CHAPTER I.   GENERAL INTRODUCTION

Problem Statement

The twentieth century has witnessed a substantial boom in nature-based recreation and tourism from anecdotal activities to worldwide phenomena with significant and sometimes controversial economic, environmental, and sociocultural implications. Meanwhile, protected areas have gained in social and ecological values as they provide nature-based recreational opportunities and experiences on the one hand, and preserve refuges of relatively unspoiled natural ecosystems in an increasingly altered world on the other. Unfortunately, these two parallel growths are more often found in conflict than harmony when protected areas become a prime magnet of ever-growing nature-based recreation and tourism demands. The tension between recreation and tourism and nature preservation is often manifested in various forms of biophysical damage to recreation resources, or recreation resource impacts. In the eve of the next millennium, protected area researchers and managers are challenged to develop effective and efficient ways to contain such undesirable recreation resource impacts before the sustainability of protected areas for integrating recreation/tourism and nature preservation is compromised.

In the United States, recreation resource impacts are a perennial management problem in many protected areas, such as national parks, national forests, and designated or *de facto* wilderness areas (referred to as parks hereafter) (Washburne and Cole 1983, Marion et al.

1993). Recreational and tourist activities degrade the quality and utility of recreation resources, which encompass functional entities such as campsites, trails, and beaches; ecological entities such as soil, vegetation, wildlife, water, and ecosystems; and psychological entities such as perceived naturalness and landscape aesthetics.

Recreation resource impacts are a legitimate management concern for both ecological and social reasons. Ecologically, previous research has demonstrated that recreational activities can induce substantial local impacts on soil and vegetation (Hammitt and Cole 1987). For certain types of recreational activity, such as the use of off-road vehicles, and for certain ecological components, such as wildlife and water resources, recreational disturbance can be spatially extensive and temporally enduring (Cole 1990, Cole and Landres 1996).

Recreation resource impacts have also been found to have undesirable social consequences. Recreation experiences can be compromised by the existence of resource impacts through their direct effects on resource functionality, visitor safety, and aesthetic quality, or through their indirect influence on perceived crowding and conflicts (Roggenbuck et al. 1993, Hammitt et al. 1996).

In order to contain and minimize recreation resource impacts and their undesirable consequences, park managers have been striving for knowledge on the causes and nature of impacts, as well as techniques and tools that can be used to effectively assess, evaluate, and monitor the magnitude of impacts. Such a knowledge need gave birth to the field of *recreation ecology*, defined broadly as the study of reciprocal ecological influences between humans and the environment in recreation/tourism contexts.

Traditionally, recreation ecology investigations have primarily responded to management needs that accentuated a carrying capacity framework (Hammitt and Cole 1987). Under this framework common research questions include how the severity or intensity of recreation impacts can be documented, and what the functional relationship is between impact intensity and amount of use. It was anticipated that answers to these questions could aid in making decisions for determining use limits as a means for containing recreation impacts (Cole 1987, Marion and Rogers 1994). Other common topics include evaluative studies on the effectiveness of various impact management measures, including visitor and site management techniques.

Over the last three decades recreation ecology studies have generated a substantial body of literature and knowledge that are managerially useful. For instance, curvilinear use-impact relationships have been established for many impact indicators (Cole 1987). The resistance and resilience of different plant species to recreational trampling have been determined (Liddle 1991). A large number of environmental attributes have been examined for their influence on the intensity and form of impact (Leung and Marion 1996). Nevertheless, many research questions have not been fully explored or remain unexplored. Examples include the effects of recreational activities on less discernible ecological components such as microbial communities, the effects of group size and user behavior on the intensity of impacts, and methodological refinements for assessing, evaluating, and monitoring recreation resource impacts. The spatial and temporal scale of previous studies are also limited (Cole and Landres 1996).

The present study investigates a neglected aspect of recreation ecology research, the methodological and analytical issues involved in assessing the spatial dimension of recreation resource impacts. Few efforts have been made to develop methods capable of assessing the spatial qualities of resource impacts. Similarly, there have been limited attempts to characterize and examine spatial patterns of resource impacts. Some basic spatial questions are:

1. How can the spatial extent, distribution and variation, and association of recreation resource impacts be characterized, quantified, and summarized for evaluation?
2. How do alternative impact assessment methods differ in their ability to characterize the type, extent, and distribution of recreation resource impacts, and what factors should be considered in selecting an assessment method and sampling strategy?
3. To what extent are these spatial properties of recreation resource impacts scale-dependent?

The need for greater spatial insights into recreation- and tourism-caused environmental impact studies have been recognized by Mitchell and Smith (1989). Cole (1989b) also acknowledged such a need and called specifically for contributions from geographers to recreation ecology research. Three particular research areas Cole pointed out were: (1) spatial distribution of recreation impacts, (2) differential susceptibility of sites, and (3) integrating capabilities of the geography discipline.

Spatial analytical approaches are commonly adopted in geography and its sub-discipline of recreational geography, which focuses on the spatial issues of leisure, recreation and tourism (Mitchell and Smith 1989). Common topics in recreational geography include estimation of regional recreation supply and demand, and recreational transportation, although Mitchell and Smith (1985) noted that impact studies were a growing research focus within recreational geography.

The need of spatial knowledge for impact assessment and natural resource management has also been recognized (Wathern 1988, Machlis and McKendry 1996). As far as recreation resource impacts and their management are concerned, spatial knowledge is important for at least three reasons. First, since the overall magnitude of recreation resource impacts is determined by both the intensity and spatial extent of impacts (Cole 1994), methods for quantifying the spatial extent and patterns of impact need to be developed as much as for quantifying the intensity of impact. Previous research have shown that recreation resource impacts affect only a very small portion of land area directly (Hammitt and Cole 1987). However, determination of the significance of recreation impacts based on the total proportion of land disturbed is at best inadequate, which tends to underestimate the ecological and social consequences of impact. Second, most existing indicators and standards developed in management frameworks such as Limits of Acceptable Change (LAC) (Stankey et al. 1985) reflect the intensity of impact, while spatial indicators and indices are seldom explored albeit their significance. Third, while standardizing recreation ecology research methods have been called for (Kuss 1986, Cole and Bayfield 1993), developing techniques for standardizing the reporting of recreation resource impacts should compliment these efforts, facilitating communication of research results from researchers to managers for decision making.

Objectives of the Study

The overall objective of this study is to fill some knowledge gaps on the spatial dimension of recreation resource impacts and their assessment and evaluation, with a primary focus on methodological and analytical issues. Specific study objectives are:

1. Review spatial analytical approaches and methods in geography and other disciplines, with special reference to their applicability to the assessment and evaluation of recreation resource impacts,
2. Characterize camping-related resource impacts using multivariate techniques, and examine the spatial patterns of such a characterization,
3. Examine the effects of changing sampling interval on the accuracy of point sampling methods in estimating the lineal extent and frequency of trail impact problems,
4. Develop and apply spatial indices for quantifying and evaluating the spatial dimension (extent, distribution, association) of recreation resource impacts, and
5. Provide management recommendations and guidelines in light of the research results.

