



Evaluation of the impact of human use on native vegetation in Bridge Bay Campground, Yellowstone National Park, Wyoming
by Robert Clarence Wagner

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Agronomy
Montana State University
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Abstract:

Two campsites with different use intensities were evaluated for camper use for two years in Bridge Bay Campground, Yellowstone National Park, Wyoming. Groundcover readings were taken inside and outside both campsites to compare the vegetative status of these campsites. These vegetative readings also allowed comparisons of the campsites. Measurements of use intensities were made inside the campsites with footstep counters and by soil compaction estimates. Flow patterns of use within campsites were determined by counts obtained with the footstep counters.

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The areas of maximum trampling within a campsite were determined by flow patterns.

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EVALUATION OF THE IMPACT OF HUMAN USE ON NATIVE VEGETATION
IN BRIDGE BAY CAMPGROUND, YELLOWSTONE NATIONAL PARK, WYOMING

by

ROBERT CLARENCE WAGNER

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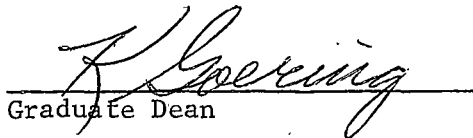
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ABSTRACT

Two campsites with different use intensities were evaluated for camper use for two years in Bridge Bay Campground, Yellowstone National Park, Wyoming. Groundcover readings were taken inside and outside both campsites to compare the vegetative status of these campsites. These vegetative readings also allowed comparisons of the campsites. Measurements of use intensities were made inside the campsites with footstep counters and by soil compaction estimates. Flow patterns of use within campsites were determined by counts obtained with the footstep counters.

Human trampling has apparently caused deterioration of groundcover in both campsites as shown by the differences in % groundcover inside and outside. There was more vegetation present in the limited use site than in the heavy use site. Footstep counts also showed a difference in intensity of use of these two campsites. Soil compaction estimates were not correlated with use intensities in this study. The areas of maximum trampling within a campsite were determined by flow patterns.

INTRODUCTION

The use of campsites and recreational areas is ever increasing in the United States. This increased use of recreational areas can in part be attributed to: 1) increased population, 2) shorter work weeks, 3) higher income per capita, and 4) increased numbers and use of pickup campers and camping trailers.

Groundcover conditions within many campsites and recreational areas are deteriorating due to the activities of man. Improvement of groundcover in existing recreation areas and effective development of new areas will be necessary in the years immediately ahead to preserve our environment and protect it from destruction. Previous research efforts on recreational sites have been limited to surveys based upon visual evaluations of damage caused presumably by human trampling. Accurate methods of measuring use intensities are needed as aids in the development of better design and management systems for recreational areas. Because factors such as topography, environmental, and climatic conditions differ from place to place, a variety of methods for measuring use intensities is needed in different areas.

The purpose of this study was to evaluate the impact of human use on native vegetation within campsites. Specific objectives toward this purpose were:

- 1) To survey the vegetative status within apparent heavy and light use campsites as related to adjacent minimal use areas.
- 2) To obtain quantitative measurements of use intensities within

- 2 -

campsites.

- 3) To determine flow patterns of traffic or use within campsites.

LITERATURE REVIEW

Increased technology has created more leisure time for more people resulting in a sharp increase in outdoor recreation. In man's attempt to escape from the urban congestion to less crowded areas, a new problem has occurred (8, 5, 11). Areas of retreat usually are established recreation areas, many of which are identified as campgrounds. However, with many moving to campgrounds and other outdoor recreational facilities, recreational areas, are, like cities, becoming over-crowded and in some instances seriously damaged.

DeVoto (5) pointed out the growing concern among the populus of the United States for the preservation of existing recreation areas and areas in planning and construction stages. The prime concern is for the restoration of areas deteriorated due to overuse.

Jones (11) reported that by the year 2000, the U. S. population will nearly double, and the overall demand for outdoor recreation will triple. Between 1946 and 1962, visits to Corps of Engineer reservoirs increased from 5 million to 126 million, nearly a 26 fold increase in use. Also, within this same period, visits to National Forest increased from 18 million to 113 million, an increase in use of approximately 6.3 fold. Clawson (3) estimated that recreational use of Federal lands is growing steadily at the rate of about 10% per year, with doubling of use about every eight years. With this increase in use of our lands for recreational purposes, we are faced with the problem of protecting our natural resources. Provision of minimum facilities are required in an

area for recreational use. For an area to reach its full use potential, more than minimum facilities are necessary. LaPage (12) stated, "... length of camping visits tends to increase directly with campground size, apparently because of a large number of attractions at big campgrounds".

A marked reduction in the abundance of vegetative cover and a decline in the number of plant species was noted after a single seasons use of the Buckaloons Campground in the Allegheny National Forest in Northwestern Pennsylvania (15). Magill (18) reported that heavy use of National Forest campgrounds and picnic areas in California resulted in critical site deterioration. Jilka and Beidleman (10) noted that three years after a season of heavy use, the effect of man's presence was still obvious in an outdoor recreation site. Paths could be detected and areas of heavy use could be recognized.

Some measure of the quality or character of recreational use is needed to explain the destruction of groundcover more realistically than simple visual appraisal. One of the most comprehensive studies in this area was done by LaPage (14). The effect of man's activities upon native vegetation was studied. Vegetative cover loss and change of plant species was determined over a three year period in a newly opened campground using a grid system. An initial and inevitable heavy loss of groundcover was observed following the onset of camper use; the extent of the loss was strongly related to the intensity of use the

first year. In heavily used areas, the plant species composition of the original cover underwent a gradual rearrangement the first year, in which species resistant to drought and to trampling become increasingly abundant. In following years, the species more tolerant to trampling spread while the original less-resistant species continued to diminish.

Changes in campsite vegetative composition have been reported in the Bear Trap Recreation Area - Madison County, Montana due to camper use, (2, 7, 20).

Vegetation changes are not the only method of estimating recreational use of an area. Changes in soil conditions also reflect use. An increase in soil density along with a decrease in pore volume and air capacity with recreational use of forest parks was reported by Lutz (16).

Soil compaction measurements in recreation areas have revealed that soil compaction as a result of trampling appears to be most severe in the surface six inches (root zone) of the soil (6, 13).

Due to the generally severe site damage in the immediate vicinity of the picnic table, it has been suggested that occasional shifting of tables will permit the heavily used areas to recuperate (9, 14).

As the recreational pressures continue to build in our country, satisfactory methods for assessing human impact on vegetation and soils will have to be developed. Data from assays will have to be used as

guides to protect and rehabilitate popular recreation areas, along with preventing deterioration of areas in the planning stages (8; 9, 17, 18, 19). Allison and Leighton (1) have developed tables useful in determining the feasibility of proposed forest campground sites for recreational use. These tables numerically rate a proposed site with respect to physical factors (such as water, topography, potable water, vegetation, natural attractions, vista, forest pests, animal and birdlife, and climate and microclimate) and socio-economic factors (such as location, economic and business management, and proposed campground facilities).

MATERIALS AND METHODS

In this study a "campsite" is considered to be a single camping unit consisting of a table and a fireplace; a campground being a composite of campsites. Frequently, campgrounds differ in the facilities and conveniences provided. Highly developed campgrounds have running water, wash rooms, and sanitary waste disposal facilities. Less developed campgrounds may have only a single community pump and toilets.

Following a study of campground history of Yellowstone National Park, Wyoming, the Bridge Bay Campground was selected as the test site for this study. Research data were collected during the 1969 and the 1970 camping seasons. Bridge Bay Campground is located in a lodgepole pine forest on the north shore of Yellowstone Lake about two miles southwest of Lake (Fig. 1). The elevation of the campground is approximately 7,735 feet. It has a frost free period of 50 to 90 days and receives approximately 25 inches of precipitation annually.

Based on use data, two campsites were selected within the Bridge Bay Campground which, due to location and management, had received different levels of use. The heavy use site chosen was number 47 in Loop-C (hereafter referred to as C-47) and the light use site was in Loop-E (Plate 1). C-47 is located near the entrance of the loop and about 150 feet from water and toilet facilities. The campsite in E-Loop is about 450 feet from water and toilet facilities. This loop is restricted to group camping and, therefore, receives considerably less total season use. All campers were excluded from E-Loop during the

