# The Relative Influence of Microhabitat Constraints and Rock Climbing Disturbance to Vegetation on Ontario's Niagara Escarpment

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## Abstract

*Rock climbing has been reported to have significant negative effects on cliff vegetation. Two aspects of prior research on the effect of rock climbing, however, limit its utility to conservation practice: (1) microsite heterogeneity was not accounted for between climbed and control cliffs; and, (2) rock climbing styles and difficulty levels examined previously do not represent current trends in the sport. We solved these problems by sampling cliffs used by advanced 'sport' climbers and by quantifying differences in microtopography between climbed and control cliffs. When we examined the differences in vegetation between cliffs without controlling for microsite variation our results were consistent with the majority of prior work, i.e., sport-climbed cliffs supported fewer species and different species frequencies than pristine cliffs. However, when we investigated the relative influences of microtopography and climbing disturbance, we discovered that the differences in vegetation were not related to climbing disturbance but rather to climber selection of cliff faces with specific microsite characteristics that naturally support different vegetation. A policy is proposed for establishing new climbing routes with limited impact.*

***Keywords:*** *vegetation disturbance, rock-climbing, micro-habitat, Niagara Escarpment*

## Introduction

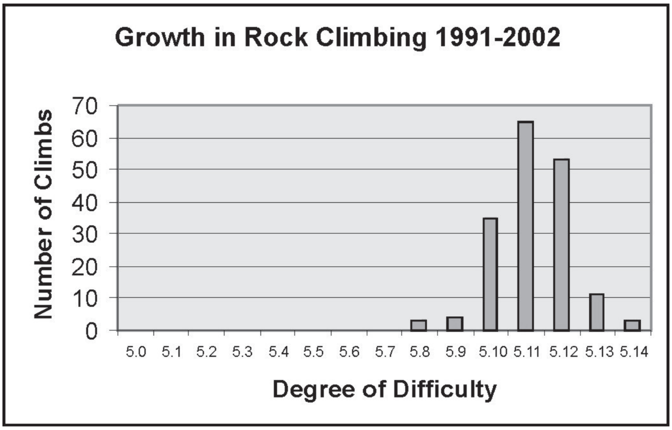
Cliff faces in Ontario have for some time been recognized as sites that harbour ancient forests, endangered biota and high levels of biodiversity (Larson *et al.*, 2000). Knowing the value of cliffs, park managers are being challenged by the recent expansion of recreational rock climbing. Numerous studies have reported significant negative effects of rock climbing on cliff face vegetation communities (Nuzzo, 1995, 1996; Herter, 1996; Kelly and Larson, 1997; Camp and Knight, 1998; Farris, 1998; McMillan & Larson, 2002; Rusterholz *et al.*, 2004; Müller *et al.*, 2004). Unfortunately, the utility of many of these studies to conservation practice is limited because of two serious shortcomings in experimental design: (1) microsite heterogeneity was not compared between pristine and climbed cliffs; and, (2) rock climbing styles and difficulty levels examined previously do not represent current trends in the sport.

Comparative studies in ecology present a tremendous number of challenges as we are observing complex systems after events have taken place and without a clear picture of what existed before. One challenge when designing a study to evaluate recreational disturbance to a natural system is controlling for natural variation in that system. We have recently discovered for undisturbed cliffs of the Niagara Escarpment that vascular plant, bryophyte, and lichen richness and abundance are controlled by local and fine scale physical factors of the cliff face (Kuntz, 2004). Therefore, variation occurring because of differences in microtopography must be quantified before conclusions about disturbance can be made.

When investigating the impact of a recreational user group, an additional challenge is designing a study that reflects current trends in that activity. Rock climbing is a general term which encompasses several distinct sports including aid climbing, traditional climbing, sport climbing and others (Child, 1995). However, the growth in climbing on the Niagara Escarpment has been limited to sport climbing routes of advanced difficulty levels (see Figure 1). No prior studies on impacts of climbing have taken into account this trend.