Structure of the Dissertation

This dissertation adopts a journal-article structure that comprises three separate papers under a common theme of understanding the spatial dimension of recreation resource impacts and their assessment. Each of three papers addresses a specific topic, and includes an introduction, literature review, research methods, results and discussion, and implications and conclusions. The dissertation also contains four additional supporting chapters. Following is a list of all dissertation chapters:

I. General Introduction (problem statement, study significance, study objectives, structure of the dissertation)

II. Literature Review (definitions, spatial analytical approaches, spatial perspectives on outdoor recreation, spatial dimension of recreation resource impacts and their management)

III. Research Methodology (study area, study design, field measurements, data handling, manipulation and analysis)

IV. First Paper: *Characterizing Backcountry Camping Impacts and Their Spatial Patterns in Great Smoky Mountains National Park*

V. Second Paper: *The Influence of Sampling Interval on the Accuracy of Trail Impact Assessment*

VI. Third Paper: *Spatial Indices for Evaluating Recreation Resource Impacts*

VII. Summary and Conclusions

CHAPTER II. LITERATURE REVIEW

Introduction

Outdoor recreational activities occur in space, so do their environmental effects. Similarly, as outdoor recreational activities distribute unevenly across the landscape, so do their concomitant resource impacts (Hammitt and Cole 1987). An understanding of the spatial dimension of recreational use and impacts is essential if undesirable resource impacts are to be contained within acceptable levels through site and visitor management. While spatial patterns of recreation use and travel have received considerable research attention, systematic investigations on the spatial dimension of recreation resource impacts are scarce.

In order to gain better spatial understanding of recreation resource impacts we need impact assessment methods that are capable of identifying, quantifying and summarizing spatial properties of impacts. Such capabilities, however, are very limited in most existing recreation impact assessment methods. While improvement and standardization of experimental trampling studies and campsite assessment and monitoring methodology have been attempted (Cole 1989a, Marion 1991, Cole and Bayfield 1993), similar attempts for trail impact assessment are limited (Marion and Cole 1986, Lemky 1996). One major design consideration in trail impact assessment methods is the determination of sampling strategy and intensity, which is in essence a research question of spatial sampling.

This chapter begins with a discussion on the definition of impact assessment and spatial analytical approaches. Spatial analytical approaches and techniques developed in geography and ecology are reviewed with respect to their potential use in the present study, followed by a review of the spatial perspective to the study of outdoor recreation in general, and in recreation resource impacts and their management in particular. The chapter concludes by identifying some major knowledge gaps that exist in the field of recreation ecology, which provide the impetus for the present study.

Some Definitions

Impact Assessment

Impact assessment as a systematic field of study has its origins in the U.S. National Environmental Policy Act (NEPA) that became law in 1969. This law requires an environmental impact statement (EIS) be submitted for any project or development that would incur environmental impacts. Accordingly, Vanclay and Bronstein (1995:xi) define impact assessment as “the prediction or estimation of the consequences of a current or proposed action”. A more elaborate definition is provided by Treweek (1995:172) within an ecological context. He describes ecological impact assessment as “a formal process of defining, quantifying, and evaluating the potential impacts of defined actions on ecosystems”. These two definitions, however, emphasize the predictive capability of impact assessment.

Westman (1985) identifies two major components in impact assessment. They are *impact analysis*, which is objective identification, quantification, and summarization of the occurrence of impacts; and *impact evaluation*, which is a subjective process of determining the significance of impacts based on the results of impact analysis. Parallels can be found in determining the acceptability of recreation resource impacts and social carrying capacity in outdoor recreation management (Clark and Stankey 1979, Shelby and Heberlein 1986).

While impact assessment can be performed on any subject (social, ecological, policy, etc.), the present study focuses on two major recreation resources, campsites and trails, which may also be considered as recreational facilities. Under this context, impact assessment is conducted to identify, quantify, and evaluate resource damage on campsites and along trails due to their creation and use.

Spatial Analytical Approaches

Analysis of physical and human phenomena in space is the defining interest in the discipline of geography (Hartshorne 1959). The quantitative revolution in geography further fostered the growth in practice of spatial analysis (Berry and Marble 1968). There is also a growing interest in understanding spatial patterns and processes of ecological phenomena at landscape or ecosystem scales (Forman and Godron 1986, Turner and Gardner 1991). Geographers and landscape ecologists have employed various analytical approaches to understand spatial patterns, variations, and relationships of these phenomena through the application of conventional statistics, mathematics, cartography, and geographic information systems (GIS).

Numerous attempts have been made to define and classify spatial analysis. In the broadest sense, spatial analysis may be defined as any analysis that involves the use of maps (Unwin 1981), or that includes one or more spatially explicit variables (Meentemeyer 1989). These spatial variables encompass basic spatial measures of area, distance, and direction, as well as metrics or indices indicative of spatial patterns, spatial connectivity, spatial associations, and spatial scale.

Haining (1990) classifies spatial analysis into two related categories of spatial data analysis and spatial statistics. A similar dichotomy of spatial analysis is also proposed by Fischer et al. (1996). Spatial data analysis involves application of classical statistical techniques to spatial data that are geo-referenced. Spatial statistics, also referred to as geostatistics (Davis 1986), take into account locational information (e.g. coordinates) in data analysis. Instead of assuming independence of observation, spatial statistical analysis attempts to characterize spatial dependence using modeling methods such as spatial autocorrelation and regionalized variables. An understanding of spatial dependence can inform spatial sampling. Descriptive spatial statistics include spatial mean, spatial median, standard distance, and areal frequency distribution (Griffith and Amrhein 1991).

Influenced in part by the development of GIS, Goodchild (1987) and Openshaw (1991) adopt a toolbox or operational approach in which spatial analysis is viewed as a repertoire of techniques based on type of geographical data (i.e. points, lines, areas, and surfaces). Two fundamental questions addressed by these spatial analytical methods are spatial pattern description and spatial pattern relationships (Openshaw 1991). This dissertation adopts a broad sense of the definition of spatial analysis, illustrated in Figure 2.1. A spatial analytical approach can then be defined as the use of spatial analysis, in its broadest sense, in understanding the static and dynamic qualities of a phenomenon in space, including its spatial extent, distribution and variation, and association and relationships.

Spatial analysis is the fundamental skill of geographers. Recent interests in landscape ecology and ecosystem management, together with technological advances such as the use of GIS, global positioning systems (GPS), and remote sensing, have pointed to the importance of understanding spatial issues and have fostered the development of spatial analytical techniques (Lam and Quattrochi 1992).