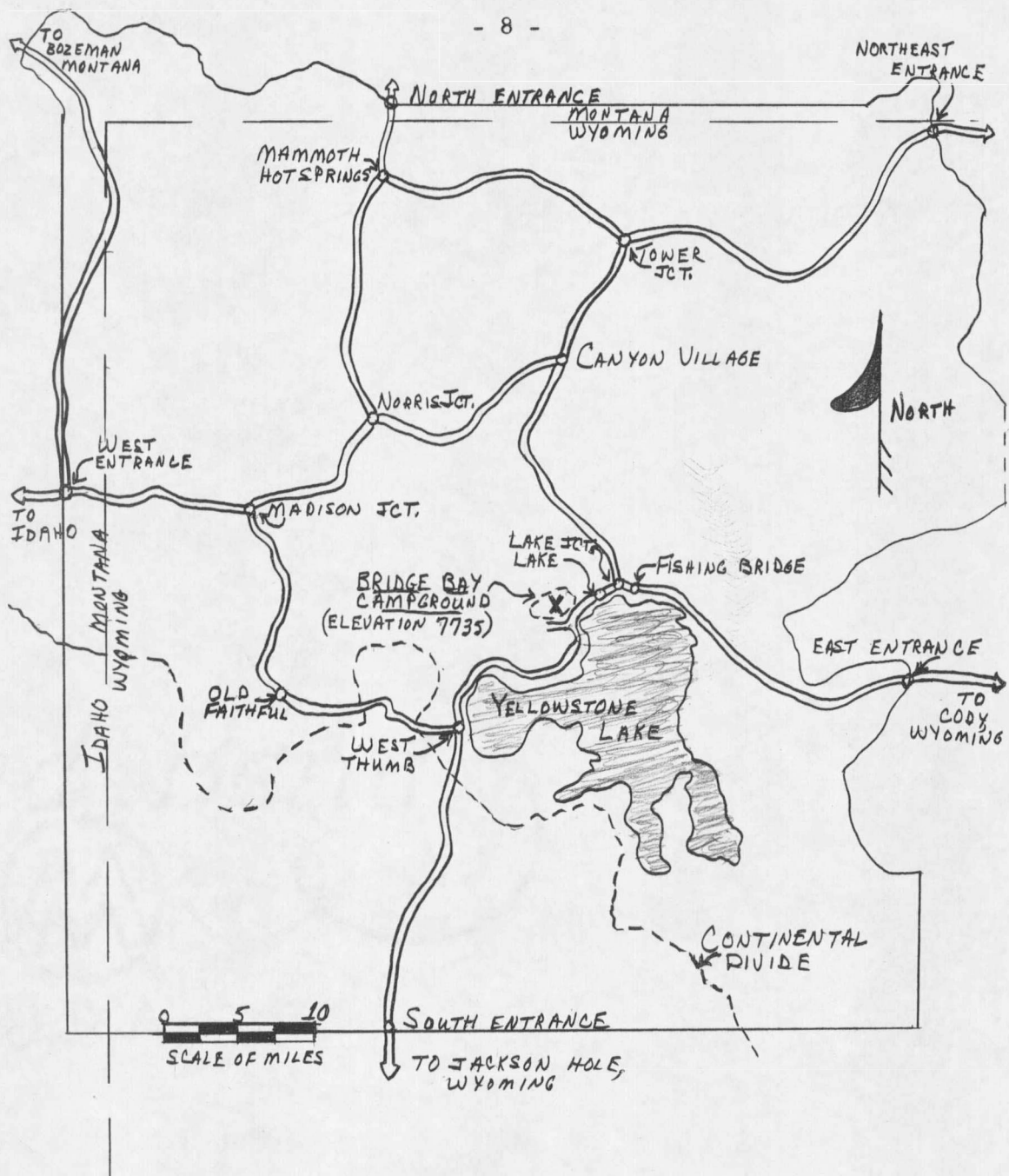


Figure 1. Map of Yellowstone National Park, Wyoming.
 (Redrawn from a folder prepared by Sage Advertising
 Service, Helena, Montana, 1963).

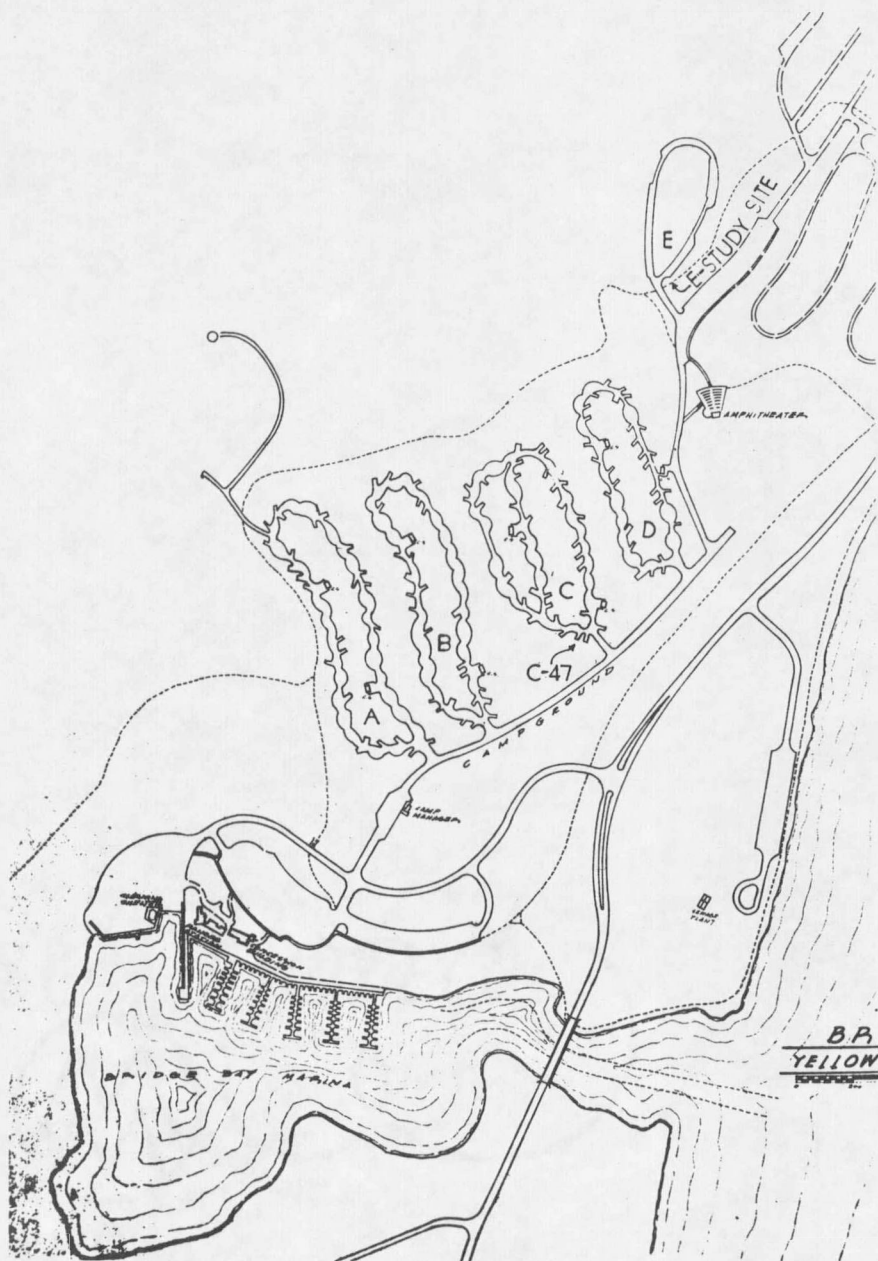


Plate 1. Map of Bridge Bay Campground, Yellowstone National Park, Wyoming. (Photographed from a blue print, drawn by J. A. Abbie, 1965).

1970 camping season. Both campsites were fairly level, but the E-Loop campsite was slightly higher in elevation (about 50 ft.) than C-47. C-47 receives a little less sunlight than the E-Loop campsite, but both sites would be considered shaded areas.

Readings of groundcover were made inside each campsite (between table and fireplace) and outside each campsite (about 50 feet from table) to determine the effect of human trampling on native vegetation. Each plot transect consisted of two parallel lines forming a rectangle 5 m. x 1.5 m. with markers placed 1 m. apart along the long sides (Fig. 2). Ten 2 x 5 dm subplots (5 on each side of the rectangular plot) were read for each plot transect. These ten subplot readings were equivalent to one square meter. A Daubenmire plot frame was used at each subplot to estimate percent cover (Plate 2) (4).

Readings, consisting of (A) % vegetative cover, (B) % coverage by litter, and (C) % area covered by rocks and bareground, were taken at the beginning and end of each camping season. These dates were June 11 and September 18, in 1969, and June 17 and October 1, in 1970. All readings were made on permanently selected areas within the two campsites.

To estimate camper use quantitatively with regard to trampling, footstep counters were systematically placed within the two selected campsites (see Figs. 3 and 4). Five counters were buried within each site at measured distances from permanent fixtures. This allowed the

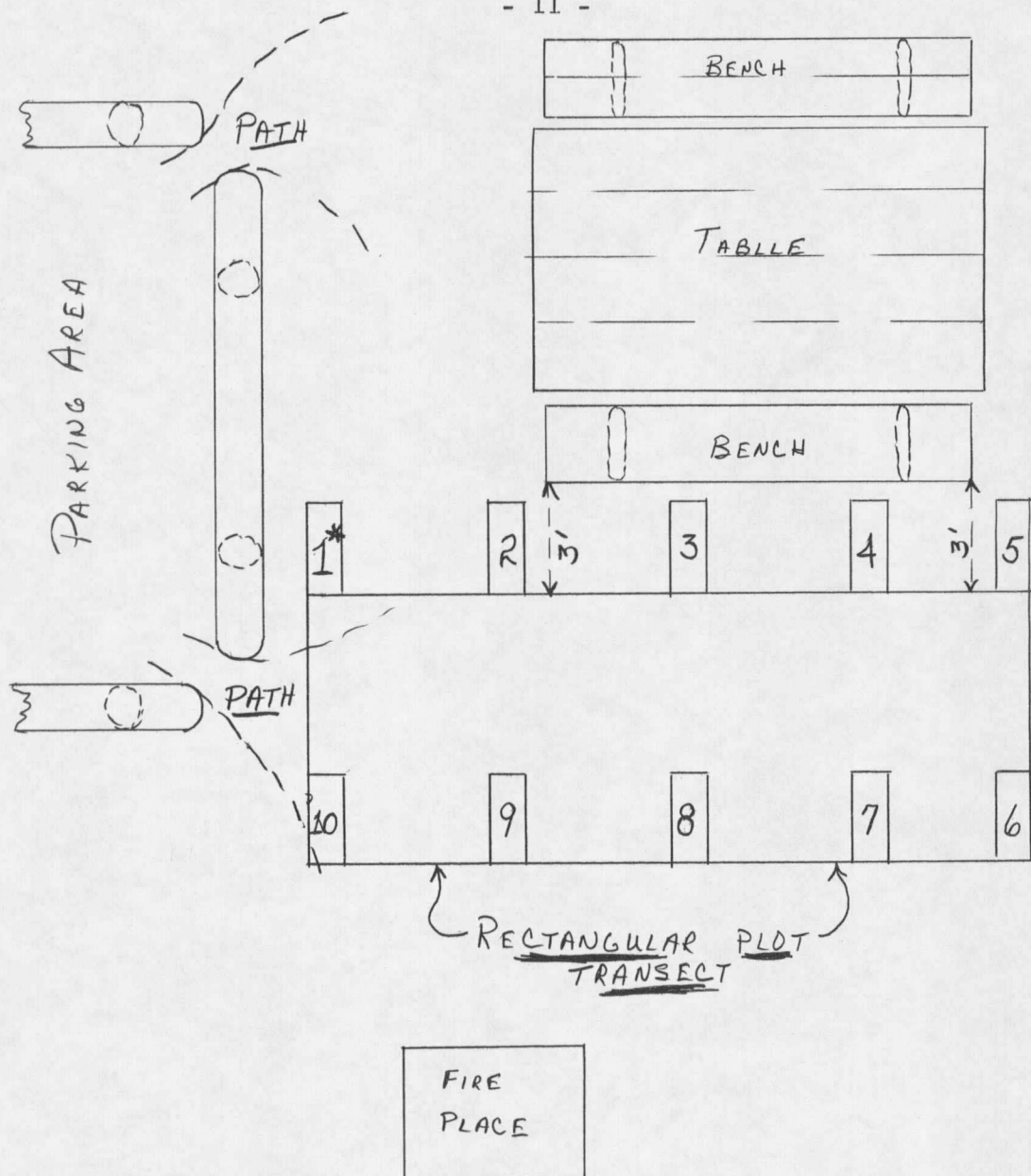


Figure 2. Diagrammatic illustration (not to scale) of the rectangular plot transect for groundcover determinations inside a campsite.

