SELECTED ECOLOGICAL IMPACTS OF OUTDOOR RECREATION: THE BERG LAKE TRAIL IN MOUNT ROBSON PROVINCIAL PARK

by

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Abstract

A study on visitor impacts was carried out in Mount Robson Provincial Park along the Berg Lake trail corridor in 2002. Based on the existing trail monitoring database established in Mount Robson Provincial Park, a longitudinal analysis of trail impact indicators such as width, incision, vegetation cover, proliferation of social trails, and visitor use level was conducted. This was complemented by a field visit in July 2002, which identified all monitoring sites on the Berg Lake trail and collected most recent data on the above-mentioned indicators.

Results indicate that out of twelve monitoring sites, eight exceeded the acceptable limit in trail width. Four sites exhibited deeply incised trail surface. Vegetation cover on trail had not changed, however, vegetation loss and soil compaction were severe problems on campgrounds. Since the implementation of a quota system in 1996, visitor use on campgrounds had been evenly distributed; however, displacement of visitors had been reported to be an issue.

The results suggest that insufficient indicators, the lack of consistency in measurement, and improper site selections are issues that Mt. Robson Provincial Park management, and BC Parks in general, must address if the goal is to develop a science-based visitor management strategy.

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Chapter 1: Introduction

1.1 Background

The World Conservation Union, IUCN (1991, p. 29) defines a protected area as an "area dedicated to the protection and enjoyment of natural and cultural heritage to maintain biodiversity and ecological life support services." Protected areas are set aside for the conservation of natural resources and provision of recreational opportunities for the public. The dual mandate of a park is a formidable challenge as recreation use in parks and protected areas continues to increase significantly. As a result, many parks and protected areas around the world have experienced significant ecological impacts and user conflicts contributing to diminished visitor satisfaction (Krumpe, 2000). The promises of high quality recreational opportunities have ensured public support for parks and protected areas; however, over use and abuse of public parks has now become a serious challenge to park managers (Hammitt and Cole, 1998).

The twin goals of the Canadian national parks policy are "to protect natural areas of Canadian significance in a system of national parks, and to encourage public understanding, appreciation, and enjoyment of these natural heritage so as to leave it unimpaired for future generation to come" (Stephenson, 1997, p.1). Thus, Canada's National Parks Act has given priority to the maintenance of ecological integrity. Ecological integrity is defined as the condition of an ecosystem where (1) the structure and function of the system are unimpaired by stresses induced by visitor activities, and (2) the system retains resilience in that its biological diversity and supporting processes are likely to persist (Parks Canada, 1995, p. 24). Implementation of this concept, as relevant to visitor use, necessitates an increased understanding of visitor activities and their effects on resource conditions, the resiliency of the resources that are impacted upon, and management strategies that address the underlying causes of impacts and resource degradation.

The province of British Columbia, with its numerous parks and protected areas, is a popular nature/adventure tourism destination in Canada. Since the late 1980s, the number of visitors to British Columbian parks has risen dramatically, resulting in significant ecological impacts in many areas (Thurston, 1992). The concept of ecological integrity is equally important to British Columbia's wilderness and protected areas. British Columbian parks, established under the authority of the Park Act, is "dedicated to the preservation of natural environments for the inspiration, use, and enjoyment of the public." Inherent in this mandate is the requirement to maintain a balance between BC Parks goals for conservation and recreation (BC Parks, 1991a, p. 9). However, as the provincial parks become increasingly popular for outdoor recreation, it is important to determine the balance between recreation use and conservation. One of the ways to find this balance is to understand the intricate processes involved between recreation use and associated ecological impacts. This research aims to contribute to this understanding by examining the spatial and temporal patterns of recreation impacts, particularly the effects of hiking and camping on the Berg Lake trail in Mount Robson Provincial Park.

The increasing visitor use in Mount Robson Provincial Park illustrates the growing popularity of a park and the potential challenges in balancing recreation and conservation. The Berg Lake trail in particular, faces tremendous visitor pressure and substantial ecological damage to its natural resources. The ecological damage includes soil compaction, trail degradation, vegetation trampling and removal, and wildlife disturbances (Thurston, 1992). Such ecological impacts may potentially diminish visitor satisfaction.

Based on trail-specific ecological data collected over a six-year period, this study examines the type and extent of visitor impacts. It then identifies gaps in the existing trail monitoring system, and suggests strategies to strengthen the capability and utility of a sound ecological monitoring system. The results of this study could be used in the formation of effective visitor management strategies aimed at mitigating impacts and protecting ecologically sensitive sites from further degradation.

1.2 Study significance

Recreation resource impacts and declining visitor satisfaction from wilderness experience are currently major issues in the management of British Columbian parks and protected areas. Mt. Robson Provincial Park is no exception; its management is entrusted with the challenging task of managing visitor use to prevent any harmful effects on its natural resources. The park, since 1992, has been monitoring certain trail sites, as indicative of resource degradation from visitor use. In order to make rational decisions about trail maintenance and visitor management tactics, park managers need to know in sufficient detail site-specific ecological characteristics and impact processes. Monitoring of the Berg Lake trail is based on this principle.

1.3 Study objectives

The goal of this research is to assess site-specific ecological impacts along the Berg Lake trail in Mount Robson Provincial Park. Specifically, it:

- examines issues of trail degradation as a response to increased levels of visitor use;
- analyzes existing data on selected trail impact indicators; and

- recommends strategies to strengthen impact assessment and monitoring techniques.

1.4 Organization of the project report

This report is organized into seven chapters. Chapter 1 provides a brief introduction to the study objectives. Chapter 2 provides a review of literature on three interrelated themes including the dilemma in recreation and conservation, ecological impacts of outdoor recreation, and visitor management with particular reference to carrying capacity. Chapter 3 highlights the study methods. Chapter 4 provides some background information of the study area, i. e., the Mount Robson Provincial Park. Chapter 5 summaries the main results of the study, with particular focus on visitor use, analysis of trail depth and width, vegetation transect survey, and proliferation of social trails. Chapter 6 provides a discussion of the main issues. Chapter 7 outlines the main conclusions and provides suggestion for further research.

Chapter 2: Literature Review

2.1 Introduction

This chapter provides a review of literature on three inter-related aspects: the dilemma in recreation and conservation, recreation ecology research with particularly focus on trail impact studies, and visitor planning and management frameworks. These aspects were selected because this study examines trail impacts as visitor-related management issues in the broader context of recreation and conservation.

2.2 The dilemma in recreation and conservation

The Wilderness Use Act (1964) of the United States recognized the value of wilderness recreation, by stating that recreation is a legitimate use (Hammitt and Cole, 1998). Increasing trends in wilderness recreation and tourism have fuelled global concern for the vulnerability and integrity of parks and protected areas (Swinnerton, 1999). In Canada, over the last decade there has been widespread environmental degradation in protected areas (Dearden and Rollins, 2002). One of the reasons for this degradation is the high levels of recreation use, and inadequate resource management. The National Parks Act stated that "maintenance of ecological integrity through the protection of natural resources should be the first priority" (Parks Canada, 1995, p. 24). However, parks including provincial parks of British Columbia are facing tremendous amount of stress mainly due to the development of visitor facilities, transportation/utility corridors, and various recreation activities (Dearden and Rollins, 2002). Thus, achieving the balance between natural heritage conservation and outdoor recreation has been an immensely challenging and complex ideal for park managers.

The growing body of literature in outdoor recreation suggests that the contentious relationship between recreation and conservation stems from the historic debates about use-versus-protection (Leung and Marion, 2000; Marion, 1993; Swinnerton, 1999). As recreation use in protected areas is legitimate, some degree of resource impairment is, and should be, expected. However, the development of diverse range of recreation activities, aided by assorted equipments and technological advances, have fuelled the intensity of visitor use. This has caused significant changes in park resources, thereby affecting the wilderness experience of many visitors (Leung and Marion, 2001). Parks and other protected areas face changes in quality when recreationists unintentionally trample vegetation, erode soil, and disturb wildlife (Hammitt and Cole, 1998). Rapid growth in activities such as kayaking, mountain hiking and climbing, and skiing have led to increased pressure on environmentally sensitive resources (Swinnerton, 1999). In many cases, parks and protected areas are often seen as ideal grounds for the development of facilities of these sports.

Recreation is about people and their interactions with the environment. The relationship between people and parks, therefore, is critical for protecting natural resources and providing wilderness opportunities for people. The involvement of a significant number of people in seeking more natural experiences has led to conflicts between resource use and its conservation, which are paramount issues in the twenty-first century (Hunt, 1995 cited in Swinnerton, 1999). These issues are further exacerbated, as people have increasing access, means, and opportunity to use sophisticated and commercialized recreational tools in outdoor recreation activities.

Identifying and understanding the processes involved in recreation resource impacts and finding solutions to their impacts fall under the broad mandate of striking a balance between recreation and conservation. Recreation impact studies involve identifying causes and effects of recreation use on the environment, and finding site-specific solutions to these issues. These studies are concerned with (1) examination of resource impacts with a view to protect the integrity of natural environments, and (2) protecting and enhancing the quality of recreational experiences (Leung and Marion, 2000). These impacts can be minimized if managers use science-based knowledge to identify effective solutions to these problems (Cole and McCool, 2000). Table 1 shows some major recreation impacts in backcountry areas.

Table1: Summary of ecological impacts of backcountry recreation.

	Ecological component			
Type of impact	Soil	Vegetation	Wildlife	Water
Direct	Soil compaction	Reduced height	Habitat alternation	Introduction of exotic species
	Loss of organic litter	Loss of ground vegetation cover	Loss of habitats	Increased turbidity
	Loss of mineral	Loss of fragile Species	Wildlife harassment	Increased nutrient inputs
		Loss of tress and shrubs	Modification of wildlife behavior	Increased levels of pathogenic bacteria
		Tree trunk damage, introduction of exotic species	Displacement from food, water, and shelter	Altered water quality
Indirect/ Derivative	Reduced soil moisture	Composition change	Reduced health and fitness	Reduced health of aquatic ecosystems
	Reduced soil pore space	Altered microclimate	Reduced reproduction rates	Composition change
	Accelerated soil erosion	Accelerated soil erosion	Increased mortality	Excessive algal growth
	Altered soil microbial activities		Composition change	Excessive algal growth

Source: Leung and Marion, 2000, p. 24.

The severity of ecological problems from backcountry recreation stems from the fact that current levels of use of backcountry areas for recreation is very high compared to the 1970s. In the late 1970s, very few people intended to experience wilderness recreation. Management problems during that period were few and less complicated (Hammitt and Cole, 1998). Today, the diverse range of recreational opportunities, technological advances, and societal needs challenge managers to explore innovative ways of managing recreational settings, and controlling and regulating visitor experience without jeopardizing their recreational satisfaction. In these circumstances, managers must look at all possible alternatives to maintain the balance between the provision of recreation and protection from the problems associated with it (Cole and McCool, 2000).

Many researchers in outdoor recreation, particularly in the context of parks and protected areas, have argued that there is a significant knowledge gap about recreation resource impacts and techniques for monitoring and assessing the impacts (Krumpe, 2000; Leung and Marion, 1998; Leung and Marion, 2000). The following section highlights the main findings of recreation impacts related to hiking and camping.

2.3 Trail degradation research

Recreation ecology, or the disturbance to natural areas as a result of recreational use, is an emerging field in wilderness management. The goal is to understand the human-nature interaction in recreational contexts, including the identification of recreation impacts on ecosystems and the landscape, the influence of use-related and environmental factors, and the role that management can play in modifying these factors (Cole, 1990; Graefe et al., 1990; Hammitt and Cole, 1998). As this research focuses on trail impacts and monitoring, this section will review some major issues and findings of trail research. Studies on recreation ecology have traditionally focused on campsite and trail impacts. Most studies have examined impacts on vegetation and soil (Leung and Marion, 2001; Nepal, 1999); a few studies have looked into water quality and wildlife issues (Hammitt and Cole, 1998).

Trail impact issues are considered to be of greater importance than those of campsites because trails are used by everyone (day hikers and campsite users), whereas campsites are used by fewer people. Because trails usually wind through many different landscapes, the area disrupted is larger as well as more visible, and directly affects visitors' perception of the environmental quality of the surrounding areas. Well-maintained trails allow hikers more comfortable access and encourage a more positive view toward its management (Hammitt and Cole, 1998).

Trail impact studies have used three different methods: (i) the cross-sectional method is used to assess various forms of trail degradation due to use-related or environmental attributes (Bratton et al., 1979; Helgath, 1995), (ii) the longitudinal method uses replicate assessments that compare the same site over time, and (iii) experimental trampling studies are conducted in a controlled environment to determine the relationship between use intensity and amount of impacts. Leung and Marion (1996) state that the major weakness in trail degradation research is the lack of standardization of impact variables examined and methods employed.

A trail survey involves taking detailed inventory on trail related resource conditions and collecting data on impact parameters and on-site trail maintenance features (Marion, 1994). According to Marion (1994), a *trail inventory* involves collecting data on trail features such as type of trail, use type, segment length, natural and cultural features along the trail, degree of hiking difficulty, and the number of bridges and signs. The objective of this data is to provide an overall assessment of the trail environment. *Trail conditions* refer to data relevant to trail-specific natural resources such as vegetation type, soil type, locational information including trail position, width, depth, and other parameters that characterize resource impacts. *Trail maintenance* refers to appropriate engineering solutions to trail erosion, such as drainage, rock steps, and bog bridging.