Descriptive spatial analytical approaches include the use of maps, descriptive spatial statistics, and spatial indices to describe spatial phenomena (Figure 2.1). Cartographers have developed various types of maps to visualize and communicate the spatial extent, distribution and variation, and relationship of events in space (Robinson et al. 1995). Recent advancements in geographic information technologies have greatly enhanced the sophistication of spatial mapping and visualization.

Inferential approaches address questions related to spatial or non-spatial qualities of phenomena through limited sampling in space (Figure 2.1). These approaches include spatial sampling and its associated problems with interpolation, demarcation of spatial units (also referred to as the Modifiable Area Unit Problem), and aggregation effects (Lam 1983). The most common inferential approach is, however, hypothesis testing on spatial data, which is often incorporated in descriptive and modeling approaches as well.

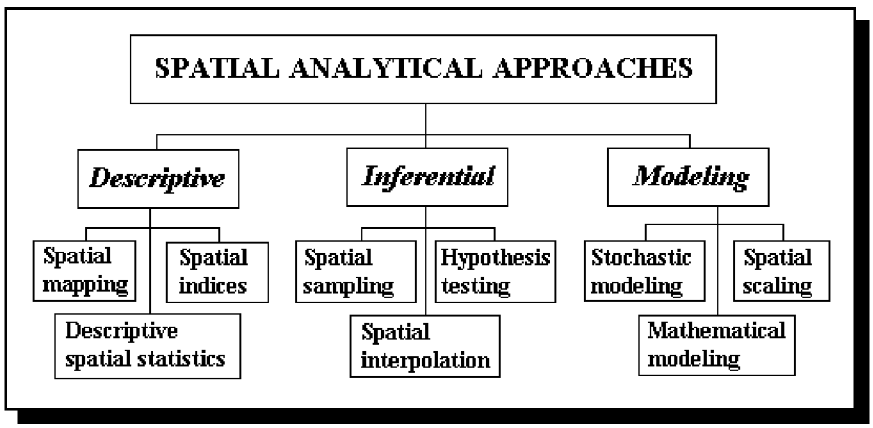

Figure 2.1. A classification of spatial analytical approaches (partially based on Hammond and McCullagh 1974).

Modeling approaches are used to characterize spatial patterns and variabilities, and relationships through construction of stochastic or mathematical models (Figure 2.1). These models can be explanatory and predictive in purpose. Examples are trend surface analysis adapted from regression analysis and gravity models, respectively. Modeling approaches involve the abstraction and representation of spatial patterns and processes of the phenomenon of interest (Cliff and Ord 1981, Huggett 1993). Spatial scaling, or determination of characteristic scale at which spatial relationships can be maximized, is of growing interest to geographers and landscape ecologists (Wiens 1989). It is generally recognized that an understanding of the scale factor and scale-dependency should improve our knowledge of ecological patterns and processes, and can aid in sampling design and formulating management strategies. Common spatial scaling techniques include geostatistics, fractals, and spectral analysis.

The three major approaches listed in Figure 2.1 are often integrated. Hypotheses, for instance, can be formulated and tested on descriptive spatial statistics and indices as well as spatial models. Results of spatial interpolation and modeling are often visualized by various mapping techniques.

In summary, then, recreation impact assessment using spatial analytical approaches is concerned with the identification, quantification, and summarization of the spatial dimension of recreation resource impacts using various spatial analytical techniques shown in Figure 2.1. Spatial dimension, in turn, includes spatial patterns (extent, distribution and variation), spatial association, and spatial relationships. Although many recreation impact assessment programs are designed with a monitoring capability in mind, the present study focuses more attention on the assessment of impact conditions. It should be noted that the utility of the above-mentioned spatial analytical approaches and methods are limited by the nature and type of impact condition data. As an exploratory study, this dissertation attempts to examine those methods that fit into the data collected from common recreation impact assessments. Future advancements in recreation impact assessment and monitoring methodology would probably expand the applicability of spatial analytical approaches and methods, thus improving our understanding of recreation resource impacts in space.

Spatial Perspectives of Outdoor Recreation

Outdoor recreation occurs in a multitude of places and usually involves traveling, which results in spatial patterns and processes that interest geographers (Wall 1989). Geographer's interest in outdoor recreation can be traced back to the 1930s. It was, however, Wolfe's (1964) comprehensive survey of the outdoor recreation literature that turned such an interest into the systematic study of recreational geography. This discipline utilizes diverse spatial perspectives to understand leisure, recreation, and tourism (Mitchell and Smith 1989). This diversity is illustrated in Figure 2.2. Smith (1989) provides a review of some basic spatial concepts, such as nodes, networks, hierarchies, and regions. A more simplistic typology of points, lines, and areas is discussed by Wall (1997).