* Numbers 1-10 indicate subplots.

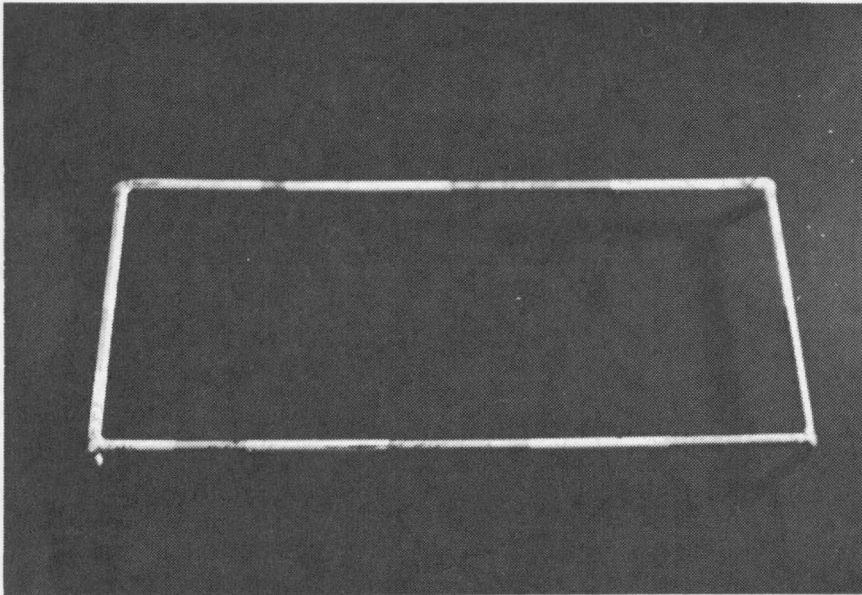


Plate 2. Two dm x five dm Daubenmire plot frame painted for rapid estimation of % groundcover.

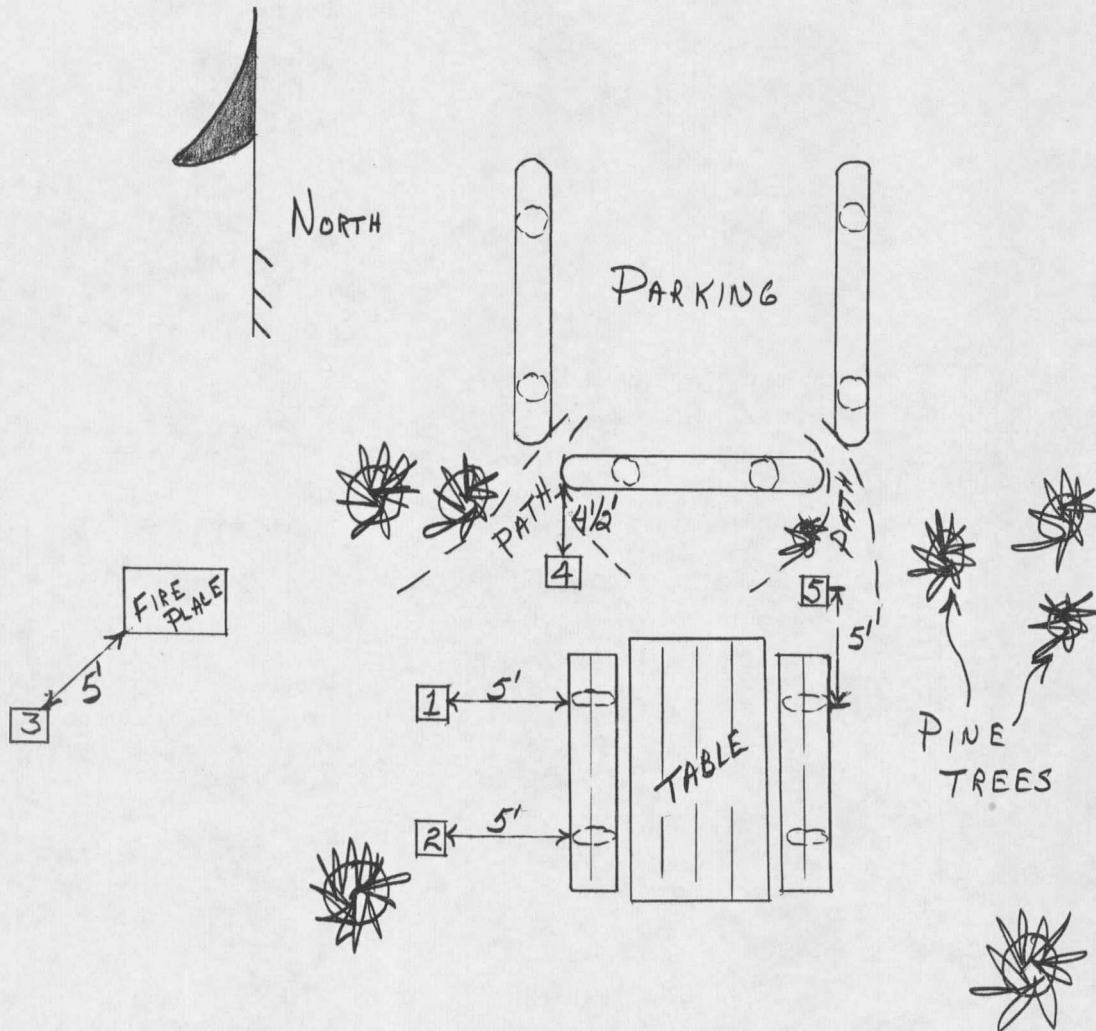


Figure 3. Diagram of campsite studied in Loop-C, Bridge Bay Campground, Yellowstone National Park, Wyoming, showing location of five footstep counters.

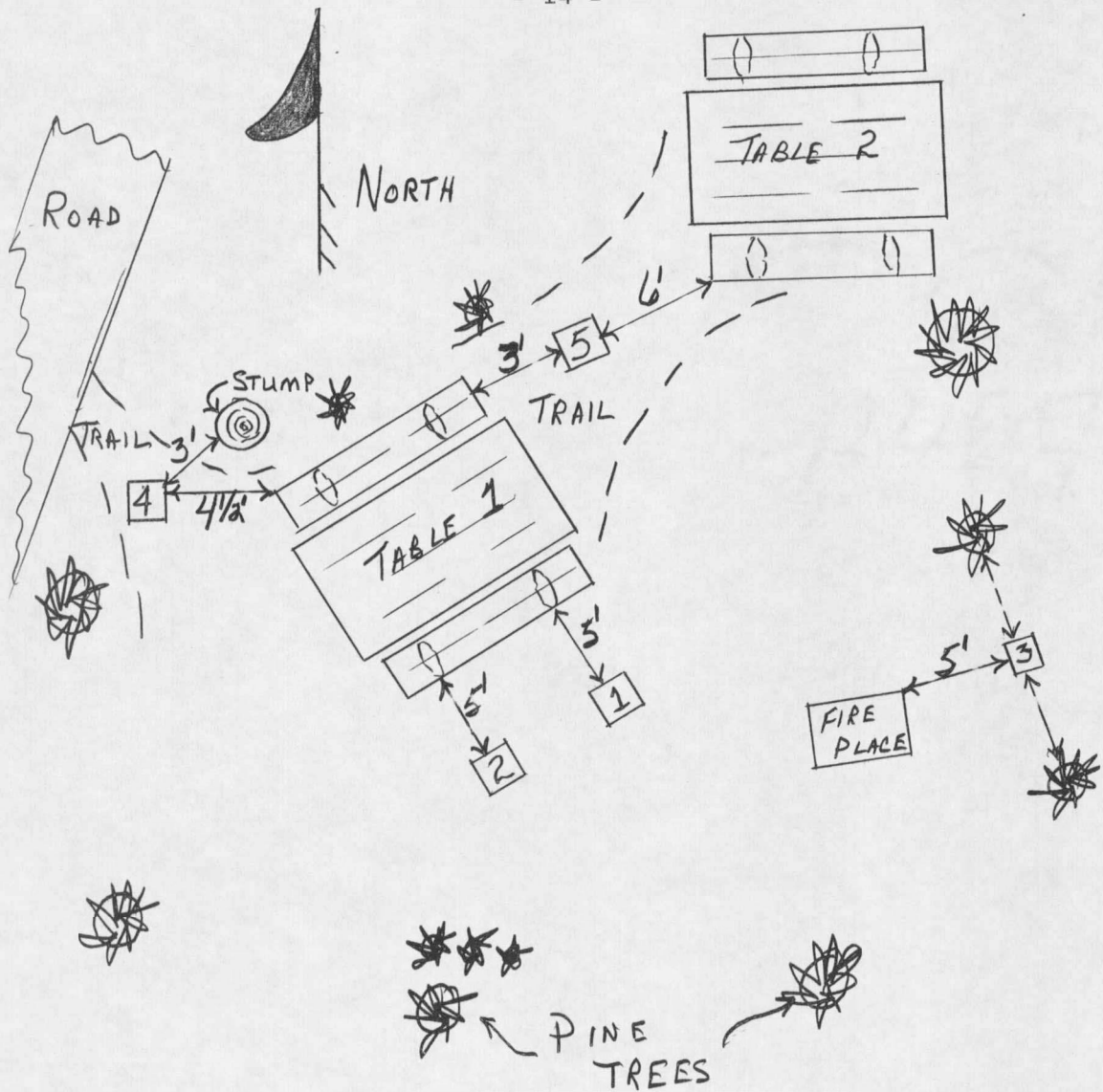


Figure 4. Diagram of the campsite studied in Loop-E, Bridge Bay Campground, Yellowstone National Park, showing location of five footstep counters.

