IMPACT OF RECREATION ON VEGETATION AND SOILS IN RUSHING RIVER PROVINCIAL PARK, ONTARIO

E. E. MACKINTOSH

DEPARTMENT OF LAND RESOURCE SCIENCE

UNIVERSITY OF GUELPH

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Information Office,
Great Lakes Forest Research Centre,
Canadian Forestry Service,
Department of the Environment,
Box 490,
Sault Ste. Marie, Ontario.
P6A 5M7

Provincial Parks Branch,
Ontario Ministry of Natural Resources,
Parliament Buildings,
Queen's Park,
Toronto, Ontario.
M7A 1W3

PREFACE

Work on this project was begun in the summer of 1973 and was concluded in the spring of 1977. Phase A of the investigation consisted of an evaluation of the impacts of recreation on vegetation and soil and was funded directly by the Great Lakes Forest Research Centre in Sault Ste. Marie. Phase B was funded jointly by the Great Lakes Forest Research Centre and the Provincial Parks Branch of the Ontario Ministry of Natural Resources. Research in this phase of the investigation was aimed at devising and testing methods of minimizing and ameliorating adverse impacts of recreation use upon campground areas.

The project was carried out under the supervision of Dr. D. W. Smith, Department of Botany, and Dr. E. E. Mackintosh, Department of Land Resource Science, University of Guelph. Much of the work was completed by research associates and graduate students, of whom Messrs. M. K. Hoffman, T. James and P. Monti in particular deserve recognition.

This report summarizes the investigation and draws on material from the following reports and theses:

Grant, G. 1976. Physical site characteristics and user preference for campsites. Univ. Guelph, Dep. Land Resour. Sci., BSc thesis.

Hoffman, M. K. 1975. Quantification of vegetation change concomitant with recreation use. Univ. Guelph, Dep. Land Resour. Sci., MSc thesis. 147 p.

Hoffman, M. K., Mackintosh, E. E. and Smith, D. W. 1974. Impact of recreational use on soil and vegetation in Rushing River Provincial Park. Interim Report - Phase A. Prepared for Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. 31 p.

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James, T., Monti, P., Mackintosh, E. E. and Smith, D. W. 1976. Impact of recreation use on soil and vegetation in Rushing River Provincial Park, Kenora, Ontario. Interim Report - Phase B. Prepared for Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. and Ont. Min. Nat. Resour., Prov. Parks Br., Toronto, Ont. 100 p.

Monti, P. 1977. Effects of intensive recreational activities on soil organic matter loss in the boreal forest region. Univ. Guelph, Dep. Land Resour. Sci., MSc thesis. 89 p.

Monti, P., James, T., Mackintosh, E. E. and Smith, D. W. 1977. Impact of recreation use on soil and vegetation in Rushing River Provincial Park. Final Report - Phase B. Prepared for Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. and Ont. Min. Nat. Resour., Prov. Parks Br., Toronto, Ont. 52 p.

AVANT PROPOS

Les travaux relatifs à ce projet furent entrepris à l'été 1973 et terminés au printemps 1977. La phase A de l'enquête consistait en une évaluation des incidences des activités récréatives sur la végétation et le sol et était directement financée par le Centre de recherche forestière des Grands lacs, à Sault Ste-Marie. La phase B tirait ses fonds de la même source conjointement avec la Division des parcs provinciaux, du ministère des ressources naturelles de l'Ontario. Dans cette phase, la recherche avait pour but d'imaginer et d'expérimenter des méthodes de minimisation et d'amélioration des effets adverses des activités récréatives sur les terrains de camping.

Le projet fut conduit sous la supervision du Dr. D. W. Smith, du département de Botanique et du Dr. E. E. Mackintosh, du département de Sciences des ressources de la terre, Université de Guelph. Une bonne partie des travaux fut complétée par des rechercheurs associés et étudiants gradués, dont Messrs. M. K. Hoffman, T. James et P. Monti en particulier méritent une mention spéciale.

Ce rapport résume l'enquête en s'étayant sur les thèses et rapports suivants:

Grant, G. 1976. Physical site characteristics and user preference for campsites. Univ. Guelph, Dep. Land Resour. Sci., BSc thesis.

Hoffman, M. K. 1975. Quantification of vegetation change concomitant with recreation use. Univ. Guelph, Dep. Land Resour. Sci., MSc thesis. 147 p.

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FOREWORD

Unmanaged recreational use can lead to the deterioration of fine camping areas as well as other interesting recreation sites. Only recently have scientists joined forces to examine the effects of such use upon wildland ecosystems and to find ways of preventing their deterioration. By integrating their efforts, researchers and practitioners are gaining a deeper appreciation of man's recreational use of forest stands and are more aware of opportunities for better management in the future.

This manual is an offshoot of research conducted between 1972 and 1977 at Rushing River Provincial Park near Kenora in northwestern Ontario. The University of Guelph, Department of Land Resource Science conducted the study under contract as part of ongoing work at the Great Lakes Forest Research Centre concerned with the impact of forest management practices on the forest ecosystem. The study was funded jointly by the Provincial Parks Branch, Ontario Ministry of Natural Resources and the Great Lakes Forest Research Centre, Environment Canada.

The first two years of the study were spent determining the impact of various intensities of use upon the soil and vegetation of recreation sites in the boreal forest, with emphasis on camping sites. The remaining years were devoted to a study of methods of promoting the recovery of degraded campsites by watering, seeding, exclusion, fertilization, etc., as well as reviewing the basic design of campgrounds to suggest methods of limiting the size of heavy impact areas on recreational sites. In formulating this park management manual the authors have drawn on the literature as well as on their own experience gained in the course of the study.

Between 1965 and 1975 Ontario provincial park statistics show that visitations increased from 8.8 to 11.1 million, the number of campsites increased from 15,427 to 20,322 and, what is most important, camper numbers almost doubled from 2.5 to 4 million. The numbers are expected to increase annually, and this indicates a continuing need for all levels of government to maintain a fundamental expertise in park planning and management for the ultimate benefit of all Canadians. Though directed mainly toward Ontario provincial parks, this manual should also be of interest to other recreation land managers, whether they be in the national, provincial, municipal or private enterprise categories.

J. H. Cayford
Director
Great Lakes Forest Research Centre
Canadian Forestry Service

R. J. Vrancart
Director
Provincial Parks Branch
Ontario Ministry of Natural Resources

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BACKGROUND

Significant increases in the recreational use of parks have been recorded in Canada over the past decade. In response to the increasing demand, numerous federal and provincial parks have been created to supplement older established parks. As a result of increased use, however, some of the older parks are beginning to show signs of deterioration.

Camping, in particular, has various adverse effects on surrounding vegetation and soil, among them losses in ground cover, changes in species composition, soil erosion and compaction, loss of overstory vegetation, and eventually, a reduction in aesthetic quality (Frissell and Duncan 1965, La Page 1967, Settergren and Cole 1970, Echelberger 1971). Continued use of campsites under these conditions gradually leads to deterioration in overall site quality and, in extreme cases, abandonment of site.

Detailed information relating the intensity and duration of recreational use to site degradation is lacking. A number of recent studies have addressed the problem and these provide a limited factual base on which to develop design alternatives (Orr 1971, Verburg[1]), but there is little information for Canadian conditions. Further, a number of management techniques are now available to minimize site degradation within campground areas, increase their carrying capacities and ameliorate adverse impacts where they occur, but again, scant information is available for the boreal forest.

There is also strong evidence to suggest that site degradation is closely associated with site design. Development of design alternatives in relation to resource constraints can help minimize the adverse impacts of camping and improve the quality of recreational experiences.

This investigation was undertaken to evaluate the impact of intensive recreation upon soil and vegetation in camping grounds in the boreal forest region of northwestern Ontario. At the request of the Great Lakes Forest Research Centre, work was carried out at Rushing River Provincial Park. Phase A of the contract was designed to answer the question: "What changes occur in vegetation and soils as a result of recreation traffic?", while Phase B addressed the problem of minimizing and ameliorating adverse impacts of recreation use.

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[1]Verburg, K. 1974. The carrying capacity of selected outdoor recreational facilities. Part I. Planning and management guidelines for selected recreational facilities. Prepared for Dep. Ind. North. Aff., Parks Can. 70 p. (unpubl. rep.)

SITE CHARACTERISTICS

General

The study was undertaken at Rushing River Provincial Park southeast of Kenora in northwestern Ontario (Fig. 1). The site is within Rowe's (1972) Section 11 of the Great Lakes—St. Lawrence Forest Region but is characterized by the prominence of boreal tree species, including jack pine (*Pinus banksiana* Lamb.), trembling aspen (*Populus tremuloides* Michx.,), white birch (*Betula papyrifera* Marsh.), balsam fir (*Abies balsamea* [L.] Mill.), white spruce (*Picea glauca* [Moench] Voss), and black spruce (*Picea mariana* [Mill.] B.S.P.).

The climate of the region is characterized by cold winters and cool summers. The January mean daily minimum temperature is -22°C and the July mean daily maximum temperature is 25°C (Rowe 1972). The mean annual precipitation is 61 cm with a summer concentration. However, precipitation varies considerably both seasonally and annually.

The area is composed of bare rock hills and ridges of Precambrian origin, with narrow and broad glacial filled valleys interspersed with lakes. Soils throughout the area are extremely acid (pH 4.5-5.4) and have an inherently low nutrient status. The upland areas are characterized by numerous rock outcrops and shallow soils (dystric brunisols) overlying bedrock. Lowland areas are generally of two types: well drained, humo-ferric podzols developed on colluvial-glacial till, and imperfectly to poorly drained soils developed on colluvial and alluvial sands. The bog areas consist of organic soils (mesisol) of intermediate decomposition (Anon. 1971.).

Park Area

Those portions of the park in which the campsites are found support two communities of vegetation described and named by their dominant tree species[2]: jack pine and trembling aspen. The pine community is restricted largely to areas of broken topography characterized by frequent outcroppings of granitic bedrock. The soils consist of shallow regosols, dystric brunisols or humo-ferric podzols overlying bedrock, with pockets of deeper material in bedrock fissures or depressions.

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[2]Hoffman, M.K., James, T., Mackintosh, E.E. and Smith, D.W. 1975. Impact of recreational use on soil and vegetation in Rushing River Provincial Park, Kenora, Ontario. Final Report - Phase A. Prepared for Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. 74 p. (unpubl. rep.)

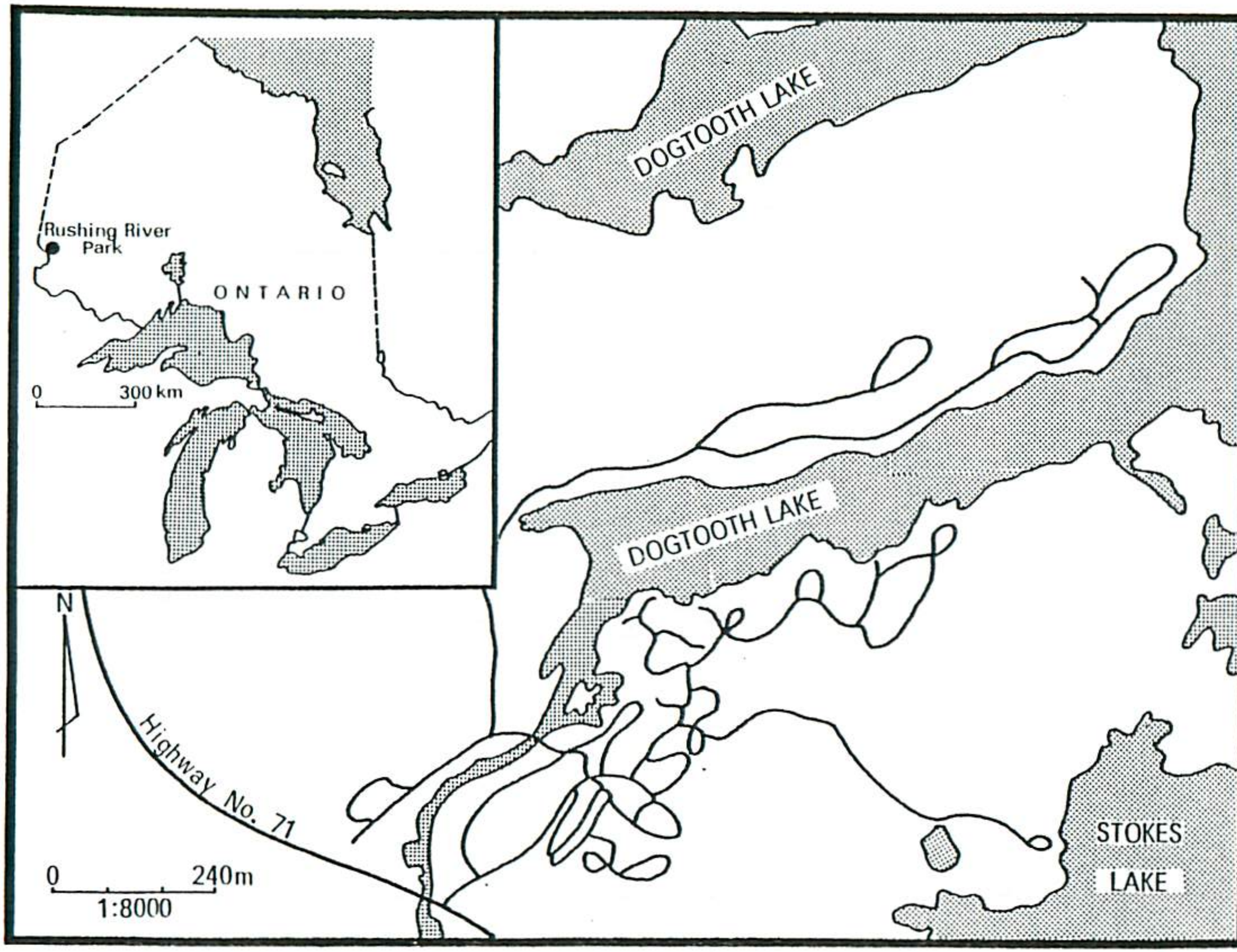

Fig. 1. Rushing River Provincial Park.

The trembling aspen community occurs in areas of variable topography, but is most common where there are gentle slopes and little or no bedrock exposure. The soils are generally deeper and more poorly drained than those supporting the pine community.

Campsite Use Characteristics

The park is heavily used for daytime activities and camping and is usually filled to near capacity during July and August[3]. The main users are weekend campers from Winnipeg and urban areas on the western shore of Lake Michigan. The park is used heavily by tourists travelling east and west along Highway 17 as well. In a recent report[4] prepared by the Ontario Ministry of Natural Resources it is classified as a recreation park.

