PROBLEM ASSESSMENT AND VEGETATIVE REHABILITATION OF VIEW POINTS AND CAMPGROUNDS AT BRYCE CANYON NATIONAL PARK

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INTRODUCTION

Bryce Canyon National park, like many other national parks in the United States, is showing the effects of increased visitor use. Because of the configuration of the park which places roads in close proximity to the unique geological features, visitor activity is concentrated at scenic overlooks on the rim of Bryce Canyon. Intensive use of scenic view areas (Figure 1) and campground facilities (Figure 2) results in soil compaction and vegetation damage which accelerate soil erosion and decrease aesthetic quality.

The effects of visitor use on soils and vegetation in recreational areas have been described in previous studies (12, 15, 23, 28, 33, 34). La Page (21) suggested that the constant repetitious use of an area constitutes an additional environmental impact supplementary to the effects of factors such as climate and topography. This additional environmental impact may be amplified in recreational areas in relatively dry regions of the West. Peak visitor numbers during the dry summer months can result in rapid deterioration of relatively slow growing ground cover vegetation (2). At Bryce Canyon National Park visitor use impact has accelerated the erosional process at scenic viewpoints (Figures 3 and 4) and campgrounds, and in some instances has increased canyon rim recession (8).

The broad management policy for scenic, scientific and historic areas in the National Park system inseparably combines use and preservation (4, 9, 20). Accordingly, present use must not result in impairment of interest for future generations (31). However, heavy visitor use in excess of the physical and ecological carrying capacity of many parks makes it difficult to maintain the preservation function.



Figure 1. Denudation of a portion of Farview Point resulting from visitor trampling.



Figure 2. Loss of vegetation and accelerated soil erosion as a result of intensive camper use at North Campground.

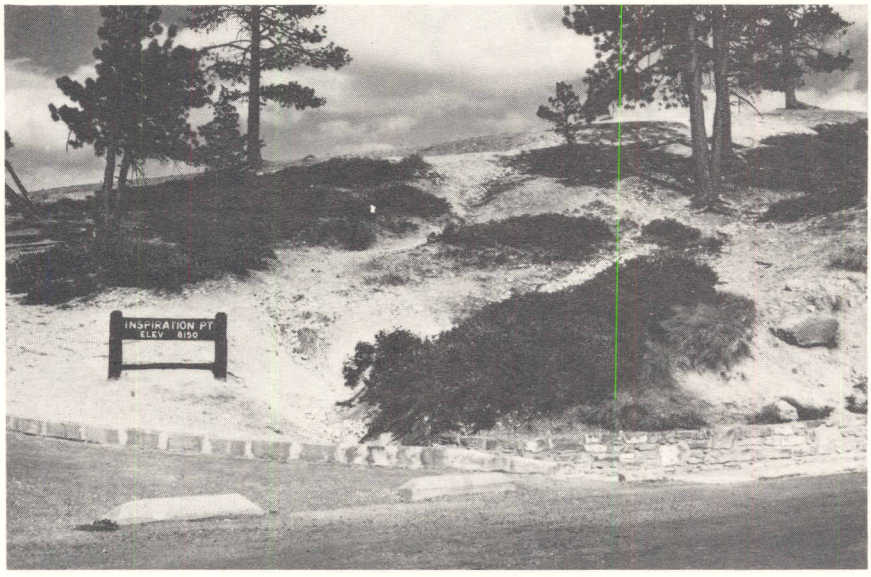


Figure 3. Accelerated soil erosion resulting from visitor use impact at Inspiration Point.

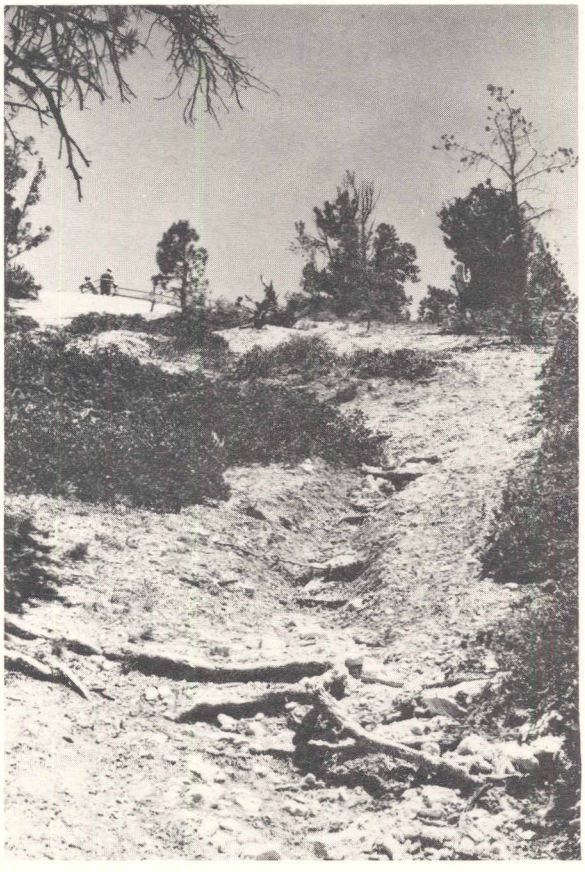


Figure 4. Close-up of accelerated soil erosion at Inspiration Point caused by visitors leaving the established path in route to the scenic overlook.

With this in mind, this study was initiated at Bryce Canyon National Park in April, 1978 to assess the physical impact of visitors on heavily used areas and to gather information on methods to rehabilitate and ecologically manage these areas. This study examines differences in vegetation characteristics, soil infiltration rates, runoff sediment concentrations and soil bulk densities on low and high-use areas in the park. Propagation and revegetation techniques are also described.

STUDY AREA

Bryce Canyon National Park comprises a narrow strip of scenic land (14,262 hectares) on the southeastern rim of the Paunsaugunt Plateau in southern Utah (7). The escarpment of this plateau is recognized as an outstanding example of accelerated erosion caused by rain, frost, and streams (8, 16). Elevation varies between 2027 meters on the west boundary to 2775 meters at Rainbow Point. Peak visitor use of the park is May through October. Visitor days for calendar years 1970 and 1978 were 346,035 and 680,328, respectively, showing a two-fold increase over an eight year span.

The average winter has long periods of extreme cold, and heavy snowfall, with summers being relatively short. Temperatures vary between summer extremes of 32 C to winter lows of -32 C. Precipitation is uniformly distributed, and averages approximately 432 mm yearly. Frequent thunderstorms occur during July and August (6, 8).

