The Consequences of Trampling Disturbance in Two Vegetation Types at the Wyoming Nature Conservancy's Sweetwater River Project Area

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Abstract—The consequences of human trampling disturbance on two codominant vegetation types at the Wyoming Nature Conservancy's Sweetwater Preserve were examined. Small trampling lanes (1.5m x 0.5m) were established in both vegetation types and trampling treatments ranging from 0 to 800 passes were applied. *Artemisia* (Sagebrush) vegetation type was more sensitive to initial trampling disturbance than the *Equisetum* (Smooth scouring rush) community. After one year, however, both communities closely resembled predisturbance conditions, in terms of relative cover, relative height and percent bare ground. These results suggest that these vegetation types could withstand a moderate amount of visitor use without extensive degradation, although it would be prudent to continue monitoring conditions and regulating use levels to ensure that impacts do not proliferate.

The demand for recreational opportunities in the Rocky Mountain Region has resulted in increases in visitation in wilderness and nonwilderness lands. Many accessible "wildlands," while not designated wilderness, represent important areas ecologically and if managed correctly, could also provide areas for primitive recreation experiences. For example, many areas managed by The Nature Conservancy (TNC), although primarily managed for biodiversity and habitat protection, are near federally protected lands and can offer opportunities for primitive recreation. Extending wilderness management techniques to these areas, where appropriate, would benefit these lands directly and also provide a significant extension of wilderness preservation concepts. Moreover, these areas are often closer to population centers than designated wilderness and have a high potential for primitive recreation, provided that the human activities can coexist with resource preservation.

Information on the relative tolerance of ecosystems to human use is essential to land management. Frequently there are apparent conflicts between allowing access for recreation and the preservation of natural conditions (Cole 1995a). Experimental trampling of groundcover vegetation has often been utilized as an index of tolerance to human use. It has the advantage of eliminating confounding variables and utilizes small plots of previously undisturbed vegetation. This approach was initiated by Wagar (1964) and has been used on many vegetation types worldwide, including arctic tundra (Monz and others 1996), mountain regions in the United States (Cole 1995 a,b), and heath communities in Scotland (Bayfield 1979). The standard methodology, as suggested by Cole and Bayfield (1993), has been utilized in many of these studies and therefore comparisons across different ecosystem types are possible.

The objective of this project was to investigate the consequences of human trampling on two distinct vegetation types at TNC's Sweetwater Preserve. We conducted experiments in which controlled levels of trampling were applied to plant communities in areas of potential increased recreation use. This technique is particularly applicable to this preserve for several reasons. First, few developed trails exist, and the development of trails is deemed undesirable by management objectives. Second, the vegetation and soils in certain areas of the preserve could be subject to significant disturbance given the current visitor use patterns. Last, regulating use levels below thresholds of disturbance to maintain pristine conditions is a feasible management option for the preserve.

Methods

Study Site

The Sweetwater River Preserve is located roughly at 42° N 108° W at an elevation of 2000 m and totals approximately 1200 ha. The land and conservation easements on an adjacent 600 ha were purchased 1991 by the Wyoming chapter of The Nature Conservancy. The Sweetwater River is a major tributary of the North Platte River and the area represents

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one of the few relatively undisturbed riparian habitats in Wyoming.

Plant Communities

We selected the two codominant plant communities on the preserve for trampling experiments; one with a dominant overstory of *Artemisia tridentata* (big sagebrush) and the other dominated by *Equisetum laevigatum* (smooth scouring rush) and other graminoids such as *Poa* spp. and *Koeleria macrantha* (june-grass). At the initiation of the experimental work the pre-trampling species abundance for experimental plots in both sites (table 1) were assessed with standard techniques. For the purposes of this project, *Artemisia* was not directly affected by the trampling treatments (since it is not a groundcover) and is therefore not included in the results. Both of these communities are in an area selected for potential increased use as they are adjacent to visitor cabins and are in an area of fishing access to the Sweetwater River. Experimental plots were located approximately 100 m apart and roughly 50 m from the river's bank. Soils are a relatively uniform sandy loam.

