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Effects of Rock Climbers on Vegetative Cover, Richness and Frequency in the Boulder Front Range, Colorado

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Abstract:

The Boulder Front Range offers some of the finest rock climbing in North America. As a result many rock climbers find their way into the remote cliff regions of the Front Range (Climbing Management Guide). These areas often serve as refugia for a variety of plant and animal species that are not found in more disturbed areas (McMillan & Larson 2002). The aim of this study is to quantify the impacts on vegetative cover, species richness, frequency and introduction of invasive plant species in the talus below climbing routes in the Boulder Front Range due to trampling caused by recreational climbers. This data will provide a baseline for further monitoring of the impacts to these unique areas. The results of which can contribute to more accurate park management and closure plan for cliffs with climbing present. Data containing an aggregate distribution of climbing frequency was used to ascertain the prevalence of climbers visiting cliffs throughout the Boulder Front Range and to assess which locations to sample. It was found that cover, richness and frequency decreased significantly in experimental plots, indicating negative impacts from the disturbances caused by rock climbers in the area. It is noteworthy that three invasive species were identified, however, the relation to recreational climbers was not attainable.

Introduction

Current estimates of Americans participating in rock climbing and mountaineering for recreation each year range from 500,000 to over one million people in the United States alone (Climbing Management Guide 2006). Since the early 1980s, the popularity of this sport has expanded significantly. The quality, diversity and concentration of rock climbing resources along Colorado's Front Range has made the latter area one of the primary climbing destinations in North America. Many climbing enthusiasts live in this area, and thousands more travel here annually (Climbing Management Guide 2006). Consequently, increasing numbers of visitors inevitably contribute negative effects to fragile natural and cultural resources. Such visitation-related resource impacts can degrade natural conditions and processes and the quality of recreational experiences (National Park Service 2006).

Rock climbing, along with other recreational activities, can pose environmental concerns including alterations to the natural environment, trail proliferation, human waste issues and natural resource impacts (Climbing Management Guide 2006). One of the goals of conservation biology is to conduct research aiding in the preservation of natural landscapes. Of particular concern to scientists and environmentalists are natural areas that have remained relatively undisturbed for long periods of time. These areas often serve as habitats for a variety of plant and animal species not found in disturbed areas (McMillan & Larson 2002). The cliff ecosystem represents one of these areas. Cliffs can function as refugia and provide secure shelter for plants within the regional landscape (Graham & Knight 2004; Muller *et al*.). Refugia allows for unique communities of vascular plants, those containing a phloem and xylem, and lichens, a fungus and alga growing in symbiotic union to persist.

Humans are now coming into contact with the relatively undisturbed habitat of the cliff ecosystem. This raises the question of what impacts rock climbing related activities have on these unique habitats, for which this study seeks to address. One of the problems with answering this question is that alterations produced by climbing are largely undocumented. The effects of rock climbing have received little attention in the scientific literature, despite the rising popularity of this sport over the past two decades (Valis 1991; Herter 1996). Additionally, the available literature offers no consensus on the impacts of rock climbing. Some research indicates that certain aspects of cliff plant communities differ depending on climbing use (Camp & Knight 1998). While others disagree and maintain that proximity to climbing has no significant influence on cliff-face vegetation (Camp & Knight 1998).

The techniques and methods used to quantify the impacts of climbing also differ. In preliminary studies, researches have attempted to assess climbing disturbance by comparing pristine cliffs (unclimbed) with cliffs where climbing is present. Kuntz and Larson (2006b) describe how a lack of control for variation in microsite characteristics during comparison of areas with and without climbing disturbance limits the usefulness of these studies on conservation practice. On undisturbed cliffs it was recently discovered that vascular plant, bryophyte, and lichen richness and abundance are controlled by local and fine-scale physical factors (microsite characteristics) of the cliff face (Kuntz, 2004). Thus, undisturbed sites must precisely match the geological and environmental qualities of climbed sites if differences in vegetation are to be linked conclusively to climbing disturbance. This has not, however, generally been the case (Kuntz & Larson 2006 a) and has led to inconsistencies within the literature. Methodological inconsistencies, the limited volume of this literature, and conflicting conclusions have led to heated debates between land managers and climbers, with both sides requesting further scientific study (Baker 1999; Jodice *et al.* 1999; Krajick 1999; Young 1999).