Three scenic view areas (Fairyland View, Inspiration Point, and Rainbow Point) and two campgrounds (North Campground and Sunset Campground) were selected to assess the impact of visitors (Figure 5). Also, three scenic view areas (Fairyland View, Sunrise Point, and Farview Point) were selected for revegetational studies. Fairyland View is located

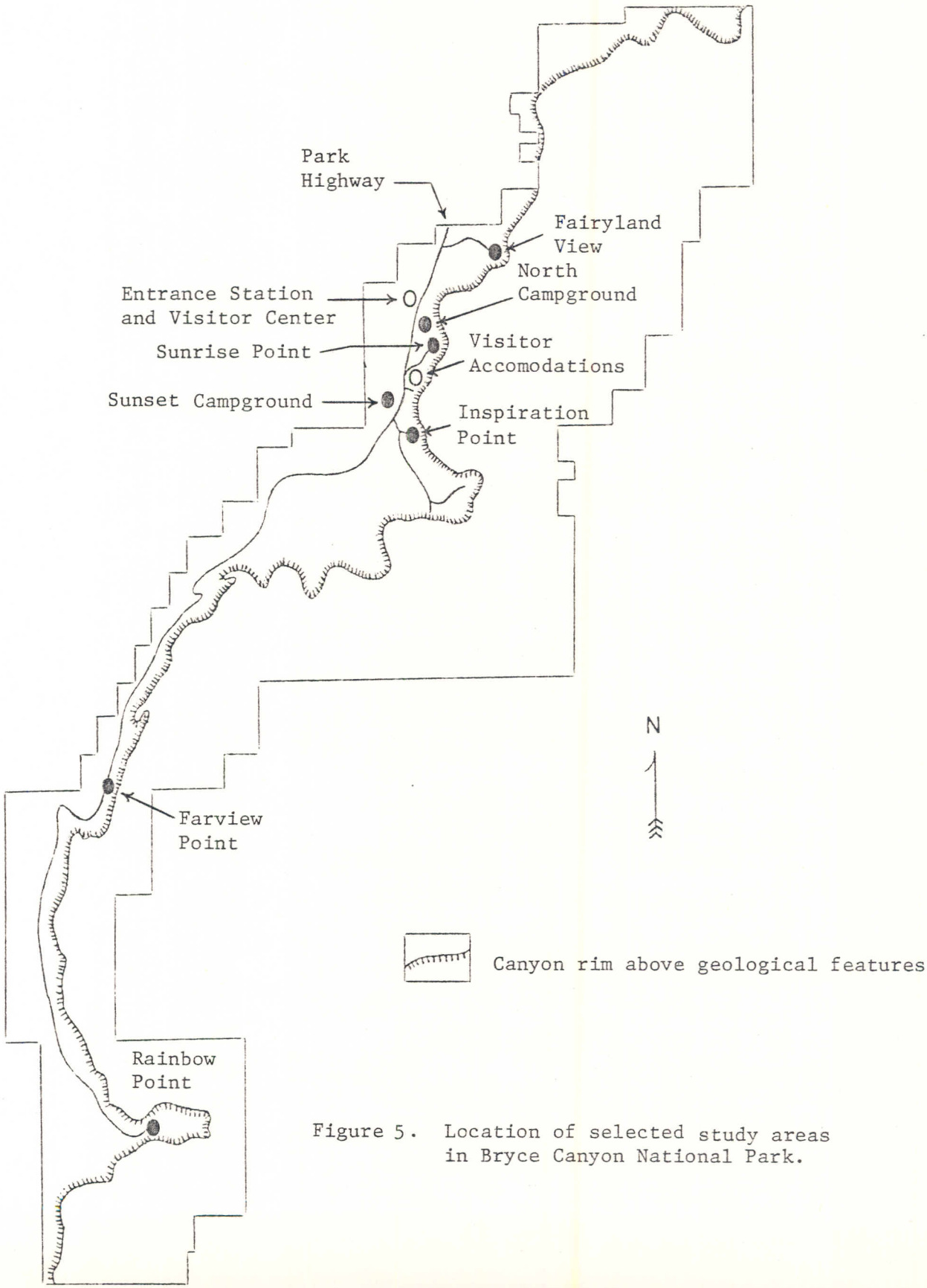


Figure 5. Location of selected study areas in Bryce Canyon National Park.

near the park entrance, Inspiration Point and Sunrise Point are close to visitor accommodations and the two campgrounds, Rainbow Point is located in the southern end of the park, and Farview Point is approximately half way between the entrance station and Rainbow Point. Elevation, percent slope, surface soil, and vegetation type vary among the selected campgrounds and view areas (Table 1). Soils in the selected study areas are all well drained, but differ in permeability, waterholding capacity, runoff rate, erosion hazard, depth to limestone bedrock, and soil reaction (29).

Dominant understory species (7) in the submontane ponderosa pine vegetation type (Fairyland View, Sunrise Point, Inspiration Point, North Campground, and Sunset Campground) include greenleaf manzanita (Arctostaphylos uva-ursi), bitterbrush (Purshia tridentata), western wheatgrass (Agropyron smithii) and Indian ricegrass (Oryzopsis hymenoides). In the montane spruce-fir vegetation type (Farview Point and Rainbow Point) the dominant understory species include greenleaf manzanita, common juniper (Juniperus communis), mountain lilac (Ceanothus martinii), creeping barberry (Berberis repens) and mountain snowberry (Symphoricarpos oreophilus).

MATERIALS AND METHODS

Classification of high and low-use areas for soil and vegetation studies at each view point and campground was based on the following criteria: proximity to parking areas, developed campsites and established trails; visual evidence of trampled ground cover species; soil compaction and erosion; visual assessment of understory species composition and cover; and observation of visitor foot traffic patterns. Extensive visitor use of the canyon rim area and the campground facilities precluded the selection of no-use areas in close proximity to high and low-

Table 1. Elevation, percent slope, surface soil characteristics and vegetation type at study areas (7, 29).

Study Area	Elevation (m)	Slope (%)	Surface Soil	Vegetation Type
Fairyland View	2378	4-8	friable, very fine sandy loam to 30 cm deep	submontane ponderosa pine
Inspiration Point	2535	5-15	friable, very gravelly loam to 10 cm deep	submontane ponderosa pine
Rainbow Point	2775	0-2	friable, very gravelly loam to 5 cm deep	montane spruce-fir
Sunrise Point	2444	5-15	friable, very gravelly loam to 10 cm deep	submontane ponderosa pine
Farview Point	2684	1-6	friable, very cobbly, very fine sandy loam to 5 cm deep	montane spruce-fir
North Campground	2402	5-15	friable, very gravelly loam to 10 cm deep	submontane ponderosa pine
Sunset Campground	2426	4-8	friable, very fine sandy loam to 30 cm deep	submontane ponderosa pine

use areas at each study area. As a result, this study is limited to a comparison of visitor impact on high and low-use areas.

Understory vegetation at each study area was sampled by the line-intercept transect method described by Brower and Zar (5). Percent plant cover was determined by measuring plant intercept length along a 20 m intercept line replicated three times for each use at each study area. Randomization of transect location and direction, and selection of transects with similar slopes were, at times, restricted by the shape of the use areas. Percent litter cover and bare ground were also measured along the line transect. In addition, importance values for understory species were calculated by adding the separate values of relative frequency, relative desntiy, and relative cover (5). The maximum importance value for a given species is 3.0.

