HUMAN IMPACT ON THE ALPINE ECOSYSTEM OF MOUNT RAINIER

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Progress Report Submitted to Mount Rainier National Park

Contract No. CX-9000-3-E060

December 12, 1984

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PURPOSE OF THE STUDY

The purpose of this study is to determine the requirements for long-term survival of alpine plant communities on Mount Rainier and to seek ways to minimise adverse human impacts upon them. An important goal is to establish acceptable levels of environmental condition, especially at campsites and other impacted areas. This will provide an objective basis for management and provide a way to measure the success of management manipulation.

INTRODUCTION

Phase I (1983) of the project entailed design of a new monitoring system to assess the long-term growth patterns and requirements of the vegetation of the alpine zone and the long-term consequences of visitor activities in the alpine habitats.

Phase II (1984-85) of the project had the following objectives:

1) Set up long-term sampling plots.
2) Prepare inventory of campsites.
3) Document recovery of vegetation at campsites.
4) Document changes in extent of heather meadows.
5) Determine principal natural factors affecting plant survival.
6) Make recommendations for possible management actions that may be used to minimise the impacts of park visitors on alpine ecosystems.

This year's report records progress and findings from the first field season of Phase II. All of the pilot plots set up during Phase I were revisited to field-check the new system for its appropriateness, practicality and durability. Additional plots were set up around Muir Snowfield to expand the range of habitats monitored there. Permanent plots have now been laid out in the fellfields at 7000, 7400, 7600 and 8600 feet elevation and in the heath

meadows at 6500, 7000 and 8000 feet. Next, work has begun to monitor and assess the condition of the other major alpine localities around the mountain. A long spell of fine weather enabled surveys of Upper Spray Park, Ptarmigan Ridge, Curtis Ridge and Burroughs' Mountain.

PROGRESS, PHASE II

Long-term Sampling Plots

To date 13 permanent plots have been set out (11 around the Muir Snowfield and one each at Upper Spray Park and Curtis Ridge). Of these, 11 were laid down in the same community as were plots from an earlier survey in 1978 (Edwards, 1980). While the precise placement of the individual quadrats was not the same, the percent cover of the vegetation and substrate were measured each time using the same criteria. Thus, comparisons can already be made which suggest trends in habitat condition over the past eight years, (Table 1 1). In the future, comparisons will be more accurate because the individual quadrats can now be re-measured at intervals.

Campsite Inventory

1) Upper Spray Park: The corridor leading to the edge of the Flett Glacier was searched for campsites. Several small bare areas were found which could well have been used occasionally as campsites, but, as there was little impact, these sites were neither recorded nor photographed.

In contrast, a conspicuous and well-worn campsite was found near the lower edge of the Flett Glacier, situated directly on the main traffic corridor up to Observation Peak and then Ptarmigan Ridge. It is an area of interweaving social trails, seemingly a popular endpoint for hikers. This campsite was inventoried and photographed on 8/21/84 and given a Condition Class of 7

TABLE 1: Comparison of components of heath meadows in the Muir Snowfield-Paradise locality from transect surveys made in 1978 and 1984.

COMPONENT	PERCENT COVER VALUES					
	Study Area #7 Permanent Plot #7 (Mature Meadow)		Study Area #7 Permanent Plot #8 (Mature Meadow)		Study Area #8 Permanent Plot #11 (Young Meadow)	
	1978	1984	1978	1984	1978	1984
Stone	0	0	0	0	30 ± 14	31 ± 18
Gravel	0	0	0	0	20 ± 11	9 ± 12
Bare Soil	13 ± 13	10 ± 9	3 ± 8	26 ± 25**	8 ± 5	2 ± 5
Litter/dead plant	9 ± 6	16 ± 9**	13 ± 8	18 ± 12	1 ± 4	2 ± 3
Moss/lichen	0	4 ± 8	0	3 ± 3	7 ± 4	27 ± 15**
Total Plant	80 ± 15	69 ± 18**	84 ± 13	51 ± 21**	34 ± 14	29 ± 26
Dominant heathers	60 ± 21	54 ± 20	81 ± 14	34 ± 13**	26 ± 2	25 ± 24
Increasor Spp.	<1	8 ± 4**	2	13 ± 6**	1	2 ± 4
Minor Spp.	3 ± 2	3 ± 3	1	4	7 ± 5	2 ± 2
Lupinus latifolius	14 ± 11	4 ± 7**	<1	0	4 ± 4	3 ± 4

** Difference between years significant at 0.05 level, Mann-Whitney U-Test, normal approximation.

for the tentpad (substrate stabilized but frost-lifing between stones) and 9 for the adjacent ground (some vegetation regrowth substrate stabilized).

The campsite nestles against large boulders on one side and opens onto densely-turfed sedge meadow and fellfield communities (Figure 1). Previous deterioration at the edge of the sedge meadow had been effectively halted (date unknown) as follows: an area ca. 20 m^2 had been tightly paved over with flat stones, between which a dense planting of exotic fescue had effectively stabilized the soil beneath. Small plants of native species (sedges, aster, Luetkea) were seen and the rehabilitation was thereby considered to have been successful.

