THE IMPACT OF CAMPING ACTIVITY ON VEGETATION AND SOILS:
A CASE STUDY AT TYLER STATE PARK

A Thesis

by

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ABSTRACT

The Impact of Camping Activity on Vegetation and Soils:
A Case Study at Tyler State Park. (December 1979)
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Chairman of Advisory Committee: Dr. Clarissa Kimber

The impact of camping on vegetation and soils was examined at Tyler State Park, a forty-year old state-owned recreational facility. Camping disturbance was measured for each of four categories of park use: intensive, managed, transition, and control sites.

Of the four use categories, intensive use areas have received the most impact, the managed areas less, the transition less again and control sites least of all. Intensive areas are characterized by fewer individual plants, fewer plant species, less plant cover, and less plant litter than any other use areas. Soils in intensive areas have more organic matter, more potassium, greater soil compaction, greater bulk densities and less porosity than other use types. Although restorative measures have been recently applied to heavily-used camping units, managed sites have sustained considerable impact over the years. Transition sites, spatially located between intensive use sites or between intensive use sites and control sites, show some evidence of modifications resulting from recreational activity, also. Data from control sites, compared to those of other East Texas studies, indicate that these sites have undergone little or no human disturbance in comparison to other use categories.

Although the presence and number of pines and grasses gave no clear indication of the association with camping impact, southern red oak was established as a disturbance indicator species. The number of southern red oaks increased significantly as camping pressure decreased. Relief and aspect exert some control over the composition and spatial distribution of the vegetation, but the precise amount of influence was not established.

Two edaphic characteristics underwent modification through the camping season: pH and phosphorus. Phosphorus decline and an increase in pH were related to camping impact.

From multiple regression analyses, ten vegetation and soils variables were found to be critically affected by camping. These variables provide the elements for a descriptive model, depicting how camping activity may disturb a portion of the complex park ecosystem.

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I am indebted to Mr. Larry Lodwick, Biologist, and the Texas Parks and Wildlife Department for allowing and encouraging this study at Tyler State Park. Mr. Lodwick was gracious in providing me with pertinent information on the history, attendance, facilities, vegetation and soils of the park. I appreciated the support and cooperation I received from the superintendent and staff at Tyler State Park.

I am grateful to Dr. Robert Bednarz and Dr. Larry Meyers for the time and effort they expended in special aspects of my research. Dr. Bednarz collaborated with me on the statistical design of my data, and Dr. Meyers allowed me the use of his lab for the cation exchange capacity experiment and analyzed my samples.

So much of the credit for this work goes to my parents. I express my love and heartfelt thanks for their unselfish love, generosity, financial and moral support of my endeavors.

A special "thank you" goes to Susan, my dear friend in Tyler, for extending her home and hospitality to me during those hectic months of field work. I treasure the friendships that have developed through the course of this research.

I deeply appreciate Ken, my brother, who volunteered numerous weekends to assist me in the field. Others who assisted me in the field were Al, Mike, Susan and Pete.

Special thanks are given to Mit Looney, who gave me permission to use his laboratory to prepare soil samples for analysis and to Chris Coughran who advised me on the graphics. Sandy Jobes typed the manuscript.

Finally, I thank my Lord that through this research I have developed a deeper appreciation of the beauty and intricacy of His creation and a greater awareness of my responsibility to manage it wisely.

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INTRODUCTION

Parks at the local, state and national level have shown an substantial increase in visitor use over the years. Recreational use of public lands has more than tripled since World War II (Clawson, 1959). In Texas, the attendance at state parks has risen from ten million in 1971 (McGlathery, 1977) to over 16 million in 1978, an increase of 50%.* Although new state parks have been established during this period, usage figures indicate that additional recreational areas have not alleviated the pressure on older parks. McGlathery (1977) estimates that in 1980, 21 million people will enter Texas state parks and historical sites.

The increased pressure from visitor use on recreational areas is due to a number of factors. The population of the United States has continued to rise steadily. People have an increasing amount of leisure time as a result of the shorter work week and longer vacation periods. Increasing mobility allows travel to more destinations more frequently than every before. However, future energy shortages and increased fuel costs may curtail this freedom considerably. Generally, larger incomes give increased buying power, permitting more people to invest in recreational equipment and to allot more money for travel to recreational areas.

These factors apply to Texas and Texans as well. However, the

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The format and style of this thesis follows that of the Journal of Biogeography.

*Personal communication, Mr. Larry Lodwick 1979.

rise in Texas' population over the past ten years or so is in part due to the large number of immigrants from northern states. Better job opportunities, lower cost of living and a warmer winter climate have attracted many northerners to this state, thus exacerbating the pressure.

With increasing visitor pressures on park facilities, the quality of the landscape has often declined. Evidence of deterioration can be seen in both the vegetative and edaphic components of the environment. In forest recreation areas, the shrub layer and ground cover are often reduced drastically or eliminated from areas of intense use such as in picnic sites and campgrounds (Packer, 1953; Solan, 1976). Intense recreational use also affects runoff and erosion by decreasing permeability, increasing bulk density and decreasing organic matter. (Lutz, 1945; LaPage, 1962; Magill, 1963). Vegetation and soils are interrelated. This interrelationship is, however, only a portion of the entire set of interactions within a park ecosystem. It follows, therefore, that camping activities will and do impact not only the vegetation and soils but other components of the system as well if only indirectly.

Because of past negative influences on recreational landscapes, managers are becoming increasingly aware of "recreational carrying capacity," that is, the level of use an area can support and still maintain quality (Wagar, 1964). If use exceeds the carrying capacity, impairment will occur; and management policies must be devised to counteract deterioration. Frequently, restoration or maintainance cannot compensate for past abuse or mismanagement, and manipulative activities must be continuous in order to keep deterioration from accellerating.

A large number of recreational impact studies have been made for the West and North, but thus far, only a few such investigations have been completed in Texas, and no management studies have been initiated to examine the effectiveness of existing maintenance practices in Texas parks. Dunham (1975) examined national forest campgrounds in East Texas and distinguished plant communities based on disturbance in two campgrounds. No research has been undertaken to assess the impact of camping pressure on Texas soils by levels of use or changes through time, but two experimental studies have been completed. Holers (1970) tested the effects of simulated trampling on soil compaction and runoff, and Farnham (1976) applied various management techniques at campsites to determine their effectiveness in alleviating soil compaction.

This research was designed to assess the impact of recreational use at Tyler State Park. This research had three objectives: 1) to determine the nature and extent of camping impact by use categories on selected vegetation and soil characteristics, 2) to determine if some soil characteristics are modified through one camping season, and 3) to determine how effective ameliorating practices have been in the partial restoration of impacted areas.

During this investigation, several ideas were examined. These may be stated as informal hypotheses concerning camping impact on vegetation and soils:

1) Vegetation and soil characteristics within an area clearly

exhibit a gradient of use intensity. Intensive use sites sustain the most use followed by managed, transition and control sites.

2) Of the four use categories--intensive, managed, transition and control--intensive use areas display characteristics most indicative of camping disturbance such as few individual plants, few species, less crown cover, less litter, greater soil compaction, higher bulk densities, less porosity, less nutrients and less organic matter than other use areas.
3) Ameliorating practices in managed sites reduce impact.
4) Transition sites, located between intensive use and control areas are modified by camping but to a lesser extent than either intensive or managed areas.
5) Control areas have received little or no human disturbance by campers, and appear to be in biological and environmental balance.
6) The presence and number of pines, grasses and southern red oaks* are clear evidences of disturbance.
7) Relief and aspect exert some control on vegetation composition and spatial distribution.
8) The measured values of soil characteristics change through the camping season as a result of camping impact and interaction with the five soil-forming factors: climate, time,

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*The scientific names of individual species will be introduced in the discussion of vegetation in the park. The scientific names of all plants mentioned in the study are listed in Appendix A.

relief, parent material, and biological activity. Soil compaction, bulk density, nutrient content and pH increase but organic matter and porosity decline through the season.

Testing of these hypotheses should yield results that will extend knowledge of the nature and extent of recreational impact on vegetation and soils. The results should assist managers in seeking the best practical solutions and programs in maintaining quality in recreational landscapes.

LITERATURE REVIEW

A great deal has been written on the biotic and abiotic response to recreational pressure in a variety of environments. This literature review will be limited largely to those papers and studies specifically related to the impact of campers on established campground vegetation and soils in forested environments.

Recreational use at campsites is usually concentrated in a small area near the center of activity such as the tentpad or picnic table. Intensive use tends to decrease in a radial pattern from the center, leaving areas between sites and away from camping areas relatively undisturbed (Ripley, 1962b). Most recently, however, Celentino's study (1978) at Whiteshell Provincial Park in Manitoba revealed that areas peripheral to campgrounds also undergo some disturbance. She discovered that use was spreading to these surrounding areas as indicated by a decrease in the number of plant species.

Scientists concerned with the impact camping activity has on vegetation have made some important discoveries. Heavily used areas are characterized by a reduction in the number of tree species (Magill, 1963; Dunham, 1975). Magill found in three California national forests that five of eight tree species were more numerous on unused sites than on intensively used areas. Dunham (1975) studied East Texas campgrounds and discovered that 50% fewer trees occur on disturbed sites than undisturbed sites. Based on the study of a tree species' ability to withstand impact measured by decline, insect infestation and disease, Ripley (1962a) found that several species are more sensitive to recreational impact than others. These are red oak, magnolia and black cherry.

The understory can also be adversely affected by trampling, giving rise to damaged or reduced numbers of plant species, and often giving a competitive advantage to trampling-tolerant species if the disturbance is not too severe. Research by Frissell and Duncan (1965) at Quentico-Superior canoe campsites in Minnesota and Ontario showed that there was no tree reproduction on heavily used sites, and most saplings were either cut or damaged. Foin and his associates (1977) at Yosemite National Park noted a considerable loss of the understory, and Magill (1963) found a reduction in the number of shrubs from 1,250 to 467 per acre in campsites.

The ground cover is probably the vegetation layer most directly affected by camping activities. An examination of ground cover species at Riding Mountain National Park in Canada showed that over one third of the species were exotics (de Vos and Bailey, 1970). Two studies, one by Young (1978) and the other by LaPage (1967), support the claim that monocots are more resistant to camping impact and thus have better rates of survival than dicots.

The amount of plant litter is a useful measure of impact. Frissell and Duncan (1965) noted a 65% decrease in litter at heavy use sites compared with control sites, while Young (1978) found a range of litter cover on control sites to heavy use sites of 98% ground cover to 27% ground cover.

Magill (1970) and Echelberger (1971) present evidence against the deteriorating trend other scientists have documented in camping facilities. Both discovered general improvements in the vegetation conditions, suggesting that after initial disturbance, the vegetation will adjust to recreational use because of wise management practices or improved environmental conditions.

Other scientists have focused their research primarily on recreational pressure as it affects soil characteristics and how edaphic conditions may influence the vegetation response. One of the earlier studies was done by Papamichos (1966) at Rocky Mountain National Park. He found that soils in heavily used camping areas have greater bulk densities, higher pH and increased compaction but less organic matter and lower moisture content than the soils in lightly used areas. He concluded that medium textured, well drained, fertile soils are more tolerant of impact. In 1973 Ward and Berg conducted a study at Waterloo Recreational Area designed to determine the spatial extent of impact by measuring soil compaction and showed that compaction is definitely greater in camping sites as opposed to the surrounding areas.

In addition to those factors associated with heavy use such as increased compaction and higher soil pH, Young and Gilmore (1976) discovered that intensively used areas also have soils with greater amounts of nutrients: calcium, potassium, sodium and phosphorus. Contrary to results in Papamichos study (1966), more organic matter was found in intensively used areas than control areas.

At the Sylvania Recreation Area in the Ottawa National Forest, Legg and Schneider (1977) studied the changes in soil characteristics over two consecutive camping seasons. In both seasons the depth to the A2 horizon and macropore space decreased. During the winter porosity increased somewhat, but the rejuvenation was less than the deterioration noted in the summer. The off season may not provide enough time for campgrounds to recover from a season of intensive use.

In recent years, several researchers have conducted in-depth studies on the impact of both vegetation and soils in recreation facilities. Solan studied three established campgrounds in Pennsylvania (1976). There, ground cover decreased from control areas to concentrated use areas, and species composition changed. No differences were found in tree heights or diameters. Soils in heavily used areas had greater bulk densities and compaction, lower cation exchange capacities and less available phosphorus. There was no significant difference in pH and available potassium in campgrounds versus control areas.

In a detailed study of campgrounds in northeast Iowa, Dawson, Countryman and Fittin (1978) found considerable differences between measured parameters for campsites and adjacent control areas. The shrub layer was eliminated, and plant species were fewer in intensive sites. Bulk density and pH were higher for the campgrounds, but macropore space was less.

STUDY AREA

Tyler State Park is a 993-acre state-owned park located eight miles north of Tyler, Texas in Smith County (Fig. 1). It was purchased by the State of Texas in 1934-1935 and was developed into a park by the Civilian Conservation Corps. Prior to 1934, the land was privately owned. It is a particularly popular park, attracting 303,698 day visitors and 80,810 overnight guests in 1978.