ENVIRONMENTAL ASPECTS OF RECREATIONAL CARRYING CAPACITY

The Approach

Vegetation was sampled systematically in the summer months of 1973 to include areas distant from established campgrounds, the land occupied by campsites, and associated facilities within the park boundaries. The density, basal area and frequency of trees (over 5 cm DBH) were measured by the point-quarter method while frequency and cover of shrub and herbaceous vegetation were estimated using a 2 m line-intercept. Cover estimates included measures of bare rock, exposed mineral soil and surface leaf litter layer.

The initial step in the synthesis and interpretation of the vegetation data involved cluster analysis (Ward 1963, Lance and Williams 1966) to distinguish the main vegetation communities for the park, i.e., jack pine and trembling aspen. This information, together with the age-use information on campsites, was used in selecting individual campsites for further detailed investigation.

The campsite use-intensity classes were determined from analysis of 1972 and 1973 campsite permits and assigned the numerical

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[3]Hoffman, M.K., Mackintosh, E.E., and Smith, D.W. 1974. Impact of recreation on soil and vegetation in Rushing River Provincial Park. Interim Report - Phase A. Prepared for Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. 31 p. (unpubl. rep.)

[4]Anon. 1978. Ontario provincial parks: planning and management policies. Ont. Min. Nat. Resour., Toronto, Ont. (unpubl. rep.)

values of 3 (high use), 2 (medium use) and 1 (low use), on the basis of the total number of camper-days per year that sites were occupied (Fig. 2). Age-use interaction terms were then developed[2] by multiplying the campsite development ages by the numeric use values and dividing these into four age-use classes: Class 1-(1-14); Class 2-(15-29); Class 3-(30-44); and Class 4-(45-56).

The changes in biotic communities arising from these different durations and intensities of use were assessed by quantitative vegetation analysis. Vegetation on individual campsites was sampled in June and August by estimating plant species cover on 2 m line-intercepts placed at 0, 5, 10, 15 and 20 m intervals at right angles to the 20 m transect lines (Fig. 3). The data were analyzed by means of principal component analysis. The ordinations were based on the vegetation-ground cover data for each intercept data set; e.g., data from intercept 1 were analyzed separately from those of intercept 2 and from the other three intercepts. The segregation of data into intercept groups was necessary to avoid confusion arising from variation in cover along gradients of recreational impact within campsites. The analysis was designed to test the impact of recreation on different campsites within each vegetation unit.

The effects of differing intensities of recreational impact within the two vegetation units were further examined by comparing the mean total cover values of non-alien species (normally found on undisturbed sites) and alien species (not normally found on undisturbed sites) in each of the age-use interaction classes.

Recreation and Vegetation Changes at Rushing River Provincial Park

Modification of the vegetation and surface soil by recreational use occurred essentially along two gradients, spatial and temporal, through: (1) changes in vegetation and soil within each campsite along a gradient of intensity of use extending from high use to undisturbed areas; and (2) changes in vegetation and soil along a gradient of variation in the combined impacts of intensity and duration of recreational use.

<u>Changes in vegetation along gradients of intensity of use within campsites</u>: Ordination of intercepts from the pine community (Fig. 4) showed them to be distributed mainly along principal component 1. The distribution of points along the horizontal axis representing intercepts located at the edge of high impact areas (intercept 1) and undisturbed areas (intercept 5) verifies the observed dissimilarities in their vegetation and ground cover. The ordinations serve to define objectively the observable changes in vegetation along gradients of intensity of use within campsites. These changes include replacement of the recreation-intolerant natural vegetation by tolerant species. The changes

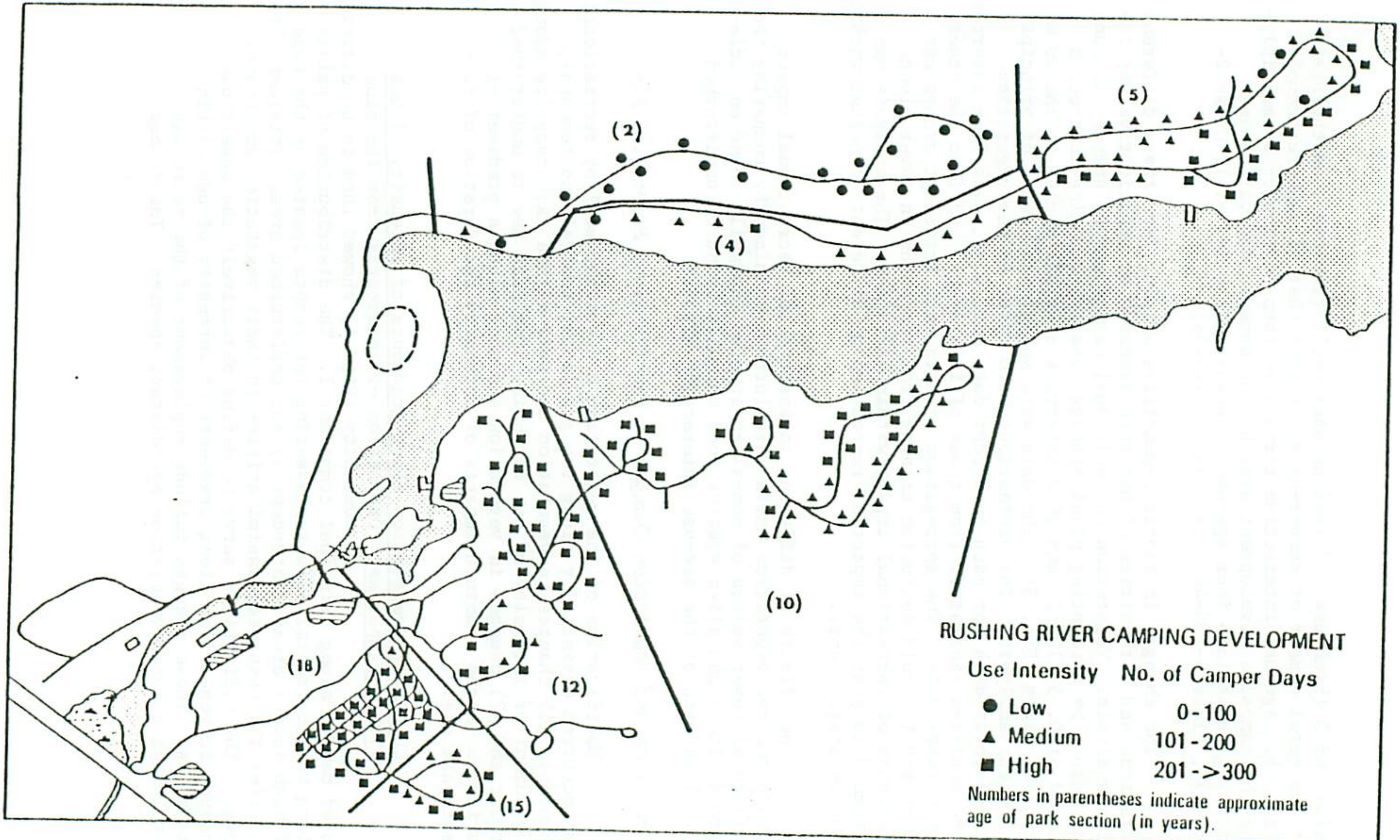
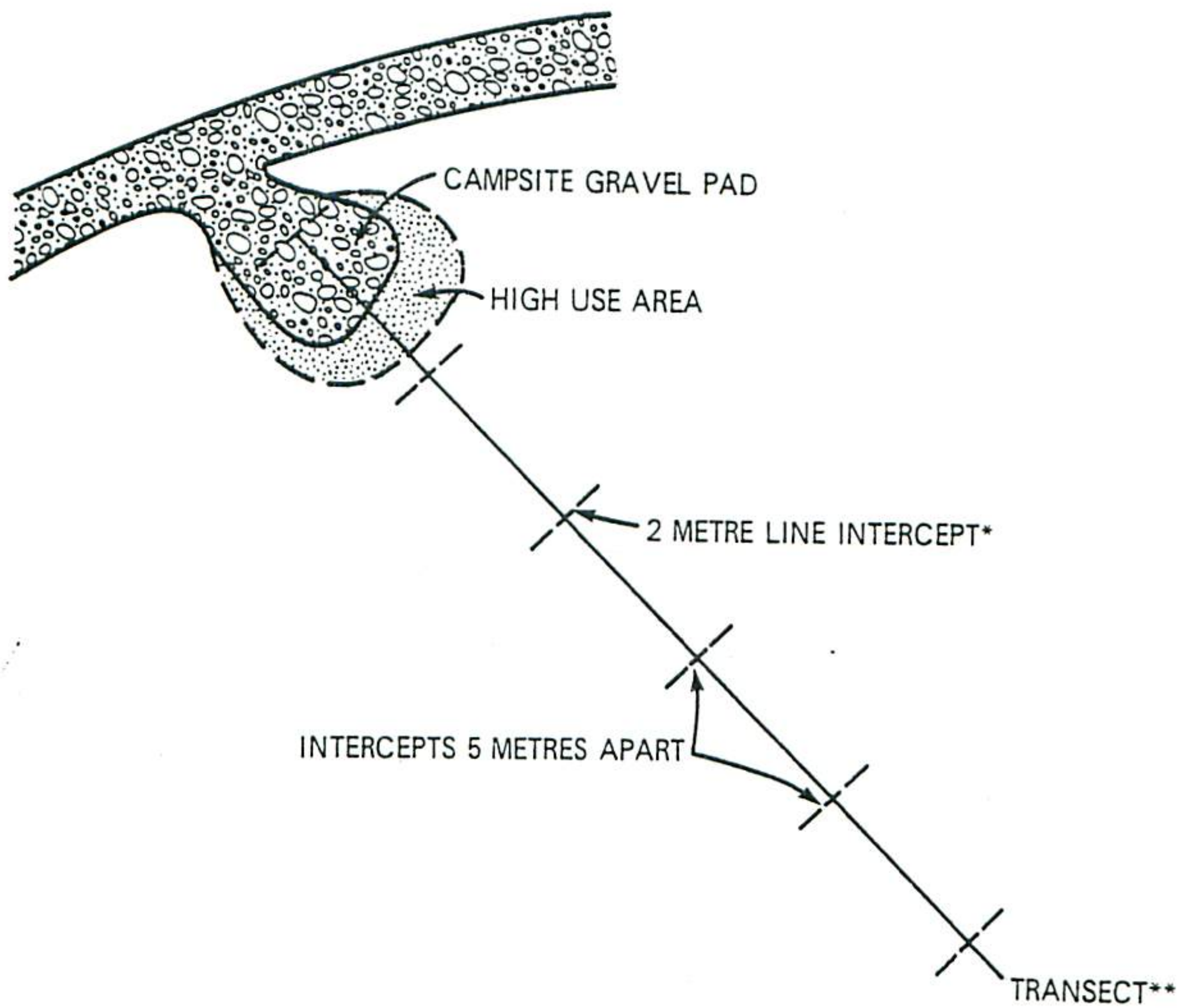


Fig. 2. Campsite use-intensity (average values for 1972 and 1973) and development age of park sections up to 1974.



*Measurements on line intercept:
i plant species
ii plant cover

** Transect follows a straight line through a jack pine or trembling aspen vegetation unit.

Fig. 3. Sampling scheme for vegetation analysis of individual campsites.

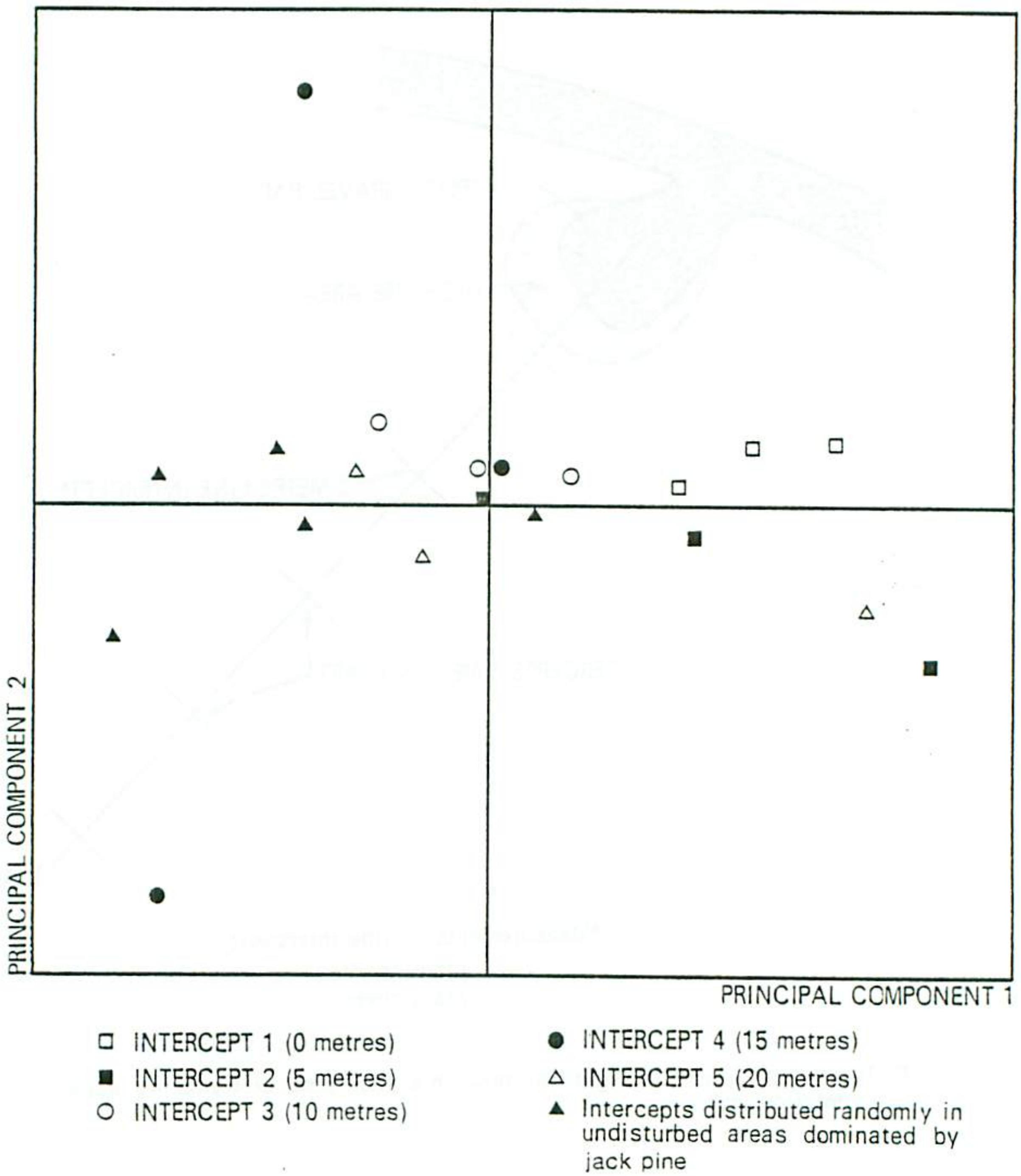


Fig. 4. Ordinated positions of intercepts from a jack pine campsite showing the gradient of user impact on principal component 1 and the gradient of floristic variation on principal component 2.

in plant cover on campsites were not uniform for all species but it was possible to group species according to their cover at each intercept (Table 1).