We found that the total area impacted by this campsite covered 48 m^2, of which less than 9 m^2 was occupied by the tentpad. A low pile of stones bordered the tentpad. A new permanent plot, #9, was set out 12 m away to monitor future changes in the fellfield habitat.

This campsite was re-visited on 9/9/84 and again on 9/21/84. At some time between 9/9/84 and our initial visit, several modifications had been made. These are shown in Figures 2, 3 and 4. Stones and gravel were moved to clear space for a second tentpad (6 m^2), and a third, smaller area - possibly a cooking center. Alongside all of this, a massive wall, extending 8 m long x 1.2 m high and containing more than 600 stones, had been built. This new wall lies over ground that was previously vegetated. It completely obliterates the rehabilitated part of the sedge meadow. Many stones were lifted out of the fellfield (Figure 5). Many individual plants were uprooted, exposing roots to desiccation and soil to erosion (Figure 6). The total area now impacted is 138 m^2. Our second visit, on 9/9/84 after a snowstorm, showed how the wall had modified the local microclimate (Figure 4). On 9/21/84 there were extremely strong winds and we found that the wall gave minimal protection to the tentpad areas. Before the wall, Condition Class for the tentpad was 7 (soil

stabilized but frost-lifting between stones); 7 for the adjacent ground (some vegetation growth). After the wall, Condition Class for the tentpads was 6 (active soil erosion) and 5 for the adjacent ground (drastic alternation, plants destroyed except at protected places).

2) Ptarmigan Ridge: A 1979 survey of Ptarmigan Ridge (Edwards, 1980), found that due to the rubbly scoriaceous substrate on the ridge, the soils were droughty and very poorly developed, and that consequently, vegetation was extremely sparse, being confined to local seepages or bedrock exposures. At that time there seemed to be little incentive for visitors to leave the narrow social trail that led along the ridge crest, so that what little vegetation did exist, was well protected from trampling. Four tentsites were recorded in 1979.

Now, five years later, little seems to have changed. An excpetion is that the stone wall of the most strategically placed campsite has been extended so that it now completely encloses the tentpad area, (Figure 7a, b). At this time, inpact, on existing vegetation or on its potential development, is considered to be minimal.

No new campsites have been built within the elevation range of plants on the ridge.

3) Curtis Ridge: In contrast to Ptarmigan Ridge, Curtis Ridge arises from a quite low elevation, ca. 6000 feet, above Moraine Park and Mystic Lake, and is wider, more gently sloping and has a greater variety of plant habitats and species. In the 1979 survey, 10 campsites were found, three at the junction of the ridge-crest trail with Mystic Lake and seven at the climbing route turnoff to Liberty Ridge. At that time, a well-worn social trail led along the ridge-crest and off-trail trampling was deemed insiginificant in its effect on the vegetation.

Since 1979, off-trail trampling has increased so that now footprints occur all over the gentler slopes (potentially vegetated) of the ridge, up to 8500 feet. During this year's survey, 18 campsites were found and described as follows:

The same three platforms lie on the morainal ridge at the junction with Mystic Lake. There is no significant impact associated with them as they have been leveled out in sandy barren areas.

Seven campsites were again found at the place where the standard climbing route leaves Curtis Ridge to cross the Carbon Glacier to Liberty Ridge, ca. 7500 feet (Figure 8). It appears that no new camps have been added here. However, five camps now have enclosing walls, instead of just two in 1979. The total area of the seven campsites occupied 38 m^2. At this location, the ridge is broad and its slope gentle; vegetation is sparse but widely spread. Eight species were tallied. Although a few plans grow at the margin of each campsite, and are consequently at risk, plants in the general vicinity appear to be adequately protected; the stones are stable around them.

Permanent plot #10 was laid out nearby, its upper endpoint 5 m downslope from the lowermost campsite in the gorup. Plants along the transect line were not discernably affected by trampling or removal of stones. The number of individual plant clumps measured in the plot averaged five per m^2. Since the total area of all seven campsites was 38 m^2, we can estimate that the number of plans lost during their construction to be ca. 190 (this number does not include additional plants lost when stones were collected to make the walls). Thus, even though plant cover is low (1.9 percent), extensive campsite construction soon accounts for considerable loss in numbers of plants.

Eight campsites were found well beyond the climbers' turnoff to Liberty Ridge. Of these, six were beyond the end of the lateral moraine and above the vertical cliff of Upper Curtis Ridge. None of them were discovered during the

1979 search. A group of four camps occupies a total area of 20 m^2 (Figure 9). Vegetation here is very sparse (less than 1 percent) but consists of 12 species. None of these are threatened or endangered but the comparatively high number suggests a favorable habitat. Further up the ridge, at ca. 8500 feet, two more walled camps occur. Vegetation here is also very sparse, with just five species, and the substrate is coarse and stony. While none of these new, higher elevation campsites pose an immediate threat to the surrounding vegetation, their appearance suggests an increase in camping activities on this part of Curtis Ridge.