Camping facilities in the park (tent, trailer, and shelter areas) number 185 sites which are located in close proximity to a 64-acre lake at the center of the park (Fig. 2). The four exclusive tent-camping units--Dogwood, Red Oak, Hickory Hollow, and Sumac Bend--are approximately ten years old and have not been subjected to any rigorous maintenance programs or restorative practices since their construction (Fig. 3). Multi-use areas (tent and trailer camping) are designated at Lakeview, the oldest area in the park, dating back to the purchase of the park (Fig. 4), and at Cedar Point, a relatively new area constructed in 1975-1976. The one unit exclusively for trailers is Big Pine, built in 1969. These last three areas have been subjected to numerous maintenance and restorative measures. Twenty-eight closed-in shelters, built ten years ago, are close to the lake. The shelter area farther away from the lake has seven cabins, including a group shelter than can accommodate up to 100 people. An overflow camping unit and a group trailer unit are among the camping facilities at Tyler, but have not been considered in this study since they are not subject to regular, sustained use and are not considered to be the primary camping areas.

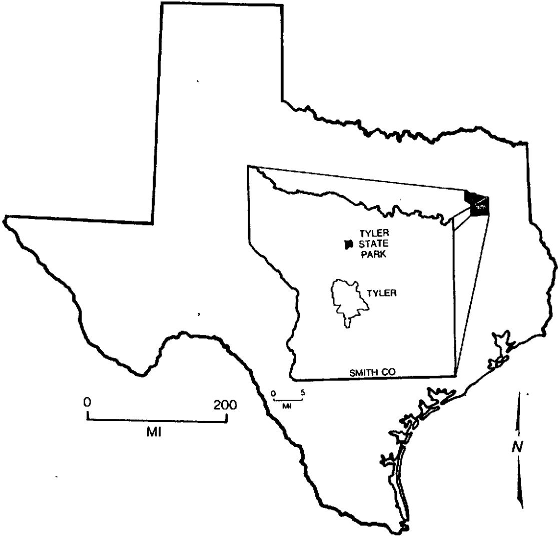


Fig. 1. Location of Tyler State Park in Texas.

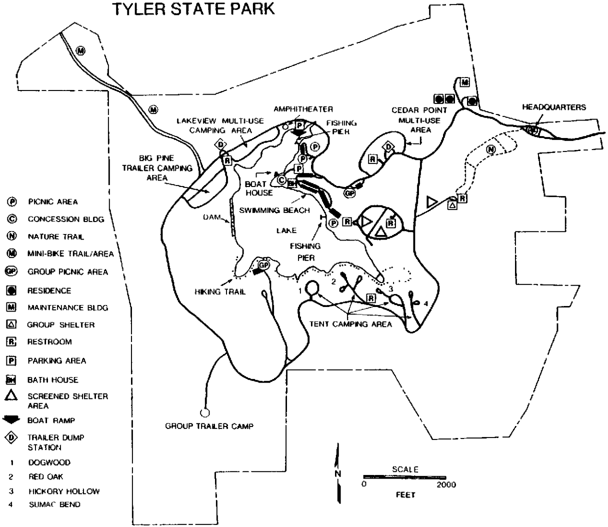
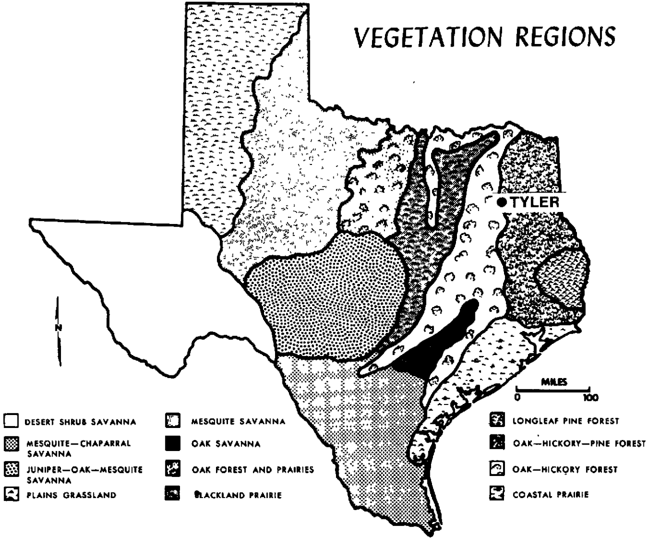


Fig. 2. Map of Tyler State Park

Fig. 3. Tent-camping site, Tyler State Park

Fig. 4. Multi-use sites, Lakeview unit.



SOURCE: Adapted from BENJAMIN C THARP, in Texas Looks Ahead. The Resources of Texas, 1944, W. T CHAMBERS, Texas—It's Land and People, 1952; A W KUCHLER, Potential Natural Vegetation of the Conterminous United States, 1965, and Texas Almanac, 1966

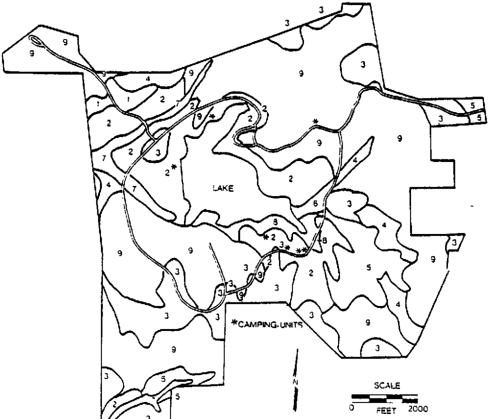
Fig. 5. Location of Tyler State Park in terms of vegetation regions of the state

Tyler is located in the oak-hickory-pine forest region of the state (Arbingast, et al., 1972) (Fig. 5). The vegetation structure is generally the same throughout the park, a mixed forest of pine and hardwoods. However, hardwood trees tend to dominate the overstory in bottomland regions, whereas a more even mix of pine and hardwoods is found on the mid to upper slopes.

Nine soil series occur in Tyler State Park: Bowie, Cuthbert, Darco, Elrose, Fuquay, Hannahatchee, Iuka, Kirvin and Nacogdoches series (Fig. 6). All of the series except Elrose, Hannahatchee and Iuka are Udults and are characterized by a freely drained, sandy, ochric epipedon with low humus content. Elrose, Hannahatchee and Iuka belong to the Udalf, Ochrept and Fluvent suborders respectively. All camping sites are located on Cuthbert soils except for Cedar Point and the group of seven shelters, which are on Nacogdoches soils.

The park is in an area of primarily humid subtropical climate with hot summers (United State Department of Commerce, 1973). The average daily maximum temperature for August is 93.8°F. Thirty-year means are given in Table 1. Winter temperatures are mild, and on the average only two days per year have daily maximum temperatures below freezing. Thus, frost heaving of soils is not a factor in this region. The winter season is characterized by occasional cold fronts of short duration in which temperatures drop following frontal passage, but a warming trend usually takes place within a few days. January is the coldest month with an average maximum temperature of 55.8°F and average minimum of 34.6°F.

Prevailing winds are from the south-southeast. The Gulf of



LEGEND

1	*BOWIE SERIES*	- FINE-LOAMY, SILICEOUS, THERMIC PLINTHIC PALEUDULT
2	*CUTHBERT SERIES*	- CLAYEY, MIXED, THERMIC TYPIC HAPLUDULT
3	*DARCO SERIES*	- LOAMY SILICEOUS, THERMIC GROSSARENIC PALEUDULT
4	*ELROSE SERIES*	- FINE-LOAMY SILICEOUS, THERMIC TYPIC PALEUDALF
5	*FUQUAY SERIES*	- LOAMY, SILICEOUS, THERMIC ARENIC PLINTHIC PALEUDULT
6	*HANNAHATCHEE SERIES*	- FINE-LOAMY, MIXED THERMIC DYSTRIC FLUVENTIC EUTROCHREPT
7	*IUKA SERIES*	- COARSE-LOAMY SILICEOUS ACID, THERMIC AQUIC UDIFLUVENT
8	*KIRVIN SERIES*	- CLAYEY, MIXED, THERMIC TYPIC HAPLUDULT
9	*NACOGDOCHES SERIES*	- CLAYEY, KAOLINITIC, THERMIC RHODIC PALEUDULT

Source: USDA Soil Conservation Service, 1968 (unpublished)

Fig. 6. Soils map of Tyler State Park

Table 1. Temperature and precipitation, thirty-year means for Tyler, Texas from 1943 to 1972.

Month	Temperature Daily Maximum (°F)	Daily Minimum (°F)	Monthly Mean (°F)	Precipitation Mean (in.)	Snow, Ice Pellets Mean (in.)
January	55.8	34.6	45.2	3.14	1.2
February	60.0	38.2	49.1	3.49	0.4
March	66.8	44.1	55.5	3.66	0.1
April	76.3	54.3	65.3	5.09	---
May	82.9	61.4	72.2	5.48	---
June	89.6	68.6	79.1	2.93	---
July	93.5	71.5	82.5	2.57	---
August	93.8	70.7	82.2	2.48	---
September	87.5	65.0	76.2	3.32	---
October	78.8	54.4	66.6	3.36	---
November	66.9	43.6	55.3	3.72	---
December	58.6	37.2	47.9	4.08	0.2
Year	75.9	53.6	64.8	43.32	1.9

U.S. Department of Commerce (1973)

Mexico plays a dominant role in determining the weather patterns for the region.

Precipitation is evenly distributed throughout the year. Rainfall averages 43.32 inches annually. Snowfall is about two inches per year, however, this accumulation is erratic. For example, four to five inches may fall in one year which may be followed by several years of no measurable snowfall.

The climatic data for Tyler, Texas in 1977 and 1978 is given in Table 2. The 1978 temperature and precipitation means deviate somewhat from the averages. Tyler experienced that year, as did the majority of the U.S., an unusually cold winter and above normal snowfall. Total precipitation, however, was well below the thirty-year mean. Six months--February, April, May, June, September and October--had precipitation totals below their respective thirty-year means.

Table 2. Climatic data for Tyler, Texas in 1977 and 1978.

	1977					1978				
	Temperature (^{o}F)			Precipitation (in)		Temperature (^{o}F)			Precipitation (in)	
Month	Avg. Max.	Avg. Min.	Avg.	Total	Total Sleet/Snow	Avg. Max.	Avg. Min.	Avg.	Total	Total Sleet/Snow
January	46.3	23.2	34.8	3.08	5.8	43.0	24.2	33.6	4.31	3.9
February	63.0	34.7	48.9	4.98	---	48.0	28.0	38.0	3.10	4.3
March	70.1	44.6	57.4	6.99	---	66.1	39.2	52.7	4.08	0.4
April	77.3	51.9	64.6	5.48	---	78.4	52.9	65.7	1.91	---
May	84.8	61.7	73.3	0.99	---	83.6	59.2	71.4	4.02	---
June	91.3	68.1	79.7	3.46	---	92.4	66.1	79.3	1.16	---
July	97.1	70.5	83.8	0.72	---	98.4	70.5	84.5	3.16	---
August	93.5	70.2	81.9	4.04	---	94.4	68.8	81.6	2.74	---
September	90.7	67.2	79.0	0.65	---	87.1	66.0	76.6	2.18	---
October	80.9	51.4	66.2	0.90	---	81.0	49.1	65.1	1.51	---
November	68.0	46.1	57.1	4.79	---	68.3	45.8	57.1	7.22	---
December	59.3	32.9	46.1	1.42	---	56.8	32.2	44.5	2.60	0.1

N.O.A.A. (1977, 1978)

METHODOLOGY

Intensive field research was conducted in Tyler State Park. Vegetation data were gathered from the onset of the camping season when visitor use began to rise until the season was virtually over, i.e., April to November, 1978. Soils data were collected at the mid and latter months of the camping season.

Three levels of use intensity were identified in order to gather data to distinguish degrees of impact: intensive use, light use and no use. Areas of heavy or intensive use are those areas chosen in or near the center of camping activity, i.e., the picnic table, tentpad, campfire pit, barbeque grill, or shelter (Fig. 7). Intensive use sites were subdivided into two types, those sites having been subjected to management programs and those without restoration. Light use areas are those areas between intensively used sites where disturbance is less than in those areas. They are also located between intensive use sites and control sites. These lightly used sites are called transition sites in this study. No use areas are those where little or no human disturbance is evident and are called control sites. Thus, four use types were studied: intensive, managed, transition and control sites.

Plot Selection

Data were systematically collected from a set of nested quadrats corresponding to the size growth forms to be sampled. Quadrat sizes for the tree layer were 10x10 m, for the woody understory 4x4 m, and for the herbaceous layer 1x1 m (Oosting, 1956). These are commonly

Fig. 7. View of shelter area.

used sizes for measuring quantitative vegetation parameters (Dombois and Ellenberg, 1974).

To maintain objectivity, ramdom sampling was required. The park was color-coded by use categories using Texas Parks and Wildlife Department blue line topographic maps at a scale of 1:1200. A grid of equal-cell sizes corresponding to the size of the tree quadrats was overlain on the maps. With the assistance of a random numbers table, 50 cells in each use category were selected for a total of 200 sampling plots.

Vegetation Methodology

Once the set of plots was chosen, each site was visited and subdivided by quadrat size for vegetation sampling. Within the 10x10 m tree plot, a shrub quadrat (4x4 m) was randomly chosen in one of the four tree quadrat corners by drawing a number corresponding to one of the four corners. Within the shrub quadrat, a herb quadrat (1x1 m) was selected in one of the four shrub quadrat corners in the same manner. Litter depth and soils data were randomly collected in the tree quadrat at points located by dropping a marker over the shoulder.

Stratification of the vegetation made it necessary to set height limits for each growth form. Thus, the tree layer was defined as any plant taller than five meters, the shrub layer boundaries were between one and five meters, and anything less than one meter was considered a component of the herb layer (Dombois and Ellenberg, 1974).

Within corresponding quadrats of a sample plot, the individual plants and species were counted and recorded. For those species that could not be recognized in the field, specimens were collected, identified and verified later in the Texas A&M Tracey Herbarium. Voucher specimens will be housed there permanently.