Group A essentially represented the more common indigenous species that were intolerant of recreational use. The cover of this group diminished along a gradient of increasing intensity of use from undisturbed (intercept 5) to high impact (intercept 1) areas. Group A was the most prominent in both communities because it contained species which together accounted for over 65% of the total plant cover on the campsites.

The reaction to use of the recreation-tolerant group B species was opposite to that of group A. The cover of group B was highest in areas of intense recreational use but diminished in less disturbed areas. Group A accounted for less total plant cover than did group A (14% jack pine, 9% trembling aspen).

Group C accounted for less than 10% and 25%, respectively, of the total plant cover on campsites in the jack pine and trembling aspen communities. However, the group contained most of the species in both vegetation types. These were of irregular distribution with very low total cover per line-intercept.

Changes in vegetation along gradients of intensity x duration of use. At intercepts 1 to 3 in the trembling aspen community, campsites were ordinated mainly on principal component 1 in groups corresponding to their use-intensity/duration classes (Fig. 5). The separation between campsites in low (1) and high (4) use intensity-duration classes in most instances was considerable, and this indicates a high degree of dissimilarity between these groups. In contrast, little or no separation of campsites was evident at intercept 5 (Fig. 5), and this suggests that there was little recreational impact at 20 m from high impact areas in campsites, irrespective of intensity and duration of use.

The ordinations at intercepts 1 and 3 showed greater separation of the least disturbed campsites (I.D. class 1) on principal component 2 than was the case on sites in the higher age-use classes (Fig. 5). These results supported the observation that high intensities and long duration of recreational use resulted in a vegetation of increased homogeneity in floristic composition and reduced species richness.

General observations. Visual observations of the land occupied by campsites at Rushing River Provincial Park indicated a close relationship between intensity of recreational use, vegetation, and soils. The basic relationships observed were as follows:

Table 1. Grouping of species from campsites within the jack pine and trembling aspen communities for the June, 1974 sampling; species grouped according to their total cover value per intercept.

Group A: Species that generally showed increased cover with increasing distance from high impact areas.

Jack pine community	Trembling aspen community
Amelanchier sanguinea	*Agrostis stolonifera*
Diervilla lonicera[a]	*Alnus rugosa*[a]
Gaultheria procumbens	*Aster macrophyllus*[a]
Juniperus communis	*Betula papyrifera*
Lichens (all spp. incl.)[a]	*Clintonia borealis*[a]
Lycopodium clavatum	*Cornus canadensis*[a]
Maianthemum canadense	*Corylus cornuta*[a]
Melampyrum lineare	*Danthonia spicata*
Mosses (all spp. incl.)[a]	*Diervilla lonicera*[a]
Oryzopsis racemosa	*Equisetum sylvaticum*
Pteridium aquilinum	Lichens (all spp. incl.)
Vaccinium angustifolium[a]	*Lycopodium clavatum*
	Lycopodium obscurum
	Maianthemum canadense[a]
	Petasites frigidus var. *palmatus*
	Populus tremuloides
	Streptopus roseus
	Vaccinium angustifolium[a]

Group B: Species that generally showed decreased cover with increasing distance from high impact areas.

Jack pine community	Trembling aspen community
Agrostis stolonifera	*Carex debilis*
Aster macrophyllus	*Carex* spp.
Aster sagittifolius	*Plantago major*
Fragaria virginiana	*Poa annua*[a]
Grass spp.	*Rubus strigosus*
Plantago major[c]	*Solidago* sp.
Poa annua	*Taraxacum officinale*
Spiraea latifolia	*Trifolium repens*
Taraxacum officinale[c]	
Trifolium repens	

(continued)

Table 1. Grouping of species from campsites within the jack pine and trembling aspen communities for the June, 1974 sampling; species grouped according to their total cover value per intercept. (concluded)

Group C: Species that generally showed variable cover and distribution.

Jack pine community	Trembling aspen community
Alnus rugosa[b]	*Acer spicatum*
Anemone quinquefolia[c]	*Amelanchier sanguinea*
Antennaria neglecta	*Anemone quinquefolia*
Aralia nudicaulis	*Apocynum androsaefolium*
Arctostaphylos uva-ursi	*Aralia nudicaulis*
Betula papyrifera	*Arctostaphylos uva-ursi*
Carex debilis[b]	*Aster sagittifolius*
Chimaphila umbellata	*Comandra umbellata*
Clintonia borealis	*Dryopteris austriaca* var. *spinulosa*
Comandra umbellata	*Epilobium angustifolium*
Cornus canadensis	*Fragaria virginia*
Corylus cornuta	*Galium triflorum*
Danthonia spicata	*Gaultheria procumbens*
Epilobium angustifolium	*Juniperus communis*
Equisetum sylvaticum[b]	*Lathyrus ochroleucus*
Lathyrus ochroleucus	*Ledum groenlandicum*
Lycopodium obscurum[b]	*Melampyrum lineare*
Lycopus asper[b]	Mosses (all spp. incl.)
Populus tremuloides	*Oryzopsis racemosa*
Potentilla tridentata	*Potentilla tridentata*[c]
Prunus pensylvanica	*Prunu pensylvanica*
Prunus pumila	*Pteridium aquilinum*
Pyrola rotundifolia[b]	*Pyrola rotundifolia*[b]
Salix humilis	*Ribes hirtellum*
Trientalis borealis	*Rosa carolina*
Viola conspersa	*Salix humilis*
	Salix spp.
	Trientalis borealis
	Viburnum opulus var. *americanum*[b]
	Viola conspersa[c]

[a] species contributing at least 4% of total vegetation cover.

[b] species that occurred only 15-20 m from high impact areas.

[c] species that occurred only 0-5 m from high impact areas.

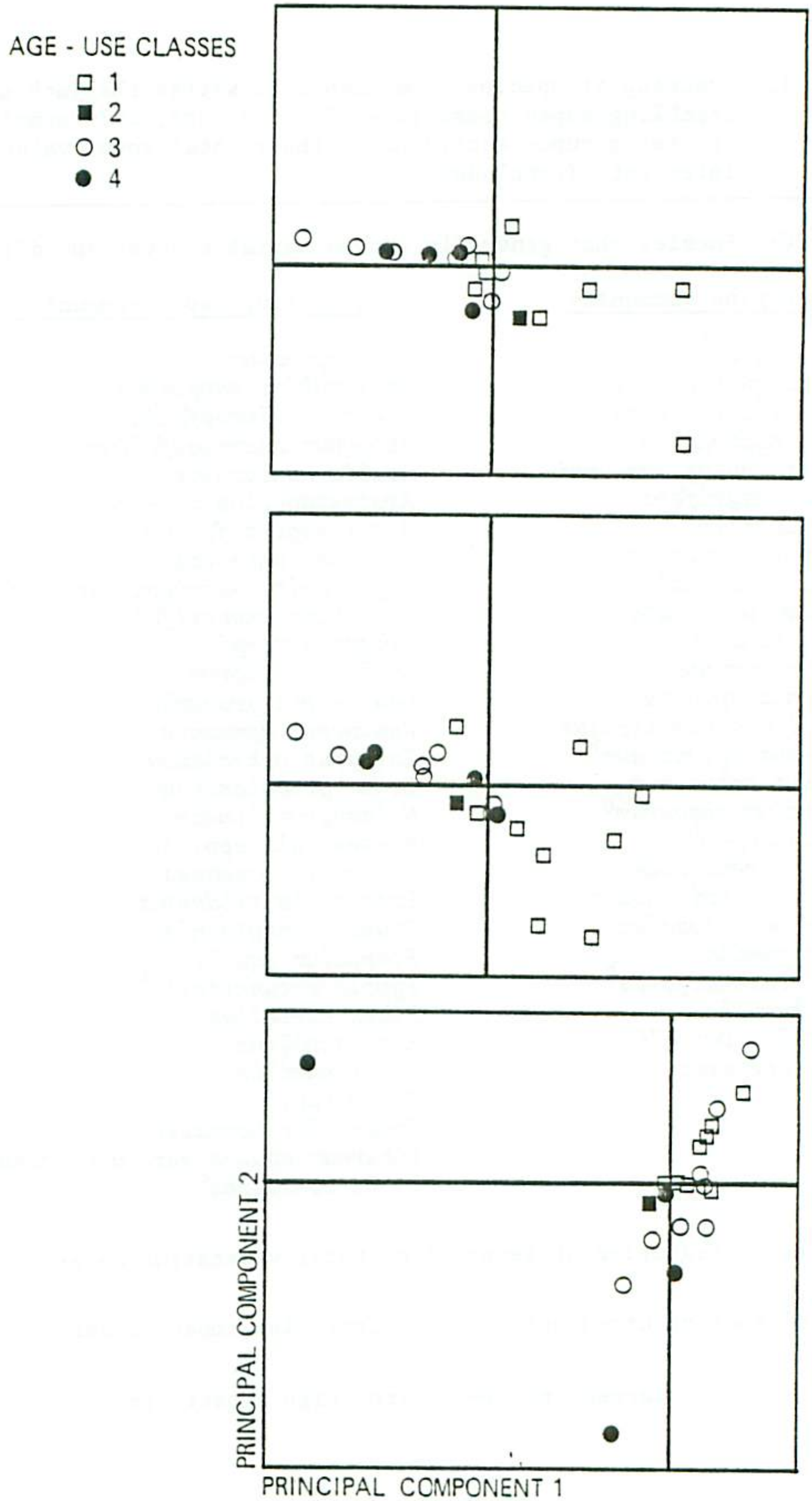


Fig. 5. Ordinated positions of campsites from trembling aspen communities subjected to varying intensities and durations of recreational use. Campsite vegetative cover estimates for June, 1974 at intercepts: 1 at 0 m (top); 3 at 10 m (middle); and 5 at 20 m (bottom).

i) Changes in vegetation and soils occurred along gradients of use intensity within campsites.

ii) Differences in vegetation and ground cover existed between campsites subjected to varying intensities of recreational impact.

Observations indicated changes in vegetation and ground cover along use-intensity gradients extending from the centre of the high impact area within campsites. The changes in vegetation are indicated in a generalized schematic cross-section of an average campsite (Fig. 6). Maximum camper activity occurred in the high impact area (zone A). This zone was generally characterized by:

i) little or no ground cover of vegetation;

ii) highly compacted soils often resulting in high surface runoff;

iii) soil erosion, especially on sloping sites with shallow soils;

iv) frequent exposure of tree roots, primarily as a result of compaction of soil and erosion of the surface litter layer;

v) frequent damage to trees as a result of vandalism or negligent parking of trailers or cars.

Soil erosion and tree root exposure were particularly common on sites in the jack pine vegetation unit. The thin, L-H horizons on these sites appeared very susceptible to erosion by surface runoff, especially on sloping sites following heavy rain.

A zone of 'weedy' species, zone B (Fig. 6), was usually present immediately adjacent to the high impact area. The natural vegetation in this zone was replaced by alien species such as *Poa annua*, *Plantago major* L., *Trifolium repens* L., *Taraxacum officinale* Weber., and various species of grasses and sedges. Some of the modifications of the natural vegetation noted in this zone and in adjacent high impact areas (zone A) are as follows:

i) Most fleshy plants, such as *Clintonia borealis*, were absent.

ii) Most species of lichen were absent or showed diminished abundance in campsite areas but were very common in drier undisturbed habitats.

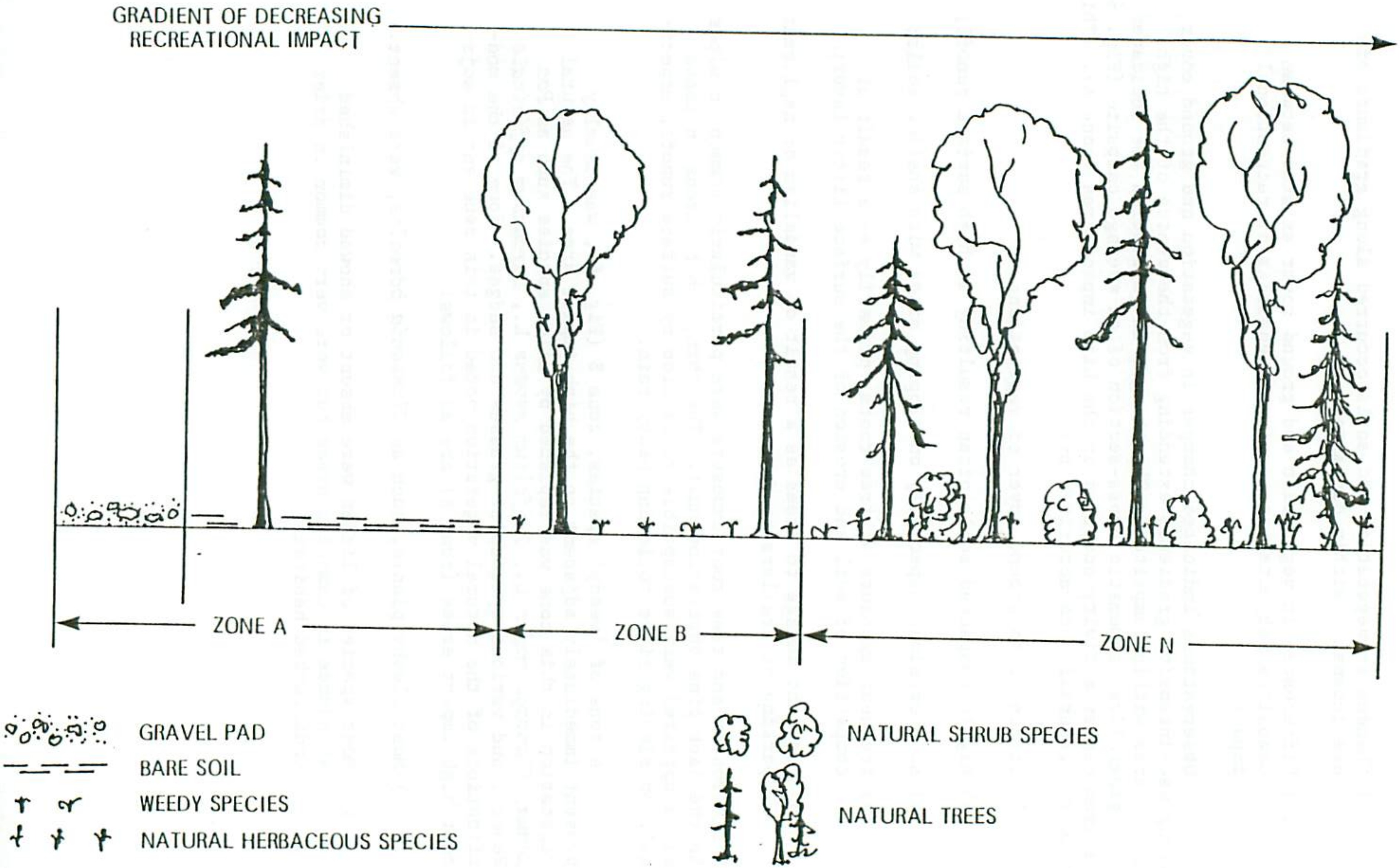


Fig. 6. Generalized schematic representation of plant cover for a campsite.

iii) Only a few natural species (mainly woody or low lying) seemed capable of survival near high impact areas, e.g., *Diervilla lonicera, Vaccinium angustifolium, Gaultheria procumbens, Fragaria virginiana, Maianthemum canadense* and *Cornus canadensis*. (All of these had a dwarfed habit when growing in high traffic areas.)

iv) Shrubby species such as *Vaccinium angustifolium* appeared very stunted, never produced fruit and were rarely seen to flower when growing in high traffic areas.

v) Many natural shrubs and young trees such as *Juniperus communis, Alnus rugosa, Corylus cornuta* and *Populus tremuloides* appeared absent or markedly diminished in abundance in high traffic areas.

