

INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

- 1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.**
- 2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.**
- 3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.**
- 4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.**
- 5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.**

Xerox University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

74-6078

LEGG, Michael Hampton, 1946-
SITE FACTORS USEFUL IN PREDICTING DETERIORATION
ON FOREST CAMPSITES IN NORTHERN MICHIGAN.

Michigan State University, Ph.D., 1973
Agriculture, forestry & wildlife

University Microfilms, A XEROX Company , Ann Arbor, Michigan

**SITE FACTORS USEFUL IN PREDICTING DETERIORATION
ON FOREST CAMPSITES IN NORTHERN MICHIGAN**

by

Michael Hampton Legg

A THESIS

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

DOCTOR OF PHILOSOPHY

Department of Forestry

1973

ABSTRACT

SITE FACTORS USEFUL IN PREDICTING DETERIORATION ON FOREST CAMPSITES IN NORTHERN MICHIGAN

by

Michael Hampton Legg

A three phase study to determine the ecological impact of recreation on forest ecosystems was conducted in the Crooked Lake Region of the Sylvania Recreation Area in the Ottawa National Forest of Northern Michigan. The first phase utilized a mechanical trampling device to simulate recreation use upon potential forest campsites. This permitted close monitoring of the changes occurring under known levels of trampling. The second phase was concerned with measuring the amount of deterioration that takes place on established boat access campsites at several levels of visitor use. The last part of the study involved the recovery to natural conditions of abandoned campsites. All phases of the study were located on well drained sandy loam to loamy sand soils.

Simulated Recreation Use

Recreation use was simulated by means of a mechanical trampler on four potential campsites, two hardwood and two conifer, during the 1971 and 1972 camping seasons. At each site, 16 one-meter square plots were established. The plots were randomly divided into four groups: controls, lightly trampled, moderately trampled, and heavily trampled. Levels of trampling were 0 passes, 6 passes, 12 passes, and

18 passes per week, respectively. The trampler applied an average pressure of 350 g cm^{-2} on each pass.

The response to trampling was monitored by measuring the following parameters four times each season:

1. Soil moisture content (% by volume)
2. Soil bulk density (g cm^{-3})
3. Percent natural litter cover
4. Soil air permeability.

Multiple regression analysis was utilized to develop prediction equations estimating the change in each parameter over the two-year period. The range of variability explained was from 68 percent for change in oven dry weight of litter to 91 percent for the change in percent by volume of noncapillary pore space in the soil.

After determining the predictability of the measured parameters, the actual percent changes in them, as measured in the field, were utilized to develop an index of detrimental change in the type of sites monitored. The equation, with an R^2 of 0.89, ranks campsite deterioration on a scale of one to four, and is most useful on newly established camping units.

Established Campsites

Twelve primitive camping units selected by degree of visitor use were divided into light, moderate, and heavy use classes and further subdivided into timber type. The camping unit was divided into three concentric sampling zones: the heavily used center of the camping unit, the moderately used area near the margin, and a control zone beyond the margin of the campsite. The biweekly measurements made on the camping units were the same as those on the simulated plots.

Multiple regression prediction equations estimating the change in each measured parameter were developed for the two sampling zones within the camping units' boundaries. The equations explained from 47 to 72 percent of the variation in the dependent variables. The level of use was the most important and consistent variable, appearing in eleven of the twelve equations. In general, the conifer sites proved to be the most durable in all of the parameters monitored.

A second equation, furnishing an index of detrimental change, was developed utilizing the site changes as actually measured on the camping units. This equation had an R^2 of 0.76 and is most useful in ranking the durability of established campsites to determine maintenance priorities.

Campsite Recovery

Abandonment alone does not seem to be an acceptable means to restore campsites to natural conditions in the Sylvania Recreation Area, when considered for short periods of time. Of the four campsites monitored during the two-year study period, only camping units which were previously very lightly used made satisfactory progress toward natural conditions. Three other previously heavily used sites showed only limited improvements, primarily due to a densely compacted soil surface.

VITA

Michael H. Legg

**Candidate for the Degree of
Doctor of Philosophy**

Final Examination: July 9, 1973

Guidance Committee: Drs. G. Schneider (Chairman), D. P. White, P. G. Murphy, and J. J. Kielbaso.

Dissertation: Site factors useful in predicting deterioration on forest campsites in Northern Michigan.

Biographical Items:

**Born September 11, 1946, Jasper, Alabama
Married, one son**

Education:

**Auburn University, B. S., 1969
Michigan State University, M. S., 1970
Michigan State University, Ph. D., 1973**

Experience:

**September, 1972 to June, 1973
Research Assistant, Michigan State University
September, 1969 to June, 1971
Teaching Assistant, Michigan State University
Summer 1970
Assistant Project Forester, Gulf States Paper Corp.
Tuscaloosa, Alabama
Summer 1969
Forest Technician, Holman Lumber Co.
Northport, Alabama**

Organizations:

**Xi Sigma Pi
Alpha Zeta
Society of American Foresters**

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. Gary Schneider, who acted as both advisor and guidance committee chairman, for his valuable assistance during review and editing help. The author is also indebted to the other members of his guidance committee - Drs. D.P. White, P.G. Murphy, and especially to Dr. J.J. Kielbaso for their guidance throughout the course of study.

The assistance of the U. S. Forest Service is also acknowledged, especially Marsh Lefler, District Ranger of the Watersmeet District and Bill Bradshaw also of the Watersmeet office.

Gratitude is extended to Michigan State University and the National Wildlife Federation for the financial support which the author received.

Sincere appreciation is expressed to the author's parents for not only encouraging and supporting his educational endeavors, but for instilling a deep appreciation of natural resources which helped to point the authors direction in choice of careers.

Most of all the author is forever indebted to his wife Hettie for her untiring devotion. The successful conclusion of this study would not have been possible without her understanding, encouragement and sacrifice. Last, but certainly not least, the author extends appreciation to his son Christopher for the hours of entertainment and inspiration he has provided during the final stages of this study.

TABLE OF CONTENTS

	<u>page</u>
VITA.....	ii
ACKNOWLEDGMENTS.....	iii
LIST OF TABLES.....	vii
LIST OF FIGURES.....	ix

Chapter

I. INTRODUCTION.....	1
II. REVIEW OF LITERATURE.....	3
Soil compaction.....	3
Bulk density.....	4
Noncapillary pore space.....	5
Ground Cover.....	5
Simulation of Recreation Trampling.....	8
Measuring Campsite Deterioration.....	10
III. THE STUDY AREA.....	12
Location and Historic Background.....	12
Management.....	14
Vegetation.....	16
Climate.....	17
IV. SIMULATED RECREATIONAL USE OF POTENTIAL FOREST	
CAMPSITES.....	18
Methods.....	18
Results.....	25

CHAPTER	Page
Effects of treatment on natural litter.....	25
Effects of treatment on soil properties.....	34
Usefulness of aerial photographs in campsite selection.....	41
Utilization of Trampling Data.....	42
V. RECREATION IMPACT ON ESTABLISHED CAMPSITES.....	46
Methods.....	46
Results.....	55
Effects of recreation use on natural litter.....	55
Effects of recreation use on soil properties.....	57
Effects of recreation use on crown cover.....	53
Effects of recreation use on camping unit size....	55
Sylvania Camper Survey.....	58
Ranking Camping Unit Durability.....	70
VI. RECOVERY OF ABANDONED CAMPSITES.....	73
Methods.....	73
Results.....	73
VII. DISCUSSION AND CONCLUSIONS.....	78
LITERATURE CITED.....	89
APPENDICES.....	92
A. Upland plants of Sylvania Recreation Area As Identified by Dr. Edward Voss, Curator, University of Michigan Herbarium.....	92
B. Comparison of Climatic Observations During The 1971 and 1972 Study Period With The 30 Year Average at Watersmeet, Michigan.....	94

CHAPTER	<u>Page</u>
C. Description of the Gogebic Soil Profile.....	95
D. Cover Sheet of the Sylvania Camper Survey.....	97
E. Questionnaire Form Used in the Sylvania Camper Survey.....	98

LIST OF TABLES

Table	<u>Page</u>
1. Description of study sites receiving simulated recreational use.....	19
2. Average percent decrease in litter depth on simulated recreation sites at four levels of trampling over two seasons.....	27
3. Average percent decrease in oven dry weight of litter on simulated recreation sites at four levels of trampling over two seasons.....	32
4. Average percent decrease in percent litter cover on simulated recreation sites at four levels of trampling over two seasons.....	32
5. Average percent decrease in noncapillary pore space on simulated recreation sites at four levels of trampling over two seasons.....	36
6. Average percent increase in bulk density on simulated recreation sites at four levels of trampling over two seasons.....	38
7. Average percent decrease in depth of the A0 horizon on simulated recreation sites at four levels of trampling over two seasons.....	40
8. Prediction equations utilizing parameters obtainable from aerial photographs and with estimates of visitor use.....	43
9. Prediction of the relative rate of site deterioration on two similar campsites.....	45
10. Site characteristics of camping units used in estimating user impact.....	50
11. Average percent decrease in natural litter cover on established camping units at three levels of visitor use over two seasons.....	56

Table		<u>Page</u>
12.	Average percent decrease in noncapillary pore space on established camping units at three levels of visitor use over two seasons.....	58
13.	Average percent increase in bulk density on established camping units at three levels of visitor use over two seasons.....	60
14.	Average percent decrease in depth of the AO horizon on established camping units at three levels of visitor use over two seasons.....	62
15.	Average decrease in percent crown cover on established camping units at three levels of visitor use over two seasons.....	65
16.	Enlargement of camping units on established campsites at three levels of visitor use over two seasons.....	67
17.	Criteria used by Sylvania visitors in campsite selection.	69
18.	Criteria used by Sylvania visitors in choosing a particular camping unit.....	70
19.	Prediction of the relative extent of site deterioration on two similar campsites using the predictive equation established from campsite measurements.....	72
20.	Characteristics of Sylvania camping units chosen to monitor site recovery.....	74
21.	Changes in percent litter cover, noncapillary pore space, and dry bulk density showing the recovery of closed camp-ings units in one year.....	75
22.	Comparison of initial or control values and final measure-ments of the parameters monitored on Sylvania.....	82
23.	A rating comparison of camping unit conditions by camp-ers and predictive equations.....	85

LIST OF FIGURES

Figure	<u>Page</u>
1. Map of Sylvania Recreation Area.....	13
2. Before (a) and after (b) preparation of an upland hardwood potential forest campsite for simulated recreational use by removal of the maple understory.....	21
3. Lawn roller modified by the addition of metal strips to simulate recreation use.....	21
4. Calibration curve used to convert soil air permeameter readings to percent by volume of noncapillary pore space...	23
5. Decrease in depth of litter with timber type and level of simulated use over a two-year period.....	26
6. The impact of trampling upon an upland hardwood plot having a moderate use level.....	30
a. Immediately following removal of the understory.....	30
b. After one season of trampling.....	30
c. Prior to trampling the second season.....	30
d. After two consecutive seasons of trampling.....	30
7. Decrease in noncapillary pore space in the upper 7.5 cm soil layer in simulated use site with timber type and level of use over a two-year period.....	35
8. Typical three-unit boat-access campsite on Sylvania Recreation Area.....	48
9. A large conifer (a) and small hardwood (b) camping unit on Sylvania.....	49
10. One complete replication of the design used to determine the impact of recreational use upon established campsites..	52
11. Plot from sampling zone one (a) of a moderately used camping unit and a control plot (b) from the same unit.....	53
12. Comparison of a control plot (a) just off the margin of a previously heavily used campsite abandoned for three years and a used plot (b) from the center of the same unit.....	76

CHAPTER I

INTRODUCTION

Increases in population, leisure time, usable income, and mobility have lead to increased demand upon forest land for recreation. While man's activities are only one input into the forest ecosystem, it has been recognized that use of forest areas for recreation by large numbers of people may lead to drastic changes in the system. The impact is most intense in areas where use is concentrated; thus campsites and trails usually show the greatest and most rapid changes. As more people venture outdoors for recreation it becomes increasingly important that sites be selected and managed so that they need not be abandoned or rehabilitated due to excessive site deterioration.

The determination of the type and extent of ecological changes that will take place on a forest site at different levels of use represents one of the greatest problems in estimating the ecological carrying capacity of a recreational area. Knowledge of what site changes to anticipate will aid recreation area managers in:

1. Selecting sites with qualities that will inhibit detrimental changes;
2. Estimating what type of maintenance will be required to keep the sites at a specified quality level;
3. Permitting design features to be incorporated that take site characteristics into account;

4. Allowing for close surveillance to be made with subsequent action taken following early indications of deterioration.

This three part study examined the extent and nature of the site changes that could be expected to occur on forest campsites with specific levels of use. The first phase utilized an artificial trampler to simulate recreation use upon potential campsite areas. This permitted close monitoring of changes that occur under known levels of trampling. The second phase was concerned with the amount of deterioration that takes place on established campsites at several levels of visitor use. The last part of the study followed the recovery rate to natural conditions of abandoned campsites.

The objective of the study were, therefore:

1. To quantify the nature and extent of the changes which occur in the forest ecosystem due to varying levels of recreation use.
2. Utilize knowledge of these changes to develop prediction equations which would allow the ranking of campsites according to their durability.

CHAPTER II

REVIEW OF LITERATURE

The effect of recreation upon forest sites may be divided into two broad categories: the impact upon soil and litter, and the impact upon the vegetation. Vegetative changes in the overstory often become immediately obvious, as exemplified by weakened and broken trees located on heavily used campsites. More subtle, but equally, if not more, harmful are the changes which take place in the soil. With recreational use commonly concentrated in a small area, such as a campsite, the effects of trampling by the users can cause drastic changes in soil properties. Appel (1950) noted that the changes were similar to those that take place on overgrazed pastures. "Hundreds of feet trample daily over the same area, breaking down the litter and humus into a dusty powder, which is either blown or washed away, or carried away on the legs and clothing of the campers. The remaining mineral soil is packed to 'stone-like hardness.'"

Soil Compaction

Soil compaction is often monitored to estimate the influence that campground use has had upon the site. Soil compaction is defined by Lull (1959) as "... the packing together of soil particles by instantaneous forces exerted at the soil surface resulting in an increase in soil density through a decrease in pore space." Pore space reduction

significantly decreases the water and air infiltration capacity and the movement of water, oxygen, and carbon dioxide in the soil is retarded.

The reduced air movement may cause unfavorable oxygen-carbon dioxide ratios within the soil. Yelenosky (1964) reported that low O_2/CO_2 ratios induced by a compact soil surface could result in reduced growth and ultimate death of the vegetation on the site.

Bulk Density

Several studies have shown that significant increases in bulk density of the surface horizons of forest soils may occur following intensive recreation use. Lutz (1945) found significant increases in bulk density on two state park campgrounds in Connecticut. The densities of the surface 10 cm in used areas exceeded those at the 20-30 cm depths by 5 to 10 percent. Pore volume in the upper layer was also less than that found in the deeper layer. Neither of these conditions were found on unused sites. Most of the damage was confined to the surface 10 cm of the soil.

Papamichos (1966), in a study done on 40-year-old campsites in Colorado, reported differences of 30 to 55 percent in bulk density of the surface 15 cm between light and heavy use areas. He also established correlations between the change in bulk density and percent organic matter content, moisture, texture, and pH of the soil. Results indicate negative correlations between bulk density and percent organic matter, soil moisture, and percent silt-plus-clay in the soil. The correlation between bulk density and pH was positive, indicating that sites which were highly compacted were significantly less acid than lightly used sites. The pH found on heavy use sites averaged 6.0 while on lightly used sites it dropped to 5.6.

Noncapillary Pore Space

A further result of soil compaction is the reduction in number and size of existing noncapillary pore spaces. Much of the research into this soil property has come from studies on range management, but the results are applicable to recreation areas. Farm woodlots and shelter-belts open to grazing have shown reductions of greater than 50 percent in macropore space in the surface 15 cm of the soil (Steinbrenner, 1951; Read, 1956; Orr, 1960). Steinbrenner also noted that the permeability of core samples taken from the surface 5 cm from ungrazed woodlots was 3 to 245 times greater than that of grazed woodlots in Wisconsin. In a study on the Boundary Waters Canoe Area, Frissell (1964) found significant differences in infiltration rates between used and unused sites in 88 percent of the campsites examined. He noted that the reduced infiltration rate of the used sites was due primarily to the reduction of macropores. This also resulted in increased overland flow of precipitation, and increased soil erosion.

Ground Cover

Perhaps the most obvious effect of recreation use of wildlands is the change in natural vegetation. A survey of 137 National Forest campgrounds and picnic areas in California identified several factors indicative of site deterioration (Magill and Nord, 1963). Reproduction was completely missing from over half of the campsites in the survey, and it was concluded that reproduction rarely survived more than a few years on any site. Most trees had been abused by campers; small trees, limbs, litter, and even wood barriers had been removed and used as firewood, bedding material, and tent poles. The vegetation on most

sites was considered weakened and susceptible to insect and disease attack. The litter cover on the soil was sparse or missing in 73 percent of the campsites. The authors indicate that it was not only worn away by campers, but was sometimes raked away by overzealous maintenance crews.

Frissell (1964) reported that campsites on the Quetico-Superior Canoe Country have lost from 5% to 99 percent of their original ground cover, with the average amount being 85 percent. The amount of bare ground did not increase gradually with increasing use; over 80 percent of the ground cover was lost with light use and this percentage increased only slightly with heavy use. Litter and humus volume on the campsites was reduced an average of 65 percent from that found on unused sites. The loss of organic matter was related to the loss of vegetation and to increased erosion from surface runoff.