Trail survey procedures involve two methods: (1) *continuous trail survey*, and (2) *point survey*. The *continuous trail survey* method is used when the objective is to provide a general description of the entire trail system. A simple field form is developed and general information on trail resource conditions and wheel distance (begin and end) are recorded. This method is useful for a rapid trail assessment and can be easily completed with two people pushing a measuring wheel along the trail. The outcome is a large number of management relevant information such as environmental features, recreation or attraction features, trail resource conditions, design, and maintenance features.

A *point survey* method is designed to investigate site-specific information on heavily impacted trail sections or appropriate sites deemed important to be monitored. A global positioning system (GPS) is used during the trail assessment in order to geo-reference each monitoring sites. These sites then can be mapped and comparative information on trail sites, impact variables, and the influence of locational variables can be analyzed (Nepal, 1999).

Trail impacts include a variety of problems such as compaction, loss of vegetation, incision, erosion, loss of soil, widening treads, and multiple trail formation (Hammitt and Cole, 1998). Trail research findings indicate that the majority of environmental change occurs with the beginning of trail construction (Cole, 1990; Hammitt and Cole, 1998). Environmental factors are important determinants of the type and severity of trail degradation (Hammitt and Cole, 1998).

The relationship between use and impact tend to be curvilinear, indicating that the extent of impact slows down after continued use (Hammitt and Cole, 1998; Leung and Marion, 2000; Marion, 1993). For example, soil compaction appears to occur rapidly after a first few years of light use. Studies in Eagle Cap, the Missions Mountains, and the Rattlesnake Wilderness in U. S. A. found that low use campsites exhibited lower soil penetration resistance than other sites that were used heavily (Cole and Fichtler, 1983). The curvilinear relationship between use and impact implies that managers should reduce or disperse activities from high impact sites to low impact sites (Hammitt and Cole, 1998; Farrell and Marion, 2002). Research has also shown that the amount and type of impacts depend not only on the visitor numbers, but also on the season, timing, and the type of activity (Wall, 1994). These findings imply that with proper management of the site, managers may be able to reduce the level of impacts. Mitigating recreation impacts or modifying use-related factors are central to park managers' decisions on visitor management. Managers can also minimize trail degradation through appropriate trail layout and design by selecting routes through resistant and resilient soil and vegetation types, site hardening, and by avoiding sensitive landforms and topography (Farrell and Marion, 2002; Price, 1983).

2.4 Visitor management in outdoor recreation

Visitor management is the direction and guidance of people, their numbers, their behavior, permissible activities, and the provision and maintenance of the necessary infrastructure (BC Parks, 1991a). Rational visitor use planning and management allows people to visit protected and natural areas without damaging their ecological integrity and quality of experiences (Parks Canada, 1997).

The post–war explosion in outdoor recreation activities in North America substantially changed the nature of parks and protected area management (Krumpe, 2000). Visitor management in the 1970s and 1980s was largely based on the assumption that resource impacts were directly related to amount of use.

Parks and protected areas have been traditionally managed based on principles of natural sciences. However, it is increasingly evident that managing national parks requires knowledge beyond natural sciences. It has been argued that park management is essentially the management of people (Payne and Nilsen, 2002). No matter what the extent of impairment in resource quality or visitor experience is, managers' value judgments are a major step in all management decision-making processes. This implies that park and wilderness management must ultimately render judgments about the levels of impacts and related visitor use levels that are acceptable. As indicated earlier, the growing body of research illustrates that while such relationships may be complex, the increasing use levels of parks and wilderness may lead to increasing impacts to biophysical resources and the quality of the visitor experience (Manning, 2001). Thus, concepts such as carrying capacity require a strong element of "informed judgment." This underlines the importance of scientific studies that help managers make an informed decision about appropriate visitor management practices.

Sound visitor management requires that all intervening variables that affect the quality of resources and visitor experiences are examined and considered in the management plan (Hammitt and Cole, 1998). Management strategies then can be devised that seek to manipulate each variable that affect not only the amount of use but also its quality (Cole and Stankey, 1998). Appropriate management strategies should be based on factual information illustrating visitor use types and resultant biophysical and social impacts (Manning, 2001).

Some visitor management policies tend to be controversial when it directly affects public participation (Hammitt and Cole, 1998). Due to the large variation in visitor interests and choice in recreational opportunities, visitor management often becomes a complicated task. This requires an understanding of visitor interests, motivation, leisure behavior, perception of environmental quality, and visitor satisfaction. An integrated approach which examines recreation resource impacts from both natural and social science perspective is required for effective visitor management (Manning, 2001).

One of the fundamental bases for visitor management in protected areas requires inventory and description of impacts (Manning, 2001). Managers need to be familiar with the problems and causes of impacts. After systematic detection of impacts, it is essential to develop monitoring protocols to maintain or reduce the impact level within an acceptable limit (Cole and Stankey, 1998). Developing indicators is not enough to mitigate impacts; regular monitoring and evaluating the effectiveness of used indicators would make visitor management more effective (Manning, 2001).

Ecological indicators usually provide information about resource conditions, magnitude of stresses, and exposure of biological components to stress (Schiller et al., 2001). Selection of appropriate indicators depends on resource characteristics, levels of use, and management objectives. For example, if trail depth (incision) is considered to be an important indicator of trail degradation, then it is possible to set certain standards of trail depth (for example, depth < 15 cm is acceptable). However, this requires not only detailed information on site-specific resource conditions, but also general agreement between park managers and users if a certain standard would be appropriate and acceptable. This then brings us back to the issue of informed judgment about carrying capacity.

2.5 Carrying capacity as informed judgment

Science can inform management judgments about carrying capacity in at least two ways. First, research findings should serve as the basis of the descriptive component of carrying capacity, which is concerned with the relationships between visitor use and the biophysical and social impacts of such use. Second, research findings can also help inform the prescriptive component of carrying capacity (Manning, 2001). The prescriptive component of carrying capacity concerns the maximum acceptable level of biophysical and social impacts.

The idea of carrying capacity has generated considerable discussion in outdoor recreation. Carrying capacity focuses on the type of visitor experiences to be provided and monitoring resource conditions over time, so that resources could be maintained on a sustainable basis (Manning, 2001). However, knowledge of carrying capacity and implementation of adequate management requires park managers' broad understanding of impact assessment and monitoring techniques.

The evolution of visitor management principles and practices has its roots in the concept of recreation carrying capacity. Borrowed from the field of range management, carrying capacity is simply the amount of recreation use an area can tolerate without causing unacceptable damage to its resource and social conditions (Manning et al., 1996). The amount of use is only one of many variables that influence the quality of recreation experiences and ecological conditions. According to Lime and Stankey (1971), carrying capacity is the character of use, supported over a specific time by an area developed at a certain level, without causing excessive damage to the physical environment and visitor experiences. The underlying supposition of this definition is that the goal of recreation management is to maximize user satisfaction and take into consideration the administrative and budgetary constraints of the areas (Stankey, 1997).

Carrying capacity, however, does not answer the question of amount of use, and what the desired resource and social conditions are (Cole and Stankey, 1998).

The relation between resource impacts and use is complicated by several factors including different types of recreation activities, duration of activity, timing, and user behaviors. Other factors such as location, mode of travel, group size, and behavior of other visitors encountered are more critical to recreation impacts and satisfaction than the number of visitors. Environmental characteristics of recreational sites and efficiency of management are crucial factors as well (Hammitt and Cole, 1998). Therefore, it has been argued that reduction in use will not necessarily result in reduction in impact (Stankey and McCool, 1988). Due to this realization, concepts such as carrying capacity have shifted their focus from the original need to control and regulate numbers to the concept of "management-by-objectives". This has given rise to several visitor planning and management frameworks.

Frameworks such as the Limit of Acceptable Change or LAC (Stankey et al., 1985), Recreation Opportunity Spectrum or ROS (Clarke and Stankey, 1979), Visitor Impact Management or VIM (Graefe et al., 1990), Visitor Activity Management Process or VAMP (Graham et al., 1987), and Visitor Experience and Resource Protection or VERP (Hof and Lime, 1997), address issues of managing user impacts and user satisfaction. Essentially, these concepts are all about balancing recreation and conservation.

Application of the above-mentioned visitor management frameworks rely on site specific problems. However, these management frameworks are not able to solve the root causes of the problems (Nilsen and Tayler, 1997). In fact, managing resource impairment in parks and protected areas needs to emphasize ecosystem based management so park managers can understand both primary and secondary factors.

The objective of each management framework is to complement the norms of park objectives, protect natural resources from over exploitation, and provide visitors satisfaction from their wilderness experience. Implementation of each framework depends on the characteristics of the landscape, its size, availability of recreation opportunities, visitation pressure, and the value judgments of park managers. These management decision-making models address questions of carrying capacity, appropriate visitor use, and bio-physical impacts caused by recreation use. Further review of LAC is provided below, as its application has been attempted on the Berg Lake trail in Mount Robson Park.

The LAC addresses public consultation issues and defines economic, recreational, and ecological interests in wilderness area (Hendee et al., 1990). Its primary aim is to meet visitor's desired conditions and identify how much use an area can tolerate (Stankey et al., 1985). LAC basically relies on the standard[1] of each indicator[2] based on peoples' use, understanding, and evaluation of natural areas (Payne and Nilsen, 2002).

LAC represents an alternative approach to resolve carrying capacity issues (Hendee et al., 1990). It was first applied in the Bob Marshall Wilderness Complex in 1987, and by the early 1990s, there were 23 separate LAC planning efforts in six western states in USA (McCoy et al., 1995).

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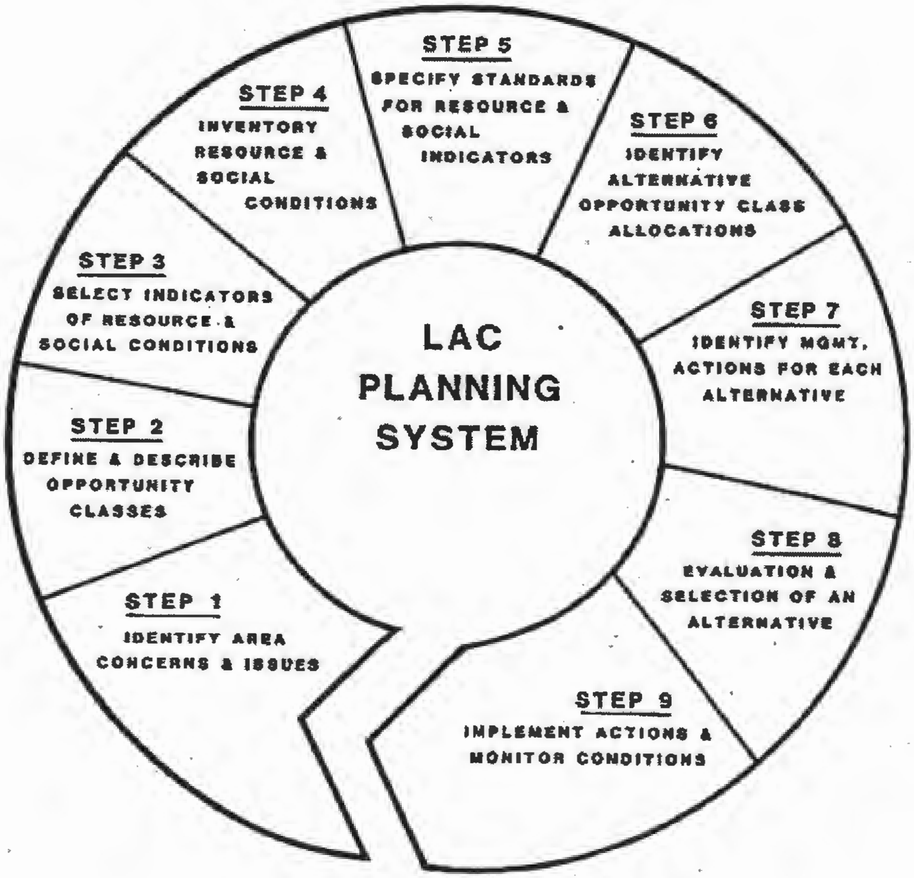
[1] **Standards** are the criteria of the ecological and social parameter set by managers aiming maximum visitor can satisfy.
[2] **Indicators** are the parameter biophysical and social components that determine the quality of visitor experience.
(Source: Kettle, 1999, pp. 52-53)

The LAC framework consists of four basic components (Stankey et al., 1985):

1. identifying acceptable and achievable social and resource standards;
2. documenting gaps between desired and existing circumstances;
3. identifying management actions to close these gaps; and
4. monitoring and evaluating management effectiveness.

Based on these four components the LAC planning process involves nine steps, as noted below in Figure 1:

Fig. 1: The Limit of Acceptable Change (LAC) planning system



Stankey et al., 1985

One of the positive aspects of the LAC planning process is the public consultation. The environmental and social acceptability of resource conditions seek public input in the LAC planning process. It is based on the transactive planning model, and offers desired conditions of visitor experiences and expectations in making ecological and social elements standard to enjoy a maximum number of visitors in different opportunity classes. Selecting proper indicators and acceptable standards from the public point of view is an important step toward visitor management (White et al., 2001). LAC also offers how much change in resource and social conditions will be allowed, and where changes occurs and what management actions are needed to maintain acceptable conditions (McCoy et al., 1995). However, continual monitoring is essential to determine relative effectiveness and success of this process.

