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The impact of bouldering on rock-associated vegetation

Michael Tessler [a,b,*], Theresa A. Clark [c]

[a] Richard Gilder Graduate School, American Museum of Natural History, New York, NY 10024, USA
[b] Louis Calder Center, Fordham University, Armonk, NY 10504, USA
[c] School of Life Sciences, University of Nevada, Las Vegas, NV 89154, USA

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ABSTRACT

Many popular sites for recreational boulder climbing lie within protected natural areas, yet no research has assessed whether bouldering threatens associated vegetation – a diverse community regularly including rare species. This paucity of research is disconcerting because 1) bouldering involves removal of vegetation and soil, 2) the sport's popularity is growing quickly, and 3) cliff-climbing has been linked to lowered vegetation diversity. Our study is the first to quantify the impact of bouldering on vegetation. Following global trends of increased development in remote bouldering sites, we sampled such sites in the Shawangunks, New York – a world-renowned climbing destination. We implemented a paired climbed-unclimbed design that successfully removed potentially confounding environmental variation. Thus, bouldering appears to have caused our observed differences in vegetation between pairs. Climbed boulders had lower species richness and cover, with the greatest reduction found on mid-height boulder faces where most climbing occurs. Community composition and species frequency did not differ between pairs. This impact is weaker than that reported in most cliff-climbing studies, but the number of climbers and usage at our sites was lower. Accordingly, while bouldering in these remote sites may not be a major threat presently, the clear impact strongly suggests that even moderate increases in bouldering activity will have a substantial impact on vegetation. We recommend that visitation rates and the proportion of boulders climbed in conservation areas be monitored and kept at low levels.

1. Introduction

The sport of bouldering (unroped climbing of boulders generally <3.5 m tall) has seen rapid growth recently, with sites regularly being established and the number of climbers continually increasing (Attarian and Keith, 2008; Burg, 2005; Csiacsek, 2010; Josephsen et al., 2007; Story, 2011; Thiel and Spribille, 2007; Ven der Merwe and Joubert, 2014). For example, bouldering in Rocklands, South Africa has had yearly doubling in visitors (Ven der Merwe and Joubert, 2014). This trend is indirectly evidenced by rapid rises in boulder specific equipment sales, YouTube videos, competitions, and gyms (Burg, 2005; Csiacsek, 2010; Josephsen et al., 2007; Story, 2011).

Bouldering has several desirable characteristics over roped climbing which may explain its growing popularity: lower mortal danger, lower cost, less equipment, no required knowledge of rope-systems, and higher sociality (Attarian and Keith, 2008; Macdonald and Callender, 2011; Story, 2011). There are 4.6 million boulderers, sport climbers, and indoor climbers in the U.S.A. (The Outdoor Foundation, 2013), and the aforementioned trends suggest these numbers will continue rising.

Bouldering sites are more widespread than roped climbing sites, many lying within protected natural areas that had not seen climbing prior to recent bouldering (Burg, 2005; Earle and Carmichael, 2005). Bouldering destinations include areas renowned for roped climbing (e.g., Yosemite, California), as well as boulder-specific areas (e.g., Fontainebleau, France) (Burg, 2005; Story, 2011). Bouldering areas are characterized by massive rock aggregations or short cliffs formed through myriad geological events, including those not producing rocks tall enough for roped climbing (e.g., glacial retreat) (Burg, 2005; Josephsen et al., 2007).

Boulders often act as "islands," housing a diverse, rare, and obligate saxicolous flora (Spitale and Nascimbene, 2012; Thiel and Spribille, 2007; Virtanen and Oksanen, 2007; Weibull and Rydin, 2005). This flora's patch dynamics, productivity, and diversity may be sensitive to bouldering disturbance, as species richness in these communities can be sensitive to connectivity (Virtanen and Oksanen, 2007). Boulder habitat may also protect non-obligate vegetation, as it can provide refugia for plants harmed by overabundant herbivores (Rooney, 1997). Saxicolous vegetation communities are already conservation foci in Europe (Council Directive 92/43/ECC, 1992), but North America has no such measures.