Shrubs and herbaceous vegetation are systematically removed by campers "improving" the campsite, and a human browse line is evident around each site. In a recent study of campsites established in 1967, in the Boundary Waters Canoe Area, Merriam (1971) reported that between 1968 and 1970 all sites increased in size. The greatest percent increase was on spruce and aspen-birch sites where the initial size was limited by a dense understory. Heavily used spruce sites increased in size by an average of 21.7 percent and aspen-birch sites increased by 16.1 percent. On open pine sites with little understory, sites were initially larger and the percent increase in size was only 1.6 percent. Merriam also noted that once a site was expanded, campers continued to utilize the entire area.

Ripley (1962) indicated that increasing amounts of detrimental change in ground cover were associated with an increase in crown closure, and that more fertile sites were better able to withstand use and maintain both understory and overstory vegetation. He suggested that canopy reduction by selective cutting would encourage understory growth and reduce soil losses due to erosion.

Several studies have reported that vegetative conditions on campsites may improve with time. LaPage (1967) reported that after initial severe losses in ground cover, more durable species invaded, and by the third year coverage was increasing. However, species diversity diminished by over 50 percent on most sites, with narrow leaf species being more resistant to wear than broad leaf species.

According to Magill (1970), conditions on U. S. Forest Service campgrounds in California improved during the five-year period following their establishment. Ground cover increased at every site, primarily due to the invasion of more durable, shade-intolerant species. This was probably due to the open condition of the campsite following the loss of overstory and sapling size trees to mechanical damage. However, heavily used areas near the center of each campsite remained bare.

Echelberger (1971) reported that there was no correlation between level of recreation use and growth of the overstory vegetation. Overstory density, as measured by percent crown closure, increased during the study by three percent. During the same period the total number of stems per campsite decreased by an average of 59 percent, resulting in a loss of lateral screening between sites. The reduction was primarily due to physical damage by campers.

Simulation of Recreation Trampling

Artificial trampers have been utilized in only a few studies in attempts to develop methods of rating durability of potential campsites. In most cases there has been no attempt to relate the damage done by the trampler to damage done by recreationists. According to Cieslenski (1970), "If the only goal of the study is to develop a rating system for durability, it is not important whether or not the trampler does greater or less damage than that resulting from human use. The rating system can be developed by measuring the site changes that occur due to trampling and relating them by regression to various descriptive site measurements." However, if one does not attempt to relate actual and simulated use it is impossible to know whether the ranking system is truly valid for recreational use or whether the rating system is correct at all levels of use. Therefore, this author feels that the relationship between simulated and actual use must be shown before valid use can be made of the more precise estimates of deterioration available from simulated trampling.

Wagar (1964) was the first to report the use of regression analysis with artificial trampling data to predict the relative durability of vegetation for recreation. He was able to explain 65 percent of the variability ($R^2 = .65$) in the percentage change in dry weight of vegetation on trampled plots in Southern Michigan by the following equation.

$$Y_1 = 12.901 + .670b_1 + .389b_2 + .255b_3, \text{ where}$$

Y_1 = the percentage by which treatment reduced the weight of
surviving vegetation

b_1 = drops of the trampler during each treatment application

b_2 = percentage of plot vegetation composed of species other than grasses and trailing raspberry

b_3 = percentage of sunlight during the growing season.

The results indicated that at high rates of use, damage levels off and great increases in use cause only small increases in damage.

A similar study in Northern Utah indicated that it may be possible to predict the durability of vegetation of potential campsites from aerial photographs. Cieslinski and Wagar (1970) were able to explain 64 percent of the variability in durability of trampled plots by measuring the slope of the plot, slope of the plot location, plot position on slope, aspect, and elevation from aerial photographs.

Generally, the greater the number of passes over an area with a trampler the greater the compaction up to the point of maximum density. However, numerous studies have shown that initial passes do a greater percentage damage than subsequent passes (Steinbrenner, 1955, Hatchell, 1970). Steinbrenner (1955) showed water infiltration rate to be the soil characteristic most sensitive to compaction. He reported that a crawler tractor reduced infiltration in a stand of old growth timber from 88 cc min^{-1} to 13 cc min^{-1} after the first pass. The second pass reduced it to 4 cc min^{-1} and the third reduced infiltration to 1 cc min^{-1} . This implies that most of the soil compaction on campsites occurs with the first users.

In central Minnesota, Thorud and Frissell (1969) measured the recovery of an artificially trampled site over a four-year period. Soil was compacted using a gasoline-powered trampler. The treatment caused significant increases in bulk density at all depths up to 30.5 cm. Annual measurements taken over the four-year period showed a gradual decrease in bulk density. Linear projections indicated that the soil

would return to pre-treatment conditions in approximately six years.

Measuring Campsite Deterioration

Soil compaction has been quantified by measurements of bulk density, pore size distribution, permeability of soil cores, infiltration, and resistance to penetration. In studies primarily concerned with recreation, water infiltration and resistance to soil penetration have been most widely used. Frissell (1964) used water infiltration rates to quantify soil compaction in the Quetico-Superior Canoe Country. Hartesveldt (1962) also used infiltration to measure soil compaction, after he determined that gravimetric sampling was too time-consuming and caused excessive disturbance to the site. Magill (1970) found that penetrometers were useful, but did not give constant results. Both proctor and cone-type penetrometers showed increasing resistance to penetration as the soil dried. Papamichos (1966) utilized radioactive surface gauges to determine both soil moisture and bulk density. This author also found radioactive surface probes to be the most satisfactory means of measuring bulk density.

Changes in vegetation have been measured by clipping and drying above ground plant parts (Cieslinski, 1970; Wagar, 1964). Magill and Nord (1963) developed a pentallometer angle gauge for estimating vertical and lateral vegetative screening between campsites. This device was used by LaPage (1967) and Echelberger (1971) in analyzing changes that occur in campground vegetation. Changes in tree height and diameter growth rates have been measured as a means of quantifying recreation impact (Magill, 1970; LaPage, 1967; Echelberger, 1971; Hartesveldt, 1962). However, in most cases, they have proven to be too variable to

be of value in recreation management. Therefore, on Sylvania only the basal area and the crown density of the dominant vegetation was measured.

CHAPTER III

THE STUDY AREA

Location

Sylvania Recreation Area is located in the western end of the Upper Peninsula of Michigan in the Ottawa National Forest (Figure 1). It is approximately 600 Km (360 miles) northwest of Chicago and 100 Km east of Ironwood, Michigan, in Gogebic County. The entire tract consists of approximately 8500 ha and occupies the entire township of T44N and R40W. The southern boundary is the Wisconsin-Michigan border. About 1600 ha of the area is water surface for a water to land ratio of one to five (The University of Michigan, School of Natural Resources, 1965).

The Sylvania tract lies near the center of a large upland plain and has relatively minor relief with elevations varying from 510 m to 558 m above sea level. The ground surface is composed of undulating moraines and short, unoriented ridges with numerous bogs and lakes where the intermorainal depressions drop below the water table. The ridges are low rarely exceeding 12 m above the plateau (Veatch, 1953).

Historic Background

The U.S. Forest Service acquired Sylvania in 1966. Public use of the area was first allowed in June, 1967, and the first over-night camping was in May, 1968. Prior to 1966, while in private ownership,

Map of the Pennsylvania Recreation Area showing various zones and facilities. The map includes labels for 'boat launch (carry down)', 'boat launch', 'day use area', 'entrance area', 'boat launch campground', 'organization center', and 'u.s. center'. A legend on the right defines symbols for travel influence zone, water influence zone, trails and service roads, portages, pioneer area, botanical area, and lake ocean coquilles. The map also shows 'INITIAL DEVELOPMENT' and 'PENNSYLVANIA RECREATION AREA'.

Sylvania was closed to the public and patrolled by guards to prevent trespass. The area received only very slight use, and at the time of governmental purchase was in relatively virgin condition (U. S. Forest Service, 1970).

Management

"The principal objective in management of Sylvania is to maintain the unique quality of its forest lands and waters, while providing opportunity for a variety of outdoor recreation opportunities." (U. S. Forest Service, 1968). To prevent over development, access by automobile is limited to the periphery of the area. Access to most of the interior lakes is limited to waterways with portages or by hiking. The use of motorized transportation including outboard motors is prohibited within the area on all lakes and land completely controlled by the U. S. Forest Service. However, until the winter of 1973-1974, snowmobiles were allowed on marked trails when the snow base exceeded 15 cm.

Campsites were established during the spring of 1968 and opened to the public later that same year. Initially, 33 campsites were opened, each containing 3 camping units. Currently, only 83 of the 99 camping units are open for use. Some have been closed due to either hazards to campers, overuse, or nesting eagles. Use of the area has climbed steadily from 20,000 twelve hour visitor days in 1968 to 27,000 in 1971. However, use is not evenly distributed to all campsites. Between 1968 and 1971, use varied from 208 visitor days on the lightest used site to 5492 on the heaviest used site.

Upon entering the Area, campers must register at the Sylvania Visitor Information Center on the north edge of the tract and choose

their campsite. Access to most of the campsites is limited to hiking or canoe. On Crooked Lake, however, where much of this study occurred, the use of outboard motors is allowed.

A system of management zones was proposed in the 1968 U. S. Forest Service management plan. The zones are as follows:

1. The Pioneer zone is to be maintained in its natural state, and camping will be allowed only on designated sites. Currently the 83 campsites established in this zone are the only camping areas on Sylvania.
2. The Botanical zone includes a combination of bogs, muskeg, virgin forest, and other ecological communities of botanical significance. Management is directed toward preservation of the natural environment for scientific study and education. Development is limited to a few trails and informative signs.
3. The Water and Travel Influence zone consists of areas of varying width along the lake shore, roads, and trails. It includes most of the lands intended for intensive development. Included is a half-mile long swimming beach and a hundred unit drive-in campground, soon to be opened.
4. The General Forest zone includes all land not contained in other zones. There are no recreation developments in this zone other than portages and trails. Management is directed toward improving habitat for favored species of wildlife such as grouse and deer. Timber harvest is allowed in this zone (U. S. Forest Service, 1968).

To date, however, these management zones have not been clearly established on the ground and have only been used as general guides for management.

Vegetation

The vegetative type of Sylvania is climax northern hardwood. The dominant tree species include: (U. S. Forest Service, n.d.)

Hardwood

Acer saccharum March.....Sugar Maple
Acer rubrum L.....Red Maple
Betula alleghaniensis Britton.....Yellow Birch
Betula papyrifera March.....White Birch
Tilia americana Vent.....Basswood
Populus tremuloides Michx.....Trembling Aspen

Conifer

Tsuga canadensis (L.) Carr.....Eastern Hemlock
Picea glauca (Moench) Voss.....White Spruce
Picea mariana (Mill.) B.S.P.....Black Spruce
Abies balsamea (L.) Mill.....Balsam Fir
Pinus resinosa Ait.....Red Pine
Pinus strobus L.....Eastern White Pine
Pinus banksiana Lamb.....Jack Pine
Thuja occidentalis L.....Northern White Cedar

Most of the upland areas are covered by a mature stand of mixed sugar maple, yellow birch, and hemlock. There are scattered stands of red and white pine on upland areas. The lakeshores and low areas are

predominantly white cedar and balsam fir. Young sugar maples from .5 m to 2 m tall cover large areas of the understory with densities as high as 25 stems m^{-2} (100,000 stem/acre). For a more complete list of plants found on Sylvania, see Appendix A.

Climate

The climate of the western end of the Upper Peninsula is marked by cold winters and mild summers. During the 30 year period (1940-1969), the average annual temperature was 4.3°C (39.8°F.). The average temperature for July is 18.4°C (65°F.) while for January it is -11.0°C (12.7°F.) (Appendix B). The average length of the growing season is 61 days. Precipitation is uniformly distributed throughout the year with May through September receiving 66 percent of the 70.1 cm total, mostly in the form of thunderstorms. The average annual snowfall of 237 cm accounts for approximately one-third of the total precipitation (U. S. Dept. of Commerce, 1971).

CHAPTER IV

SIMULATED RECREATIONAL USE OF POTENTIAL FOREST CAMPSITES

Most impact studies on forest recreation areas have been conducted on established campsites that often have been used for several years. The exact amount of use these sites have received is usually difficult to determine accurately. By simulating use with an artificial trampling device it is possible to quantify the forces which are applied to the site. Simulation also permits accurate measurement of site conditions prior to any disturbance and continual monitoring during the trampling period.

The specific objectives of this portion of the study were: (1) to determine the type and extent of the changes which occur on potential forest recreation sites under three levels of use, (2) to utilize these measurements establishing a predictive index of detrimental change.

METHODS

Study Area

Four study sites, representative of the campsites in Sylvania, were selected in the Crooked Lake area. The sites were essentially level areas of at least 36 m². A description of each site is given in Table 1.

Soils were of the fine sandy loam phase of the Gogebic soil series (Appendix C). The series consists of moderately coarse to medium textured typic fragiorthods with a distinct fragipan on noncalcareous reddish sandy loam to loam. The Gogebic series is confined primarily to the moraines and shorelines of the Lake Superior region in the western part of the Upper Peninsula of Michigan and northern Wisconsin. It is commonly associated with the well to moderately well drained Iron River, Wakefield, Marenesco, and Ahmeek soil series (National Cooperative Soil Survey, 1958).

Table 1. Description of study sites receiving simulated recreational use.

Characteristics	Site Number			
	1	2	3	4
Elevation Level	Upper ^{a)}	Lower ^{b)}	Lower	Upper
Timber type	Hardwood	Hardwood	Conifer	Conifer
Understory	Maple	Maple	None	Club moss
Crown density (%)	82.6	85.1	86.1	80.3
Basal area (m ²)	13.0	8.5	12.1	9.0
Initial depth of litter (cm)	5.5	6.4	6.7	7.0
Initial depth to A2 horizon (cm)	5.0	6.3	11.3	9.5

a) Upper level sites were at least 5 m above the water table.

b) Lower level sites were less than 3 m above the water table.

Experimental Design

The response of forest sites to trampling was studied using a completely nested design. Each study site was divided into 16, one meter square treatment plots with a 0.5 m strip separating the plots. Prior to treatment the plots were cleared of large limbs and advanced reproduction (Figure 2).

Trampling was simulated over a two-year period by means of a mechanical trampling device which was a modified, water-filled lawn roller (Figure 3). The addition of alternating 7.5 cm and 12.5 cm track-like metal strips at intervals around the drum more closely approximated the type of wear attributable to human use than the unmodified roller. Although the ground surface configuration caused the pressure to vary, the drum applied an average pressure of 350 g cm^{-2} (5 lbs in^{-2}), approximately the pressure exerted by a man walking.

The treatment plots were randomly divided into four groups: controls, lightly trampled, moderately trampled, and heavily trampled. The lightly trampled plots received six passes of the trampling device for a total of 2.1 Kg cm^{-2} (30 lb in^{-2}) per week. The moderately trampled plots received twelve passes or 4.2 Kg cm^{-2} (60 lb in^{-2}) per week whereas the heavily trampled plots received eighteen passes per week or 6.3 Kg cm^{-2} (90 lb in^{-2}). Control plots received no trampling. The treatments were applied in 1971 and 1972, during June 20 through September 15, the approximate duration of the visitor season for this area.



(a)



(b)

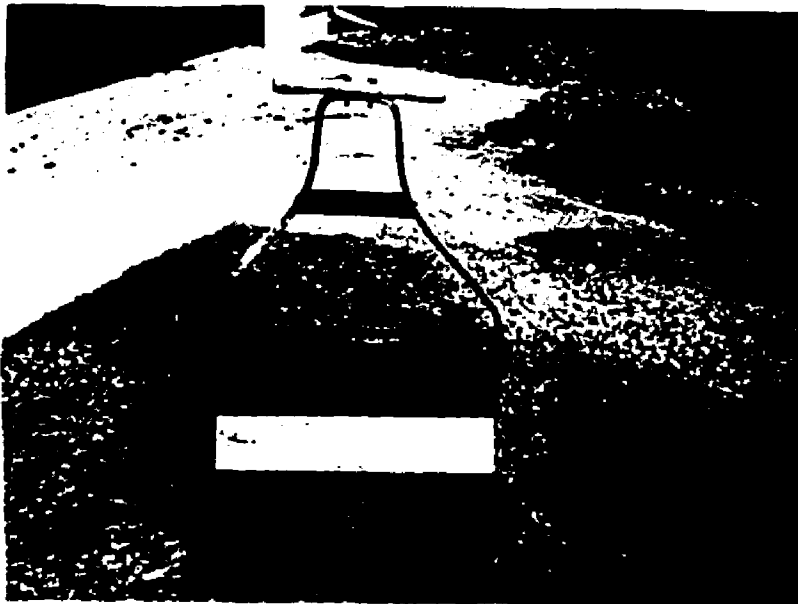


Figure 2. Before (a) and after (b) preparation of an upland hardwood potential forest campsite for simulated recreational use by removal of the maple understory.

Figure 3. Lawn roller modified by the addition of metal strips to simulate recreation use.