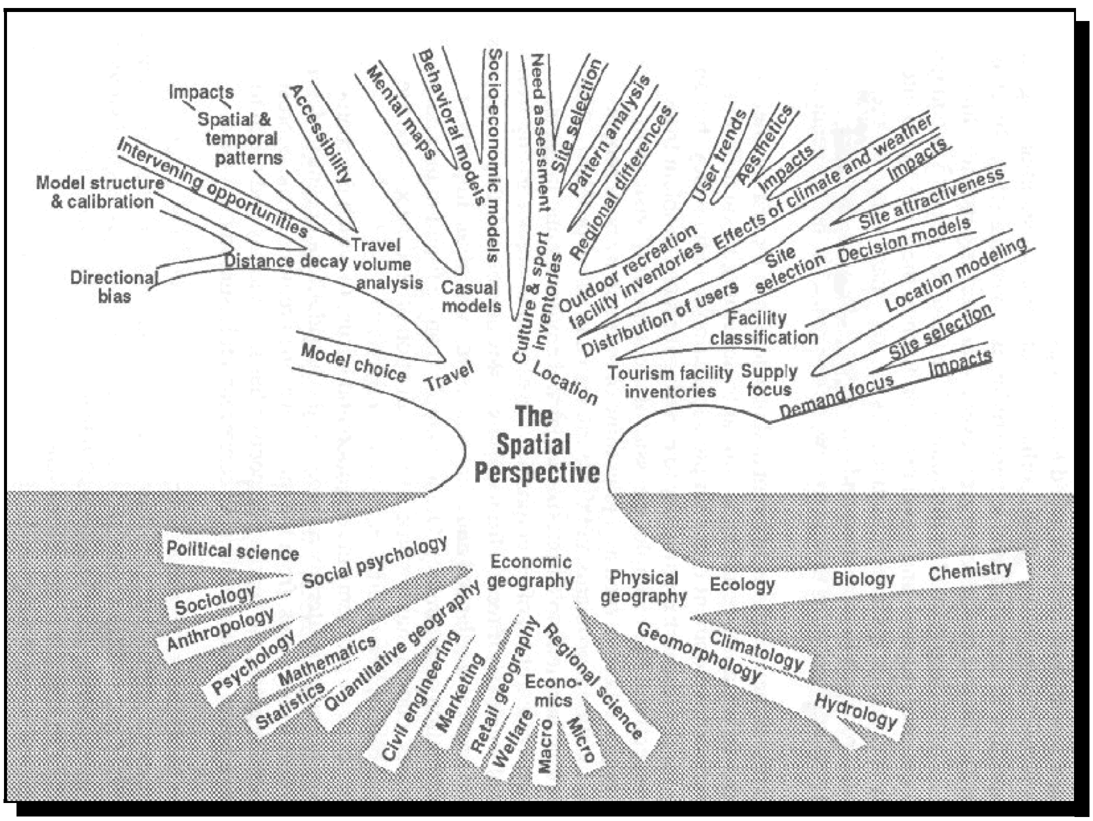

Figure 2.2. Spatial perspective to leisure, recreation, and tourism research (Smith 1989; Reprinted by permission of Addison Wesley Longman Ltd.).

Originated from the discipline of economics, many recreational geography studies follow a demand-supply or production-consumption model (Coppock and Duffield 1975, Wall 1989, Mitchell 1994). Smith (1983, 1989), on the other hand, adopts a locational-travel dichotomy to examine recreation-related spatial patterns and processes. Various spatial analytical approaches have been employed by recreational geographers and other researchers interested in spatial characteristics. Descriptive approaches, such as mapping and the use of spatial statistics and indices, are common in recreation and tourism geography (Smith 1995). For example, the utility of spatial mapping was demonstrated by Lucas (1964) who revealed the spatial variation in wilderness perceptions in Boundary Waters Canoe Areas Wilderness in Minnesota. Kliskey and Kearsley (1993) also adopts a mapping approach to illustrate wilderness perceptions in New Zealand. Flow maps were used by Hendee et al. (1990) to illustrate distribution of recreation use, and by Confer et al. (1992 and 1995) to evaluate the degree of spatial concentration in visitor satisfaction with the use of a GIS.

Descriptive spatial statistics are also employed in outdoor recreation research. For example, Lorenz curves and associated spatial indices (Index of Concentration, and Index of Dissimilarity) were used by Clawson and Knetsch (1971). Hendee et al. (1990) applied the Lorenz curve and Index of Concentration to quantify and evaluate the degree of spatial concentration of wilderness visitors in Montana. The Effectiveness Index is another spatially explicit index developed by Clawson (1982) to provide a regional supply measure of availability of recreation opportunities relative to demographic characteristics, including location and number of people, and their willingness to travel.

Inferential spatial analytical approaches, particularly spatial sampling and interpolation, are less commonly used in outdoor recreation and wilderness studies since most recreation phenomena are often finite in existence. Moreover, they do not often address situations in which continuous spatial phenomenon need to be characterized by a limited sample, necessitating the use of spatial interpolation (Lam 1983). However, spatial sampling and sampling units are often of concern in recreation impact assessment and monitoring programs, in which sample size and sampling interval need to be determined.

Modeling approaches have been used to describe recreation patterns and processes. Smith (1983, 1989) reviews various models used in recreational geography, including gravity models and intervening opportunity models. In wilderness research, Lucas and Shechter (1977) have attempted to simulate travel patterns at a park scale.

The above synopsis demonstrates that spatial issues of recreation and tourism have been a core interest in recreational geography. Spatial dimension of recreation resource impacts and their management is reviewed in the following section.

Spatial Dimension of Recreation Resource Impacts and Their Management

Recreation ecology as an emerging field of study finds its position at the interface between the ecological and social sciences. Traditionally, recreation ecology has focused on the description of recreation impacts and relationships with use characteristics such as amount of use and type of use. Impact-environment relationships have been investigated, but in a less vigorous manner. The spatial dimension of recreation resource impacts and their assessment has seldom been systematically investigated or has been examined only at a micro or within-site spatial scale. The following is a review of previous studies with an explicit focus on the spatial dimension of recreation impacts.

Spatial Patterns of Recreation Impacts

Spatial Extent

The spatial extent of recreation impacts have been quantified by aggregate or density measures. For example, sizes of individual campsites or areas of various trail corridors have been aggregated to indicate total land disturbance, which can then be compared among park districts (Marion and Leung 1997, Cole et al. 1997).

Spatial indices have also been constructed for quantifying spatial extent of trail impacts (Bayfield and Lloyd 1973) at site and regional levels (Harden 1992) in terms of trail density. Similar density measures can be found in studies on linear features such as roads and streams. More examples of using descriptive spatial analytical approaches in recreation impact studies are provided in Table 2.1.

Spatial Distribution and Variation

Spatial distribution and variation in recreation impacts have been addressed using mapping (Hickler and Bratton 1980, Cole 1983). In fact, mapping procedures have been suggested as part of the LAC process to facilitate visualization of resource conditions (Stankey et al. 1985).

Table 2.1. Some examples of using spatial analytical methods in recreation impact studies.

Approach/Citation	Study Location	Impact Type	Scale
Descriptive Approaches			
Mapping			
Root & Knapik (1972)	Great Divide Trail, Canada	Trail	Parkwide
Overton (1991)	Comanche Peak Wilderness, CO	Campsite	Site
Bayfield (1986)	Cairngorm Mountains, Scotland	Trail	Parkwide
Cole (1993)	Lee Metcalf, Selway-Bitterroot, and Eagle Cap Wildernesses, MT and OR	Campsite	Parkwide
Spatial Indices			
Stohlgren & Parsons (1992)	Sequoia and Kings NPs	Campsite	District
Modeling Approaches			
Conceptual Models			
Cole (1992)	Hypothetical	Campsite	Site
Scaling			
Taylor et al. (1993)	Ontario,Canada	Trampling	Site

A number of studies have focused the examination of the spatial variation in camping impacts at the micro or site scale. Substantial within-site variation has been reported by Stohlgren (1986), and more recently by Marion and Cole (1996). Serving as the center for activities, the core of campsites receive most trampling and campfire-related impacts. For example, Overton (1991) mapped each campsite in detail, providing accurate information on changes over time.

Trail deterioration studies have also examined the spatial distribution and variation in impact. Root and Knapik (1972), for example, mapped degraded trail locations. Many studies have examined the variation in impact level with distance from the center of trail treads or from water (Ward and Berg 1973, Matlack 1993).