Many social trails now criss-cross the upper part of the ridge. These were not conspicuous in 1979. While direct harm to individual plants is not yet discernible, the increased cross country trampling with its consequent disruption of the soil, may yet exert an adverse effect on the future spread of plant clumps and on seedling establishment. Because the roots of these high alpine plant species typically extend up to two meters away from the clump, trampling within this distance is potentially damaging. It may now be an appropriate time to develop one of these social trails in order to concentrate the visitor traffic and better protect the plant habitat.

Recovery of Vegetation at Campsites

In short, there has been none. Around the Muir snowfield, campsites known to have been made between 1975-1980 have, since that time, been periodically searched for evidence of recolonization. The campsites found on Ptarmigan and Curtis Ridges in 1979 were similarly searched this season.

In no campsite, with without NPS rehabilitation (in 1979, between McClure and Little Africa around the Muir Snowfield), has plant colonization, either by seedling establishment or vegetative spread from existing colonies, been

observed on any sector of the mountain. Since 1975, plant establishment anywhere in the alpine zone has been extremely rare by seedlings and extremely slow by vegetative spread of existing plants. The only exception is the alpine lupine Lupinus lepidus (see page 11). It may be pertinent that the most recent widespread establishment of the subalpine fir, Abies lasiocarpa, into the subalpine zone, took place in the 1930's and has been generally attributed to the peculiar regional climate that prevailed during that time. If other mountain plant species respond to similar environmental stimuli, this could explain the absence of their recent establishment by seedlings. It is concluded that seedling establishment, for whatever reason, is a rare event in the alpine zone and consequently, we cannot expect any lost vegetation to be soon replaced.

Changes in the Extent of Heath Meadows

This year, three permanent plots were set out in the Muir Snowfield - Paradise Locality - to monitor future changes in the development and extent of the heath meadows. The three plots were set in the same communities analyzed in 1978 (Edwards, 1980). The positioning of the 1984 transect lines approximated those of 1978. Data from 1978 and 1984, for each of the three communities, is sumarized in Table 1 and confirms changes in the heaths since 1978 that were apparent from field observation in 1984. (The changes are statistically significant at 0.05, Mann Whitney U-Test, normal approximation.) Furthermore, the trends recorded in the data sets of all three communities can be explained in terms of environmental constraints on community development (Edwards, 1980). The results from this eight-year period give confidence that in future years, through regular monitoring, we should be able to recognize trends in community development, to distinguish between the effects of visitor and natural perturbations and finally, to apply these insights to a rational

management program.

1) The first heath community is in Study Area 7 (Edwards, 1983) and lies immediately above the trail that runs along the cliff-face of the Skyline Trail at Panorama Point, and to the west of the established trail to Pebble Creek, ca. 6900 feet. It is an old, mature heath community, established about 10,000 years ago, as estimated from the relative positions of datable ash layers in the soil profile.

Permanent Plot #7 was set out in the most western end of this community, overlying the transect line of 1978 (Study Site 43). There has been no significant change in percent cover of the dominant heather species (Cassiope mertensiana, Phyllodoce empetriformis, P. glanduliflora). Decline in the total vegetation cover (80 to 69 percent) is attributed to decline in the cover of Lupinus latifolius (14 to 4 percent), which in turn can be explained by the particularly late spring of 1984, which greatly delayed the sprouting and growth of the lupines. Bare soil (the danger signal for irreversible damage in heath communities), has not increased, being well-protected by an increased litter cover (9 to 16 percent), and to the "increasor" species (Luetkea pectinata, Carex spectabilis, Antennaria alpina, and Aster alpigenus) which have made a modest gain (1 to 8 percent). This part of the community is considered, for the moment, to be comparatively stable, despite the changes in some of the components. The declining cover of the dominant heath species however, merits further monitoring. Several explanations could apply: random sampling error; effects of trampling pressure: a heather vole over-grazing episode: abnormal winter killing of the shoots; or effects of increasing regional acid rain precipitation.

In the past, alpine heath communities on Mount Rainier have shown no capacity for self-repair after perturbations that exposed bare mineral soil

(Edwards, 1980). This failure is strikingly evident from a comparison of Figures 10a and 10b which show a series of bare areas in this meadow, first photographed in 1976 and again in 1983. Many footprints attest to chronic trampling through the meadow. The slope is gentle here, so there has been no gully erosion. Neither has there been any regrowth or seedling establishment of any species whatsoever since at least 1976. If the present patterns and pressures of visitor activities continue, it is predicted that deterioration of this part of the meadow will continue as the bare patches expand by wind and meltwater erosion, until eventually, the heath vegetation will be lost.