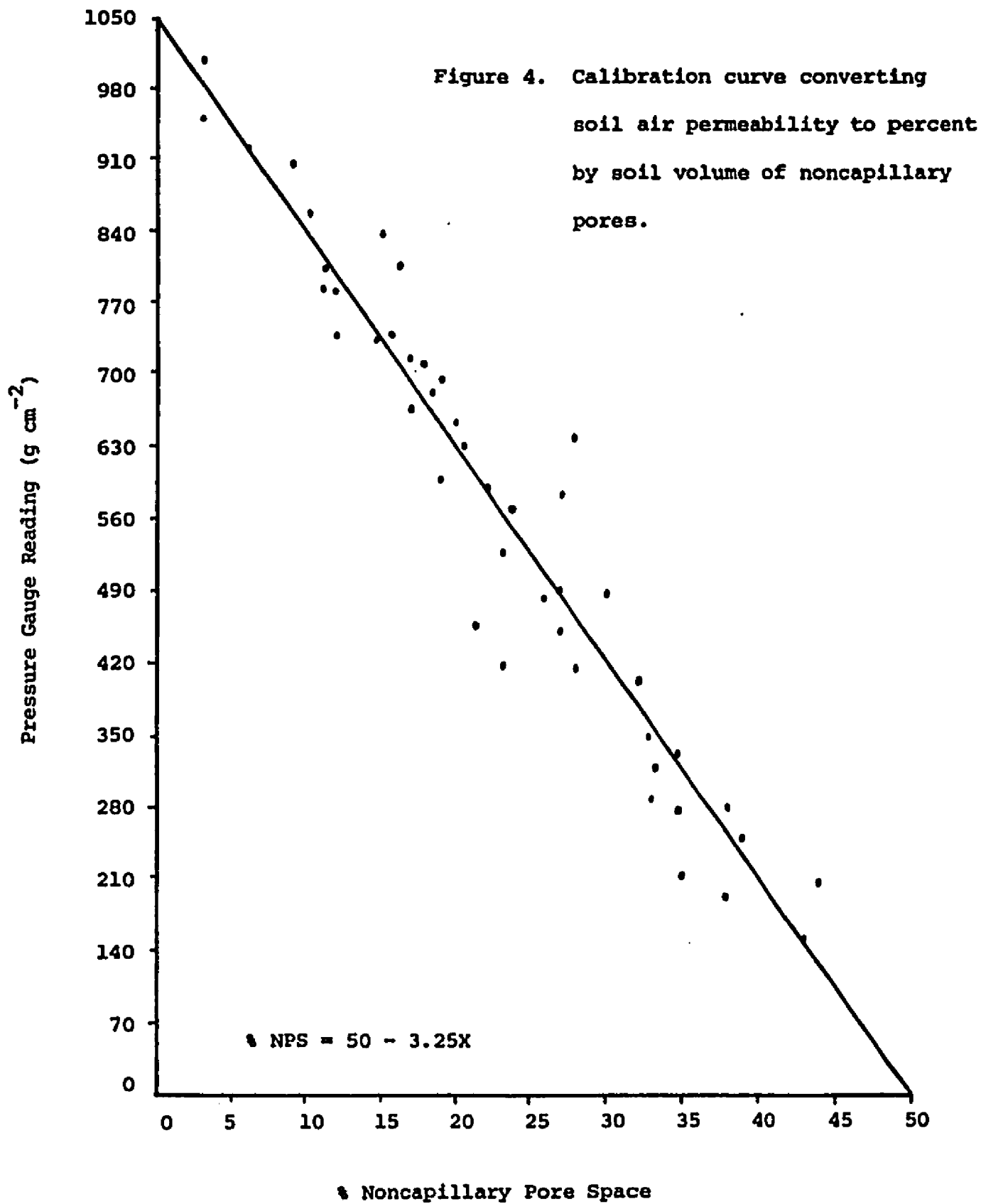
Measurements

To estimate the impact of trampling, the following parameters were measured upon four separate occasions each season immediately following one of the weekly trampling treatments:

1. Soil moisture content (percent by volume)
2. Soil bulk density (grams cm^{-3})
3. Percent natural litter cover
4. Soil air permeability.

Soil moisture and bulk density in the upper 0.3 m of soil was determined using a nuclear surface probe (Nuclear Chicago, model P-21, P-22). An average value from two readings was taken for each plot. The use of these probes proved very satisfactory since measurements could be made with minimal site disturbance. Gravimetric sampling would have caused undue site disturbance and made repeated measurements on the same site impossible. However, at the termination of the study, gravimetric samples were taken to verify the accuracy of the surface probe measurements.

Percent natural litter cover was ocularly estimated on each plot using a 50 cm by 50 cm square grid. Air permeability of the soil was measured using an air permeameter similar to the model developed by Steinbrenner (1959). It consists of an "E" type oxygen tank with a Hudson therapy regulator. Oxygen is fed through a line from the tank to a steel cup at 1000 g cm^{-2} . The cup is pushed 2 cm into the soil and the resistance to air movement is measured. Using a calibration curve, this resistance is then converted to percent noncapillary pore space (Figure 4).



Other parameters measured at the end of each season included:

1. Percent crown cover over the plot
2. Oven dry weight of natural litter
3. Average depth of natural litter
4. Average depth of the AO soil horizon.

Percent crown cover was determined by projecting a vertical slide photograph taken from each plot on a dot grid and estimating what percent of the sky was covered by the canopy layer.

The natural litter sample was taken from a $.09 \text{ m}^2$ (1 ft.²) area from each 1 m^2 plot. Only the litter material that could still be identified as to its source was removed, and then oven dried and weighed. The depth of the litter, as well as the depth of the AO horizon, was measured to the nearest centimeter at four places on the plot and averaged.

Analysis of Data

At the end of the second season of trampling, the total change in bulk density, natural litter cover, litter depth, percent noncapillary pore space, and depth of the AO horizon were calculated. Using these parameters as dependent variables, multiple regression analysis was employed to develop prediction equations to estimate the type and extent of change due to different levels of simulated recreational use. Independent variables which were not significant at the .25 level were excluded from the equations. After determining the predictability of the changes in these ecological parameters, actual measurements of the changes were utilized to develop an equation which would rank the relative deterioration of recreation areas according to an index of detrimental change.

Following the development of baseline data from the field study the use of aerial photographs was evaluated as a source of information that could prove useful in predicting the amount of deterioration that would occur due to various levels of recreation use.

Some of the independent variables used in these equations were coded for ease in calculation. Elevation was classified as either upper level (=1) or lower level (=2). Timber type was classified as either dominantly hardwood (=1) or conifer (=2). Four levels of use were simulated and coded as heavy (=1), moderate (=2), light (=3), and control (=4). Wide ranges in values required the use of arcsin transformations in analyzing the percent litter cover on the plots (Sokal, 1969).

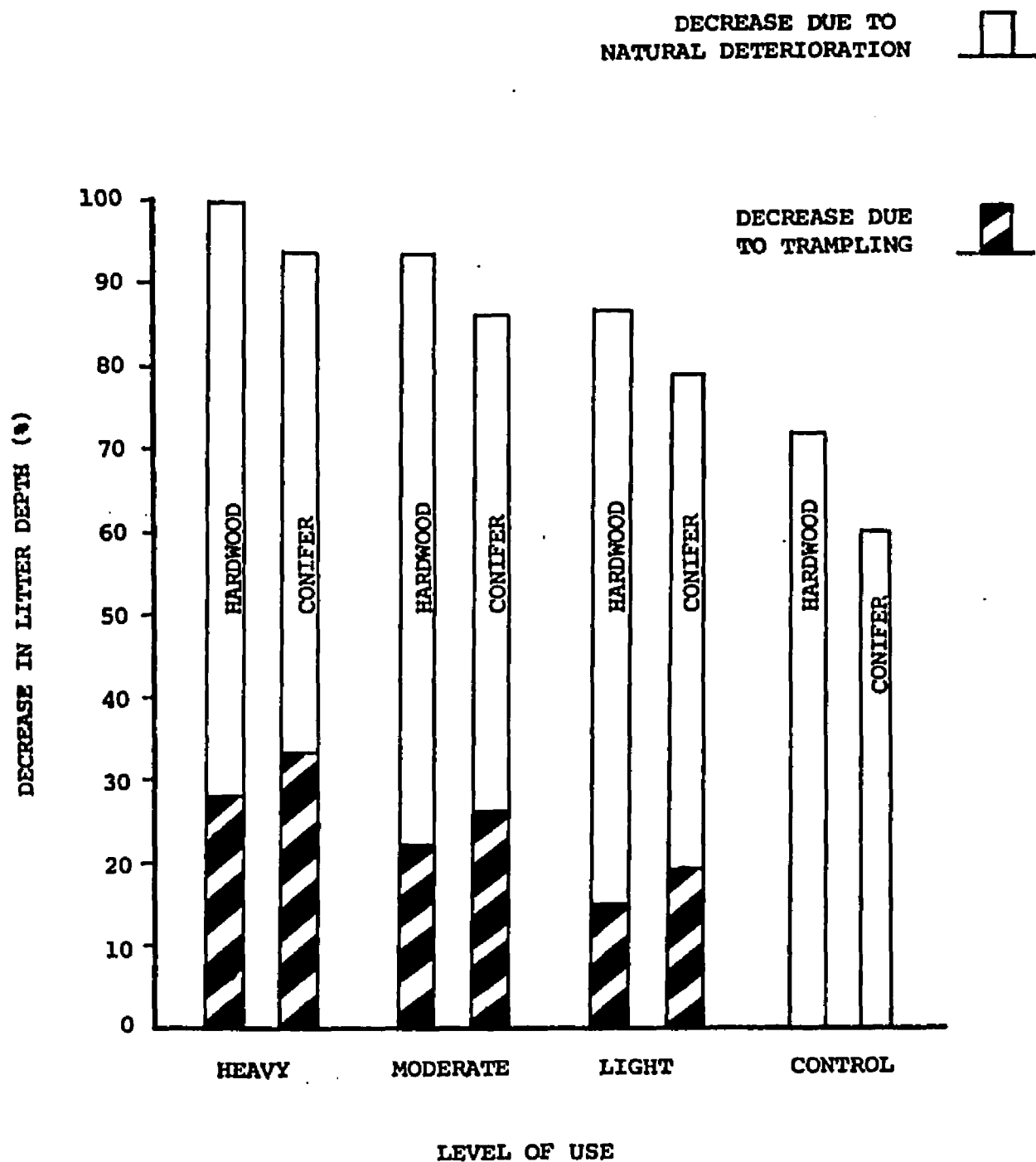
RESULTS

Effects of Treatment on Natural Litter

Litter Depth

In the study areas, litter depths of greater than 10 cm were often found on undisturbed coniferous sites, while on hardwood sites it rarely exceeded 7.5 cm. Much of the litter loss over the two year study period on both hardwood and conifer sites was due to natural causes, instead of trampling. On control plots, with no trampling, the hardwood plots had a 71 percent decrease in the litter depth and the conifer plots lost 61 percent (Table 2). When natural losses are subtracted from total losses, the hardwood litter appears slightly more durable to trampling than conifer litter (Figure 5). However, losses due to trampling and natural decay are difficult to separate on a site,

Figure 5. Decrease in depth of natural litter on simulated recreation sites, with timber type and level of use over a two year period.



and when viewed collectively the conifer litter proved to be the more durable.

Table 2. Average percent decrease in litter depth on simulated recreation sites at four levels of trampling over two seasons.

Site	Levels of Use ^{1]}			
	Heavy	Moderate	Light	Control
Upper level hardwood	100	95	88	71
Lower level hardwood	100	91	85	71
Upper level conifer	95	86	79	61
Lower level conifer	93	85	77	66

1) Any difference among these values greater than 7 is significant at the 5% level.

The decrease in the litter depth on control plots may be in part due to the removal of the dense understory of maple. The plots were thereby more open to incoming solar radiation and air movement which would increase the decomposition rate in the litter layer. Also, a potential source of litter deposition was destroyed by the removal of the understory.

During the first season of trampling, the litter layer was not completely destroyed on any plant under any level of trampling. The litter cast during the fall of 1971 averaged $2.5 \pm .7$ cm on hardwood plots and $0.9 \pm .4$ cm on conifer plots. However, by the end of the 1972 season, heavily trampled hardwood plots were essentially devoid of all the past season's litter. Only leaves and twigs that dropped during the summer and early fall remained on the heavily trampled

plots (Figure 6).

There was no significant difference in durability of the natural litter between upper and lower level sites. This indicates that elevation, within the limits established for this study, does not represent a limiting factor, as pertains to changes in litter depth, in selecting potential campsites.

The multiple regression equation for predicting the change in depth of litter is as follows:

$$Y_1 = 1.297 + .022b_1 - .049b_2 - .097b_3 - .001b_4 - .017b_5, \text{ where:}$$

Y_1 = change in the depth of natural litter due to simulated use

1.297 = constant

b_1 = elevation

b_2 = timber type

b_3 = level of simulated use

b_4 = percent crown cover

b_5 = initial depth of litter cover.

This equation explains 90 percent ($R^2 = .90$) of the variability in change in litter depth at four levels of use with a standard error of estimate of .04. It also shows that with use:

1. The decrease in litter depth is greater on lowland sites than upland sites;
2. The decrease in litter depth is greater on hardwood sites than conifer sites;
3. As the level of trampling increases the decrease in depth of litter increases;
4. As the percent crown cover decreases the decrease in litter depth increases;

Figure 6. The impact of trampling upon an upland hardwood plot having a moderate use level.

- a. Immediately following removal of the understory**
- b. After one season of trampling**
- c. Prior to trampling the second season**
- d. After two consecutive seasons of trampling**



(b)



(d)



(a)



(c)

5. The smaller the initial depth of litter, the greater the decrease.

Litter Dry Weight

The changes measured in dry weight of litter followed the same trends as those in litter depth (Table 3). The oven dry weight of litter on undisturbed areas on Sylvania was approximately 30,000 Kg ha⁻¹ (25,000 lbs/acre). The equation predicting changes in oven dry weight of litter is:

$$Y_2 = 1.335 - .216b_1 - .077b_2 + .057b_3 - .48b_4, \text{ where:}$$

Y_2 = change in oven dry weight of litter

1.335 = constant

b_1 = timber type

b_2 = level of simulated use

b_3 = initial depth of litter cover

b_4 = initial depth of the AO horizon.

This explains 69% of the variability found in litter weight with a standard error of estimate of 0.13. It differs from the equation for litter depth in that elevation and percent crown cover were deleted because they did not add significantly to the accounted for variation. The initial depth of the AO horizon was added because it significantly contributed to the observed variation in litter weight.

Percent Litter Cover

At the beginning of the study period all plots had 100 percent litter cover. With trampling, all of the plots except those located

on the lower level conifer site showed a decrease in percent litter cover during the study (Table 4).

Table 3. Average percent decrease in oven dry weight of litter on simulated recreation sites at four levels of trampling over two seasons.

Site	Levels of Use ¹⁾			
	Heavy	Moderate	Light	Control
Upper level hardwood	100	92	91	83
Lower level hardwood	100	92	84	79
Upper level conifer	76	77	58	51
Lower level conifer	77	64	49	42

¹⁾ Any difference among these values greater than 7 is significant at the 5% level.

Table 4. Average percent decrease in percent litter cover on simulated recreation sites at four levels of trampling over two seasons.

Site	Levels of Use ¹⁾			
	Heavy	Moderate	Light	Control
Upper level hardwood	41	31	20	0
Lower level hardwood	35	26	6	0
Upper level conifer	45	31	7	0
Lower level conifer	0	0	0	0

¹⁾ Any difference among these values greater than 10 is significant at the 5% level.

The lower level conifer plots maintained 100 percent litter coverage at all levels of trampling. This may be due to the spongy nature of the deep litter layer and organic mat which uniformly covered the site. The organic mat reduced the abrasive effect of the steel strips on the trampler and prevented the incorporation of the litter layer. Also, a great deal of the litter consisted of hemlock cones which were more resistant to destruction by trampling than leafy material. There were no significant differences between the other three sites in percent change in litter cover at each level of use. However, significant differences did exist between levels of trampling with heavy trampling producing the greatest change.

There were no significant differences in percent litter cover between the end of the season measurements in the two treatment years. They may indicate that over-winter recovery was sufficient to restore litter during the study period. However, the lack of recovery in litter depth would probably lead to greater reductions in litter cover under continued use.

The equation predicting change in percent litter cover, and accounting for 73 percent of the variation with a standard error of 0.09 is as follows:

$$Y_3 = .252 - .123b_1 - .087b_2 - .101b_3 + .418b_4, \text{ where:}$$

Y_3 = the change in percent litter cover on the plot

0.252 = constant

b_1 = elevation

b_2 = timber type

b_3 = level of simulated use

b_4 = dry bulk density prior to trampling.

Analysis of the independent variables included in the equation indicate that:

1. Upper level hardwood sites were most susceptible to decreases in litter cover and lower level conifer sites were least susceptible;
2. More mineral soil was exposed by higher use levels;
3. The more compacted the soil, the greater the change in percent litter cover.

Effect of Treatment on Soil Properties

Noncapillary Pore Space

The simulation of recreation use caused significant decreases in noncapillary pore space on all trampled plots (Table 5). There were also significant differences between treatments. On heavily trampled plots, macropore space was reduced to less than 5 percent on the total soil volume. Light and moderate levels of trampling resulted in less destruction. However, at least 50 percent of the noncapillary pore space was lost on all trampled plots. Conifer sites proved to be significantly more susceptible to destruction of macropores by trampling than hardwood sites when averaged over elevation (Figure 7).

The resistance of the hardwood sites to change in pore space was partially due to extensive earthworm activity. Earthworm tunneling promotes the generation of macropores following reduction by trampling. During the study period, few earthworms were observed on conifer sites, but they were abundant on hardwood sites. The lack of earthworms on conifer sites is explained by the high acidity (pH 4.2-5.0) and lack of appropriate food found there.

Figure 7. Decrease in noncapillary pore space in the upper 7.5 cm soil layer on simulated recreation sites, with timber type and level of use over a two year period.