Spatial variation of recreation impacts among various districts of a park or among different parks has been investigated. At the park level, McEwen and Tocher (1976) notes that recreation impact patterns include nodes and linkages. Spatial variation of campsite impacts and its change over time has been mapped by Merriam et al. (1973) and Cole (1982 and 1993). More discussion on spatial patterns of recreation impacts can be found in Hart (1982) and Hammitt and Cole (1987).

Spatial Association and Relationships

A number of recreation impact studies have examined the spatial association and relationships between different types of impact, and between impacts and environmental attributes (Cole 1987). Ward and Berg (1973), for example, found that there was a negative relationship between soil compaction and distance to water and distance from trail center. Similar results were also reported by Taylor et al. (1993). Illegal campsites have been found to be located close to trail systems, as visitors prefer certain campsite attributes that can be found near trail corridors (Canon et al. 1979).

Spatial Strategies for Minimizing Recreation Impacts

Contrasting to the fact that there is limited knowledge on the spatial dimension of recreation resource impacts, spatial decisions are routinely made, and spatial strategies are among the most popular resource management tools. At least four basic spatial strategies are identified. *Spatial segregation* in form of zoning or site/area closure is probably the most commonly used strategy for insulating already damaged localities or sensitive habitats from impacting use (Hammitt and Cole 1987). Harris et al. (1995), for example, used a GIS to resolve wildlife-recreationist conflict by minimizing the overlap between wildlife habitats and corridors and areas with substantial recreational use. There are also social reasons for implementing spatial segregation, such as separating incompatible recreational activities or conflicting user groups (McEwen and Tocher 1976).

Spatial Containment and *spatial dispersal* are two major strategies for minimizing recreation impacts. Spatial containment concentrates use within limited portions of an area, thereby enhancing resource protection for remaining areas (Lloyd and Fischer 1972, Cole 1982, Cole and Landres 1996). A spatial dispersal strategy, on the other hand, seeks to spread use sufficiently to avoid permanent impacts in any single place. Finally, proper *spatial* *configuration* of recreational facilities may reduce unnecessary impacts. For instance, Leonard et al. (1981) recommends a linear configuration of facilities in campgrounds to minimize the creation of social trails.

Some Knowledge Gaps

The above review of our current understanding of the spatial dimension of recreation resource impacts and their management reveals several major knowledge gaps, listed as follows:

1. Issue of spatial sampling.

Trail impact assessment and monitoring is exemplary of the issue of spatial sampling. Two major approaches were adopted in previous studies (Leung et al. 1997). Sampling-based approaches involve some unbiased sampling strategy to determine locations where measurements are taken. Two major methods under the sampling-based approach are systematic point sampling (e.g., Cole 1983) and stratified point sampling (Summer 1980). Census-based approaches, on the other hand, focus on the location and spatial extent of pre-defined problems. Recent surveys conducted by Marion (1994) and Cole et al. (1997) have adopted this approach.

The determination of sampling intervals for the sampling-based methods, and of section lengths for sectional evaluation, are haphazard, with little consideration of impact patterns and environmental factors (Lemky 1996). However, representation of spatial patterns and estimates of lineal extent of impact problems along a trail could be affected by choice of a sampling interval or unit. Sampling intervals might be related to landscape complexity and terrain characteristics, including topographic types and positions. Finally, sampling intervals may also need to be calibrated to differing impact types or to relationships between impacts and topographic types.

2. Spatial characterization of recreation resource impacts.

There is a need for exploring the potential indicators and indices available for characterizing the spatial dimension of recreation impacts. Such an effort has an immediate utility to the evaluation of overall magnitude of recreation impacts under contemporary management frameworks such as LAC.

3. Scale dependence of impact patterns and impact-environment relationships.

A study conducted by Taylor et al. (1993) may be the only one in recreation ecology literature that examines the scale inconsistency of trampling responses. We have a limited understanding of how spatial patterns of impacts and impact-environment relationships are influenced by the size of a study area, the size of individual sampling units, and the intensity of sampling.

Summary

The above literature review demonstrates that spatial dimension is a significant yet underexplored topic in recreation ecology. If recreation resources are to be managed in a proactive manner, both spatial patterns and the intensity of resource impacts should be assessed and evaluated. This dissertation is therefore intended to address the first and second research gaps mentioned above using spatial analytical approaches, augmented by various univariate and multivariate statistical methods.

CHAPTER III. RESEARCH METHODOLOGY

Introduction

The goal of this dissertation is to examine the spatial dimension of recreation resource impacts and their assessment and evaluation. Data were collected as part of a parkwide backcountry trail and campsite impact assessment (TCIA) project in the Great Smoky Mountains National Park (GSMNP). TCIA field work was conducted in the Summer of 1993. Specific management reports for trail (Marion 1994) and campsite (Marion and Leung 1997) survey work have been completed.

Due to the structure of this dissertation, elaborate descriptions on research methods and procedures are included in individual articles (chapters). This chapter is intended to provide the overall context and research design of the TCIA project. It begins with a definition of some commonly used terms, followed by an overview of the study area. The general TCIA study and research design and campsite and impact assessment procedures are described. This chapter concludes with an account of overall data handling and analytical procedures, and a discussion of some study limitations.

Definition of Terms

For clarity, several terms that are used throughout the dissertation are defined. *Backcountry* is referred to the undeveloped and roadless portions of a national park (NPS

1988). Ninety percent of the park area of GSMNP is considered as backcountry, which is managed as wilderness due to its “proposed wilderness” status (NPS 1981). *Backcountry campsites* refer to localities in the backcountry where change in groundcover is both discernible and attributable to overnight use (Marion 1991). These campsites do not have permanent developments except for bear-proof storage facilities and horse corrals.

In the context of this study, two types of backcountry campsites are distinguished. A campsite is considered a *legal campsite* if it is located at or is reasonably close to one of the 84 designated backcountry campgrounds (campgrounds hereafter). The typical campground consists of two or three individual campsites. In contrast, campsites that are located away from designated campgrounds are considered to be *illegal campsites*.

Trails are defined as officially maintained travel routes in the backcountry used by hikers and horse-riders. These official park trails are all named and marked on park maps and literature. Trails outside the official trail system are considered as informal trails, regardless of their construction standards and conditions. Informal trails located at designated backcountry campgrounds are defined as *social trails*. These social trails often connect two campsites or provide access to water sources, toilet areas, or scenic lookouts.

Study Area

Environmental Settings

The Great Smoky Mountains National Park (GSMNP) is located in the southern Appalachian Mountains along the state line between Tennessee and North Carolina (Figure

3.1). Its approximately 209,000 hectares of park area comprise the main divide of the Great Smoky Mountains and extensive ridges, spurs and foothills at lower elevations.

The climate of GSMNP is characterized as continental warm temperate with abundant rainfall, an annual average between 1500 to 2500 mm (Shanks 1954). Rainfall is distributed evenly throughout the year, but a vertical gradient of increasing rainfall towards higher elevations is evident. Intense torrential rainstorms are common in summer (Bogucki 1972), generating tremendous runoff loads that affect the park's road and trail systems.