counters to be placed in the same positions both years. All counters were removed at intervals (5 dates) throughout the camping season for both years. The number of footsteps was recorded at each removal date and the counters were then reburied at the same spots. Counter readings for the 1969 camping season were taken on June 11, July 15, August 6, August 27, and September 18. Readings for the 1970 camping season were taken on July 1, July 15, August 12, August 31, and September 23.

The counters used for recording foot steps were standard hand tally counters^{1/} inserted into 4 x 4 x 4 inch boxes constructed of $\frac{1}{2}$ inch plywood. A one inch hole was drilled in one side and sealed with clear hard plastic which provided visual access for reading the number of counts on the counter. The top was made movable (up and down) by gluing foam rubber strips on the top edges and sealing the top side to the rest of the box with a rubber strip made from a tire inner tube (Plate 3). This allowed the up and down action required to work the inserted tally counter. Each entire unit (box, rubber, and counter) was sealed in clear six mill plastic to water proof it (Plate 4). Approximately 15 pounds of pressure was needed to trip each counter.

In an attempt to correlate soil compaction and use, soil bulk density was determined over the course of the 1970 camping season for

^{1/} Tally Register Co., 74 Lafayette St., New York, 13, New York 10013

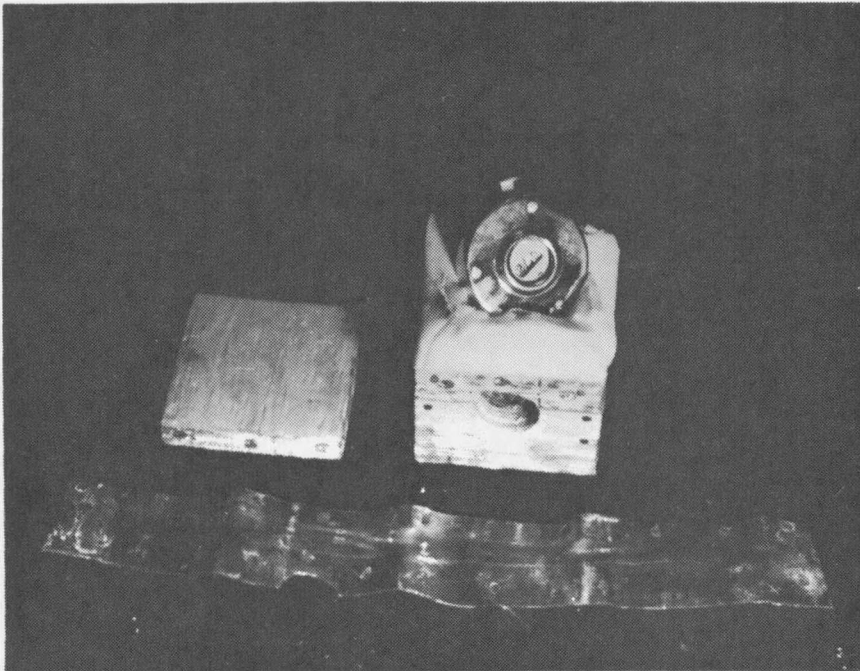


Plate 3. Disassembled footstep counter showing materials used in construction.

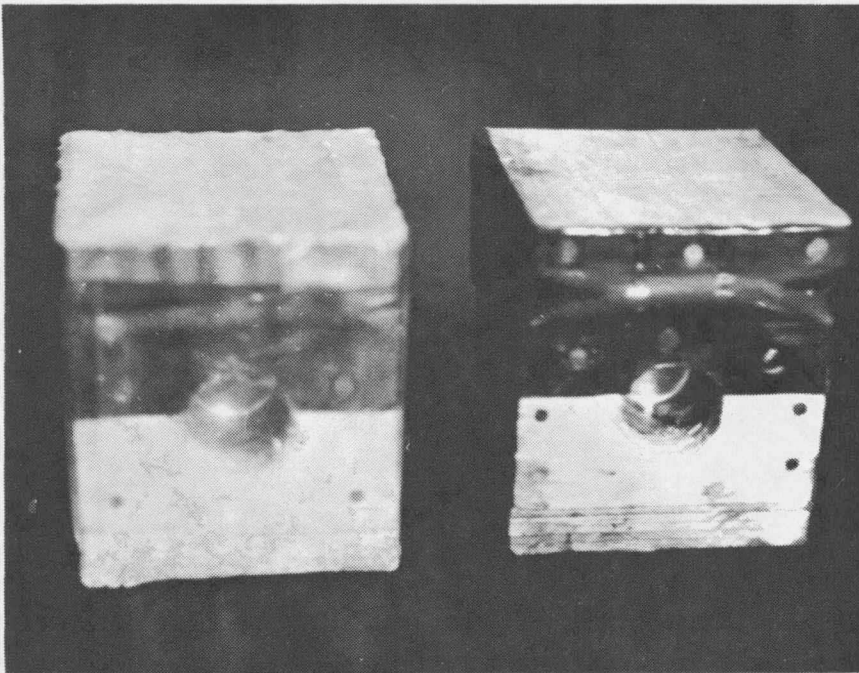


Plate 4. Finished footstep counter on the right, finished counter sealed in six mill plastic for water proofing purposes on the left,

both campsites. Soil samples were taken on the following dates: July 1, July 15, August 12, and August 31. Due to wet conditions on September 23 (last date footstep counts recorded), soil samples for purposes of bulk density determinations were not taken. Soil volumes were measured in the field.

A core sample approximately 3.2 cm in length and 2.9 cm in diameter (20 cubic centimeters) was obtained with the use of the Eley Volumeter^{2/} (Plate 5). To obtain a soil sample, the tool, with piston withdrawn completely into the cylinder, was pressed into the soil to the depth flange (about 55 mm) and removed with the sample. The core sample was extruded to the zero mark on the threaded stem and using a knife, was cut off flush with the cutting edge of the cylinder. With zero as an index, the core sample was extruded twenty graduates on the threaded stem and again cut off flush. Each graduate on the threaded stem equals one cubic centimeter yielding a soil core sample with a volume of 20 cc. The surface 11-12 mm of soil were excluded. Five 20 cc soil core samples were taken within each campsite. Each sample was placed in a soil sample can, brought back to the laboratory and weighed after being oven-dried for 24 hours at 105°C. The bulk density for each core sample was computed according to the formula:

$$\text{Bulk density (gms/cc)} = \frac{\text{Oven-dry weight of soil sample (gms)}}{\text{Volume of sample (cc)}}$$

^{2/} Distributed by the Alpha-Lux Company, Inc., Lincoln Building, 60 East 42nd Street, New York, New York.

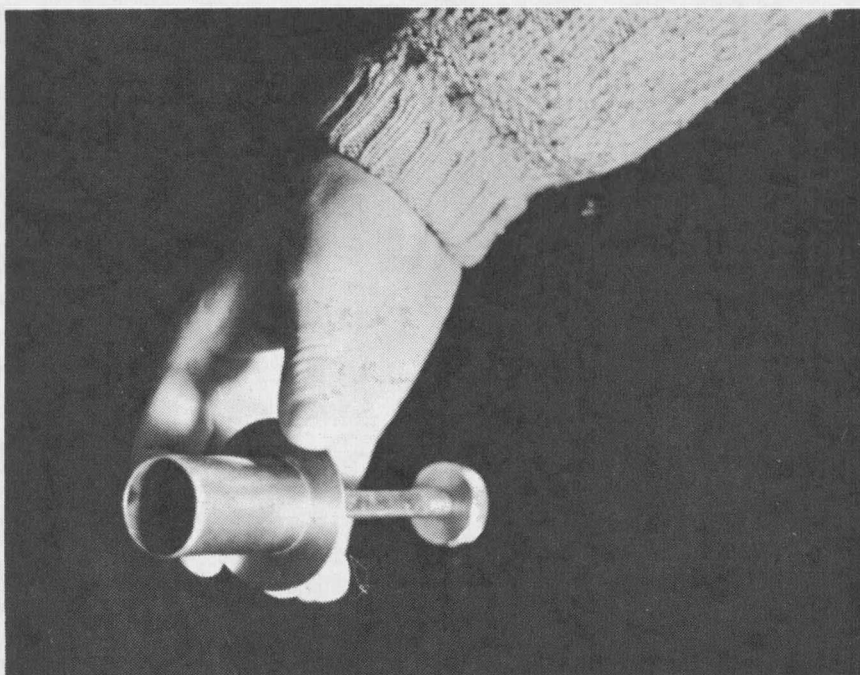


Plate 5. Eley Volumeter with the stem threaded out and the piston resting against the end of the cylinder.