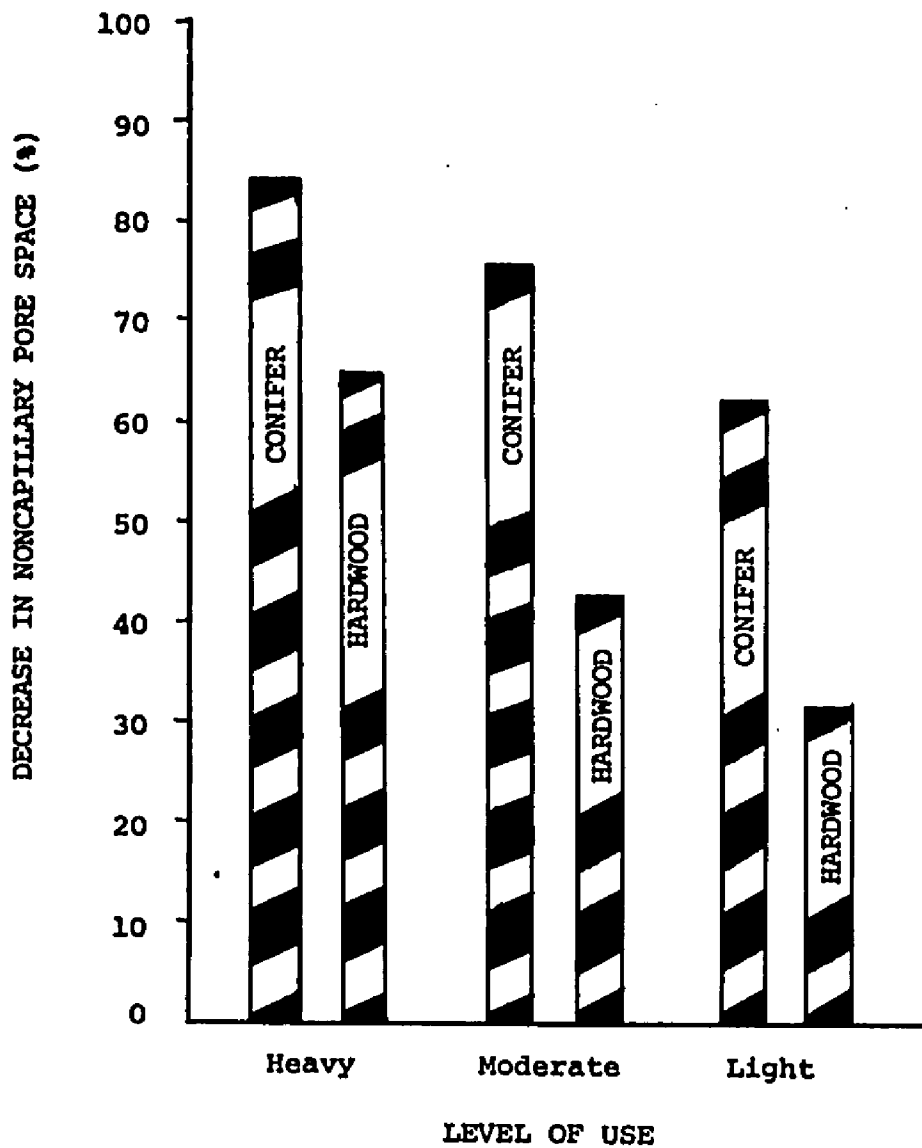


Table 5. Average percent decrease in noncapillary pore space on simulated recreation sites at four levels of trampling over two seasons.

Site	Levels of Use ¹⁾			
	Heavy	Moderate	Light	Control
Upper level hardwood	-90	-69	-52	-19
Lower level hardwood	-90	-78	-55	- 1
Upper level conifer	-85	-74	-56	+16
Lower level conifer	-81	-61	-54	+ 6

¹⁾ Any difference among these values greater than 8 is significant at the 5% level.

Actual measurements of noncapillary pore space indicate that on undisturbed plots about $30 \pm 6\%$ of the soil volume is macropore space. Overwinter recovery averaged approximately 70 percent of the initial macropore space and was not significantly different at each level of trampling. However, following the second trampling period of the 1972 season, macropore space had been reduced to approximately the same level as the end of the 1971 season.

The total change in noncapillary pore space can be estimated by the following equation:

$$Y_4 = .648 + 1.543b_1 - .290b_2 + .023b_3 - .085b_4 - .654b_5, \text{ where:}$$

Y_4 = change in noncapillary pore space

0.648 = constant

b_1 = timber type

b_2 = level of simulated use

b_3 = initial noncapillary pore space

b_4 = initial depth of the AO horizon

b_5 = initial bulk density.

The coefficient of determination was 0.91 and the standard error was 0.12. The independent variables included in this equation indicate that with use:

1. The percent decrease in noncapillary pore space is greater on conifer sites than hardwood;
2. The percent decrease in noncapillary pore space increases as the level of trampling increases;
3. The higher the initial noncapillary pore space, the greater the percent decrease;
4. As the depth of the AO soil horizon increases, the percent in noncapillary pore space decreases;
5. As the initial oven-dry bulk density increases the change in noncapillary pore space decreases.

Dry Bulk Density

The average bulk density prior to trampling on conifer sites was 1.38 g cm^{-3} and on hardwood sites it was 1.43 g cm^{-3} , a nonsignificant difference. However, following trampling there was a significant difference in the percent change in bulk density between timber types (Table 6).

Differences between levels of trampling were not significant in all cases. On conifer sites only heavy trampled plots showed a significant increase in bulk density while on hardwood sites all levels of trampling produced significant changes.

Table 6. Average percent increase in bulk density on simulated recreation sites at four levels of trampling over two seasons.

Site	Levels of Use ¹⁾			
	Heavy	Moderate	Light	Control
Upper level hardwood	39	43	18	5
Lower level hardwood	29	29	23	8
Upper level conifer	16	5	1	2
Lower level conifer	2	-10	- 8	-10

¹⁾ Any difference among these values greater than 6 is significant at the 5% level.

After two seasons of simulated use the bulk density on conifer sites had increased to as much as 1.65 g cm^{-3} on heavily used plots while hardwood sites increased up to 1.92 g cm^{-3} . The change in density followed a linear trend over the two year trampling period at each level of use. There was no significant difference, however, in over-winter reduction in density.

The multiple regression equation established to predict changes in bulk density explained 78 percent of the variability with a standard error of 0.11 and is:

$$Y_5 = -1.942 + .203b_1 + .270b_2 + .058b_3 + .049b_4 + .764b_5, \text{ where:}$$

Y_5 = change in bulk density

-1.942 = constant

b_1 = elevation of the site

b_2 = timber type

- b_3 = level of simulated use
 b_4 = initial depth of litter cover
 b_5 = initial dry bulk density.

This indicates:

1. Lower level sites were more resistant to changes in bulk density than upper level sites;
2. Increases in bulk density are greater on hardwood sites than conifer sites;
3. Higher levels of simulated use cause greater increases in bulk density;
4. Sites with deep litter are most resistant to increase in bulk density;
5. Sites with high initial densities increase less than low density sites.

Depth of the AO Horizon

The depth of the AO horizon of the soil is a measure of the amount of erosion that has occurred as well as compaction of the surface layers. There were significant differences in the percent change in depth of the AO horizon between timber types and elevation at all levels of simulated use (Table 7).

Initial depths of the AO averaged 5 cm on hardwood sites and 10 cm on conifer sites. Measurements after two seasons of simulated use indicate a mean depth of 3 cm on hardwood sites and 8 cm on conifer sites. Lower level sites had smaller decreases in depth of the AO than upper level sites. The average decrease at heavy levels of simulated

use on upper level sites was 72 percent while sites nearer lake level decreased by 50 percent.

Table 7. Average percent decrease in depth of the AO horizon on simulated recreation sites at four levels of trampling over two seasons.

Site	Levels of Use ¹⁾			
	Heavy	Moderate	Light	Control
Upper level hardwood	88	81	31	5
Lower level hardwood	74	50	17	0
Upper level conifer	56	39	18	0
Lower level conifer	26	12	4	2

¹⁾ Any difference among these values greater than 11 is significant at the 5% level.

The extent of change in depth of the AO soil horizon is estimated by the following equation which has an R^2 of .81 and a standard error of 0.14.

$$Y_6 = 1.142 - .015b_1 - .083b_2 - .203b_3 - .105b_4 - .804b_5 + .192b_6, \text{ where:}$$

Y_6 = decrease in depth of the AO soil horizon

1.142 = constant

b_1 = elevation level of the site

b_2 = timber type

b_3 = level of simulated use

b_4 = initial depth of litter cover

b_5 = initial depth of the AO horizon

b_6 = initial dry bulk density.

The parameters included in the equation reveal that with simulated use:

1. Lower level sites are more durable than upper level sites;
2. Conifer sites are less subject to decrease than hardwood sites;
3. High levels of use cause greater changes than low levels of use;
4. Sites with deep litter cover change less than sites with thin litter layers;
5. The deeper the initial depth of the AO the smaller the change;
6. Sites with low initial bulk densities are more durable than sites with high initial densities.

Usefulness of Aerial Photographs in Campsite Selection

Aerial photographs have proven useful in successfully selecting potential campsite areas (Lindsay, 1969). It would be advantageous to be able to rank the durability of such sites with criteria measured from the same photographs. Table 8 illustrates the equations that predict change in several ecological parameters using elevation and timber type measurements which are obtainable from aerial photographs, and visitor use data from camper registration. The percent of variability accounted for was lower in each case than from those equations generated using only ground measurement. However, in the majority of cases, the prediction equations dropped only a few percentage points. This seems to indicate that there is a good possibility of ranking sites

according to durability from aerial photos using ground observations for verification of results. Elevation level and timber type were chosen as independent variables because of photo identification simplicity. By adding such parameters as slope, aspect, and stand density to the equation, even higher coefficients of determination could probably be achieved.

Utilization of Trampling Data

The equations developed in the previous pages each estimate the percent change which occurs in only one parameter. While any one parameter may be useful as an indicator of one type of site deterioration, it is necessary to incorporate several parameters into the same equation in order to successfully compare several sites with a high level of predictability. Using the coded levels of trampling as the dependent variable and the actual changes in the six ecological parameters which were measured on the simulated use plots, the following equation was developed using multiple regression analysis. Since it is the level of trampling which is being predicted this actually then becomes an index of detrimental changes in the independent variables. The equation is most useful on sites which are ecologically similar, or on sites which receive approximately the same levels of use. The equation accounts for 89 percent of the variability with a standard error of 0.04. This equation is:

$$Y_7 = 6.825 - 1.070b_1 - 0.890b_2 - 3.808b_3 + 0.396b_4 - .636b_5 - 2.475b_6,$$

where:

Y_7 = index of detrimental change

6.825 = constant

Table 8. Prediction equations utilizing parameters obtainable from aerial photographs and with estimates of visitor use.

		INDEPENDENT VARIABLES				Correlation coefficient (Std. Error)
		Constant	Elevation b_1	Timber type b_2	Level of Use b_3	
DEPENDENT VARIABLES	Change in noncapillary pore space $Y_1 =$	1.363	$-.017b_1$	$-.075b_2$	$-.279b_3$	.79 (.17)
	Change in percent litter cover $Y_2 =$	.722	$-.121b_1$	$-.084b_2$	$-.104b_3$	.72 (.09)
	Change in litter depth $Y_3 =$	1.195	$-.001b_1$	$-.071b_2$	$-.098b_3$	.88 (.04)
	Change in litter dry weight $Y_4 =$	1.470	$-.043b_1$	$-.312b_2$	$-.073b_3$	.67 (.13)
	Change in depth of AO horizon $Y_5 =$	1.393	$-.153b_1$	$-.220b_2$	$-.206b_3$	.77 (.15)
	Change in dry bulk density $Y_6 =$	-.674	$+.168b_1$	$+.237b_2$	$+.053b_3$	.65 (.12)

- b_1 = change in noncapillary pore space
- b_2 = change in percent litter cover
- b_3 = change in depth of natural litter cover
- b_4 = change in oven dry weight of $.09m^2$ of litter
- b_5 = change in depth of the AO soil horizon
- b_6 = change in dry bulk density.

Resulting Y_7 values that are close to 1.0 would indicate great changes in the measured parameters and values approaching 4.0 would indicate slight changes. Actual data and sample calculations from two ecologically similar sites are shown in Table 9.

Table 9. Prediction of the relative rate of site deterioration on two similar campsites.

Factor	Site 1	Site 2
b_1 = Change in noncapillary pore space =	.862	.703
b_2 = Change in percent litter cover =	.436	.090
b_3 = Change in depth of litter cover =	.973	.783
b_4 = Change in oven dry weight of litter =	.635	.297
b_5 = Change in depth of AO horizon =	.529	.096
b_6 = Change in dry bulk density =	.026	.084

$$Y_{\text{change}} = 6.825 - 1.070b_1 - .890b_2 - 3.808b_3 + .390b_4 - .636b_5 - 2.475b_6$$

where Y_{change} = index of detrimental change in measured parameters

$$Y_{\text{site 1}} = 6.825 - .922 - .388 - 3.219 + .251 - .336 - .064 = 1.645$$

where $Y_{\text{site 1}}$ = index of detrimental changes on site 1

$$Y_{\text{site 2}} = 6.825 - .752 - .080 - 2.892 + .117 - .061 - .207 = 2.860$$

where $Y_{\text{site 2}}$ = index of detrimental changes on site 2

and where a relative detrimental change of: 1 = great, 2 = moderate, 3 = little, and 4 = no change.

CHAPTER V

RECREATION IMPACT ON ESTABLISHED CAMPSITES

Many studies have measured the extent of ecological changes taking place on recreation areas with some unknown level of visitor use. However, such data is lacking on newly established areas having good records of levels of visitor use. Neither has there been an attempt made to relate actual visitor use to simulated use on comparable areas. Specific management recommendations can only be made when the relationship between level of visitor use and site deterioration is understood.

The specific objectives of this portion of the study were:

(1) to determine the type and extent of ecological changes which take place on established campsites under various levels of visitor use, (2) to develop predictive equations which will estimate these changes at each level of use, and (3) to develop a system for estimating the deterioration of camping units based upon an index of detrimental change.

Methods

Study Area

This portion of the study was located on water access campsites in the Crooked Lake region of the Sylvania Recreation Area. The majority of users are overnight campers, although there is some use of the unoccupied units as picnic areas by day users. All overnight campers are required to register and select their campsite at the Sylvania Information Center.

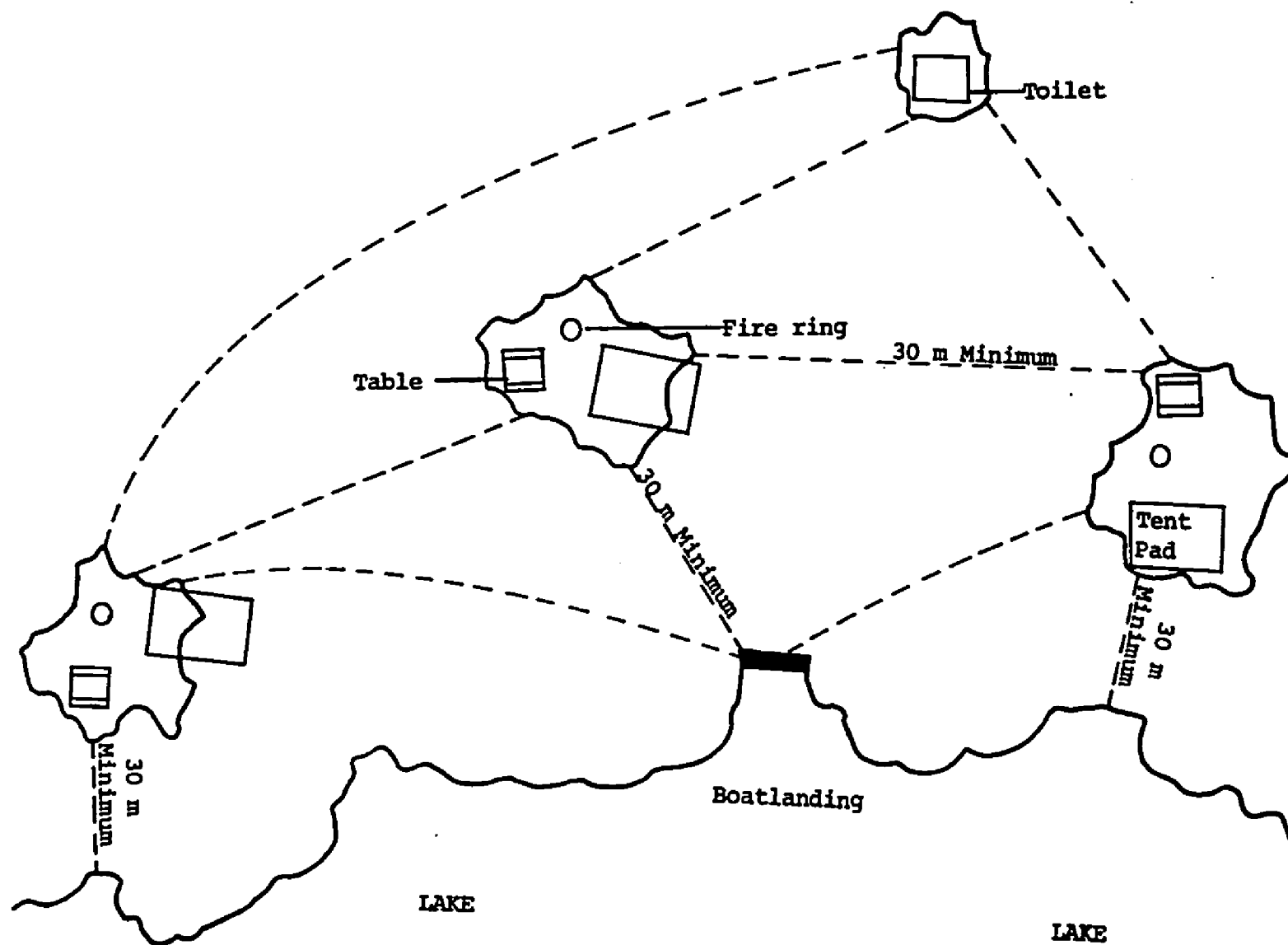
Each designated campsite consists of three separate camping units (Figure 8). They are located in the pioneer zone of Sylvania, with minimum distances of 0.5 Km between sites. The management plan specifies that units within each numbered site would be at least 30 m apart and 30 m from the water's edge (U. S. Forest Service, 1968). An added prerequisite for each site, although not specifically mentioned in the management plan, is that it be hidden from direct lake view. The campsites were established during the spring of 1968. All large limbs and underbrush were removed from the campsite. Facilities at each unit include a table, fire ring, and tent pad. In addition, for each three unit site there is a pit toilet and boat landing. Figure 9 shows two typical camping units on Sylvania.