Most of the park area is underlain by metamorphosed sedimentary rocks of the Ocoee Series formed during the Later Precambrian Age (King et al. 1968). Common rock types include sandstones, shales, conglomerates, phyllites, slates, and schists. Outcrops of Ordovician limestones are confined to lower elevations in the western part of the park. The park is dominated by steep terrains, only 10 % of which have slopes of less than 10 degrees. Elevations change dramatically from 256 m near the western park boundary to 2025 m at Clingman's Dome near the park's center. Such a steep topography poses significant limits to soil development, and is prone to landslides and other forms of mass movement. Little bedrock is exposed, however, despite these pedological limitations.

GSMNP accommodates one of the most diverse flora and fauna in North America as a result of its moist climate and large range in elevations. The park represents all major coniferous and deciduous forest types in the eastern North America (Whittaker 1956), and possesses the largest remnant of virgin or 'old-growth' forests in the eastern United States. The total number of tree species is estimated at 130 and other plant species about 4,000.

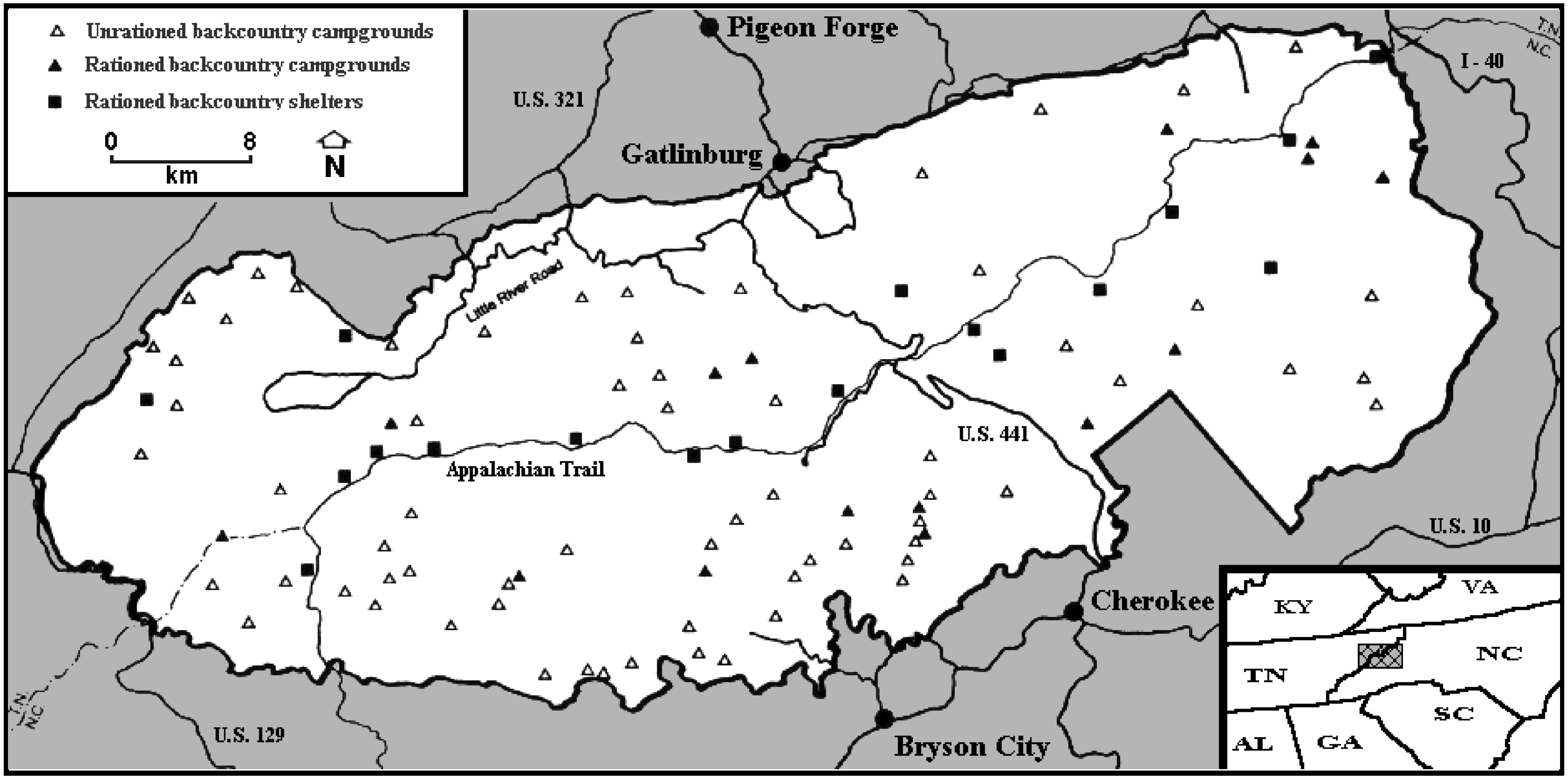

Figure 3.1. The Great Smoky Mountains National Park and its backcountry camping system.

Dominant forest types classified by Whittaker (1956) include: (1) boreal spruce-fir (*Picea* spp. and *Abies* spp.) forests, (2) xeric pine (*Pinus* spp.) forests, (3) intermediate oak-hickory (*Quercus* spp. and *Carya* spp.) hardwoods, and (4) mixed mesic hardwoods, dominated by eastern hemlocks (*Tsuga canadensis*), maples (*Acer* spp.), yellow poplars (*Liriodendron tulipifera*), buckeyes (*Aesculus octandra*), yellow birch (*Betula alleghaniensis*), and beeches (*Fagus* spp.). Faunal abundance and diversity are also high, including one of the highest populations of black bear (*Ursus americanus*) in North America.

The outstanding conservation and scientific value of GSMNP has received national recognition by its designation as a national park early in 1926, and international recognition by its subsequent inclusion as both an International Biosphere Reserve and World Heritage Site. Eighty-three percent, or 170,000 ha of the park area, has been recommended for wilderness designation and is managed as *de facto* wilderness. Despite such recognitions and concomitant protection efforts, the GSMNP, like other protected areas in the country, has been subject to a series of internal and external threats (Cole and Landres 1996). Some of the most serious external threats to the park's ecosystem health are associated with the introduction of exotic species and parasites such as chestnut blight (*Endotheca parasitica*), balsam woolly aphid (*Adelges piceae*), European wild boar (*Sus scrofa*), and recently the gypsy moth (*Lymantria dispar*). Degrading air quality associated with increasing levels of acid deposition and ozone pollution is another major external threat, which is likely to complicate the effects of exotic species invasions (Shavel et al. 1994). While anthropogenic fires were the single most important internal threat before the establishment of GSMNP, resource impacts associated with recreation, tourism, and other forms of visitation, constitute a recent and growing internal threat, which forms the basis of the TCIA project and present study.

