Yosemite National Park Trampling Study

Final Report

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Introduction and Project Scope

Recent trends in outdoor recreation in the United States suggest that public interest in nature-based recreation and appreciation of natural areas continues to grow (Cordell 2008). Participation in most outdoor activities has increased significantly since 1960 with activities such as camping, hiking, mountaineering and skiing increasing as much as tenfold during this time (Cordell and others 2008). Associated with rising visitation are human disturbances and impacts to the environmental conditions of national parks, forests, and wilderness areas. Understanding these resultant impacts and the thresholds of tolerance of ecosystems to human use and disturbance are key components of contemporary park capacity management frameworks.

This "Final Report" presents results from a recent study of vegetation responses to experimental trampling disturbance in select locations of Yosemite National Park (YOSE). Overall, the project builds on an existing program of research (Leung et al., 2011) and planning (Bacon et al., 2006) in YOSE via an experimental trampling study conducted in riparian areas to determine their tolerance to recreational use.

Significance to Yosemite National Park

In 2004, Yosemite National Park began the User Capacity Management Program for the Merced River corridor, using the Visitor Experience and Resource Protection (VERP) framework. The VERP framework employs indicator variables and monitoring protocols for both ecological and social conditions at locations within the river corridor (Bacon et al., 2006). Two important suites of indicators examine informal trail formation on Yosemite Valley meadows and persons at one time (PAOT) at riverbank locations. Recent research has examined the location, extent and intensity of resource changes to meadow locations (Leung et al., 2011), but currently no work has examined the functional tolerance of the meadow areas or riverbank locations to alterations in visitor use behavior or intensity. This project was conduced in close collaboration with other related research in Yosemite (Walden-Schreiner and Leung 2011).

Methods

Riparian (riverbank) environments

The trampling study was conducted in two vegetation types in riparian areas adjacent to the Merced River. We followed standard recreation trampling protocols developed by Cole and Bayfield (1993) and employed in numerous studies since (e.g., Cole 1995; Monz 2002; Cole and Monz 2002; Hill and Pickering 2009). While some related work has been conducted in similar environments (Monz et al., 2000) and in Yosemite along the Merced River (Madej et al., 2004), this work quantifies the use-impact relationship for these important and sensitive areas.

Four replicates of five levels of trampling disturbance were applied in small experimental trampling lanes (1.5m x 0.5m). Locations were purposively selected based on the suitability of application of trampling and homogeneity of the vegetation. Each replicate block consisted of five lanes; control (undisturbed), 25, 75, 200 and 500 trampling passes. A pass is a one way walk conducted with at a natural gate along the lane by a person weighing 55–75 kg and wearing a lug sole boot. Treatments were applied once during July 2011. Measurements were taken pre and two weeks post disturbance and final measurements were taken one year later in July 2012. In this report we present both initial *resistance* of the vegetation to trampling disturbance, and subsequent measurements of regrowth one year later allow for the determination of overall *tolerance* to disturbance. Specifically, measurements conducted pre and post disturbance consisted of visual estimates of canopy coverage of each vascular plant species (only green material) and of mosses and lichens; independent ocular estimates of bare ground; soil penetration resistance measured with a pocket type soil penetrometer; and measurements of average vegetation height assessed with fifty random measurements from the ground surface to the standing height of the vegetation. We also obtained nadir overhead digital images of each plot at each assessment as an archival record of conditions. These images can also be analyzed with image analysis procedures to verify and calibrate ocular estimates if needed.

Findings and Discussion

Experimental Trampling in Riparian Environments

Although there is a significant literature on the resistance and resilience of plant communities (e.g., Cole 1993, Monz 2002, Hill and Pickering 2009 and others) and this information has been synthesized across some ecosystem types (Cole 1995; Hill and Pickering 2009), site-specific information on the response of plant communities to human disturbance is often desirable for management decisions. This specific information is particularly useful for land managers developing use regulations, visitor capacities and educational practices. Applied trampling studies, such as the approach used here, do not exactly mimic disturbance from actual visitor use, but do provide an effective means for examining the responses to recreational disturbance while controlling or evaluating the influence of extraneous variables. This approach can therefore provide an index by which to base visitor use and capacity management decisions (Cole and Bayfield 1993).