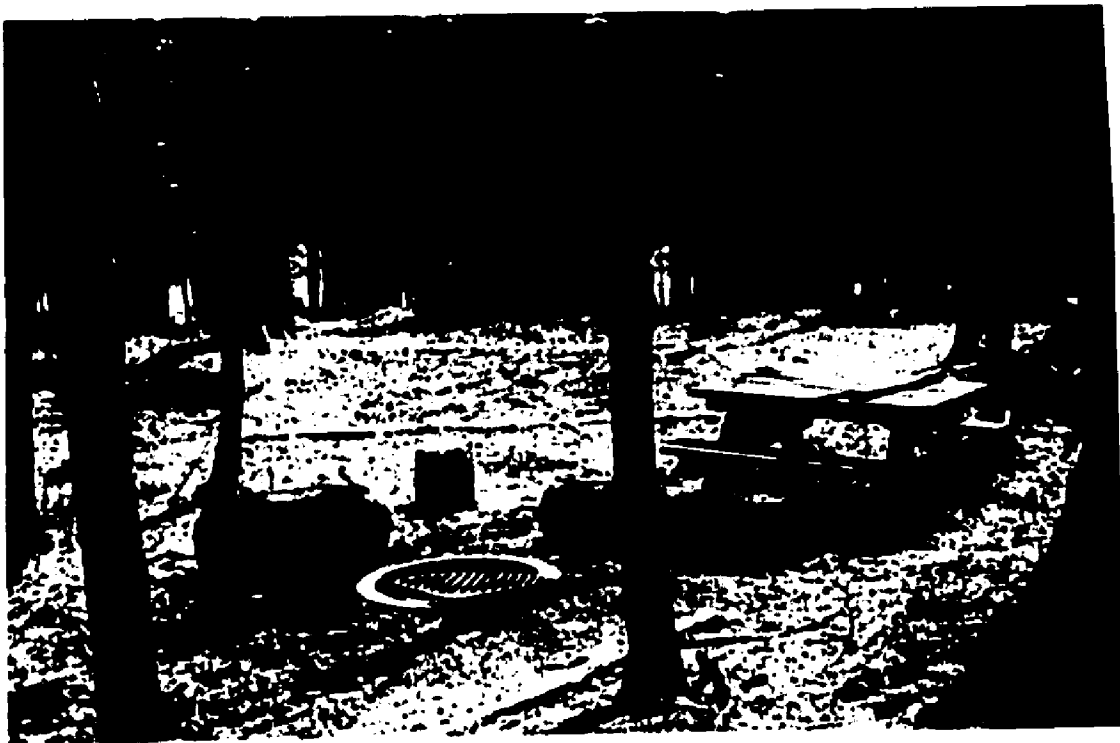
Six of the seven campsites on Crooked lake were included in this study. Campsite Fox was excluded because it was atypical of the campsites, being located on a high ridge that was difficult to reach from the water. A description of the twelve units selected from the six campsites in the study is given in Table 10. Six units each of timber types predominantly hardwood and conifer were chosen for the study. The units were further stratified into average seasonal use levels. A visitor day is here defined as one person occupying a campsite for one 12-hour period. As determined from camper registration, these were: light (100 to 150 visitor days), moderate (200 to 250 visitor days), and heavy (300 to 350 visitor days).

Experimental Design

The impact of recreation use upon campsites was investigated using a completely nested factorial design. On each camping unit the

Figure 8. Typical three-unit boat-access campsite on Sylvania Recreation Area.





(a)

Figure 9. A large conifer (a) and small hardwood (b) camping unit on Sylvania.



(b)

Table 10. Site characteristics of camping units used in estimating user impact.

Site	Use level	Timber type	Initial radius (m)	Basal area (m ²)	Average crown closure (%)	Condition as rated by users
Porcupine N1	Light	Hardwood	4.0	11.8	94	Good
Porcupine N2	Moderate	Hardwood	6.9	6.4	63	Good
Squirrel N1	Heavy	Hardwood	5.9	13.2	92	Fair
Squirrel N2	Heavy	Conifer	7.1	9.1	81	Good
Squirrel N3	Heavy	Conifer	6.1	9.5	89	Good
Badger W1	Heavy	Hardwood	4.7	9.5	86	Good
Fisher W3	Moderate	Hardwood	5.1	7.7	94	Fair
Mink N2	Light	Conifer	6.1	12.3	89	Fair
Mick N3	Light	Hardwood	4.7	9.5	97	Good
Chipmunk N1	Moderate	Conifer	5.8	14.1	90	Good
Chipmunk N2	Moderate	Conifer	9.8	8.6	85	Very Good
Chipmunk N3	Light	Conifer	4.9	12.2	88	Very Good

center of use was visually determined. From the center of each unit three transects, each with three one-meter plots were laid out (Figure 10). Two of the plots on each transect were located within the bounds of the campsite, and the third was off the campsite and served as a control plot. Camping units were further subdivided into three concentric circular sampling zones, with three plots being located in each ring. Zone one was the high use area near the center of the campsite. Zone two was the intermediate use zone near the margin of the campsite. Zone three was located off the campsite as a control area. Figure 11 illustrates a plot from zone one on a moderately used unit and a control plot from the same unit.

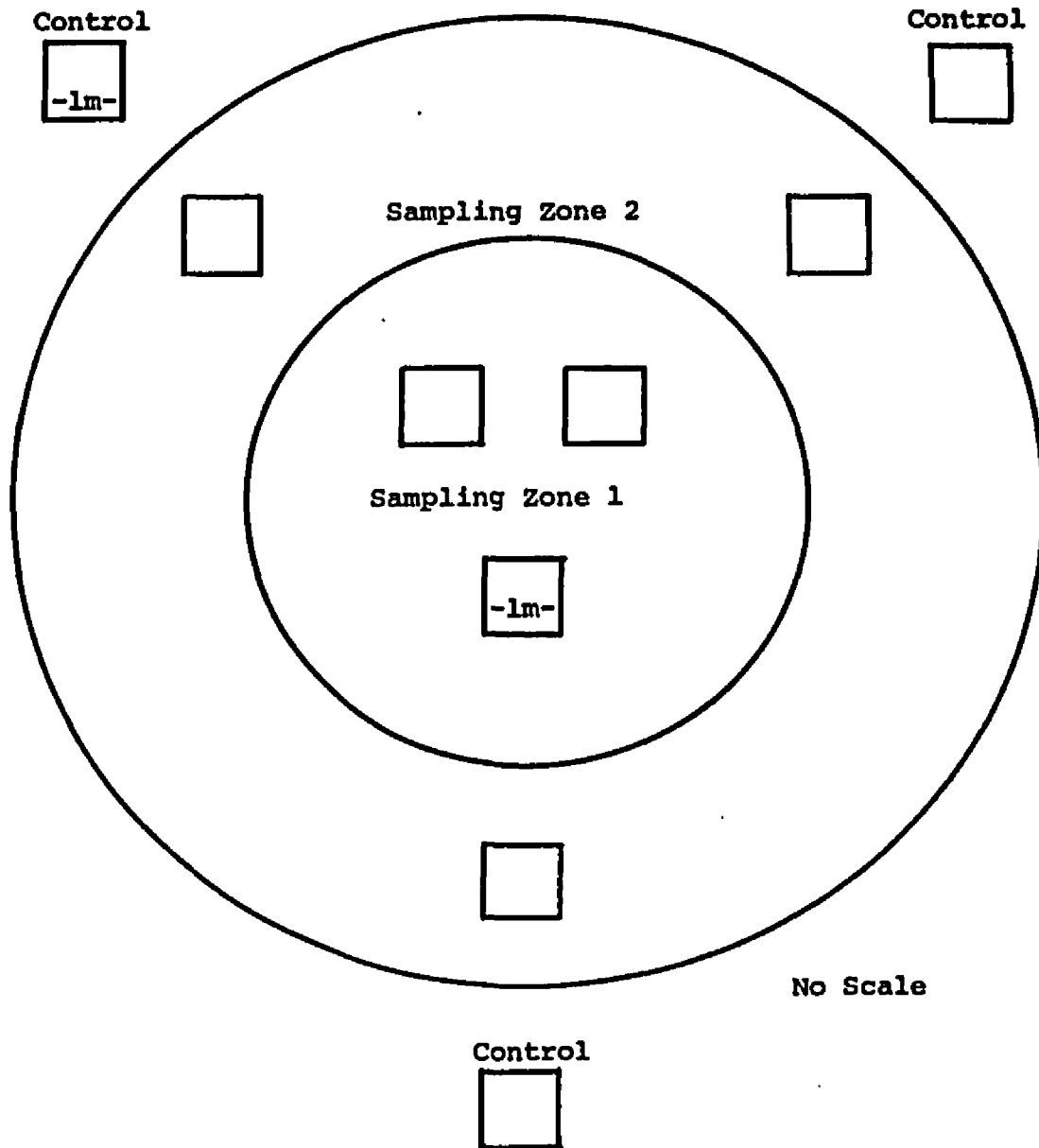
Measurements

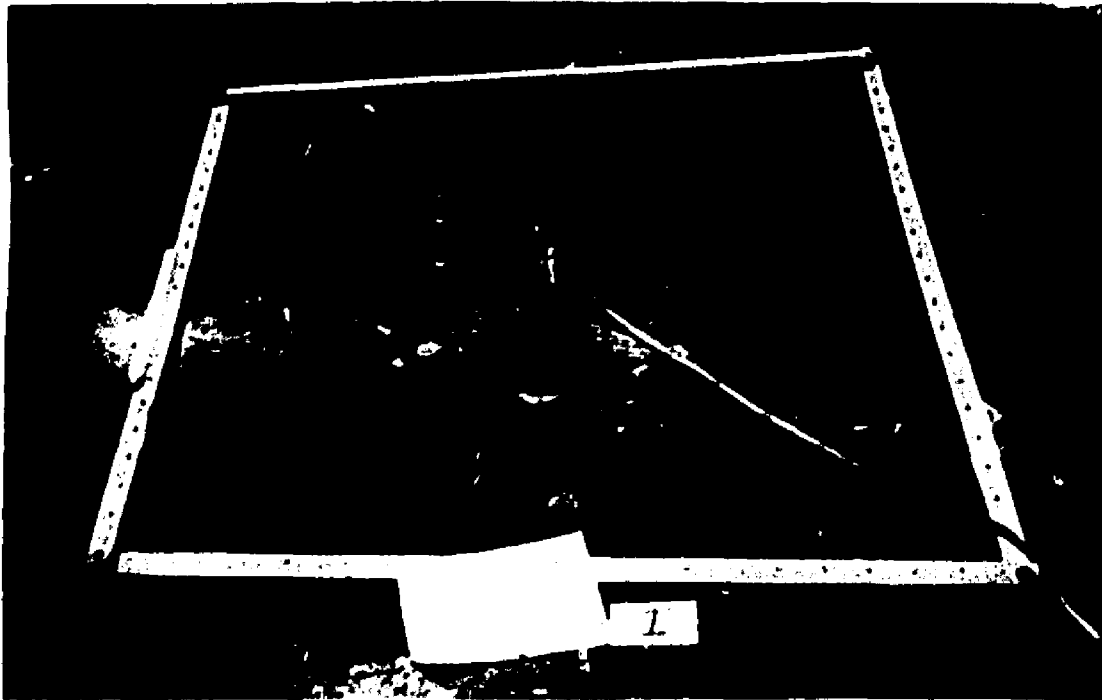
The measurements made on campsite plots were the same as those made upon the simulated recreation use sites but oven dry weight of litter and depth of litter were excluded. In addition, the distance from the center to the edge of the campsite was measured in four places to determine if the campsite expanded in size. All measurements were made four times at two week intervals during the period of June 20 to September 15.

Analysis of Data

The total change in bulk density, natural litter cover, percent noncapillary pore space, depth of the AO horizon, and percent crown cover was calculated for the two seasons of visitor use. These parameters were then utilized as dependent variables in multiple regression analysis to estimate the type and extent of change due to different

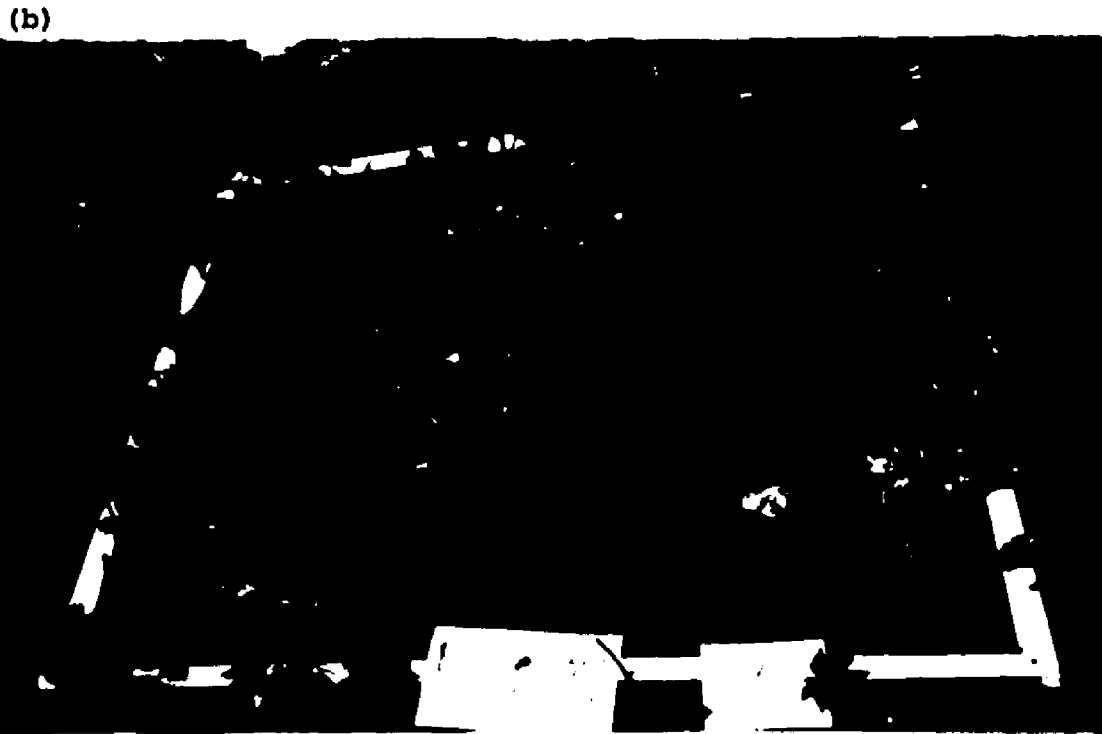
Figure 10. One complete replication of the design used to determine the impact of recreational use upon established campsites.





(a)

Figure 11. Plot from sampling zone one (a) of a moderately used camping unit and a control plot (b) from the same unit.



(b)

levels of camping unit use. Independent variables which were not significant at the 10 percent level were excluded from the equation. Equations were developed for each sampling zone since there were significant differences between the zones. As on the simulated sites, some of the independent variables used in the development of the equations were coded for ease in calculation. Timber type was classified as either dominantly hardwood (=1) or conifer (=2). Levels of use were: 300-350 visitor days (=1), 200-250 visitor days (=2), and 100-150 visitor days (=3). Wide ranges in values required the use of arcsin transformations in analyzing the percent litter cover on plots (Sokal, 1969).

Sylvania Camper Survey

To assess the ecological impact of camping it is necessary to determine visitor criteria for site selection, and to determine the amount of time that they actually spent on the camping unit (tent pad). Since overnight campers had to register and select their campsites upon entering Sylvania, campsites were selected on some basis other than physical appearance for all but return visitors. It was important to account for the vast differences in use levels between campsites.

In order to establish visitor criteria for campsite selection, and determine the amount of time each camper actually spent on the camping unit, a voluntary, self-administered questionnaire was distributed from the Visitor Information Center (Appendix D). In the questionnaire each participant was asked to rate the condition of his campsite as either very good, good, fair, or deteriorated. Return boxes and additional questionnaires were placed at the major boat landings and portages on the area. Of the 700 questionnaires issued, 300 were returned.

Results

Effects of Recreation Use on Natural Litter

There was a significant effect of sampling zone upon the percent litter cover present at all levels of use in both timber types (Table 11). Near the center of use, the campsite's annual leaf litter was rapidly destroyed. Litter cover at the beginning of the season varied from 100 percent on lightly used units to 40 percent on heavily used units. On heavily used camping units, over 90 percent of the litter was removed by the end of the visitor season regardless of timber type. However, on moderately and lightly used camping units, the conifer sites maintained greater litter cover than hardwood sites in the center of use zone. In zone two the percent decrease was significantly less than in zone one. There were no significant differences between timber type or level of use within this zone.

Since there were significant differences between the sampling zones, prediction equations were developed for both zones within the camping unit.

The equation for zone 1 had a R^2 of .65 and a standard error of 0.18.

$Y_8 = .9857 - .188b_1 - .006b_2 + .459b_3 + .003b_4 - .177b_5$, where:

Y_8 = decrease in percent litter in the peak use zone of a camping unit.

0.9857 = constant

b_1 = timber type

b_2 = initial percent crown cover

b_3 = initial dry bulk density

b_4 = initial percent litter cover

b_5 = level of use.

Table 11. Average percent decrease in natural litter cover on established camping units at three levels of visitor use over two seasons.