Experimental Treatments

Trampling—Experimental design for the trampling treatments follows the standard protocols described by Cole and Bayfield (1993). Four replicates of experimental trampling lanes (1.5m x 0.5m) were established in each of the two vegetation types. Lanes were selected within experimental blocks on the basis of suitability of application of trampling and homogeneity of the vegetation. Each replicate consists of five lanes; control (untreated), 25, 75, 200 and 500 trampling passes. A pass is a one-way walk at a natural gait along the lane; the people weigh 60-75 kg and wear lug sole boots. Treatments were applied once during early summer at the time of maximal seasonal biomass. For examinations of the overall ability of vegetation to tolerate recreational use, application of trampling at one time has been shown to be equally as effective as multiple treatments throughout the season. (Bayfield 1979; Cole 1985).

All areas on the preserve are sometimes subjected to cattle grazing at various times during the growing season. Plots were isolated from this potential confounding disturbance by using grazing exclosures, and a complete set of trampling

Table 1—Initial frequency and mean percent cover of the more abundant species in each of the two vegetation types.[a]

	Vegetation type			
	Equistetum laevigatum		*Artemisia tridentata*	
Species	**Freq.**	**Cover**	**Freq.**	**Cover**
Equisetum laevigatum	98	3		
Koeleria macrantha	88	21		
Poa juncifolia var. *juncifolia*	88	35		
Poa palustris	83	48		
Elymus trachycaulus	80	11		
Erigeron glabellus	80	16		
Taraxacum officinale	75	22		
Trifolium longipes	73	7		
Astragalus agrestis	70	9		
Agrostis variablilis			100	72
Sporobolus cryptandrus			100	31
Moss			73	3
Erigeron caespitosus			58	2
Carex spp.	65	3	50	14
Iva axillaris			43	2
Elymus lanceolatus	68	17	23	5
Muhlenbergia richardsonis	63	7		
Juncus balticus	53	4		
Erigeron sp.	48	9		
Iris missouriensis	45	15		
Elymus trachycaulus var. *andinus*	20	5		
Polygonum vivaparum	20	9		
Sporobolus sp.	13	6		
Deschampsia caespitosa	8	11		
Agoseris glauca	5	8		
Phleum pratense	5	3		
Stellaria longipes	5	3		
Castilleja flava			15	5
Elymus cinereus			10	5
Chrysothamnus viscidiflorus			8	10
Cryptogam			3	5

[a]Only species with mean cover of at least 2% are included. Frequency is the percent of the forty 30 x 50-cm plots in which the species was found.

lanes were also exposed to potential grazing in each vegetation type.

Trampling Response Variables

Standard indices of trampling effects (Cole and Bayfield 1993) were recorded in each lane in one 30 x 50 cm subplot. Measurements consisted of 1) visual estimates of canopy coverage of each vascular plant species (only green material) and of mosses and lichens; 2) visual estimates of the cover of bare ground, which included mineral soil, organic material and plant litter; and 3) determinations of vegetation height, using a point quadrat frame with five pins five cm apart within the width of the subplot, for a total of 50 pin drops. Every effort was made to standardize and calibrate ocular cover estimates by using 100 random pin drops per subplot as a baseline in initial trial runs, and then basing final ocular estimates on these results. Soil compaction was estimated using a pocket soil penetrometer (Forestry Suppliers, Inc. Jackson, MS 39284-8397 USA) and two random measurements per subplot. Measurements were performed approximately two weeks after trampling to determine the initial resistance and repeated one year later to determine the subsequent resilience.