The relative rarity of vascular plants within cliff and rocky areas (talus) is the result of many factors, including a challenging biophysical environment with periodic flooding and droughts, limited soil substrate, and disturbance associated with recreational visitation (Marion *et al.* 2011). Cliff vegetation characteristics, such as species richness (the total number of species in a given area) and plant cover (the percent area of ground cover) often differ between sections of the cliff that are climbed and sections of the same cliff that are unclimbed (Camp & Knight 1998; Farris 1998; Kuntz & Larson 2006b; McMillan & Larson 2002; Muller *et al*. 2004; Nuzzo 1995, 1996; Rusterholz *et al.* 2004). The latter difference is often attributed to both natural variation in environmental conditions and impacts of recreational rock climbing (Adams *et al.* 2012). Vascular plant density has also been found to be lower in climbed versus unclimbed areas (McMillan & Larson 2002) and Herter (1996) and Camp and Knight (1998) also noted a decline in overall plant density with climbing.

Impacts of climbing are not restricted to the cliff face. Climbers must access cliff faces from either the plateau above or the talus below (boulder strewn area). Both McMillan and Larson (2002) and Muller *et al.* (2004) investigated the impacts of climbing on talus plant communities and found more severe trampling impacts on the talus of climbed cliffs than on talus of unclimbed cliffs (Wezel 2005). Additionally, differences in the community composition of vascular plants between climbed and unclimbed cliff bases were influenced by the presence of more alien species in climbed areas. Rock climbing increases the likelihood of alien invasions by increasing the number of available microsites (by reducing plant density) and by introducing alien propagules into the area (McMillan & Larson, 2002). Often, species that are tolerant to disturbance survive and may establish proportionally more individuals, whereas species sensitive to trampling and disturbance may disappear or show reduced numbers of individuals (Parikesit *et al*. 1995).

Plan Summary

The present project work was designed to ascertain if there are impacts on vegetative cover, species richness and frequency in the Boulder Front Range due to recreational climbing. Specifically, this study proposes to quantify impacts that can be attributed to climbing in the talus of climbing routes. Such results could establish a baseline data set from which continued monitoring could proceed. Also, the research could contribute to a more accurate management plan for climbing in the Boulder Front Range. The Boulder County Open Space and Mountain Parks (OSMP) identified and quantified the number of climbers that many cliffs received over the course of several years in the Boulder Front Range. These data were used to choose sampling locations for the project. At all climbing routes sampled, vegetative cover, species richness and frequency were estimated. Furthermore, invasive species were identified from the total identifiable plant species.

Procedures and Materials

Study Area

The OSMP contributed data on the numbers of climbers a cliff receives. Data were separated into three categories based up intensity of use, i.e. popular (over 500 climber visits/year), moderate (100-500 climber visits/year) and infrequent (1-100 climber visits/ year). Twenty-seven of these locations were chosen for sampling, including 7 infrequent, 13 moderate and 7 popular locations. Climbing routes (where the climber begins the ascent) in the talus region of the cliff (the base) across the Boulder Front Range were sampled to obtain the comprehensive impacts caused by climbers to vegetation in these areas. At each location, a sample was taken from the talus region closest to the climbing route (and used for an experimental plot) and a sample was taken 15 feet away from the climbing route at a 90° from the cliff face (and used as a control plot), which resulted in a total of fifty-four samples. Four locations were sampled in Gregory Amphitheatre and the surrounding cliffs, 2 were sampled at the First Flatiron, 1 at the Second Flatiron, 2 at the Third Flatiron, 9 were sampled from the areas surrounding Mallory Cave and another 7 from the areas surrounding Bear Canyon (Appendix 1). All locations had raptor closures (for nesting raptors) except for the areas surrounding Mallory Cave.

Vegetative Cover

Vegetative cover was assessed at all locations using the FIREMON Point Intercept (PO) method (Lutes *et al.* 2006) with minor changes. A grid quadrat frame was constructed (2' x 2') with 25 points of interception (or cross-hairs) spaced evenly at 4" intervals. The vertical interceptions of cross-hairs with plant parts were considered hits and contributed to the percent cover. Data were taken at the base of climbing routes 2 feet from the cliff base and restricted to the center of the route. A control sample was taken at each location 15 feet from (and at a 90°) the face of the cliff. If a perpendicular sampling location did not exist or was inaccessible, measurements were taken at a 45° from the cliff face. A distance of 15 feet was deemed acceptable as disturbance (trampling) from climbing is often centralized at the base of climbing routes.

Cataloguing and Identification of Species

The number of species and frequency with which the taxon occurred within the grid quadrat frame were collected at all sampled locations in both experimental (at the base of the cliff) and control (15 feet away from the cliff face) locations. For each species found, the frequency (how often it occurred) of the species was reported for each location. Photographs of each species found were taken and a catalogue was created with site information (GPS coordinates, route name, cliff name, use rating). For some species, several photos were taken to aid in their identification at the CU-Boulder herbarium. Once species photographs had been reviewed and plants identified, their status as invasive or native was ascribed.