The present study was designed to overcome the limitations of previous work by separating the presence of climbing from confounding natural environmental factors including microtopography and specifically examining the impact of sport climbing on the cliff face vegetation community of the Niagara Escarpment. We first determined whether differences in vascular plant, bryophyte, and lichen richness and individual species frequencies and community composition existed between sport-climbed and pristine cliff faces when physical differences between disturbance categories were *not* controlled. This was done to reflect the design of many prior studies and to

**Figure 1**. The number of climbing routes established since 1991 categorized by difficulty level. (Information acquired from Bracken *et al.*, 1991; Oates & Bracken, 1997; pers. obs.)




illustrate the results that are achieved when confounding factors that may influence vegetation patterns are not removed. We then evaluated the actual influence of sport climbing on the cliff face vegetation by determining the relative influence of climbing presence, cliff face microtopography, local physical factors that influence microclimate, and regional geography.

## Methods

### *Study Area*

We sampled in the three main geographic areas of the Niagara Escarpment in Ontario where sport climbing occurs: the Bruce Peninsula, the Beaver Valley and Milton. We sampled bolt-protected climbing routes rated 5.10-5.14 in difficulty to reflect trends in new climbing route growth. All sampling was conducted May through August of 2003 to coincide with the vascular plant flowering season.

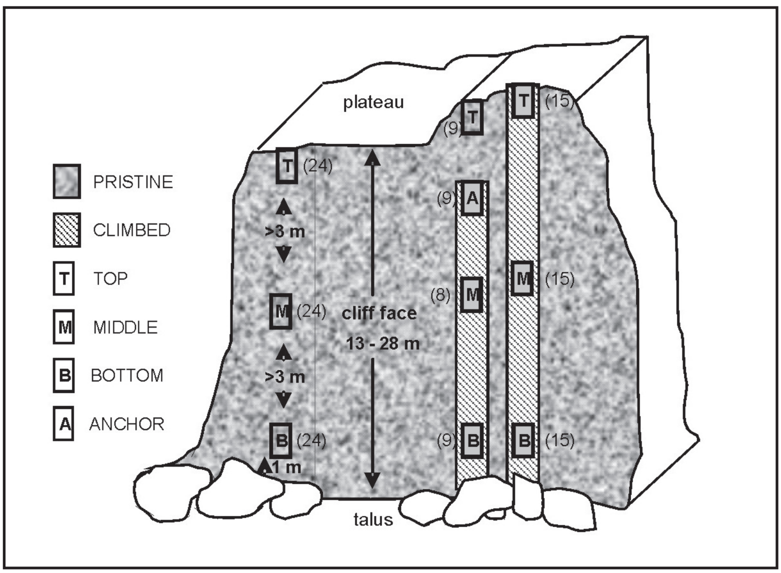
### *Sampling design*

We randomly selected 24 pristine and 24 sport-climbed transects from the thirty-five cliffs which met the following criteria: cliff height was between 13 and 28 m; cliff faces were vertical to overhanging; cliffs were accessible from above to fix ropes for sampling while on rappel; and transects had continuous cliff face extending at least 2 m on either side. Only sport-climbed transects rated 5.10 to 5.14 in difficulty were eligible for selection as climbed transects. Random selection of transect location resulted in some eligible cliffs not being selected for sampling, while others were selected multiple times. Within each transect, we placed three or four 1 m x 2 m rectangular quadrats, subdivided into 18, 33.3 x 33.3 cm subquadrats, such that the plots extended vertically down the cliff face (Figure 2). This design resulted in 152 quadrats across 20 separate cliff faces being sampled.