Data Analysis

For the trampling results, analysis follows the suggested protocols of Cole and Bayfield (1993) where the primary response variable for each vegetation type is relative cover. This is a measure of the proportion of the original vegetation that survives trampling and is adjusted for changes occurring on control plots. It is calculated by summing all the percent covers of individual species to obtain total cover and then calculating relative cover as:

$$\frac{\text{Surviving cover on trampled subplots}}{\text{Initial cover on trampled subplots}} \times cf \times 100\%$$

Where:

$$cf = \frac{\text{Initial cover on control subplots}}{\text{Surviving cover on control subplots}}$$

For some widespread individual species, we also calculated relative cover in response to trampling impact. Relative height of the vegetation was calculated by summing the heights and dividing by the number of values greater than zero and then substituting the mean height values in the formula given above for relative cover. Calculations of resistance and resilience indices follow the procedures outlined by Cole (1995a). Statistical analysis was performed with SPSS software (SPSS, Inc. Chicago, Ill, USA).

Results

The *Artemisia* vegetation type (fig. 1a & b) showed little initial resistance to trampling disturbance, with significant decreases in overall cover with as little as 75 trampling passes. The highest level of trampling (500 passes) resulted in approximately 20% relative cover remaining. In the *Equisetum* vegetation type overall responses were similar, but much higher trampling intensities (800 passes) were required to induce a moderate cover loss of approximately 50% (fig. 1c & d). Both vegetation types demonstrated significant ability to recover (resilience), with almost all of the relative cover measurements close to 100% one year after disturbance. After one year of regrowth, T-test results revealed no evidence of a grazing effect on relative cover for either vegetation type ($t = 1.31$, $p = 0.26$ for *Artemisia* and $t = 3.09$, $p = 0.091$ for *Equisetum*).

Relative height (fig. 2) followed a similar trend as relative cover, but significant decreases occurred with just 25 passes. The *Equisetum* vegetation type was particularly sensitive to trampling in this regard, with relative heights approaching zero with moderate to high levels of disturbance. After one year of recovery, plant heights in the *Equisetum* plots exposed to potential grazing had 44% greater relative height ($t = 5.31$, $p = 0.030$) and *Artemisia* plots had 23% greater relative height ($t = 20.51$, $p < 0.00$) than comparable nongrazed plots.

Responses immediately after trampling are reported for individual species (table 2). In the *Equisetum* vegetation type, *Koeleria macrantha*, *Poa juncifoli*a, and *Poa palustris* demonstrated a high resistance to disturbance, with significant cover remaining after even 800 passes. *Erigeron glabellus* and *Equisetum laevigatum* were highly susceptible with almost zero cover remaining after the same level of disturbance. In the *Artemisia* vegetation type, *Agrostis variabilis* was susceptible to disturbance, while *Sporobolus cryptandrus* was moderately resistant.

Although significant increases in bare ground were observed in both vegetation types immediately after trampling (table 3), there were no significant differences remaining one year later. No clear trends were evident in soil penetration resistance, with high levels of trampling disturbance showing no significant effect.

The resistance, resilience and tolerance indices (table 4) demonstrate that both vegetation types are of moderate resistance (in the 50–60% range), of high resiliency (above 70%) and of high tolerance (above 90%). Interestingly, the grazed plots were consistently more resilient than the respective nongrazed plots.

Discussion

Although information is available on the resistance and resilience of plant communities (for example, Cole 1995 a & b), site-specific information on the response of plant communities to human disturbance is desirable when making important management decisions. Applied trampling studies do not exactly mimic the disturbance from actual use, but these approaches are an effective means of examining the responses to short term trampling and they provide an accurate index by which to base visitor use management decisions (Cole and Bayfield 1993).

The overall durability of a vegetation type is a function of its ability to resist the initial disturbance of trampling and its ability for regrowth. The ability of a vegetation type to withstand initial disturbance is termed resistance (Cole and Bayfield 1993; Sun and Liddle 1991). Others such as Grime (1979) refer to this property as inertia. In this experiment, we assessed resistance by measuring plant properties two weeks after initial disturbance.