Managerial Settings

The overall management policy of the GSMNP is guided legislatively by the National Park Service (NPS) Organic Act of 1916, which mandates the NPS to:

> "conserve the scenery and the natural and historic objects and wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (16 U.S. Code 1)

Specific administrative policies and management guidance of national parks and other NPS units are directed by the NPS Management Policies (NPS 1988). With respect to backcountry recreation use and resource impacts, NPS Management Policies state that:

> "Backcountry use will be managed to avoid unacceptable impacts on park resources or adverse effects on visitor enjoyment of appropriate recreational experiences. The National Park Service will identify acceptable limits of impacts, monitor backcountry use levels and resource conditions, and take prompt corrective action when unacceptable impacts occur." (NPS 1988:8-3)

At the park level, the GSMNP General Management Plan (GMP) reiterates that the purpose of park management is to preserve its exceptionally diverse resources and to provide public benefit from and enjoyment of them in ways that will leave the resources essentially unaltered (NPS 1981). The GMP also defined a number of management zones. The backcountry zone, also referred to as Natural Zone in the parks' GMP, constitutes 93% of the park area (NPS 1981). The park's two management districts are delineated by the Tennessee/North Carolina state line, and each management district has its own Ranger and Maintenance subdistrict systems.

Historically, a carrying capacity paradigm has been dominant in park and recreation resource management practices in GSMNP, and in most other U.S. protected areas. Under this paradigm managers and scientists sought to determine the maximum number of visitors without compromising the resource protection mandate. Unsatisfied with this paradigm, management-by-objective (MOB) frameworks such as Limits of Acceptable Change (LAC) (Stankey et al. 1985) and Visitor Impact Management (VIM) (Graefe et al. 1990) have been developed. These frameworks have shifted the management focus from the number of visitors permissible to the acceptable conditions defined by resource and social standards and monitored by objective indicators. In order to adapt these new frameworks to national park settings, the NPS has developed the Visitor Experience and Resource Protection framework (VERP), and has applied it to Arches National Park in Utah and several other park units (NPS 1997). The TCIA project was initiated with an intent to develop resource indicators that have the potential of being adopted in the assessment and monitoring components of any of the above MOB management frameworks.

Recreation Resource Use and Impacts

Recreation resources and facilities in GSMNP are generally located either in the frontcountry zone along road corridors and park boundaries, or in the backcountry zone along the extensive trail network. There are approximately 590 official trail segments with a total sum of 1,534 km in length (Williams and Parker 1995). The origin and design of these trails vary considerably. Some trails follow historic wagon roads and railroad grades created by early Appalachian settlers. During the 1930s the Civil Conservation Corps constructed the majority of the trail system. The NPS was also involved in building some of the trails and roadbeds for accessing park facilities (Bratton et al. 1979). These trails, regardless of their origin, are designated either as hiker-only trails or horse trails where hiker use is also accommodated. Mountain bikes and other motorized modes of travel are prohibited on backcountry park trails. Trail maintenance is performed by park crews and volunteers. Funding and staffing for this work is limited, and budget cuts over the past decade have greatly reduced the extent and effectiveness of these efforts.

Coupled with the trail network is the park's backcountry camping system that includes 84 backcountry campgrounds located throughout the park, and 18 shelters located primarily along the Appalachian Trail. All backcountry campgrounds are designated, numbered and posted. Each backcountry campground consists of one or more campsites (i.e., backcountry campsites), many of which are user-created. Except for a fire permit requirement, no other restrictions were placed on backcountry visitors until 1976 when park managers faced ever-growing numbers of visitors and rapidly expanding resource impacts (Wightman 1989). Since then, all backcountry camping has been restricted to the designated campgrounds and shelters. While all backcountry visitors are required to obtain a self-registered permit, 15 backcountry campgrounds and all shelters are rationed, meaning that these facilities have quotas and require prior reservations. There are also restrictions on group size (eight persons) and campsite length of stay (three nights per site).

Since its establishment in the 1930s, GSMNP has been one of the most visited national parks in the United States, reporting 8.6 million recreation visits in 1994 (NPS 1994). Recent surveys indicate that the majority of visitors is in small family-based groups, and typically more than 60% of them engage in day-use activities, such as scenic driving and wildlife viewing (Littlejohn 1997). While frontcountry recreation sites and road corridors receive the majority of visitation, a considerable number of visitors engage in day hiking and overnight backcountry activities, putting substantial use pressure on recreation resources and facilities in the backcountry zone.

Table 3.1 provides a synopsis of recreation impact studies previously conducted in the park. Bratton and her colleagues conducted the first parkwide trail and campsite impact assessment study in the mid-1970s (Bratton et al. 1978, 1979 and 1982). They reported that resource impacts on campsites and shelters were extensive, with widespread existence of illegal campsites, which contributed significantly to the total camping disturbance (Bratton et al. 1978). Trail impacts were also substantial, and were mostly related to steeper slope gradients (Bratton et al. 1979). Similar conclusions were reached by Renfro (1985), who surveyed resource conditions of the Appalachian Trail and shelters.

This research is the second parkwide trail and campsite impact assessment study, incorporating improved measurement techniques, precision, and replicability. While no program for monitoring trail and campsite conditions currently exists as part of the park's

Table 3.1. Some previous studies on recreation resource impacts in Great Smoky Mountains National Park.

Type of Impact	Study Area	Impact Variables	Reference
Trails			
General Assessment	Parkwide	Percent estimate of various impact problems in each sample section	Bratton et al. (1979)
	Appalachian Trail	Width, incision depth, cross-section loss	Renfro (1985)
	520 km of trails (35% total trail length)	Lineal extent and frequency of six impact problems	Marion (1994)
Horse and Hiker Use	3 experimental sites	Soil compaction, vegetation height, litter depth	Whittaker and Bratton (1978)
Soil Erosion	Cades Cove, TN	Sediment yield by simulated rainfall	Harden (1992)
Illegal Collection of Flowering Plants	Not provided	Change in plant morphology	Bratton (1985)
Campsites & Shelters			
General Assessment	Parkwide	Site size (areal disturbance), condition rating, cover change of ground vegetation, soil exposure, tree damage, fire pits, human waste, trash	Bratton et al. (1978), Marion and Leung (1997)
	Along Appalachian Trail	Same as above	Renfro (1985)
	A sample of 10 campsites and 6 shelters	19 variables selected from Bratton et al. (1978), Wightman (1981), and Renfro (1985)	Klein and Burde (1991)
Firewood Collection	A sample of 8 campsites	Biomass indicators: standing stems, stumps, vegetation coverages, woody fuel loadings	Bratton et al. (1982)
Rivers & Streams			
General Assessment	Deep Creek, NC; Smokmont, NC; Townsend Wye, TN	Channel disturbance, cover change of moss, proliferation of river access trails, trash, human waste	Larson and Hammitt (1981)

backcountry management efforts, such work has been attempted (Wightman 1981) and is called for in a new Backcountry Management Plan (GSMNP 1995). In these contexts the TCIA project was designed to provide baseline data on recreation resource conditions as well as a standardized methodology for future monitoring efforts. The goal of this dissertation was to refine the assessment methodologies and to enhance the spatial understanding of the data collected, thereby contributing to a more comprehensive recreation resource evaluation.

