four goals of the RMFI’s Garden of the Gods Community Restoration Program (Byers et al., 2000). The intentionally-planned training Program provides academic-level training to ensure reliable citizen scientist-collected data collection.

Niobrara Trail Characterization

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ENTER TRAIL SPECS> HISTORY>GEOLOGY

The Niobrara trail meets the Ute trail in the central valley of the Garden of the Gods, at the southern end of the historic dam above Rock Ledge Ranch. The first 400 feet of the Niobrara

Trail are steep switchbacks that gain the Niobrara Ridge. This section of trail is the focus of the citizen science monitoring efforts. The Niobrara Ridge is a north-south oriented geologic formation that the Niobrara trail follows to its end at the southern reservoir and dam, on the southern border of the Garden of the Gods park.

Niobrara Trail Measurements: Baseline Measurements

What follows are the first interpretations of the trail measurement data collected on the Niobrara trail in the Garden of the Gods. The Niobrara trail was chosen as the first trail to monitor because it met the specifications, including significant length, no previous structure implementation, and future restoration work scheduled. Furthermore, the Niobrara trail is in a high traffic area bordering the wildlife conservation area of the Garden, the Reservoir valley. Trail degradation in the Reservoir valley, which the Niobrara ridge protects on its eastern flanks, can contribute to social trail development, another restoration problem citizen scientists are mitigating and monitoring on the southern end of the Reservoir valley.

We used a point sampling method inspired by Marion, Wimpey, & Park (2011) along the longitudinal profile of the measured trail. We started with 10m as the baseline interval for measurements, but we made additional measurements at significant trail features like hardened steps or switchbacks. At each point, we measured the trail width from vegetation to vegetation on either side, noting which side was uphill to capture the slope orientation. We measured the trail depth from the height of the cross-section tape at both the center of the trail and the thalweg, which were not always the same location on the trail. We attempted to collect GPS coordinates but the margin of error was confounded by the sinuosity of the trail. We also collected slope and aspect data.

Svajda, Korony, Brighton, Esser, & Ciapala (2016) conducted an extensive monitoring study of trail impacts in Rocky Mountain National Park (RMNP). They measured 56km of 8 trails that represent the types of trails and ecosystems present in RMNP. They collected measurements of trail depth, width, incision, rugosity, and cross-sectional area (CSA) soil loss. Their methodology and analysis informed the Program's methodology and data analysis. We collected similar data with more primitive tools and in a much smaller study area. The following interpretations employ extrapolated data from Svajda et al (2016) as points of comparison (Figure 2). The comparison between Rocky Mountain National Park and Garden of the Gods park was made originally in the Community Restoration Plan (Byers et al., 2000).

Commented [MG5]: I changed the presentation in this graph, making trail depth negative numbers since they are below the cross section trail surface measurements. Let me know what you think.

Commented [MG6R5]: I have seen the Waldo elevational profile graph before and I was hoping to produce something like that, but we couldn't even obtain reliable GPS points with the equipment at our disposal so elevation data was beyond reach. Let's talk about this more. I have been asking for a student to take this on as an internship and I think Emilie has the equipment and a potential student to work on this.