## Vegetation sampling

We sampled each quadrat for species richness, vegetation abundance, and community composition for vascular plants, bryophytes, and lichens. We calculated the abundance of vascular plants, bryophytes, and lichens for each quadrat as the percentage of subquadrats within the 2 $m^2$ quadrat (percent frequency) which contained any vascular plant, bryophyte, or lichen. The community composition of a quadrat was calculated using the abundance value for each vascular plant, bryophyte, and lichen species in that quadrat. For each species we also calculated its overall frequency on climbed and

**Figure 2**. Placement of quadrats on pristine and sport-climbed cliff faces of the Niagara Escarpment showing positioning of Top (T), Middle (M), Bottom (B), and Anchor (A) quadrats. The number in brackets beside each quadrat position reflects the number of replicates for each sample position. Separate Climbed-Anchor and Unclimbed-Top quadrats were sampled for the nine transects where the climbing route finished short of the top of the cliff.



pristine cliffs as the percentage of climbed or pristine quadrats that contained that species.

### Physical measurements

Each quadrat was classified according to the presence of climbing (pristine or sport climbed) and geographic region (Bruce Peninsula, Beaver Valley or Milton). It was ranked based upon latitude, and measured for differences in microtopography and factors influencing microclimate. As the relative importance of various local and fine-scale physical variables was unknown, we collected data incorporating as many aspects of the physical environment as was practical. Local physical factors included: (1) cliff height, (2) transect slope, (3) aspect, (4) canopy cover, and (5) quadrat position.

Individual microtopographic features of the rock face (ledges, crevices and solution pockets) were counted and measured within each quadrat. We determined eight measures of microtopographic heterogeneity for each quadrat: (1) ledge frequency, (2) crevice frequency, (3) pocket frequency, (4) total feature frequency, (5) mean ledge area per quadrat, (6) mean crevice volume per quadrat, (7) mean pocket volume per quadrat, and (8) maximum total volume of soil per quadrat.

### Statistical Analyses

Two-tailed t-tests were performed to determine whether significant differences in vascular plant, bryophyte or lichen species richness existed between pristine and climbed cliff faces. Chi-square ($\chi^2$) tests were performed to determine whether significant differences in overall frequency existed for each vascular plant, bryophyte or lichen species between pristine and climbed cliff faces. We used Detrended Correspondence Analysis (DCA) to explore patterns in community composition across pristine and climbed cliff faces.

Stepwise multiple linear regressions were then performed to attribute variation in the response variables: (1) vascular plant species richness; (2) vascular plant abundance; (3) bryophyte species richness; (4) bryophyte abundance; (5) lichen species richness; and, (6) lichen abundance; to differences in regional geography, local physical factors, microtopographic factors, and the presence of climbing. We next used partial Canonical Correspondence Analysis (CCA) to examine the proportion of variation in community composition that could be accounted for by regional geography, local physical factors, microtopographic factors, and the presence of climbing, independently. The relative strength of each category of environmental factors to explain variation in community composition is indicated by their Eigenvalues, where higher values indicate that a greater proportion of variation is explained. All univariate analyses were performed using SAS version 8.2 (SAS Institute, 2001) and all multivariate analyses were performed using CANOCO version 4.5 (ter Braak & Smilauer, 2003).

## Results & Discussion

### Differences in Vegetation between Pristine and Sport-Climbed Cliffs

In the current study, we began by examining vegetation patterns across pristine and climbed cliffs suspecting that these two classes of sites were qualitatively different in their microtopography. As in most previous research on climbing impact on cliff vegetation, sport-climbed cliff faces on the Niagara Escarpment supported a lower mean species richness of vascular plants (approx. 1 per plot vs. 2, $P$=0.028) and bryophytes (0.4 vs. 0.7, $P$=0.227) and significantly different frequencies of individual species when compared to pristine cliff faces when microsite differences between cliffs were not controlled (see Table 1). However, when examining the location of quadrats in DCA ordination space there was no separation of sport climbed from pristine quadrats indicating that climbed sites have not diverged toward a separate community of species (Figure 3). Instead, sport-climbed quadrats appear to support a subset of the flora found on pristine cliff faces.