Given the above review, it is important to consider how these issues are relevant to recreation resource impacts in the Mt. Robson Provincial Park. The following section provides an overview of these issues in that Park, with specific reference to the Berg Lake trail.

2.6 Visitor-related issues in Mount Robson Provincial Park

The central attraction in Mount Robson Provincial Park is the Berg Lake trail, which leads to many scenic sites, views and other attractive features. This has resulted in high visitor use at certain locations and corresponding impacts along the trail and its natural environment.

Mount Robson Provincial Park is categorized into four zones including the wilderness conservation zone (58%), the recreation zone (22%), the natural environment zone (16%), and the intensive recreation zone (3%) (BC Parks, 1992a, p. 9). The Berg Lake trail is included in the natural environment zone. The objectives of this zone are to protect scenic landscapes and provide a buffer between intensive recreation and wilderness conservation zones. This trail provides backcountry recreational opportunity for visitors and has a moderate development of visitor services.

The most common type of ecological problems on the Berg Lake trail are soil erosion, muddiness, trail widening, the creation of multiple trails and a few switchback shortcuts, and user group conflicts (Thurston, 1992). During certain seasons, especially on weekends, campgrounds and trail users were reported to have experienced overcrowding at select scenic sites (Thurston, 1992).

The Berg Lake trail is being managed with the aid of annual management plans, which provide specific guidelines and action plans. Prior to the 1970s, there was no trail management plan (Roemer, 1975). The Berg Lake trail was upgraded and measures were taken to minimize erosion and surface runoff in 1980 (Thurston, 1992). For example, at popular sites wood bars and signage were placed to avoid resource degradation. Hiking, biking, and horse riding trails were separated whenever possible to reduce user group conflicts. Boardwalks were placed for easy walking on muddy trail segments. Bridges were built over major river crossings, steps were constructed or carved on steep slope, with handrails for comfortable hiking, and rest benches were placed at selected viewpoints.

Despite the above mentioned measures, resources impacts continue to be a problem. Upgrading the trail infrastructure with boardwalks, steps, and rails has reduced hikers' wilderness experience. After the Emperor Falls portion of the trail, bridges have not been provided, and hikers have difficulty crossing the river, especially during high water seasons. Over-crowding in campgrounds such as Whitehorn has been a perpetual problem (Thurston, 1996). As a result, proliferation of social trails around campgrounds is common, which potentially prevents wildlife movement. Thurston (1992) recommended a detailed study of changes in wildlife movement and habitat segregation due to heavy traffic to reduce the number of encounters between people and wildlife.

The Berg Lake trail corridor also has problems with signs and exhibits. International visitor numbers are increasing every year. It is likely that some international visitors can not understand the signs in English. Some visitors simply ignore the signs; for example, hikers do not keep their pets on lease, even when signs are posted stating the park regulation that prohibits such behaviors. Vandalizing park facilities and damaging trees, carving unacceptable words on trees, and peeling the bark of trees are common problems as well. In an effort to reduce these impacts, BC Parks implemented many plans and recommendations, including restrictions on mountain bikes and campfires, as well as the implementation of a quota-system. Selected trail locations and campgrounds were monitored since 1992 but the information collected has not been incorporated in its visitor management policies.

Due to increasing problems of trail and campsite deterioration, an impact assessment and monitoring system was put in place on the Berg Lake trail corridor. Although it is not clear if this was considered a step toward the full application of the LAC concept, it is clear that selection of impact indicators and monitoring indicators are what steps 3-5 of the LAC process suggest. Therefore, in that sense the Berg Lake trail monitoring could be considered as partial steps toward the implementation of the LAC concept.

The Berg Lake trail monitoring, which is discussed in the Chapter 5, should be seen from the above perspective. Increased levels of visitor use and deteriorating conditions of the trail prompted the establishment of a baseline data on key impact indicators. The LAC provided the conceptual basis for accomplishing this goal.

2.7 Summary of literature review

The following main points can be derived from the above discussion:

1. Studies on recreation resource impacts (in parks and protected areas) are important to understand how the twin goals of use and resource protection could be achieved.
2. Studies on the disturbance to natural areas as a result of recreational use are gaining a wider acceptance in the conservation literature.
3. Recreation resources impact assessment are conducted under the broad mandate of identifying carrying capacity levels, and more recently, the need to set acceptable limits of use and resource degradation.
4. Impacts on campsites and trails are the most studied topics. Most studies focus an inventory and description of resource conditions. The underlying assumption of these studies is that baseline information is crucial to examine impacts over time, and to evaluate the effectiveness of visitor management strategies implemented based on the initial knowledge of resource conditions.
5. Analysis of use type, user behavior, environmental factors, and implication of management actions are essential for managers to better understand the underlying factors of impacts and seek solutions that are location-specific.

Chapter 3: Study Area

3.1 Introduction

Mount Robson is the highest peak (3954 m) in the Canadian Rockies and is the main attraction in Mount Robson Provincial Park. Due to its historical and ecological importance, it has been designated as a World Heritage Site. Officially, this area was made a provincial park in 1913 and has a rich history, connected with the fur trade and early exploration for transportation access (BC Parks, 1992a).

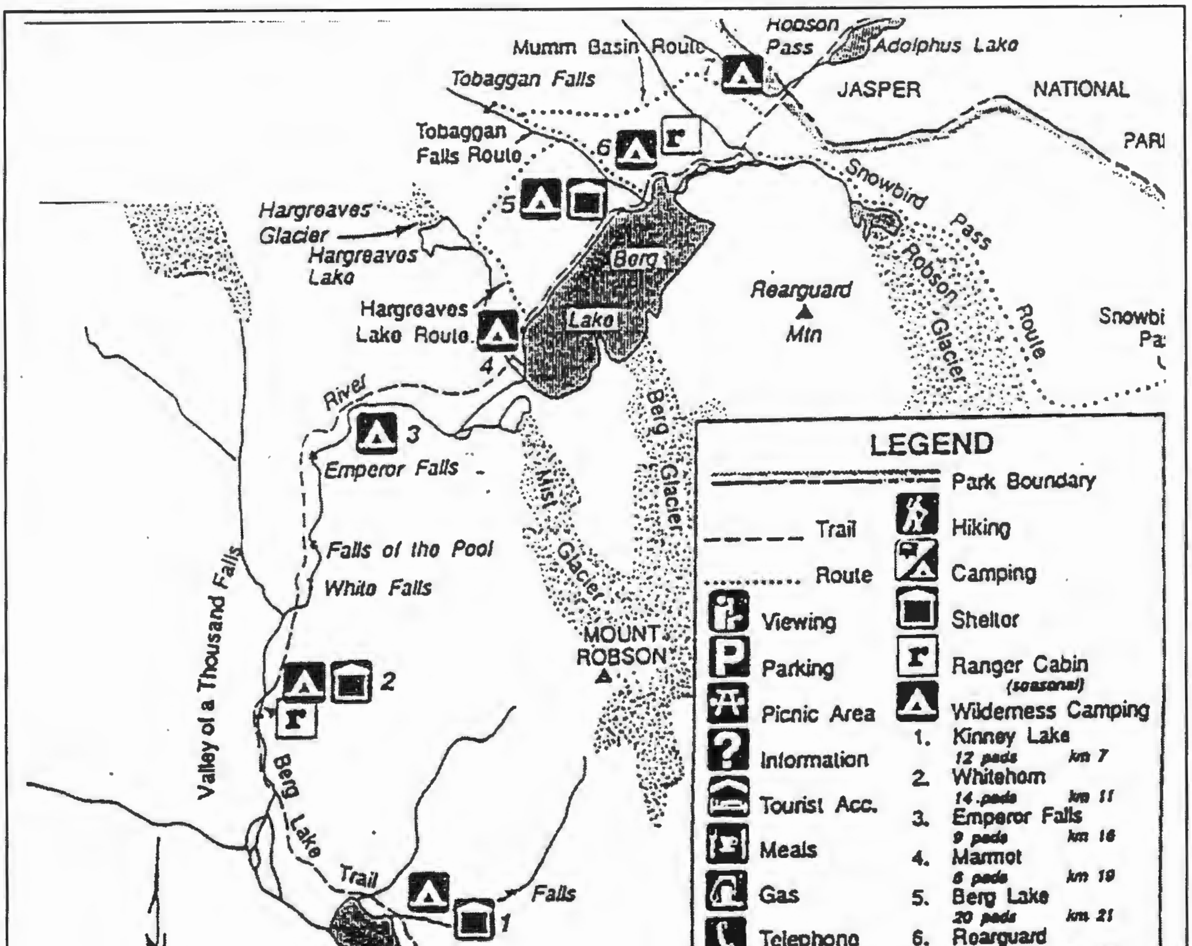
Mount Robson Provincial Park is the second oldest and fifth largest park in the province of British Columbia. Its land mass is 219,534 hectares, which includes rugged mountains, glaciers, alpine meadows, waterfalls, and valleys (BC Parks, 1992a). Mount Robson Provincial Park draws an average of 17380 visitors annually (BC Parks, 2001).

The Berg Lake trail, the main trail in the Park, is 23 kilometers in length. It passes through many different types of habitat, including Cedar/Hemlock forest, Sub-alpine Engelmann, and Spruce/Sub-alpine Fir (BC Parks, 1992a). The trail provides easy access to the Park's alpine environment, which is the central attraction for many visitors.

3.2 Location

Mount Robson Provincial Park lies at the northern end of the Rocky Mountains on the Alberta-British Columbia border, next to Jasper National Park. It is 300 kilometers east of Prince George. The Berg Lake trail leads to spectacular views on the way to Berg Lake, where there are two glaciers, the Berg glacier and the Mist glacier, both originating from Mt. Robson (Fig. 2).

Fig. 2: Location of Berg Lake trail in Mount Robson Provincial Park



Source: Thurston, 1992, p. 24.

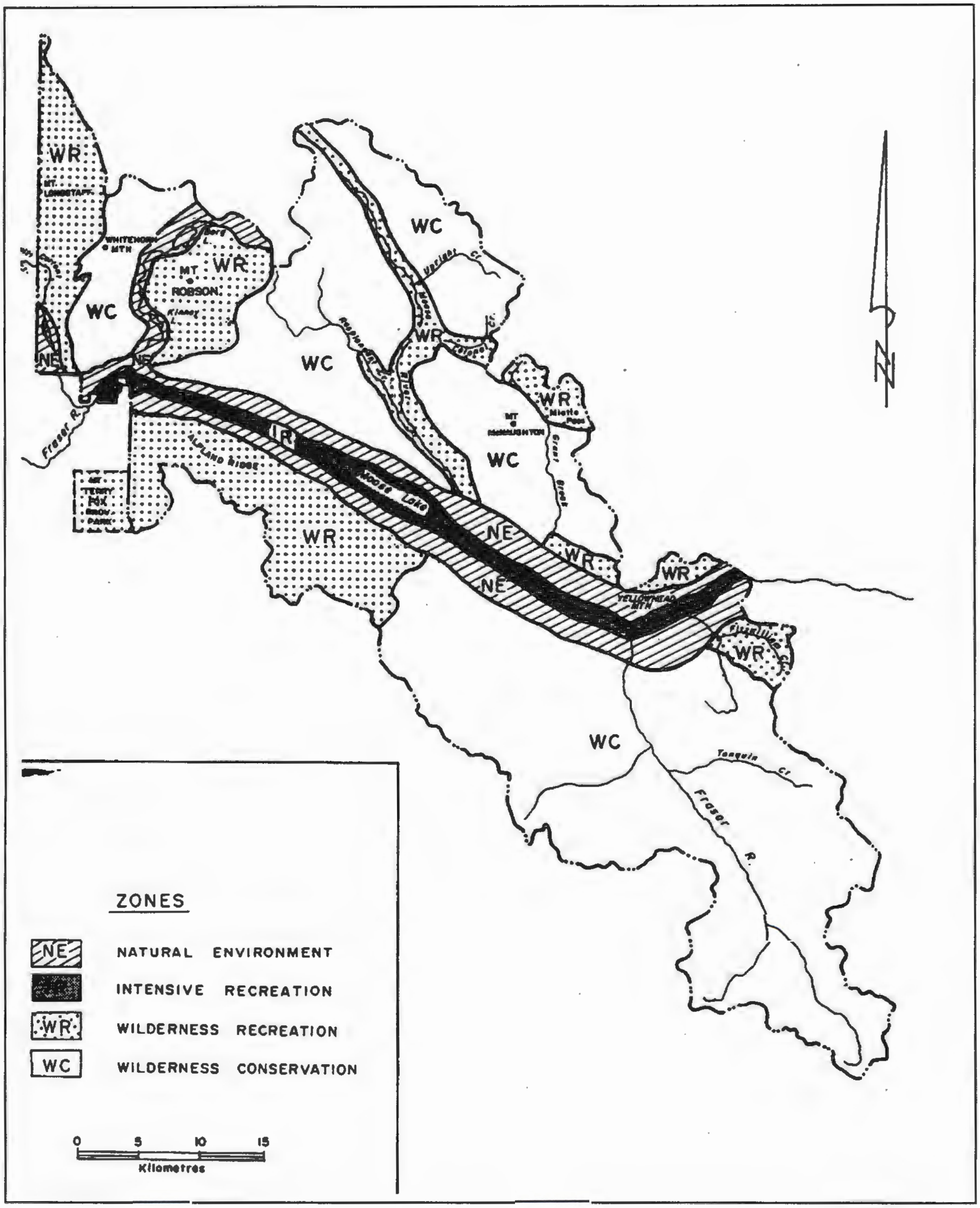
3. 3 Biogeoclimatic zones

Mount Robson Provincial Park represents a northern continental landscape in BC and contains complex mountain ecosystems, represented by four biogeoclimatic zones: the Interior Cedar Hemlock zone (ICM), Sub-boreal Spruce zone (SBS), the Engelmann Spruce-Sub-alpine Fir zone (ESSF), and Alpine Tundra zone (AT), (Lea and Maxwell, 1989). These biogeoclimatic zones have supported diverse habitat for animals and plants (Lea and Maxwell, 1989).