Soil infiltration rates were determined by using a modular soil infiltrometer (Figure 2) at one randomly-selected point along each transect line (10). A rainfall intensity of 6 cm per hour, for a duration of one-half hour, was applied from a water chamber placed 1.2 m above the soil surface. At this height the waterdrops (2.42 mm in diameter) reach a velocity of 4.08 m per second before striking the soil surface (10, 22). One hour prior to starting the simulated rainfall each 60 x 60 cm infiltration plot was prewetted with eight liters of water to bring the soil near field capacity. Surface runoff, if available, was collected at the end of the 30 minute simulated rainfall period. The difference between applied rainfall and collected runoff closely approximates the soil infiltration rate (3).

In addition to the infiltration measurements, sediment production and surface soil bulk density were also determined. Sediment concentration was measured by evaporating a one liter composite sample taken from the total runoff from each infiltration plot. Soil bulk density was measured

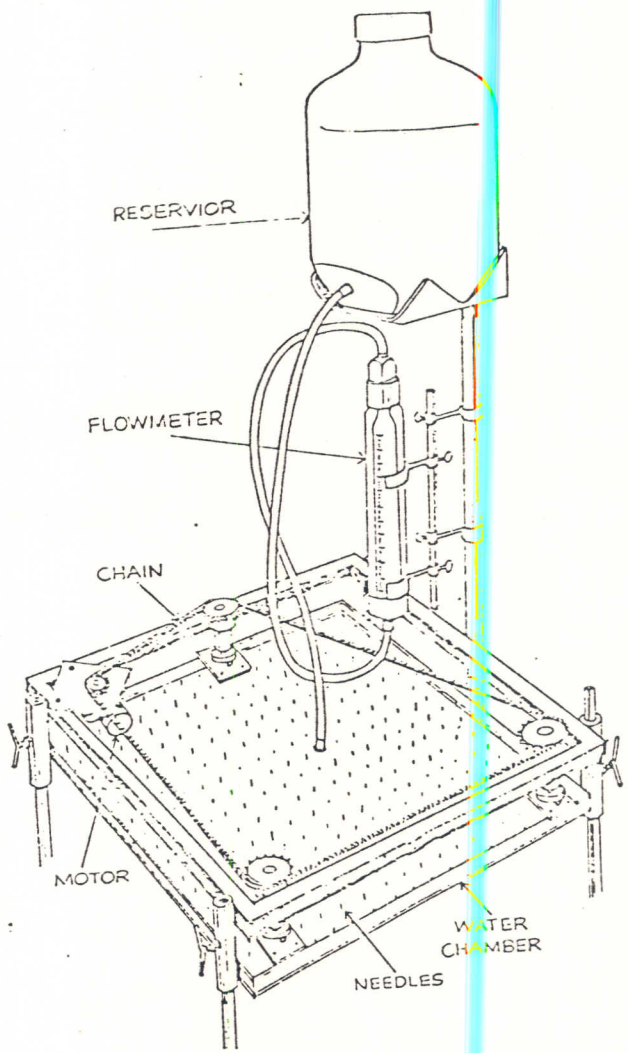


Figure 6. Modular soil infiltrometer used for determining infiltration rates and sediment rates.

by the ring method (30). An integrated bulk density value was obtained from a 5 cm deep soil sample from each infiltration plot.

Plant species for revegetation study sites were selected for one or more of the following criteria: adaptation to disturbed site; ability to withstand abuse; aesthetic quality; native to the park; and ability to provide ground cover and erosion control. Revegetation sites were selected on the basis of recommendations by park personnel, availability of planting space, and accessibility for planting and maintenance.

Seed and vegetative propagation were used to obtain planting stock. Stem cuttings of greenleaf manzanita, bitterbrush, low sagebrush (Artemisia arbuscula) and common juniper were taken in the park during late spring, summer and early fall. During, the late spring collection period (May 5, 1978), hardwood cuttings were taken from the previous years growth. During the summer (June 20, 1978) and early fall (September 18, 1978) collection periods semi-hardwood cuttings were obtained from semi-mature, current year's growth. Greenleaf manzanita stem-tip cuttings were collected from plants near the Fairyland View turnoff and at Rainbow Point. Bitterbrush stem-tip cuttings were also taken near the Fairyland View turnoff. Low sagebrush stem-tip cuttings were obtained from plants near Fairyland View. Common juniper stem-tip and heel cuttings (17) were collected near Aqua Canyon and at Rainbow Point. A small piece of older wood from a secondary or tertiary branch is retained at the base of the hardwood heel cutting (17).

Stem tip and heel cuttings, varying from 8 to 12 cm in length, were treated with three concentrations (0.3%, 0.8%, and 2.0%) of indole-butyric acid (IBA) powder. An untreated control was used in addition to the IBA treatments. All cuttings were stuck in a peat-perlite (1:1 by volume) rooting medium and with the exception of low sagebrush, placed under intermittent mist (12 seconds every 12 minutes) in a greenhouse. Air

temperatures varied between 20 C (night) and 32 C (day), and bottom heat was maintained at 20 C. Each plant species had 50 cuttings per treatment. After four months in the propagation bench, cuttings were harvested, and percent rooting and root development were evaluated.

Seeds of greenleaf manzanita and bitterbrush were collected at the appropriate time (October, 1978) from the same plants that were used as a source for stem cuttings. Seeds of Indian ricegrass, bitterbrush and big sagebrush (Artemisia tridentata) were obtained from a local, native seed collector (William Roger Steward and Sons, Ephraim, Utah). Seeds of some of these plant species required scarification and or stratification to increase their germination potential (26, 27). Seeds of greenleaf manzanita were separated from the outer fleshy part of the fruit by hand and divided into three separate lots (approximately 200 seeds per lot) which were immersed in concentrated sulfuric acid (H_2SO_4) for three different time periods (2, 3, and 4 hours). Following acid scarification, all three seed lots were placed in moist peat in plastic bags and stratified at 4 C for 120 days. Bitterbrush seeds were artifically stratified in a 3 percent solution of thiourea for 3 to 5 minutes. Indian ricegrass seeds were scarified for 30 minutes in 95 percent H_2SO_4. Big sagebrush seed did not require a pregermination treatment. Seeds of all four species were germinated in plastic flats containing a soil-sand-peat-perlite mix (1:1:1:1 by volume) in a greenhouse. Air temperatures varied between 15 C (night) and 24 C (day), and bottom heat was maintained at 20 C. Germination percentages were evaluated for all plant species after two months.

Following adequate root development, seedlings and rooted cuttings were transplanted into plastic containers (4 cm x 5 cm x 18 cm) containing

the same soil medium used for seed germination. Container-grown plants were maintained in the greenhouse for four to six months. Three weeks prior to outplanting, plants were moved outside for hardening off.