Groundcover analysis followed a randomized complete block design with % litter, % bareground and rocks, and % vegetation analyzed independently within and without each campsite with sample sites treated as blocks. All analyses were carried out on non-transformed, percentage data. Per cent vegetation was not analyzed within campsite C-47 due to the complete lack of vegetation and the marked difference existing between inside and outside C-47. A standard "t" test using a pooled estimate of error was used to compare % litter, % bareground and rocks, and % vegetation inside versus outside for the light use area (E-Loop campsite).

Analysis of camper use with regard to trampling, as measured by the counters followed a completely random design. The five counters in each location were considered random observations within dates and locations. Duncan's Multiple Range test was used to separate differences among dates averaged over both years.

To associate bulk density with trampling, a simple correlation was estimated between bulk density and number of counts obtained for four particular dates (July 1, July 15, August 12, and August 31). Soil samples were taken in the immediate area of each counter in both campsites on the same dates that counter data were recorded. Only four dates were used in correlations because all counters were at zero on June 17 (initiation date of study for 1970 season) and on September 23 (last date footstep counts recorded) wet conditions did not allow soil samples to be taken.

RESULTS AND DISCUSSION

From a plant species composition point of view, the two campsites C-47 and the E-Loop campsite, are similar (Table 1). Sixteen of 22 species identified were common to the undisturbed areas of both campsites. Of the six species not common to both campsites, two were found outside C-47 only, and the other four species were found in the E-Loop campsite area. Seven of the species were found inside the E-Loop campsite which suggests that these species can withstand light to moderate trampling or use.

Table 1. Campsite inventory of plant species in Bridge Bay Campground, Yellowstone National Park, Wyoming.

Common Name	Generic Name	Occurrence ^{1/}
Slender Hawkweed	Hieracium gracile	1, 2, 3
Rose Pussytoes	Antennaria rosea	1, 3
Wild Strawberry	Fragaria sp.	1, 3
Northern Sweet Vetch	Astragalus miser	1, 3
Yarrow	Achillea lamulosa	1, 2, 3
Grouse Whortleberry	Vaccinium scoparium	1, 2, 3
Great Willowherb (Fireweed)	Epilobium angustifolium	1, 2, 3
Heart-leaf Arnica	Arnica cordifolia	1, 3
Raceme Pussytoes	Antennaria racemosa	1, 3
Corydalis	Corydalis aurea	1, 3
Sedge	Carex geyeri	1, 3
Wild Phlox	Phlox longifolia	1
Silvery Lupine	Lupinus argenteus	3
Quackgrass	Agropyron repens	1, 3
Tufted Hairgrass	Deschampsia caespitosa	1, 3
Alpine Timothy	Phleum alpinum	1, 3
Skyline Bluegrass	Poa epilis	1, 2, 3
Subalpine Needlegrass	Stipa columbiana	3
Spike Trisetum	Trisetum spicatum	1
Red Sandspurry	Spergularia rubra	1, 2, 3
Trifolium (Clover)	Trifolium longipes	3
Dog Tooth Lily	Erythronium grandiflorum	2

^{1/} Occurance of species in campsites with the following designations:

1 = Outside C-47, 2 = Inside E-Loop, and 3 = Outside E-Loop.

Groundcover Estimates Inside C-47 and E-Loop

Estimates of % groundcover inside C-47 and the E-Loop campsite for 1969 and 1970 are presented in figure 5. Vegetation was not evaluated inside C-47 in either year because previous human trampling had apparently destroyed all vegetation. In C-47, the increase in % litter from 1969 to 1970 approaches significance which offsets the significant decline in % bareground and rocks. No change in % vegetation occurred from 1969 to 1970 for the E-Loop campsite. A slight decrease occurred for % bareground and rocks inside the E-Loop campsite which is associated with the slight increase in % litter. The trend for % bareground and rocks to decrease while % litter increases is present inside both heavy and light use campsites.

Spring and fall readings of % groundcover for the combined years 1969 and 1970 did not differ statistically inside the two campsites for % litter, % vegetation, or % bareground and rocks (Fig. 6). An apparent trend for bareground and rocks to increase while litter decreases is shown in the figure for C-47 (the heavy use site). This trend indicates that changes in groundcover may occur within a campsite due to continuous wear and tear during a camping season. No differences are shown in % groundcover for the E-Loop campsite.

Groundcover Estimates Outside C-47 and E-Loop

Estimates of % litter and % vegetation outside C-47 did not differ from 1969 to 1970 (Fig. 7). Although a significant decrease

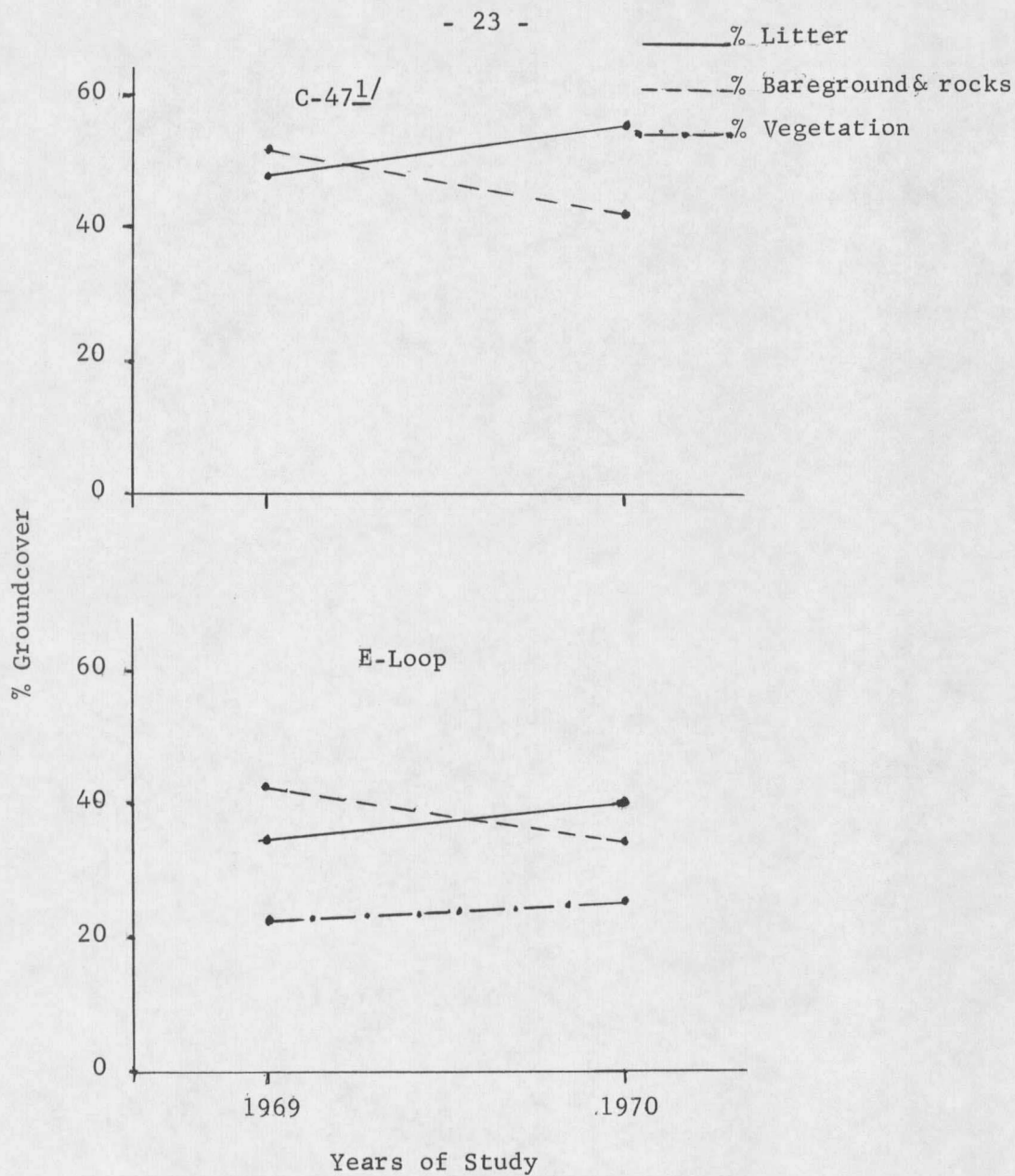


Figure 5. Estimates of % groundcover inside two campsites for 1969 and 1970, Bridge Bay Campground, Yellowstone National Park, Wyoming.

^{1/} No vegetation was present in C-47 for either year.