The degree to which a plant community can support human use is a combination of the ability to resist the initial disturbance of trampling and its subsequent capacity for re-growth. The property of withstanding initial disturbance is most often referred to as resistance (Cole and Bayfield 1993) though Grime (1979) called this property inertia. In this experiment, resistance was determined by measuring plant properties approximately ten days after the applied trampling. A post-disturbance waiting period is needed before assessing resistance to accurately discern viable plant tissue from damaged material.

Resilience has been used commonly in the literature (Grime 1979; Cole and Bayfield 1993) to describe the ability of an ecosystem to recover from disturbance. Here, resilience was assessed by comparing the relative cover after disturbance with the relative cover after one year of recovery. Tolerance is another useful measure employed by Cole and Bayfield (1993), that characterizes the ability of vegetation to both resist and recover from disturbance. Tolerance was assessed in this study by determining the maximum number of passes resulting in at least 80% relative cover approximately one year later. In this work, responses of groundcover vegetation to trampling disturbance were assessed in two vegetation types (meadow and forest understory) in areas proximate to the Merced River.

The meadow groundcover exhibited a relatively high resistance and a considerable capacity for regrowth as is typical with graminoid-dominated environments (Figure 1 and Table 2). At one-year post disturbance, trends of all trampling treatments show a substantial ability of the vegetation to regrow, indicating a high degree of resilience and ultimately, tolerance to disturbance. Forest understory groundcover (Figure 3) appears to be somewhat less resistant than the meadow areas based on overall vegetation cover. For example, forest groundcover required only 75 trampling passes to reduce relative cover to 50%, while meadow areas required 140 passes to show a similar level of cover reduction (Table 2). This vegetation type demonstrated considerable resilience, however, with all levels of disturbance demonstrating considerable regrowth (Figure 3). It is not uncommon for disturbance to stimulate growth in the first year following trampling. This phenomenon has been previously reported in the trampling literature in other vegetation types (Monz 2002).

Individual species responses show the resistance of species present in all plots at greater than 10% cover (Figures 2, 4 and Table 1). Across both vegetation types, *Stachys albens* in the forest plots was the least resistant, but the most resilient. Initial response to disturbance yielded a 50% cover loss with just approximately 50 trampling passes, but one year later considerable regrowth occurred. Both *Elymus glaucus* and *Carex lanuginosa* were moderately tolerant of trampling but *Carex* *lanuginosa* demonstrated more resilience, with a high recovery at both 200 and 500 trampling passes (Figure 2).

While vegetation cover is the primary response variable examined in may studies, we also examined vegetation height (Figure 5), bare ground, soil penetration resistance and species richness (Table 1). Examination of these parameters provides additional soil and vegetation characteristics up which to ultimately make management conclusions and suggestions. Responses of vegetation height in each vegetation type, indicate a significant "flattening" of the vegetation as a consequence of even low levels of trampling (Figure 5). This is particularly pronounced in the meadow vegetation and is a common response in tall, erect graminoids (e.g., Monz, et al., 2000). Lower levels of trampling less affected the forest understory. Both vegetation types exhibited considerable resilience in vegetation height, rebounding to at least pre disturbance levels one year later. Past studies have also reported a stimulation of growth for height, with some treatments being more than 100% one year later (e g., Monz 2002).

Bare ground and soil penetration resistance generally show significant increases in both vegetation types at both 200 and 500 passes immediately after trampling (Table 1). No differences among treatments were observed for these parameters one year later. Both before and after trampling, no differences in species richness were observed among the treatments. Variations in species richness from one year to the next are likely due to seasonal differences as similar increases were observed in control and trampled plots in both vegetation types.