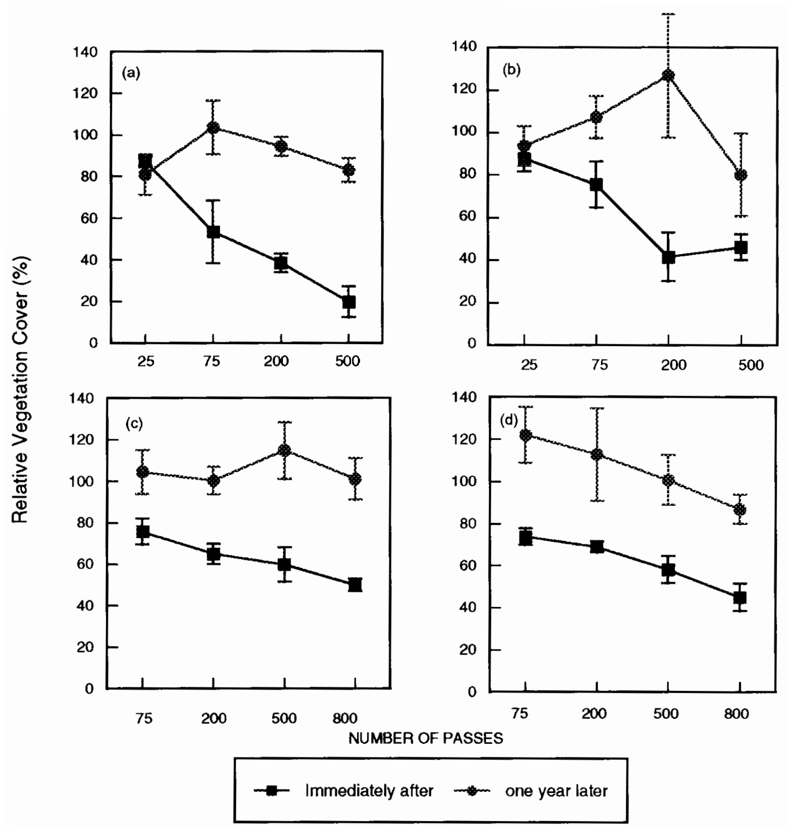

Figure 1—The relationship between vegetation cover and amount of trampling in the a) *Artemisia*, no grazing, b) *Artemisia*, grazing, c) *Equisetum*, no grazing, d) *Equisetum*, grazing vegetation types. Bars are one standard error.

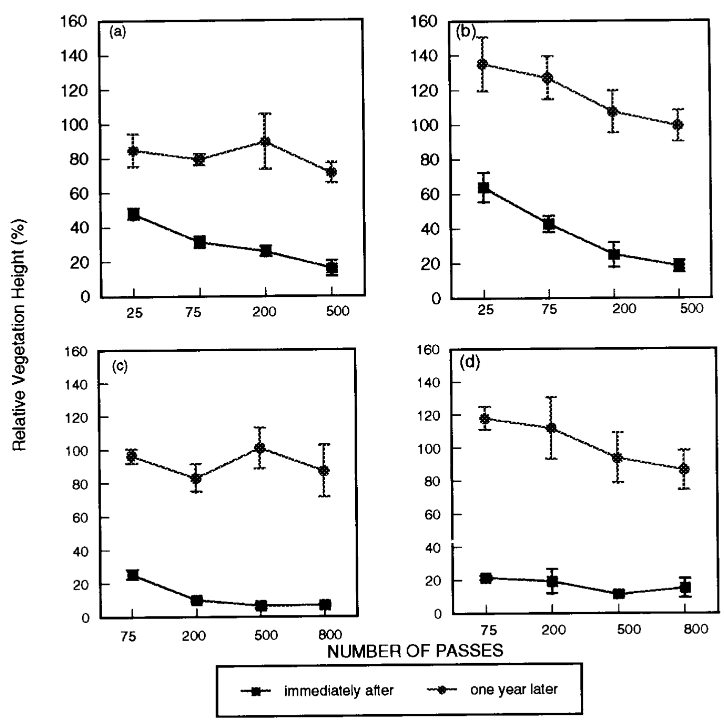

Figure 2—The relationship between vegetation height and amount of trampling in the a) *Artemisia*, no grazing, b) *Artemisia*, grazing, c) *Equisetum*, no grazing, d) *Equisetum*, grazing vegetation types. Bars are one standard error.