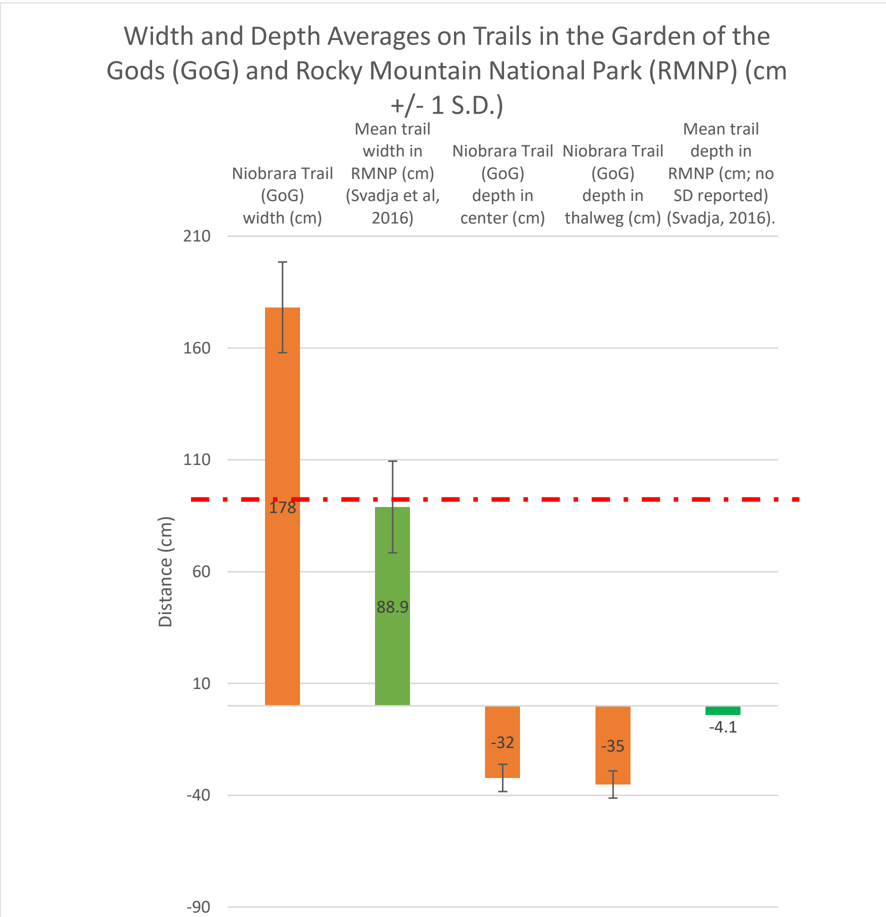


Figure 2. Trail depth measurements are presented as negative numbers because they are below the level trail surface from which the trail width measurements are taken. The Niobrara trail (179cm +/- 20cm) has nearly twice the average trail width measured in RMNP and twice the maximum tread width specified in the Super Friends Trail Standards Agreement (2017), which is indicated by the red dashed line at 91 cm. The Niobrara trail is also deeply incised with an average depth of 35 cm (+/- 6cm).

Both RMNP and the Garden experience 2-3 million visitors annually. However, the total area of the Garden of the Gods is 2 square miles. RMNP is 415 square miles. The Garden visitor density is 100 times greater than that of RMNP. This likely explains trends shown here (Figure 2). These measurements indicated a deeply incised trail with excessive width. Anecdotally, the trail is difficult to travel while running or biking, which is the likely reason for evidence of switchback-cutting and social trail development (Figure 3).

Figure 3. Watch this video to walk along the Niobrara trail: **https://youtu.be/4Y1IsbejuM4**

According to the Super Friends Trail Agreement (Colorado Springs Parks, Recreation and Cultural Services Department, 2017), trail widths are determined by the difficulty of the trail. For accessible and green trails, 91 cm is the minimum trail design specification. For blue and black trails, 91 cm is the upper width parameter. The Niobrara trail in this section is a blue or black trail in the restoration project area. The red dashed line indicates this parameter. The orange bars are Niobrara measurements and the green bars are RMNP measurements (Figure 2).

The average width of the Niobrara trail is 178 cm (n=13; s=20.3). When analyzed with a chi-square test, the Niobrara trail width is significantly wider than the expected width of 91 cm (X^2=1147, n=13, p>0.05). The sample size is very low so this chi-square test statistic should be taken with a grain of salt, but more data in the future will make similar interpretations far more robust.

The desired trail depth is not specified in the Super Friends Trail Standards Agreement (2017) since ideally a trail would lose no tread and have a depth of zero. The depth in the center of the trail and the thalweg is not statistically different, but it is between 31 and 35 cm on average (n=13; s= 6.1) (Figure 2).