Heights of trees and shrubs were classified by a scheme developed by Cain and Castro (1959) and modified for this study. The woody vegetation was stratified into a total of five classes: 1) low shrubs were up to three meters tall; 2) high shrubs were three to five meters tall; 3) low trees were five to seven meters tall; 4) intermediate trees were seven to 15 meters tall; and 5) tall tree strata were 15 meters and above.

Plant cover was calculated by estimating the foliar canopy in percent of total area within each plot. Four measurements were taken, one from each corner, in each plot, and these figures were averaged to give the plant cover value for that species. All species in all plots were given cover estimates.

Plant litter depth was randomly sampled and measured in each plot. Three depth measurements for each plot were taken and averaged. Tree diameters were calculated from tree circumference measurements taken at breast height for each individual tree.

Dominance, like cover, is a measure of the prominence a species or species have in a given area in terms of bulk. The tree diameter readings are converted to basal area using the equation:

$$BA = (\tfrac{1}{2}d)^2\pi \quad .$$

where "BA" is basal area and "d" is diameter. This information can then be submitted in the total dominance equation:

Total dominance = number of plots/hectare X number of square meters of basal area/plot.

Whereas plant cover gives the dominance of species and growth form using foliage, basal area gives the importance of stem bases (Smeins and Slack, 1977).

Percent pine, percent grass and the number of red oaks were taken from species counts in the quadrats. It was thought that variations in these parameters would lend support to the other findings on indicator plants of impact.

Topographic influences such as the degree and aspect of slope in the plot and the plot position on the slope, were interpolated from the topographic maps of the park. The categorization of the slope position follows Ripley's usage in his camping study (1962b). The five position categories and their code values are: 1) ridge, 0.0; 2) upper one-third slope, 0.25; 3) middle one-third slope, 0.50; 4) lower one-third slope, 0.75; and 5) bottom, 1.00. These ascending values correspond to increasing site potential for camping. The plot's dominant orientation direction was assigned a value based on Doolittle's findings (1957) transformed to a sine curve: 1) north, 1.7; 2) northeast, 2.0; 3) east, 1.7; 4) southeast, 1.0; 5) south, 0.3; 6) southwest, 0.0; 7) west, 0.3; and 8) northwest, 1.0.

Field notes were taken on species vitality and any noticeable evidence of plant damage inflicted by campers. Because poor growth may be the result of camping disturbance, plant appearance such as premature yellowing leaves and leaf drop were recorded. Obvious signs of camper-inflicted harm to plants such as signs of hacking in tree bark, uprooted plants or broken stems were also written in the field notebook.

Soil Methodology

Soil samples and other edaphic measurements were taken in the sampling sites. Three soil samples were extracted and stored for each soil series in each use category at both the surface and subsurface levels during the months of June-July and September-October, 1978 for a total of 174 samples. The two sampling periods were needed to compare results of camping on the parameter values.

Field data gathering included testing for compaction and taking soil samples. A pocket penetrometer was used to measure compaction in kilograms per centimeter squared. Three measurements were averaged for each of three sampling sites within the quadrat.

Soil samples were extracted and stored in airtight plastic bags for further testing. The volume of the hole left by the removal of soil was measured with the Soiltest Volumeasure. The dry weight of the sample was used together with the Volumeasure to compute bulk density in gm/cm^3. From the value, porosity was calculated by this formula:

$$\% \text{ pore space} = 100 - \frac{\text{bulk density}}{\text{particle density}} \times 100$$

A constant of 2.65 gm/cm^3 was used as the particle density for each calculation of porosity.*

Numerous laboratory tests were performed on the extracted surface and subsurface samples. Soil moisture was determined by

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*Personal communication, Dr. Murray Milford, 1976.

calculating the percent moisture by weight in each sample. Organic matter content, pH and available calcium, magnesium, nitrogen, phosphorus and potassium contents were obtained for all samples from the results of tests runs by the Texas A&M Soil Testing Laboratory. Particle size analysis was determined by the pipette method (Day, 1965).

Cation exchange capacity is the ability of a soil to absorb cations, expressed in milliequivalents of charge per 100 gm of soil. The procedure for getting this value involved saturating a soil sample with calcium followed by replacement with magnesium using the chloride salts of both elements (Meyers, 1978). The concentration of replaced Ca^{++} in the filtrate was determined using atomic absorption spectroscopy.

Notes were taken in the field concerning soil conditions such as the amount (in percent) of bare soil in the sampling plots. The presence of any exposed tree roots or evidence of sheet, rill or gully erosion were recorded.

Methods of Analysis

Statistical Package for Social Sciences (SPSS) computer programs were utilized in the analysis of vegetation and soils data. The Condescriptive subprogram was used which gives the means, standard error, standard deviation, variance, kurtosis, skewness, range, minimum value, maximum value and sum of values for all data by use categories. Pearson correlation, scatter diagrams, analysis of variance (ANOVA) and multiple linear regressions subprograms were run, also.

Analyses of variance were run on vegetation and soil variables to determine if the means for each variable are significantly different by use type, indicating that camping disturbance may be the underlying cause. Soil variables were also analyzed to see if any variation in means is related to the date of collection.

Pearson correlation tests every variable against every other to see if positive or negative linear relationships exist; and, if so, the strength and significance of those associations. Scatter diagrams were computed to pictorially display these correlations.

Multiple linear regressions were performed for both soil and vegetation variables to see which variables most strongly distinguish use categories, and which variables can be used to predict further camping impact. Although park use categories are considered independent variables, use was assigned as the dependent variable with vegetation and soils measures as the independent variables in order to perform the SPSS subprogram, Regression.

THE IMPACT PRODUCED BY CAMPING ON TYLER STATE PARK VEGETATION

In the 200 sites examined at Tyler State Park, a total of 140 species representing 49 families were identified. The largest number of species come from the Gramineae followed by Leguminosae and Compositae. A list of the park flora appears in Appendix A. All plants were identified to the species level except for several members of the Cyperaceae which could be classified only to the genus, i.e., Carex.

The overstory of the vegetation consists of a mixture of pine and hardwoods.* Those species most representative of the upper canopy are shortleaf pine (Pinus echinata), loblolly pine (Pinus taeda), mockernut hickory (Carya tomentosa), post oak (Quercus stellata), winged elm (Ulmus alata) and sweet gum (Liquidambar styraciflua) trees. Southern red oaks (Quercus falcata) are less common.

The understory or shrub layer consists of tree saplings, true shrubs, and woody vines. Those shrubs most prevalent to the park are southern wax myrtle (Myrica cerifera), sugar hackberry (Celtis laevigata), sumac species (Rhus spp.), flowering dogwood (Cornus florida), black-haw species (Viburnum spp.), and American beauty berry (Callicarpa americana). Japanese honeysuckle (Lonicera japonica), greenbriar (Smilax spp.), and poison ivy (Rhus toxicodendron) represent the majority of climbing species in the park. The last two species occur primarily in scattered patches or clumps. Japanese honeysuckle,

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*Plant community classification was not the objective of this study. Description of the communities are thus very informal. The analysis of impact is made predicated on the assumption that communities are assemblages of individuals with similar tolerances and habitat requirements.

which was introduced apparently accidently some years ago, has spread over extensive areas of the park along ravines and creek beds.

A heterogeneous mixture of tree seedlings, juvenile shrub species, grasses and other herbaceous plants comprise the naturally-occurring growth forms in the ground cover. The only exceptions are the pure stands of annual ryegrass (Lolium perenne) in the Lakeview (Fig. 8) and Cedar Point camping units, and the scattered carpets of common bermuda grass (Cynodon dactylon) in the Big Pine trailer unit.

The popularity of Tyler State Park is evident from 1978 visitation figures (Table 3). Over the course of the year, the attendance values fluctuate considerably. The monthly figures show that the peak of the camping season occurs during June and July for both overnight and day users, and that spring visitation is greater than fall visitation.

Given the large influx of people to Tyler State Park over the course of a year, impact on the vegetative and soils components of the environment is inevitable. Results from the hypotheses tested should disclose important information on the nature and extent of impact caused by camping activity.

As expected, values for vegetation parameters were sharply differentiated along a gradient of park use from heavy to none. Table 4 summarizes the means and standard deviations for all vegetation variables by use categories. One-way analysis of variance was used to determine if, indeed, these vegetation means were unequal when tested against park use categories. Results of ANOVA appear in Table 5.

Fig. 8. Lakeview unit showing area covered by annual ryegrass.

Table 3. Tyler State Park visitation figures for 1978.

Month	Overnight Attendance	Day Attendance
January	435	7,203
February	694	9.543
March	6,603	38,394
April	8,185	28,518
May	8,588	45,152
June	13,634	53,604
July	11,701	40,561
August	9,815	28,471
September	7,391	18,221
October	7,451	18,287
November	5,286	9,131
December	1,027	6,613
TOTAL	80,810	303,698

(Personal communication, Texas Parks and Wildlife Department, 1978)

Table 4 Means and standard deviations for vegetation variables classified by park use categories.

Variable	Intensive Sites		Managed Sites		Transition Sites		Control Sites	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D
No. of Individual Trees	5.24	3.58	4.82	3.75	5.56	3.48	7.76	3.42
No. of Individual Shrubs	1.56	3.52	6.98	9.90	12.34	11.75	16.10	11.43
No. of Individual Herbs	2.92	6.63	45.30	41.35	24.68	32.19	15.32	18.35
Total No. of Individuals	9.74	8.71	57.10	37.04	42.64	34.90	39.14	21.30
No. of Tree Species	2.40	1.54	2.36	1.59	2.94	1.62	3.64	1.45
No. of Shrub Species	0.54	1.18	1.92	2.42	3.78	3.03	4.70	2.11
No. of Herb Species	0.70	1.15	2.52	1.90	3.08	2.30	3.02	2.01
Total No. of Species	3.64	2.82	6.80	4.03	9.78	4.45	11.36	3.72
Tree Height	2.28	0.78	2.04	0.83	2.14	0.78	2.00	0.57
Shrub Height	0.32	0.59	0.52	0.58	0.98	0.47	1.00	0.00
Tree Cover (%)	83.20	33.35	53.70	30.59	90.60	40.83	79.00	24.22
Shrub Cover (%)	9.50	19.90	24.70	31.95	50.50	43.63	76.10	32.82
Herb Cover (%)	7.30	14.65	45.00	29.01	44.20	32.69	34.70	24.27
Total Cover (%)	100.00	49.83	123.40	51.52	185.80	77.49	189.80	44.50
Litter Depth (cm.)	0.70	0.82	0.77	0.17	2.19	1.53	3.56	1.69
Tree Diameter (cm)	22.38	9.22	21.87	13.68	20.61	8.17	18.55	6.78
Total Dominance	24.63	16.30	21.12	14.31	22.16	13.28	26.32	15.30
Percent Pine	43.08	41.58	27.19	39.37	38.38	36.47	27.67	31.13
Percent Grass	21.84	39.63	54.61	41.71	28.39	36.32	18.84	29.47
No. of Red Oaks	0.18	0.52	0.26	0.72	0.74	1.23	0.76	1.71
Percent Slope	11.37	6.30	8.13	3.61	13.24	5.19	14.95	10.01
Slope Position	0.54	0.18	0.47	0.24	0.45	0.24	0.53	0.22
Aspect	0.61	0.65	0.75	0.66	0.94	0.70	0.82	0.67

Table 5. One-way analysis of variance tests on vegetation variables by park use categories.

Dependent Variable	Percent Variance Explained	Percent Significance for F
Litter Depth (cm.)	42.9	0.99
Total No. of Species	37.2	0.99
Shrub Cover (%)	36.5	0.99
No. of Shrub Species	32.8	0.99
Total Cover (%)	31.0	0.99
Shrub Height	27.1	0.99
Total No. of Individuals	26.8	0.99
Herb Cover (%)	24.8	0.99
No. of Individual Shrubs	23.4	0.99
No. of Individual Herbs	22.7	0.99
No. of Herb Species	19.9	0.99
Tree Cover (%)	14.1	0.99
Percent Grass	11.5	0.99
Percent Slope	11.4	0.99
No. of Tree Species	8.9	0.99
No. of Individual Trees	8.0	0.99
No. of Red Oaks	3.8	0.99
Percent Pine	1.8	0.92
Aspect	1.8	0.90
Tree Diameter (cm.)	0.8	0.79
Total Dominance	0.4	0.71
Tree Height	0.1	0.75
Slope Position	0.0	0.89

With the exception of percent pine, aspect,tree diameter, total dominance, tree height and slope position, the findings indicate that all the vegetation variables are highly significant by use type at the 99% significance level. The variables that most strongly explain the variance in use types are litter, total number of species, shrub cover, number of individual shrubs, and total cover. These findings are similar to the findings in other camping studies in which researchers found significant differences in vegetation variables by use types. For instance, Young (1978) noted a decrease in individual plant species, shrub numbers and litter with increased use. Solan (1976) found a substantial difference in cover between control sites and concentrated use areas. Dykema (1971) and Dawson, Countryman and Fittin (1978) noted an absence of a shrub layer in camping areas. Thus, these studies lend significant support to previous findings.

The lack of interaction among tree heights, tree diameters, and total dominance by use types has been confirmed in other campground research, particularly by Solan (1976) and Young (1978). Solan noted no relationship among tree height, tree diameters and use types. In addition, Young (1978) found no difference in basal area between heavy use areas and control sites. This measurement is the primary one in computing dominance. Thus, findings in this research coincide with those of Young.