3. 4 Park zoning

The Park has been divided into four zones: (i) the natural environment zone, (ii) the intensive recreation zone, (iii) the wilderness recreation zone, and (iv) the wilderness conservation zone (Fig. 3). Based on the natural and recreational values, these zones define levels of use and criteria for natural resource and visitor management (BC Parks, 1992a). The Berg Lake trail is in the wilderness recreation zone, where a low-level of backcountry recreation is encouraged. Facilities such as bear poles, primitive campsites, stairs and rails are installed. The Berg Lake trail corridor is primarily a hiking trail; horse-riding and biking are permitted on certain trail sections only.

Fig. 3: Park zoning.



Source: BC Parks, 1992a, p. 9.

3.5 Biodiversity

3.5.1 Flora

The main composition of vegetation around the park consists of lodgepole pine, white spruce, black spruce, and trembling aspen (BC Parks, 1991b). Several Willows are common throughout the park. Hygrophytic (wet growing) plant species, including sedges meadows, forbs, horsetails, rushes, orchids, and grasses are extensive in the wetland areas (BC Parks, 1991b). Several unique orchids are found in the Park such as the yellow ladyslipper, (*Cypripedium parviflorum*), which has been exterminated elsewhere by flower-picking (Porsild, 1974 cited in Roemer, 1975). In Kinney Lake and Whitehorn Cabin area, sparrow egg ladyslipper (*C. passerinum),* round leaved orchid (*Orchis rotundifolia),* one leaved rein orchid *(Hebenaria obtusata),* northern twayblade (*Listera borealis),* and fairy slipper *(Calypso bulbosa)* are threatened by high levels of visitation (Roemer, 1975). Horses have been reported to graze in and around the Berg Lake Chalet area; however, the grassland habitat was reported to be damaged more by trampling of horses through extensive trail use rather than grazing (Roemer, 1975).

3.5.2 Fauna

The main fauna in this park consists of grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), moose (*Cervalces scotti*), elk (*Cervus elaphus*), mountain goat (*Oreamnos americanus*), mule deer (*Odocoileus hemionus*), and caribou (*Rangifer tarandus*). Bighorn sheep and cougar have been sighted occasionally (BC Parks, 1991b). Due to high levels of visitation, wildlife sightings, particularly of black bear and moose are now rare in the park. No evidence of feces or dropping of black bear, moose or other animals were noted during the fieldwork; however, mountain goats and mule deer were seen around Robson Pass and Berg Lake.

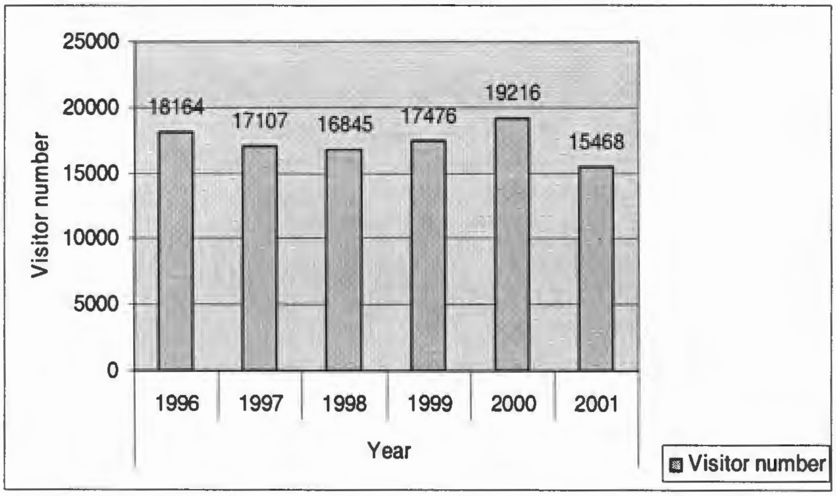
The wetlands in Mt. Robson Park support a diversity of bird species, particularly during the summer season. Golden eagle (*Aquila chrysaetos*), harlequin duck (*Histrionicus histrionicus*), white-tailed ptarmigan (*Lagopus leucurus*), and gray-crowned rosy finch (*Leucosticte tephrocotis*) are among the migratory birds (BC Parks, 1991b). Permanent avian fauna include raptors (goshawk, great horned owl, boreal owl, great gray owl), grouse (spruce, blue grouse, willow, white-tail ptarmigan), corvids (gray jay, black-billed magpie), wood peckers (hairy and black-backed three-toed wood peckers), chickadees (black-capped, bohemian waxing), and finches (pine grosbeaks, gray-crowned rosy finch, red and white-winged crossbills) (BC Parks, 1991b).

It is possible that visitation may have affected wildlife movement and behavior. Visitors can also cause avoidance behavior in some animals and attraction behavior in others (to obtain human foods) (Leung and Marion, 2000). Human food not only changes the food habits of animals but also could be a threat when these animals accidentally chew plastic wraps (Bhandary, 1994). The cutting of saplings for firewood also threatens wildlife habitat. These tree saplings provide nesting to bird species including Common Merganser (*Mergus* sp.), Northern Hawk Owl (*Surnia ulula*), Three Toed Woodpecker (*Picoides tridactylus*), and Chickadees (*Parus* sp.) (Thurston, 1992). Thurston (1992) reported that hiker's dogs had killed an adult and a juvenile mountain goat, and several marmots in the Park.

3.6 Visitor use on the Berg Lake trail

Total visits to the Berg Lake trail in the year 2001 were recorded at 15,468 (Fig. 4) (BC Parks, 2001). Of these, 11,812 were day hikers and 3,656 were campsite users (see Figs. 5 & 6). With exceptions in 1999 and 2000, the number of visitors hiking the Berg Lake trail has gradually declined since 1996. The reduction in visitor numbers is largely attributable to the implementation of the quota system in 1996.

Fig. 4: Number of hikers on the Berg Lake trail

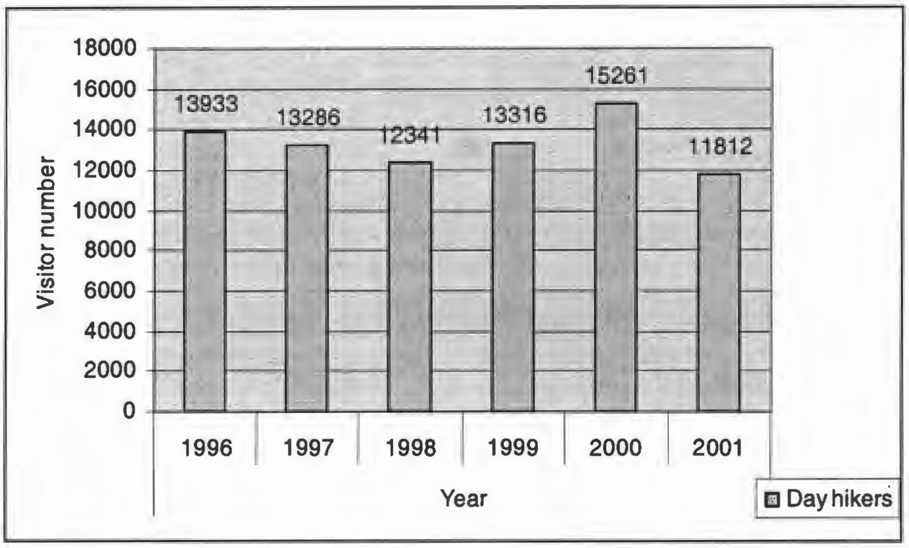


Source: BC Parks, 2001

Based on a survey conducted in 1992, the majority (88%) of visitors hike to see Berg Lake. Thurston (1992) reported that about 56% of hikers experienced high traffic especially on the Berg Lake campground. Many visitors have had to share campsites or tent pads with others. The survey also showed that about 61% of the respondents favored the quota system, although it restricted numbers of users on the trail (Thurston, 1992).

In terms of visitor origins, current data are not available. The 1992 survey indicated that 50% of Berg Lake trail hikers were from Alberta, 25% from United States and British Columbia, and 25% were from other provinces of Canada and overseas (BC Parks, 1992).

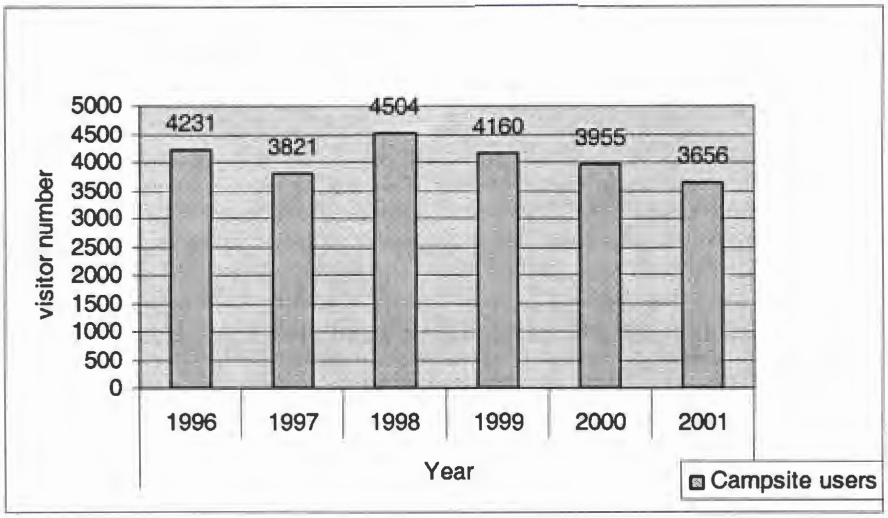
Fig. 5: Number of day hikers on the Berg Lake trail



Source: BC Parks, 2001

Of the total number of visitors hiking the Berg Lake trail, day users overwhelmingly outnumber overnight users. Available records indicate that the number of day users gradually declined between 1996 and 1998, but significantly increased in 1999 and 2000. In the year 2001, there was a dramatic drop in the number of day users, from 15,261 to 11,812, a decline of almost 23 percent (Fig. 5).

Fig. 6: Number of campsites users on the Berg Lake trail



Source: BC Parks, 2001

The number of overnight visitors (campsite users) shows a similar trend, declining since 1996. With the exception in 1998, the number of overnight visitors has gradually declined (Fig. 6). Again, this reflects the Park management's policy of imposing the camping quota system in 1996. Park management's goal has thus focused on protecting the natural ecosystem without drastically altering visitor use levels. There are positive and negative impacts of the quota system; it protects the resources from exploitation but also causes displacement of users. Diverting some of the demand from the Berg Lake trail corridor would reduce ecological impacts and social conflicts. The park management has been exploring opportunities to divert use from the Berg Lake trail and has looked into the possibility of providing access to other backcountry areas (Park Warden, pers. comm., 2002). However, due to Berg Lake's strong appeal, diverting use has been a problem.

3.7 Summary

Mt. Robson Provincial Park is popular for both frontcountry and backcountry recreationists. Spectacular mountains, rich wildlife, and scenic landscapes make this park very attractive to visit. A study conducted in 1992 suggested implementing an overnight camping quota system. This was in response to the growing problems of recreation resource impacts and visitor crowding. A camping quota system was put in place in 1996, and since then there has been a gradual decline in overnight campers. More or less same trend is seen regarding day hikers. Nevertheless, Mt. Robson Provincial Park remains a very popular park to visit, and visitor related problems will have to be addressed.

Chapter 4: Study Methods

Two different methods have been used in this study. First, based on secondary data, analysis of trail impact indicators including trail width, trail incision, vegetation cover, and proliferation of social trails is conducted. The data are based on the Berg Lake trail monitoring database initiated by Thurston in 1996, and collected until 2001. Second, fieldwork was conducted to update the data for 2002. With the help of two park rangers, monitoring sites were located, and data on impact indicators collected. Trail-related data collection is based on standard trail monitoring procedures discussed by Marion (1994) and Leung and Marion (1998).

During the fieldwork, photographs of all monitoring plots were taken, and were compared with photographs taken in 1996. Data on visitor use are based on park records.

4.1 Impact indicators

This study focuses on the following trail indicators: trail width, trail incision (depth), vegetation cover (percentile estimates), and visitation level. Proliferation of trail in one campground is also presented to illustrate the severity of visitor-induced problems in Mt. Robson Park. Thurston (1996) describes in detail data collection methods; key points are noted hereunder.

4.1.1 Trail width and incision

Width and incision were measured at existing trail monitoring plots. According to this method, two nails were positioned at both trail edges (Plate 1). Each site was marked by fixing a metal tag on a mature tree close to the location of the nails (Plate 2). The nails were hidden to make sure that they were not removed by visitors and that they stayed in the same position year after year. A string was tied to one end and stretched to the other end. Using the string, the widths of the trail were measured from where vegetation stopped to where it started again. During the course of field measurement, errors were minimized by concentrating only on the most obvious tread work. In the same way, incision was measured at the same point; measurement of the most incised portion of the trail taken.