I calculated an estimate of cross-sectional area (CSA) soil loss based on the width and depth measurement per point sampling. The depth and width measurements at each point constitute the two sides of a right-angle triangle (Figure 4). The area of a right-triangle can be determined by multiplying these two sides and dividing them by 2. However, we are conceptualizing two triangles, hence the width and depth measurement multiplied should complete the calculation to estimate CSA soil loss based on an estimate of eroded cubic area in the tread surface. By this calculation, the average CSA soil loss is 5845 cm^2. Svajda (2016) reported a CSA soil loss range of 0-1510 cm^2 and average of 441 cm^2. The huge discrepancy between their measurements and ours is likely due to the depth of the Niobrara trail.

Figure 4. This image is a model for the cross-sectional area (CSA) soil loss measurement. The geometric area measured at each point and then averaged provides a rough estimate of the soil already lost from the trail.

Niobrara Trail Restoration Summary

Commented [MG7]: RMFI staff will best summarize the work done. This should be a paragraph that summarizes the work impacts.

Post-Restoration Measurements

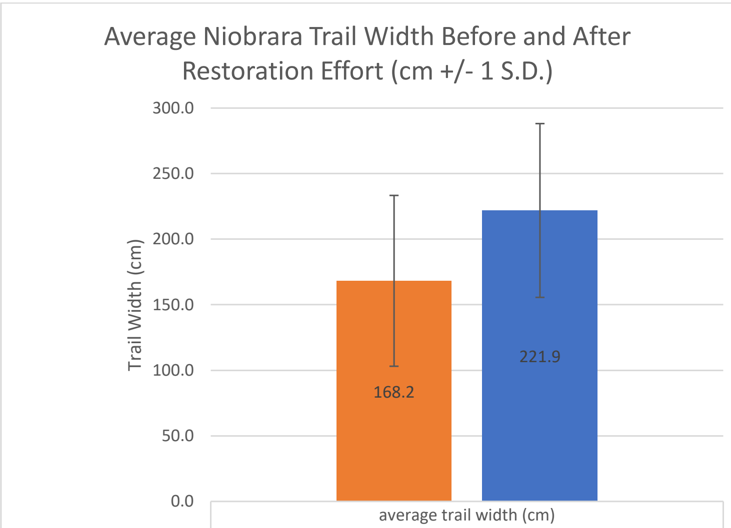
Since the restoration work was completed, the citizen scientists have collected measurements one time. The following interpretation is before and after snapshot. Over time, we will assess the trends in these data. These longitudinal interpretations will indicate the rate of trail degradation over time, which can be compared to the restoration techniques employed. At this time, these measurements illustrate the shape of the trail before restoration and the shape of the trail after restoration.

The lower 200 feet of trail were restored in November 2017. This longitudinal profile of the trail had 13 cross-sectional measurements along it in these 200 feet of trail. At each point, we measured the cross-sectional width. At each cross-section measurement, we measured the trail depth at the mathematical center of the trail. We also measured the trail depth at the thalweg, the lowest point in the trail.

After the restoration effort, we used the longitudinal measurement to find each cross-section measurement point. As a result, the dataset has paired measurements, anchored by the fixed longitudinal measurement, for pre- and post-restoration contexts. We continue to measure both the thalweg and center depth at each cross-section, even though earlier analysis indicated that these measurements were not statistically different from each other. A total of 13 paired measurements were included in this analysis.

A simple scatter plot of the data does not confirm normality, $F(13) = 0.63$ (pre-restoration) and $F(14) = 0.83$ (post-restoration), $p = 0.05$, but the sample size is small. Nonetheless, the assumption of normality is predicted for future data collections of larger sample size. Assuming normality, a Student's t-test indicates that the center depth and thalweg depths are not significantly different, $t(13) = 0.56$, $p = 0.05$ (pre-restoration).