### The Relative Influence of Microsite Factors and Climbing Disturbance to Cliff Vegetation

When we evaluated the relative contribution of the presence of climbing vs. other physical factors to the variation in vegetation patterns across these cliffs, our results revealed that vegetation differences are not directly related to climbing disturbance, but rather reflected microsite differences between cliffs selected by climbers and the remaining pristine cliff faces (Table 2). In particular, species richness or abundance for all three vegetation groups was correlated with differences in soil volume. Vascular plant richness and abundance increased with increasing volumes of soil; bryophyte richness and lichen abundance increased with decreasing volumes of soil. Climbing presence was a significant factor influencing both lichen richness and abundance; however, the presence of climbing was correlated with increases, not decreases, in these two measures.

CCA Eigenvalues for axes 1 and 2 were high for vascular plants (0.611, 0.498) and bryophytes (0.852, 0.787) when compared with those from the DCA, indicating that most of the variation between quadrats can be accounted for by the environmental variables chosen in this study (Table 3). CCA Eigenvalues were lower for lichens (0.274, 0.221), indicating that other environmental variables than those measured in the present study are responsible for at least some of the variability in species composition among quadrats. Results from partial CCA analyses indicated that the presence of climbing was the factor least able to explain variation in community composition for every vegetation group Instead, the cliff face vegetation communities responded to local and fine-scale physical factors of the cliff face (Table 3).

**Figure 3**. Ordination diagram of vascular plant, bryophyte and lichen species produced by Detrended Correspondence Analysis of species frequencies on the Niagara Escarpment, Ontario, Canada (λ1= 0.579, λ2= 0.542). Polygons represent ordination of pristine and climbed quadrats. Named symbols represent the 40 most common taxa (see Table 1).

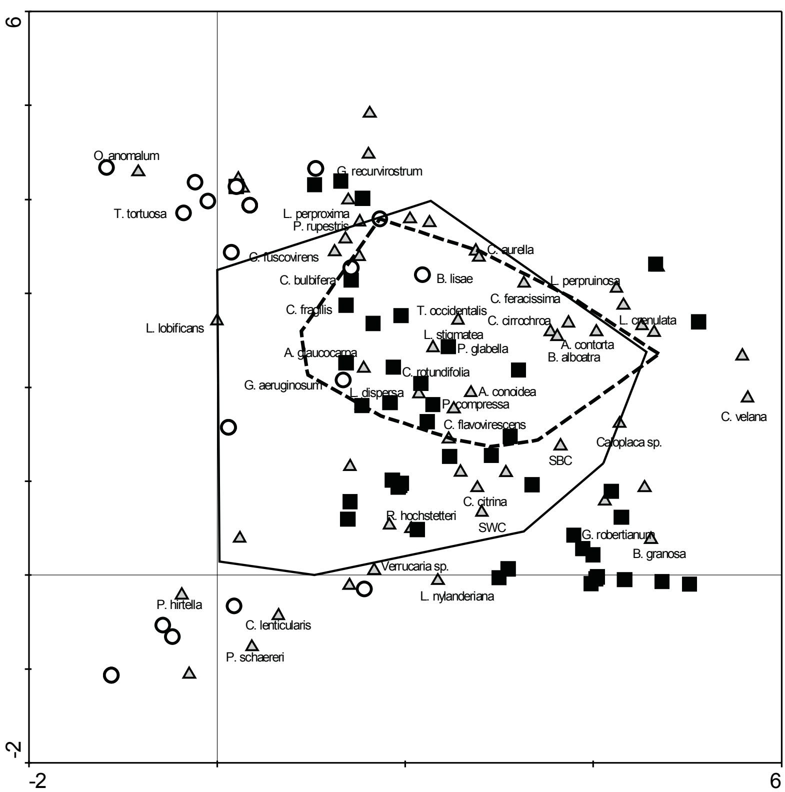


**Table 1**. Percent frequencies of the 40 common[a] species on pristine and climbed cliff faces of the Niagara Escarpment in southern Ontario, Canada. Percent frequency is defined as percentage of quadrats in which each species was present. Species are listed under the disturbance category (pristine or climbed) where they were more frequent, and by the magnitude of the difference in frequency between disturbance categories. Significant differences between disturbance categories for each species were determined by $\chi 2$ (chi-square) tests; only significant values at $P<0.05$ are listed.