Categorically, all of the regrowth data showed some variability across treatments and experimental blocks. Individual species data were particularly variable. While some degree of variability is expected with trampling studies, some of the results observed here suggest considerable seasonal variability in ambient conditions. We note that our initial season was exceptionally wet (summer 2011) and one year later was very dry. An examination of these plots again in 2013 to see if the recovery has stabilized may be worthwhile, as in past studies pre-disturbance conditions return after additional seasons of regrowth.

Conclusions and Management Implications

- An assessment of experimental trampling in meadow and forest understory environments suggests the meadow environments to be moderately resistant and highly resilient. The forest groundcover examined was of lower resistance and moderate resilience.
- The above results suggest t a high potential for tolerance of recreation use in the meadow groundcover. Moderate disturbances, provided there is limited disturbance to perennial plant structures, will likely be unnoticeable with a season or regrowth

- Forest understory environments, however, appear more susceptible to long lasting impacts, due to their limited regrowth in a one-year time frame, particularly at high disturbance intensities
- Low levels of disturbance affected vegetation height meadow community. This "flattening" of erect vegetation has a tendency to create informal trails that then attract additional visitors, thus increasing the potential for high levels of disturbance that may lead to longer lasting impact.
- Some variability and inconsistency in regrowth was observed, particularly in the forest understory vegetation type, one year following disturbance. This variability may diminish with subsequent seasons of regrowth.

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Figures and Tables-Experimental Trampling Results