Study Design

In order to provide baseline data for comparison with future measurements, the TCIA project adopted a complete census for all designated backcountry campgrounds and shelters. Extensive searches were performed to locate and assess as many unofficial, or illegal campsites in the backcountry as possible. Due to funding and logistical constraints, not all of the backcountry park trails were included in the study. Efforts were made to ensure the sample of trails was representative of the park's trail system with respect to use type and intensity, environmental settings, and construction and maintenance standards. Some trails in the sample, however, were selected for management reasons such as a high frequency of visitor complaints. The trail data might therefore be biased somewhat towards more highly impacted trails. However, these potential biases of the trail sample do not hinder this dissertation work.

The TCIA project includes the entire process of identification, measurement, analysis, and evaluation of current resource conditions, and may be classified as an after-the-fact research design (Wall and Wright 1977). This type of design can provide useful documentation of the extent and patterns of existing problems, but its explanatory and predictive capabilities are often limited due to the lack of sampling and experimental control of extraneous and confounding factors.

Due to differences in research methods, the comparability of two assessment projects, namely Bratton et al. (1978, 1979 and 1982) and the TCIA project (Marion 1994, Marion and Leung 1997), should be viewed with caution. For this reason the TCIA project, instead of Bratton's work, should be considered as the first cycle of the park's monitoring program.

The Campsite Impact Assessment

All campsites at designated backcountry campgrounds were assessed. Extensive searches were also conducted to locate and assess illegal campsites that could not be associated with any designated backcountry campgrounds. Resource conditions of 18 backcountry shelters were also assessed, but they were excluded from the following analyses.

A multi-parameter campsite assessment approach coupled with a descriptive condition class rating system was applied to each campsite (the unit of observation). Procedures were based on Marion (1991) with certain modification to fit the particulars of this study area. The assessment begins with demarcating a campsite boundary, and all other measurements are made within the defined site boundary. Measurements include campsite size, ground vegetation cover, soil exposure, tree damage, fire pits, evidence of human waste and trash. For relocation and monitoring purposes, a metal tag was buried on each assessed campsite.

The exact location of the metal tag was recorded by making distance and angular measurements to at least two permanent features, and by taking a photograph from a known point. For complete details of the procedures please refer to Appendix I.

The ability to identify a campsite, define boundaries, and take accurate measurements likely varies from one field staff to another. To minimize such interrater variation, a five-day field-based staff training program was provided prior to the initiation of field work. This training was intended to ensure that every staff member was proficient in applying the field procedures. Precision of the measurements was enhanced by providing a comprehensive manual containing complete details of definitions and measurement procedures. Interrater precision of the campsite impact measurements was also assessed and evaluated.

The Trail Impact Assessment

Approximately 520 km of 72 backcountry trails were surveyed, which is equivalent to 25% of all park trails in number and 35% in total trail length. On each selected trail, a census-based approach was adopted in which each occurrence of the following six impact problems were identified and measured in lineal extent (length). These tread surface problems include: (1) excessive tread incision or soil erosion, (2) excessive wet or muddy soil, (3) excessive tread widths, (4) excessive occurrence of exposed roots, (5) occurrence of running water, and (6) occurrence of multiple or secondary treads. The minimum observation unit of impact problems was set at 3.3 m (10 ft). In other words, only problem segments that had a lineal extent of 3.3 m or more were recorded. These six problems were defined carefully by consulting the literature and park staff. Other attributes were also recorded on each trail. These include inventory information such as use type, average width; maintenance information such as trail drainage features (water bars, drainage dips, etc.); and aesthetic information such as the existence of attraction features (e.g. waterfalls, overlooks). For complete details of the procedures please refer to Appendix II.

The ability to identify a trail impact problem and define the beginning and ending distance likely varies from one field staff to another. To minimize such interrater variation, a manual with complete details of definitions and procedures was provided, augmented by a one-day staff training on these procedures. Interrater precision was assessed and evaluated by having all crew members measure the same trail and comparing the results across crew members.

Data Handling and Analysis

Data collected were coded and input using dBase IV, while data analyses were mostly performed using SPSS 7.5 for Windows. The quality of the campsite and trail assessment datasets was assured by performing manual checking and by applying some exploratory data analysis procedures such as descriptive statistics, histograms, and scatterplots.

Accurate visitor use data on specific campsite and trail levels are unavailable, precluding elaborate examination on the factor of amount of use. Only rationed backcountry campgrounds and shelters maintain reasonably reliable backcountry permit statistics. However, campsite use levels can be broadly categorized with the assistance of park staff.

Types of use for campsites and trails were also determined.

Some trail-related variables were collected from the GIS database recently compiled by the park staff (Williams and Parker 1995). These variables include trail length and elevation change (gain/loss). This information was included in the analyses on which the second paper (Chapter V) is based.

Study Limitations

Recreation ecology studies have been criticized as being mostly after-the-fact designs which are limited in their ability to evaluate causal relationships and to disentangle environmental factors from human recreation influence (Wall and Wright 1977, Cole 1987). The present study also suffers from this significant limitation.

Most parks, however, cannot afford an experimental research approach to assess recreation resource impacts. Park managers require a scientifically defensible and efficient methodology for impact assessment and monitoring that provides managerially relevant data for evaluating the magnitude of recreation resource impacts against acceptability standards. A primary goal of this dissertation is therefore to advance such efforts. Elaborate examination of casual relationships for predictive purposes is beyond the scope this study.

Trails included in this study were not selected at random, implying that there are possibilities of selection bias involved. In addition, only the frequency of occurrence and lineal extent of trail impact problems were documented. Measures on the intensity of impact were limited to an ordinal scale, such as various levels of soil erosion and trail widths.

Like many other recreation impact assessment studies, information on amount of use is largely unavailable. While accurate trail and campsite use data, particularly spatial patterns of visitation, would probably contribute to the understanding and explanation of the spatial patterns and variabilities of recreation impacts, use information is not critical in this dissertation as its primary focus is on methodological and measurement issues of impact assessment.