When the use categories are analyzed individually, the amount of impact on each use type becomes apparent. Intensive use areas were expected to display the most impact followed by managed, transition and control sites. Pearson correlation tests between vegetation variables and use categories show strong significant linear correlations between the vegetation values and the above sequence of use categories (Table 6). The only variables that were not significant by this sequence of use were number of individual herbs, tree height, tree cover, total dominance, percent pine, percent grass and slope position.

The sharpest contrast in use categories occurs between the intensive and control sites. For instance, note the precipitous rise in means for the number of shrubs, total numbers of species, shrub cover and litter depth from areas of concentrated use to control sites (Table 4, p. 33). These findings parallel results from other campground studies (Magill and Nord, 1963; Solan, 1976; Dawson, Countryman, and Fittin, 1978; Young, 1978) implying that campers greatly modify the natural landscape by inhibiting the natural processes that take place in the forested environment.

Pearson correlation subprogram which was also used to determine the existence and strength of relationships between any two vegetation variables adds further information on the nature and extent of camping disturbance in the four use types. Discussion of correlations will be limited to only those significant at the 95 or 99% significance level.

The composition and morphology of the upper canopy or tree layer in intensive sites is closely linked with the shrub layer or understory. Positive correlations exist between many of the tree and shrub variables (Table 7). The strongest relationships and corresponding correlation coefficients are: tree cover and shrub cover (0.40); number of individual shrubs and tree cover (0.37); and the number of

Table 6. Pearson correlation coefficients for vegetation variables by sequence use categories.

Variable	Correlation Coefficient
Litter Depth	0.63**
Total No. of Species	0.61**
Shrub Cover	0.61**
No. of Shrub Species	0.58**
Total Cover	0.54**
Shrub Height	0.50**
No. of Individual Shrubs	0.49**
No. of Herb Species	0.40**
No. of Tree Species	0.30**
Herb Cover	0.30**
Percent Slope	0.25**
Total No. of Individuals	0.25**
No. of Individual Trees	0.25**
No. of Red Oaks	0.21**
Tree Diameter	-0.15*
Aspect	0.14*

* 95% significance level
** 99% significance level

Table 7. Pearson correlation coefficients for overstory vegetation variables.
Key: I, Intensive use sites; M, Managed sites; T, Transition sites; C, Control sites.[1]

Variable	Site Category	Number of Individuals Trees	Number of Tree Species	Tree Height	Tree Cover	Tree Diameter	Total Dominance
No. of Individual Trees	I		0.40**	0.26*	0.53**	-0.07	0.76**
	M		0.63**	0.33**	0.63**	-0.10	0.59**
	T		0.74**	0.21	0.72**	-0.23	0.52**
	C		0.47**	-0.01	0.63**	-0.50**	0.40**
No. of Individual Shrubs	I	0.32*	0.32*	-0.24*	0.37**[2]	-0.22	0.11
	M	0.23	0.22	-0.04	0.35 **	-0.22	0.08
	T	-0.29*	-0.19	-0.15	-0.15	-0.15	-0.32 *
	C	-0.18	-0.18	-0.12	-0.26 *	-0.01	0.02
No. of Individual Herbs	I	-0.06	-0.02	-0.04	-0.12	0.09	-0.02
	M	-0.24 *	-0.29 *	-0.12	-0.46**	0.15	-0.02
	T	-0.29 *	-0.29 *	-0.05	-0.33**	0.21	-0.16
	C	-0.07	0.12	0.07	-0.05	-0.06	0.01
No. of Tree Species	I	0.40**		-0.04	0.71**	-0.05	0.21
	M	0.63**		0.24*	0.64**	-0.07	0.37*
	T	0.74**		0.02	0.72**	-0.21	0.33**
	C	0.47**		-0.12	0.37**	-0.34**	0.05
No. of Shrub Species	I	0.33**	0.24*	-0.23	0.33**	-0.27*	0.06
	M	0.31*	0.38**	0.01	0.44**	-0.21	0.09
	T	-0.18	-0.06	-0.10	-0.06	-0.07	-0.16
	C	0.13	0.04	-0.07	-0.12	-0.35**	-0.05
No. of Herb Species	I	0.16	0.22	-0.13	0.27*	0.01	0.10
	M	0.07	0.01	0.06	0.13	0.12	-0.04
	T	-0.34**	-0.36*	-0.18	-0.14	-0.10	-0.27*
	C	-0.26*	-0.01	0.04	-0.12	0.08	-0.17

Table 7. (Continued).

Variable	Site Category	Number of Individual Trees	Number of Tree Species	Tree Height	Tree Cover	Tree Diameter	Total Dominance
Shrub Cover	I	0.31*	0.30*	-0.30*	_0.40_**	-0.29*	0.02
	M	_0.30_*	_0.34_**	0.03	_0.41_**	-0.21	0.09
	T	-0.13	-0.03	-0.27*	0.13	-0.27*	-0.31*
	C	-0.12	-0.07	-0.07	-0.18	-0.20	-0.13
Herb Cover	I	0.13	0.18	-0.12	0.08	-0.04	0.01
	M	-0.18	_-0.36_**	-0.06	_-0.34_**	0.25*	-0.01
	T	-0.20	-0.11	-0.23	-0.09	-0.11	-0.17
	C	-0.23	0.02	0.04	-0.10	0.04	-0.12

* 95% significance level
** 99% significance level
[1] This notation will be used in subsequent tables in the text.
[2] Those figures italicized are referred to directly or indirectly in the text.

shrub species with the number of individual trees and tree cover (both 0.33). In most instances then, an increase in the shrub layer whether it is species, individual plants or cover will be paralleled by an increase in the overstory, and conversely as the one layer diminishes a parallel response is evident in the other layer. These findings are inconsistent with the results in studies of other mature East Texas forest stands where woody understory is usually less in dense stands and increases as the overstory diminishes (Schuster, 1967; Halls and Homesley, 1966). These findings are, however, consistent with data from other campground studies (Frissell and Duncan, 1965; Dawson, Countryman and Fittin, 1978). The trampling of sensitive plants, damaging of bark on trees with hatchets and removing of understory vegetation for firewood most convincingly links responses in the overstory and understory. The enormous impact man imposes on heavy use areas puts a strong constraint on the diversity of species, the numbers of individuals that can survive in both the overstory and understory, and any potential for regeneration as long as this impact is sustained.

Not only are the responses of the understory similar to the responses in the overstory, but the ground cover is also closely tied to modifications in the understory at intensive sites (Table 8). With the exceptions of variable pairs correlated with shrub height and numbers of herbaceous plants, shrub variables are positively associated with every other herb variable. For instance, number of herb species and herb cover is significantly related to the number of individual shrubs, number of shrub species and shrub cover. These relationships

Table 8. Pearson correlation coefficients for understory vegetation variables.

Variable	Site Category	Number of Individual Shrubs	Number of Shrub Species	Shrub Height	Shrub Cover
No. of Individual Trees	I	0.32*	0.33**	0.18	0.31*
	M	0.23	0.31*	0.14	0.30*
	T	-0.29	-0.18	0.25*	-0.13
	C	-0.18	0.13	--	-0.12
No. of Individual Herbs	I	0.03	0.01	-0.01	-0.03
	M	-0.51**	-0.54**	-0.59**	-0.55**
	T	0.16	0.16	-0.31*	0.03
	C	0.00	0.26*	--	-0.10
No. of Tree Species	I	0.32*	0.24*	0.17	0.30*
	M	0.22	0.38**	0.24*	0.34**
	T	-0.19	-0.06	0.24*	-0.03
	C	-0.18	0.04	--	-0.07
No. of Herb Species	I	0.47**	0.45**	0.24*	0.32*
	M	-0.01	0.14	0.14	0.15
	T	0.48**	0.45**	0.02	0.45**
	C	-0.02	0.36**	--	0.07
Tree Height	I	-0.24*	-0.23	-0.15	-0.30*
	M	-0.04	0.01	-0.04	0.03
	T	-0.15	-0.10	-0.27*	-0.27*
	C	-0.12	-0.07	--	-0.07
Herb Cover	I	0.38**	0.42**	0.16	0.26*
	M	-0.25*	-0.29*	-0.35**	-0.19
	T	0.57**	0.51**	-0.06	0.40**
	C	0.17	-0.35**	--	0.08

* 95% significance level; ** 99% significance level

appear as anomalies if compared to other East Texas forested areas. Hall and Homelsey (1966) found that herb density in a mature pine-hardwood forest appears to be negatively correlated with the cover directly above, and Schuster (1967) noted a decrease in ground cover as the overstory and mid-story canopy closed. These parallel responses in the ground cover and understory concur with results found by Dawson, Countryman and Fittin in their 1978 study in which shrub and herb cover is positively correlated in concentrated use areas by camping disturbance. Thus, trampling may be responsible for these associations. There is also the possibility that moisture availability may account for positive correlations between variables in the two growth forms. For instance, if drought conditions occur, as they did that summer, lack of water may inhibit regeneration or reduce plant survival in both growth forms.

Table 9 shows positive correlations of variable pairs relating plant litter to number of trees and shrubs, number of shrub species, total species and total cover in intensive sites. Corresponding correlation coefficients are 0.33, 0.29, 0.31, 0.28 and 0.27. These results suggest that an increased number of plants is necessary to increase the litter depth. Thus, if camping disturbance limits the numbers and species of plants, as the data indicates, litter depth will diminish.

Managed sites were expected to display characteristics indicative of reduced impact because of imposed management activities, but mean values in Table 4 (p. 33) do not support this claim. Some factors such as number of shrubs increase in value along the use

Table 9. Pearson correlation coefficients for litter depth as related to park use categories.

Variable	Intensive Sites	Managed Sites	Transition Sites	Control Sites
No. of Individual Trees	0.33**	0.32*	0.00	-0.02
No. of Individual Shrubs	0.29*	0.65**	0.29*	-0.06
No. of Individual Herbs	-0.12	-0.41**	-0.02	-0.29*
Total No. of Individuals	0.17	-0.26*	0.08	-0.29*
No. of Tree Species	0.16	0.37**	0.17	-0.10
No. of Shrub Species	0.31*	0.66**	0.44**	-0.12
No. of Herb Species	0.17	0.08	0.31	-0.01
Total No. of Species	0.28*	0.58	0.52**	-0.11
Tree Cover	0.19	0.42**	0.36**	0.15
Shrub Cover	0.23	0.76**	0.46**	-0.04
Herb Cover	0.17	-0.03	0.24*	-0.08
Total Cover	0.27*	0.70**	0.54**	0.01
Percent Pine	-0.21	0.09	-0.26*	0.22

* 95% significance level
** 99% significance level

gradient. However, other means such as numbers of trees and total dominance are less than corresponding means in intensive sites, while values of such factors as number of herbaceous plants and percent grass are not only greater than the values in intensive sites, but also greater than the same measurements in the control areas. There are two possible explanations for these results.

First of all, the difference between mean values for managed sites and for intensive sites may be the result of long sustained use in the Lakeview and Big Pine units where numbers of individual trees, total species, total cover and total dominance are reduced considerably. In the cases where means are larger than those in control areas, particularly as they directly relate to the herbaceous layer, imposed grass planting by park managers in Lakeview, Cedar Point and Big Pine units probably accounts for the differences in these figures. Note the contrast in mean number of herbs by use categories (Fig. 9).

In managed sites like intensive areas, Pearson correlations show that the overstory fluctuates with modifications in the understory. In Table 7 (p. 38) significant coefficients all range from about 0.3 to 0.5 indicating fairly strong positive correlations between variables for the two growth forms. As in heavily used sites, these positive relationships are atypical of naturally occurring forest communities, and camping use is presumed to be the underlying basis for their association and parallel response to impact.

Unlike intensive areas, the shrub layer is inversely related to the ground cover in managed plots. For instance, note the association of shrub variables to number of herbs and herb cover (Table 8, p. 41).

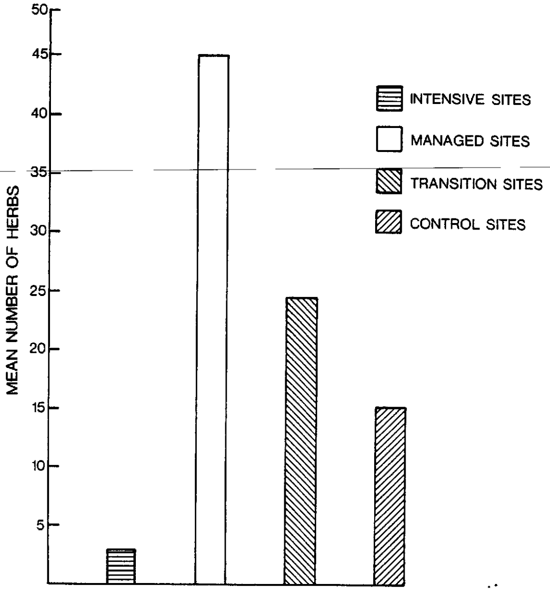

Fig. 9. Mean number of herbs by park use categories.

These relationships are clearly the result of management practices. The vegetation community at Lakeview, the oldest and most heavily used camping unit, has been modified considerably since it was built. In order to prevent further erosion and reduce compaction in this area characterized by few shrubs and grasses, managers rototilled the entire area and planted annual ryegrass.* Similar tasks were executed in Cedar Point, but in this particular unit, the goal was preventive maintenance.

In managed sites the ground cover relationship to the tree and shrub layers is primarily negative (Tables 7 and 8, pp. 38 and 41). This finding is contrary to the idea that a herb layer decreases as a result of increased shade. Grass planting strategy in areas where shrubs and trees are few explains the actual situation. Intensive use in these plots over decades, particularly in the Lakeview and Big Pine units, has reduced the quantity of the woody vegetation at these sites.