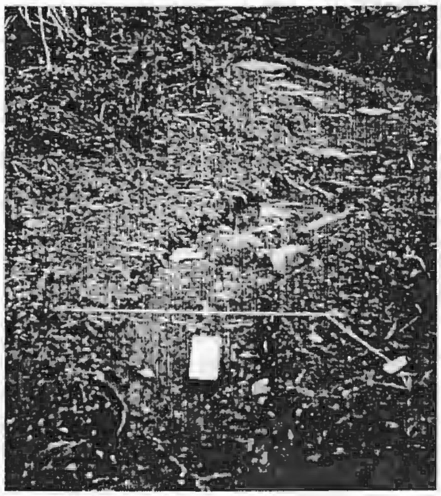


Plate 1: Trail width measurement technique

Plate 2: Monitoring site marked (note the metal tag on the tree)

4.1.2 Vegetation cover

Analysis of vegetation cover (percentile estimates) is based on monitoring of selected vegetation transects between the end markers established by the Park. Along the 3 transects established in the Park, each transect was further divided into 9 equal quadrants ($1m^2$) at 1 m intervals. Each quadrant was further divided into 9 equal quadrants. Any live plants, including lichens and mosses, were considered vegetation. Lack of vegetation or rock within the quadrants were considered as bare ground and subtracted from the total percentage cover for the whole transect.

4.1.3 Visitor use-level

Analysis of visitor use level is based on the Park attendance record sheet obtained from Park headquarters.

The Berg Lake trail monitoring data sets were scrutinized carefully and gaps identified. Informal discussions with park staff were conducted during the field trip to put trail problems in perspective from a management standpoint. Intensive review of the most recent literature on trail impacts and visitor management was conducted. Based on the review of literature and analysis of trail data, strategies for improving the quality of monitoring were suggested.

4.2 Limitations of the study

This study relies on the existing trail monitoring developed by Thurston (1996) and implemented by the park management. During the field survey, it was observed that site measurements were subjective and based on the surveyors' skills. It was noted that there were inconsistencies in measurement; for example, when measuring trail incision, the most deeply incised section was measured even if that may not have been contributed by increased compaction due to hikers. Similarly, arbitrary decisions were made on trail width (i.e., the decision where to start and where to end depended entirely on the surveyors). Percentile estimates of vegetation cover are highly subjective. Thus, data quality, precision in measurements, and validity of a non-probability based research design are issues that are beyond the control of this study.

Chapter 5: Results

This chapter discusses results of a longitudinal study of visitor use patterns in the Berg Lake trail and its campgrounds. Selected indicators of trail degradation, proliferation of trails, vegetation cover, and visitor use are examined.

5.1 Visitor use

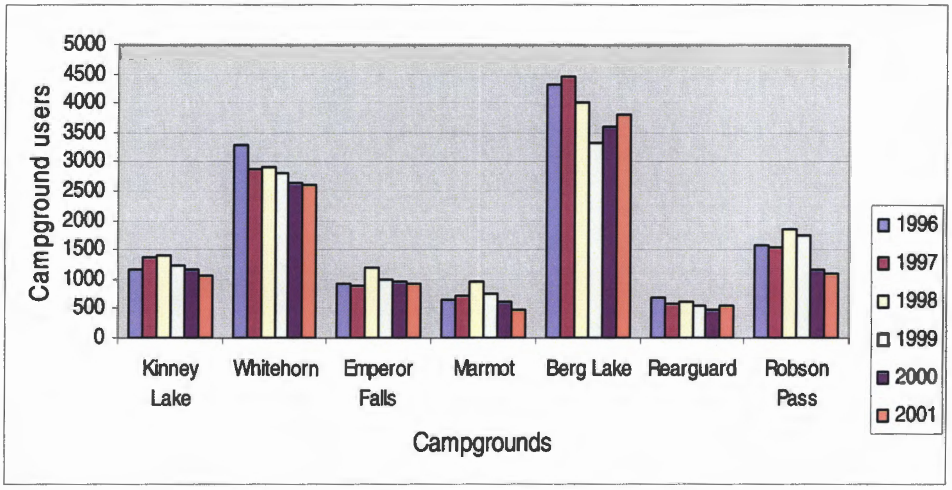
5.1.1 Overnight-users: Since the implementation of a quota system, there has been a decline in overnight campsite users. The Berg Lake trail usually requires 2 days of hiking to complete a 23 kilometers long journey to the final destination, Berg Lake. Hikers have the option to camp at Whitehorn or Emperor Falls on their first day before heading toward Berg Lake. The Whitehorn Campground is located almost half-way to Berg Lake. Hikers going to and returning from Berg Lake often find it convenient (in terms of distance) to camp here. As such, this campground sees relatively more users than others.

Campground use data after the implementation of the quota system show an even distribution of campers across the seven campgrounds. The data show that Berg Lake and Whitehorn are the most popular campgrounds (Fig. 7), followed by Robson Pass and Kinney Lake.

In terms of use levels, Berg Lake receives close to 4,000 overnight campers per year (Fig. 7). The number of campers has declined since 1997, partly a reflection of the quota system imposed. Similarly, Whitehorn campground is the second most popular campground with use levels close to 3,000 campers per year. Similar to Berg Lake, there has been a gradual decline in the total number of users.

Similar patterns exist for other campgrounds, although the level of use is much lower. For example, the 2001 data show that Emperor Falls received less than a thousand campers, Robson Pass and Kinney Lake both received a little over 1000 campers. The Marmot campground received roughly 500 or more campers; for Rearguard it is around 500 campers (Fig. 7).

Fig. 7: Number of campground users over time

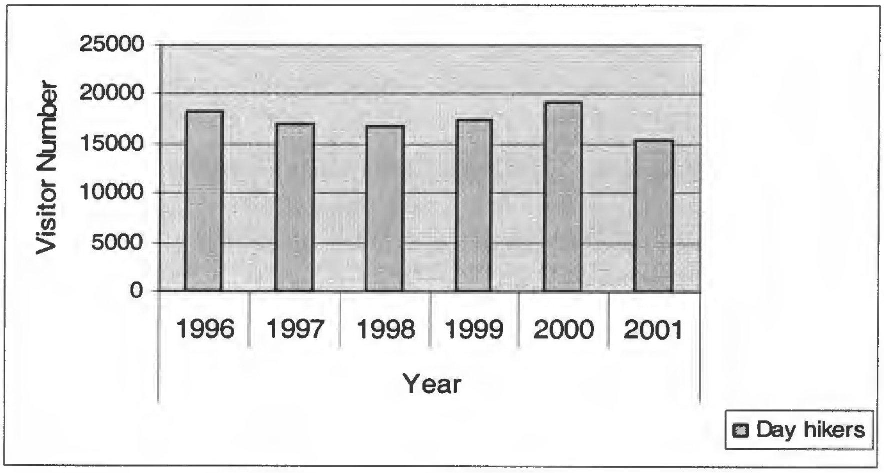


Source: BC Parks, 2001

5.1.2 Day-users: The Berg Lake trail attracts significant number of day hikers. The day-hikers usually go as far as White Falls, but for the majority Kinney Lake is the final destination. This section of the trail is well maintained, and is wide enough to facilitate a two-way pedestrian traffic. On occasions, the Park maintenance crew uses this trail for motorized access. In terms of use levels, since 1996 the number of day hikers has been relatively stable and is between 17,000-19,000 users (Fig. 8). The year 2001 shows a decline in the number of users with just a little more than 15,000.

The Mount Robson Provincial Park management has expressed concern that day use traffic sometimes can reach unacceptable limits, and is particularly an issue when the same trail is used by hikers, mountain bikers, horse riders, and hiker with dogs. In fact, Kinney Lake is a popular destination for families, where there were reports of threats posed by dogs not on leash (Park personnel, pers. Comm., 2002).

Fig. 8: Number of day hikers over time



Source: BC Parks, 2001

During the time of field survey in July 2002, two dogs were observed without leash. Hikers may not be serious about respecting park rules in the backcountry, as employees cannot monitor visitor behavior and the acceptance of park-imposed rules. This could negatively affect other hikers; encounters between dogs and wildlife are also possible.

5.2 Trail degradation

BC Parks has categorized hiking trails, based on the nature and physical features of trails and facilities that parks can provide (Table 2). Based on these standard, the Berg Lake trail sections are classified as "Type I" and "Type II" trails.

For the Mt. Robson Provincial Park, trail width standards for Type I and Type II trails are set at 0.8-2.4 m and 1.2 m, respectively. Trail depth for Type I is set at 25 cm and for Type II it is 20 cm. Similarly, standard for vegetation cover ranges between 50% at Falls of the Pool to 65% at Berg Lake (Thurston, 1996).

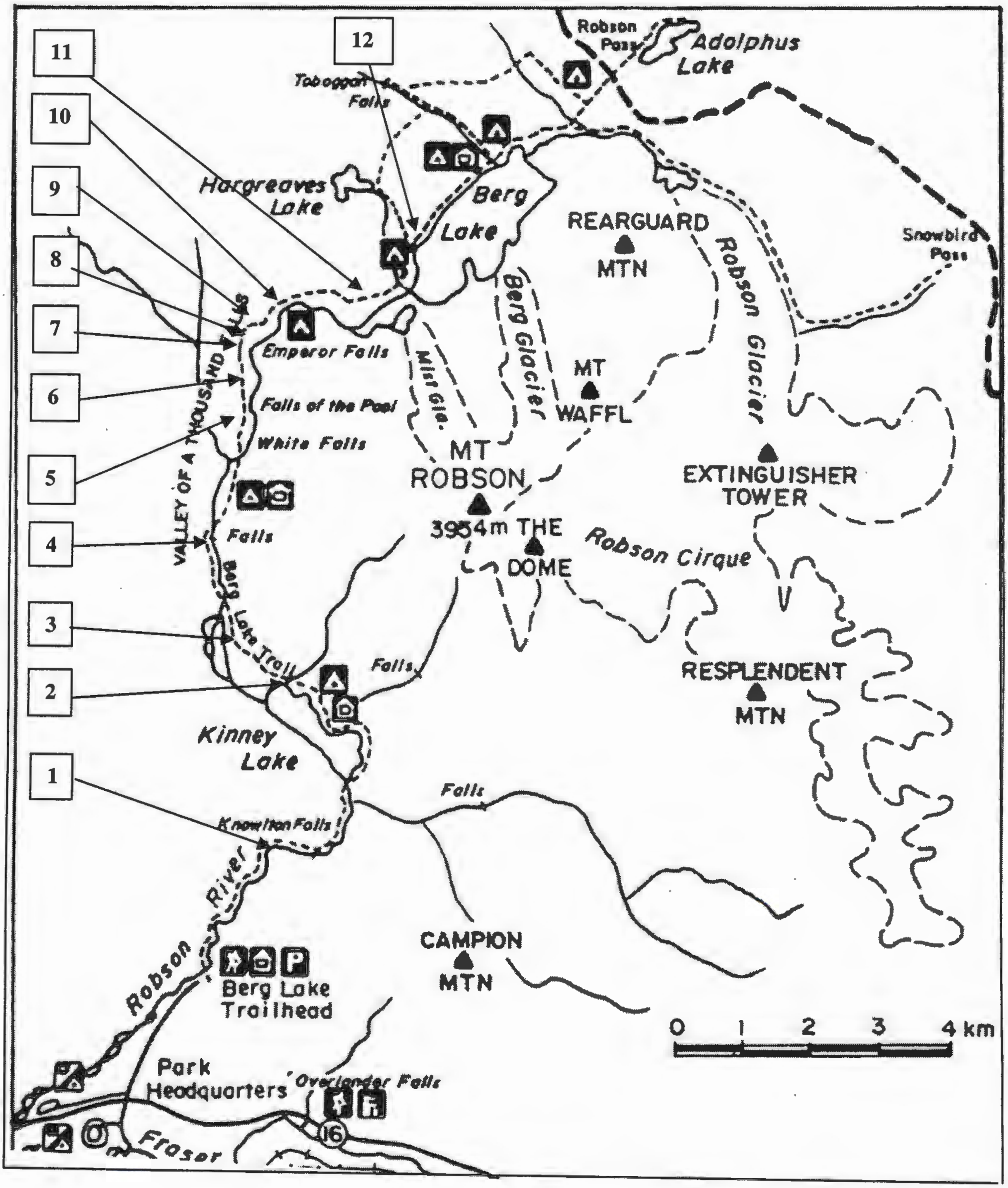
A total of 12 trail plots were selected for monitoring purposes. The location of these plots is shown on Figure 10. A summary of trail location description is provided in Table 3. This section summaries trail data collected over a seven year period, from 1996 to 2002. The focus is on trail width and trail depth, as these were the only two indicators selected for examining patterns of trail impacts on the Berg Lake trail.

Table 2: Facility standards for BC Parks trails

Type I	Type II
• short walks, 5 to 30 minutes duration; • provide base course and surface tread; • 2m wide, less than 5 % grade; • accessible to wheel-chairs; • provide interpretive signs, benches, viewing areas where appropriate; • use as ski trails in winter if criteria met;	• walking trails, 10 minutes to 2 hours duration; • leads to higher elevation points; • designed as 1.2 meter wide, surfaced, suitable for walking two abreast; • trail grade maximum 10%; • day use areas, view points, campgrounds, interpretive areas, or access to backcountry trails; • consider as ski touring trails in winter if criteria met;

Source: BC Parks, 1992b, p. 32.