Use / Site	Sampling Zone ¹⁾		
	Zone 1	Zone 2	Control
Heavy / Conifer	96	29	0
Heavy / Hardwood	92	31	0
Moderate / Conifer	70	41	0
Moderate / Hardwood	95	35	0
Light / Conifer	65	31	0
Light / Hardwood	72	39	0

¹⁾ Any difference among these values greater than 20 is significant at the 5% level.

The selection of these independent variables means that with use:

1. Conifer sites show smaller decreases in percent litter cover than hardwood sites;
2. Sites with dense canopies will decrease less in percent litter cover than sites with open crowns;
3. As bulk density increases the change in litter cover decreases;
4. The higher the initial percent litter cover, the smaller the decrease;
5. Higher levels of use produce greater decreases in litter cover.

The fact that there were no significant differences between use levels in zone 2 is reflected in the equation which was developed for that portion of the site. Level of use was not included in the equation at the 10 percent level of significance. The equation for zone 2 explains 57 percent of the variability in percent litter cover with a standard error of 0.16.

$$Y_9 = .432 + .007b_1 - .009b_2 + .321b_3, \text{ where:}$$

Y_9 = decrease in percent litter cover in the light use zone
of the camping unit

0.432 = constant

b_1 = initial percent litter cover

b_2 = initial percent crown cover

b_3 = initial dry bulk density.

Just as for zone 1, the same type of relationship exists here between percent litter cover and the independent variables.

Effects of Recreation Use on Soil Properties

Noncapillary Pore Space

The results of measurements of noncapillary pore space are similar to those for litter cover (Table 12). However, differences between the two zones were not as clearly defined. Initial mean noncapillary pore space for conifer sites was 11.6 percent while on hardwood sites it was 12.4 percent. Conifer sites showed no significant differences between zones 1 and 2. This was due to the low percent change that occurred in zone 1 on the moderately and lightly used coniferous units. Significant differences between timber type occurred at the moderate and light use levels in zone 1 and at the moderate and

heavy levels of use in zone 2.

Table 12. Average percent decrease in noncapillary pore space on established camping units at three levels of visitor use over two seasons.

Use / Site	Sampling Zone ¹⁾		
	Zone 1	Zone 2	Control
Heavy / Conifer	68	60	8
Heavy / Hardwood	64	45	-5 ²⁾
Moderate / Conifer	16	19	1
Moderate / Hardwood	41	58	4
Light / Conifer	13	17	2
Light / Hardwood	36	18	-3 ²⁾

¹⁾ Any difference among these values greater than 13 is significant at the 5% level.

²⁾ Negative numbers indicate an increase in noncapillary pore space.

The prediction equation for zone 1 explained 47 percent of the variability with a standard error of 0.35.

$Y_{10} = 1.039 - .345b_1 + .043b_2 - .007b_3$, where:

Y_{10} = decrease in noncapillary pore space in zone 1

1.039 = constant

b_1 = use level

b_2 = initial noncapillary pore space

b_3 = initial percent crown cover.

These indicate that with use:

1. High use levels produce greater decreases in noncapillary pore space;
2. The larger the initial percent by volume of noncapillary pore space the greater the decrease;
3. Sites with high initial crown covers decrease less than open sites.

The prediction equation for zone 2 explained 52 percent of the variability and the standard error was 0.38.

$$Y_{11} = .667 - .009b_1 - .285b_2 + .043b_3, \text{ where:}$$

Y_{11} = percent decrease in noncapillary pore space in zone 2

0.667 = constant

b_1 = initial percent litter cover

b_2 = use level

b_3 = initial noncapillary pore space.

The only change from the prediction equation for zone 1 is the deletion of percent crown cover and the addition of percent litter cover. This indicates that camping units which have high initial percent litter cover are more resistant to changes in noncapillary pore space. The role of percent litter cover in the equation for zone 2 and percent crown cover in zone 1 are important even though they are multiplied by a small number in the equation. Since their values may vary from zero to 100 percent, they can bring about large variations in the predicted change in noncapillary pore space.

Bulk Density

Changes in bulk density due to visitor use were significantly different between sampling zones. However, zone 2 showed greater increases in bulk density than zone 1 (Table 13). This was due to the higher initial bulk densities encountered in zone 1 of each camping unit. Initial bulk densities in zone 1 averaged 1.77 g cm^{-3} and zone 2 averaged 1.63 g cm^{-3} .

Table 13. Average percent increase in bulk density on established camping units at three levels of visitor use over two seasons.

Use / Site	Sampling Zone ¹⁾		
	Zone 1	Zone 2	Control
Heavy / Conifer	22	33	25
Heavy / Hardwood	16	33	15
Moderate / Conifer	17	42	25
Moderate / Hardwood	16	28	12
Light / Conifer	13	22	12
Light / Hardwood	15	30	15

¹⁾ Any difference among these values greater than 7 is significant at the 5% level.

The area near the center of use is apparently approaching its maximum density due to compaction by recreation users. Since the outer zone is presently being compacted at a faster rate, it will probably become as compacted as zone 1.

The prediction equations for zones 1 and 2 contain the same independent variables. The coefficient of determination for the equation for zone 1 was 0.64 and the standard error was 0.08.

$$Y_{12} = .9037 - .001b_1 - .043b_2 - .421b_3, \text{ where:}$$

Y_{12} = the increase in dry bulk density within sampling zone 1

0.9037 = constant

b_1 = initial percent litter cover

b_2 = use level

b_3 = initial dry bulk density.

The independent variables for the equation generated for predicting the change in bulk density of zone two on the camping units are the same as those for zone 1. The equation with an R^2 of 0.72 and a standard error of 0.08 is as follows:

$$Y_{13} = 1.030 - .002b_1 - .033b_2 - .482b_3.$$

The independent variables included indicate that high use levels coupled with low percent litter cover and low initial dry bulk density will lead to the greatest changes in dry bulk density.

Depth of the AO Horizon

Soil depths of the AO horizon indicate that with recreation use, camping units tend to become saucer-like depressions. The percent decrease in depth of the AO horizon was significantly greater in the heavy use areas of the camping unit and gradually diminished toward the margins (Table 14). There were also significant differences between use levels and between timber types. Conifer sites proved somewhat more resistant to change than hardwood sites at moderate and light levels of use, but at heavy levels of use there were no significant

differences. On all of the heavily used camping units and the moderately used hardwood units, there was only one plot within sampling zone 1 in which the A2 horizon was not at the surface. On the more lightly used plots near the camping unit margins, the depths ranged from 0 cm to 6 cm. Only the lightly used conifer units suffered less than a 50 percent decrease in depth of the AO horizon in zone 1. Their depths ranged from 2 cm to 5 cm.

Table 14. Average percent decrease in depth of the AO horizon on established camping units at three levels of visitor use over two seasons.

Use / Site	Sampling Zone ¹⁾		
	Zone 1	Zone 2	Control
Heavy / Conifer	100	67	0
Heavy / Hardwood	98	68	0
Moderate / Conifer	61	55	0
Moderate / Hardwood	100	74	0
Light / Conifer	49	18	0
Light / Hardwood	60	51	0

¹⁾ Any difference among these values greater than 11 is significant at the 5% level.

The multiple regression equation predicting the change in depth of the AO horizon in zone 1 of each camping unit explains 71 percent of the variation with a standard error of 0.20.

$Y_{14} = .4148 + .030b_1 - .126b_2 + .363b_3 - .003b_4 - .101b_5$, where:

Y_{14} = decrease in depth of the AO horizon in sampling zone 1

0.4148 = constant

b_1 = initial radius of the camping unit

b_2 = initial depth of the AO horizon

b_3 = initial dry bulk density

b_4 = initial percent litter cover

b_5 = use level.

These variables show that the decrease in depth of the AO horizon in zone 1:

1. Increases as the size of the camping unit increases;
2. Is smaller on sites where the initial depth of the AO is greater;
3. Is less on sites with high initial bulk densities;
4. Is greater on sites where the percent litter cover is low;
5. Is greatest at high levels of use.

For sampling zone 2 the prediction equation explains 49 percent of the variation and the standard error was 0.26.

$Y_{15} = .6007 - .355b_1 - .139b_2 + .039b_3$, where:

Y_{15} = decrease in depth of the AO horizon in zone 2 of the camping units

0.6007 = constant

b_1 = timber type

b_2 = use level

b_3 = initial radius of the camping unit.

This means that with use:

1. Hardwood sites suffer greater decreases in depth of the AO than conifer sites;
2. High levels of use produce greater decreases than lower levels;
3. The larger the initial radius of the campsite the greater the decrease.

Effects of Recreation Use on Crown Cover

The percent change in crown cover over the camping unit was determined by comparing plots within the camping units to controls. The differences could be due to camper impact or to clearing which took place during campsite construction, or both. There was significantly less crown cover over the central portion of each tent pad than near the margins (Table 15). Conifer sites underwent greater decreases in crown cover at all levels of use than hardwood sites. The changes which occurred in zone 2 were consistently smaller, but showed no relationship between timber type and level of use. This may be due to the encroachment of tree crowns from off the unit and into the space above zone 2. The equation for the change in percent crown cover over zone 1 explains 60 percent of the variation with a standard error of 0.12, and is:

$$Y_{16} = -.662 + 1.40b_1 - .091b_2 + .011b_3 + .387b_4, \text{ where:}$$

Y_{16} = percent decrease in crown cover over zone 1

$-.662$ = constant

b_1 = change in camping unit radius as measured over a two-year period

b_2 = use level of the camping unit

b_3 = average shade cover over the control plots

b_4 = initial percent litter cover on zone 1.

These independent variables indicate that with use:

1. The greater the growth in camping unit radius the greater the decrease in percent crown cover;
2. The higher the level of use the greater the decrease in percent crown cover;
3. The greater the crown cover over the control plots the greater the decrease in percent crown cover;
4. The higher the initial litter cover the greater the decrease.

Table 15. Average decrease in percent crown cover on established camping units at three levels of visitor use over two seasons.

Use / Site	Sampling Zone ¹⁾		
	Zone 1	Zone 2	Control
Heavy / Conifer	27	9	0
Heavy / Hardwood	14	4	0
Moderate / Conifer	25	5	0
Moderate / Hardwood	13	13	0
Light / Conifer	14	8	0
Light / Hardwood	6	1	0

¹⁾ Any difference among these values greater than 6 is significant at the 5% level.

The equation for zone 2 includes the same variables except that b_4 becomes the initial litter cover on zone 2. It has a R^2 of 0.49 with a standard error of 0.09.

$$Y_{17} = -.696 + .802b_1 - .057b_2 + .009b_3 + .172b_4, \text{ where:}$$

$$Y_{17} = \text{percent decrease in crown cover over zone 2.}$$

Effects of Recreation Use on Camping Unit Size

When the study began, individual camping unit radii varied in size from 4.05 m to 9.75. Conifer sites had an average radius of 6.6 m and hardwood sites 5.2 m. During the two-year study period the size of the conifer units increased in radius by 8 percent and hardwood units increased by 14 percent (Table 16). However, due to the larger initial size of the conifer units, both types increased about the same number of square meters. Increase in size did not follow a continuous linear trend. Instead, the units grew in spurts as an especially ambitious camper would "improve" his campsite by clearing some of the surrounding underbrush and thereby increase the size of the unit. One set of campers was observed increasing the size of a small hardwood campsite from 4 m to 5.5 m in radius.

The conifer camping sites probably increased in size more rapidly in the period immediately after they were installed than the hardwood sites because of their open understory. The hardwood sites were usually surrounded by a dense stand of maple reproduction. Once a site was enlarged, campers would continue to utilize the new space.

A prediction equation was developed to estimate the change in radius which would occur on a camping unit in a two-year period. The equation had a coefficient of determination of 0.65 and a standard

error of 0.36.

Table 16. Enlargement of camping units on established campsites at three levels of visitor use over two seasons.

Use / Site	Initial Radius	Final Radius	% Change
	(m)	(m)	
Heavy / Conifer	6.4	7.6	15.8
Heavy / Hardwood	5.3	6.2	17.8
Moderate / Conifer	7.8	7.8	0.0
Moderate / Hardwood	6.0	6.3	5.7
Light / Conifer	5.6	6.0	7.1
Light / Hardwood	4.4	5.2	19.2

$$Y_{18} = .630 - .808b_1 - .039b_2 - .045b_3 + .001b_4, \text{ where:}$$

Y_{18} = percent increase in the radius of a camping unit

0.630 = constant

b_1 = timber type

b_2 = use level

b_3 = initial radius of the site

b_4 = initial percent crown cover on the site.

The effect of each independent variable when the others are held constant is shown below:

1. Radius increased more on hardwood sites than conifer sites;
2. High levels of use cause greater increases than low levels;

3. A large initial radius leads to successively smaller increases in radius;
4. The larger the percent crown cover the greater the increase.

Sylvania Camper Survey

The camper survey indicated that almost 41 percent of Sylvania's campers were repeat users. This figure ranged from a low of 27 percent on Crooked Lake to a high of 50 percent on Clark Lake. The choice of lakes was primarily controlled by the type of boating and fishing regulations. Campers were attracted to Crooked Lake because it has regular Michigan fishing regulations and also it allowed use of outboard motors. The dominant reason for selecting other lakes was because access was limited to nonmotorized craft, predominantly canoes.

Seclusion was the reason most often given for choosing a particular campsite (Table 17). Even though 27 percent of the campers had previously camped on Crooked Lake, only nine percent indicated that having seen the campsite on a previous visit influenced their selection. Other reasons given by campers for choosing a particular campsite included that it was easy to find, centrally located, or that all the units on the site were empty.

Upon arriving at a campsite, campers had to select which of the three available camping units (tent pads) they wanted to use. The most important factor in unit selection was that the others were occupied (Table 18). On Crooked Lake, where use was lower, the larger, more secluded sites were selected first. Nearness to the boat landings was almost as important as seclusion and size. Miscellaneous reasons

furnished by campers for choosing a particular camping unit included that the unit was better-drained, highest, had a better breeze, or had the fewest insects.

Table 17. Criteria used by Sylvania visitors in campsite selection.

Selection Criteria	Crooked Lake Campsites	Other Campsites
	Percent of total	Percent of total
More Secluded	36	27
Closer to boatlanding	11	6
Closer to beaches and portages	10	13
Recommended by receptionist	10	14
Seen on previous visit	9	13
Recommended by friends	3	4
Name of the campsite	3	2
Others	$\frac{18}{100}$	$\frac{21}{100}$

The average daily number of hours spent on activities away from the campsite varied from zero to 12. On Crooked Lake the average was 10 hours, while on the remaining lakes the average was 7 1/2 hours. Thus only 14 hours were spent on the study campsites each day, and allowing time for sleep, less than half of the waking hours were spent in camp. Therefore, the total impact would be less than in an area where a greater percentage of the time is spent on the site.

Table 18. Criteria used by Sylvania visitors in choosing a particular camping unit.

Selection Criteria	Crooked Lake Campsites	Other Campsites
	Percent of total	Percent of total
Largest camping area	17	9
More seclusion	17	16
Closest to boat landing	16	12
Better view of lake	11	12
More shade	7	2
More sunlight	5	12
Other units occupied	13	21
Others	<u>14</u> 100	<u>16</u> 100

Ranking Camping Unit Durability

To rank camping unit durability over a wide range of use levels and conditions, it is necessary to monitor several site parameters. After establishing the predictability of ecological changes at several use levels, the next logical step is to determine if actual measurements of those changes can be utilized to develop an equation which would provide an index to the complex changes that occur on a camping unit with use.

Using multiple regression the following equations was generated employing data which was gathered on Sylvania camping units during the visitor seasons of 1971 and 1972. It explains 76 percent of the

variance of the dependent variable with a standard error of 0.46.

$$Y_{19} = -1.90 - 4.81b_1 - .757b_2 + .066b_3 - .752b_4 - 1.357b_5 - 1.271b_6 \\ + .355b_7 + 5.3b_8, \text{ where:}$$

Y_{19} = index of detrimental change on established campsites

-1.90 = constant

b_1 = change in radius of the camping unit

b_2 = change in dry bulk density in sampling zone 2

b_3 = initial percent crown cover over sampling zone 1

b_4 = change in noncapillary pore space of sampling zone 1

b_5 = change in dry bulk density in sampling zone 1

b_6 = change in depth of the AO horizon in sampling zone 1

b_7 = change in noncapillary pore space in sampling zone 2

b_8 = change in percent crown cover in sampling zone 1.

This equation may be used in the same manner as the equation developed with data from simulated trampling plots. Resulting values of Y_{18} close to 1.0 indicate large changes in the measured parameters and values approaching 4.0 indicate slight changes (based upon a coding system where 1 = heavy, 2 = moderate, 3 = light, and 4 = no use). A sample problem using the above equation and employing measurements from two of the study campsites is shown in Table 19.

The results indicate that site 1 has not deteriorated as much as site 2. This is probably due primarily to the difference in use level of the two sites. Unit 1 received an average of 240 visitor days per year during the past 5 years while unit 2 received an average of 350 visitor days of use per year. Also, unit 1 was a conifer site and unit 2 was predominantly hardwood. Results indicate that overall hardwood sites are less durable than conifer sites.

Table 19. Prediction of the relative extent of site deterioration on two similar campsites using the predictive equation established from campsite measurements.