Like most climbing, bouldering often leaves impressions on the landscape, but research has not quantified this impact (Attarian and Keith, 2008; Ven der Merwe and Joubert, 2014). Vegetation at the base of boulders is often trampled, or it is removed along with logs and rocks

* Corresponding author at: Central Park West at 79th St., Richard Gilder Graduate School, American Museum of Natural History, New York, NY 10024, USA.
E-mail address: mtessler@amnh.org (M. Tessler).

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for the placement of mats ("crash pads") that reduce the danger of falls (Attarian and Keith, 2008; Ven der Merwe and Joubert, 2014). Similar impacts are common on the tops of cliff climbs (Attarian and Keith, 2008). Rock faces are impacted passively by climbing or actively to improve climbing by removal of vegetation, soil, or loose rock from footholds and handholds (Attarian and Keith, 2008). Lastly, chalk (primarily $MgCO_3$) is used on handholds to improve grip (Attarian and Keith, 2008; Thiel and Spribille, 2007). Preliminary work has found chalk to influence algae positively and moss and lichens negatively on cliffs (Pereira, 2005).

Most studies investigating the impact of roped climbing on vegetation suggest that climbing negatively effects vegetation diversity (Adams and Zaniewski, 2012; Camp and Knight, 1998; Farris, 1998; McMillan and Larson, 2002; Müller et al., 2004; Rusterholz et al., 2004; Walker et al., 2007). Additionally, one study linked reduced genetic differentiation between subpopulations of a rare, saxicolous plant to cliff climbing, forewarning of the potential impacts from climbing and bouldering on rock-associated plant genetics (Vogler and Reisch, 2011). However, Kuntz and Larson (2006b) illustrated the importance of accounting for environmental variation potentially confounded with climbing in impact assessments. They found negligible impact from sport climbing on vegetation after statistically removing rock feature variability. Unfortunately, few studies have controlled for environmental variation, making firm conclusions on the impact of rock climbing difficult to draw (Holzschuh, 2016). Controlling for such non-randomly distributed environmental variation may be critical to accurate estimates of bouldering impact as well, because boulderers anecdotally target challenging climbs and avoid deep ledges and positive inclination that render the face moist or uninteresting (Müller et al., 2004) unless they are using them as a descent route.

We are unaware of prior impact assessments of bouldering on vegetation despite 1) bouldering's rising popularity, 2) the wide distribution of boulders, 3) unique boulder vegetation, 4) the visible disturbance bouldering can cause, and 5) the implications of cliff-climbing research. One climbing report did include six boulder transects (three climbed), but this sample size was too small for a full comparison (Walker et al., 2007). Therefore, we sought to conduct the first formal bouldering impact assessment. Our study centered on the Shawangunks (Ulster County, New York), a premier climbing destination.

The principal Shawangunks climbing destination, Mohonk Preserve, houses a unique suite of habitats and organisms with eight ecosystems rare to New York and over 1400 recorded species, including over 35 rare, threatened, or endangered species – many of which are restricted to cliffs or boulders (e.g., *Pseudotaxiphyllum distichaceum*) (Feldman and Thompson, 2008; Latham, 2003; Reeves, 1974; Tessler et al., 2016a; Town et al., 1994). Additionally, the park has impressive historic documentation of species occurrence and phenology, which has revealed a biota sensitive to climate change (Cook et al., 2008). Assessing the impact of bouldering on rare and threatened vegetation is perhaps more critical now in a changing climate, which may compound these species' vulnerabilities to human disturbance.

Our study targeted the more remote bouldering sites of Mohonk Preserve for reasons of conservation concern. Although "The Trapps" attracts most of the preserve's climbers and boulderers (Swain, 1995), our sites corresponded instead to trends in bouldering where experienced boulderers are seeking unexploited sites with challenging unclimbed or uncompleted routes – a trend fueled by the sport's emphasis on first-ascents (Henry, 2010; Sherman, 1997). In line with this global trend, avid boulderers are commonly developing routes at relatively remote sites in Mohonk (e.g., have long, unmarked access trails; pers. comm. John Thompson and Andrew Zalewski). Mohonk, like many other places, has recently closed several of these sites to boulderers, fearing that the unique ecosystems therein are at risk from recreational impact. Our study helps to assess this risk in remote bouldering sites.