Fig. 9: Location of monitored trails



Source: Field Survey 2002. Base map: BC Parks, 1991a. Number refers to plot identification.

Tale 3: Location of monitoring sites

Trail monitoring locations are marked with surveying markers at the tree for quick tracking. Colored spikes are fixed at two points of the trail edge section for easier locating.

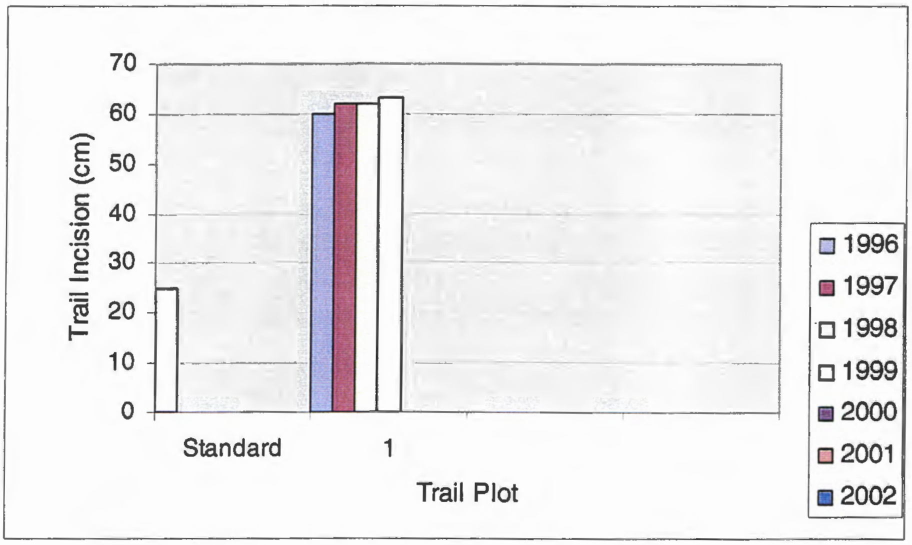
Trail plot 1:	This section is located around the 2 km mark at a wide site in the old growth forest. Small boulders are located on the side of the trail.
Trail plot 2:	Kinney Lake area. On second switchback leading up from beyond the outflow picnic area. This section was reconstructed in 1994.
Trail plot 3:	Kinney Lake area. About 150 m beyond the highest point of the trail alongside Kinney Lake. Three birch trees on upslope side of trail with exposed roots about 1 m away.
Trail plot 4:	Kinney Lake area. In the groove of trees about 100 m beyond the bridge from Kinney Lake campground.
Trail plot 5:	Whitehorn area. About 35 m before the highest point on the 1991 re-route section above the Kinney Lake flats.
Trail plot 6:	Whitehorn area. About 15 m uphill from the first railing on the switchbacks above the rock slide areas.
Trail plot 7:	Emperor Hill area. Uptrail from White Falls sign between the 1st and 2nd water bars. Trail surface is primarily bedrock.
Trail plot 8:	Emperor Hill. About 30 m downhill from the Falls of the Pool viewpoint.
Trail plot 9:	Emperor Hill area. Along the edge of dry gorge several hundred meters uptrail from Falls of the Pool.
Trail plot 10:	Emperor Hill area. This section is five meters below the old horse gate. Today, this plot is located near horse trail junction.
Trail plot 11:	Berg Lake area. Several hundred meters beyond Emperor Falls campground. 20 m before the bridge leading towards the rock wall and screen slope.
Trail plot 12:	Berg Lake area. This section is between Chalet and Rearguard campground. In 2000, this trail was rerouted to the gravel flats land along Berg Lake.

Source: Thurston, 1996

5.2.1 Trail depth

From the trailhead to the Kinney Lake Bridge (Plot 1): This plot is located within 2 kilometers of the trailhead, in the old growth forest, and is fairly stable and accessible to horse users and bikers. Due to the problem encountered in locating this plot, measurements for 2002 are not available. Previous data indicate that this trail was severely incised (Fig. 10). BC Parks has considered 25 cm of trail depth as the acceptable standard for Type 1 trails. Data indicate that between 1996 and 1999, there has been a slight increase in trail depth, and is more than twice the acceptable standard.

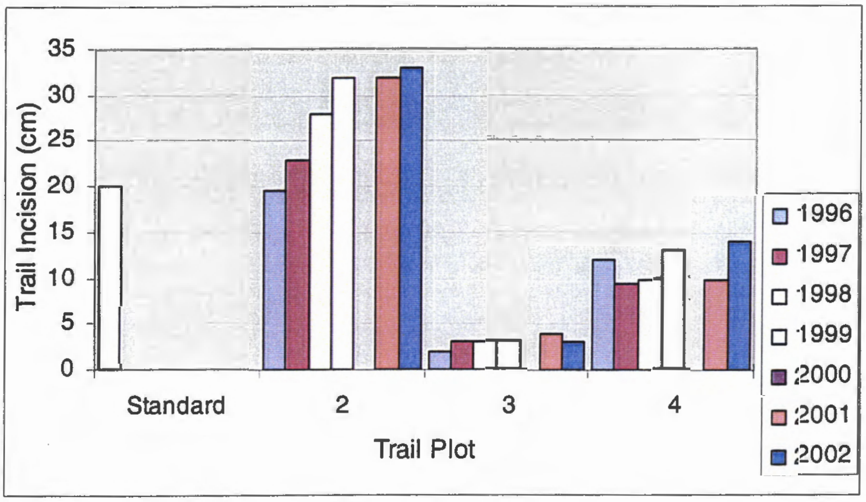
Fig. 10: Trail incision over time (Plot 1)



Kinney Lake Area (Plots 2, 3, & 4): Plot 2 is located adjacent to Kinney Lake, on a slightly undulating terrain. At this location, over-story is semi-open, and the trail is partially graveled. It is one of the most incised trail points on the Berg Lake trail. Data show that the rate of incision during the first four years of trail construction was very high and has leveled off since

1999. The 2002 data show trail incision to be 33 cm and is 13 cm higher than the standard set by BC Parks (Fig.11).

Fig.11: Trail incision over time (Plots 2, 3 & 4)



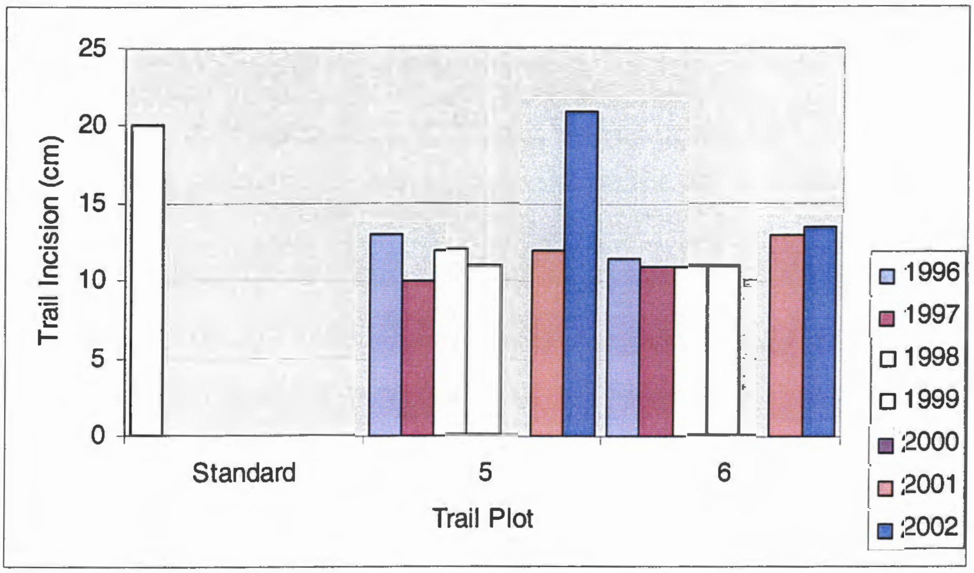
Data for Plot 3 show that trail incision is not a major problem at this location (Fig. 11). Comparison of trail surface photos taken in 1996 and 2002 indicates that there has been no loss of trail side (edges) vegetation. On the contrary, there has been a remarkable improvement in vegetation cover (Plates 3 and 4). This section of the trail is well-aligned with the contour of the topography. The drainage system in this area seems to be working well, which could have helped in reducing trail surface erosion. Data on Plot 4 show that between 1996 and 2002, the ratio of change in incision is not very significant (Fig. 11). The data must be interpreted cautiously. Trail depth (incision) in 1996 was 12 cm which reduced to less than 2 cm in 1997 and 1998, but increased again in 1999. Trail depth reduced again in 2001 but increased significantly in 2002. It is possible that there were discrepancies in measurement, mainly because the person taking the measurements is not always the same. In the absence of proper formal training, such measurements can be subjective.

Plate: 3: Plot 3 (1996)

Plate: 4: Plot 3 (2002)

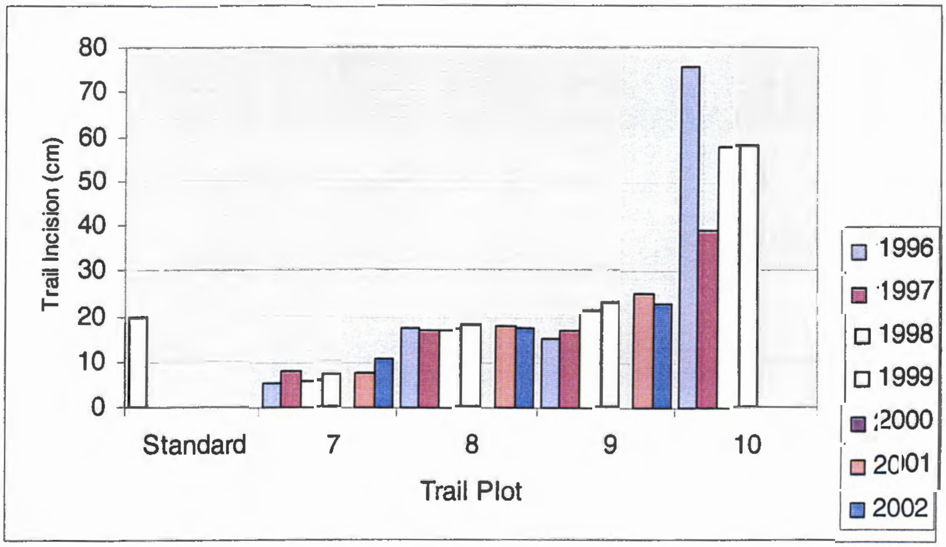
Whitehorn Area (Plots 5 & 6): The Whitehorn area is prone to soil erosion, as the trail is located on a steep slope. Data on Plot 5 show that there is an increase in trail depth than in the previous years (Fig. 12). An increase by 9 cm between 2001 and 2002 should be considered high, given the fragility of the site. Data prior to 2001 is no longer valid, as the Park management has reconstructed the trail. Hence, the 2001 data should be considered as baseline. Data on Plot 6 suggests that total depth over the last seven years has been increasing, but the rate of change is minimal (Fig 12). Absolute change between 1996 and 2002 is only 2 cm. Overall, both plots are within the standard prescribed for this type of trail.

Fig. 12: Trail incision over time (Plots 5 & 6)



Emperor Hill Area (Plots 7, 8, 9, & 10): This section of the trail is located on a steep slope. Trail surfaces of plots 7 and 8 are hard, where chances of soil compaction and erosion are minimal (see Appendix, Plates k & l). Compared to the previous year, trail surface of Plot 7 has eroded, but is well within the standard (Fig. 13).

Fig. 13: Trail incision over time (Plots 7, 8, 9 &10)



Trail depth on Plot 8 is much higher compared to Plot 7; however, the overall rate of change is negligible, and between 2001 and 2002, depth was reduced by 0.5 cm. What is noticeable on Plot 8 (Fig. 13) is that erosion has occurred on the upper slope of the trail, and deposition has occurred on the bottom of the trail (Plates 5 & 6). Trail width has increased, as hikers tend to go around it to avoid the rocky and eroded section of the trail. Data on Plot 9 (Fig. 13) show a striking difference in trail surface characteristics between 1996 and 2002 (Plates 7 & 8). Compared to the 1996 photo, the 2002 photo show excessive amount of bedrocks exposed, probably a result of downhill soil erosion. Trail depth has increased significantly over the last seven years; a net increase of 7 cm. This section is located on a rocky outcrop where light penetration is high due to the absence of tree canopy.

Plot number 10 is now closed off (in 2000) due to high levels of soil erosion. Available data show that trail depth had increased considerably since 1997 and greatly exceeds the standard set by the Park management (Fig. 13).