The magnitude of these modifications to the natural vegetation and the abundance of 'weedy' species appeared to decline with increasing distance from high impact areas and the composition of zone N was similar to that of the natural control areas.

Many campsites were crossed by paths that modified the vegetation and ground cover in areas distant from the high impact zones. A zoning of vegetation similar to the use-intensity gradients within campsites was observed along paths, but the zones of impact were generally narrow. The deleterious effects of paths on the natural vegetation were most pronounced on sites dominated by jack pine.

Differing intensities of recreational impact seemingly altered the dimensions of the zones illustrated in Figure 6. The campsites in age-use classes 30-56 had larger A and B zones than did those in age-use classes 1-30. In the least used, newest campsite, zone A was frequently restricted to the gravel pad, while zone B was absent or very diminished, and undisturbed vegetation often extended to the edge of the high impact areas. The campsites subjected to the most intense impact contained greater numbers of trees with exposed roots in zones A and B, showed greater soil compaction, and were more prone to soil erosion than less used sites.

Highly resistant species possessed the following features: i) flattened leaves and reduced length of stems, e.g., *Plantago major* and *Taraxacum officinale*; ii) a capability for producing an abundance of seed under conditions of stress, e.g., grasses, sedges, *Taraxacum officinale* and *Trifolium repens*; and iii) small, narrow leaves growing from the base, e.g., sedges and *Poa annua*. Hence, resistance to recreational pressure could be related largely to plant morphology and reproductive response.

Natural Durability of Jack Pine

Many studies have suggested that recreational use of forested areas results in deterioration of the tree overstory. Adverse effects may range from slight changes in tree vigor and performance to death of individuals and consequent depletion of the forest stands. The nature and severity of these effects are largely a function of the tree species, intensity and duration of use, and site conditions.

A wide spectrum of impacts on forest trees that are related to recreation use have been documented and reviewed in detail[5]. A trend of increased root exposure with increasing duration and intensity of recreational use was quite evident.

Root exposure (Fig. 7) in campsites was closely related to soil compaction as reflected by increases in penetration resistance. Frisell and Duncan (1965) and Settergren and Cole (1970) also related root exposure to compaction, although they noted that erosion may be equally important, especially on sloping sites. The effects of soil compaction and erosion are difficult to segregate in the field. However, visual observations at Rushing River suggested that lowering of the soil surface by compaction was the major cause of root exposure[5]. Adverse effects of root exposure on the pine overstory included susceptibility of trees to drought and windthrow.

Also, there was little evidence of tree regeneration in impacted areas; hence, replacement of overstory losses is very slow. Similar observations have been made elsewhere (Lutz 1945, Frissell and Duncan 1965, Kalisz[6]).

The growth of jack pine trunks was significantly reduced in recreationally impacted areas (Table 2). The 38% reduction in trunk growth in the high impact areas of the most heavily used campsites compared to that in the undisturbed areas closely confirms observations made elsewhere on other tree species (La Page 1962, Magill and Nord 1963, Kalisz[6]). The results demonstrate conclusively that there is a close relationship between pine trunk growth and recreation-induced

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[5]James, T., Monti, P., Mackintosh, E.E. and Smith, D.W. 1976. Impact of recreation use on soil and vegetation in Rushing River Provincial Park, Kenora, Ontario. Interim Report - Phase B. Prepared for Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. and Ont. Min. Nat. Resour., Prov. Parks Br., Toronto, Ont. 100 p. (unpubl. rep.)

[6]Kalisz, S.B. 1975. The impact of use on vegetation, water relations, and physical site characteristics of forested recreation sites. Univ. Rhode Island, unpubl. MSc thesis. 135 p.

Fig. 7. Intense recreation use results in loss of surface litter layer and soil compaction. On shallow rooting soils, characteristic of the jack pine community, this leads to widespread root exposure and often loss of the overstory.

soil changes. Water stress resulting from soil changes is probably the most important factor responsible for reductions in tree vigor and production in recreation-impacted areas. Removal of L-F-H horizons (surface litter) by human traffic reduces the water holding capacity of the soil and moisture deficits are further increased by subsequent soil compaction, which results in reduced rates of water infiltration and increased surface runoff. As well, these soils contain only 4-5% available water storage capacity and therefore are subject to drought under normal conditions. The effects of compaction are enhanced by the formation of a hard erosion pavement of rocky fragments which accumulates at the soil surface. Overstory water stress resulting from these soil changes is aggravated on shallow soils by widespread root exposure and restriction of rooting volume.

Table 2. Relation of selected properties of jack pine to intensity of recreation use.

	Undisturbed area	Campsite age-use class 1	Campsite age-use class 3
Number of scars per trunk[a]	0	1.9 ± 0.5	4.3 ± 1.1
Trunk diameter 1 m above ground (cm)[a]	17.2 ± 0.7	18.6 ± 1.0	19.0 ± 1.0
Mean annual radial trunk growth 1 m above ground (cm/yr)[a]	0.11 ± 0.03	0.09 ± 0.03	0.09 ± 0.03
Mean annual radial trunk growth 2.5 m above ground (cm/yr)[b]	0.13 ± 0.03	0.10 ± 0.03	0.08 ± 0.02

[a] no significant difference at P.05 (Duncan's test)

[b] Age-use class 1 and 3 significantly different from those in undisturbed area at P.05 (Duncan's test)

Extensive mechanical damage to trunks in high-use areas was one of the more visually obvious effects of recreational activity on jack pine (Table 2). The average number of trunk scars per tree increased with use and was greatest in the high impact areas of the most intensively used campsites.

There was no evidence to suggest any correlation between trunk heart rot and the effects of recreational use, such as mechanical damage. Presumably, the resins and waxes exuded from the trunk of the pine following wounding form an extremely effective barrier to infection.

Substantial crown deterioration was indicated by significant reduction in needle area and production in high impact campsite areas compared to undisturbed areas (Table 3). Foliage production is reduced by even low levels of use and prolonged and intensive use has little additional effect. Widespread defoliation and consequent "stag-heading" were not evident at Rushing River Park; however, these problems have been noted in other parks (Settergren and Cole 1970). Reduced needle area in recreation-impacted areas probably has an adverse effect on pine production because of a reduction in its photosynthetic capability. There was no evidence for any compensating mechanism, such as increased numbers of needles on trees growing in high use areas. Reductions in needle area and production were closely related to increases in soil strength and decreases in infiltration rate and organic litter thickness. There was no evidence to suggest any correlation between foliage growth and indices of vigor, such as rust infection of needles. This result generally parallels the observation of Ripley (1962) who noted no difference in insect or disease damage to trees between campsites and undisturbed areas in the southeastern United States.

Table 3. Relationship of foliage properties of jack pine to recreation use.

Undisturbed area	Campsite age-use class 1	Campsite age-use class 3
Needle length (cm)[a]		
3.8 ± 0.1	3.4 ± 0.1	3.2 ± 0.7
Area of 100 needles (cm^2)[a]		
37.2 ± 1.8	28.9 ± 1.6	28.6 ± 1.4
Dry weight of 100 needles (g)[a]		
1.2 ± 0.1	1.0 ± 0.1	0.9 ± 0.4

[a] classes 1 and 3 significantly different from those in undisturbed area at $P_{.05}$ (Duncan's test)

The reactions of the various tree components to recreational use, while noticeable, were generally undramatic. Jack pine is relatively tolerant of stress resulting from recreation. A high tolerance by this species of natural environmental stress is indicated by the distribution of stands in areas of shallow, drought-prone, nutrient-poor soils.

Recreation and Soil Changes at Rushing River Provincial Park

Surface litter (L horizon). Observations on recreational impact in the southern boreal forest have indicated that one of the dominant factors in campsite degradation is the rapid loss of surface organic matter that exists primarily as partially decomposed or undecomposed leaf litter[5]. On many forested campsites, this thin covering of organic litter plays a crucial role in the survival of plant and tree species.

The initial effect of recreation is the trampling of the ground vegetation and the compression and reduction in thickness of the L-H horizon (Fig. 8). This results in a high mortality rate and loss of the living plant cover. Excessive traffic causes physical breakdown of the large undecomposed organic components of the litter (i.e., leaves, twigs, stems) into small particles, a process normally undertaken by the soil macro-fauna (Burges 1965). The reduction in particle size (i.e., an increase in surface area) increases the susceptibility of the organic matter to biological attack. The results of investigation of microbial respiration patterns[7] in litter and mineral soil from campsites indicate that the organic matter is well decomposed and resistant to further microbial breakdown.

The loss of litter appears to proceed quickly once recreational activities are introduced into natural areas. Complete litter loss after periods of four to five summers of medium to heavy recreational use is common. Under extreme conditions, this process can occur within one or two weeks. An investigation of 11 campsites (Table 4) has revealed significant reductions in litter thickness from undisturbed to high use areas. Differences range on the average from less than 1 cm to greater than 4 cm and presumably represent compaction of the litter by human traffic, accelerated decomposition of the organic matter, and/or erosion of surface material.

On campsite areas subjected to intensive recreational pressure for long periods of time (e.g., zone A, Fig. 6) complete loss of litter

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[7]Monti, P., James, T., Mackintosh, E.E. and Smith, D.W. 1977. Impact of recreation use on soil and vegetation in Rushing River Provincial Park, Kenora, Ontario. Final Report - Phase B. Prepared for Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont., and Ont. Min. Nat. Resour., Prov. Parks Br., Toronto, Ont. 52 p.

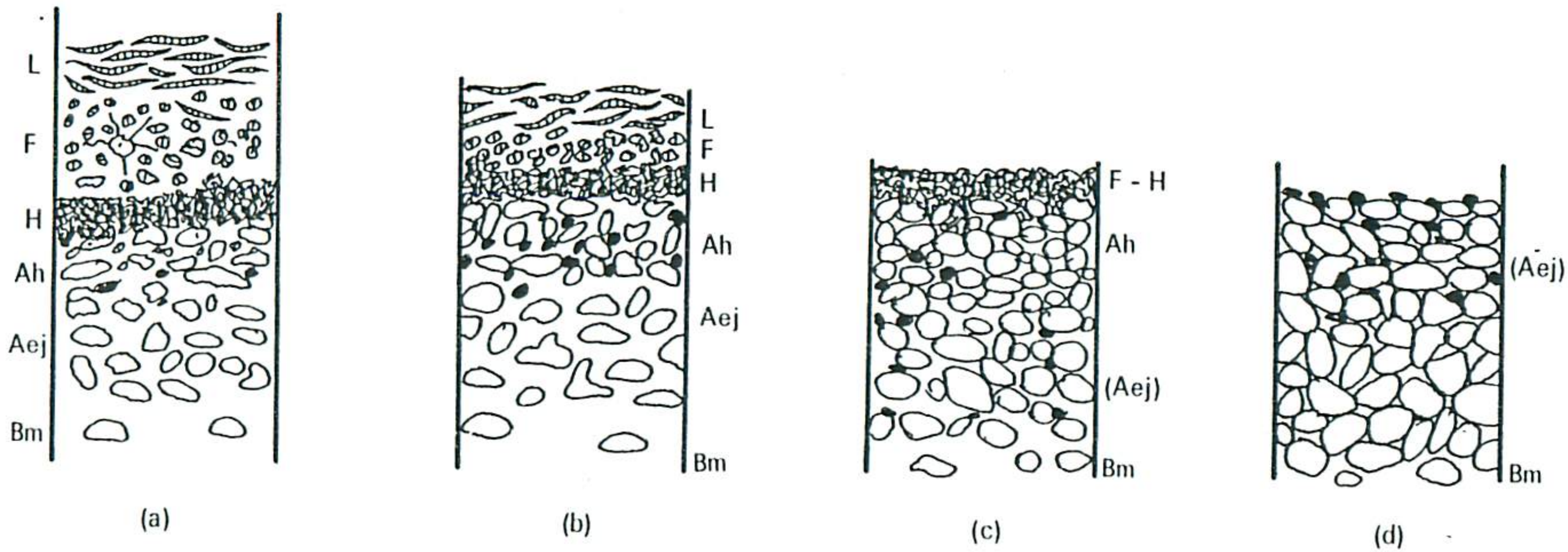

Fig. 8. Generalized model showing changes in surface litter (L-H horizon) with increasing recreation use: a) Zone N, Figure 6; b) Zone B, Figure 6; c) Zone A, Figure 6; and d) Zone A, Figure 6.

Table 4. Effect of recreation activity on thickness of L-H horizon.

Campsite no.	Tree species on site			Use intensity class[a]	Thickness of L-H horizon			
					Control area		Impacted area	
					Mean[b] (cm)	Stand dev. (cm)	Mean[b] (cm)	Stand dev. (cm)
27	jP[c]	wB	wS	High	5.7	1.6	1.9[d]	1.9
57	jP	wB	tA	High	5.6	1.1	3.3[d]	1.5
63	jP			High	5.4	1.1	1.9[d]	1.7
64	jP			High	5.4	1.1	1.9[d]	1.8
67	jP			High	5.4	1.1	1.6[d]	1.7
96	jP			Medium	4.3	0.8	3.5[d]	1.5
110	jP	wB	tA	High	5.5	1.4	1.0[d]	1.4
205	jP			Low	4.8	0.9	3.0[d]	0.9
243	jP	tA		High	6.0	1.1	2.3[d]	1.6
258	jP			Medium	5.1	0.8	3.5[d]	1.2
264	jP	wB		Medium	6.0	1.1	2.2[d]	0.8

[a] Use intensity classes pertain to the number of camper-days a site is in use per camping season
High = 200; Medium = 100-200; Low = < 100

[b] 50 samples per site

[c] jP = jack pine, tA = trembling aspen, wB = white birch, wS = white spruce

[d] Significant at P.01

from the soil surface is common. A few remnants of roots or occasional twigs and branches may be present, but for the most part, the soils from these areas are devoid of all organic litter (Fig. 8).