Table 2—Relative cover[a] of abundant species after trampling and after one year recovery.

Species	After trampling				After one year recovery			
	Number of passes				Number of passes			
Artemisia	25	75	200	500	25	75	200	500
Grazing								
Agrostis variablilis	82	45	25	20	86	96	200	107
Sporobolus cryptandrus	91	118	69	75	83	96	68	54
Without grazing								
Agrostis variablilis	90	55	29	14	57	80	104	82
Sporobolus cryptandrus	118	65	74	44	80	91	102	43
Equisetum	75	200	500	800	75	200	500	800
Grazing								
Elymus trachycaulus	55	100	75	49	91	20	17	19
Erigeron glabellus	80	28	7	0	*	*	*	*
Equisetum laevigatum	44	64	10	5	*	*	*	*
Koeleria macrantha	94	93	94	65	*	*	*	*
Poa juncifolia	86	77	78	83	*	*	*	*
Poa palustris	100	100	87	49	*	*	*	*
Poa spp.	90	87	82	66	162	174	116	127
Taraxacum officinale	75	109	39	11	50	93	51	94
Without grazing								
Elymus trachycaulus	100	66	80	100	15	35	2	13
Erigeron glabellus	53	109	33	29	*	*	*	*
Equistetum laevigatum	67	19	14	6	*	*	*	*
Koeleria macrantha	80	82	78	86	*	*	*	*
Poa juncifolia	64	87	60	67	*	*	*	*
Poa palustris	96	92	96	67	*	*	*	*
Poa spp.	91	90	89	67	111	105	121	118
Taraxacum officinale	88	63	27	75	62	77	33	75

[a]Relative cover is the proportion of original cover that survives trampling, adjusted for changes on controls. For the *Artemisia* plots, relative covers were calculated following Cole and Bayfield (1993). For the *Equisetum* plots, relative covers were calculated without using a correction factor due to excessive variability in the control plots.

*Indicates missing species data due to lack of flowering over the course of the season (see Discussion).

The term resilience has been used commonly in the literature (Grime 1979; Cole and Bayfield 1993) as the ability of an ecosystem to recover from disturbance. Here, we assessed resilience by comparing the relative cover immediately after disturbance with the relative cover after one year of recovery. Tolerance is another useful measurement suggested by Cole (1988), Cole and Trull (1993) and Cole and Bayfield (1993), and is a measure of the vegetation to both resist and recover. We measured tolerance by comparing the vegetation cover after one year of recovery with the initial cover prior to disturbance.

The groundcover in the *Artemisia* vegetation is fairly sensitive to trampling, with a 50% overall cover loss occurring at less than 200 trampling passes. This is in contrast with the more initially resistant *Equisetum* vegetation type that does not reach 50% loss, even at 800 passes (fig. 1). Both vegetation types are highly resilient (fig. 1 and table 4), with overall cover approximating predisturbance levels in just one year of regrowth.

In *Equisetum*, vegetation height was significantly reduced with just 75 passes (fig. 2). Due to the morphology of this vegetation type (collectively tall graminoids and horsetails, in the 30 cm range), plants can be easily flattened by human use. This may or may not be of important management consequence, given the degree resiliency we observed. It could be problematic for management since areas of disturbance become obvious with just a few passes. These areas will tend to attract more use, and therefore concentrate impact, which could lead to trail formation.