Plants were outplanted at the revegetation sites on September 18, 1978 and June 12, 1979. Big sagebrush, low sagebrush, and bitterbrush transplants were outplanted at Fairyland View. Greenleaf manzanita, bitterbrush and Indian ricegrass transplants were outplanted at Sunrise Point. Greenleaf manzanita, bitterbrush, and common juniper transplants were outplanted at Farview Point. All plants were spaced 45 cm apart within and between rows. The following outplanting treatments (10 plants per treatment) were used at each revegetation site: (1) slow release fertilizer 50 lbs./acre (56 kg/ha) nitrogen and phosphorus; (2) wire cages to prevent rodent damage and visitor trampling; (3) combination of treatments 1 and 2; and (4) control. All plants received 2 liters of water following outplanting. Survival and growth data were taken in June and September, 1979.

Vegetation and soil data were analyzed by a two-way analysis of variance for a completely randomized design. We chose to use the 90 percent confidence level to indicate significance because of the variability in this rangeland system.

RESULTS AND DISCUSSION

Vegetation and Soil Analyses

Percent plant cover and bareground varied significantly between use intensity levels at scenic view areas (Table 2) and campgrounds (Table 3). Plant cover decreased and bareground increased from low to high-use areas. However, percent plant cover and bareground were not significantly different among the scenic view areas and among the campgrounds. In addition,

Table 2. Percent plant cover, litter cover and bareground for low and high-use areas at scenic view areas.

View Area	Ground Cover	Cover (%) Low-Use	High-Use
Fairyland	Plant	40.6	14.9
	Litter	17.2	11.1
	Bareground	42.2	74.0
Inspiration	Plant	44.1	21.6
	Litter	17.6	24.4
	Bareground	38.3	54.0
Rainbow	Plant	45.3	27.3
	Litter	30.1	25.6
	Bareground	24.6	47.1
Average value for three scenic view areas	Plant	43.3^{a*}	21.1^{b}
	Litter	21.6^{a}	20.6^{a}
	Bareground	35.1^{a}	58.3^{b}

* Plant cover, litter cover and bare ground values between low and high-use areas within the same row followed by different letters are significantly different at the 90 percent confidence level.

Table 3. Percent plant cover, litter cover and bareground for low and high-use areas at campgrounds.

Campground	Ground Cover	Cover (%) Low-Use	High-Use
North	Plant	29.1	11.2
	Litter	39.5	19.9
	Bareground	31.4	68.9
Sunset	Plant	34.2	16.2
	Litter	36.8	25.5
	Bareground	29.0	58.3
Average value for two campgrounds	Plant	31.6[a]*	13.7[b]
	Litter	38.2[a]	22.7[b]
	Bareground	30.2[a]	63.6[b]

* Plant cover, litter cover and bareground values between low and high-use areas within the same row followed by different letters are significantly different at the 90 percent confidence level.

interactions between use areas and scenic viewpoints, and use areas and campgrounds were non-significant.

Uncontrolled visitor foot traffic is a major cause of the reduction in plant cover and the increase in bareground on high-use areas at scenic view areas (Figures 7, 8, 9, 10, 11 and 12). Natural breaks in ground cover vegetation are used as more "direct" routes to points of interest in favor of established paths. After a period of use, these more "convenient" trails widen and form a network of denuded areas (Figure 12). Dale and Weaver (11) indicated that trail width increases linearly with logrithmic increases in the number of users.

The reduction in plant cover and the increase in bareground on high-use areas in campgrounds is associated with continual camper trampling around campsite and campground facilities. A network of paths form between parking areas, fireplaces, tables, tent sites, water faucets, restrooms, garbage disposal areas, and outdoor amphitheaters. As with the paths at the scenic view areas, these paths continually widen with increased camper use.

Percent litter cover did not vary statistically between the low and high-use areas or among the scenic view points (Table 2). Also, the interactions between use areas and view points were non-significant. This was expected at Fairyland View and Inspiration Point since the majority of the litter was composed of needles and twigs from ponderosa pine (Pinus ponderosa). At Rainbow Point, needles and twigs from white fir (Abies concolor) and Douglas-fir (Pseudotsuga menziesii), and leaves and branches from dominant understory species provided an abundance of litter. However, litter depth was reduced on high-use areas (average depth .65 cm) compared to low-use areas (average depth 1.05 cm) at all scenic view points due to scattering by visitor foot traffic.



Figure 7. Understory vegetation (bitterbrush, low sagebrush, perennial grasses) providing plant cover on a low-use area at Fairyland View.



Figure 8. Reduction in plant cover and increase in bareground on a high-use area at Fairyland View resulting from uncontrolled visitor foot traffic.

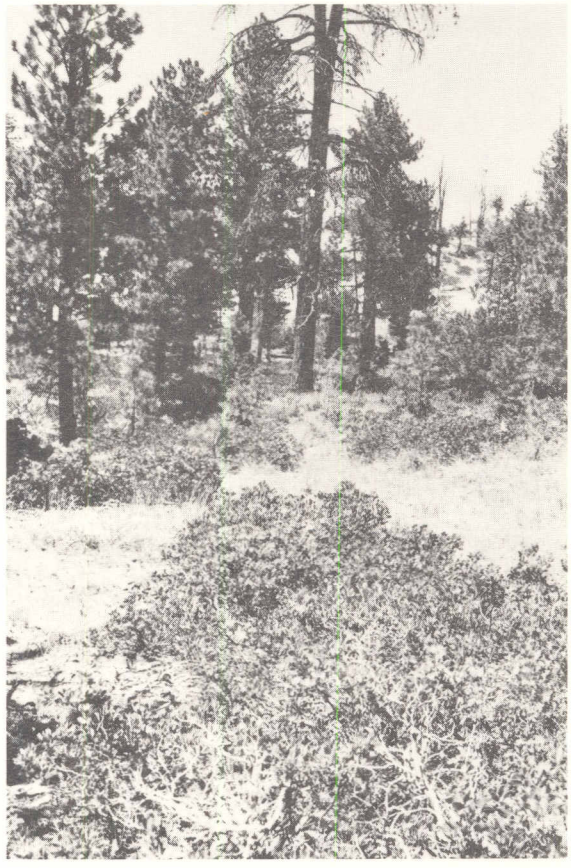


Figure 9. Understory vegetation (greenleaf manzanita perennial grasses) providing plant cover on a low-use area at Inspiration Point.



Figure 10. High-use area in the foreground shows a reduction in plant cover and an increase in bareground resulting from uncontrolled visitor foot traffic at Inspiration Point.