Independent Variables	Unit 1	Unit 2
b_1 = Change in radius of the camping unit	= .025	.153
b_2 = Change in dry bulk density in sampling zone 2	= .340	.303
b_3 = Initial crown cover over zone 1	= 80.000	90.000
b_4 = Change in noncapillary pore space in zone 1	= .147	.550
b_5 = Change in dry bulk density in zone 1	= .101	.181
b_6 = Change in depth to the A2 horizon in zone 1	= .000	1.000
b_7 = Change in noncapillary pore space in zone 2	= .404	.414
b_8 = Change in percent crown cover over zone 1	= .102	.041

$$Y_{19} = -1.800 - 4.811b_1 - .751b_2 + .066b_3 - .752b_4 - 1.357b_5 - 1.27b_6 + .355b_7 + 5.300b_8, \text{ where: } Y_{19} = \text{index of detrimental change in measured parameters}$$

$$Y_{\text{site 1}} = -1.900 - .120 - .257 + 5.280 - .110 - .137 - 0.000 + .134 + .540 = 3.340 \text{ where: } Y_{\text{site 1}} = \text{index of detrimental change on site 1}$$

$$Y_{\text{site 2}} = -1.900 - .736 - .229 + 5.940 - .413 - .245 - 1.270 + .138 + .217 = 1.412 \text{ where: } Y_{\text{site 2}} = \text{index of detrimental change on site 2}$$

and where a relative detrimental change of 1 = great, 2 = moderate, 3 = little, and 4 = no change.

CHAPTER VI

RECOVERY OF ABANDONED CAMPSITES

It has been suggested that campsites suffering from serious deterioration be temporarily closed to allow them to recover to natural conditions (Brockman, 1959, Lime, 1971). The objective of this portion of the study was to monitor the rate of natural recovery of abandoned campsites.

Methods

Study Area

Four campsites were selected on the Sylvania tract which had been closed by the U. S. Forest Service. Two units were located on Crooked Lake, one on Clark Lake and one on East Bear Lake. Parameters monitored were percent litter cover, bulk density, and noncapillary pore space. Measurements were made in September, 1971, and July and September, 1972. A description of each site is given in Table 20.

Results

The recovery made in bulk density, percent litter cover, and noncapillary pore space is shown in Table 21.

The camping units at Muskrat, on Crooked Lake, had been abandoned for over 3 seasons at the time the measurements were made in 1972. During that period only small improvements were observed in bulk density and noncapillary pore space. Although percent litter increased

by 25%, it did not approach natural conditions (Figure 12). No seedling reproduction was found on the campsites even though the cover was dense at the edge of the units.

Table 20. Characteristics of Sylvania camping units chosen to monitor site recovery.

Characteristic	Camping Unit			
	Muskrat W2	Muskrat W3	Hemlock N2	Wolf W3
Last full season of use	1968	1968	1970	1970
Number of seasons open	1 1/3	1 1/3	3	3
Total use while open (visitor days)	421	421	1607	69
Timber type	Hardwood	Hardwood	Conifer	Hardwood
Average percent crown cover (1971)	80	70	72	96

Although it had received nearly four times as much use, the camping unit at Hemlock appeared to be in about the same condition as the Muskrat sites. In fact, it showed a slightly more rapid recovery during the study. The camping unit at Wolf on East Bear Lake had been the least used campsite on Sylvania during the three years prior to the beginning of the study. The U. S. Forest Service closed these units to camping for purposes of this study. The conditions on the camping unit were nearly natural. Reproduction had begun to return to the unit and soil conditions on the unit were about the same as the controls. However, the litter cover was not as complete or as deep as that found off

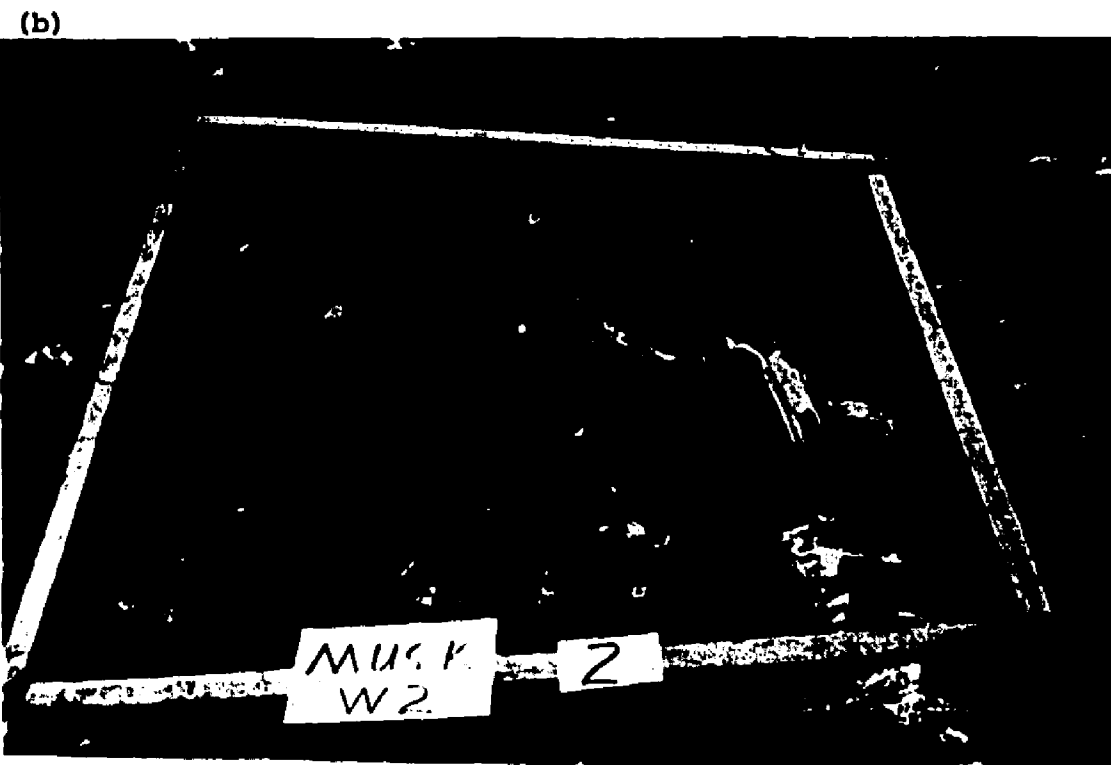
Table 21. Changes in percent litter cover, noncapillary pore space, and dry bulk density showing the recovery of closed camping units in one year.

Camping Unit	% Litter Cover			Noncapillary Pore Space (% by volume)			Dry Bulk Density (grams/cm ²)		
	Initial	Final	Control	Initial	Final	Control	Initial	Final	Control
Hemlock N2	16	64	100	10	16	30	1.70	1.67	1.41
Muskrat W2	55	80	100	7	9	33	1.65	1.63	1.35
Muskrat W3	70	96	100	11	11	30	1.58	1.50	1.28
Wolf W3	52	80	100	22	25	27	1.47	1.42	1.40



(a)

Figure 12. Comparison of a control plot (a) just off the margin of a previously heavily used campsite abandoned for three years and a used plot (b) from the center of the same unit.



(b)

the units.

Abandonment does not appear to be an acceptable means of restoring campsites to natural conditions in a reasonable short time. Sites which receive high levels of use, even for short periods of time, showed only slight recovery after being idle for four years. Conifer sites showed a slightly greater rate of recovery than hardwood sites during the two-year study period. The primary limiting factor to site recovery on heavily used units was the dense soil surface layer formed while they were in use. Some form of cultural activity to prepare a more satisfactory seedbed will be necessary on these sites before they will return to natural conditions in a reasonably short period of time.

CHAPTER VII

DISCUSSION AND CONCLUSIONS

Simulated Trampling versus Actual Use

Both of these forms of analysis of recreation impact upon forest ecosystems have advantages and disadvantages. The chief advantage of studying actual campsites is the asurity that the changes which are occurring are due to recreation and probably could be duplicated at different sites. With artificial trampling there is always the question of high closely one is simulating actual recreational use.

However, the use of simulated trampling does have many advantages that at least partially offset its handicaps. It provides a source of use which can be precisely controlled as to amount and timing. This allows the investigation of several different levels of use in one small area, or on sites where the potential establishment of actual campsites is to be evaluated. Simulation also permits accurate measurements of conditions prior to trampling, and allows continual monitoring during the trampling period. This enables one to express any measured changes on the trampled plot as a function of level of use.

The trampling levels applied in this study may or may not have duplicated recreational use. The timing and duration of the trampling was not the same as would occur on an actual campsite. On the trampled plots the use was applied but once a week in a period of only a few minutes, while on camping units the use was spread relatively evenly

over a longer period of time. The trampling schedule may have allowed some recovery to occur from week to week. The simulated use plots received no treatment other than trampling; however, the campsites were at various times swept, raked, and covered by tents or shelters. An additional error factor may perhaps be the difference in relative age of the two areas. The actual campsites had already been in use for three years before the trample plots were established.

Even with all of these differences, the results from the two areas were surprisingly similar and produced comparable equations on the index of detrimental change. However, due to more precise control of the use levels, the prediction equations established for the simulated use sites yielded consistently higher coefficients of determination than equations estimating the same dependent variables with measurements taken from camping units.

Of the independent variables utilized in the prediction equations, for both simulated and actual campings, level of use was the most important factor. On the simulated sites it appeared in every equation, and showed the highest partial correlation coefficient in all but one instance. Timber type also appeared in each equation and elevation occurred in four of six situations in the simulated use equations. On actual campsites, use level appeared in ten of eleven equations. No other independent variable appeared in more than four equations.

Changes in Ecological Parameters

Natural Litter

Initially the simulated use plots were covered by a deep layer of natural litter made up of several years' leaf cast and with an

equally thick humic layer. On the actual campsites the litter consisted of only one year's leaf fall and there was no humic layer between the litter and mineral soil. The results of the artificial trampling indicate that this was to be expected. At all levels of trampling there were reductions in depth of the litter and on heavily and moderately trampled plots mineral soil was exposed by the end of the second year. Therefore, the initial natural litter is probably destroyed on the campsites during the first year or so of use.

The actual conifer camping units as well as conifer simulated use plots, showed the smaller changes in percent litter cover than hardwood sites. This is primarily due to the nature of the conifer litter and its seasonal fall. The composition of the natural litter on conifer sites had a greater proportion of woody material, twigs, and cones, and leaf fall occurred over the entire visitor season. However, even with this constant litter increment, the percent litter cover dropped below 75 percent on all of the plots within the margin of the camping unit. According to Orr (1971) and Parker (1953), if the ground cover is less than 75 percent, significant soil movement will take place under use. Although this type of soil erosion was not observed on the study area, the maintenance of some form of litter cover on the camping unit is undoubtedly important in the prevention of excessive soil erosion.

Soil Properties

Soil compaction was monitored in two different ways. Dry bulk density was measured directly and the percent by volume of noncapillary pore space as a function of air permeability.

As expected, bulk density varied directly with level of use on both simulated use sites and camping units. The camping units showed a great deal of compaction with the formation of a surface layer firmly cemented by organic matter. This layer varied from one to two centimeters in thickness and dried to rock-like hardness. Such a layer was beginning to form on some of the heavily trampled simulated plots on hardwood sites where much of the litter layer had been destroyed. This indicates that crust formation on the soil surface probably begins after litter destruction and the speed of its formation is a function of use level. The compacted surface layer probably caused increased surface runoff. Due to the bowl-shaped nature of some camping units, runoff water from other parts of the unit collected in the center zone. This zone of the camping units showed the highest moisture levels.

It may be debatable whether this crust formation is an undesirable factor. It certainly hinders the establishment of vegetation on the camping unit, and restricts air and water infiltration. However, its presence also retards soil erosion problems and reduces the dustiness of the camping unit in dry weather. If it is impossible, as some authors suggest, to maintain ground cover on heavily used camping units, a hard surface layer may be a desirable feature. With lighter levels of use, the simulated as well as camping unit plots showed no crustal formation and higher bulk density values.

The percent by volume of noncapillary pores in the soil proved to be a sensitive indicator of site changes, especially at low levels of use. Light levels of use produced large reductions in macropore space while higher levels of use produced only slightly greater changes. Most plots showed an off-season recovery in noncapillary pore space at

about 70 percent. Orr (1960) indicated similar results in a study in South Dakota. He reported that decreases in noncapillary pore space due to trampling are usually balanced by increases in noncapillary pore space, and that increases in noncapillary pore space during the recovery period are offset by decreases in capillary pores.

The decrease in depth of the AO horizon is probably most useful on established camping units where the surface litter has been worn away and some degree of sheet erosion has taken place on the unit. It should be noted, however, that the change is a function of the original depth of the AO. Soils having initial shallow AO horizons would suffer greater percent changes with the same amount of erosion than soils with thick AO's.

Other investigators (Frissell, 1964, Hartesveldt, 1962) have used the percent of the site covered by exposed tree roots to measure erosion. Problems inherent to this method include: the necessity to wait until roots are exposed; the resultant damage that may occur before measurements can be made; and tree root depths vary greatly between species, and comparisons cannot therefore be readily made between timber types.

Table 22 shows comparisons between initial or control values and final values after two seasons of simulated recreation use and five seasons of actual use.

Increase in Camping Unit Size

The increase in size of camping units with use has been reported by several authors (Merriam, 1971, Echelberger, 1971). This increase in radius, noted in this study, has positively correlated with the

Table 22. Comparison of initial or control values and final measurements of the parameters monitored on
Sylvania.

Camping Units													
(zone 1)	Litter Cover		Litter Depth		Oven Dry Weight of Litter on .09 m ²		Bulk Density		Noncapillary Pore Space		Depth of AO		
	%		cm		g		g c ⁻³		%		cm		
	Control	Final	Control	Final	Control	Final	Control	Final	Control	Final	Control	Final	
<u>Established Campsites</u>													
Hardwood													
Heavy	100	10	--	--	--	--	1.9	2.0	10.0	2.9	5.0	0	
Moderate	100	5	--	--	--	--	1.7	1.9	11.1	5.1	5.5	0	
Light	100	30	--	--	--	--	1.7	1.8	16.7	11.5	4.7	2.0	
Conifer													
Heavy	100	5	--	--	--	--	1.8	2.0	9.3	3.1	6.1	0	
Moderate	100	30	--	--	--	--	1.7	1.9	10.0	7.5	5.0	1.5	
Light	100	35	--	--	--	--	1.6	1.8	15.0	13.0	7.1	27	
<u>Experimental Plots</u>													
Hardwood													
Heavy	100	66	5.6	0.0	270	00	1.4	1.8	30	3	5.0	.5	
Moderate	100	77	6.0	.5	251	30	1.4	1.8	27	9	5.3	1.1	
Light	100	89	5.7	1.0	283	45	1.4	1.7	29	13	5.1	3.1	
Control	100	100	6.3	1.0	266	60	1.5	1.5	30	25	4.6	4.5	
Conifer													
Heavy	100	50	7.1	.8	300	80	1.3	1.5	27	4	9.5	6.0	
Moderate	100	77	7.8	1.2	279	74	1.3	1.4	33	10	11.1	7.5	
Light	100	95	8.7	2.1	285	140	1.4	1.4	35	15	10.2	8.7	
Control	100	100	9.0	5.0	268	160	1.4	1.4	32	32	9.0	9.0	

number of visitor days of use the unit receives. This relationship may be the source of a management problem, since questionnaires returned by campers stated that one of their primary selection criteria was camping unit size. The larger sites were the most desirable. Thus as camping units become larger, they will also be more heavily used and this in turn will tend to promote a further increase in size. To prevent continued expansion of the camping units on Sylvania, it may be necessary to permanently delineate unit boundaries by some means which will not detract from the natural environment, such as logs or stones.

Indices of Campsite Deterioration

In previous studies of campsite deterioration, results have been limited to the establishment of equations which predict the change in some one ecological parameter. Since the changes which take place on camping units under use are the result of the interaction of many factors, it becomes desirable to establish a system by which several indicators could be used to produce a single predictive equation. This would then provide a means by which camping areas over a wide range of ecological conditions could be compared and ranked according to their level of deterioration. Equations 7 (simulated recreational use) and 19 (actual campsite use) in this study provide the tools for such a rating system.

After establishing the predictability of individual parameters as indicators of campsite deterioration at various levels of use, the actual measured changes in these parameters were utilized to establish two equations in which the dependent variable is an index of the detrimental changes in the independent variables. The lower the calculated

value of Y for a particular camping unit, the greater is the detrimental change. Camping units whose Y values approach 1.0 on the scale have shown large detrimental changes while units which have Y values near 4 have undergone only small changes.

Table 23 offers a comparison between the prediction equations that were generated in this study and the attitudes expressed by the campers for each camping unit. As can be seen from the ratings, campers are not generally aware of or concerned with the ecological factors which limit a site's durability, and their opinions are probably not based on the physical quality of a site. The equations, which used only ecological parameters in rating, gave the camping units consistently lower values than what the campers thought of the areas. For simulated use plots the values were near 1.00 and none was greater than 2.381. Using the coding system for levels of trampling on the simulated use plots where: 1.0 = heavily trampled, 2.0 = moderately trampled, 3.0 = lightly trampled, and 4.0 = controls, most established camping units were in about the same condition as the heavily trampled simulated use plots.

Therefore, equation 7 should perhaps only be used on camping units which have been recently established and receive only light use. The extensive use of measurements involving litter cover make it more useful for sites on which natural litter has been been destroyed by overuse. Equation 19 was established using data from actual camping units and may be best suited for use on established campsites where most of the litter has been worn away and measurements upon soil parameters take on increased importance.

Table 23. A rating comparison of camping unit conditions by campers and two predictive equations.