Soils in both sites are essentially unaffected by trampling. This is an indicator that there will be little long-term surface soil compaction. Direct comparisons of the measurements immediately after trampling to those one year later were difficult since the second season was unusually wet in the *Equisetum* plots, and penetration resistances consequently are very low in year two (table 3). This wet season also resulted in a lack of flowering in these plots, and we were therefore unable to correctly identify many individual species (data omitted from table 2).

Work by Cole (1995b) demonstrates that tolerance is largely a function of resilience rather than the initial resistance to disturbance. Similar trends are observed here, where both vegetation types are of moderate resistance (~49 to 66%), but of high resilience and therefore high tolerance (table 4). Growth form has also been identified as a predictor of durability, with chamaephytes (plants with penetrating

Table 3—Exposure of bare ground and changes in soil compaction due to trampling after one year recovery.[a]

Treatment	After trampling				After one year recovery			
	Bare ground		Soil penetration resistance		Bare ground		Soil penetration resistance	
	Percent		*kg/cm²*		*Percent*		*kg/cm²*	
Grazing								
Artemisia control	10 ± 3.5	a	4 ± .4	a	18.8 ± 10.5	a	4.1 ± .5	a
25 passes	15 ± 5.4	a	4.3 ±.3	a	5.5 ± 2.6	a	3.4 ± .5	a
75 passes	33.8 ± 7.5	a	4.1 ± .5	a	5.1 ± 2	a	4.1 ± .3	a
200 passes	55 ± 14.4	b	3.6 ± .45	a	8.8 ± 3.8	a	3.1 ± .5	a
500 passes	47.5 ± 6.3	ab	3.3 ± .3	a	27.5 ± 8.3	a	4.2 ± .2	a
Equisetum control	.1 ± .06	a	3.3 ± .2	a	.05 ± .05	a	1.3 ± .03	a
75 passes	1.6 ± 1.2	a	3.1 ± .3	a	.05 ± .05	a	1.5 ± .3	a
200 passes	6.3 ± 2.4	a	3.4 ± .3	a	1.25 ± 1.25	a	1.3 ± .2	a
500 passes	11.5 ± 4.1	a	3.5 ± .11	a	1.3 ± 1.2	a	1.5 ± .2	a
800 passes	45 ± 9.6	b	3.6 ± .2	a	3 ± 2.4	a	1.4 ± .2	a
Without grazing								
Artemisia control	8.8 ± 3.8	a	3.3 ± .4	a	2.8 ± 2.4	a	2.6 ± .3	a
25 passes	10 ± 2	a	3.5 ± .13	a	2.8 ± 1.3	a	3.7 ± .7	a
75 passes	41.3 ± 19.6	ab	3.8 ± .46	a	0.8 ± .2	a	3.1 ± .6	a
200 passes	67.5 ± 4.8	b	2.9 ± .65	a	4.0 ± 1	a	3.3 ± .2	a
500 passes	75 ± 6.5	b	3.1 ± .5	a	15.3 ± 8.5	a	3.9 ± .8	a
Equisetum control	0.0 ± 0	a	3.6 ± .07	a	0.0 ± 0	a	.67 ± .04	a
75 passes	.25 ± .25	a	3 ± .2	a	.05 ± .05	a	.96 ± .14	a
200 passes	1.8 ± 1.1	a	3.1 ± .13	a	.13 ± .07	a	.88 ± .14	a
500 passes	9 ± 2.9	a	2.6 ± .3	a	0.0 ± 0	a	1.4 ± .3	a
800 passes	32.5 ± 4.8	b	3.1 ± .2	a	.05 ± .05	a	1.0 ± .3	a

[a]Means not followed by the same letter are significantly different using the modified LSD at $\alpha = 0.05$.