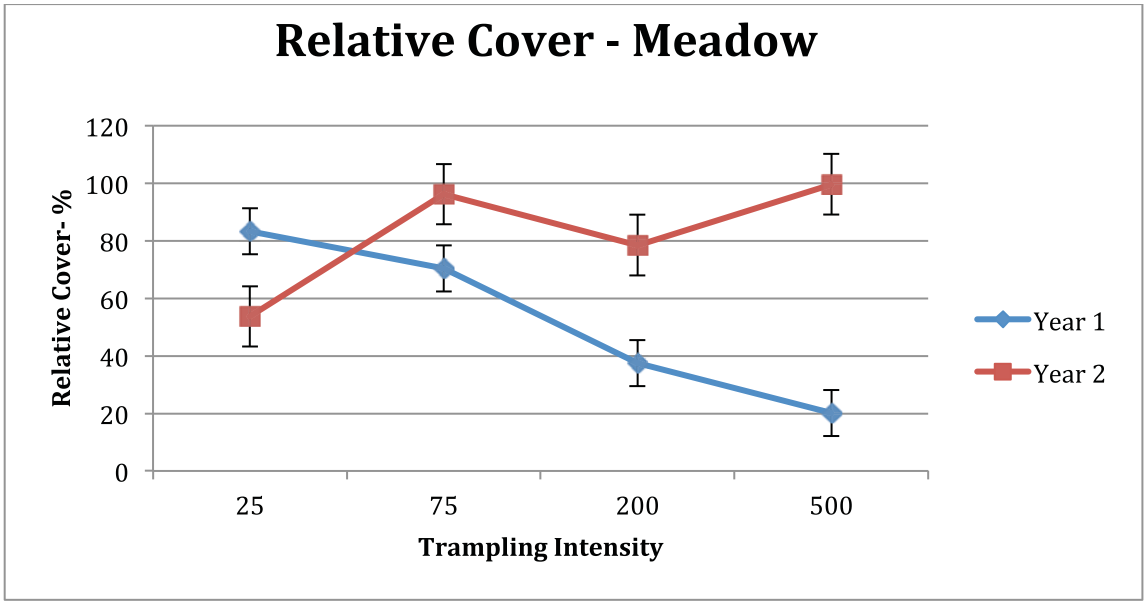


Figure 1. Experimental trampling results in the meadow vegetation type

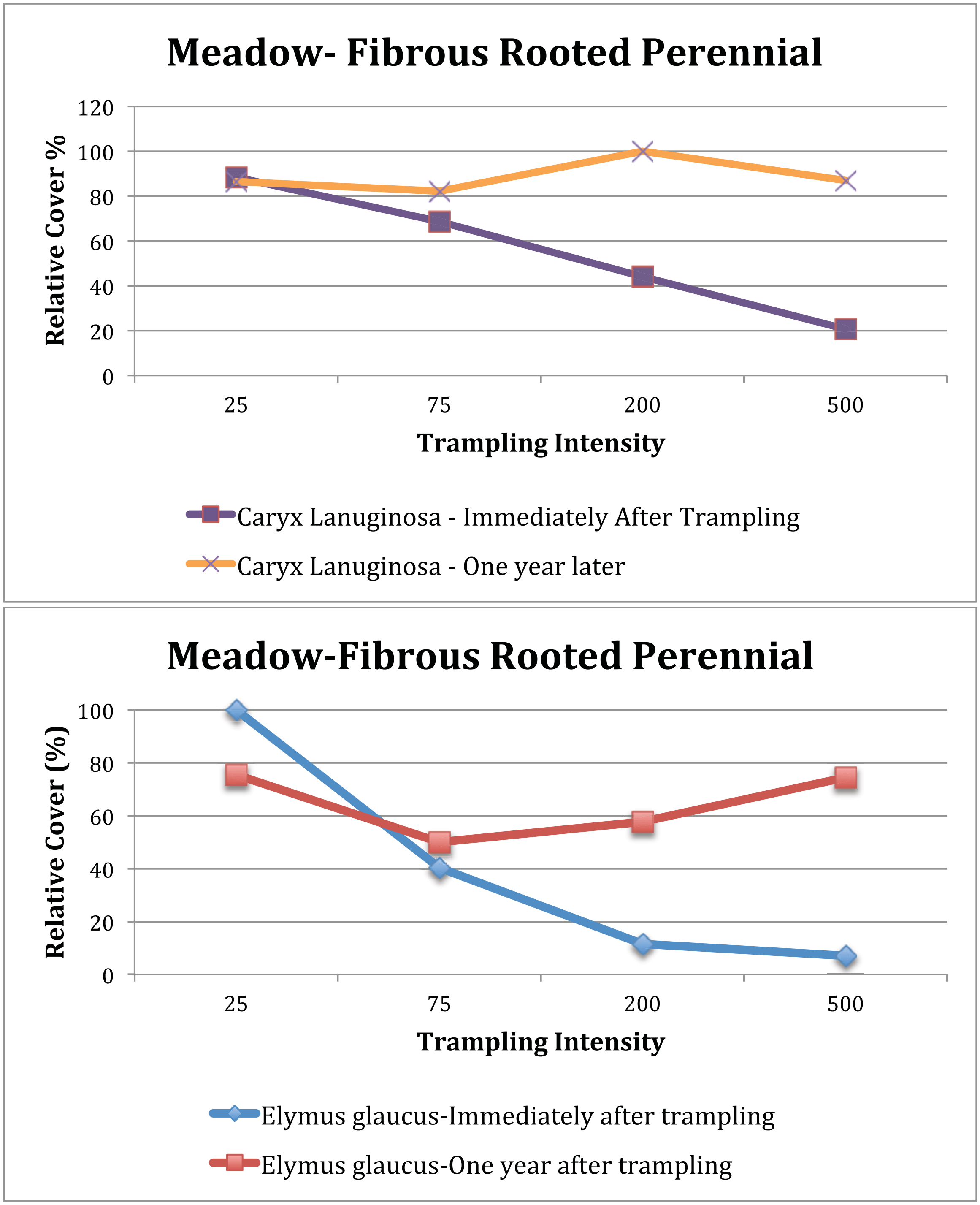


Figure 2. Experimental trampling results for select species in the meadow.