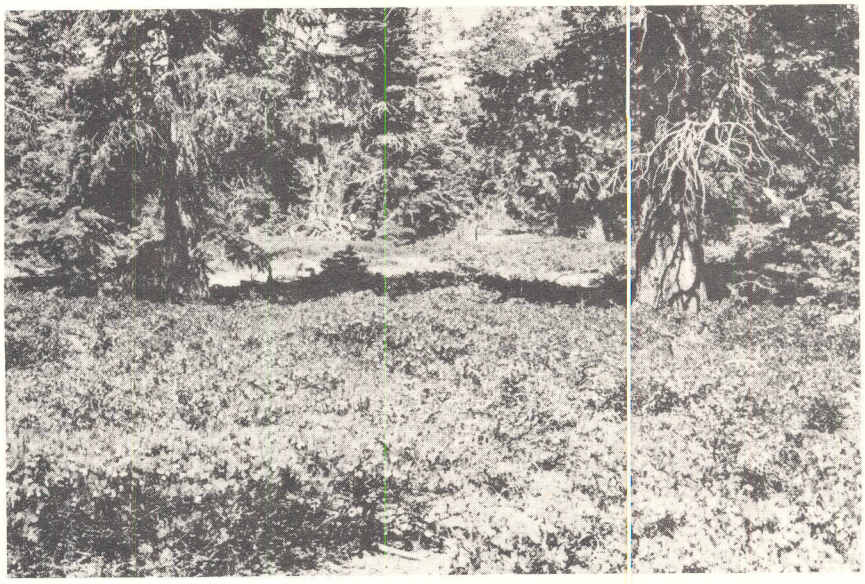


Figure 11. Dense cover of greenleaf manzanita on a low-use area at Rainbow Point.

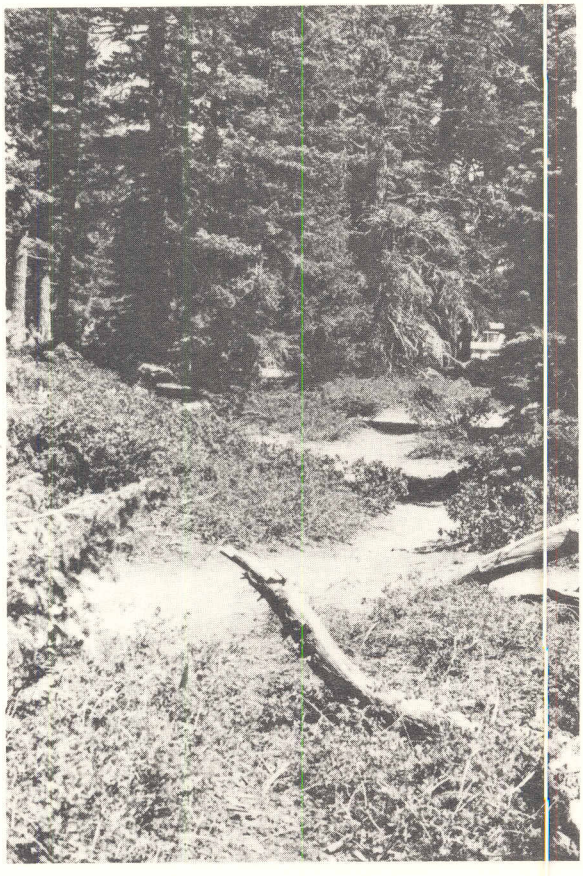


Figure 12. Uncontrolled visitor foot traffic has lead to the formation of more "convenient" trails (denuded areas) on a high-use area at Rainbow Point.

Percent litter cover decreased significantly from low to high-use areas in the campgrounds. As with Fairyland View and Inspiration Point, the majority of the litter at North Campground and Sunset Campground was composed of needles and twigs of ponderosa pine. However, collection of this litter for campfire fuel, in addition to scattering by camper foot traffic, caused the significant decrease in litter cover on high-use areas.

Differences in understory vegetation composition, based on plant importance values, are presented for each scenic view area in Table 4 and each campground in Table 5. The importance value is an indication of the vegetational importance of the species within a community. At lower elevations (Table 4) grasses and forbs were the more important components of the plant community, where as shrubs become increasingly important with increasing elevation. Relatively small cover values for grasses and forbs were compensated by higher frequency and density values.

Dale and Weaver (11) divided trail-side vegetation into plant groups (decreasers, increasers, invaders and neutral) in accordance with their response to trail activities. Similar categories are used here to describe plant response to trampling and soil compaction resulting from intensive visitor and camper use. The differences in vegetation composition provide an approximate measure of the change that has taken place in the plant cover at scenic view areas and campgrounds.

Importance values of understory species at low and high-use areas at Fairyland View show a change in plant cover resulting from increased visitor use (Table 4). Western wheatgrass and greenleaf manzanita are fewer, and Indian ricegrass and the remaining forbs are greater when comparing the low and the high-use area. Broom snakeweed (Xanthocephalum sarothrae), an invader on the high-use area, is another indicator of a deteriorating site.

At Inspiration Point, the decline in manzanita, Indian ricegrass

Table 4. Dominant understory species (based on importance value) for low and high-use areas at scenic view areas.

View Area	Low-Use Species	RF_i	RD_i	RC_i	IV_i*	High-Use Species	RF_i	RD_i	RC_i	IV_i
Fairyland	Agropyron smithii	.24	.56	.28	1.08	Agropyron smithii	.18	.44	.34	.96
	Arctostaphylos patula	.19	.02	.41	.62	Oryzopsis hymenoides	.13	.16	.25	.54
	Ceanothus martinii	.14	.08	.20	.42	Eriogonum spp.	.10	.06	.02	.18
	Oryzopsis hymenoides	.05	.04	.02	.11	Hymenopapus cinereus	.07	.06	.04	.17
	Oenothera lavandulaefolia	.05	.02	.02	.09	Xanthocephalum sarothrae	.08	.05	.04	.17
Inspiration	Arctostaphylos patula	.34	.19	.73	1.26	Arctostaphylos patula	.20	.17	.67	1.04
	Oryzopsis hymenoides	.16	.15	.10	.77	Oryzopsis hymenoides	.10	.12	.06	.28
	Purshia tridentata	.06	.04	.06	.16	Purshia tridentata	.13	.10	.04	.27
	Juniperus communis	.06	.04	.05	.15	Ceanothus martinii	.06	.05	.08	.20
	Berberis repens	.09	.05	.01	.15	Hyemnoxys acaulis	.07	.05	.01	.13
Rainbow	Arctostaphylos patula	.36	.46	.84	1.65	Symphoricarpos oreophilus	.32	.32	.49	1.13
	Symphoricarpos oreophilus	.20	.14	.04	.38	Berberis repens	.16	.31	.15	.62
	Ceanothus martinii	.13	.09	.04	.26	Arctostaphylos patula	.02	.07	.16	.25
	Ribes cereum	.06	.09	.04	.19	Stipa lettermanii	.12	.07	.05	.24
	Juniperus communis	.06	.07	.01	.14	Juniperus communis	.06	.03	.08	.17

* RF_i = relative frequency, RD_i = relative density, RC_i = relative cover, IV_i = importance value

Table 5. Dominant understory species (based on importance value) for low and high-use areas at campgrounds.