Loss of surface litter and its effect on soil physical properties. Maintenance of surface litter or a protective mulch is crucial to the performance of soils for campsite purposes. Most, if not all, of the subsequent soil problems arise from removal of this protective cover which acts as an organic cushion against compactive forces.

Loss of the surface litter results in severe soil compaction. An investigation of disturbed and undisturbed sites by electro-optical image analysis[8] shows a substantial reduction in noncapillary pores (.03-3 mm diameter; Fig. 9). In particular, there are large decreases in pores >1.0 mm in size. The pronounced decrease in macro-pore space increases bulk density and decreases infiltration rates (Table 5). Reductions in infiltration rate cause an increase in surface runoff which accelerates erosion of litter and nutrient-rich surface soil (Fig. 10). Recharge of soil moisture is retarded to the extent that the water content of these soils rarely reaches field capacity. Drought then becomes frequent, especially in summer. The problem is even more acute when the soils are shallow and are located on sloping sites, as is frequently the case in the jack pine community in northwestern Ontario.

The loss of macro-pore space also restricts the rate of gaseous movement through the soil and can reduce oxygen supply to the plant roots. Soil strength, as measured by penetration resistance, is appreciably higher in high impact areas than in the undisturbed areas and is greatest in the oldest, most heavily used campsites.

In addition to restricting root movement, compact surface soils prevent the establishment of new vegetation, making the replacement of ground cover extremely difficult. Hence, replacements to the litter layer are small and site conditions deteriorate even further. The removal of soil from tree roots by erosion increases the susceptibility of overstory loss by windthrow (Fig. 11), a problem common to intensively used campgrounds.

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[8]Monti, P. 1977. Effects of intensive recreational activities on soil organic matter loss in the Boreal Forest Region. Univ. Guelph, MSc thesis. 89 p.

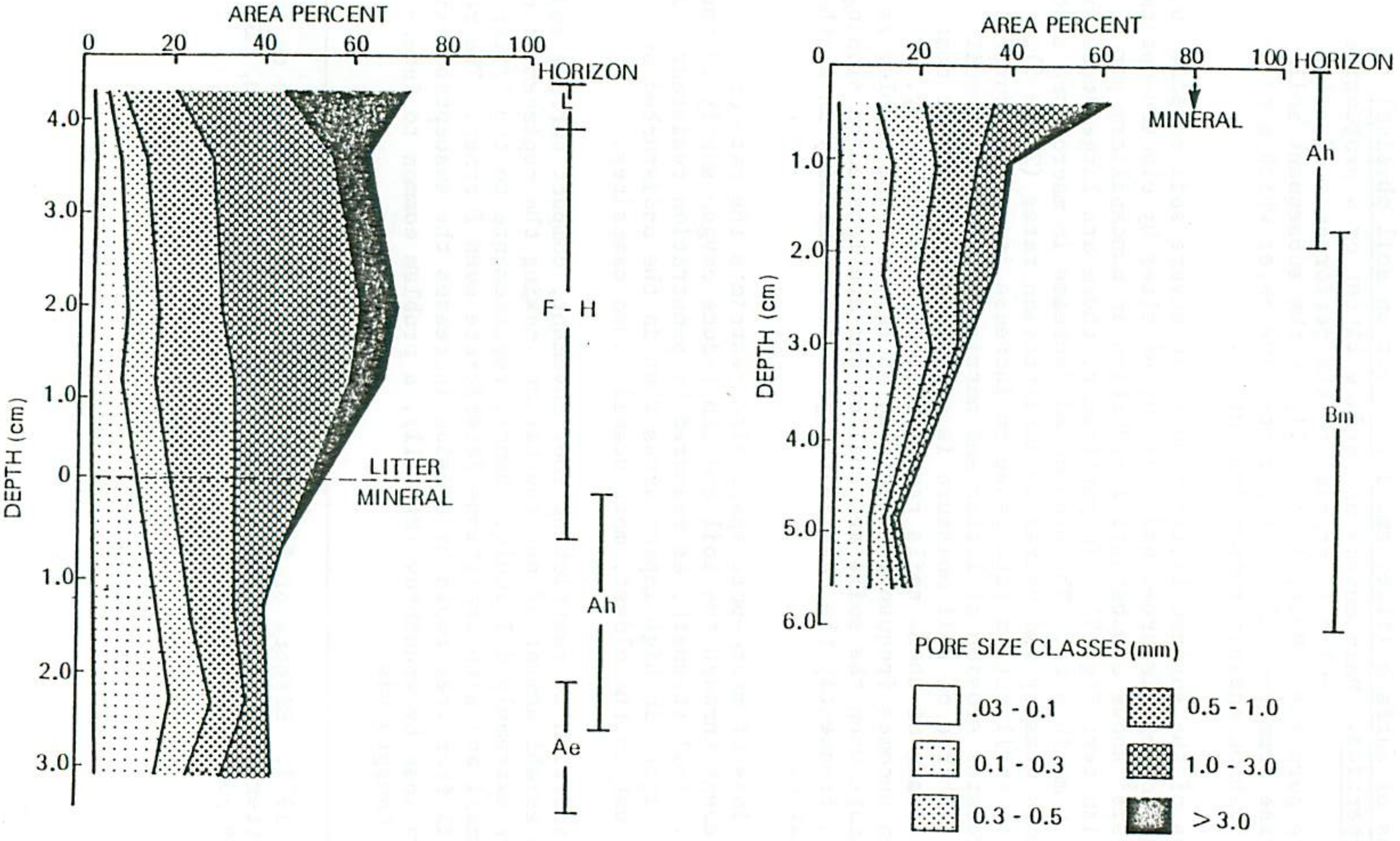

Fig. 9. Relationship of pore size distribution to use intensity for trembling aspen sites (left - Zone N; right - Zone A).

Table 5. The effect of recreational activities on infiltration and bulk density on jack pine sites.

		Infiltration rate (cm/min)	Average bulk density (g/cm^3)
Zone N (natural area)	1	1.54	1.14
	2	1.88	1.25
	3	2.61	1.00
Zone A (high impact)	1	0.10	1.59
	2	0.09	1.52
	3	0.09	1.42

Recreation Impact Thresholds and Campsite Physiognomy

Recreation impact and ecological carrying capacity. The most important aspects of recreational use-environmental change relationships can be summarized as follows:

i) The use of any ecosystem for recreational purposes always results in change.

ii) The type and extent of change are determined by the natural durability of ecosystems and the intensity and duration of recreational use.

Ecological carrying capacity therefore represents a threshold beyond which further changes to the physical-biological environment will affect recreational quality adversely. Consequently, determining ecological carrying capacity is a problem of determining how much change is acceptable.

Predicting the natural durability of recreation areas is a prerequisite for determining acceptable levels of environmental change. Wagar (1964) has suggested that regression relationships may be useful for predicting the survival of vegetation from measured site factors and from estimates of expected visitor use. However, the predictive accuracy of these regressions is low because of high levels of

Fig. 10. Severe compaction of surface soil reduces infiltration of water and increases surface runoff. This fresh deposition of needle litter is quickly eroded from sloping campsites following an intense rainstorm (Campsite No. 64).

unaccountable variability in the models and colinearity problems between the independent variables[2]. As well, regression models have limited use for extrapolation of data to other regions.

The natural durability of ecosystems at Rushing River Provincial Park can be predicted by defining the magnitude of environmental change occurring at particular levels of recreational stress. Unfortunately, this information cannot be used to establish ecological carrying capacities without a clear statement of management objectives. Without

Fig. 11. Windthrow of jack pine is common. The wind firmness of trees is reduced through intensive recreation use as a result of root exposure and opening of stands subsequent to removal of dead and decadent trees.

further information, it is impossible to define a recreational carrying capacity for the park, since this process involves defining social, economic and ecological goals in relation to management objectives. The identification of threshold levels related to environmental damage would, however, be useful to management in the interim to gain some appreciation of levels of use and expected site degradation.

Natural durability of vegetation communities and recreation impact thresholds. Examination of the changes in a biotic community resulting from varying intensities and duration of recreational use permits definition of impact thresholds beyond which certain environmental responses can be anticipated. Four impact thresholds, corresponding to the four age-use interaction classes discussed previously, can be recognized at Rushing River Provincial Park.

Age-use class	Recreational Impact Threshold (RIT)
1	1 e.g., age 2 yr, use intensity: low
2	2 e.g., age 10 yr, use intensity: medium
3	3 e.g., age 12 yr, use intensity: high
4	4 e.g., age 18 yr, use intensity: high

The changes in high impact area dimensions and some ground cover variables, viz., natural vegetation, 'weedy' species and percentage bare soil and rock, were used to assess environmental modification at various thresholds of impact. A number of other variables could be used; however, alterations in those selected represent the most visually obvious effects of recreational impact. These visual effects assume considerable importance when one is determining acceptable levels of environmental change in recreation areas.

Models of campsite physiognomy for Rushing River Provincial Park. The environmental changes at various recreational impact thresholds may be integrated and summarized in general models of campsite physiognomy. A series of these models has been prepared for both the jack pine (Fig. 12) and the trembling aspen (Fig. 13) communities.

Recreational use of campsites in both biotic communities resulted in zonation of vegetation and soils. Essentially three zones can be recognized:

i) zone A (high impact area) - largely devoid of vegetation except for occasional 'weedy' species

ii) zone B - codominated by elements of the original (natural vegetation) and 'weedy' species ('Weedy" species were dominant adjacent to high impact areas in some campsites.)

iii) zone N - largely undisturbed, natural vegetation.

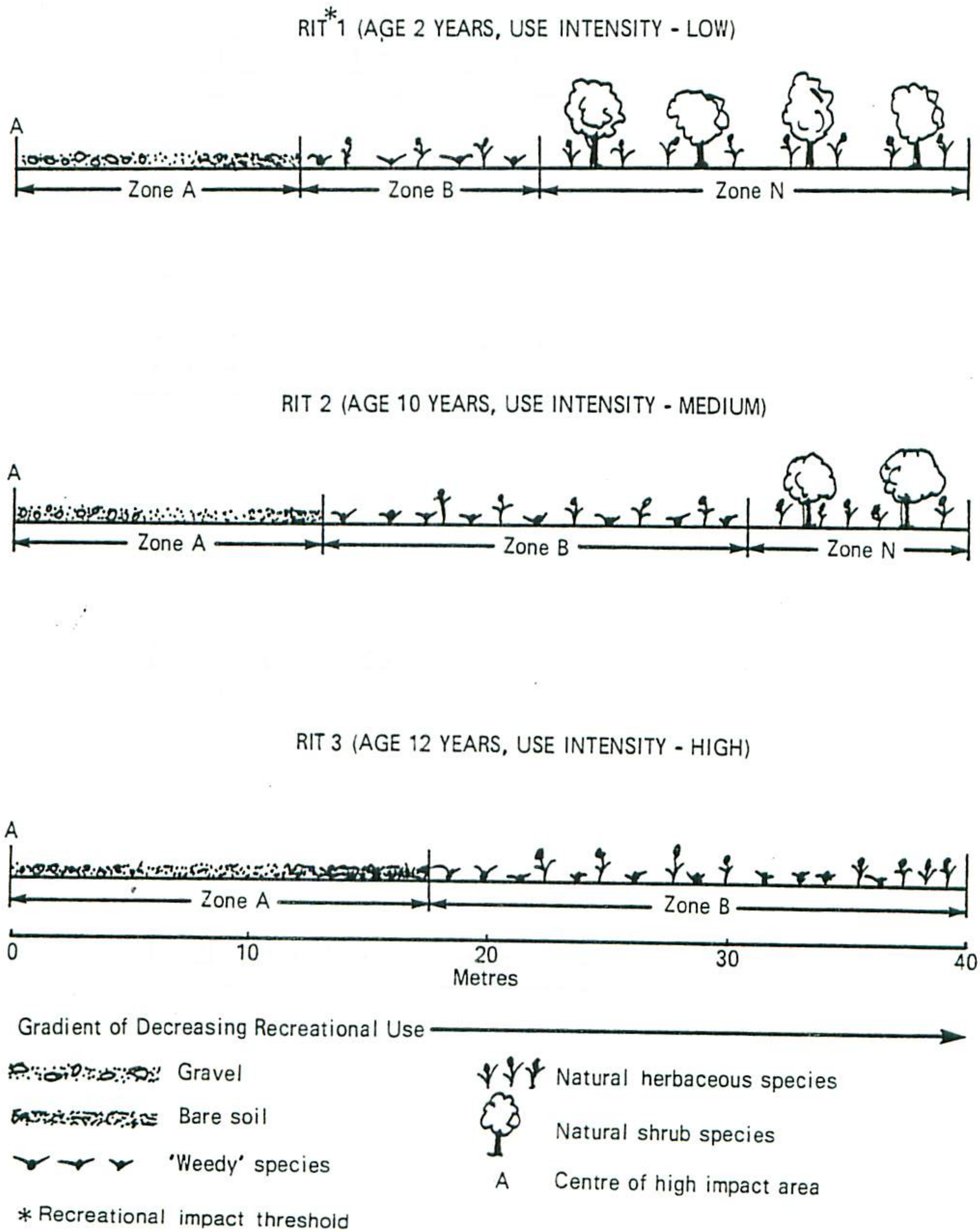

Fig. 12. A campsite physiognomy model for ground cover in the jack pine community.