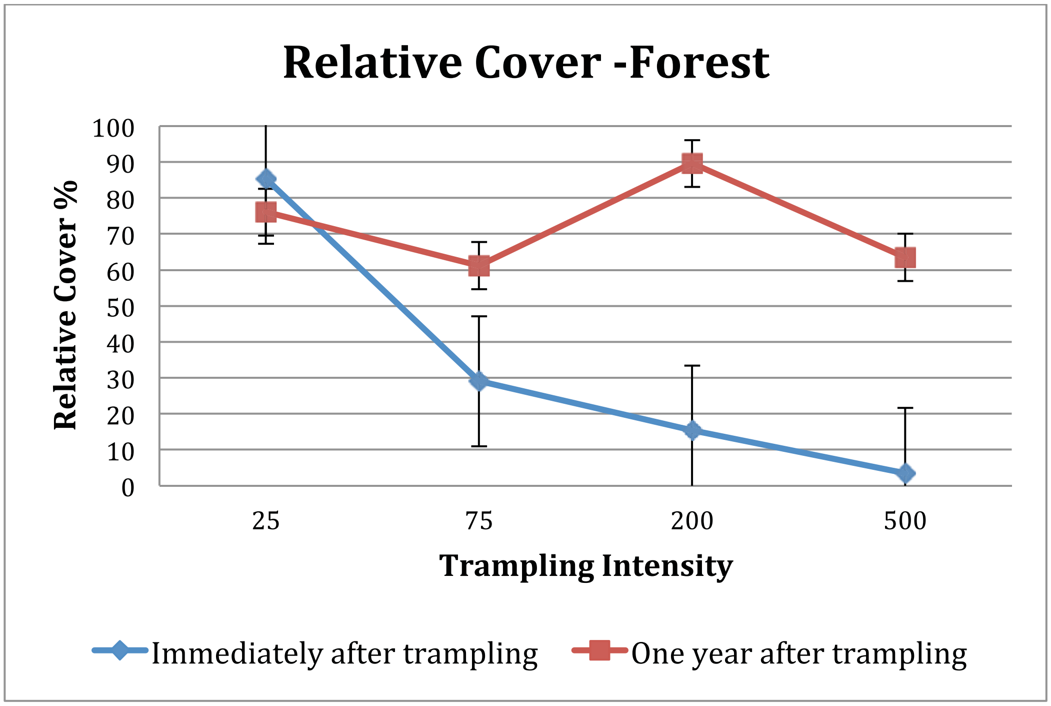


Figure 3. Experimental trampling results in the forest understory.