| **Species** | **% Frequency** | | **Difference** | ***P*** |
|---|---|---|---|---|
| | **Pristine** | **Climbed** | | |
| **Vascular Plants** | | | | |
| ***Pristine*** | | | | |
| *Thuja occidentalis* | 25 | 7 | 18 | <0.0001 |
| *Geranium robertianum* | 14 | 1 | 13 | 0.0003 |
| *Campanula rotundifolia* | 6 | 1 | 5 | |
| *Cystopteris bulbifera* | 18 | 14 | 4 | |
| ***Climbed*** | | | | |
| *Pellaea glabella* | 18 | 37 | 19 | <0.0001 |
| *Cystopteris fragilis* | 7 | 14 | 7 | 0.0050 |
| *Poa compressa* | 19 | 20 | 1 | |
| **Bryophytes** | | | | |
| ***Pristine*** | | | | |
| *Tortella tortuosa* | 6 | 0 | 6 | 0.0153 |
| *Orthotrichum anomalum* | 7 | 1 | 6 | 0.0294 |
| *Gymnostomum recurvirostrum* | 11 | 8 | 3 | |
| ***Climbed*** | | | | |
| *Gymnostomum aeruginosum* | 6 | 13 | 7 | 0.0019 |
| *Bryum lisae* var. *cuspidatum* | 4 | 8 | 4 | 0.0320 |
| **Lichens** | | | | |
| ***Pristine*** | | | | |
| *Lepraria lobificans* | 35 | 17 | 18 | 0.0002 |
| *Lecania nylanderiana* | 18 | 1 | 17 | <0.0001 |
| *Acarospora glaucocarpa* | 36 | 24 | 12 | 0.0113 |

| Species | % Frequency | | Difference | P |
|---|---|---|---|---|
| | Pristine | Climbed | | |
| *Caloplaca citrina* | 65 | 56 | 9 | |
| *Catillaria lenticularis* | 8 | 0 | 8 | 0.0026 |
| Sterile White Crust [b] | 46 | 38 | 8 | |
| *Psorotrichia schaereri* | 7 | 0 | 7 | 0.0063 |
| *Collema fuscovirens* | 21 | 14 | 7 | |
| *Verrucaria sp.*[c] | 17 | 11 | 6 | 0.0003 |
| *Protoblastenia rupestris* | 15 | 10 | 5 | |
| *Bacidia granosa* | 7 | 3 | 4 | |
| *Caloplaca velana* | 10 | 6 | 4 | |
| *Caloplaca sp.*[d] | 15 | 11 | 4 | |
| *Lecania perproxima* | 6 | 4 | 2 | |
| ***Climbed*** | | | | |
| *Caloplaca cirrochroa* | 50 | 73 | 23 | <0.0001 |
| *Caloplaca feracissima* | 33 | 55 | 22 | |
| *Lecanora perpruinosa* | 11 | 28 | 17 | <0.0001 |
| *Lecidella stigmatea* | 11 | 27 | 16 | <0.0001 |
| *Lecanora dispersa* | 32 | 44 | 12 | 0.0120 |
| *Aspicilia contorta* | 3 | 13 | 10 | <0.0001 |
| *Caloplaca flavovirescens* | 25 | 31 | 6 | |
| *Candelariella aurella* | 11 | 17 | 6 | |
| *Phaeophyscia hirtella* | 1 | 6 | 5 | 0.0003 |
| *Rhizocarpon hochstetteri* | 1 | 6 | 5 | |
| *Buellia alboatra* | 11 | 15 | 4 | |
| *Lecanora crenulata* | 38 | 41 | 3 | |
| ***No difference*** | | | | |
| *Acrocordia conoidea* | 14 | 14 | - | |
| Sterile Brown Crust [e] | 56 | 56 | - | |

[a] Present in at least 5% of pristine or climbed quadrats

[b] Without apothecia, with or without diffuse soralia or soredia; genus unknown.