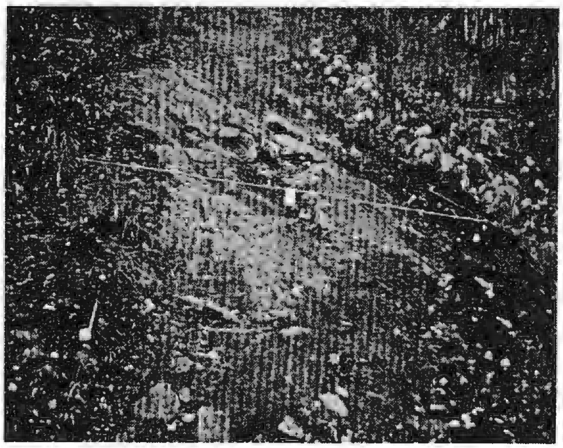


Plate 5: Plot 8 (1996)

Plate 6: Plot 8 (2002)

Plate 7: Plot 9 (1996)

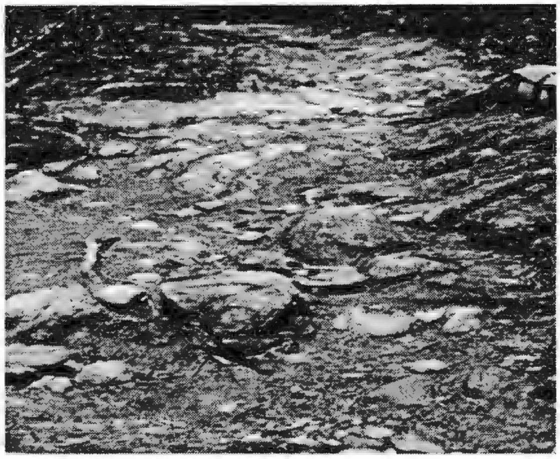


Plate 8: Plot 9 (2002)

Berg Lake area (Plots 11& 12): Plot 11 is located near the Berg Lake Campground. Data show that trail depth has not increased so much (Fig. 14). However, this should be taken cautiously. Root exposure on this trail has now become a problem. Compared with the 1996 photo, excessive amount of root exposure is visible on the 2002 photo (Plates 9 and 10). This is another example of data inconsistency and measurement error. Root exposure is usually associated with soil erosion and compaction. The net increase in soil depth is only 2 cm while the photos indicate that it could have been greater than 2 cm, as indicated by extensive root exposure at this location. Therefore, taking incision measurement at one point (the most deeply incised part of the trail surface) can be misleading. This calls for more accurate measurement techniques to be applied in trail monitoring. Trail depth on Plot 12 is also within the standard. The rate of change is very negligible (Fig. 14). This plot is no longer monitored, and a new trail has been constructed on the gravel flats where erosion is not an issue.

Fig. 14: Trail incision over time (Plots 11 & 12)

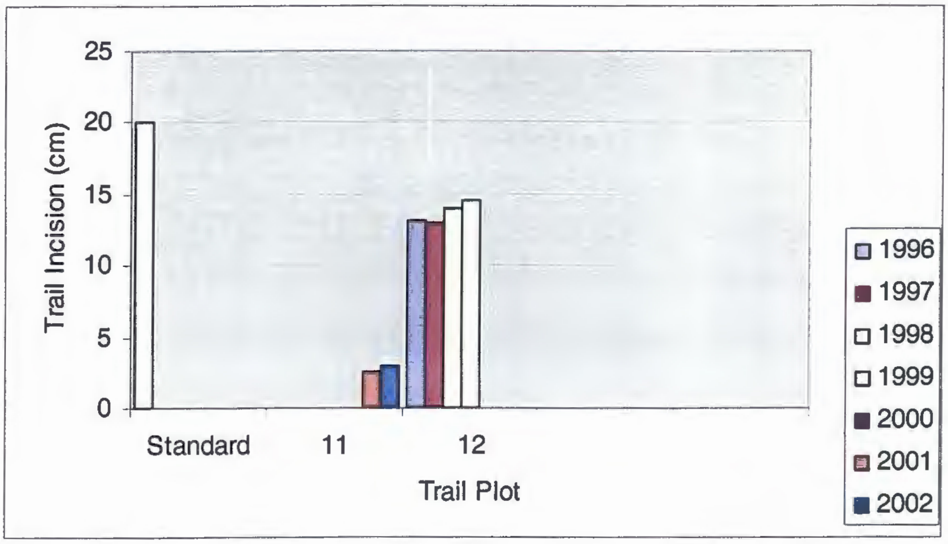


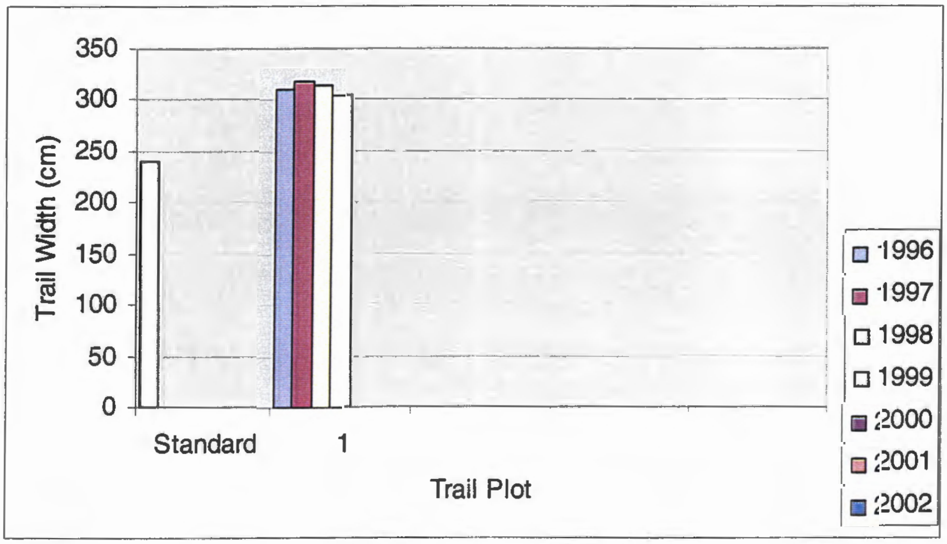
Plate 9: Plot 11 (1996)

Plate 10: Plot 11 (2002)

5.2.2 Trail width

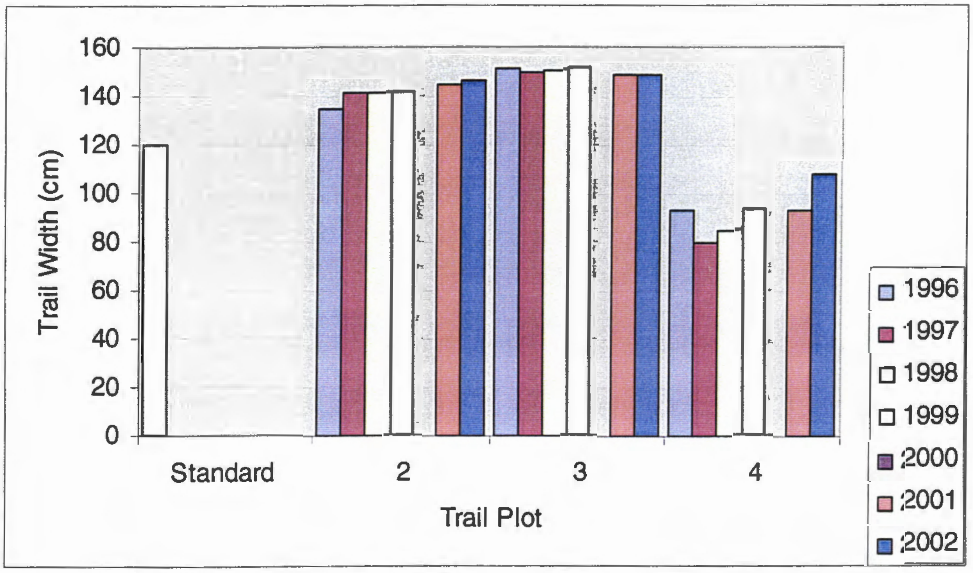
From the trailhead to Kinney Lake Bridge (Plot 1): BC Parks has set width standards for various types of trail. The Berg Lake Trail in this area is classified as a "Type 1" trail and its width is set at 240 cm. Compared to this standard, the width of Plot 1 exceeds by almost 60 cm as recorded in 1999 (Fig. 15). However, previous data suggest that width has gradually decreased, possibly an indicator of a good trail management strategy at this location.

Fig.15: Trail width over time (Plot 1)



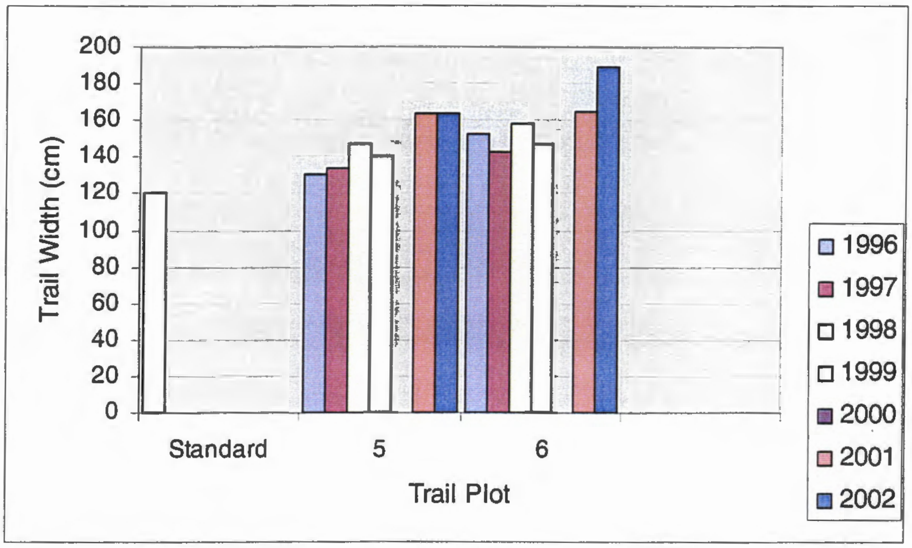
Kinney Lake Area (Plots 2, 3, & 4): Width standard for the trail (Type 2) is set at 120 cm. Trail width on Plot 2 exceeds the standards by more than 30 cm (Fig. 16). Width has gradually increased over time. Plot 3 also exhibits similar pattern, though difference in increase or decrease in width over time is negligible (Fig. 16). Plot 4 is still within the standards; however, past trends indicate that this standard will be exceeded very soon if adequate measures are not taken. The difference in trail width between 1996 and 2002 is almost 15 cm. The graph shows a clear pattern of increasing width compared to the previous years (Fig. 16).

Fig. 16: Trail width over time (Plots 2, 3 & 4)



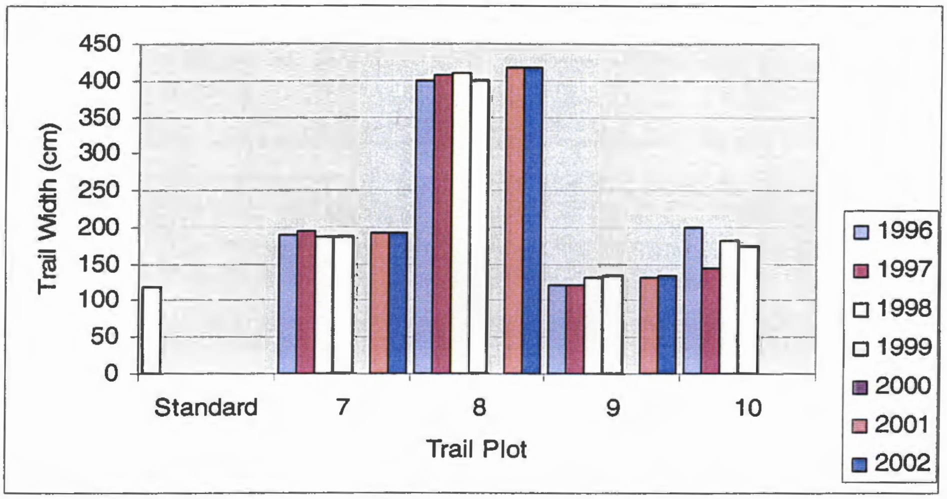
Whitehorn Area (Plots 5 & 6): Trail widths at both plots have constantly increased over time and exceed the standard (Fig. 17). Plot 6 exhibits high trail surface erosion and exposed bedrocks. As this plot is located on a hilly terrain, topography seems to be a factor contributing to trail widening (see Appendix, Plates i-j). Photographs indicate the widening of trail surface, partly due to soil erosion at trail edges. The difference in the trail width between 1996 and 2002 is more than 40 cm. The trail width at Plot 6 is significantly higher (70 cm) than the standard. This section requires adequate maintenance.