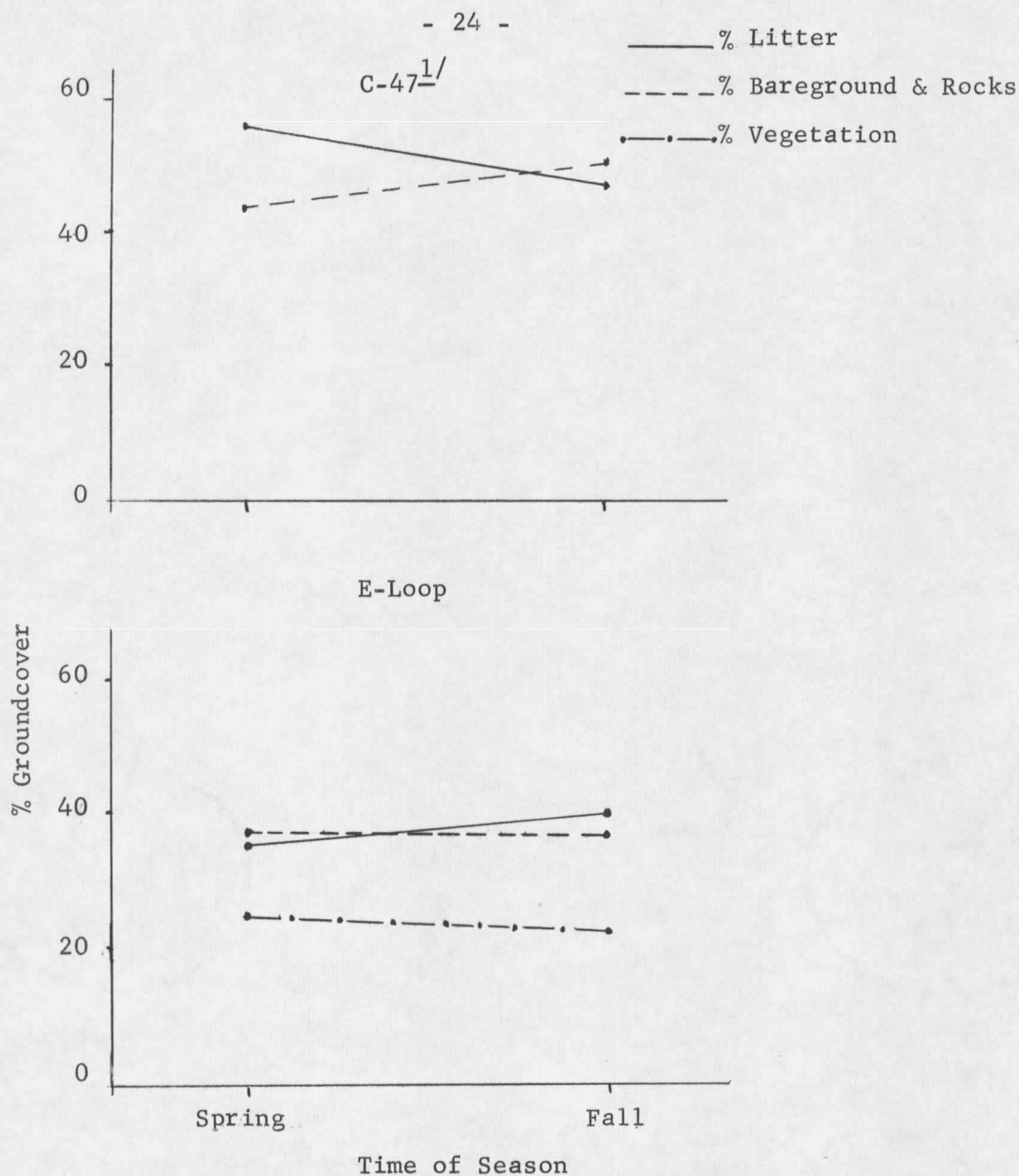


Figure 6. Estimate of camper use by footstep counters for two campsites, Bridge Bay Campground, Yellowstone National Park, Wyoming, 1969 and 1970.

^{1/} No vegetation was present in C-47 for either year.

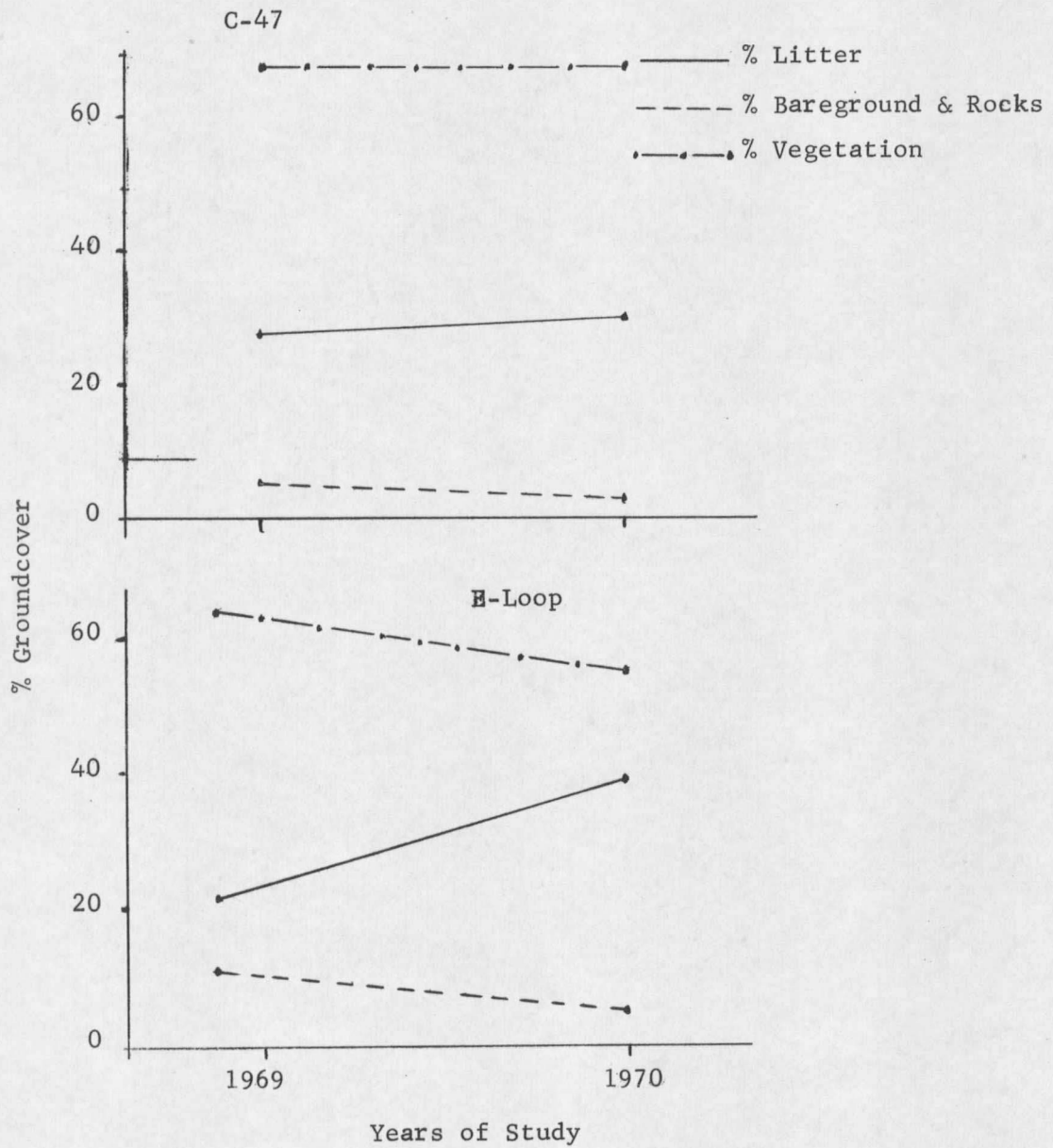


Figure 7. Estimates of % groundcover outside two campsites for 1969 and 1970, Bridge Bay Campground, Yellowstone National Park, Wyoming.

was obtained between years for % bareground and rocks, this category constitutes such a small percentage of the total campsite composition (5.97% in 1969 and 2.63% in 1970), the detected difference has little meaning. Perhaps, if litter and vegetation were combined, a significant increase between years may be detected accounting for the decline in bareground and rocks.

Per cent bareground and rocks did not differ between years outside the E-Loop (Fig. 7). The increase in % litter outside the E-Loop campsite was associated with the decrease in % vegetation. These are normal contrasting results. As plants die or winter kill, they become litter cover the next year.

Spring and fall readings gave similar estimates of groundcover for the outside readings at both locations (Fig. 8). Apparently, a single reading per year would provide adequate information for conditions outside campsites.

Groundcover Estimates Inside and Outside Campsites

The effect of human trampling on native vegetation is reflected in the comparisons of inside and outside readings for years and spring and fall readings combined over years (Figs. 5, 6, 7, 8). Human trampling resulted in an increase of about 25 to 50% bareground and rocks inside as compared to outside in one campsite. Per cent litter was greater inside the campsites than outside. In the E-Loop campsite, per cent vegetation ranged from about 30% to 65%. The heavily used