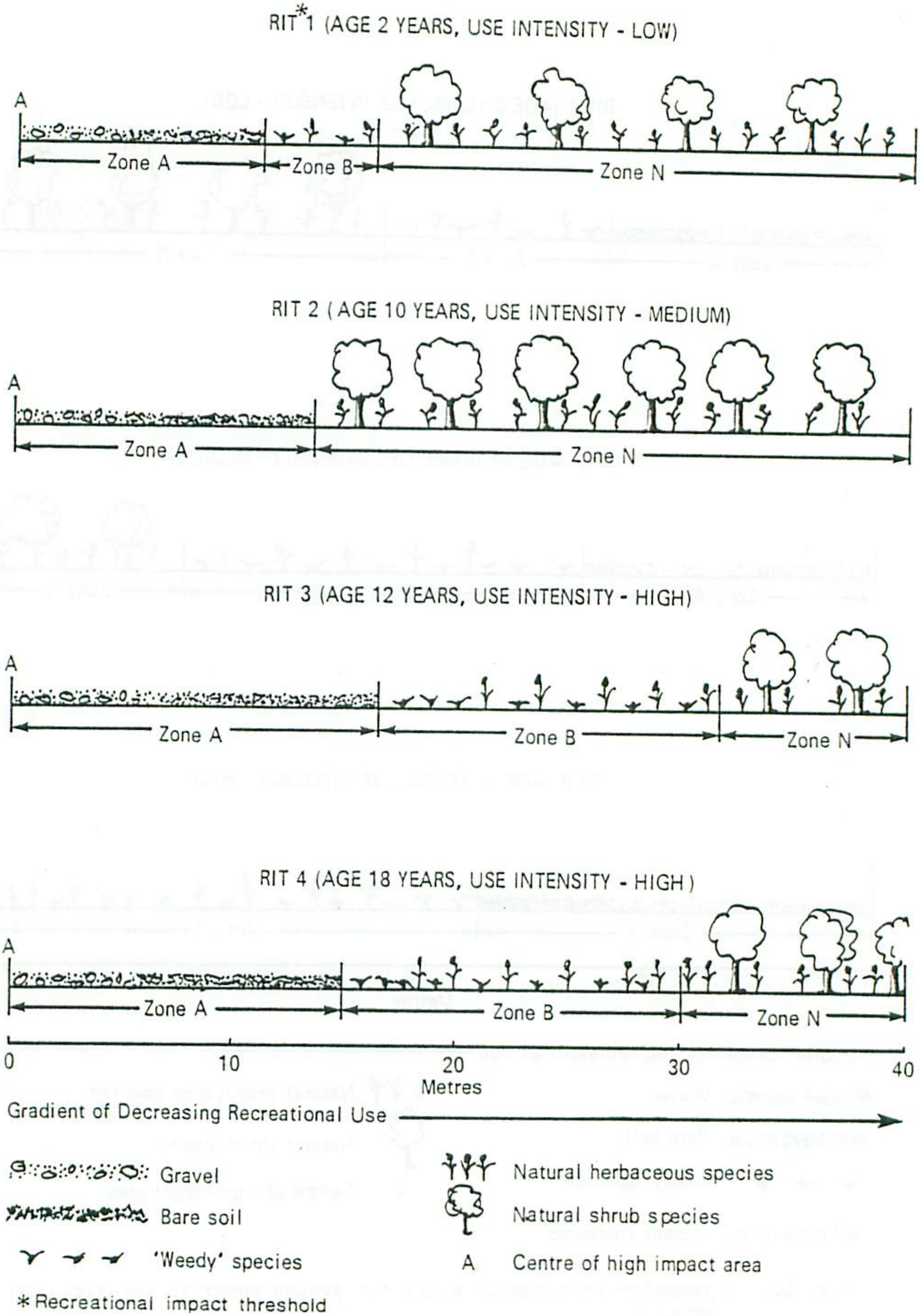

Fig. 13. A campsite physiognomy model for ground cover in the trembling aspen community.

The dominant elements of the natural vegetation were slightly different in each community. Natural species dominant in the jack pine community included: *Gaultheria procumbens, Diervilla lonicera, Vaccinium angustifolium,* lichen and moss species. A greater number occurred in the trembling aspen community, including: *Alnus rugosa, Aster macrophyllus, Clintonia borealis, Cornus canadensis, Corylus cornuta, Diervilla lonicera, Maianthemum canadense, Vaccinium angustifolium, Pteridium aquilinum,* and some moss species. The same 'weedy' species occurred in both communities and included: *Poa annua, Plantago major, Trifolium repens, Taraxacum officinale,* and various species of grasses and sedges.

The campsite physiognomy models (Fig. 12 and 13) indicate that ground cover changes occurred at all recreational impact thresholds in both biotic communities. However, widespread changes did not occur until RIT 2 was exceeded. Recreational use beyond RIT 2 clearly resulted in considerable environmental modification; e.g., zones A and B were greatly expanded and zone N was reduced. This suggests that recreational impact beyond RIT 2 is undesirable in both communities if the ecological integrity of areas is to be preserved. Further, recreational activity was generally more damaging in the jack pine community; ground cover changes in RIT 2 on jack pine sites more closely resembled the changes at RIT 3 on trembling aspen campsites, and zone N was entirely absent at RIT 3 on jack pine sites but was present even on the most highly impacted trembling aspen sites. These observations indicate that the natural durability of trembling aspen campsites is greater than those in the jack pine community and suggest that, from an ecological standpoint, future recreational development at Rushing River Provincial Park should be directed toward the former community.

The models of ground cover changes in the trembling aspen community indicate that no appreciable changes in campsite environments occurred beyond RIT 3 (Fig. 13). This may suggest that if the changes at RIT 3 are acceptable, then further use of campsites in this community can be permitted without risk of greatly increased deterioration.

The recreational impact thresholds used in this durability study were based on joint considerations of use intensity and duration. Unfortunately, these use effects could not be separated because no single age unit at Rushing River Provincial Park displayed the full range of use intensities (e.g., low use sites were confined to the two year old park section); and determination of mean use intensity for the whole period of use (development age) was not feasible in most cases. Hence a number of questions concerning the relationship between use intensity and duration remain unanswered. For example, it is not clear whether high intensity use of short duration will produce an environmental response similar to that produced by medium use of long duration. Also, the question of which factor is more important under different stress conditions--intensity or duration--remains unanswered.

MANAGEMENT OF RECREATION AREAS AT RUSHING RIVER PROVINCIAL PARK

The carrying capacity of recreation areas is determined largely by management objectives (Wagar 1964, Stankey 1972). These may vary from recreational activities in a near natural setting with a low level of development to high density use with well developed facilities. Obviously, areas fulfilling the first objective will have a much lower carrying capacity than those fulfilling the second; they may also provide a recreational experience of higher quality. However, high use and high recreational quality need not be incompatible if management seeks to reduce the conflict of competing uses, minimize the destructive tendencies of some users, increase the durability of areas, and provide increased opportunities for the enjoyment of recreation areas. These management goals may be achieved through the use of a variety of techniques including zoning, engineering, education and site rehabilitation.

A number of suggestions for increasing the carrying capacity of park areas without large reductions in recreational quality are discussed below.

Site Rehabilitation

It is evident from this study that the organic surface litter on forested campsites in the boreal forest plays an extremely important role in the maintenance of a stable soil-plant ecosystem. Once this layer is destroyed, rapid deterioration in soil conditions occurs and site degradation is severe.

Under these conditions, attempts at site rehabilitation have met with limited success because the substantial physical and economic inputs required render such attempts impractical on a general basis in parks. It is therefore critical to preserve surface litter and ground cover in recreational areas where the soils contain L-H horizons. Any management programs aimed at minimizing recreational site degradation must include a scheme for the conservation of these materials.

<u>Soil preparation</u>. The initial impact of recreation on soils is reflected in the loss of litter (L-H) and/or surface mineral horizons. Regardless of how these losses arise, i.e., from erosion, compaction and/or oxidation, the outcome is reflected in poor soil structure, soil compaction, increased surface runoff, and a deterioration of the soil medium for plant growth. All of these changes have a drastic effect on vegetative growth and regeneration. Further, many ecosystems in the boreal forest region are particularly susceptible to modification and degradation because of their thin soil mantle.

Rehabilitation measures for degraded campsites will vary with the vegetative community ahd soil conditions. The aspen sites are located on deeper soils and, because of their topographic location, they are often water receiving areas. Consequently, soil moisture conditions are improved, plant stress due to moisture deficiencies is lessened, and the chances of success for rehabilitation measures are improved. As a result, aspen sites are generally revegetated successfully (with grasses).

In contrast, the jack pine campsites often have a thin mantle of soil, which limits total moisture storage capacity and induces soil moisture stress at an early stage. The problem is further aggravated by loss of the surface litter which retains soil moisture and reduces evaporation. Re-establishing a plant cover on these sites is difficult and can be accomplished only with labor-intensive programs.

Renovating degraded sites. Revegetating degraded campsites (Fig. 14) will require one to two years depending on when the program is begun. The initial step is scarification of the compacted soil surface to a depth of 4-8 cm with pick and shovel, since most of the soil surfaces in the park are too stoney for mechanized equipment. For successful site renovation a surface organic mulch must be applied. This should consist of 5-10 cm of decomposed or partially decomposed bark and wood chips (from a nearby pulp mill) spread over the immediate campsite area and partially worked into the mineral soil.

Seeding of grass species should be done in late summer or early fall for best results. Of the two species tested for a dry, shady environment, redtop (*Agrostis alba* L.) outperformed Canada bluegrass (*Poa compressa* L.). Both of these species occur in this region but are 'alien' in the sense that they were introduced by early settlers. Spring applications of NP fertilizers together with supplementary watering over the spring-summer period are also required.

On new or partially degraded campsites where little or no soil compaction has occurred, remedial measures should consist of surface applications of organic mulch (preferably containing a 5-10 cm layer of wood chips). The mulch acts as a cushion and prevents soil compaction by trampling; furthermore, it reduces soil moisture loss by evaporation. Over a period of several years, the wood chips will gradually decompose and add much needed organic matter to improve soil structure and water holding capacity.

Since surface litter can be lost very quickly under adverse conditions, applications of mulch to new campsites prior to use should become standard practice.

Fig. 14. Campsite No. 65. The size of the high impact area (devoid of plant cover) increases with intensity and duration of use. Rehabilitation under these conditions requires a labor-intensive program.

Management and rehabilitation of plant communities in recreation areas. The role of management in preserving and rehabilitating natural vegetation in recreation areas has been discussed by a number of workers. A variety of manipulative techniques including seeding, fertilization and watering have been suggested. Herrington and Beardsley (1970), for instance, found that vegetative cover returned to 70% in badly worn campsite areas if the ground cover was watered, fertilized and seeded. Other possibilities for increasing carrying capacities include planting traffic-resistant plant species such as grasses and encouraging growth of ground vegetation by selective removal of overstory (Ehrenreich 1959). However, much of the rehabilitation work has been carried out south of the boreal forest and caution should be exercised in applying these results to northern Ontario conditions.

The choice of techniques depends upon a number of factors such as the type of community affected by recreational impact, the extent and severity of impact, the degree of environmental modification that can be tolerated, the rate and extent of natural rehabilitation, e.g., revegetation by 'weedy' species, management objectives, availability of labor power and time, and economic feasibility.

Rehabilitation trials undertaken on campsites No. 64 and No. 65 in the jack pine community indicated that scarification, mulches, fertilization, watering and seeding grasses have potential for increasing the carrying capacities of sites in this unit (Fig. 14). Biotic management of impacted areas on these sites is essential since natural revegetation is extremely slow. The situation is not as critical in the trembling aspen community where highly impacted areas are rapidly invaded by weedy species such as *Poa annua*.

Maintaining the health, productivity, and aesthetic qualities of jack pine stands at Rushing River Provincial Park is highly desirable. The importance of these stands as recreation areas was indicated by Frissell and Duncan (1965) who found that the overwhelming majority of users in the Quetico-Superior canoe area preferred pine sites as they are aesthetically attractive, parklike and brush-free.

Some practical suggestions for ameliorating the adverse effects of recreation on forest stands include fertilization, especially with nitrogen (Wagar 1965), scarification of the soil surface to improve aeration, and selective watering.

One of the more pressing problems at Rushing River Provincial Park is replacement of overstory losses in campsite areas. Natural regeneration of jack pine in the absence of fire is extremely slow and no seedlings were noted in heavily used areas of the park. Stand regeneration can be aided by a program of controlled surface burning but the practicability of this is severely limited in a campsite environment. The problem is further aggravated by the fact that jack pine regenerates following a fire; consequently, most stands are even-aged, and this compounds disease problems and losses resulting from windthrow.

Observations made over a 3-year period on campsites No. 64 and No. 65 indicate that little or no natural revegetation takes place on high impact areas, or in the transition zone between the high impact and natural areas, when sites are removed from use. This is consistent with the soil measurements. One of the major problems connected with regeneration is severe soil compaction. Over a 2-year period there was little evidence to indicate that soil amelioration had taken place. Bulk densities were still excessively high (1.5-1.8) and infiltration rates remained essentially unchanged as did the soil strength measurements. Without scarification it appears as though the success of both natural and artificial regeneration is marginal.

Indeed, on these soils, natural revegetation does not appear to be a feasible alternative in a management program, at least for those campsites that have been allowed to degrade to the level of No. 64 and No. 65 (Fig. 14).

Campsite Layout

The extent of environmental damage is frequently related to campsite layout, distance between neighboring campsites and the presence of natural barriers which impede free user traffic between sites. The importance of these factors in campsite planning and design should not be overlooked.

Campsite design

i) Loop design. The layout of campsites on the inside of a 'looped' roadway (Fig. 15) is common to many parks in Ontario. Unfortunately, layouts of this nature tend to aggravate site deterioration unless some sort of physical barrier is present to impede traffic flow. In the case of campsites No. 48, No. 50 and No. 52 (Fig. 15) there were no constraints to traffic movement within the loop and individual high impact areas merge with time. In contrast, campsites No. 80 and No. 82 are separated by a bedrock outcrop (Fig. 15) which forces traffic flow to the perimeter of the loop and reduces intraloop degradation. A similar situation exists for campsites No. 247, No. 249, and No. 266; however, in this instance vegetation screens form a barrier (Fig. 16) which directs traffic flow and reduces impact. Although it is recognized that the location of campsites on the inside of loop roads may be popular from a recreational viewpoint because it facilitates interaction between neighbors in adjacent campsites, caution should be exercised using this design when planning campsite layouts. The planner should bear in mind the need to retain physical barriers so as to impede human traffic flow and maintain critical minimum distances between campsite centres.

ii) Physical barriers. The existence of physical barriers between campsites helps to reduce the level of degradation. The barriers may take the form of rock outcrops or natural vegetation screens (Fig. 16); each performs the function of directing traffic flow in predetermined directions, thereby reducing the size of impacted areas. The distance between campsites