[c] With apothecia and thallus, spores one-celled, ellipsoid; may include *V. calkinsiana, V. fuscella, V. muralis, V. nigrescens*, and possibly others.

[d] With apothecia and poorly developed thallus; may include *C. feracissima, C. holocarpa, C. cf. dalmatica, C. flavovirescens, C. velana*, and possibly others.

[e] Withouth apothecia, soralia or soredia, probably includes *Verrucaria* sp., *Lecania* sp., *Bacidia* sp., *Catillaria* sp. and others.

**Table 2**. Test statistics, correlation coefficients, and significance levels from stepwise linear multiple regressions for six response variables of vegetation types on cliff faces of the Niagara Escarpment, Ontario. Vascular plants, bryophytes and lichen species richness and other physical factors are listed as increasing or decreasing. Only those factors significant at *P*<0.05 are listed.

| Response Variable | (df) | $F$ | $R^2$ (adjusted) | $P$ | Physical Factors | sign | Partial $r^2$ | P |
|---|---|---|---|---|---|---|---|---|
| Vascular plant richness | (5, 131) | 18.04 | 0.408 | <0.0001 | Quadrat position (height) | + | 0.23 | <0.0001 |
| | | | | | Volume of soil | + | 0.09 | <0.0001 |
| | | | | | Pocket frequency | + | 0.04 | 0.0040 |
| | | | | | Crevice volume | - | 0.03 | 0.0132 |
| | | | | | Crevice frequency | + | 0.02 | 0.0487 |
| Bryophyte richness | (5, 40) | 6.68 | 0.455 | 0.0001 | Crevice volume | + | 0.16 | 0.0054 |
| | | | | | Volume of soil | - | 0.11 | 0.0087 |
| | | | | | Ledge area | + | 0.10 | 0.0185 |
| Lichen richness | (6, 136) | 15.50 | 0.417 | <0.0001 | Pocket frequency | + | 0.21 | <0.0001 |
| | | | | | Aspect - Northness | + | 0.11 | <0.0001 |
| | | | | | Quadrat position (height) | + | 0.05 | 0.0020 |
| | | | | | Crevice frequency | + | 0.03 | 0.0293 |
| | | | | | Climbing presence | + | 0.02 | 0.0487 |
| Vascular abundance | (5, 131) | 12.00 | 0.314 | <0.0001 | Pocket frequency | + | 0.18 | <0.0001 |
| | | | | | Quadrat position (height) | + | 0.07 | 0.0004 |
| | | | | | Volume of soil | + | 0.02 | 0.0402 |
| Bryophyte abundance | (4, 41) | 3.20 | 0.238 | 0.0225 | Total feature frequency | + | 0.07 | 0.0438 |
| Lichen abundance | (5, 40) | 9.92 | 0.554 | <0.0001 | Quadrat position (height) | + | 0.24 | 0.0005 |
| | | | | | Ledge frequency | + | 0.14 | 0.0038 |
| | | | | | Climbing presence | + | 0.11 | 0.0044 |
| | | | | | Volume of soil | - | 0.04 | 0.0500 |

**Table 3**. Eigenvalues for the first two axes* of ordinations conducted showing the relative influence of climbing presence, regional geography, local physical factors, and microtopographic factors on the species composition of vascular plants, bryophytes and lichens on cliff faces of the Niagara Escarpment, Ontario.