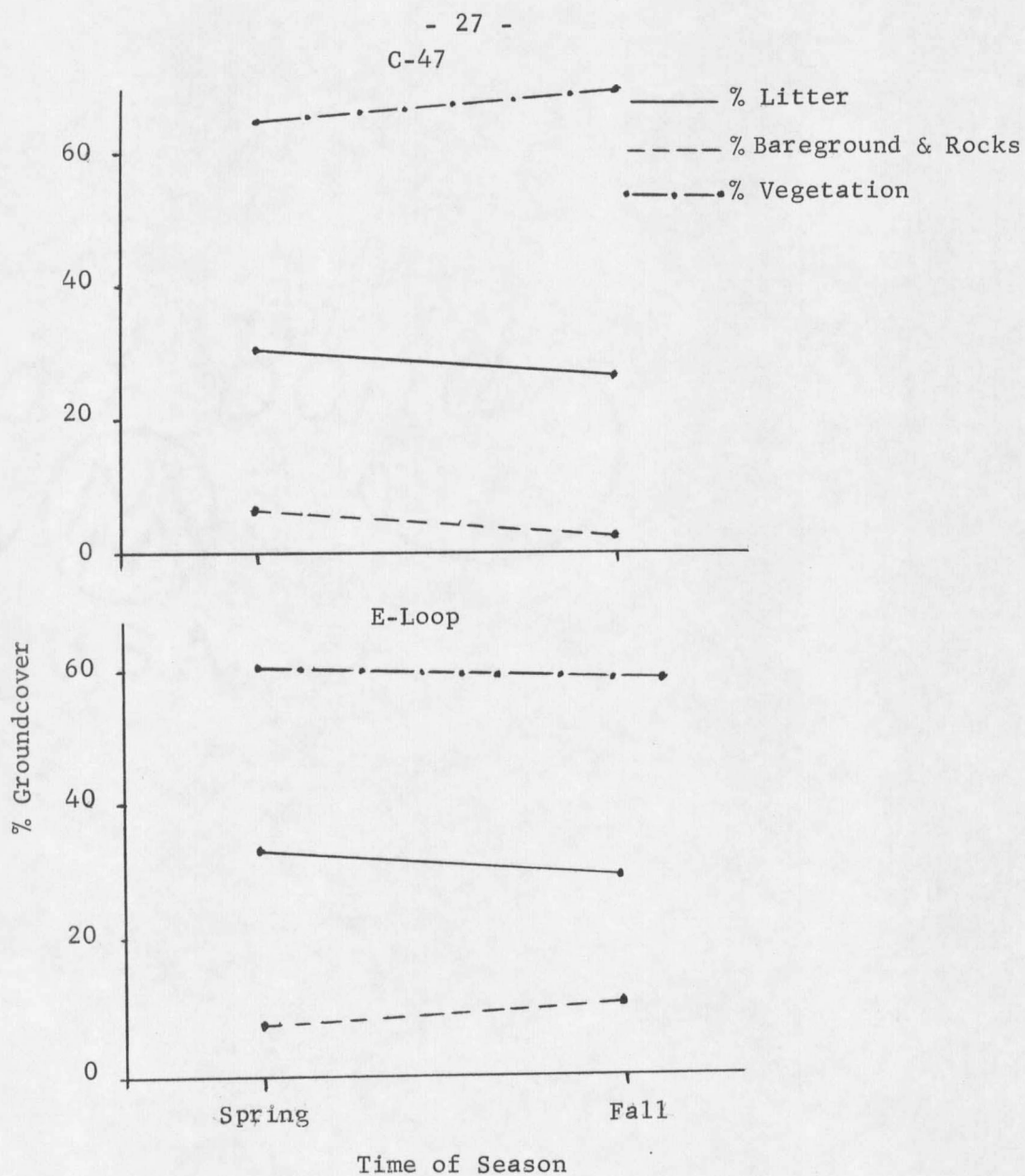


Figure 8. Estimates of % groundcover outside two campsites for spring and fall readings for the combined years 1969 and 1970, Bridge Bay Campground, Yellowstone National Park, Wyoming.

site (C-47) showed a greater effect of use inside (vegetation "0" for both years) than the restricted use site (E-Loop). The E-Loop contained more vegetation inside than C-47 (no vegetation present). Also, the E-Loop had less litter and bareground and rocks inside than C-47. Thus, by limiting the intensity of use during a season, the deterioration of groundcover within a campsite may be reduced.

Inside readings are compared to outside readings for the E-Loop campsite in tables 2, 3, and 4. Comparison of readings for C-47 were not made because % vegetation readings inside were zero in 1969 and 1970. Obviously, there must be a difference in % vegetation between inside and outside C-47.

The 1969 fall reading for % litter inside and outside E-Loop differed (Table 2). Trampling of vegetation by campers destroyed many plants in the campsite during the 1969 season. This accounts for most of the increase in litter inside the campsite between the spring and fall of 1969. The amount of litter outside the campsite did not change from the spring to the fall of 1969. The amount of litter outside the campsite did not change from the spring to the fall of 1969.

Estimates of % vegetation inside and outside E-Loop differed for all readings (Table 3). This indicates a difference of use inside and outside the E-Loop campsite. A decrease in % vegetation occurred inside the campsite from the spring reading 1969 to the fall reading of that year. Some camping was allowed during the 1969 season,

and, presumably due to trampling by campers a decrease in % vegetation occurred. Only a slight decrease occurred for % vegetation for the outside readings taken in the 1969 season.

Table 2. Estimate of mean % litter inside and outside E-Loop, Bridge Bay, Campground, Yellowstone National Park, Wyoming.

	% Litter		
	Inside	Outside	Mean Difference
1969 Spring	25.67	22.94	2.73
1969 Fall	45.97	23.46	22.51*
1970 Spring	46.38	43.22	3.16
1970 Fall	34.23	35.87	1.64

* Significant difference at P.05.

Table 3. Estimate of mean % vegetation inside and outside E-Loop, Bridge Bay Campground, Yellowstone National Park, Wyoming.

	% Vegetation		
	Inside	Outside	Mean Difference
1969 Spring	32.16	69.36	37.20**
1969 Fall	11.88	62.64	50.76**
1970 Spring	18.38	52.94	34.56**
1970 Fall	32.83	57.08	24.25**

** Significant difference at P.01.

Exclusion of campers from the E-Loop area during the 1970 season presumably resulted in an increase in % vegetation inside the campsite and a slight increase in % vegetation outside. Although campers were

excluded from the area, some traffic was indicated. This small amount of traffic was presumably due to wildlife, workers in the area, or unauthorized campers, and apparently had negligible influence on the increase of % vegetation inside and outside the E-Loop campsite. Thus, campers being restricted from an area may allow for restoration of some vegetation. The species of plants (native or cultivated) which will revegetate deteriorated campsites is not known and needs to be determined.

In table 4, all inside and outside readings are compared for % bareground and rocks. There was considerable more bareground and rocks

Table 4. Estimate of mean % bareground and rocks inside and outside E-Loop, Bridge Bay Campground, Yellowstone National Park, Wyoming.

	% Bareground and Rocks		
	Inside	Outside	Mean Difference
1969 Spring	43.15	8.49	34.66**
1969 Fall	42.98	14.93	28.05**
1970 Spring	36.24	4.79	31.45**
1970 Fall	33.93	8.00	25.93**

** Significant difference at P.01.

inside than outside each site. This, along with the results obtained for % vegetation (Table 3), indicate more localized use occurring inside a campsite than outside which is normally expected in a camping area.

The increase in % vegetation inside the E-Loop campsite for the

1970 season, along with the decrease in % litter and % bareground and rocks, showed that an area can revegetate some groundcover if given the chance to do so (Tables 2, 3, 4). Whether an area depleted of all vegetative cover (C-47) could replenish itself by restricting use alone is unknown. Plantings of cultivated species resistant to harsh conditions created by campers may be desirable in a case such as this. In the E-Loop campsite where all the groundcover has not been crowded out, planting of groundcovers may not be necessary. If given ample time, areas with partially destroyed groundcover may replenish themselves to their normal state. Additions of fertilizers and possibly irrigation may greatly increase the likelihood of revegetation. Also, the use of fertilizer may increase plant resistance to trampling in the future. Altering the use of campgrounds from year to year or week to week may be ways to preserve native groundcover in campsites. Resting pastures is a common management practice thus, resting of campsites should not be too unrealistic.

The camping season at Bridge Bay Campground exceeded the number of frost free days (50 to 90). This merits special attention for the establishment of campground management practices in Yellowstone National Park. This creates a situation of intensive traffic and use upon vegetation before sufficient spring growth has occurred to withstand some of the pressures of camper use. Also, camper use extending into the fall does not allow for plants to replenish and build up root reserves

before the onset of winter .

Estimates of Campsite Use

Estimates of camper use by the footstep counter method for both campsites over two years are given in table 5. Footstep counts were recorded on five dates throughout the camping season for each year. Date 1 represents the first recording date made in the spring of each years. Dates 2, 3, and 4, represent progressive dates throughout each summer on which recordings for footstep counts were made. The last recording, date 5, was made in September of both years. The opening date of Yellowstone National Park for camping varies from year to year due to variation of favorable spring weather for camping. An early spring in 1969 and a late spring in 1970 accounts for the differences of recording dates between years.

Footstep counts differed between dates for both years (Table 5). As shown by the date means for footstep counts, camper use was low at the beginning of each camping season, increasing to a maximum between the last half of July and the first part of August, and subsiding again in the fall. This use pattern is supported by park records which show that more people visit and camp in Yellowstone National Park in mid-summer than in the spring or fall.

More footsteps were recorded inside C-47 than inside the E-Loop campsite (Table 5). Differences between campsites within the average of each year and the average of both years were consistant for footstep

counts; in all comparisons C-47 (heavy use site) had significantly more traffic than the E-Loop campsite (light use site).

Table 5. Estimate of camper use in two campsites by footstep counters for dates, Bridge Bay Campground, Yellowstone National Park, Wyoming, 1969 and 1970.

Date	1969			1970			Combined Years		
	Heavy*	Light**	$\bar{X}$	Heavy	Light	$\bar{X}$	Heavy	Light	$\bar{X}$
1	26.4	4.0	15.2	6.2	2.8	4.5	16.3	3.4	9.8
2	18.0	9.0	13.5	25.4	5.4	15.4	21.7	7.2	14.4
3	42.2	12.4	27.8	70.6	5.6	38.1	56.9	9.0	32.9
4	28.0	16.4	22.2	26.4	1.8	14.1	27.2	9.1	18.1
5	19.2	3.6	11.4	19.0	2.4	10.7	19.1	3.0	11.0
$\bar{X}$	26.9	9.1	18.0	29.5	3.6	16.6	29.2	6.3	17.2

* Heavy = C-47 in C-Loop, Bridge Bay Campground.

** Light = E-Loop, Bridge Bay Campground.

The dates x location interaction was found to be highly significant which suggests that seasonal use patterns were not the same for both locations (Table 13). The seasonal use patterns were similar for both campsites in 1969. The exclusion of campers from the E-Loop in 1970 prohibited the typical seasonal change in use. This could account for the significant date x location interaction.

The flow of traffic for the two use areas by years is shown in table 6. Counter locations for both heavy and light use areas are indicated in figures 3 and 4. Counters 1 and 2 were placed five feet from the table towards the fireplace, counter 3, five feet from the

fireplace outside the campsites, and counters 4 and 5 on regularly traveled trails. As nearly as possible, this systematic arrangement was used in both campsites. Counts from counters 1 and 2 suggest that the area between the table and fireplace is very heavily used within each campsite. Likewise, counts from counters 4 and 5 suggest the trails are also heavily used. Counts from counter 3 suggest that as the distance increases from the immediate vicinity of the table and fireplace, the amount of traffic decreases. Because campers were generally restricted from the light use area (E-Loop) in 1970, only limited data was obtained.

Table 6. Estimate of camper use by footstep counter for two campsites, Bridge Bay Campground, Yellowstone National Park, Wyoming, 1969 and 1970.