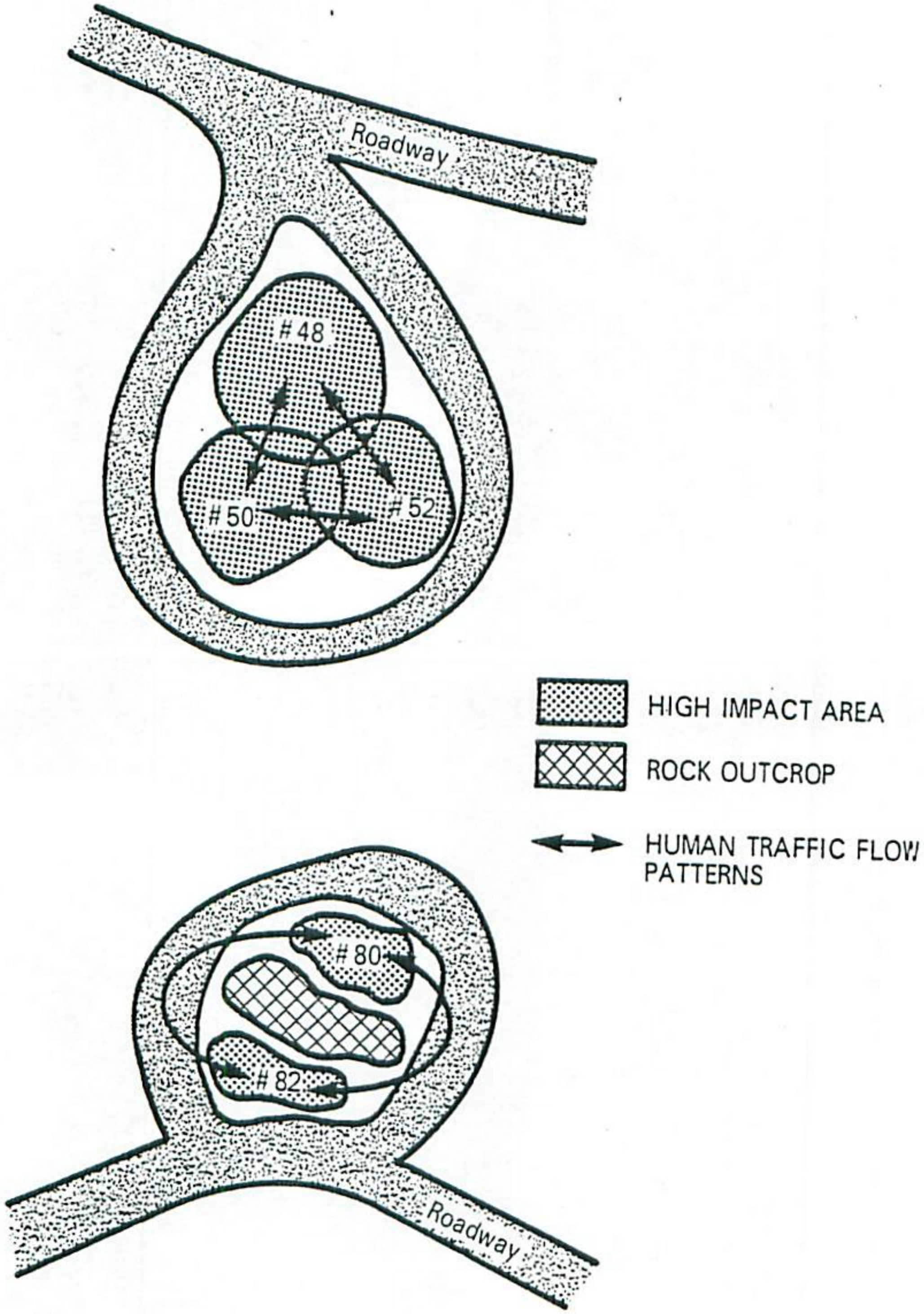

Fig. 15. Campsite layout on the inside of 'loop' roads. Top - human traffic flow in absence of physical barriers. Bottom - traffic flow patterns in presence of physical barriers.

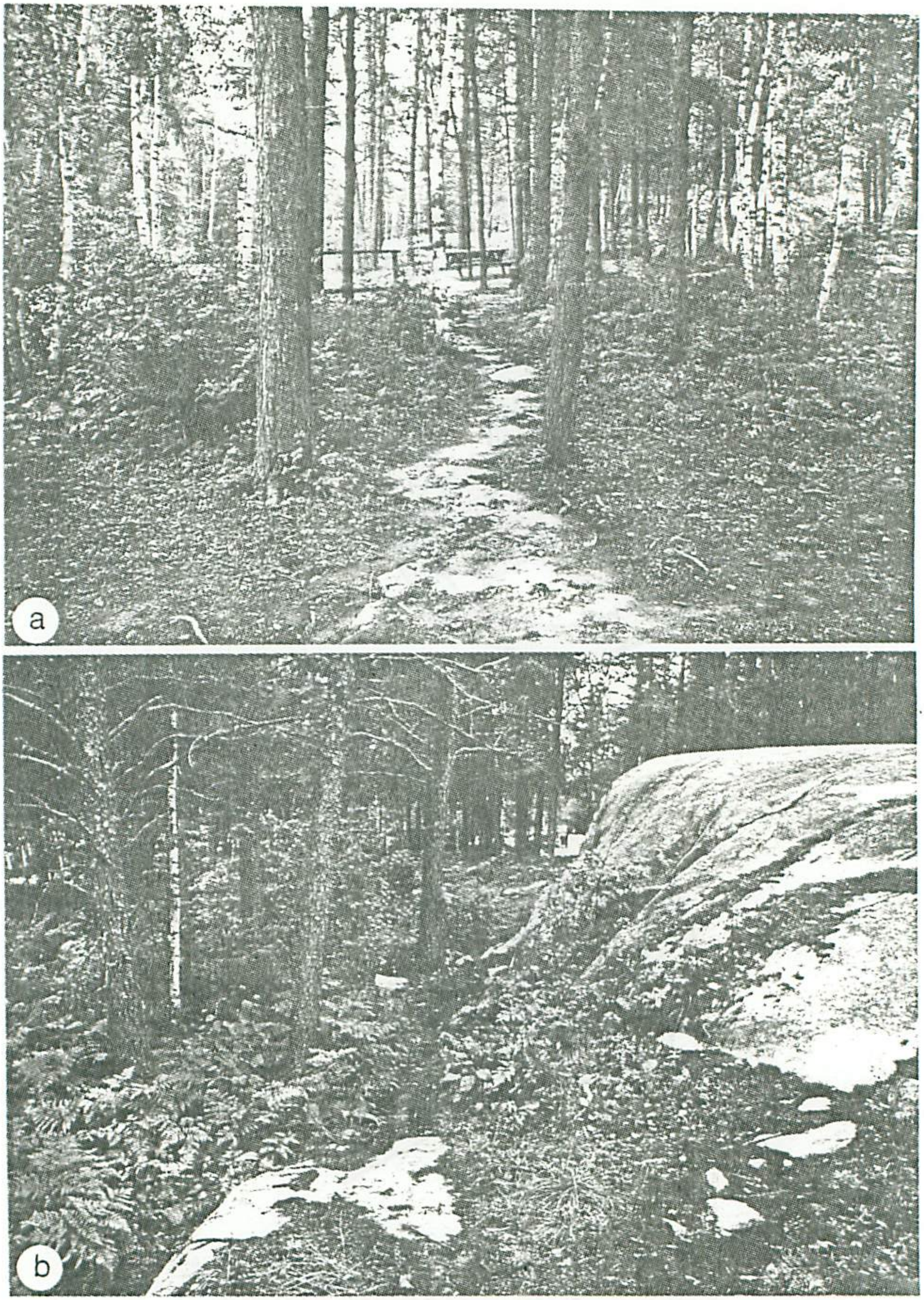

Fig. 16. Physical barriers and campsite degradation.
a) A vegetation screen separates Campsites No. 266 and No. 244. This directs traffic flow along trails between campsites and reduces impact on vegetation and soils.
b) Bedrock outcrops serve equally well as physical barriers to reduce the area of impact.

is also closely related to the presence or absence of physical barriers. This is discussed in more detail in the following section and it is sufficient to note that the closer the campsites are to each other, the greater is the need for barriers. For example, the area of bare ground (high impact area) in the foreground of campsite No. 54 has merged with campsite No. 69, which is visible on the left side of Figure 17. Because barriers are lacking between these two campsites, traffic flow is not constrained (Fig. 15), and consequently larger areas of ground vegetation are destroyed.

iii) Intercampsite distances. Measurements on campsites at Rushing River and Blue Lake provincial parks show that, if traffic movement is not constrained by barriers, the average diameter of high impact areas is approximately 13-20 m. To maintain a buffer zone of ground vegetation between adjacent campsites, a minimum distance of 30 m between centres is required (Fig. 18; see also page 9). This figure is supported by the United States Forest Service (Anon. 1957) which suggests a 100 ft (approx. 30 m) standard minimum distance between family camping units.

Although the effective distance between campsites can be reduced by the use of vegetation screens (Fig. 17), under natural conditions a minimum distance of about 15-20 m between campsite centres is still required; otherwise, the screens are destroyed. Cyprus Lake Provincial Park contains an excellent example of the ineffectiveness of vegetation barriers where campsite densities are excessively high.

Because the degree of campsite degradation is related to the intensity and duration of use, the distance between campsites could be adjusted according to anticipated levels of use. In the case of Rushing River Park, for example, an analysis of use intensity data and physical site characteristics of campsites reveals that the major determinants of use are proximity of the campsites to the core campground area, distance to the lake and distance to beaches. The closer the campsites are to these areas the greater is the use intensity, and consequently, the greater the need for screens and/or increased distances between campsites.

It can be predicted, therefore, that for any future expansion of the park, those campsites adjacent to the lakeshore and/or beaches will receive the greatest use and should be the greatest distance apart. A similar guideline should be adopted for location of campsites in ecologically sensitive areas, e.g., jack pine vegetation units.

Campsite construction. The carrying capacity of areas in the immediate vicinity of campsites may be increased by discontinuing the use of gravel for parking spurs. The continual replenishment of material lost from these spurs invariably

Fig. 17. Effect of campsite layout on site degradation. The absence of physical barriers between Campsite No. 54 (foreground) and Campsite No. 69 (upper left) has led to merging of the high impact areas. In the absence of barriers a minimum of 30 m is required between campsite centres to prevent merging.

kills the ground vegetation and some tree species, e.g., white birch, are extremely sensitive to grading and compaction around the root zone. Destruction of the ground vegetation is also increased by the abrasive action of loose gravel. La Page (1967) has also cited this as a reason for unusually high losses of vegetative cover on lightly used campsites.

In areas where plant cover has been lost, increases in erosion can be reduced by diverting surface runoff into specially designed

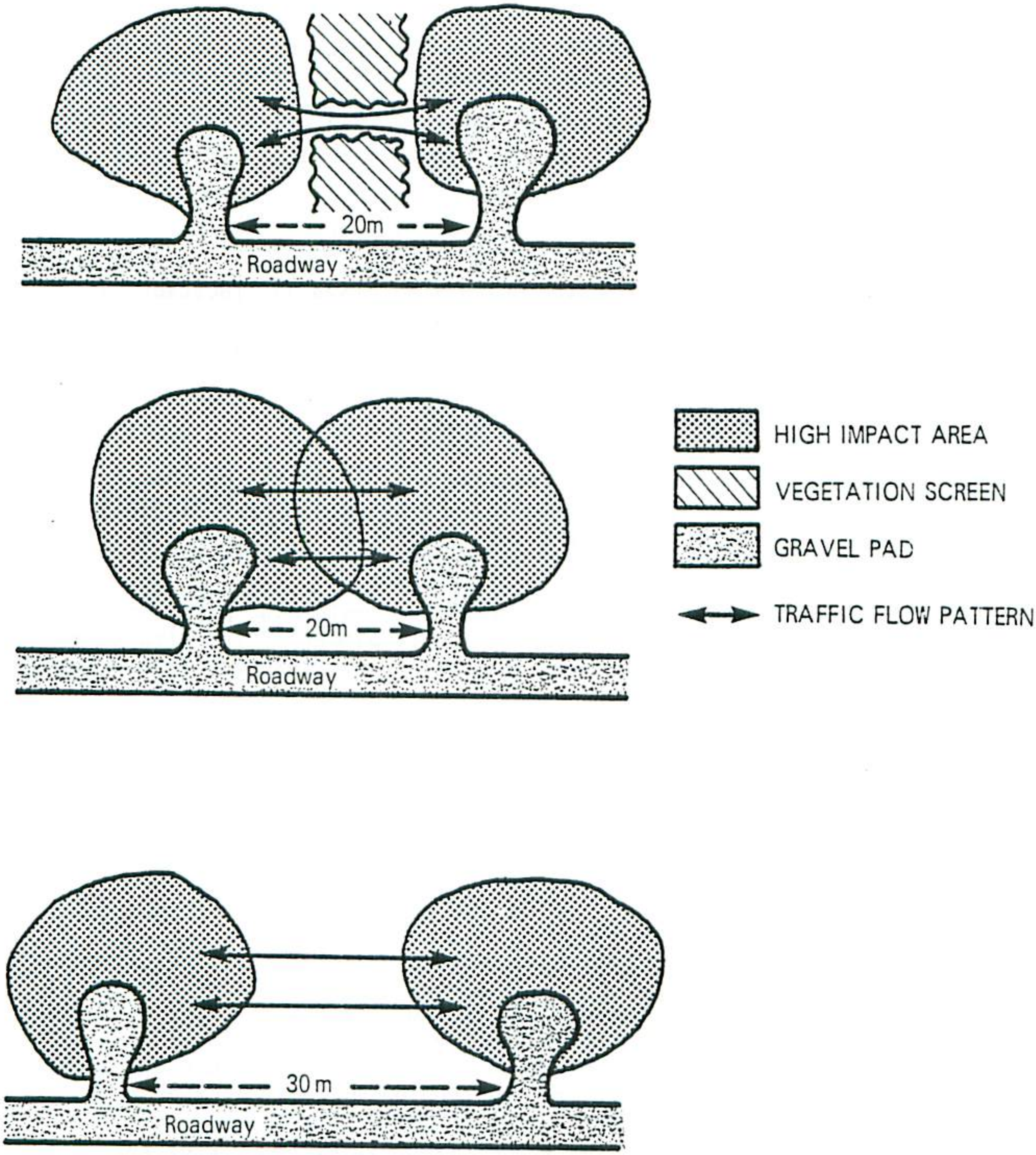

Fig. 18. Campsite layout and site degradation.
Top - Maintenance of vegetation screens reduces size of high impact areas.
Middle - Intense use of campsites located too close together results in merging of high impact areas and increases site degradation.
Bottom - Approximately 30 m should be maintained between campsite centres to prevent merging of high impact areas.

spillways (Densmore and Dahlstrand 1965). These workers also suggested that heavy use areas should be covered with wood chips, stone or pavement and if slopes are excessive, they should be reduced. For additional suggestions on campsite construction and maintenance the reader is referred to a campground manual, recently published by Parks Canada (Anon. 1977).

Detailed design requirements and impact levels. The detailed design and location of individual campsite units also plays an important role in the level of impact from recreation use. In addition to the physical site factors discussed in Parks Canada's campground manual (Anon. 1977), observations and measurements made at Rushing River and Blue Lake Provincial Parks suggest that adherence to the following guidelines would help to reduce site impacts as well.

i) The location of fireplaces and picnic tables should be fixed in relation to the remaining campsite layout pattern. Soils immediately around fireplaces and tables become severely compacted and vegetation is destroyed. If these items are moveable the size of the impact area is increased. Permanent sites for fireplaces would also permit the use of surface mulches over the remainder of the high impact area to reduce soil compaction and subsequent surface runoff and erosion.

ii) Tent and trailer pads should be fixed for each campsite and slightly raised above the level of the surrounding area. Raised pads should consist of coarse textured permeable soil, sand or wood chips. This improves site drainage and localizes impact associated with these activities.