Table 4—Indices of resistance, resilience, and tolerance for the two vegetation types.[a]

	Artemisia		*Equisetum*	
	Grazing	Without grazing	Grazing	Without grazing
Resistance				
Mean relative cover after 0-500 passes	62.71	49.66	66.97	66.82
Resilience				
Mean increase in cover one year after 0-500 passes, as a percent of the damage caused by trampling	105.27	80.82	135.85	74.91
Tolerance				
Mean relative cover one year after 0-500 passes	101.97	90.34	111.84	91.68

[a]Calculations follow Cole and Bayfield (1993).

bud above the ground surface) being the least tolerant (Cole, 1995b). In general, these observations were supported here; the vast majority of the overall cover in these plots were composed of cryptophytes, or plants with penetrating buds below the ground surface. Therefore, despite the erect nature of the grasses, particularly in the *Equisetum* plots, regenerative structures remained undisturbed and resilience high.

Our data do not address the overall effects of grazing on these vegetation communities. Trends seem to indicate a possible stimulation of the regrowth response, but this could have been due to micro site differences in water stress, since regrowth was assessed after a particularly wet season. An additional complication is that actual application of the grazing was not controlled; in other words, these plots are best referred to as having "potential grazing." Although cattle were on the property, it is not clear to what extent they affected the experimental plots. Nonetheless, the results of the nongrazed plots (within grazing exclosures) are clear, and a more carefully controlled grazing study should be employed to examine the effects of grazing more thoroughly.

Management Implications and Future Research

The results of this work indicate clearly that both studied vegetation types can tolerate a significant amount of human use, without sacrificing the ability to recover in the short term. Off-trail use is currently permitted in the area for fishing access to the Sweetwater River, and current findings show no immediate rationale for changing this practice, provided the overall use does not exceed the ability of the vegetation to recover. Proper visitor education and regulation, in combination with continued monitoring, will help guide future management decisions.

Several important questions remain that should be addressed by future research and monitoring:

- These results indicate that the plots where grazing was possible had greater vegetation height. A more carefully designed study with applied grazing and trampling treatments should be conducted to determine the combined effects of these two treatments.
- Individual species responses, and consequently, plant community changes were not possible to determine, particularly in the *Equisetum* plots. This was due to a lack of flowering of many species due to an especially wet season in year two of the project. It is possible that long-term trampling may have an effect on species composition, and this should be determined with future investigations.

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References

Bayfield, N.G. 1979. Recovery of four montane heath communities on Cairngorm, Scotland, from disturbance by trampling. Biological Conservation. (15): 165-179.

Cole, D. N. 1985. Recreational trampling effects on six habitat types in western Montana. USDA Forest Service Research Paper, INT-350, Ogden UT. 43 p.

Cole, D. N.; Trull, S. J. 1992. Quantifying vegetation response to recreational disturbance in the North Cascades, Washington. Northwest Science. 66 (4): 229-236.

Cole, D. N.; Bayfield, N. G. 1993. Recreational trampling of vegetation: standard experimental procedures. Biological Conservation. 63: 209-215.

Cole, D.N. 1995a. Experimental trampling of vegetation. I. Relationship between trampling intensity and vegetation response. J. Appl. Ecol. 32: 203-214.

Cole, D.N. 1995b. Experimental trampling of vegetation. II. Predictors of resistance and resilience. J. Appl. Ecol. 32: 215-224.

Grime, J. P. 1979. Plant strategies and vegetation processes. John Wiley and Sons, New York. 222 pp.

Monz, C.A.; Meier, G.A.; Buckley, R. C.; Cole, D. N.; Welker, J. M.; Loya, W. M. 1996. Responses of moist and dry arctic tundra to trampling and warmer temperatures. Bull. Ecol. Soc. Am. 77(3): 311.

Sun, D. and Liddle, M. J. 1991 Field occurrence, recovery and simulated trampling resistance and recovery of two grasses. Biological Conservation. 57: 187-203.

Wagar, J.A. 1964. The carrying capacity of wild lands for recreation. Forest Science Monograph 7. Society of American Foresters, Washington, DC.