We sought to estimate the impact of bouldering on associated vegetation by sampling spatially-paired climbed and unclimbed boulders to reduce confounding environmental variation linked to climbed habitats. Our goals were to determine 1) whether richness and cover differ between climbed-unclimbed boulder pairs and if impact varies by boulder microhabitat (i.e., ground, boulder face, and boulder plateau); 2) whether habitat features differ between climbed-unclimbed boulder pairs, and if any differences are confounded with climbing presence; and 3) whether species community composition of climbed boulders differs from unclimbed boulders.

2. Methods

2.1. Study area

The Shawangunk Ridge offers kilometers of quartzite-conglomerate cliffs (mostly ≤60 m high, peaking at an elevation of 698 m) (Darton, 1893; Feldman et al., 2012; Swain, 1995). Our study focused on Mohonk Preserve (ca. 7500 acres), the principal climbing and bouldering destination of this region, which attracts 50,000 climbers annually (Feldman and Thompson, 2008); 20–25% of climbers here are boulderers (pers. comm. Hank Alicandri, Director of Land Stewardship). We sampled five bouldering sites in Mohonk Preserve between 5/31/2013 and 6/26/2013: Bonticou Single Right (BS), Bonticou Triple Right (TR), Lost City (LC), White Dot (WD), and Waterworks (WW). Sites were located in mixed-hardwood or pine-oak forests. Local climate averages −4 °C in January and 21 °C in July with a mean precipitation of 119 cm (Mohonk Lake, 366 m). Local boulderer and route developer, Andrew Zalewski, showed us the bouldering routes, as published information is unavailable for these sites.

2.2. Climbed-unclimbed boulder pairs

To assess the impact of bouldering on vegetation in Mohonk Preserve, we implemented a paired sampling design to spatially control for potentially confounding effects from environmental and microtopographic variation. We randomly sampled five pairs of climbed-unclimbed boulder faces using vertical transects at five sites totaling 25 transect pairs. Climbed transects met the following requirements: climbed within the past year, ≥3 m tall, top-out plateau ≥1 m × 1 m with a slope ≤ 45°, and without rocks or large trees to prevent ground plot sampling. Route difficulty ranged from V0 to V9 and each class was represented by at least one sample unit with the exception of V7 and V8. Unclimbed boulder transects were placed 3 m randomly to the right or left of each climbed transect on a face with no evidence or history of climbing within the past 10 years. If this placement was <1 m from another bouldering route, then transect position was reduced to 2 m (or 1 m if necessary) from the paired climb. For each transect, we established five 1 m × 1 m plots (following Adams and Zaniewski, 2012), targeting five microhabitats (ground, low face, mid face, top face, and plateau; Supplementary Fig. 1).

2.3. Vegetation sampling

Species richness and cover were recorded in microhabitat plots for bryophyte, lichen, and vascular plant species, excepting crustose, squamulose, and leprose lichens, which were treated as functional groups (collectively referred to as microlichens below). Cover was estimated for total vegetation, bryophytes, lichens, vascular plants (i.e., seedlings, herbs, and woody plants), and for each species using the semi-quantitative system of Holmes and Whitton (1977) with an additional class to accommodate high cover, yielding the following classes: 0, 1 (0–0.1%), 2 (0.1–1%), 3 (1–5%), 4 (5–10%), 5 (10–50%), 6 (>50%). Nomenclature follows Flora of North America Editorial Committee (2007) for mosses and vascular plants, Ley and Crowe (1999) for liverworts, and the Consortium of North American Lichen Herbaria (lichenportal.org) for lichens. Vouchers for bryophytes and macrolichens (vascular plants were field-