	Low-Use					High-Use				
Campground	Species	RF_i	RD_i	RC_i	IV_i*	Species	RF_i	RD_i	RC_i	IV_i
North	Arctostaphylos patula	.11	.08	.39	.58	Arctostaphylos patula	.13	.05	.56	.74
	Stipa comata	.11	.21	.08	.40	Aster occidentalis	.21	.30	.11	.62
	Oenothera flava	.14	.18	.07	.39	Agropyron smithii	.06	.40	.05	.51
	Oryzopsis hymenoides	.11	.12	.11	.34	Stipa comata	.06	.20	.15	.41
	Artemisia arbuscula	.14	.08	.06	.28	Haplopappus armeroides	.13	.05	.04	.22
Sunset	Purshia tridentata	.32	.33	.52	1.17	Purshia tridentata	.22	.38	.51	1.11
	Symphoricarpos oreophilus	.10	.07	.13	.30	Symphoricarpos oreophilus	.17	.09	.18	.34
	Arctostaphylos patula	.06	.04	.18	.28	Arctostaphylos patula	.11	.06	.07	.24
	Oryzopsis hymenoides	.10	.12	.04	.26	Petradoria pumila	.11	.06	.02	.19
	Stipa comata	.06	.08	.02	.16	Artemisia ludoviciana	.06	.03	.09	.18

* RF_i - relative frequency, RD_i = relative density, RC_i = relative cover, IV_i = importance value

and common juniper between the low and the high-use area, and the presence of creeping barberry and bitterweed (Hymenoxys acaulis) indicate a decline in site condition. A similar decline in site condition is shown by the decrease of manzanita and the increase of mountain snowberry, creeping barberry and Letterman needlegrass (Stipa lettermanii) at Rainbow Point.

Importance values of understory species at low and high-use areas at North Campground show little change in plant cover as the result of increased camper use (Table 5). The decline in Indian ricegrass and needle and thread grass (Stipa comata) on the high-use area at Sunset Campground indicate a slight decline in site condition.

Importance values for dominant understory species at scenic view points and campgrounds have an additional application. Importance values for plant species at low-use areas give an indication of which species should be used to revegetate the high-use areas. Seeds and vegetative cuttings collected from plants on areas adjacent to each scenic view area and campground will provide plants specifically adapted to the environmental conditions at each revegetation site.

Bulk densities, infiltration rates and sediment production varied significantly between low and high-use areas at scenic viewpoints (Table 6) and campgrounds (Table 7). However, these soil characteristics did not vary significantly among the scenic view areas and among campgrounds; and interactions between use areas and view points, and use areas and campgrounds were nonsignificant.

Bulk densities of soils from high-use areas were, respectively, 29.1 percent, 28.0 percent, 22.5 percent and 15.9 percent greater than the bulk densities of soils from low-use areas at Inspiration Point, Fairyland View, Sunset Campground and North Campground. There was only a 2.5 percent

Table 6. Bulk density, infiltration rate and sediment production for low and high-use areas at scenic view areas.

View Area	Use Intensity	Soil Characteristics		
		Bulk Density ($g \cdot cm^{-3}$)	Infiltration Rate ($cm \cdot h^{-1}$)*	Sediment Production ($g \cdot m^{-2}$)*
Fairyland	Low-Use	1.07	5.44	1.90
	High-Use	1.37	3.93	4.30
Inspiration	Low-Use	1.03	5.33	1.17
	High-Use	1.33	3.63	10.07
Rainbow	Low-Use	1.20	5.90	1.07
	High-Use	1.23	3.66	2.98
Average value for three scenic view areas	Low-Use	1.10^{a} †	5.58^{a}	1.38^{a}
	High-Use	1.31^{b}	3.74^{b}	5.78^{b}

* After 30 minute simulated rainfall

† Bulk density, infiltration rate and sediment production values between low and high-use areas within the same column followed by similar letters are significantly different at the 90 percent confidence level.

Table 7. Bulk density, infiltration rate and sediment production for low and high-use areas at campgrounds.

Campground	Use Intensity	Soil Characteristics: Bulk Density ($g \cdot cm^{-3}$)	Soil Characteristics: Infiltration Rate ($cm.h^{-1}$)*	Soil Characteristics: Sediment Production ($g \cdot m^{-2}$)*
North	Low-Use	1.13	4.83	2.14
	High-Use	1.31	2.40	6.58
Sunset	Low-Use	1.11	4.43	3.48
	High-Use	1.36	2.76	10.11
Average value for two campgrounds	Low-Use	1.12[a†]	4.63[a]	2.86[a]
	High-Use	1.34[b]	2.58[b]	8.35[b]

* After 30 minute simulated rainfall.

† Bulk density, infiltration rate and sediment production values between low and high-use areas within the same column followed by similar letters are significantly different at the 90 percent confidence level.

difference between the bulk densities of soils from high and low-use areas at Rainbow Point. This slight difference between bulk densities at Rainbow Point can be attributed, in part, to the soil profile of this very gravelly loam. The shallow (0 to 5 cm deep) coarse-textured, surface layer lies directly over a C horizon (5 to 45 cm deep) of massive structure (29), thus allowing compaction with lighter use.

As observed by Dotzenko et. al. (15), differences in soil compaction within each use intensity level might be attributed to inherent structural and textural differences in the soil as well as differences in ground cover, litter cover and litter depth on the soil surface. In addition, the slope of a use area (Table 1) influences walking activities which in turn affect soil compaction. Downhill walkers are potentially more damaging than uphill walkers because they take more steps and their footsteps have greater impact (1). There is also a greater tendency for walkers to leave the path coming downhill (1).

Low infiltration rates after a 30 minute simulated rainfall on high-use areas were attributed primarily to a reduction in ground cover vegetation. This is in agreement with other studies on western rangelands (13, 24, 25, 32) which indicate a close relationship between soil infiltration rate and the presence and character of plant cover. The relationship between plant cover and sediment production is not as definite. Generally, as plant cover decreases sediment production increases (14), but Blackburn (3) found a poor correlation between plant cover and sediment production on semiarid rangelands with a relatively low percent plant cover (23 to 32 percent). He suggested that variations in sediment production on gentle slopes result when detached soil particles settle out in small depressions before they reach the collection trough. However, there

is no doubt that ground cover vegetation serves an important function by interfering with direct raindrop impact on the soil surface (24).

Propagation of Native Plants

The rooting ability of stem cuttings of bitterbrush, common juniper, greenleaf manzanita, and low sagebrush was affected by the interaction on the season of plant material collection with the concentration of applied IBA rooting hormone (Table 8). In general, hardwood cuttings taken in the spring and semi-hardwood cuttings taken in the fall showed the best response to externally applied IBA. During these seasons, broad-leaf evergreens (greenleaf manzanita) and narrowleaf evergreens (common juniper) have greater carbohydrate reserves and a more favorable internal hormone balance for root initiation (17). During the summer season rooting ability is generally lower because carbohydrates are readily used for vegetative and reproductive growth and development. Optimum rooting of bitterbrush and low sagebrush cuttings was with 0.8% IBA; and an inhibition of rooting occurred with 2.0% IBA. Optimum rooting of stem-tip and heel cuttings of common juniper was with 2.0% IBA. Heel cutting treatments, which contain cambial tissue from older wood, had a consistently higher rooting percentage than tip cutting treatments. Greenleaf manzanita was more variable than the other shrub species in response to the concentration of applied IBA, but 0.8% IBA appeared to stimualte the optimum rooting response.