In the segment of this heath community which lies near the turnoff to the Pebble Creek trail, more drastic deterioration has occurred since 1978. This has been caused by repeated short-cutting down the cliff-face and by avoidance of the very steep and slippery path at the trail junction during the years before the new stone steps were installed. Figures 11, 12 and 13a, b show the deeply eroded gullies that have formed as a result. Figures 14a and 14b show where a large patch of vegetation disappeared in a single year. This part of the old meadow must now be considered beyond repair. It stands as evidence that trampling of the heath meadows to the extent that bare soil is exposed and begins to erode, leads to a permanent loss.

2) The second heath community surveyed also lies in Study Area 7, but to the east of the Pebble Creek turnoff at Panorama Point from the Skyline Trail. It has the same age and past development as the first community above, and the same number and kinds of species. It is well away from the short-cut and established trails area and consequently has not suffered massive destruction. However, chronic trampling is extensive and takes place from early spring as soon as snowmelt opens up the meadow, by visitors wandering cross-country between the many social trails that criss cross in the vicinity.

This community is biologically significant in that the endangered species

Cassiope stelleriana is a component. (It is one of the few locations on the southern part of the mountain, and Mount Rainier is the most southern limit for the species).

Permanent Plot #8 was set out, overlying the transect line of 1978 (Study Site 35). Significant cover changes are as follows: Bare mineral soil has increased from 3 to 26 percent. This increase is considered a danger signal because bare soil preceeds irreversible erosion. Total vegetation cover has declined from 85 to 51 percent wiht cover of the dominant heathers down from 82 to 34 percent. Despite the great reduction in the vegetation cover, there has been no significant increase in the litter layer; had there been a compensatory increase, the additional litter might have protected the increased bare soil. Herbaceous "increasor" species, which might also protect the bare soil, have advanced from 1 to 13 percent. Cassiope stelleriana has declined from 3 to 0.6 percent. The surviving clumps of the dominant heathers are now badly worn and bear few new shoots. In comparison with the greater vigor of the heathers in Plot #7 described above, the poor condition of the heathers in Plot #8 strongly suggests that their decline is attributable to chronic trampling rather than to natural causes. Unless there is a change in patterns of visitor use, I expect this community will soon be lost. Figure 15 shows the eroding, trampled margin of the community.

3) The third heath community surveyed lies at 6500 feet, east of the Skyline Trail at Golden Gate, on terrain recently exposed by the recession of the Paradise Glacier. The community is comparatively young (less than 200 years old) and shows many typical features of a stony fellfield at the same elevation. It was predicted (Edwards, 1980) that this community would develop towards a typical mature heath madow. Examination of the data sets for 1978 and 1984 (Table 1), suggest that this is the case. This heath lies away from

visitor paths and interests and consequently is not subject to their impacts. All changes are therefore interpreted as being due either to events in the natural environment, to competitive interactions between plant species, or to selective grazing.

Comparison of the two data sets indicates an increase in community development. The declining gravel-bare soil component, 28 to 11 percent, is replaced by increasing moss-lichen cover (an ideal seed bed for the heather species) from 7 to 27 percent.

Natural Factors Affecting Plant Survival: *Lupinus lepidus*

In 1975 many dying and dead alpine lupine (*Lupinus lepidus*) plants were found. The losses were due to an epidemic of moth caterpillars which ate out the crowns and killed many individual plants. The epidemic persisted three years, after which attack was negligible. The lupine population has since recovered with greatly increased numbers since 1978, and thus increased cover in all its habitats.

This wide fluctuation in lupine numbers may be a natural cyclic phenomenon, in which case it underscores the necessity for recording the life history status (autecology) of individual species on a long time scale and taking into account the dynamics of individual species in a survey of the entire community. Table 2 shows the percent cover of *L. lepidus* in the study plots recorded in 1978 and again in 1983-1984. In each case there has been an increase in the lupine cover.

Table 3 summarizes changes in a fellfield at Panorama Point (permanent plot #6, 1984; Study Area 21, 1978). This area has suffered conspicuous trampling damage since 1978 - the established trails here are ill-defined and easily confused with the myriad social trails. However, the impact is not apparent in the data sets if only the percentages for the total cover of the

TABLE 2: Comparison of percent cover of *Lupinus lepidus* in fellfield study plots, recorded in 1978 and again 1983-84.

Plot description	Percent cover of *Lupinus lepidus* 1978	1983-84
SA1 McClure Rock	0.1 ± 0.3	0.3 ± 0.7
SA2 Below Sugar loaf	0.1 ± 0.2	0.5 ± 1.3
SA3 Panorama Point	5.0 ± 5.1	26.7 ± 22.7
SA4 Little Africa	0.2 ± 0.7	10.3 ± 9.8
SA5 7,600 ft. el.	less than 0.1	0.6 ± 1.0
SA6 8,000 ft. el.	less than 0.1	0.6 ± 1.0

TABLE 3: Comparison of percent cover of community components, between 1978 and 1983-84, in a fellfield community at Panorama Point. Note the greatly increased cover for *Lupinus lepidus* in 1984.