Results

Vegetative Cover

Total mean cover of vegetation in the experimental plots was significantly lower then the total mean cover in the control plots, with a p-value of 0.0041** (Figure 1.) Mean vegetative cover for all experimental climbing

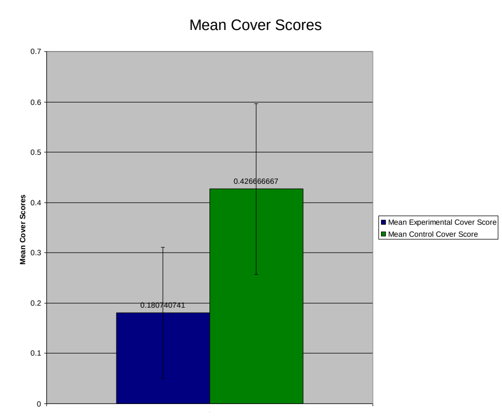

Figure 1. P-Value = 0.0041 **

Mean cover scores for experimental and control plots.

routes was 0.181 ± 0.13 for an average cover of 18.1 %. Mean vegetative cover for control areas were 0.427 ± 0.17 or 42.7% of the total area. Given that the total area of the grid quadrat frame was 4.0² feet, average cover in control plots amounted to 1.71² feet while the average covered area in experimental plots was 0.724² feet. This indicates that vegetative cover is negatively associated with trampling from recreational climbers.

Cover was analyzed at three levels of use (popular, moderate, infrequent) to ascertain differences in cover due to the amount of use climbing locations received annually (fig 2). Mean cover in experimental plots for popular climbing frequency was 0.063 ± .04, 0.221 ± 0.14 at moderate use, and 0 .222 ± 0.16 at infrequent use. Mean cover in control plots for popular climbing frequency was 0.520 ± 0.26, 0.351 ± 0.14 at moderate use, and 0.474 ± 0.16 at infrequent use. Although there was a decline in the mean cover between the popular, moderate and infrequently used climbs, there was no significant difference between climbing frequency and cover (p-value of 0.393).

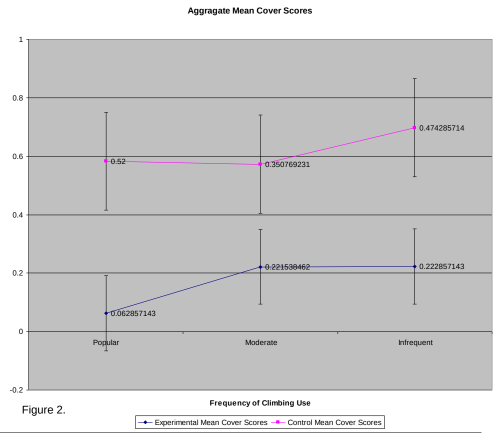

Figure 2.

Mean cover scores (experimental and control) for frequencies of climbing use.

Species Richness and Frequency

Species richness (number of plant taxa) were identified within the grid quadrats at experimental and

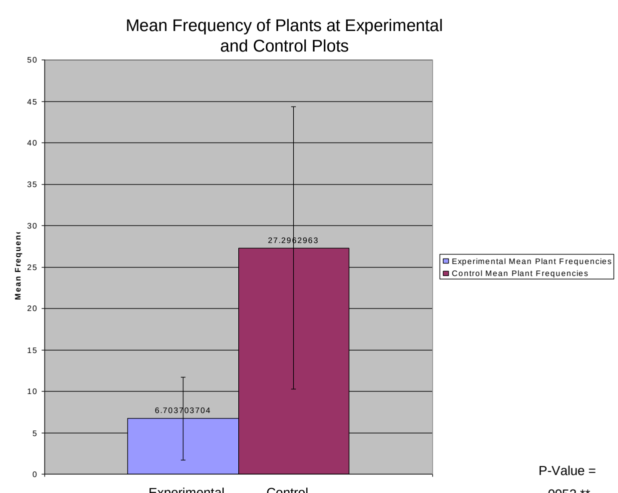

Figure 3.