Strong correlations exist between litter depth and vegetation variables in managed sites. Correlations range as high as 0.76 (Table 9, p. 43). In general, litter depth will increase as the number of species and plant cover increase while the number of herbs and total individuals decrease.

Site preparation for grass seeding at Lakeview and Cedar Point requiring the rototilling of large areas of managed sites, incorporated litter on the soil surface into the A-horizon. In these older, more heavily used sites, litter is practically nill. Thus, the number

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*Personal communication, Mr. E. Wisenbaker, 1978.

of herbs and total number of individuals are inversely correlated to litter depth, because of this practice in areas where grass now exists. In addition, trampling and gathering duff material, especially pine needles, for either kindling or adding aroma to campfires has reduced the already sparse layer even further.

Transition sites, defined as such because of their spatial position between intensive use sites or between intensive use sites and control sites, might also be referred to as lightly used or ecotone environments. Disturbance is readily apparent in some of these sites as demonstrated by networks of trails and areas without the shrub layer (Fig. 10), yet the disturbance may not be so great as to eliminate numbers of plants that can tolerate these conditions. Thus, one might expect values for transition measures to be slightly less than or greater than those for control areas. In Table 4 (p. 33), the corresponding mean values in both use areas are variable. Note that the numbers and species of trees and shrubs in transition sites, for instance, are less than the corresponding numbers in control sites, suggesting that disturbance may be the limiting factor. Findings in Tyler State Park parallel the results in Young's (1978) campground study in Illinois in which less litter and shrub cover distinguished lightly used areas from control sites. Although one camping impact study showed that species diversity increases in lightly used or in peripheral areas near camping activity (Celentino, 1978), the Tyler study shows that except for the herb layer, richness is definitely greater for all life forms in the control plots (Table 4, p. 33). This finding in transition sites may be the function of trampling, in

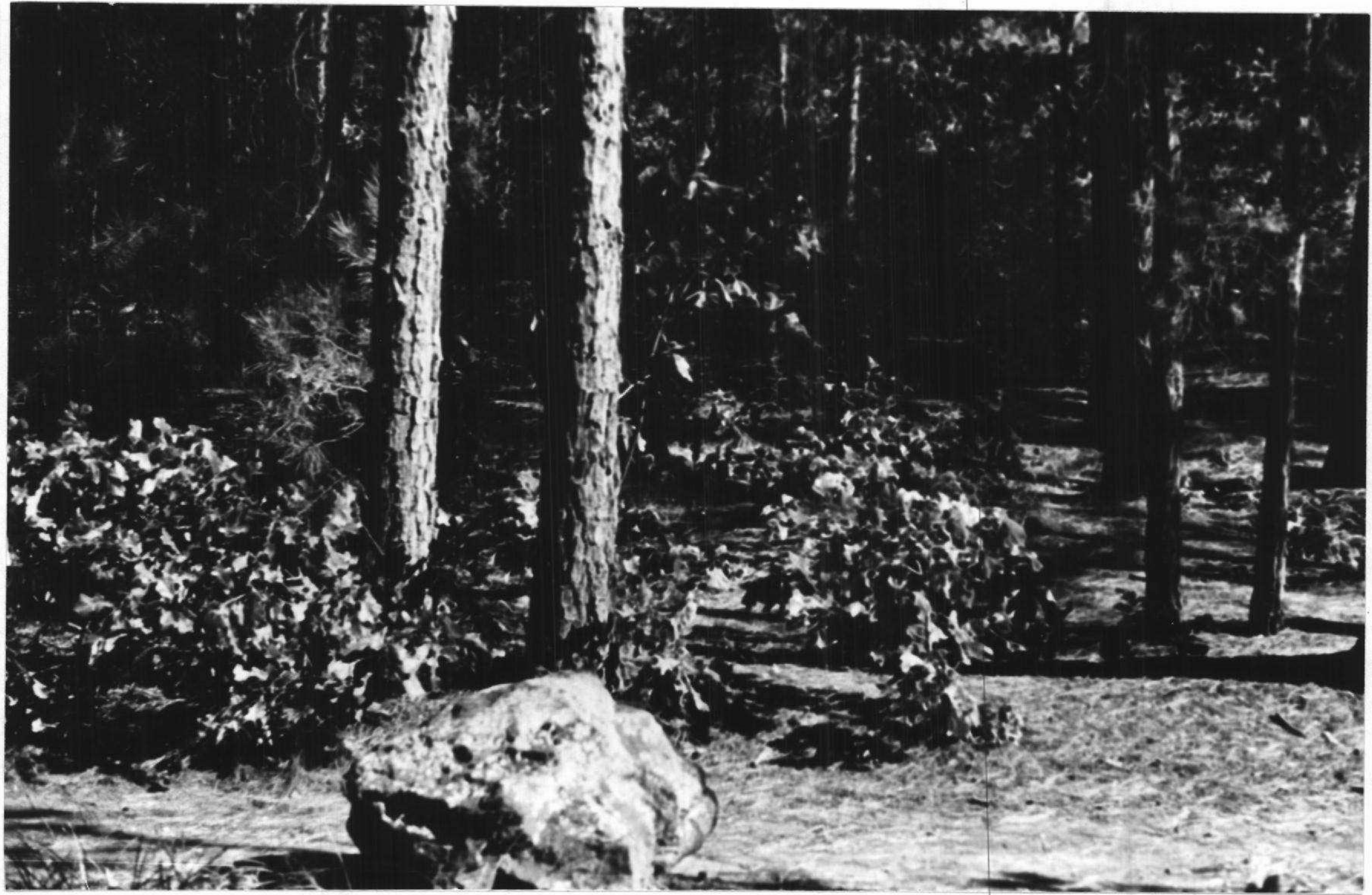

Fig. 10. Transition site with sparse understory and ground cover.

which richness is held in check by trampling impact in these ecotones, plus the likelihood that many shrubs have been exploited for campfire fuel.

Although there is less species richness in transition sites than in control areas, some variables do show greater mean values in transition zones than in control sites. For instance, mean numbers of herbaceous plants, herb cover and herb species are greater in these peripheral areas (Table 4, p. 33). The total number of individuals, tree and shrub cover, tree diameters, percent pine and percent grass are also substantially greater in transition sites than control sites. These results may be a function of their peripheral nature, the human disturbance factor, and/or site conditions: better light conditions as a result of decreased vegetation in surrounding areas (even though the canopy is dense overhead), slope position, and aspect. Transition sites, in general, are located lower on the slopes than are the other use types, and thus, based on their position, probably have more available soil moisture. In addition, these sites are oriented more northerly and easterly than the other sites. Light intensity and surface air temperatures are not as high as on west-facing slopes, and soil moisture retention is probably better on northerly and easterly slopes as well. James and Ripley (1963) found that northeast- and east-facing slopes could withstand use better than south- and west-facing slopes because of better fertility.

Contrary to the findings for intensive and managed sites, overstory individuals, species and cover in transition sites are more closely associated with the ground cover vegetation than the understory layer as demonstrated in Table 7 (p. 33). However, there is no clear indication that these inverse relationships are related only to use.

Understory variables in transition plots have virtually no relationship with the upper canopy, but positive correlations exist with herb variables (Table 8, p. 41), particularly herb species and herb cover. The significant correlation coefficients range between 0.3 and 0.5 indicating strong associations. These associations may be closely related to camping disturbance in which a reduction or increase in understory caused by trampling will be matched with a parallel response in the herb layer.

Ideally, litter depth in transition sites should be comparable to the amount found in control sites. Subjective analysis of these plots and the trails that dissect many of them suggests that litter depth may be adversely affected by this disturbance. And, in fact, depth of litter in these sites is less than that in control plots (Table 4, p. 33). Mean depth in transition areas is 2.19 cm while in controls the figure is 3.56 cm. Many of the significant positive correlations between litter depth and the other vegetation variables in transition sites are also found in managed and intensive use areas, suggesting that camping disturbance is responsible for the relationships in transition sites as well (Table 9, p. 43). Thus, the use of these areas as passageways to other sites, hinders the development of a litter layer comparable to that in control sites.

As expected, control areas coincide with other East Texas forest studies of unused sites in that they have received little or no disturbance by campers. If comparisons are made between control sites at Tyler State Park and Schuster's uncut areas (1967) where he monitored response of the understory to clearcut treatments, many similarities exit. Basal area, mid-story cover and total cover increased from clear-cut sites to uncut sites, while grasses and herb density generally decreased. The situation is the same in control areas at Tyler State Park, suggesting these control sites might be representative of other undisturbed areas of East Texas pine forests.

Unlike the use sites discussed earlier, the overstory composition and structure in control areas is controlled neither by the shrub nor herb layers (Table 7, p. 38). Significant inverse relationships exist between numbers of trees and species of herbs (-0.26) and between tree cover and numbers of shrubs (-0.26); but both of these relationships appear to be related to increasing shade that reduces the species of herbs which are shade intolerant, and number of shrubs that must compete for the remaining available light as the canopy closes.

Correlation coefficients for the shrub layer suggest that no relationship is firmly established with either the overstory or ground cover in control sites, signifying that these associations are quite variable, depending more on site conditions or environmental gradients (Table 8, p. 41). The only significant correlations are between the number of shrub species and herb variables. Because values for all shrub heights in all the control sites fall in the same height category, no correlations exist with this variable. Finally, no significant correlations occur between the herbaceous layer and canopy in control plots suggesting other parameters govern these variables.

The only site variables to which litter depth is correlated in control sites are number of herbs (-0.29) and total number of individuals (-0.29) (Table 9, p. 43). These variables are negatively but weakly related. These findings indicate that the litter depth is not only relatively stable in control areas, but that it fluctuates only slightly with changes in site conditions and the number of plants.

The values for total number of individuals, total number of species and total cover were significantly different by use category when tested by analysis of variance, and positively related to sequence of use by Pearson correlations (Tables 5 and 6, pp. 34 and 37). Thus, the general pattern that emerges in the park landscape is an increase in the total numbers of individuals, total species and total cover as user impact diminishes from concentrated use areas to control sites. A positive association between totals and components of the various growth forms due to camping pressure is difficult to establish because the control sites also exhibit the same trend. Some of the parallel, positive responses in intensive, managed and transition plots is no doubt related to reduced impact, but the amount of influence camping disturbance has on these variables is uncertain according to the data.

The presence and number of pines, grasses and red oaks were tested as indicators of camping disturbance. From the results of ANOVA only the percentage of grass and number of red oaks in quadrats were significant in distinguishing use categories (Table 5, p. 34). In the Pearson correlations, the number of red oaks were positively correlated to park use, i.e., as use follows the sequence from intensive to no use, the number of red oaks increased (Table 6, p. 37). No significant relationship was established by use type with the percentage of pines in either test. Contrary to one of the hypotheses stated earlier, pines do not respond to a use gradient. However, correlations between the percent grass and number of red oaks with the other vegetation variables gives one insight into the types of areas in which grass and red oaks can be found.

Because the percent grass varies considerably from intensive to control areas, this variable was significant in distinguishing use categories when tested by ANOVA. In intensive sites, Pearson correlations show no significant relationships between the amount of grass and either overstory or understory variables. For instance, the correlation coefficients between percent grass and the number of trees is -0.19, and the coefficient between percent grass and the number of shrubs is 0.12. Thus, changes in either of these vegetation layers will not modify the amount of grass to any great extent. Camping impact probably limits associations with the tree and shrub layers.

In managed sites, the percent grass per site is directly related to deliberate planting in heavily used areas. Pearson correlations show negative associations with the number of trees (-0.35), total species (-0.50), shrub cover (-0.52) and litter depth (-0.56) indicating that grass is found where abuse has adversely affected these measures.

In transition and control sites, the amount of grass is negatively correlated to the overstory variables. For example, the correlation coefficients for percent grass and the number of trees for transition and control areas are -0.32 and -0.25 respectively. Thus, the presence and amount of grass in these sites may be related to light availability.

The number of red oaks is affected by the use gradient as well as by the sequence of that gradient. Consequently, one will find more red oaks in control sites than intensive sites and,the number of red oaks gradually declines from control, to transition, to managed to intensive sites.

In heavily used areas, Pearson correlations indicate that the number of red oaks is positively related to variables that could only increase under reduced camping pressure such as total number of plants (0.40), total species (0.50), and total cover (0.53). In managed sites, the number of red oaks is positively correlated to variables in the shrub layer, i.e., number of individual shrubs (0.28), number of shrub species (0.43) and shrub cover (0.30). These associations are related to reduced camping pressure where a shrub layer is well established. The number of red oaks in transition and control sites are highly variable, and most likely depend on site conditions and environmental gradients.

Results from the analysis of variance for topographic controls (percent slope, slope position and aspect) reveal that only percent slope values are significantly different by use types (Table 5, p. 34). However, Pearson correlation data show that not only percent slope but also aspect are positively and linearly correlated by the sequence of park use (Table 6, p.37). In other words, as park use decreases from intensive to control sites, percent slope increases and the aspect of the slope moves to the northeast.

Significant Pearson correlations of use with percent slope occur only in managed, transition and control sites (Table 10). The number of trees (0.24) and average tree height (0.32) is correlated to percent slope in managed sites. Data indicates that as percent slope increases, the numbers of trees and height of each will increase. The strongest sloping area is Cedar Point. The positive correlation may be related to composition of the stand and/or lack of appreciable disturbance through camping. Cedar Point has experienced less abuse than the other areas, and its position on the steeper slopes where large stands of pine dominate may explain these correlations with slope.