Community component	1978	1984
Stone-gravel-bare soil	33	37
Total vegetation	44	46
Lupinus lepidus	5	27
Other dominant species (above 3 percent cover)	37	17
Minor species (below 3 percent cover)	3	2

vegetation and bare soil are considered, because neither of these have changed significantly, and, from the figures alone, it could be inferred that the community has been stable. However, closer examination shows that there has been considerable change in the component species. For instance, the dominant species have declined 20 percent while the lupines have increased 22 percent. Field observation revealed that the lupines did not overlay or displace the other species and thereby mask their presence and reduce their recorded cover value, but the lupine seedlings for the most part, had invaded bare soil. Therefore, the most likely interpretation of events since 1978, is that the dominants have indeed declined and made available 20 percent cover of bare soil which new lupine seedlings have recently colonized.

The lupines are unique in the alpine zone flora in that they are short-lived and germinate readily from seed into bare soil. It remains to be seen whether their increased cover can stabilize the bare soil before the next caterpillar epidemic wipes them out again.

From this example, it can be seen that the value of the total vegetation cover in these habitats could easily be misinterpreted on the basis of the increase of a single species which has responded independently to a specific event, and not at all to the prevailing environment nor to visitor impact. The discovery of the lupine fluctuations is clear evidence that changes in vegetation cover do occur and that unless these changes are carefully interpreted by a trained observer, meaningless and misleading conclusions can easily be drawn from the results. While the data collecting process can be performed with relatively little training, it is imperative that the results be interpreted by an adequately experienced ecologist.

Interim Recommendations for Management Actions

Fellfield Communities: In the fellfield communities campsite construc-

tion, and cross-country trampling are the two main sources of visitor impact.

Campsite construction is most disruptive in habitats favorable to plants, i.e. those which have fine-textured, moisture-holding soil and abundant individual stones of 20 cm diam. or more to act as seedling and root-run shelters and where it is accompanied by stone wall-building. Stone-lifting destroys both the current habitat as well as the potential one for future colonization and affects an area more extensive than that actually occupied by a campsite. It initiates soil erosion on steep slopes.

Campsites are least disruptive where they are made on sandy soil, or coarse, rubbly substrate, two environments unfavorable to plant colonization or where they occupy areas not normally snowfree before the first week in August, the cut-off date for an adequate growing season.

I consider the above criteria to be useful in determining the location of a minimal impact campsite.

Trampling cross-country on the fellfields does not necessarily initiate soil erosion because the stones and gravels are soon reorganized into a new surface that is resistant to wind, frost and meltwater, (Figure 16a, 16b). Trampling may, however, exert a long-term, adverse effect on the vegetation which is extremely slow-growing and long-lived. Persistant trampling abrades the established plants, disrupts the soil texture in the rooting zone (which typically extends two meters away from the plant clump) and disrupts the surface soil which in turn jeopardizes survival of new seedlings. None of these impacts may be at all apparent to a casual observer but I predict that they will inevitably lead to a decline in the fellfield vegetation.

Examination of many of the fellfield areas, especially those around Panorama Point, Curtis Ridge and Burroughs' Mountain, reveals extensive areas with footprints all over the soil surface. On the basis of field work this season, I recommend that consideraton be given to improving a few strategical-

ly routed social trails, obliterating the rest and persuading visitors to keep to the trail.

The areas most urgently in need of attention are Panorama Point and Burrough's Mountain. Both these areas support a rich array of interesting alpine species. They lie in areas where the visitor population interested in natural history can readily hike to and study them. Finally, these habitats are unique in the Pacific Northwest, being at a higher elevation than plant habitats elsewhere in the mountains of the region. On this basis alone they merit protection from unnecessary damage.

Heath Communities: The heaths, unlike the fellfields described above, have no capacity to recover from impacts that result in exposure of the soil. Thus, the only way known to retain them is to prevent such impacts. The only recommendation is to route all visitor traffic away from the heath communities at all times following snowmelt, and in all places.

The area most in need of urgent attention is around the top of the Panorama Point cliff face where chronic trail short-cutting continues to cause extensive losses to all the heath meadows.

Reference

Edwards, O.M. 1980. Vegetation of the alpine zone of Mount Rainier: an analysis of structure and human impact. Final Report to The National Park Service, Pacific Northwest Regional Office, Seattle.

Figure 1. Upper Spray Park, Campsite #3, on 8/21/84, view to SW. Observation Peak rises at the top left corner. The tentpad is at bottom left. The sedge meadow is below the figure and rehabilitated paving area immediately below that.

Figure 2. Upper Spray Park, Campsite #3 on 9/21/84, view to W. The original tentpad lies below the ice axe, the second new tentpad below the figure. The new stone wall (8 m long) extends behind the figure and lies on top of the rehab. area shown in Figure 1. Dark patches on the soil are from frost lifting.