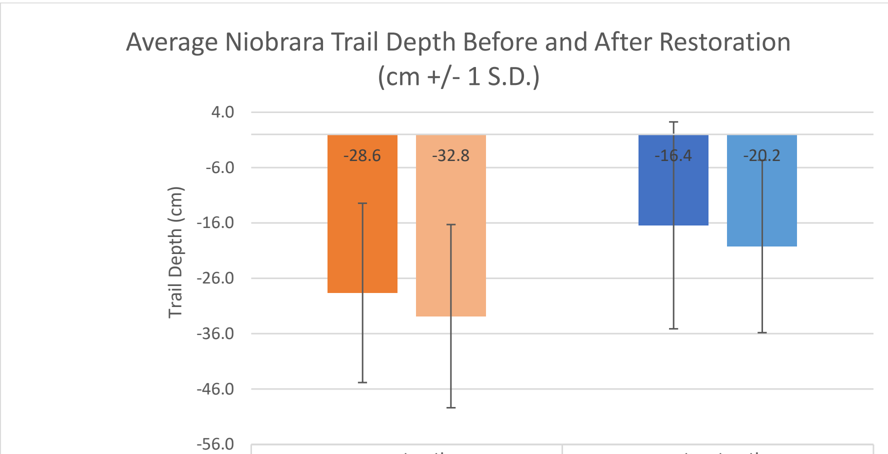
Before restoration, trail width measurements ranged from 83-211cm. After restoration, trail width measurements ranged from 163-381cm. The average trail width before restoration was 168.2cm (n=13; s=65.1). The average trail width after restoration was 221.9 (n=13, s=66.3) (Figure 5).



	average trail width (cm)
pre-restoration	168.2
post-restoration	221.9

Figure 5. Although the average trail width before and after restoration is not significantly different, the average width after restoration is 53.7cm wider than before restoration.

The average trail center depth before restoration was 28.6cm (n=13, s=16.2). The average trail center depth after restoration was 16.4 cm (n=14, s=16.5). The average trail thalweg depth before restoration was 32.8cm (n=13, s=18.7). The average trail thalweg depth after restoration was 20.2cm (n=14, s=15.6) (Figure 6).



	pre-restoration	post-restoration
average center depth (cm)	-28.6	-16.4
average thalweg depth (cm)	-32.8	-20.2

Figure 6. Although the thalweg depth and center depth measurements are not significantly different, the relative change before and after restoration are notable as convergence in these measurements indicates a more level trail, which is a goal of the restoration efforts.

Discussion

Most of the citizen scientists' early measurement efforts began at the top of the trail segment and did not make it all the way to the bottom. There were many measurements nuances to be determined once we began applying the standard measurements. As a result, in the first several days of measurement, the citizen scientists did not complete the entire longitudinal profile. The restoration occurred only on the bottom half of the trail segment where only one complete measurement was recorded. Therefore, at this time, there are no repeated measures to analyze. Repeated measures will become more important over time, as we assess whether or not the restoration slowed the change in the trail shape.

The thalweg and trail center measurements are not statistically different from each other, but they are perhaps the most interesting parameters to consider for the future. Theoretically speaking, the restoration work should reinforce the statistical insignificance between these measurements. The ideal tread surface is not furrowed; it is flat to slightly convex, with an outslope towards the downhill side of the trail so water can travel across the tread, rather than run down the tread length. If over time, the difference between the thalweg measurements and trail center measurements grows, this may suggest that the restoration effort was not as successful as planned. Parameters like slope and aspect will become important variables to consider as potential vectors for trail change as more trails are measured and the explanatory power increases with additional analyses.

The large standard deviations are due to the expanded width at the switchbacks. Future analyses can separate the switchback measurements from other measurements. Since this was such a limited sample size, all statistical computations are compromised by this factor primarily. More nuanced analyses will be carried out in the future with more robust data.

Of concern is the potential acceleration of degradation due to the machine-contouring of the backslope. We currently have no measurements to monitor this over time, but this is an opportunity for expansion in the future. Likewise, we have no measurements to assess the health of trailside vegetation overtime. This may also become an important indicator of near-trail ecosystem health, but again, no current measurements protocols for this exist currently.

Conclusion

The work of citizen scientists in the Garden of the Gods park in Colorado Springs is summarized in this report. Citizen scientists measured the Niobrara trail before and after restoration efforts by RMFI crews. Before restoration, average trail width and depth on the Niobrara trail exceeded regional trail standards and the trail surface was deeply eroded. After restoration, the average trail width increased while the trail depth decreased. Despite small sample sizes, statistical analyses are presented to foreshadow analytical possibilities with the future longitudinal dataset.

References

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