Percent slope is related to tree diameters (0.26) in transition plots (Table 10). Without further reinforcement through association with other variables, it is difficult to show that this relationship is a result of camping disturbance.

As aspect increases to the north and east, number of individual shrubs, total number of individuals, species and cover in all strata including total species and total cover increase while tree height, tree diameters and percent pine diminish in intensive sites (Table 10). Sites whose aspects are oriented more to the north and east are located primarily in the shelter, Dogwood and Hickory Hollow camping areas. Positive correlations may be related to better site conditions on more northerly slopes, such as cooler surface and soil temperatures and more moisture availability.

Cedar Point is the only managed area that has sites facing pri-

Table 10. Pearson correlation coefficients for topographic variables.

Variable	Site Category	Percent Slope	Aspect
No. of Individual Trees	I	-0.10	0.11
	M	_0.24*_	0.09
	T	-0.03	0.19
	C	-0.09	-0.12
No. of Individual Shrubs	I	-0.14	_0.49**_
	M	-0.06	0.10
	T	0.17	-0.09
	C	-0.01	-0.23
No. of Individual Herbs	I	-0.01	0.05
	M	-0.07	0.13
	T	0.00	-0.14
	C	0.06	-0.04
Total No. of Individuals	I	-0.10	_0.28*_
	M	-0.06	0.18
	T	0.05	-0.14
	C	0.03	-0.18
No. of Tree Species	I	-0.06	_0.41**_
	M	0.23	_-0.28*_
	T	0.01	_0.25*_
	C	0.11	0.05
No. of Shrub Species	I	0.03	_0.55**_
	M	0.08	-0.01
	T	0.14	0.04
	C	0.14	0.02
No. of Herb Species	I	-0.01	_0.31*_
	M	-0.12	0.19
	T	-0.01	0.03
	C	_0.34**_	-0.03
Total No. of Species	I	-0.02	_0.58**_
	M	0.08	-0.02
	T	0.09	0.14
	C	_0.30*_	_0.02_
Tree Height	I	-0.12	_-0.33**_
	M	_0.32*_	0.07
	T	0.13	-0.10
	C	0.14	_0.32*_

Table 10. (Continued).

Variable	Site Category	Percent Slope	Aspect
Shrub Height	I	-0.07	-0.33**
	M	0.01	0.09
	T	0.08	0.35**
	C	--	--
Tree Cover	I	-0.04	0.38**
	M	0.14	-0.21
	T	-0.05	0.35**
	~~C~~	~~-0.05~~	~~-0.14~~
Shrub Cover	I	-0.07	0.30*
	M	0.01	0.10
	T	0.13	0.17
	C	0.22	-0.07
Herb Cover	I	0.06	0.27*
	M	-0.22	0.31*
	T	0.01	-0.07
	C	0.18	0.05
Total Cover	I	-0.04	0.45**
	M	-0.04	0.11
	T	0.03	0.24*
	C	0.23	-0.15
Mean Litter Depth	I	-0.03	0.06
	M	-0.07	0.09
	T	0.16	0.48**
	C	-0.11	-0.20
Tree Diameter	I	0.16	-0.32*
	M	-0.05	0.24*
	T	0.26*	-0.13
	C	0.00	0.03
Total Dominance	I	-0.01	-0.09
	M	0.20	0.15
	T	0.03	-0.08
	C	-0.02	-0.10
Percent Pine	I	-0.22	-0.53**
	M	0.12	-0.41**
	T	0.06	-0.16
	C	-0.20	-0.06

Table 10. (Continued).

Variable	Site Category	Percent Slope	Aspect
Percent Grass	I	-0.15	0.05
	M	0.00	-0.08
	T	0.07	-0.12
	C	0.22	0.12
No. of Red Oaks	I	-0.20	0.21
	M	-0.16	-0.21
	T	0.08	-0.05
	C	-0.01	0.09

* 95% significance level
** 99% significance level

marily east and west. In fact, most face east. Big Pine and Lakeview units are oriented more southerly. The orientational differences, the importance of pine in the overstory at Cedar Point and its age in terms of camping use may account for the positive correlations to herb cover (0.31), tree diameters (0.24) and percent pine (0.41) and the negative correlation to the number of tree species (-0.28) as sites shift to the north and east (Table 10, p. 56).

Moving toward north and east facing slopes the number of tree species (0.25), shrub height (0.35), tree cover (0.35) total cover (0.24) and litter (0.48) in transitional quadrats increases (Table 10, p. 56). Site conditions as they directly relate to orientation may account for these relationships. Lack of further associations leads one to believe that man-made disturbances are of little influence.

The only variable associated with aspect in control sites is height of trees (0.32) which tends to increase as orientation is directed north and east (Table 10, p. 56). This may be related to site conditions, stand composition or as James and Ripley (1963) discovered better soil fertility on northeast and east-facing slopes. Thus, topographic parameters do affect the structure and composition of the sampling sites. However, further testing is needed to determine how influential percent slope, position on slope, and aspect are in light of camping impact. The results from ANOVA and Pearson correlations relating topographic variables to use categories indicate that relief factors to some extent confound the results associated with camping impact. Ideally, one would like to control for all variables besides the ones being tested for, but this task was impossible for this study and is very difficult to accomplish in most studies.

THE IMPACT PRODUCED BY CAMPING ON TYLER STATE PARK SOILS

The soils at Tyler State Park can be divided into four suborders, Udult, Udalf, Ochrept and Fluvent. Within these four suborders, nine soil series are recognized at the park. Surface soils in the nine series range in texture from fine sands to sandy loams, and subsurface soils range from fine sands to clay. Two textural triangles show a close textural similarity among all the surface samples (Fig. 11) and the lack of textural similarity among subsurface samples (Fig. 12). The textural similarities of the surface samples make them comparable for testing. The clays in both surface and subsurface soils are largely kaolinitic. The gravel content is highly variable, ranging from 0.0% to 70%. Cation exchange capacities for surface and subsurface soils are quite low, ranging from 0.95 to 5.03 milliequivalents per 100 gm of soil. The range in cation exchange capacity is due to the variable clay content in subsurface horizons.

Several hypotheses were testing on soil characteristics to determine how camping disturbance affected them. Edaphic factors should be distinguishable by a gradient of use. Significant differences between date of collection for specific variables should be related to camping impact and the interaction with soil forming factors.

Table 11 classifies the data means by use and date for each variable except cation exchange capacity. Nitrogen was not included in the table because its content in these soils in quite low, and the change through the season was insignificant. The means in the "All" column are averages for all samples by use only. Notice that

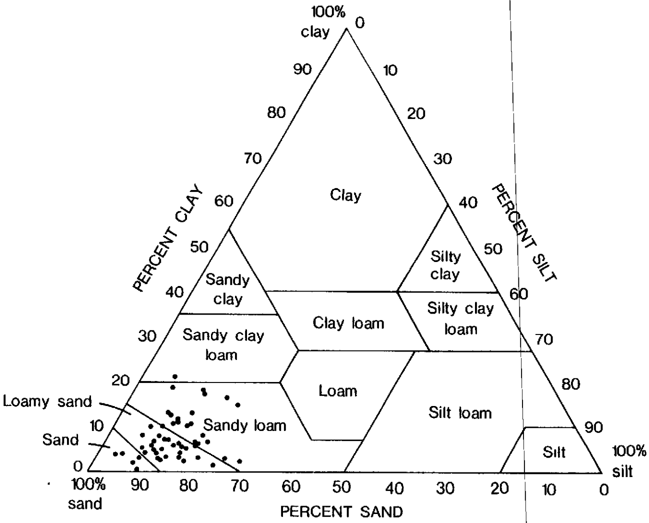

Fig. 11. Soil textural triangle of surface samples.

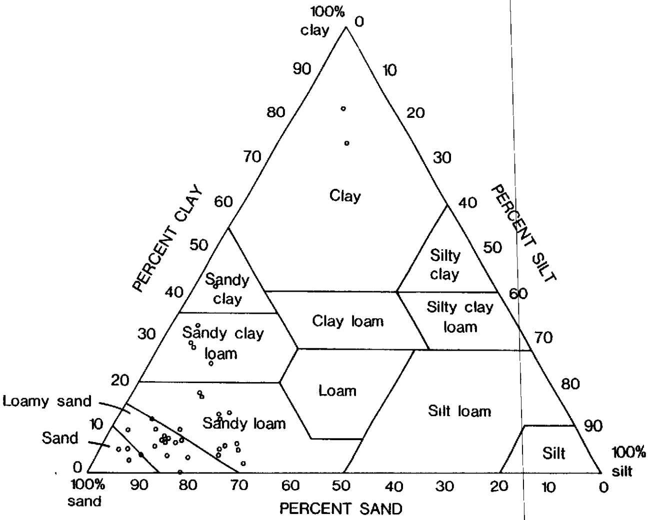

Fig. 12. Soil textural triangle of subsurface samples.

Table 11. Soil data means by park use and date of collection.

	Organic Matter			Soil Reaction			Calcium			Magnesium			Phosphorus			Cation Exchange Capacity
Use	%			pH			lb/A			lb/A			lb/A			milliequivalents/ 100 gm
	All	Jn	Oct	All	Jn	Oct	All	Jn	Oct	All	Jn	Oct	All	Jn	Oct	All
Intense	*0.8*	*0.4*	*1.2*	5.7	5.7	5.8	1420	1070	1770	190	170	200	*4.8*	*7.5*	*2.0*	2.1
Managed	*0.5*	0.5	0.5	5.9	5.8	6.1	1080	1120	1040	210	210	220	*2.7*	3.4	2.0	2.8
Transition	0.9	0.9	1.0	5.5	5.2	5.9	1420	1450	1380	200	200	190	*4.9*	*7.4*	*2.3*	3.2
Control	1.1	1.2	0.9	5.8	5.6	5.9	1260	1110	1400	240	240	250	*4.0*	4.4	3.7	2.9
Subsurface	0.6	0.6	0.6	5.7	5.6	5.8	1040	1100	980	260	280	240	4.9	4.1	5.8	4.1
Grand Mean	*0.9*			5.8			1270			220			4.0			2.8

	Potassium			Compaction			Bulk Density			Porosity			Water Content		
Use	lb/A			kg/cm^2			gm/cm^3			%			% by wt		
	All	Jn	Oct	All	Jn	Oct	All	Jn	Oct	All	Jn	Oct	All	Jn	Oct
Intense	*190*	180	200	3.5	*5.8*	*3.1*	1.8	1.8	1.8	33.4	33.2	33.6	7.3	4.0	10.6
Managed	*260*	260	250	1.8	*2.2*	*1.5*	1.7	1.7	1.7	36.1	34.5	37.8	8.8	7.6	10.0
Transition	*190*	180	190	2.4	2.1	2.7	1.6	1.6	1.6	40.4	40.9	40.0	5.5	5.4	5.6
Control	*160*	150	180	0.8	0.5	1.0	1.4	1.4	1.5	46.2	49.0	43.5	10.3	9.0	11.7
Subsurface	190	200	180	1.4	1.1	1.7	1.5	1.5	1.5	42.9	43.1	42.7	10.9	11.9	9.9
Grand Mean	190			1.6			1.5			41.9			8.9		

for all variables tested by use, means for intensive and managed areas differ more from the grand mean than do means for control and transition areas. It appears that many of these variables are distinctly different by use type and season of collection.

In order to test whether the soil variable means are significantly different by use type as well as by the date of collection, two-way analysis of variance was employed to test for these two independent variables. The findings are given in Table 12.

The only variables significantly affected by date of collection are pH and phosphorus. In categorization by use only potassium, compaction, bulk density and porosity have significantly different means. Variables whose sample means were significantly different by a combination of both use and date are phosphorus, potassium, compaction, bulk density, and porosity. Contrary to the hypothesis that compaction should increase through time as trampling increases, especially in intensive use areas, compaction showed no significance when tested against date of collection. Means generated from penetrometer readings, which are surrogates for compaction, decreased somewhat in intensive and managed areas as seen in Table 11 (p. 64). A scatter diagram was generated to test whether this decline in compaction over the camping season could be related to soil moisture content, and thus contribute to the ease with which the penetrometer enters the surface layer. The scatter diagram (Fig. 13) reveals that a strong negative correlation does exist at a significance level of 92% between soil moisture content and compaction.

Park use significantly affects physical soil properties such

Table 12. Two-way analysis of variance tests on soil variables by park use categories and date of collection.