Figure 3. Upper Spray Park, Campsite #3 on 9/21/84, view to S showing detail of end of the new stone wall and the third cleared area next to it. The second, new tentpad is at lower right, the new pile of stones at lower center. Dark patches are frost action.

Figure 4. Upper Spray Park, Campsite #3 on 9/9/84, view to W, showing detail of new stone wall. Snow from recent storm lies in the third cleared area and demonstrates effectiveness of the wall in changing the microclimate.

Figure 5. Upper Spray Park, Campsite #3 on 9/21/84, view to E, showing where stones were lifted from fellfield, plants were pulled out and roots exposed.

Figure 6. Upper Spray Park, Campsite #3 on 9/21/84, showing detail of damage to plant habitat. Stone lifting has exposed roots. Dark patch is frost-lifted soil. Quadrat frame is 50 x 50 cm.

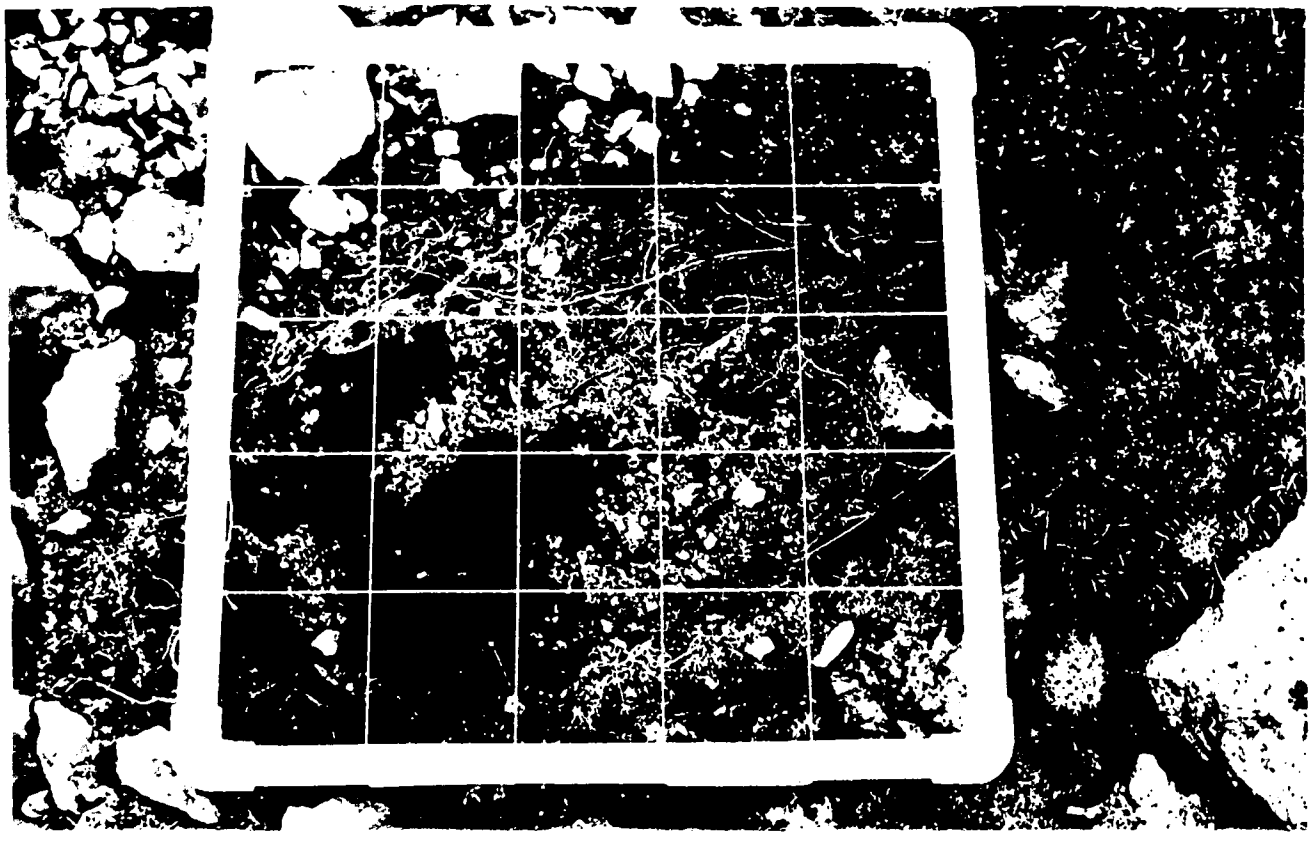

Figure 7a. Ptarmigan Ridge, Campsite #2 on 7/25/79, view to SE, showing wall behind tentpad. Substrate is rubbly, droughty and impact to vegetation minimal.

Figure 7b. Same view as Figure 7a on 8/22/84. Wall now completely surrounds tentpad. Well-used social trail follows up top left and along skyline.

Figure 8. Curtis Ridge, Camps #2 and #3, two of a group of seven, strategically situated where the standard climbing route leaves Curtis Ridge to cross the Carbon Glacier en route to Liberty Ridge.