Counter	1969			1970			Combined Years		
	Heavy*	Light**	$\bar{X}$	Heavy	Light	$\bar{X}$	Heavy	Light	$\bar{X}$
1	35.2	17.6	24.2	43.0	6.0	23.0	39.1	11.8	23.6
2	16.8	13.2	17.2	12.2	3.0	9.1	14.5	8.1	13.1
3	7.8	2.0	4.9	12.6	2.8	7.7	10.2	2.4	6.3
4	37.2	5.8	21.5	52.8	3.0	27.9	45.0	4.4	24.7
5	37.8	6.8	22.3	27.0	3.2	15.1	32.4	5.0	18.7

* Heavy = C-47 in C-Loop, Bridge Bay Campground.

** Light = E-Loop, Bridge Bay Campground.

Previous research in Colorado and Connecticut has suggested that bulk density of the soil in campgrounds increases proportionately with increased trampling or camper use (5, 15). The correlation of bulk

density to number of footstep counts for C-47 was $r = .13$ (Table 11), and for the E-Loop campsite $r = .33$ (Table 12). The r values are not significantly different from zero. Bulk density varied up and down from date to date in both campsites, due to soil texture, high organic matter, fluctuation of soil moisture, loosening of the soil by wind movement of the trees, and the inefficiency of the Eley Volumeter in Bridge Bay Campground soils. The Volumeter works well in silty, clay, and some sandy soils, but in rocky soils and soils of high organic matter such as those in Yellowstone National Park, it does not function efficiently. Thus, the use of bulk density of soil as a measure of trampling in Yellowstone National Park is not feasible.

Previously, it was suggested that limiting camper use during a camping season, or altering the use of campgrounds from year to year or week to week may be ways of protecting the vegetative groundcover. These techniques may be effective if initiated at the time an area is opened for camping use. However, many campgrounds in Yellowstone National Park have been heavily used for more than five years. Vegetation within the campsites of many campgrounds is extremely poor, if not completely destroyed. Due to the ever increasing number of people camping within Yellowstone National Park, it is not feasible to close campgrounds for the purpose of revegetation. Thus, paving or graveling of areas within campsites may be a possible solution for denuded campsites. As indicated by the counters, the paved or graveled

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areas should include the immediate vicinity around the table, the areas between the fireplace and table, and trails leading to parking areas, water, and toilet facilities.

SUMMARY AND CONCLUSIONS

The objectives of this study were: 1) to survey the vegetative status within heavy and light use campsites in relation to areas outside campsites, 2) to obtain quantitative measurements of campsite use intensities, and 3) to determine flow patterns of use within a campsite.

To accomplish these objectives, vegetative readings were taken at the beginning and at the end of two camping seasons using a rectangular plot transect partitioned into ten subplots. Use intensities were measured with footstep counters systematically arranged within each campsites and soil compaction estimates. Footstep counts were recorded at regular intervals for two camping seasons. Samples for soil compaction estimates were taken within each campsite on the same dates footstep counts were recorded during the second camping season. Flow patterns within a campsite were determined by the footstep counters.

From these studies the following conclusions were made:

- 1) Human trampling has caused deterioration of groundcover within both campsites as measured by differences in % groundcover.
- 2) Footstep counters provided quantitative measurements of traffic within a campsite.
- 3) The major use areas within a campsite include the immediate vicinity around the table, the area between the fireplace and table, and the trails leading to parking, water, and toilet facilities.
- 4) Areas with partially destroyed vegetative groundcover will

revegetate if given ample time. Altering the use of campgrounds from year to year or week to week are possible ways to preserve vegetative groundcover.

5) Paving or graveling major use areas within campsites may be necessary in campgrounds receiving heavy use.

6) Soil compaction is not a good estimate of use intensities in rocky soils or soils with a high content of organic matter when using the "Erey Volumeter" to determine volume in the field.

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APPENDIX

Table 7. Mean % groundcover inside two campsites for 1969 and 1970, Bridge Bay Campground, Yellowstone National Park, Wyoming.

	% Litter		% Bareground & Rocks		% Vegetation	
	1969	1970	1969	1970	1969	1970
C-47	47.83(a)*	56.48(a)	52.06(a)	42.99(b)	0 (a)	0 (a)
E-Loop	35.82(a)	40.31(a)	42.07(a)	34.09(a)	22.02(a)	25.61(a)

* Means followed by same letter are not different at p.05.

Table 8. Mean % groundcover inside two campsites for spring and fall readings for the combined years 1969 and 1970, Bridge Bay Campground, Yellowstone National Park, Wyoming.

	% Litter		% Bareground & Rocks		% Vegetation	
	Spring	Fall	Spring	Fall	Spring	Fall
C-47	55.86(a)*	48.45(a)	44.09(a)	50.95(a)	0 (a)	0 (a)
E-Loop	35.03(a)	40.10(a)	38.70(a)	37.46(a)	25.27(a)	22.36(a)

* Means followed by same letter are not different at P.05.

Table 9. Mean % groundcover outside two campsites for 1969 and 1970, Bridge Bay Campground, Yellowstone National Park, Wyoming.

	% Litter		% Bareground & Rocks		% Vegetation	
	1969	1970	1969	1970	1969	1970
C-47	27.73(a)*	30.62(a)	5.97(a)	2.63(b)	67.19(a)	67.76(a)
E-Loop	23.20(a)	39.55(b)	11.71(a)	6.40(a)	66.0 (a)	55.01(b)

* Means followed by same letter are not different at P.05.

Table 10. Mean % groundcover outside two campsites for spring and fall readings for the combined years 1969 and 1970, Bridge Bay Campground, Yellowstone National Park, Wyoming.

	% Litter		% Bareground & Rocks		% Vegetation	
	Spring	Fall	Spring	Fall	Spring	Fall
C-47	30.48(a)*	27.87(a)	5.49(a)	3.11(a)	64.99(a)	69.96(a)
E-Loop	33.08(a)	29.67(a)	6.64(a)	11.47(a)	61.15(a)	59.86(a)

* Means followed by same letter are not different at P.05.

Table 11. Bulk density and number of footsteps inside C-Loop, 1970.

July 1		July 15		August 12		August 31		Means over dates	
B.D.*	# Footsteps	B.D.	# Footsteps	B.D.	# Footsteps	B.D.	# Footsteps	B.D.	# Footsteps
1.09	5	.97	28	.85	105	1.05	50	.990	47.0
.55	5	1.46	11	1.31	25	.56	10	.970	12.8
.80	2	.98	13	1.26	36	1.21	7	1.040	14.5
1.08	11	1.12	57	1.03	124	1.04	29	1.068	55.3
1.19	8	.92	18	1.60	63	1.47	36	1.295	31.3
$\bar{X}$	.942	6.2	1.072	25.4	1.210	70.6	1.066	26.4	

* B.D. = Bulk Density
r = 0.13

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Table 12. Bulk density and number of footsteps inside E-Loop, 1970.

July 1		July 15		August 12		August 21		Means over dates	
B.D.*	# Footsteps	B.D.	# Footsteps	B.D.	# Footsteps	B.D.	# Footsteps	B.D.	# Footsteps
1.50	3	1.07	3	1.44	4	1.37	1	1.345	2.8
1.49	3	1.46	14	1.41	10	1.35	1	1.428	7.0
.98	2	1.16	4	1.39	5	1.35	1	1.220	3.0
1.04	2	1.14	3	1.38	5	1.30	3	1.215	3.3
1.36	4	1.37	3	1.34	4	.95	3	1.255	3.5
$\bar{X}$ 1.274	2.8	1.240	5.4	1.392	5.6	1.264	1.8		

* B.D. = Bulk Density
r = 0.13

Table 13. Analysis of variance of footstep counts in two campsites for two years.

Variation	DF	SS	MS	F
Total	99	46,076.59		
Dates	4	6,966.64	1,741.66	7.29**
Years	1	53.29	53.29	.22
Locations	1	11,990.25	11,990.25	50.24**
Dates x Years	4	1,398.16	349.54	1.46
Years x Locations	1	404.01	404.01	1.69
Dates x Locations	4	4,299.20	1,074.80	4.50**
Dates x Years x Locations	4	1,873.04	468.26	1.96
Error	80	19,092.00	238.65	

** = Significance at P.01.

Table 14. Degrees of freedom and mean squares from the analysis of variance for three traits inside C-47.

Variation	DF	MS % Litter	MS % Bareground and Rocks
Total	39		
Subplots	9	793.30**	846.47**
Readings	1	549.08	470.59
Years	1	748.23	822.65*
Readings x Years	1	132.49	113.57
Error	27	184.37	185.65

* = Significance at P.05.

** = Significance at P.01.

Table 15. Degrees of freedom and mean squares from the analysis of variance for three traits outside C-47.

Variation	DF	MS % Litter	MS % Vegetation	MS % Bareground and Rocks
Total	39			
Subplots	9	78.75	176.62*	97.68**
Readings	1	67.86	246.51	56.41
Years	1	83.23	3.31	111.89*
Readings x Years	1	1246.58**	645.61**	97.65
Error	27	44.48	77.61	23.59

* = Significance at P.05

** = Significance at P.01

Table 16. Degrees of freedom and mean squares from the analysis of variance for three traits inside the E-Loop campsite.

Variation	DF	MS % Litter	MS % Vegetation	MS % Bareground and Rocks
Total	39			
Subplots	9	464.35	284.89	433.87
Readings	1	166.05	84.97	15.37
Years	1	201.18	128.52	636.80
Readings x Years	1	2,632.42*	3,015.43**	11.45
Error	27	442.63	266.74	444.11

* = Significance at P.05.

** = Significance at P.01.

Table 17. Degrees of freedom and mean squares from the analysis of variance for three traits outside the E-Loop campsite.

Variation	DF	MS % Litter	MS % Vegetation	MS % Bareground and Rocks
Total	39			
Subplots	9	139.27	125.72	71.36
Readings	1	116.62	16.64	232.81
Years	1	2,671.59**	1,207.80**	282.49
Readings x Years	1	154.85	294.85	26.08
Error	27	132.86	130.09	71.33

** = Significance at P.01.

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