Management Practices

Rotation or rest periods. The majority of campsites at Rushing River Provincial Park are located in natural vegetation communities. Except for mowing of ground vegetation on the campsites and removal of overmature and decadent trees, there is little management of the vegetation. Prolonged use destroys plant cover and surface litter, and eventually is reflected in soil compaction and the formation of large high impact areas. Under these conditions, particularly on the jack pine sites, the use of rotation or rest periods as a maintenance practice in renovation of campsites is questionable. Little or no revegetation on two campsites (No. 64 and No. 65) at Rushing River was evident even after 3 years of no use. Similar observations have been made in the northeastern United States.

Rotation periods as a management strategy are a feasible alternative where intensive management schemes involving water sprinkler systems and sod cover are being implemented. Under natural conditions, regeneration of vegetation requires several years and does not appear to be a practical means of improving site carrying capacity.

Zoning. The concept of design for all and intensive management for some is perhaps the most sound approach to development of parks created specifically for recreation. This concept can be applied by zoning for different uses and different user preferences. A tentative zonation scheme[9] is outlined in Table 6. This scheme has a number of advantages:

i) User impacts are reduced in ecologically sensitive zone 1 areas. (Recent observation of camping styles indicates that only a small percentage of users would be attracted to zone 1 areas; a limit of four people or fewer per party on each site could be imposed.)

ii) Users who are the least tolerant of crowds are catered to by the creation of zone 1. Wagar (1964) suggests that "without zoning, uses and users with the greatest crowd tolerance and aggressiveness may drastically reduce that quality and the possibility of other types of recreation".

iii) Motorized users are catered for by zones 2 and 3.

iv) Environmental impact in the moderately sensitive zone 2 areas is reduced by limiting party size to one car per site and confining recreation vehicles, potentially carrying the largest parties, to the most durable zone 3 areas.

The present high proportion of tent-trailer and recreation vehicle camping styles indicates that zones 2 and 3 should qualify for the greatest space allocation per park and zone 1 should receive the smallest allocation.

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[9] A limited use-zonation is already in effect at Rushing River Provincial Park; viz., an area catering specifically for recreation vehicle camping has been created (campsites 1-19) and some sites have been developed for tent camping only. However, zone 1 type users are generally not catered for and all forms of motorized recreation are permitted throughout the Park.

Table 6. A scheme for use-zonation in park recreation areas.

Zone	Ecological characteristics of zone	User type and preferences	Access, facilities and use limits
1	- highly sensitive, fragile areas with a low carrying capacity - low capacity for revegetation, e.g., areas in jack pine communities with shallow soils	- users desiring recreation in a natural setting and willing to "rough it" - low crowd tolerance	- access by backpacking along clearly defined, managed trails - minimal facilities for tent camping only - limit of 4 persons per site
2	- moderate sensitivity and carrying capacity - some capacity for revegetation both naturally and artificially, e.g., areas in jack pine with deep soils and most areas in the trembling aspen community	- users desiring recreation in a semi-natural setting with easy access to facilities - moderate crowd tolerance	- access by road - on-site facilities include parking spur and water - off-site facilities (nearby) include showers and toilets - limit of 1 car per site - tent-trailer or tent camping only
3	- low sensitivity and high carrying capacity - high capacity for revegetation both naturally and artificially, e.g., trembling aspen community with deep, moist soils	- users desiring recreation in a highly managed, essentially artificial setting with all facilities provided on-site - high crowd tolerance	- access by road - on-site facilities include parking spur, water, toilets, electrical hook-ups, showers - limit of 1 recreation vehicle per site - tent, tent-trailer or recreation vehicle camping permissible

Possible disadvantages of the scheme outlined in Table 6 are as follows: i) large park areas may be required to accommodate zone 1 without reducing zone 2 and 3 allocation; ii) the development and administrative costs of zoning may be uneconomical; iii) user-pressure may suggest that zoning is unpalatable and the status quo will be maintained.

Educational programs. An educational program designed to develop among park users an appreciation of natural environments and of the need for their preservation is one of the most important aspects of park management. No effort should be spared in attempting to explain the interesting features of the park, the problems involved in managing and maintaining the environment, the consequences of normal recreational use, the consequences of abuse and wanton destructiveness, the need for preserving park environments, various methods of accomplishing this and the resultant benefits, and how users themselves can help increase the carrying capacities and improve the quality of recreation areas. All possible means, e.g., slide shows, films, lectures, conducted walks, pamphlets, informal talks with users, should be exploited to the maximum in these educational programs. A massive educational effort is needed because most attempts by management to conserve park environments, to increase carrying capacities and to maintain recreational quality will be useless without user understanding, cooperation and involvement. While research was being conducted at Rushing River Provincial Park, the public, when informed, were generally very receptive to removal of campsites from use for extended periods.

Limiting use. Limiting the use of recreation areas by keeping people out for varying periods of time is probably the least palatable and least economical method of restoring recreational quality and increasing carrying capacity. Before deciding to limit use, a park manager or administrator should consider the following (Wagar 1964):

i) alternative methods of maintaining recreational quality,

ii) the amount of damage created by specific users and user groups,

iii) the level of recreational quality for which users are willing to pay,

iv) whether users would prefer to pay for recreational quality by accepting less use or by other means,

v) the benefits gained by limiting use weighed against the values lost when use restriction reduces the number of people served,

vi) the durability of vegetation,

vii) the needs and desires of future generations.

Observations at Rushing River Provincial Park indicate that limiting use by implementing campsite rotation periods is not a practical solution to the problem of rehabilitating degraded campsites. The rates of natural revegetation in the jack pine community are extremely slow. It is estimated that even in moderately disturbed areas, campsites would have to be taken out of use for long periods (upwards of 5 to 8 years) to achieve adequate natural rehabilitation. It may be, too, that highly impacted areas in the jack pine community are already disrupted beyond the point of no return. The natural rehabilitation of areas in the trembling aspen community would be more rapid because of improved site characteristics i.e., deeper, moister soils and improved light conditions at the ground surface.

Limiting use may be a feasible method of increasing carrying capacities of lightly used natural areas as most plant communities have the capacity to recover from minor disturbance. As well, it would be a feasible alternative for those campsites where grasses are being established as ground cover.

Resource requirements. A rehabilitation program directed toward a short-term restoration of degraded campsites at Rushing River Provincial Park will require a costly, labor-intensive program. At the very least, the following steps are required:

i) scarification of the surface soil about 3-8 cm deep,

ii) application of a surface organic mulch,

iii) seeding and fertilization,

iv) water sprinkling system,

v) campsite removal for 1½ to 2 years.

Since a majority of the campsites are located in the jack pine/shallow soil community, mechanization of the procedures is impractical because of the stoniness of the soils. Consequently, it is doubtful that most campground parks like Rushing River Provincial Park could implement a full-scale project of the above nature for economic reasons.

A long-term alternative that may be attractive for economic reasons is the application of surface organic mulches to high impact areas. Yearly mulch applications may be required, and over a period of time, decomposition of the mulch would add organic matter to the soil and improve soil structure. (This process has been observed at the Forest Valley Outdoor Education Centre, Toronto.) Under these conditions, the success of reestablishing plant cover on impacted areas would be improved.

CONCLUSIONS

General

The impacts on soils and vegetation that are generated as a consequence of recreational use in campground environments follow a distinctive pattern over a wide range of geographic conditions. It is apparent that the changes in vegetation and soil conditions are a function of both the intensity and the duration of use, i.e., the number of years the site has been used. As well, the degree of impacts varies with specific site conditions and layout design.

At Rushing River Provincial Park, the campsites are located within two main natural vegetation communities: the jack pine community found on shallow soils and the trembling aspen community which usually occurs on deeper, moist soils. Although campsite degradation is more severe on the jack pine sites for a specified level of use, the changes in vegetation and soils follow similar patterns for both communities. A zonation of vegetation species occurs from the centre of the campsite and extends outward, along a gradient of decreasing use-intensity. The centre of the campsite, which is devoid of vegetation, is called the high impact area and can be used as one measure of site degradation. The size of this area grows in direct proportion to the intensity and duration of campsite use. A zone of 'weedy' species occurs immediately adjacent to the high impact area and gradually merges with the third zone which is similar in composition to undisturbed areas. In this study, the changes in species composition and cover have been measured quantitatively. With this approach, separate groupings of species can be identified on the basis of their sensitivity to human traffic and can be used as indicators of degradation levels. They also give an indication of "recreation-tolerant" species that could form the nucleus for a native planting program in site reclamation works.

It is evident that surface litter (L-H horizon) plays a crucial role in the maintenance of a stable soil-plant ecosystem in the boreal forest region and any management program aimed at minimizing recreational impacts must include a scheme for the conservation of these materials. The initial impact on soils is reflected in the loss of this litter. Regardless of how these losses occur the outcome is reflected in poor soil structure, soil compaction, and increased surface runoff. Indeed, compaction may become so severe that growth and regeneration of vegetation are nonexistent. Under these conditions, a rehabilitation program is required.

Management Considerations

The allowable levels of campsite degradation depend on individual perceptions of site deterioration and its relation to aesthetic quality and the recreational experience, and on management objectives for the park. Although Rushing River Provincial Park falls in the category of a recreation park and the general goals for such parks are defined[4], it is still unclear, for example, what level of management of the natural vegetation around campsites is to be achieved. Without a clear statement of management goals and objectives, it is impossible to develop guidelines for deriving use-capacities for parks. The term "carrying capacity" is often used in this sense but it does not appear to be a very operational concept for park management, at least at this time. Carrying capacity represents a triad of socio-economic, ecological and management components. Manipulation of the management component alone, e.g., goals and objectives, park design and campsite layout, the level of on-site soil and vegetation management, etc., can drastically alter user numbers. In this context, perhaps the term "design capacity" (Godin and Leonard 1977) is more appropriate.

It was found that various levels of site deterioration (in an ecological sense) could be related to the intensity and duration of campsite use at Rushing River Provincial Park. These levels were referred to as recreation impact thresholds (RIT) and can be used as an aid to management in establishing user levels for individual campsites. For example, it is apparent from the campsite physiognomy models (Fig. 12 and 13) that the trembling aspen community is able to withstand higher levels of use than is the jack pine community. Furthermore, for campsites in the aspen community, there appears to be a significant increase in site deterioration corresponding to the increased use observed between RIT 2 and 3. In the jack pine community this change occurs at a much lower use level, i.e., RIT 1 to 2.

Because of the high tolerance of jack pine to adverse site conditions, the ideal location for new campsites within the park is in jack pine areas with well drained, deep soils. However, such areas occur infrequently, and future campsite expansion should therefore be directed to the deeper soils which normally contain trembling aspen or aspen-birch communities. To maintain site quality, a minimum distance of 30 m between campsite centres is required, or alternatively, if dense vegetation screens or other physical barriers are maintained between campsites this distance can be reduced to 15-20 m. In the absence of such guidelines maintenance of natural vegetation between campsites is not possible and the need for a costly rehabilitation program can be expected.

Site Rehabilitation

Site rehabilitation in the aspen community will be more successful than on most jack pine sites, primarily because of greater soil depth and superior moisture conditions in the aspen community. The type of rehabilitation program will depend on management objectives. For instance, is it a park objective to maintain a ground cover of natural vegetation around individual campsites? In the development of new campsites and expansion of current ones, it is essential to know the answer to this question, among others, so that design criteria can be established which will take into account the anticipated intensity of use.

Revegetation of severely degraded campsites will require a labor-intensive program of 1½-2 years consisting of scarification, addition of organic mulches, fertilization, watering and seeding with grasses. On new or partially degraded campsites where loss of litter and soil compaction have been minimal, remedial measures should consist of surface applications of organic mulches. These mulches act as a cushion and prevent soil compaction as a result of trampling. Furthermore, they reduce losses of soil water through evaporation.

Natural regeneration of vegetation does not appear to be a feasible alternative in a management program. If native vegetation is required in the rehabilitation scheme then a planting and propagation program must be initiated. Availability of seed and propagules for some species is a problem, although many northern species of ground vegetation are available from the Ontario Ministry of Natural Resources nurseries. Detailed guidelines on planting and propagation of native species in park rehabilitation programs are also beginning to emerge (Anon. 1977, Nixey and Severs 1977).

Extrapolation of Data

Many of the general observations and principles emerging from this study are consistent with those reported elsewhere, and can therefore be extrapolated with a degree of certainty. As well, the general principles and guidelines of the rehabilitation program are transferable from one region to another. But it is also apparent that recreation impacts vary according to site conditions, i.e., the specific vegetation community and its associated soil conditions. Consequently, the degradation of plant communities (as a result of recreation use) can be expected to take place at different rates in the deciduous zone of southern Ontario than in the boreal forest. The surface organic litter has been identified as playing a prime role in site deterioration in the boreal forest. In the deciduous forest zones, litter is incorporated primarily into the surface mineral horizon as an Ah horizon. Hence, the soil problems arising from recreation use in the two regions differ and, to some extent, the rehabilitation programs may have to differ as well.

The present data should, however, be useful over a wide area of the boreal forest in northern Ontario. Throughout this region, conservation of the surface litter to prevent soil compaction and site deterioration is crucial. However, in the present study, the aspen sites were more tolerant to recreation use than were the jack pine sites. The data can be extrapolated only to those campsites where the prevailing soil conditions are the same. For example, jack pine stands on deep soils are probably more tolerant to use than are aspen sites.

Future Research

Research for the purpose of documenting the impacts of recreation on vegetation and soils has increased significantly in the past decade. Some of the most useful work has been done in ecology, particularly in ecosystem dynamics. From an ecological standpoint, there are some rather obvious needs for future research. The whole question of the relationship between use intensity, duration and the dynamics of ecosystem change remains unanswered and must be dealt with as part of the whole problem of design capacities.

From a more practical standpoint, much research is needed on site rehabilitation. There is a need for testing and evaluating techniques of seed and vegetative progagation of native species for campsite use, as well as appropriate techniques for encouraging re-establishment of native species. Associated with such research is the need for field investigation of soil amelioration techniques. These have not been well documented in the literature, and furthermore, long-term trials are required to determine their success under various levels of recreation use.

The whole area of park design, campsite layout and design criteria requires further investigation. It is obvious from this study that environmental degradation is closely related to design factors but data are scarce on the subject. A satisfactory solution to this question will also require more detailed work on goals and objectives for park management.

The obvious need to repeat a similar study in the southern Ontario deciduous forest zone should not be overlooked.

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