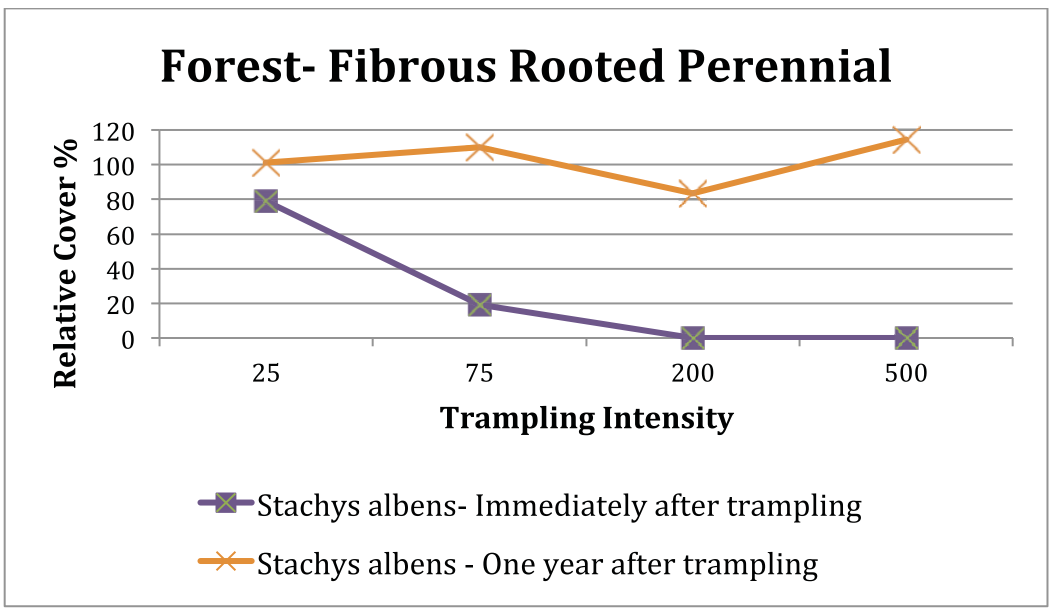
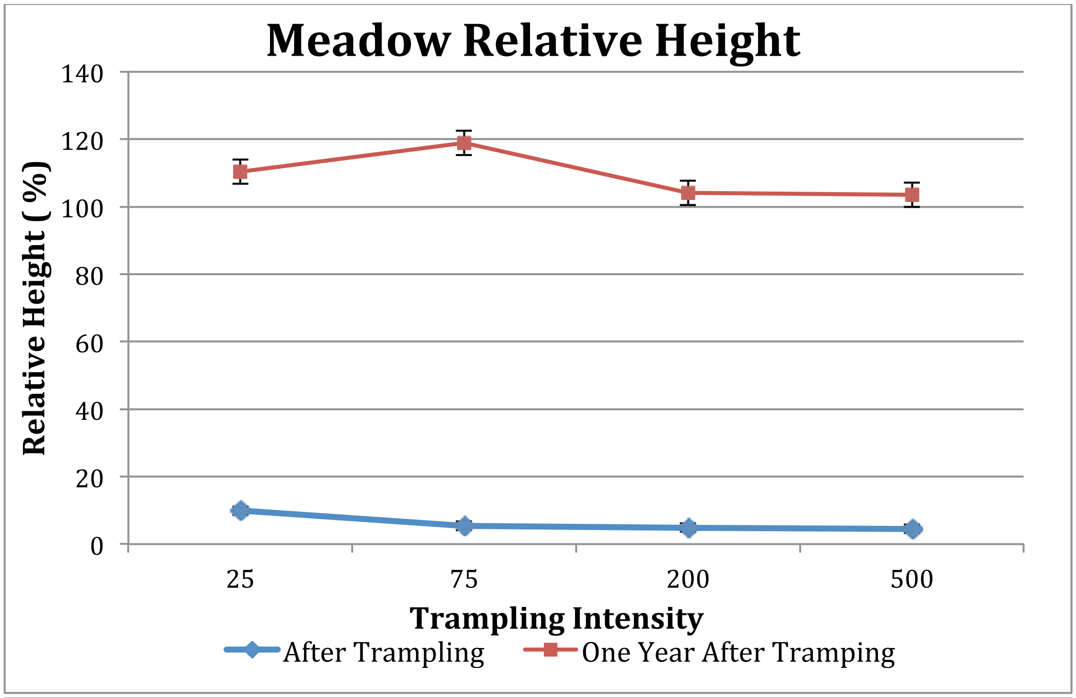


Figure 4. Experimental trampling results for select species in the forest understory.