Mean frequency of plants assessed at control and experimental plots.

control plots. 49 species were found within the areas sampled, while 29 species were identifiable. Of the 20 unidentified species 11 were graminoids (grasses, sedges and rushes). Mean species richness for experimental plots was 1.44 ± 0.84, and control plot mean species richness was 2.41 ± 0.74, with a p-value of 0.032* (Figure 3.). This indicates a significant difference in the species richness between control and experimental plots. There was no significant difference between species richness in either experimental or control plots for the three levels of climbing frequency. Additionally, there was some indication that control plots for high frequency use were spaced too close to the disturbance area. This was inferred based up the pronounced decline in the mean species richness in the control plots at high climbing frequency (figure 4.).

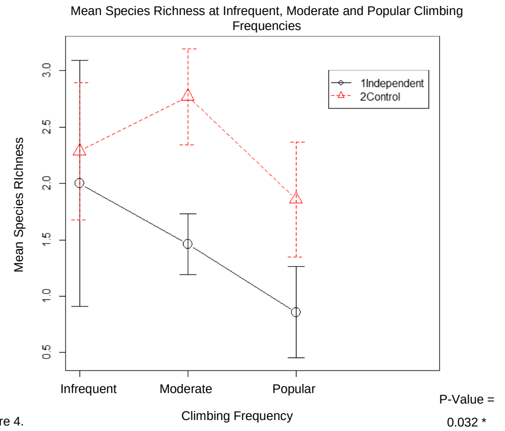

Figure 4.

Species richness (experimental and control) for frequencies of climbing use.

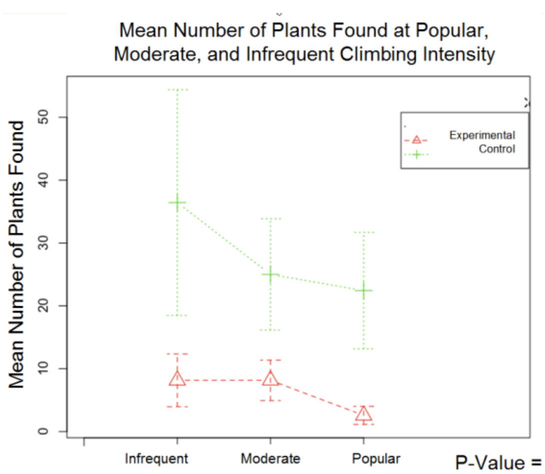

Figure 5.

Species frequency (experimental and control) for frequencies of climbing use

A total of 181 plants were found within the experimental sampled areas while a total of 737 plants were found within the control sampled areas. Mean species frequency counts in experimental plots were 6.70 ± 5.0, and mean control plot counts were 27.30 ± 17.0. There was a significant difference between mean frequencies in the experimental and control plots with a p-value of 0.00504** (Figure 4). However, there was no significant difference between climbing use and the frequency within each group (independent and control).

Invasive Plant Species

Of the 29 species that were identified 3 were invasive species and 26 were native (Table 1.). Two of the invasive species were found in control plots while the remaining invasive was found in the experimental plot. Given that 20 of the found species could not be identified and of those 11 were graminoids. It is possible that more invasive species were present but were unaccounted for. Smoothe brome (*Bromus inermis Leyss*), another invasive graminoid, was tentatively identified, however, not with enough certainty to be included.

Species Number	Experimental	Species Number	Control	Status
1	*Acetosella vulgaris*			Invasive
		1	*Achillea millefolium*	Native
		2	*Ambrosia psilostachya*	Native
2	*Apocynum androsaemifolium*	3	*Apocynum androsaemifolium*	Native
		4	*Aristida purpurea*	Native
3	*Artemesia lucoviciana*	5	*Artemesia lucoviciana*	Native
		6	*Bromus tectorum*	Invasive
		7	*Cryopteris fragilis*	Native
4	*Dicanthelium oligosanthes*	8	*Dicanthelium oligosanthes*	Native
5	*Elymus albicans*			Native
		9	*Gallium triflorum*	Native
6	*Geranium caespitosum*			Native
7	*Heterotheca villosa*	10	*Heterotheca villosa*	Native
		11	*Hydrophyllaceae fendler*	Native
8	*Mahonia repens*	12	*iMahonia repens*	Native
9	*Maianthemum stellatum*			Native
		13	*Malva neglecta*	Native
		14	*Opuntia macrorhiza*	Native
		15	*Pinus Ponderosa (Germinant)*	Native
		16	*Potentilla fissa*	Native
		17	*Prunus americana*	Native
		18	*Prunus virginiana*	Invasive
10	*Pteridium aquilinum*	19	*Pteridium aquilinum*	Native
		20	*Rosa woodsii*	Native
		21	*Solidago speciosa*	Native
11	*Thermopsis divaricarpa*	22	*Thermopsis divaricarpa*	Native
12	*Toxicodendron rydbergii*	23	*Toxicodendron rydbergii*	Native

Table 1. Identified species counts in experimental and control plots. Invasive and native species.