Rooting ability may also vary within and among populations of the same native plant species (19). Differences in rooting ability may be due to genetic and environmental differences. Environmental conditions influence carbon assimilation and hormone production and will influence the subsequent rooting of stem cuttings (17, 19). With this in mind,

Table 8. Effect of date of collection and IBA concentration on percent rooting of stem cuttings of 4 native shrub species.

Species	Date	Rooting Percentage*			
		Control	0.3% IBA	0.8% IBA	2.0% IBA
Bitterbrush	5/4/78	0	24	46	4
	6/30/78	0	6	18	0
	9/18/78	0	14	38	0
Common Juniper (tip)	5/4/78	22	--	40	82
	6/30/78	0	--	4	12
	9/18/78	20	--	32	18
Common Juniper (heel)	5/4/78	28	--	72	84
	6/30/78	4	--	16	42
	9/18/78	20	--	63	66
Greenleaf Manzanita	5/4/78	28	36	38	60
	6/30/78	2	2	20	4
	9/18/78	6	10	56	10
Low sagebrush	5/4/78	2	8	48	10
	6/30/78	--	--	--	--
	9/18/78	--	--	--	--

* After 4 months in propagation bench.

the selection of plants for rehabilitation projects in the park should be based not only on their favorable growth and survival characteristics, but also on their ease of propagation (ie. rooting ability).

The germinative ability of seeds collected from bitterbrush and greenleaf manzanita plants in the park was extremely low. Bitterbrush seed was poor in quality (as a result of insect damage) and only had a germination percentage of 12 percent when treated with thiourea. Greenleaf manzanita seed required extensive treatments (scarification and stratification) to overcome dormancy and the overall germination percentage from the three seed lots (2, 3, and 4 hrs. in H_2SO_4) was less than one percent. Seed production and seed quality in native plant populations are affected by amounts of precipitation, frost, disease, insect damage, and grazing, and can be unpredictable from year to year (19). Seeds must be collected at the appropriate time. A few days can make the difference of getting or losing the seed. Bitterbrush seed must be harvested when it is mature and dry. Berries of greenleaf manzanita should be collected as soon as possible to minimize the loss of seed to birds and small rodents.

Seeds of Indian ricegrass, bitterbrush and big sagebrush obtained from a local seed collector had a high germinative ability. Germination percentages for Indian ricegrass, bitterbrush, and big sagebrush were 98 percent, 78 percent, and 84 percent, respectively. However, these plant species were not collected within the park, and they may not be adapted to certain environmental conditions prevailing at some of the park rehabilitation sites (19).

An alternative to seed propagation for producing planting stock of some native species is the use of wildlings (seedlings collected from the wild). Seedlings found under the canopy of parent shrubs or along

roadsides can be collected and transplanted with little disturbance to the park grounds. Several hundred creeping barberry seedlings could be collected along side the park highway and transplanted onto disturbed sites at campgrounds and several of the scenic viewpoints.

Outplanting

Plant survival was generally poor at the three revegetation study sites (Table 9). Big sagebrush planted at Fairyland View and Indian ricegrass planted at Sunrise Point were the only species that had greater than 85 percent survival. With the exception of the low sagebrush planted at Fairyland View, the survival percentage for the other species was 50 percent or less.

The season of outplanting had little effect on the survival rate of bitterbrush planted at Sunrise Point and common juniper planted at Farview Point. However, percent survival for greenleaf manzanita transplants at Sunrise Point was much greater in the fall than in the spring. In general, container grown plants should have a higher survival rate when planted in the spring. At this time, transpiration rates are low and soil moisture is generally adequate for plant establishment. Following establishment, the plants can actively grow during the summer months and gradually hardenoff for the oncoming winter. It is difficult to properly harden plants for a fall planting on exposed sites such as those that exist at higher elevation scenic viewpoints in Bryce Canyon. In addition, these fall transplants may be subject to frost heaving if they have not had enough time to develop adequate root systems before freezing occurs (19).

Even with the relatively poor outplanting survival, one general trend is evident. Plant survival decreased with increasing elevation. Total plant survival at Fairyland View was 68 percent compared to 17

Table 9. Plant survival for revegetation studies at three scenic view areas.

View Area	Species	Season Planted	Survival (%)				
			Control	Fertilized	Caged	Fertilized-Caged	Total
Fairyland	Low sagebrush	Fall	44	67	--	--	56
	Bitterbrush	Spring	40	30	80	50	50
	Big sagebrush	Spring	100	100	100	100	100
							$\bar{x}$ = 68
Sunrise	Manzanita	Fall	56	44	33	44	44
	Bitterbrush	Fall	50	50	--	--	50
	Bitterbrush	Spring	40	40	60	40	45
	Manzanita	Spring	17	0	0	0	4
	Indian ricegrass	Spring	93	86	--	--	90
							$\bar{x}$ = 47
Farview	Manzanita	Fall	33	11	11	22	19
	Common juniper	Fall	11	11	22	11	14
	Common juniper	Spring	0	13	50	13	19
							$\bar{x}$ = 17

percent at Farview Point. This trend in plant survival is probably the result of an increase in environmental stress with an increase in elevation. At Farview Point temperatures are lower, the growing season is shorter, snow depth is greater, and the soil depth is much shallower than at Fairyland View. Plant materials used to revegetate disturbed sites at higher elevations in the park should be selected from areas immediately adjacent to the sites in order to insure their adaptability to existing environmental stresses.

Even when using adapted plant materials supplementary irrigation may be necessary during the first growing season to insure plant establishment on harsh sites. All plants in this study were only irrigated at the time of outplanting due to travel constraints, and in the hope that summer precipitation would provide adequate moisture for establishment. Plants transplanted into the shallow soil at Farview Point and Rainbow Point should probably be watered on a bi-weekly basis during the first growing season to insure survival.

No trends among the four treatments are evident. In many instances, survival rates for control treatments were equal to or greater than survival rates for fertilized treatments. Depending on the fertility of the soil, fertilizing when plants are outplanted may not be necessary. Studies have indicated that fertilization does not always increase plant survival above plants that are not fertilized (19). The caging treatments did not deter people from walking through the study plots or stepping on plants.

Total plant growth, as measured by an increase in plant height, was negligible for most species for both fall and spring plantings (Table 10). Only the fall planting of low sagebrush at Fairyland View, the fall planting of greenleaf manzanita at Sunrise Point, and the spring planting of Indian ricegrass at Sunrise Point had increases in plant

Table 10. Plant growth* for fall (September 18, 1978) and spring (June 12, 1979) revegetation plantings at three scenic view areas.