Variable	Combination	Use	Date	Two-way interactions
Organic Matter	0.157	0.087	0.921	0.179
pH	0.066	0.454	0.013*	0.819
Calcium	0.690	0.751	0.310	0.691
Magnesium	0.681	0.530	0.783	0.979
Phosphorus	0.021*	0.032	0.004**	0.063
Potassium	0.005**	0.003**	0.363	0.877
Compaction	0.001**	0.001**	0.371	0.066
Bulk Density	0.001**	0.001**	0.164	0.275
Porosity	0.001**	0.001**	0.175	0.289

* 95% significance level
** 99% significance level

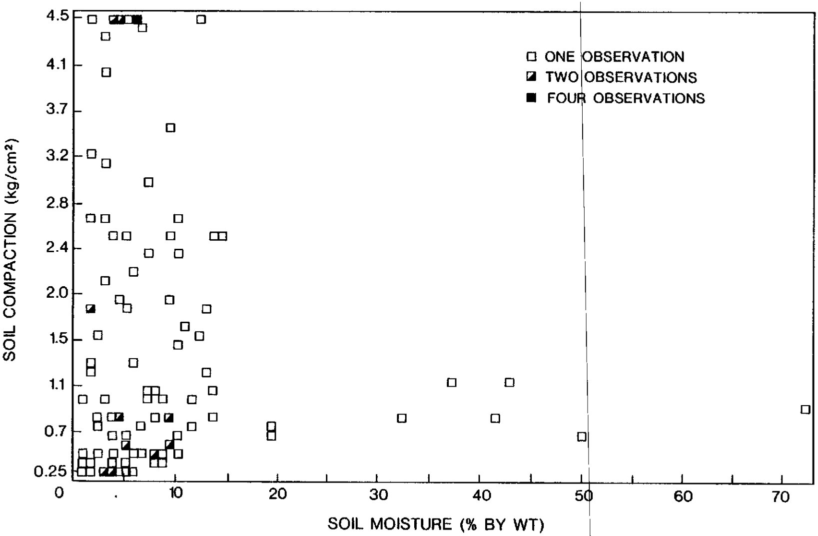

Fig. 13. Scatter diagram relating soil compaction to soil moisture content.

as compaction, bulk density and porosity, particularly in intensively used and managed areas. Trampling tends to compact soil particles, increase soil density and reduce soil porosity. The studies of Solan (1976) in Pennsylvania parks and the study of Ward and Berg (1973) in an eastern Michigan camping area support this observation. Subtle modifications in these variables over one camping season suggest that initial impact in newly-created recreational facilities may alter density and porosity rather quickly, but over many years of camping activity, the rate of change in these characteristics decreases and may, in fact, be reversed slightly over the winter period as shown by Legg and Schneider's study (1977). Although soil compaction and bulk density decreased through the season in intensive use and managed areas, this apparent change is believed to result from the affects of soil moisture on the penetrometer measurements.

The only chemical soil properties significantly affected by park use or season are pH, phosphorus and potassium. The increase in pH coincides with results by Papamichos (1966) and Young and Gilmore (1976). Several factors may account for this decrease in acidity. The addition of campfire ash and camper wastes in heavily used sites may contribute increased bases to the surface layer. Compaction reduces porosity and therefore reduces the leaching process, leaving more bases in the soil. This latter statement is reinforced by the fact that bases, i.e., calcium is considerably higher in heavily-used areas than in control areas, as seen in Table 11 (p.64).

The phosphorus content in surface soils changed considerably through the camping season. Both intensive use and transition areas experienced significant declines in phosphorus content through time. The decline of available phosphorus may be due to the mineralization of winter litter and residue through the season. As the camping season came to a close,the amount of mineralizable organic matter decreased and a high percentage of available phosphorus was tied up in the biomass.

Potassium, unlike phosphorus, is significant in relation to use as well as use and time taken together. Unlike Solan's findings (1976) that potassium was unrelated to use, higher potassium contents occurred in intensive, transition and managed areas than in control areas (Table 11, p. 64). Exchangeable potassium tends to be a function of cation exchange capacity and the kind of clay mineral present. Because the cation exchange capacity is low for these soil types, and kaolinite, the dominant clay mineral, does not adsorb potassium as readily as vermiculite and smectite clays, most of the available potassium tends to be in soil solution. In this state, potassium is very vulnerable to leaching losses. Thus, one would expect those use areas with the least amount of leaching potential to have the most potassium. However, the opposite is true. Camping residues such as campfire ash and possibly some plant residues may account for this increase, particularly in the managed areas. In those sites, annual ryegrass which was planted in the preceding spring died back during the droughty summer, and its decay may have contributed appreciable amounts of potassium to the soil. Extreme wetting and drying conditions in intensive and managed areas may also be a factor. Wet compacted soil may release available potassium into solution, but because leaching is reduced by compaction, available potassium may accumulate in these soils. Compacted soils may also inhibit uptake of potassium by plants if compaction is severe.

Pearson correlations were utilized to determined whether linear relationships exist between park use categories and soil variables. Table 13 gives the variables that are significantly related to the sequence of park use, i.e., high impact in intensive sites decreasing through the managed, transition, and control sites.

Table 13. Pearson correlation coefficients for surface soil variables by sequence of use categories.

Variable	Correlation Coefficient
Soil Compaction	-0.61**
Bulk Density	-0.48**
Porosity	0.48**
Potassium	-0.26**
Organic Matter	0.20*
Cation Exchange Capacity	0.18*

* 95% significance level
** 99% significance level

Results indicate that of all the soil variables, soil compaction is most clearly distinguishable by the above sequence of park use types followed by bulk density, porosity and potassium. A weak, positive correlation exists between use categories and cation exchange capacity, probably due to the fact that control areas are represented by all soil series and not by just a few as are the other categories of use.

Pearson correlations for surface and subsurface samples were computed by correlating each soil variable, to each other, but because of the variability of sample sizes due to unequal representation by use types, no presentation nor explanation of the results will be made.

RELATIVE IMPORTANCE OF FACTORS ON THE SYSTEM

Several multiple linear regression analyses were computed to determine the equation that best characterized the relationship of the vegetation and soils variables to park use categories. Using the variables that showed the strongest correlation to use types in the Pearson correlation procedure, step-wise regression was performed to see which variables are most predictive of use types.

To avoid multicollinearity with vegetation variables, two regressions were run, one in which total plants, total species and total cover were used without respective components such as tree species, herb cover, etc. The other regression contained only the components and other highly correlated variables without the totals. Of the two regressions, the one with totals or summed variables explained more of the variation in use types (Table 14).

This regression explained a total of 58% of the variance in use types. The variables are listed in descending order of their importance in accounting for the variance beginning with litter depth and ending with total cover. Although one would expect the coefficients to increase through each step as a variable is added, this is not always the case. Some multicollinearity between variables may account for the strength of the variables as they enter the model.

The results from this table were translated into a regression equation describing the variables most critically affected by camping impact in a sequence by importance. The equation is:

$$\begin{aligned}\text{Use} = {} & 1.04 + 0.29\ (\text{Litter}) + 0.06\ (\text{Total Species}) + \\ & 0.01\ (\text{No. of Individuals}) + 0.57\ (\text{Shrub Height}) \\ & + 0.02\ (\text{Percent Slope}) - 0.003\ (\text{Total Cover})\end{aligned}$$

Table 14. Stepwise multiple regression for vegetation variables at the 95% and over significance level listing the coefficients and standard errors.

Step	1	2	3	4	5	6
R^2	0.40	0.50	0.52	0.55	0.57	0.58
Constant	1.79	1.32	1.20	1.08	0.90	1.04
Litter	0.396 (0.035)	0.264 (0.038)	0.289 (0.038)	0.274 (0.037)	0.271 (0.037)	0.294 (0.038)
Total No. of Species		0.089 (0.014)	0.072 (0.015)	0.041 (0.016)	0.034 (0.017)	0.058 (0.020)
Total No. of Individuals			0.006 (0.002)	0.007 (0.002)	0.008 (0.002)	0.009 (0.002)
Height Shrubs				0.468 (0.121)	0.479 (0.120)	0.567 (0.125)
Percent Slope					0.018 (0.008)	0.018 (0.008)
Total Cover						-0.003 (0.001)

Although this equation cannot be readily applied to other impact studies until more work is done in this area of study, this statistical analysis does give one insight into those aspects of vegetation which will most likely be altered by visitor impact in camping areas.

Stepwise regression was also performed on soil variables to determine which factors best predict the differences in park use intensity. As expected, compaction is the variable that accounts for most of the variance by soil types, followed by porosity, potassium and cation exchange capacity (Table 15). Together these variables account for 52% of the total variance.

If transformed into a regression equation, the statement reads as follows:

$$\begin{aligned}\text{Use} = {} & 2.66 - 0.36\ (\text{Compaction}) + 0.02\ (\text{Porosity}) - \\ & 0.003\ (\text{Potassium}) + 0.027\ (\text{Cation Exchange} \\ & \text{Capacity})\end{aligned}$$

This equation of best fit only gives a description of the soil measures that best explain the difference in park use and the contribution of each variable.

A model of the effects camping has on vegetation and soils at Tyler was constructed from the results of the regression subprograms (Fig. 14). This drawing illustrates not only the association between camping disturbance and these variables, but also the interrelationships among the variables themselves.

The arrows of various widths indicate the strength of impact on the parameters enclosed in boxes. Thus, camping impact has a greater effect on plant litter than total cover. The lines and arrows

Table 15. Stepwise regression for soil variables at the 95% and over significance level listing the coefficients and standard errors.

Step	1	2	3	4
R^2	0.37	0.41	0.44	0.52
Constant	3.86	2.66	3.04	2.66
Compaction	-0.472 (0.062)	-0.381 (0.069)	-0.364 (0.068)	-0.363 (0.063)
Porosity		0.025 (0.009)	0.025 (0.009)	0.022 (0.009)
Potassium			-0.002 (0.001)	-0.003 (0.001)
Cation Exchange Capacity				0.268 (0.070)

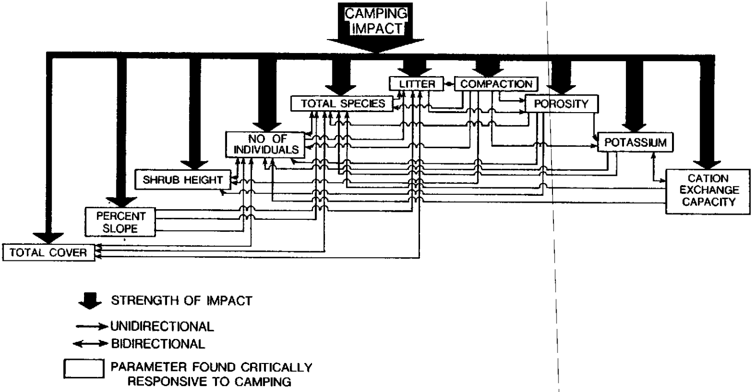

Fig. 14. Descriptive model of camping impact on vegetation and soil variables.

connecting the boxed parameters are either unidirectional, i.e., the relationship only flows in one direction or bidirectional, i.e., either parameter may be affected by the other. For instance, porosity is partially a function of compaction (unidirectional flow); however, total cover may affect the number of individual plants and vice versa (bidirectional flow). Porosity is influenced by the amount of litter and soil compaction. Porosity in turn indirectly affects the total number of species, total individuals, shrub height and potassium content in the soils. All these latter variables in turn affect other parameters.

Based on only a few of many variables that could be measured in this recreational facility, the complexity in the park is quite evident. The web of relationships demonstrates that camping impact may not only affect these variables directly and individually, but that indirectly any number of related components of this system may also be influenced by camping activities.

SUMMARY AND CONCLUSIONS

This research clearly reveals that people have played an active role in the modification of vegetation and soils through camping activities at Tyler State Park. The data sets indicate that all variables are affected by a gradient of use from intensive to no use. As hypothesized, individual plants, number of species, plant cover and litter in intensive use sites were less than the values for these same variables in control sites. Edaphic characteristics such as bulk density and organic matter content were greater in heavily used camping sites, while porosity was less and nutrient contents were variable. Contrary to the hypothesis, organic matter content in intensive use areas was greater than in control areas. Foot trampling and grinding organic matter and camping residue into the soils may account for this difference. Had the first soils data and samples been taken at the beginning of the season, it is felt that a much greater difference would have been recorded.

In the use gradient, intensive areas sustained the most impact. Managed sites follow closely behind even though restoration programs have tried to alleviate some of the impact. Data indicate that transition sites have not been exempt from disturbance, but these ecotones have not experienced as much impact as either intensive or managed sites. Controls appear to be in steady state conditions and respond to changes in environment no differently than other undisturbed areas.

The red oaks in sampling plots proved to be useful as indicators of camping impact. Grasses and pines were too variable in sites to be indicative of tolerance to impact or distinguish levels of impact. Relief and aspect exert some control over the composition and spatial distribution of the vegetative landscape, but the amount of influence can only be estimated.

Two chemical components of the soil, pH and phosphorus changed through the camping season. Phosphorus decline may be related to the decrease of mineralizable organic matter through the camping season and the transfer of phosphorus to the biomass. The increase in pH may be due to the addition of ashes and camper waste material or less leaching of minerals in compacted soils compared to control soils.

Through regression analysis ten variables were identified as most indicative of changes in use levels: litter depth, total number of species, shrub height, percent slope, total cover, compaction, porosity, potassium and cation exchange capacity. These variables were the elements used for a model of camping impact on the vegetation and soils. The diagram exemplifies only a portion of the vast complexity of relationships within the state park ecosystem. Other parameters could have been added, but the intent was to limit the diagram to only those variables tested and found significant. This illustration demonstrates that impact affects components of a park ecosystem directly as well as indirectly through interrelationships of variables. As more knowledge is gained through research in camping impact, further refinements can be made.

Use of recreational facilities has some positive but mostly negative influences on vegetation and soils. Although amounts of organic matter, pH and potassium were higher in intensive areas, the importance of these so-called benefits is questionable given the magnitude of impact on the other variables that were measured in this study.

In a publication where he reported that conditions often improve after several years of camping use, Magill (1970) stated, "Investigations of human impact on the soils and vegetation of intensively used recreation sites probably do little more than document the obvious." Some of the results in the Tyler research parallel similar studies; however, others differ from these findings. For example, the Tyler study showed significant differences in amounts of potassium in all use categories. Salon (1976) found no differences. Young and Gilmore (1976) found that the amount of phosphorus increased 50% in intensive over control areas, but the Tyler research showed no such increase. Papamichos (1966) found less organic matter in soils on intensively used sites, whereas Young and Gilmore (1976) and Tyler data indicate less organic matter in heavy use sites. Clearly, the obvious results which Magill suggests are there, are not so obvious after all. Because of the importance of these soil factors to plant growth, survival and regeneration, these discrepancies should justify continued scientific investigations to determine the exact nature of impact on these characteristics.