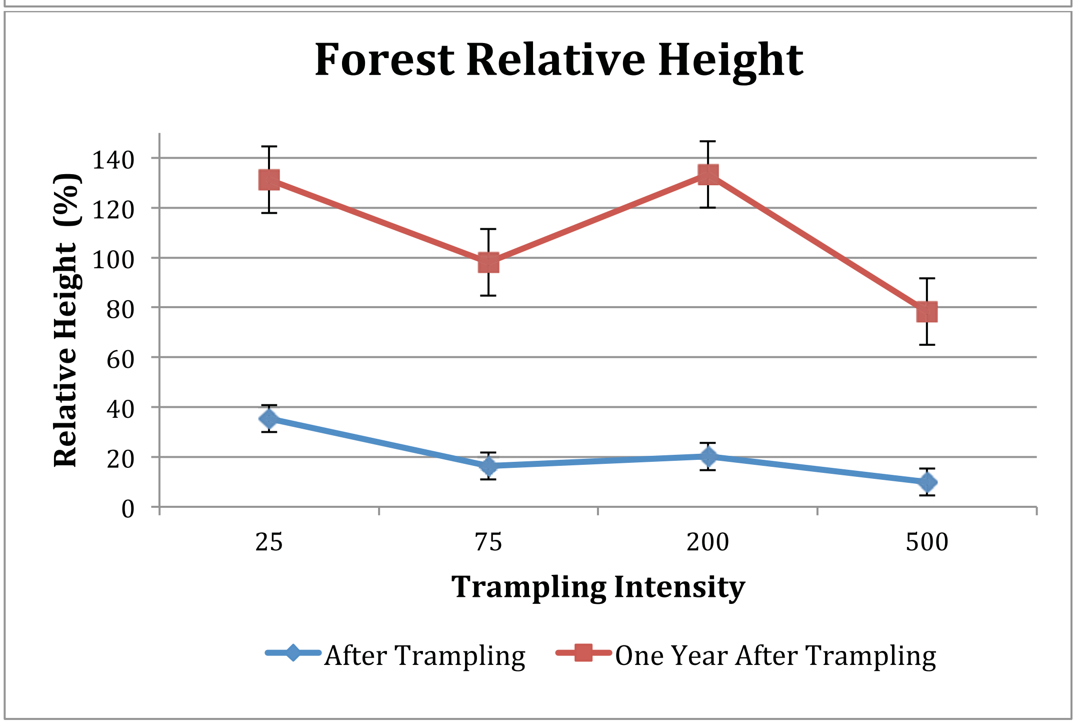


Figure 5. Experimental trampling results for vegetation height.

Table 1. Exposure of bare ground, changes in soil compaction and species richness due to trampling*

Treatment	After trampling			After 1 year of recovery		
	Bare Ground (%)	Soil Penetration resistance (kg/cm^2)	Species richness	Bare ground (%)	Soil penetration resistance (kg/cm^2)	Species richness
Forest						
Control	47.5 a	0.2 a	3.5 a	32.5 a	0.9 a	5.0 a
25passes	72.5 ab	0.2 a	3.5 a	37.5 a	0.7 a	4.0 a
75passes	83.8 ab	0.6 ab	3.8 a	42.5 a	1.1 a	4.0 a
200 passes	95.0 b	0.7 ab	3.8 a	30.0 a	1.2 a	5.5 a
500 passes	97.5 b	1.1 b	2.8 a	45.0 a	1.8 a	5.8 a
Meadow						
Control	60.0 ab	0.7 a	1.8 a	50.0 a	1.1 a	2.8 a
25passes	35.0 a	1.0 ab	2.0 a	60.0 a	1.3 a	3.0 a
75passes	62.5 ab	1.0 ab	2.0 a	52.5 a	1.5 a	3.0 a
200 passes	80.0 b	1.3 b	2.0 a	47.5 a	1.7 a	3.0 a
500 passes	92.5 b	1.4 b	2.0 a	50.0 a	1.8 a	3.3 a

*Means not followed by the same letter are significantly using ANOVA with Scheffe's post-hoc test test at α=0.05

Table 2. Indices of resistance and tolerance for vegetation types and species examined.

Vegetation Type/Species	Resistance Number of passes resulting in 50% cover loss	Tolerance Maximum number of passes leaving at least 80% cover 1 year later
Meadow		
Overall	140	500
ELGL	110	75
CALA	180	200
Forest		
Overall	75	200
STAL	50	500