| Species Group | Analysis Type | Eigenvalues | |
|---|---|---|---|
| | | Axis 1 | Axis 2 |
| Vascular Plants | DCA | 0.818 | 0.569 |
| | CCA (all variables) | 0.611 | 0.498 |
| | Partial CCA - microtopography | 0.378 | 0.270 |
| | Partial CCA - regional geography | 0.299 | 0.116 |
| | Partial CCA - local physical factors | 0.262 | 0.241 |
| | Partial CCA - climbing presence* | 0.159 | |
| Bryophytes | DCA | 0.978 | 0.713 |
| | CCA | 0.852 | 0.787 |
| | Partial CCA - microtopography | 0.520 | 0.320 |
| | Partial CCA - local physical factors | 0.433 | 0.305 |
| | Partial CCA - regional geography | 0.222 | 0.067 |
| | Partial CCA - climbing presence* | 0.212 | |
| Lichens | DCA | 0.497 | 0.400 |
| | CCA | 0.274 | 0.221 |
| | Partial CCA - local physical factors | 0.160 | 0.113 |
| | Partial CCA - regional geography | 0.154 | 0.079 |
| | Partial CCA - microtopography | 0.141 | 0.120 |
| | Partial CCA - climbing presence* | 0.102 | |

* in Partial CCA -climbing presence, only one axis could be created due to the single constraining variable.

Our results agree with Nuzzo's (1996) results that physical factors other than climbing disturbance influenced vascular vegetation in Illinois. Our results also confirm Farris' (1998) hypothesis that observed differences in vegetation between pristine and climbed cliffs in Wisconsin may not have been due to climbing, but instead resulted from climbers avoiding the more heavily vegetated cliffs. They may be avoiding vegetated cliffs because of the presence of the vegetation itself or because of the geological structure of the area. In the remaining studies of climbing impact, microtopographic variability between disturbance categories was not measured directly. Therefore, differences in vegetation between pristine and climbed cliffs in these studies may have been due to small microsite differences between sites, not disturbance by climbers.

## Management Implications

Past management recommendations have encouraged restriction of new sport-climbing route development based on the interpretation of results from previous studies on the impacts of climbing. This recommendation must now be weighed against the evidence that climbers are selecting areas of the cliff face that naturally support less vegetation. However, it should be noted that the current study did not attempt to address any other possible disturbances of climbing including limb removal, bark abrasion, reductions in average leaf or flower number or size, differences in growth rate, colony size, reproductive rate, and so forth. Should land managers have concerns regarding a specific rare species, further study on the potential impacts of climbing on that species should be considered. It must also be understood that the potential disturbance to vegetation by sport climbers on the Escarpment may not yet be measurable only ten years after the routes have been established, or at current climbing population levels. Finally, impacts of climbers are not restricted to the cliff face. Climbers must access cliff faces from either the plateau above or the talus below. Both McMillan and Larson (2002) and Müller *et al.* (2004) investigated the impacts of climbing on talus plant communities and found more severe trampling impacts in the talus on climbed cliffs when compared with unclimbed cliffs.

The following management recommendations provide a set of rules that would limit significant differences to cliff vegetation community structure. These rules are designed to serve the dual mandate of our parks and conservation areas — to preserve remaining natural areas, while providing outdoor recreational opportunities. However, as any access will cause some level of biological disturbance, it is at the discretion of land managers to determine what level of biological disturbance is appropriate.

### *Cliff face*

- Limit new climbing route development to routes with difficulty levels of 5.10 and above.
- Place bolts to direct climbers away from cliff face cedars.

### *Plateau*

- Create convenient rappelling stations at or near existing look-outs to prevent climbers from having to create multiple cliff edge trails to access gullies to the cliff base.

- Install permanent anchors (bolts) below the cliff edge to allow climbers to lower back to the talus upon completion of an ascent.
- Create a 'no top-roping policy' in areas of new route establishment.

### *Talus*

- Establish trails which only cut into the cliff base where necessary to access new climbing routes.

Overall, it is recommended that a new routing policy be established that is consistent across the entire Niagara Escarpment. As anticipatory management strategies tend to be the most effective, having management plans in place for currently unclimbed cliffs will result in less confusion and greater compliance by the climbing community. It is also recommended that a policy be created which requires climbers to submit a proposal for each individual new route to be established for cliffs under the management of parks or conservation areas. These proposals will provide managers with information about where new route development is occurring. A policy that allows individual areas to accept or reject proposals for each new route is also recommended as it would allow conservation areas and parks to manage new routing opportunities within and between generations of climbers.

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