Figure 9. Curtis Ridge, Campsite #11, one of a group of four newly discovered campsites situated above the vertical cliff of Upper Curtis Ridge and well beyond the climbing route turn-off to Liberty Ridge.

Figure 10a. Panorama Point heath community, August 1978, showing trampling damage due to trail chort-cutting, bare eroding soil and dead stems of heather plants.

Figure 10b. Same view as Figure 10a, but taken in September, 1983 (later date explains absence of flowers), showing increased soil erosion and dead stems. Note absence of colonisation by vegetation into the bare areas.

Figure 11. Panorama Point heath community near Pebble Creek trail junction, in August 1984, showing deeply eroded gully that has resulted from trail short-cutting.

Figure 12. Same heath community as in Figure 11, in August 1984, showing damage resulting from another short-cut route.

Figure 13a. Same heath community as Figure 11, in September 1978, showing deeply eroded gully resulting from trail short-cutting.

Figure 13b. Identical view to Figure 13a, in August 1984. The gully has deepened and loss of stones is evident. Heather patches in middle right are virtually lost in the ensuing six years.

Figure 14a. Same heath community as Figure 11, in August 1982.

Figure 14b. Identical view to Figure 14a but taken in August 1983. Comparison of these two figures shows the rapid deterioration of the heath meadow due to massive erosion induced by visitor trampling. The entire patch of heather, right of center in Figure 14a, was lost in a single year.

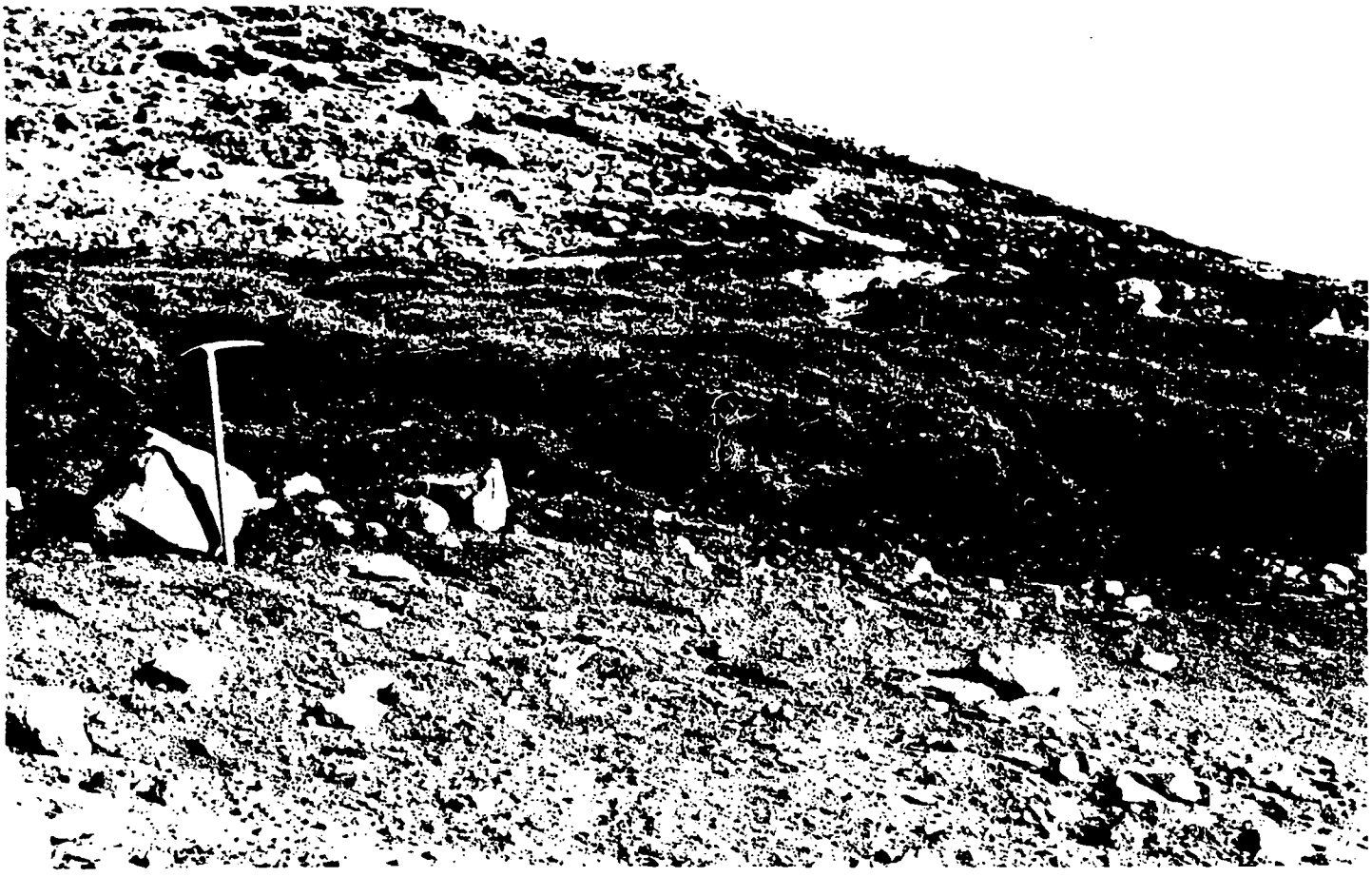

Figure 15. Panorama Point heath community, east of Pebble Creek trail, in August 1984, showing eroded, trampled western edge of the community, with deeply gullied social trail leading up the hill from it. Permanent plot #8 lies at right side of the trail.