Further research might include testing trampling-tolerance levels of particular plants to determine those which can best withstand impact in this type of environment. Pollutants in the water, air and soil undoubtedly negatively affect camping environments, but except for some water quality research, few investigations have been made.

In order to determine if improvements or further deterioration have occurred in the park, which parallel or contrast those findings of Magill, a reinvestigation at Tyler in five years or so may be of value. Additional study should also include the determination of the importance of topographic controls to impact.

Results from this study suggest that restorative measures for past abuse and future monitoring of existing conditions might well be implemented to protect the resources in Tyler State Park. Rotation of sites or temporary closure of those sites that receive the most use is advisable. Farnham's study (1976) of soil ameliorating practices for compacted soils in East Texas might be useful to consider for further management plans. He suggests two groups of ameliorating actions: 1) close sites temporarily or rotate use of sites periodically and 2) rototill the soil, add organic matter in the form of wood or bark chips and plant grass.

Periodic inventorying of existing conditions on campsites would be useful to determine the amount of change in camping facilities. Frissel (1978) has developed a scheme for classifying and judging camping areas by the degree of deterioration and suggests management programs for each type of site. Based on visual criteria, the technique may be easily applied at all sites and allows the manager to compare conditions and identify over-use areas.

A pocket penetrometer would be a useful tool to determine the amount of soil compaction at campsites. Observations by Ward and Berg (1973) indicate that trees and grasses may not be adversely affected by compaction if the penetrometer readings are less than about 14,600 kg/sq. m. If sites have readings above this value, soil restoration may be in order.

Researchers should continue to focus efforts on ways to alleviate management problems in parks. There is a need to identify and develop trampling tolerant species, to increase soil porosity and aeration, to do site planning, and to increase visitor awareness of practices that will preserve the aesthetic qualities of the environment.

Ultimately, the problem of camping impact on the environment involves a set of conflicting values. On one side is the preservationist or purist who advocates that wilderness or park ecosystems be maintained at the expense of human use if possible. On the other side is the recreationist who proposes the exploitation of the landscape to enhance or provide recreational opportunities. In between these two extremes are a host of alternate philosophies. Managers, administrators and policy makers are confronted by all of them. The dilemma is to choose which philosophy or compromise philosophy will be used as a basis for decisions on park use.

Scientists will not be able to give managers all the information they need to make decisions on the use and preservation of parks. Managers must look to society and its values to determine how much change and what kind of change will be allowed in the park landscapes.

The responsibility for our recreational facilities and their continued use rests with the public and with managers. First of all, it is the public's responsibility to voice opinions on current park policies, rules and regulations, in terms of their likes and dislikes. Without public opinion, needs cannot be adequately met. Secondly, managers must be willing to meet the public's needs through appropriate action based on a consensus of their opinions. Only through cooperative efforts on the part of the public, the park administrators and managers can sound decisions on park utilization be made. As with any resource, park management goals should focus on wise sound management for the present and the future.

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APPENDIX A

FLORA OF SITES EXAMINED AT TYLER STATE PARK

APPENDIX A

FLORA OF SITES EXAMINED AT TYLER STATE PARK

The list below represents the flora of Tyler State Park as examined by categories of park use. Species were either identified in the field or collected and keyed later. Each species is classified by the type of site in which it was found, i.e., intensive (I), managed (M), transition (T), or control (C). The nomenclature of all species follows that in Correll and Johnston (1970).

POLYPODIACEAE

Pteridium aquilinum var. _pseudocaudatum_ (Clute) Heller, bracken*

T

PINACEAE

Pinus echinata Mill., shortleaf pine

I, M, T, C

Pinus taeda L., loblolly pine

I, M, T, C

CUPRESSACEAE

Juniperus virginiana L., eastern red cedar

I, M, T, C

GRAMINEAE

Aira elegans Gaud.

M

Andropogon ternarius Michx., splitbeard bluestem

M, T, C

---

*Only common names to the Tyler area will be mentioned.

Aristida _purpurascens_ Poir., arrowfeather three-awn

T, C

Bromus _unioloides_ H.B.K., rescue grass

M

Chasmanthium _latifolium_ (Michx.) Yates, broadleaf chasmanthium

I, T

Chasmanthium _sessiliflorum_ (Poir) Yates, longleaf chasmanthium

I, T, M, C

Cynodon _dactylon_ (L.) Pers., Bermuda grass

I, M

Elymus _canadensis_ L., Canada wild-rye

M

Hordeum _pusillum_ Nutt., little barley

M

Leersia _virginica_ Willd.

T

Lolium _perenne_ L., ryegrass

M

Panicum _commutatum_ Schult.

M, T

Panicum _lanuginosum_ Ell.

M

Panicum _laxiflorum_ Lam.

I, M, T

Panicum _linearifolium_ Scribn.

M, T

Panicum oliogosanthes Schult.

I, T, C

Panicum ravenelii Scribn. & Merr.

I, T, C

Paspalum dilatatum Poir., dallis grass

I

Poa annua L.

M

Stenotaphrum secundatum (Walt.) O. Ktze., St. Augustine grass

M

CYPERACEAE

Carex digitalis Willd.

I

Carex sp.

T, C

Scleria oligantha Michx.

C

COMMELINACEAE

Commelina erecta L.

M

Tradescantia occidentalis (Britt.) Smyth

T

JUNCACEAE

Juncus effusus var. *solutus* Fern. & Wieg., soft rush

C

LILIACEAE

Nothoscordum bivalve (L.) Britt., crow-poison

M

Smilax Bona-nox L., saw greenbriar

I, M, T, C

Smilax rotundiflora L., common greenbriar

I, M, T, C

Yucca louisianensis Trel., Louisiana yucca

C

MYRICACEAE

Myrica cerifera L., southern wax-myrtle

I, T, C

JUGLANDACEAE

Carya texana Buckl., black hickory

I, M, T, C

Carya tomentosa Nutt., mockernut hickory

I, M, T, C

Juglans nigra L., black walnut

M, T, C

BETULACEAE

Alnus serrulata (Ait.) Willd., hazel alder

T

Betula nigra L., river birch

I, T

Ostrya virginiana (Mill.) K. Koch., eastern hop-hornbeam

C

FAGACEAE

Quercus falcata Michx., southern red oak

I, M, T, C

Quercus marilandica Muenchh., blackjack oak

I, M, T, C

Quercus nigra L., water oak

I, M, T, C

Quercus stellata Wang., post oak

I, M, T, C

Quercus velutina Lam., black oak

I, T, C

ULMACEAE

Celtis laevigata Willd., sugar hackberry

I, M, T, C

Ulmus alata Michx., winged-elm

I, M, T, C

Ulmus rubra Muhl., slippery elm

I, M, C

MORACEAE

Morus rubra L., red mulberry

I, M, T, C

POLYGONACEAE

Eriogonum longifolium Nutt.

C

CARYOPHYLLACEAE

Cerastrium glomeratum Thuill.

M

RANUNCULACEAE

Clemantis reticulata Walt.

C

BERBERIDACEAE

Podophyllum peltatum L., may-apple

M

ANNONACEAE

Asimina parviflora (Michx.) Dun., dwarf pawpaw

M

LAURACEAE

Sassafras albidum (Nutt.) Nees., sassafras

I, M, C

CRUCIFERAE

Lepidium virginicum var. *virginicum* L., Virginia pepperweed

M

HAMAMELIDACEAE

Liquidambar styraciflua L., sweet-gum

I, M, T, C

ROSACEAE

Crataegus brachycantha Sarg. & Engelm., blueberry hawthorne

T

Fragaria virginiana Duchn., wild strawberry

C

Prunus gracilis Engelm. & Gray, Oklahoma plum

T, C

Prunus mexicana Wats., Mexican plum

M, T

Prunus serotina Ehrh., black cherry

I, M, T

Rubus trivialis Michx., southern dewberry

M, T, C

LEGUMINOSAE

Albizia julibrissin Durazz., mimosa-tree

C

Baptisia leucantha T. & G.

M

Baptisia Nuttalliana Small., nuttall wild indigo

M, C

Cassia fasciculata var. fasciculata, Michx., partridge pea

C

Ceris canadensis var. canadensis L., eastern redbud

I, M, T, C

Desmodium laevigatum (Nutt.) D.C.

C

Desmodium Nuttallii (Schindl.) Schub.

M, C

Desmodium sessiliflorum (Torr.) T.& G.

T

Desmodium viridiflorum (L.) D.C.

T

Erythrina herbacea L., coral bean

M

Gleditsia triacanthos L., common honey locust

M

Lespedeza procumbens Michx., trailing bush clover

M

Lespedeza stuevei Nutt., tall bush clover

T

Lespedeza virginica (L.) Britt. slender bush cover

T

Medicago lupulina L., black medick

I, M

Rhynchosia latifolia (Nutt.) T. & G., broadleaf snoutbean

C

Schrankia uncinata Willd., catclaw sensitive briar

T

Strophostyles umbellata (Willd.) Britt.

M, C

Stylosanthes biflora (L.) B.S.P., pencil flower

M

GERANIACEAE

Geranium carolinianum L.

M

OXALIDACEAE

Oxalis dillenii Jacq.

M

EUPHORBIACEAE

Acalypha monococca (Engelm.) L. Mill.

M

Tragia urticifolia Michx.

T

ANACARDIACEAE

Rhus aromatica Ait.

T, C

Rhus glabra L., smooth sumac

M, T, C

Rhus toxicodendron L., poison ivy, poison oak

I, M, T, C

ACERACEAE

Acer rubrum L., red maple

M, T

RHAMNACEAE

Berchemia scandens (Hill) K. Koch., Alabama supple-jack

M, T, C

Ceanothus americanus var. *Pitcheri* T. & G., New Jersey tea

I, C

Rhamnus caroliniana Walt., Carolina buckthorn

M, C

VITACEAE

Ampelopsis arborea (L.) Koehne., pepper-vine

C

Parthenocissus quinquefolia (L.) Planch., Virginia creeper

T, C

Vitis aestivalis Michx.

C

Vitis rotundifolia Michx., muscadine grape

I, M, C

HYPERICACEAE

Ascyrum hypercoides L., St. Andrew's cross

I, M, T, C

VIOLACEAE

Viola sagittata Ait., arrow-leaved violet

T

PASSIFLORACEAE

Passiflora lutea L.

T

ARALIACEAE

Aralia spinosa L., angelica-tree

M, C

UMBELLIFERAE

Daucus carota L., Queen Anne's lace

M

Hydrocotyle umbellata L., umbrella pennywort

M

Sanicula canadensis L.

T

CORNACEAE

Cornus florida L., flowering dogwood

I, M, T, C

Nyssa sylvatica var. *sylvatica* Marsh., black tupelo

M, T, C

ERICACEAE

Lyonia ligustrina (L.) D.C.

T

Vaccinium stamineum L., common deerberry

I, M, T, C

SAPOTACEAE

Bumelia lanuginosa var. *albicans* Sarg.

I, C

OLEACEAE

Fraxinus americana L., white ash

I, M, T, C

VERBENACEAE

Callicarpa americana L., American beauty berry

I, M, T, C

Phyla incisa Small.

C

LABIATAE

Scutellaria cardiophylla Engelm. & Gray

M, C

BIGNONIACEAE

Campsis radicans (L.) Seem., common trumpetcreeper

M, T, C

ACANTHACEAE

Ruellia pedunculata Torr.

I, M, C

PLANTAGINACEAE

Plantago Hookeriana Fisch. & Mey.

C

Plantago virginica L.

C

RUBIACEAE

Cephalanthus occidentalis L., common button bush

C

Galium pilosum Ait., hairy bedstraw

C

Mitchella repens L., partridgeberry

T

CAPRIFOLIACEAE

Lonicera japonica Thunb., Japanese honeysuckle

I, M, T, C

Viburnum prunifolium L., black-haw

C

Viburnum rufidulum Raf., southern black-haw

I, M, T, C

VALERIANACEAE

Valerianella radiata var. *radiata* (L.) Dufr.

M

COMPOSITAE

Ambrosia artemisiifolia L., common ragweed

M, C

Aster patens Ait.

I, T

Baccharis halimifolia L., eastern baccharis

T

Berlandiera pumila (Michx.) Nutt.

C

Erigeron strigosus Willd.

T

Heterotheca pilosa (Nutt.) Shinners

M

Lactuca canadensis L., wild lettuce

M

Rudbeckia hirta L.

M

Solidago altissima L.

M, C

Solidago delicatula Small.

T

Solidago nemoralis Ait.

C

Solidago petiolaris Ait.

T

Solidago rugosa var. *celtiolifolia* (Small) Fern.

T

Sonchus asper (L.) Hill

C

Vernonia texana (Gray) Small.

M, T

VITA

Janet Elaine Koehler, daughter of Mr. and Mrs. E.L. Koehler, was born September 13, 1950 in Van Nuys, California. She graduated from Douglas MacArthur High School in San Antonio, Texas in May, 1969 and that fall entered Southwest Texas State University. After two years of study, she returned to San Antonio. In spring 1975 she transferred to Texas A&M University where she received a B.S. in Geography in December, 1976. In spring 1977 she entered Texas A&M University as a graduate student in Geography with a specialization in biogeography.

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This thesis was typed by Sandra Jobes.

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