View Area	Species	Season Planted	Growth (cm)				
			Control	Fertilized	Caged	Fertilized-Caged	Total
Fairyland	Low Sagebrush	Fall	5.75	1.75	--	--	3.75
	Bitterbrush	Spring	0.12	0.33	0.20	0.20	0.21
	Big sagebrush	Spring	0	0.10	0.05	0.15	0.08
Sunrise	Manzanita	Fall	1.20	2.25	1.00	2.50	1.74
	Bitterbrush	Fall	0.20	0.80	--	--	0.50
	Bitterbrush	Spring	0.20	1.20	0.50	1.20	0.50
	Manzanita	Spring	0	0.50	0	0	0.13
	Indian ricegrass	Spring	4.50	6.75	--	--	5.63
Farview	Manzanita	Fall	0.50	0.25	0.25	1.50	0.63
	Common juniper	Fall	0.20	1.00	0.50	0	0.42
	Common juniper	Spring	0	0.75	0	1.20	0.56

* Plant growth measured as increase in plant height on September 4, 1979.

height of greater than 1.0 cm for the 1979 growing season. Growth rate, like survival rate, also depends on the environmental stresses associated with the outplanting site.

In general, fertilized treatments had better growth than control treatments, and fertilized-caged treatments had better growth than caged treatments. Growth would have probably been greater for all treatments if the plants would have received supplemental irrigation during the growing season.

CONCLUSIONS AND RECOMMENDATIONS

Vegetation and soil characteristics varied between use intensity levels at three scenic view areas and two campgrounds in the park. Plant cover and infiltration rate decreased significantly, and bareground, bulk density and sediment production increased significantly from low to high-use areas. Litter cover was significantly different between use intensity levels in campgrounds, but was not significantly different between use intensity levels and scenic viewpoints. Differences in vegetation composition between use intensity levels provided an approximate measure of plant cover change on high-use areas.

Plants native to the park were propagated from seeds and stem cuttings. Plants were grown in containers for a fall, 1978, and spring, 1979, planting at three scenic view areas. The shrubs planted during fall, 1978, were low sagebrush, greenleaf manzanita, bitterbrush, and common juniper. Big sagebrush, greenleaf manzanita, bitterbrush, common juniper, and Indian ricegrass were planted in spring, 1979. Propagation success, outplanting survival, and growth rate were generally low for the majority of the plant species used in this study. Factors affecting the ease of propagation, the outplanting survival, and the

growth rate of these native species include the source of plant material, climatic conditions, soil characteristics, and the methodologies used from the collection of planting stock to the maintenance after outplanting.

The present condition of scenic overlook areas and campgrounds at Bryce Canyon National Park is a reflection of increased visitor use and park management policies. Evidence of soil compaction, decreased vegetative cover and accelerated erosion show that it is difficult to preserve these areas in their original natural condition while at the same time allowing recreational use. In a small, intensively used park, such as Bryce Canyon National Park, nature cannot maintain or restore original conditions without management help. Under park policy, all native plants and animals are left alone, except when serious damage to the plant is threatened by a certain species (7). Man is threatening the original natural conditions of many areas in Bryce Canyon. Adequate control measures should be applied to prevent further damage to these areas.

One of the management objectives of the Statement for Management of Bryce Canyon National Park (8) is to secure, through research or other means, adequate information to optimize management efficiency and to ensure long term conservation of park resources. In order to minimize the impact of heavy visitor use and maintain or restore the ecological stability of scenic overlook areas and campgrounds, the following management options should be considered:

Rest-rotation management

Horman (18) indicated that the principle of resting may be applied in many forms of wildland management in which the degree of use of the resource cannot be adequately controlled. Under rest-rotation management, one or more view areas, and one or more sections of a campground would

be closed to visitor use for a specified period of time to allow plant growth and reproduction. Following the opening of these rested areas, other areas would be closed for similar time periods in a rotation system.

When considering this management tool for small, intensively used recreational areas the disadvantages far outweigh the advantages. Some of the disadvantages include: the length of time (4-6 years) required to increase plant cover and improve soil conditions during rest; the rapid deterioration of rested areas after re-opening to public use; and the increased visitor impact on non-rested view areas in the rotation sequence.

Management of Foot Traffic

Uncontrolled visitor foot traffic is the major cause of scenic overlook deterioration at Bryce Canyon National Park. Natural breaks in ground cover vegetation are used as more "direct" routes to points of interest in favor of established paths. After a period of use, these "direct" routes take the appearance of established paths. Signs, log barriers (Figure 13), and awareness programs during interpretive activities have proved ineffective over the years (personal communication with park personnel). A more effective control measure would be the use of permanent, natural-looking, split-rail wood fences (Figure 14) along established paths at severely disturbed view areas. This type of fencing would blend with the natural surroundings of the view area, allow the vegetation and soil to recover, and permit use by native fauna. Major paths to scenic overlook areas should be graded with natural materials and lined with rock. The main path from the Camper Store parking lot to Sunrise Point is a good example. Established paths which show evidence of accelerated erosion on steeper slopes may have to be paved and equipped



Figure 13. Log barriers placed on a high-use area at Farview Point to control visitor foot traffic.



Figure 14. Split-rail wood fence controlling visitor foot traffic along established path at Mesa Verde National Park, Colorado.

with an adequate drainage system such as log diversions across the path to reduce the erosion hazard.

Rehabilitation of Disturbed Areas

The most logical and natural rehabilitation method would be the re-establishment of native plants on disturbed sites at scenic view areas and campgrounds. Native plants would stabilize the soil and be aesthetically pleasing. Prior to planting, the impacted area may have to be ripped and/or topsoiled with soil native to the park.

We recommend that plant species or ecotypes used for the rehabilitation of drastically disturbed sites in the park be taken from areas in close proximity to the disturbed site. Plants selected in this manner are adapted to the environmental conditions specific to each disturbed site. Adapted plant species should be propagated by established methods (17, 19, 27). Seedlings and rooted cuttings should spend a minimum of one year in the nursery and then be hardened-off for spring planting. This will allow time for top growth and root development. Wildings (seedlings) and bare root-stock should also be transplanted in the spring. Shrubs, forbs and grasses should be planted in a mix which resembels the composition of the surrounding vegetation. To insure adequate survival after out-planting, all species should receive supplemental irrigation (every two weeks, especially if on shallow soils) throughout the first growing season. The planting densities should be higher than the densities of the surrounding species, since plant survival, even under the best of conditions, will be somewhat below 100 percent. During the initial stages of rehabilitation biotic and abiotic factors will interact with the transplanted vegetation to determine plant composition and cover. Temporary fencing will be required to protect plants during the early establishment period. As in the case of rest-rotation management, these rehabilitated areas will

rapidly deteriorate after re-opening to public use if not given proper management and some type of protection (i.e. fencing).

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