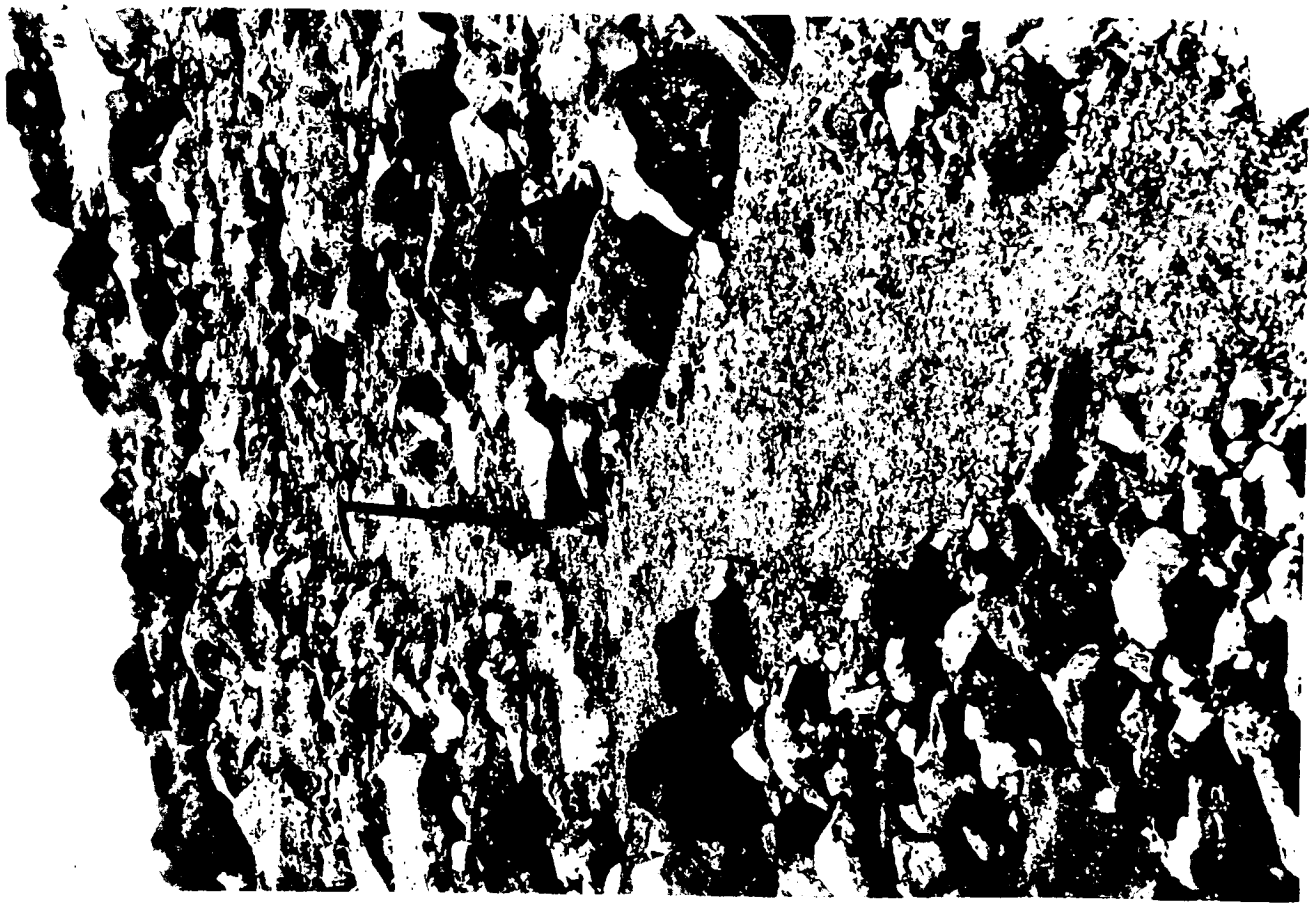

Figure 16a. Muir Snowfield Locality, Study Area #2 (above McClure Rock), in 1978. Social trail flooded by spring meltwater.

Figure 16b. Identical view to Figure 16a, in 1983. Many stones are in the same position as they were in 1978, 5 years earlier, attesting to the stability of the fellfield substrate, despite frequent foot traffic.