Camping Unit	Use/Site	Campers (Survey)	Rating Method ²⁾	
			Actual Use (Eq. 18)	Simulated Use (Eq. 7)
Squirrel N1	Heavy/hardwood	2.50	1.412	.689
Squirrel N2	Heavy/conifer	2.75	2.845	1.071
Squirrel N3	Heavy/conifer	2.60	1.563	.285
Badger W1	Heavy/hardwood	2.60	2.654	.768
Porcupine N1	Light/hardwood	2.80	2.292	1.516
Porcupine N2	Moderate/hardwood	3.50	-.463	.590
Chipmunk N1	Moderate/conifer	2.67	3.340	2.381
Chipmunk N2	Moderate/conifer	3.75	1.566	.623
Chipmunk N3	Light/conifer	4.00	2.331	1.737
Fisher W3	Moderate/hardwood	2.00	2.062	1.053
Mink N2	Light/conifer	3.00	1.974	1.667
Mink N3	Light/hardwood	2.50	3.721	1.855

a) values from: -.5 to +.5 = deteriorated
+.5 to 1.5 = fair
1.5 to 2.5 = good
above 2.5 = very good

In testing the equations on Sylvania camping units, conifer units averaged higher Y values than the hardwood units with which they were paired. This indicates that at the same levels of use, conifer units are deteriorating less rapidly than hardwood units. Possible reasons for this are that conifer sites are larger on the average, and use is thus spread over a larger area. Also, conifer units maintained a higher percent litter cover which may have served to cushion the site against trampling and raindrop impact. Crown cover was also less dense over the conifer camping units. This allowed more sunlight and wind movement to reach the soil surface, causing more rapid drying after rainfall. Since moist soils are more subject to compaction than drier ones, the conifer sites are exposed to less soil compaction and smaller reductions in macropore spaces.

Campsite Recovery

It appears that campsite retirement is not a satisfactory method of returning areas to natural conditions or in appreciably improving the deteriorated conditions over a relatively short period of time. Only the lightly used units at campsite Wolf showed consistent improvement in site conditions. The sugar maple reproduction which was removed when the site was established was returning. By the end of the second season after closing, all of the one meter square study plots contained at least one sugar maple seedling. Bulk density and noncapillary pore space had also returned to near-normal conditions.

The other three sites, which had received heavy use while open, had a densely compacted soil surface layer. This layer probably interferes with good seed germination and seedling establishment, and also is

a poor surface for holding litter against the erosive forces of wind and water.

The loosening action of freezing and thawing of the soil during the winter months has been proposed as a means by which sites naturally recover from soil compaction (Lull, 1959). In this area of Michigan, early snows protect the ground from repeated freezing and thawing, thus reducing the effect of this source of recovery. It will probably be necessary to undertake some type of cultural activity that both prepares a suitable seedbed, and adds the necessary plant cover. The feasibility of seeding abandoned sites with leguminous plants followed by irrigation and fertilization was reported by Beardsley and Wagar (1971) as a successful means of restoring deteriorated campsites. Irrigation alone was nearly as effective as irrigation plus fertilization in establishing and maintaining a good ground cover.

LITERATURE CITED

- Appel, A.J. 1950. Possible soil restoration on "overgrazed" recreational areas. J. For. 48:368.
- Beardsley, Wendell G. and J. Alan Wagar. 1971. Vegetation management on a forested recreation site. J. For. 69:728-731.
- Brockman, C. Frank. 1959. Recreational use of wild lands. McGraw-Hill, New York. 346pp.
- Cieslinski, Thomas J., and J. Alan Wagar. 1970. Predicting the durability of forest recreation sites in Northern Utah--preliminary results. USDA, For. Ser., Intermountain For. Exp. Sta., Res. Note INT-117. 7pp.
- Echelberger, Herbert E. 1971. Vegetative changes at Adirondack campgrounds 1964-1969. USDA, For. Ser., Northeastern For. Exp. Sta., Res. Note NE-142. 8pp.
- Frissell, Sidney S. 1964. Campsite preference and deterioration in the Quetico-Superior canoe country. M. S. Thesis, Univ. of Minn. 65pp.
- Hartesveldt, R.J. 1962. The effects of human impact upon Sequoia gigantea and its environment in Mariposa Grove, Yosemite National Park, California. Dissertation, Univ. of Mich.
- Hatchell, G.E., C.W. Ralston, and R.R. Foil. 1970. Soil disturbance in logging. J. For. 68(12):772-775.
- LaPage, Wilbur F. Some observations on campground trampling and ground cover response. 1967. USDA, For. Ser., Northeastern For. Exp. Sta., Res. Pap. NE-68. 11pp.
- Lime, David W. and George H. Stankey. 1971. Carrying capacity: maintaining outdoor recreation quality. Recreation symposium proc. USDA, For. Ser., Northeastern For. Exp. Sta. 174-185.
- Lindsay, J. 1969. Locating potential outdoor recreation areas from aerial photographs. J. For. 67:33-35.
- Lull, Howard W. 1959. Soil compaction of forest and range lands. USDA, For. Ser., Northeastern For. Exp. Sta., Misc. Pub. 768. 33pp.

- Lutz, H.J. 1945. Soil conditions on picnic grounds in public forest parks. J. For. 43:121-127.
- Magill, Arthur W. 1970. Five California campgrounds ... conditions improve after 5 years' recreational use. USDA, For. Ser., Pacific Southwest For. Exp. Sta., Res. Pap. PSW-62. 18pp.
- _____ and E.C. Nord. 1963. An evaluation of campground conditions and needs for research. USDA, For. Ser., Pacific Southwest For. Exp. Sta., Res. Note PSW-4. 8pp.
- Merriam, L.C., Kent Goeckermann, J.A. Bloemendal, and T.M. Costello. 1971. A progress report on the condition of newly established campsites in the Boundary Waters Canoe Area. Minn. For. Res. Note 232. 4pp.
- National Cooperative Soil Survey. 1958. Geogebic Series. 2pp.
- Orr, Howard K. 1960. Soil porosity and bulk density on grazed and protected Kentucky blue grass range in the Black Hills. J. Range Mgt. 13(2):80-86.
- Orr, Howard K. 1971. Design and layout of recreation facilities. Recreation symposium proc. USDA, For. Ser., Northeastern For. Exp. Sta. 23-27.
- Packer, Paul E. 1953. Effects of trampling disturbance on watershed conditions, runoff, and erosion. J. For. 51:28-31.
- Papamichos, N.T. 1966. Light, soil, and moisture conditions in areas of heavy recreation use. M. S. Thesis, Colo. State Univ. 101pp.
- Read, Ralph A. 1956. Effect of livestock concentration on surface-soil porosity within shelterbelts. USDA, For. Ser., Rocky Mountain For. & Ran. Exp. Sta. Res. Note RM-22. 4pp.
- Ripley, Thomas H. 1962. Recreation impact on southern Appalachian campgrounds and picnic sites. USDA, For. Ser., Southeastern For. Exp. Sta., Res. Pap. SE-153. 20pp.
- Sokal, Robert R. and F. James Rohlf. 1969. Biometry. W.H. Freeman, San Francisco. 776pp.
- Steinbrenner, E.C. 1951. Effect of grazing on floristic composition and soil properties of farm woodlands in southern Wisconsin. J. For. 49:906-910.
- _____. 1955. The effect of tractor logging on physical properties of some forest soils in southwestern Washington. Soil Sci. Soc. Amer. Proc. 19:372-376.
- _____. 1959. A portable air permeameter for forest soils. Soil Sci. Soc. Amer. Proc. 23(6):478-481.

- Thorud, David B. and Frissell, Sidney S., Jr. 1969. Soil rejuvenation following artificial compaction in a Minnesota oak stand. Sci. J. Ser. Pap. No. 7078. Univ. of Minn. Ag. Exp. Sta. 4pp.
- University of Michigan. 1965. Sylvania. Olsen Press. 16pp.
- U. S. Department of Commerce. 1971. Climatological survey: climate of Watersmeet, Michigan. No. 20-20. 2pp.
- U. S. Forest Service. 1968. Sylvania recreation area management plan. Ottawa National Forest. Ironwood, Mi. 48pp.
- _____. 1970. Sylvania recreation area situation in summary. Division of Infor. and Ed. Milwaukee. 5pp.
- _____. No date. Establishment report for the Sylvania research natural area within the Ottawa National Forest Gogebic County, Michigan. (preliminary draft). 11pp.
- Veatch, J.O. 1953. Soils and land of Michigan. Mich. St. Col. Press. E. Lansing. 241pp.
- Voss, Edward G. Curator, University of Michigan Herbarium. Correspondance dated Dec. 30, 1968, to M.W. Kageorge, Sup., Ottawa Nat. For.
- Wagar, J. Alan. 1964. The carrying capacity of wildlands for recreation. For. Sci. Mono. 7. Soc. Amer. For. Washington, D.C. 24pp.
- Yelenosky, George. 1964. Tolerance of trees to deficiencies of soil aeration. Proc. 40th Int. Shade Tree Conf. Houston. 127-149.

APPENDICES

Appendix A. Upland Plants of Sylvania Recreation Area As Identified

By Dr. Edward Voss, Curator, University of Michigan

Herbarium.

<i>Abies balsamea</i>	Fir
<i>Acer rubrum</i>	Red maple
<i>Acer saccharum</i>	Sugar maple
<i>Acer spicatum</i>	Mountain maple
<i>Actaea sp.</i>	Baneberry
<i>Allium tricoccum</i>	Wild leek
<i>Anemone quinquefolia</i>	Wood anemone
<i>Aralia nudicaulis</i>	Wild sarsaparilla
<i>Arisaema triphyllum</i>	Jack-in-the-pulpit
<i>Betula alleghaniensis</i>	Yellow birch
<i>Betula papyrifera</i>	White birch
<i>Carex spp.</i>	Sedge
<i>Chrysosplenium americanum</i>	Water-mat
<i>Claytonia caroliniana</i>	Northern spring-beauty
<i>Coptis groenlandica</i>	Goldthread
<i>Cornus canadensis</i>	Bunchberry
<i>Corylus cornuta</i>	Beaked hazelnut
<i>Dentaria laciniata</i>	Toothwort
<i>Dirca palustris</i>	Leatherwood
<i>Dryopteris sp.</i>	Wood fern
<i>Equisetum sylvaticum</i>	Wood horsetail
<i>Fraxinus americana</i>	White ash
<i>Galium triblorum</i>	Bedstraw
<i>Cymnocarpium dryopteris</i>	Oak fern
<i>Linnaea borealis</i>	Twinflower
<i>Lonicera canadensis</i>	Honeysuckle
<i>Lycopodium lucidulum</i>	Shining clubmoss
<i>Lycopodium obscurum</i>	Princess pine
<i>Maianthemum canadense</i>	Wild Lily-of-the-valley; Canada mayflower
<i>Mitella nuda</i>	Naked mitrewort
<i>Oryzopsis asperifolia</i>	Rice grass
<i>Osmorhiza sp.</i>	Sweet-cicely
<i>Ostrya virginiana</i>	Ironwood
<i>Oxalis montana</i>	Wood-sorrel
<i>Panax trifolius</i>	Dwarf ginseng
<i>Picea glauca</i>	White spruce
<i>Picea mariana</i>	Black spruce
<i>Pinus banksiana</i>	Jack pine
<i>Pinus resinosa</i>	Red pine
<i>Pinus strobus</i>	White pine
<i>Polygonatum pubescens</i>	Solomon-seal
<i>Populus tremuloides</i>	trembling aspen
<i>Prunus sp.</i>	Cherry
<i>Ranunculus abortivus</i>	Small-flower crowfoot
<i>Ranunculus recurvatus</i>	
<i>Ribes cynosbati</i>	Dogberry
<i>Rubus strigosus</i>	Wild red raspberry

<i>Sambucus pubens</i>	Red-berried elder
<i>Smilacina racemosa</i>	False Solomon-seal
<i>Streptopus roseus</i>	Twisted-stalk
<i>Thuja occidentalis</i>	White-cedar
<i>Tilia americana</i>	Basswood
<i>Trientalis borealis</i>	Starflower
<i>Tsuga canadensis</i>	Hemlock
<i>Uvularia grandiflora</i>	Bellwort
<i>Viola cucullata</i>	Blue marsh-violet
<i>Viola pallens</i>	Wild white violet
<i>Viola pensylvanica</i>	Yellow violet
<i>Viola selkirkii</i>	Selkirk's violet
<i>Viola Sororia</i>	Woolly blue violet

Appendix B. Comparison of climatic observations during the 1971 and 1972 study period with the 30 year average at Watersmeet, Michigan.¹

Month	Total Precipitation			Air Temperature					
	1971	1972	1940- 1969	Daily Maximum			Daily Minimum		
				1971	1972	1940- 1969	1971	1972	1940- 1969
May	11.10	7.09	9.98	15.6	18.9	18.9	2.2	6.1	2.8
June	11.05	11.53	12.98	24.4	17.2	23.9	10.6	8.9	7.8
July	12.14	16.89	9.47	22.2	20.6	26.1	8.3	11.1	10.6
August	7.47	20.98	9.52	21.7	21.7	25.0	9.4	12.2	10.0
September	6.35	13.61	9.02	17.8	16.7	19.4	6.1	6.1	6.1

¹ U. S. Department of Commerce, 1971

Appendix C. The Description of the Gogebic Soil Profile.

The Gogebic Series¹

SOIL PROFILE:

GOGEBIC FINE SANDY LOAM--FORESTED

A ₀	5-0 cm	Dark reddish brown (5YR 3/2) to black (5YR 2/1) spongy mor; very strongly to medium acid. 0 to 7.5 cm thick.
A ₁	0-1 cm	Very dark gray (5YR 3/2) to dark reddish brown (5YR 3/2) fine sandy loam; high in organic matter; weak fine granular structure; very friable; very strongly to medium acid. .5 to 5 cm thick.
A ₂	1-7.5 cm	Dark reddish gray (5YR 4/2) to pinkish gray (5YR 6/2) loamy fine sand to fine sandy loam; very weak fine crumb structure; very friable; very strongly to medium acid. 2.5 to 15 cm thick.
B ₂₁	7.5-17.5 cm	Dark reddish brown (5YR 3/2) to reddish brown (5YR 4/3) fine sandy loam (orterde); weak fine granular structure; friable; strongly to medium acid. 7.5 to 22.5 cm thick.
B ₂₂	17.5-52.5 cm	Dark reddish brown (5YR 3/4) to reddish brown (5YR 4/3) sandy loam to fine sandy loam; weak coarse granular to fine subangular blocky structure; friable; slightly cemented; strongly to medium acid. 15 to 35 cm thick.
B _{3m}	52.5-65 cm	Dark reddish gray (5YR 4/2) to brown (7.5 YR 5/2) sandy loam to fine sandy loam slightly mottled with weak red; platy structure in places; a distinct com- pact vesicular pan; strongly to medium acid. 10 to

¹National Cooperative Soil Survey, 1958.

SOIL PROFILE:

GOGEBIC FINE SANDY LOAM--FORESTED

25 cm thick.

C 65 cm - 1 m Reddish brown (2.5YR 4/4) to dark reddish brown (5YR 3/3) sandy loam to fine sandy loam glacial till, compact in place; many colored igneous and metamorphic rock and some reddish sandstone fragments; strongly to slightly acid.

Appendix D. Cover sheet of the Sylvania Camper Survey

MICHIGAN STATE UNIVERSITY EAST LANSING • MICHIGAN 48823

DEPARTMENT OF FORESTRY • TELEPHONE (517) 355-0090

Dear Camper:

Michigan State University's Department of Forestry and The National Wildlife Federation are conducting a three year study on the Sylvania Recreation Area to determine the recreational carrying capacity of the area. The object of the study is to determine what level of recreational use may be sustained on the area without permanent damage to the natural resources present. While one part of the research pertains to the resources (soil, water, and forest) of the area, a vital part will come from you, the camper. Your opinions and comments will play an important part in our estimation of the carrying capacity, and our recommendations for the future management of Sylvania. Your assistance by completing this questionnaire and placing it in one of the return boxes located at the following locations:

- a) main boat landing on Crooked Lake
- b) main boat landing on Clark Lake
- c) portage from Whitefish to 1000 Island Lake

would be greatly appreciated.

Lee M. James
Chairman

Appendix E. Questionnaire form used in the Sylvania Camper Survey

MICHIGAN STATE UNIVERSITY DEPARTMENT OF FORESTRY

1. Have you camped on the Sylvania area before? YES NO (circle one)
If yes, on which campsite (campsites) have you previously stayed?

2. On which lake did you choose to camp for your present stay on Sylvania? _____

Circle the reason (reasons) you chose this lake.

- | | |
|---------------------------------|----------------------------------|
| a) access by outboard motor | d) access by canoe only |
| b) regular Michigan fishing law | e) recommended by friends |
| c) recommended by receptionist | f) other reasons (specify) _____ |

3. Which campsite did you choose for your present stay on Sylvania? _____

Circle the reason (reasons) why you chose this campsite.

- | | |
|--------------------------------|----------------------------------|
| a) recommended by receptionist | e) close to beaches and portages |
| b) recommended by friends | f) close to boat landing |
| c) name of campsite | g) more secluded |
| d) seen on previous visit | h) others (specify) _____ |

4. Which particular tent pad did you choose upon your arrival at your selected campsite?

Left (facing lake)	Middle	Right (facing lake)
A	B	C

5. Why did you choose this particular tent pad area? Choose the 3 most important reasons shown below. Rank them from 1 to 3 with 1 being most important.

- | | | | |
|----------------------------|-------|------------------------------|-------|
| a) Others were occupied | _____ | e) More shade than others | _____ |
| b) Closest to boat landing | _____ | f) More sunlight than others | _____ |
| c) Better view of lake | _____ | g) More secluded | _____ |
| d) Larger campsite area | _____ | h) Other (specify) | _____ |

6. What would you say is the condition of this tentpad area? (circle one)

Very good	Good	Fair	Deteriorated
-----------	------	------	--------------

7. On the average day how many hours did your party spend on activities away from the campsite? (circle one)

2 4 6 8 10 12 over 12

8. Arrival Date _____ Time am pm (circle one)

Departure Date _____ Time am pm (circle one)

PLEASE PLACE COMPLETED QUESTIONNAIRE IN ONE OF THE RETURN BOXES AT THE
MAIN BOATLANDING ON CROOKED LAKE, MAIN BOATLANDING ON CLARK LAKE, OR
PORTAGE TO 1000 ISLAND LAKE.