Discussion

With this study, a basis for future monitoring is now available. It offers the possibility to quantitatively monitor the development of plant cover, richness and frequency. This project captures the cumulative effects of recreational rock climbers and their impacts on plant cover, richness and frequency in the talus below climbing routes in the Boulder Front Range. Resource inventories are needed to guide trail design and management to protect any special plant communities threatened or endangered plants or any species that may be adversely affected (Climbing Management Guide). However, because sampling was only done over a single season, the implications are restricted to this season (2012).The significant decrease in cover was directly related to the decline in richness and frequency of plants in the talus below climbing routes. The reduced number of species and individuals in the talus with frequent use is a response similar to that reported for human trampling (Parikesit *et al*. 1995). Vegetation cover, frequency and richness did not differ among climbing frequency, despite apparent signs of trampling in the sampled locations. This may be due to the relative numbers of climbers received at each site. A site which receives 85 climbers annuals (infrequent 1-100) has a closure disturbance signature to that of the moderate (100-500) then that of a site which receives 5 climbers annually. Additionally, sampled locations with closures present during the year may have had altered disturbances relative to sampled locations without any annual closures.

Closure areas due to raptor nesting prevented sampling at one definitive period during the season. This resulted in some of the sampled locations being collected in June to August and another set in September. Further investigation into the impacts of existing closures on characteristics of vegetation in the Boulder Front Range are necessary for implementing effective park management plans. Recreational activities may be controlled or their effects limited by temporal closures of cliffs during critical seasons (spring green-up or flowering periods) and by spatial closures (permanent trail systems to focus disturbances, thus halting the spread of trampling) (Kuntz & Larson 2006b). However, closure areas with heavy recreational use is not advised because visitors tend to respond to such closures by moving into previously undisturbed or less disturbed habitats, thus increasing the areal extent of damage (McMillan & Larson 2002). This may have been observed in the area surrounding Mallory Cave. Sampled locations (Gregory

Amphitheatre, Flat Irons, and Bear Canyon) other than Mallory Cave, had closures through spring and into summer. In the Mallory Cave area a large proportion of the sampled areas (5/18) (both control and experimental) had no vegetation present. No other areas had as many plots absent of vegetation. Furthermore, the plots with vegetation had low cover, frequency and richness scores. Plots with vegetation were restricted to one or two species, primarily *Mahonia repens* and low frequencies (no more then 13). This could indicate that the surrounding closures have caused increased concentration of climbers to come to the Mallory Cave climbing area. This indicates that there is a need for further inquiry into the effects of closures on adjacent climbing areas without closures in the Boulder Front Range.

In addition to a direct reduction in the cover, richness and frequency of plant species, alterations to the plant community structure may have been present**.** Plant communities at cliffs with heavy use had more individuals of fewer species, whereas cliffs with limited evidence of climbing had fewer individuals of more species. This indicates that species that are tolerant to disturbance survive and may establish proportionally more individuals, whereas species sensitive to trampling and disturbance may disappear or show reduced numbers of individuals (Parikesit *et al*. 1995).

Analysis of erosion and introduced invasive species would be a beneficial contribution to the baseline data for monitoring the impacts to the Boulder Front Range. Access to the base of many climbs often necessitates hiking up steep grades that are highly susceptible to erosion (Climbing Management Guide). Assessing the erosion created by recreational climbers who often use more then one path to reach the base of a climb, would provide an indication for the relative disturbance to the limited soil substrate present in the talus region of the cliff. Climbers often travel long distances while searching for climbing locations. In the process seeds and propagules can be introduced to areas previously devoid of alien species (McMillan & Larson, 2002). Cataloguing the invasive species in areas with disturbances due to recreational climbers could offer a more complete scope of the impacts in the Boulder Front Range and be applied to establish a comprehensive monitoring program.

As the popularity of climbing increases and the number of participants rise, the need for proper park management will also increase. Appropriate, comprehensive monitoring of the threats to the Boulder Front Range is necessary in order to mitigate the disturbances caused by recreational climbers. Establishing proficient monitoring practices for the many variables associated with impacts from recreational climbing will lead to better preservation of the natural landscapes as they exist, diminish the negative impacts caused by the recreational activities and allow for the enjoyment of these areas for future recreationists.

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Appendix 1. Data provided by the OSMP. Given is the frequency of climbing visitors to cliffs in the Boulder Front Range.