Fig. 17: Trail width over time (Plots 5 & 6)



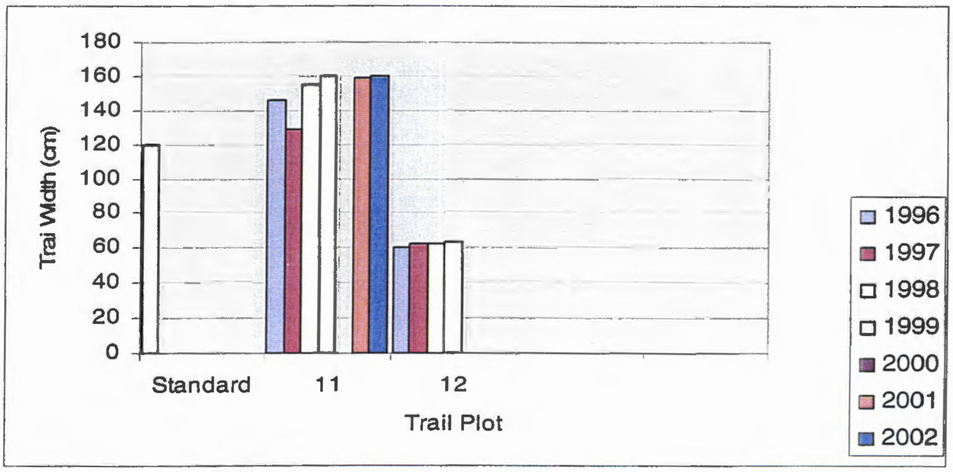
Emperor Hill Area (Plots 7, 8, 9, & 10): As stated earlier, due to the steep gradient of the trail, this section of the Berg Lake trail is susceptible to soil erosion. Visitors contribute to this problem by either loosening the soil or compacting, in which case infiltration is minimized and runoff is triggered. The width of Plot 7 greatly exceeds the standard by almost 70 cm (Fig. 18); however, the increased width has remained constant over the last seven years. This could be an indicator of the curvilinear relationship between use and impacts i.e., most impacts occur at the early stages of use and tend to level off after a certain period. Plot 8 is also highly impacted, as its width exceeds nearly 3 times the standard. Data on Plot 9 also show significant increases in its width. Since 1996, its width has increased from 121 cm to 133 cm (Fig. 18). Repeat photos indicate distinct changes in its width in 1996 and 2002 (refer to Plates 7 & 8 on page 46). Water runs along the trail, forcing hikers to avoid the mud and circumvent the trail. Over time, this process causes trail widening. As mentioned earlier, Plot 10 is no longer monitored due to changes in trail route.

Fig. 18: Trail width over time (Plots 7, 8, 9 & 10)



Berg Lake Area (Plots 11&12): Data on trail width on Plot 11 show gradual increase in width, from 146 cm in 1996 to 160 cm in 2002 (Fig. 19). The trail surface has a shallow depression, and is prone to water accumulation (see Appendix, Plate r). In such a situation, hikers tend to avoid the muddy part of the trail, which eventually causes trail widening. Plot 12 is no longer monitored as the trail has been routed along the gravel flats.

Fig. 19: Trail width over time (Plots 11 and 12)



5.2.3 Proliferation of social trails

The most common problem in the Berg Lake trail is proliferation of social trails in and around campgrounds, especially Whitehorn. Social trails are defined as those which develop as visitors search for view points or wander carelessly looking for short and straight paths to their point of interest. The development of undesired trail routes, mainly as a result of short-cut access to toilets, bear poles, and firewood collection sites by visitors and sometimes park rangers are some of the key factors contributing to the proliferation of social trails at Whitehorn. Park rangers have accepted that this might have been an unintended consequence of their actions in the past. Improper placement of tent pads, toilets, and bear poles seemed to have aggravated the problem. A campground sketch drawn by Gail Ross, a BC Park employee, clearly illustrates the severity of this issue (Fig. 20). During the field visit, an enclosure was established to block-off visitors from trampling sensitive vegetation and prevent the proliferation of social trails (Plate 11, p. 53). Blocking such impacted areas and monitoring these sites through many seasons will help to reduce the amount of impacted areas, and help vegetation to regenerate.

The Whitehorn Campground sketch indicates several issues. First, there is a need to develop designated trails within the campground, for example, to provide access to toilets, bear poles, shelter, and tent pads. In the absence of designated trail, there would be no control on how people access these areas; the normal tendency would be to search for the shortest path possible. If all campground users develop their own individual short-cuts to these utility points, the result will be a profusion of informal or social trails.

Second, the design of the campground itself is problematic, as is obvious from the sketch. There are two clusters of tent pads, one towards the northeastern section of the campground, and the other at the western section (Fig. 20, p. 54). A more sensible design would have placed the bear poles and toilets equidistant to these two clusters. From a monitoring point of view and to minimizing campground impacts, the layout of the trail poses tremendous difficulty. Solution to such problems lie in developing clearly mentioned or designated trails, creating obstructions (such as temporary fencing) and finding central locations when developing sites for campground services (toilets, bear poles etc.).

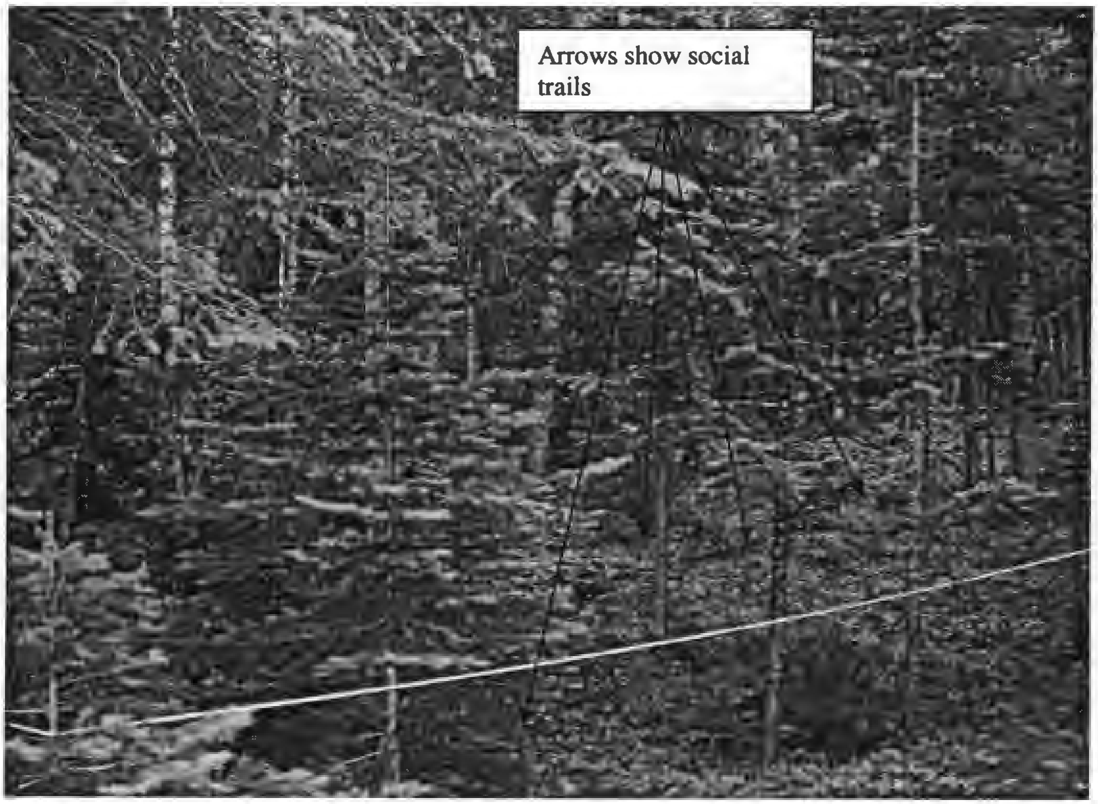
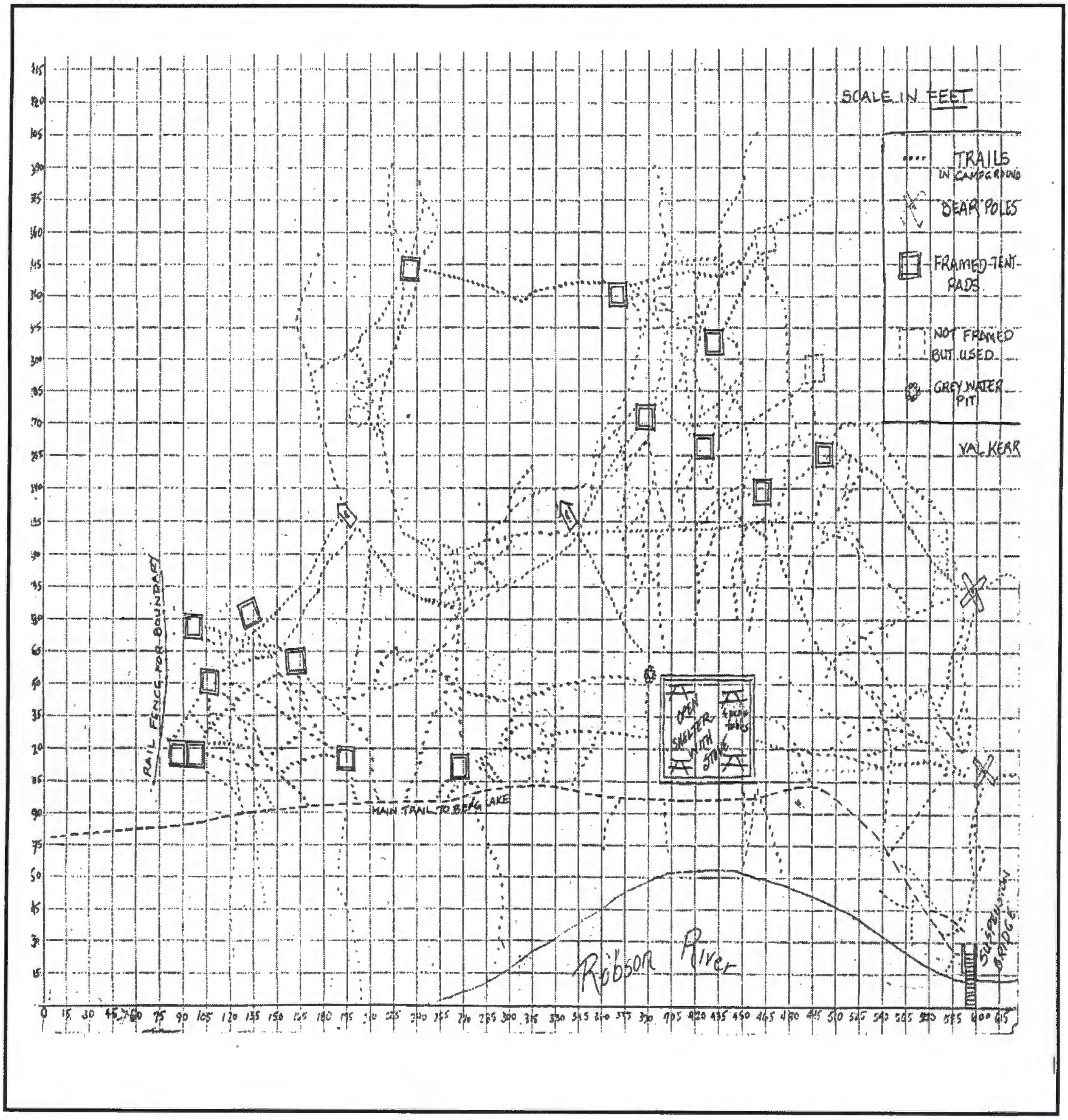


Plate 11: Enclosure established at Whitehorn campground

Fig. 20: Proliferation of trails at Whitehorn Campground

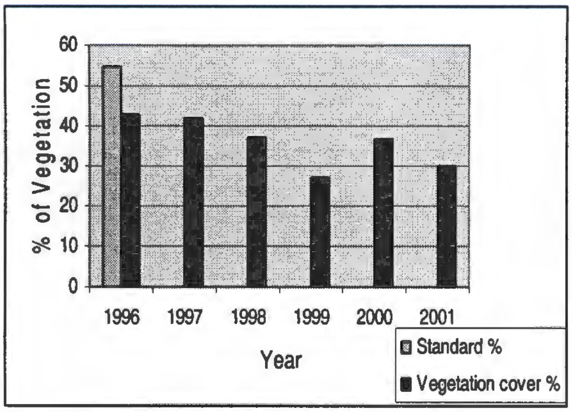


Source: BC Parks, Prince George Office

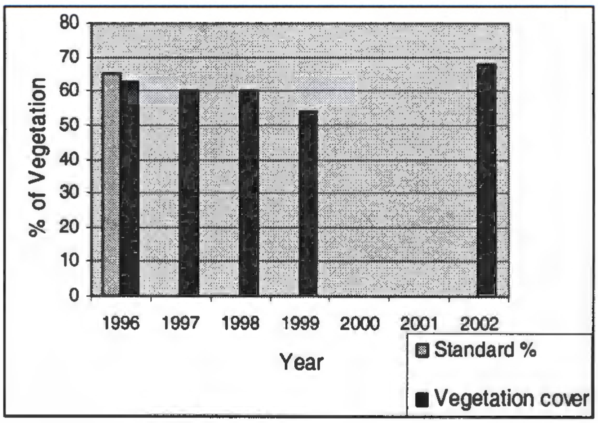
5.3 Vegetation cover

The vegetation monitoring plots (transects) are located at the Robson Pass, Chalet, and Falls of the Pool areas. All monitoring plots are located adjacent to the shelter. Each transect was divided into nine 1m² quadrants. All grasses, shrubs, forbs, and trees, including mosses and lichens, were considered as vegetation cover. Data indicate that there has been no dramatic loss of vegetation cover (interpreted in terms of % of bare ground on each transect) except in Robson Pass. The Robson Pass transect data show a slow but steadily declining cover. For example, in 1996 vegetation cover was estimated at 42 % but has now declined to 30 % (Fig. 21: A). This is a significant loss and is almost 50 % below the standard set at 55%. In the Berg Lake Chalet area, vegetation cover declined during 1996-1999. Data are not available for 2000 and 2001. The 2002 data show a remarkable improvement in vegetation cover, from 55 % in 1999 to 68 % in 2002, which is just a little above the standard set by the Park (Fig. 21: B). In the Falls of the Pool area, vegetation cover in 1996 was 35 % and in 1999 it was 42 %, which is well below the standard of 50% (Fig. 22).

Fig. 21: Vegetation cover by location

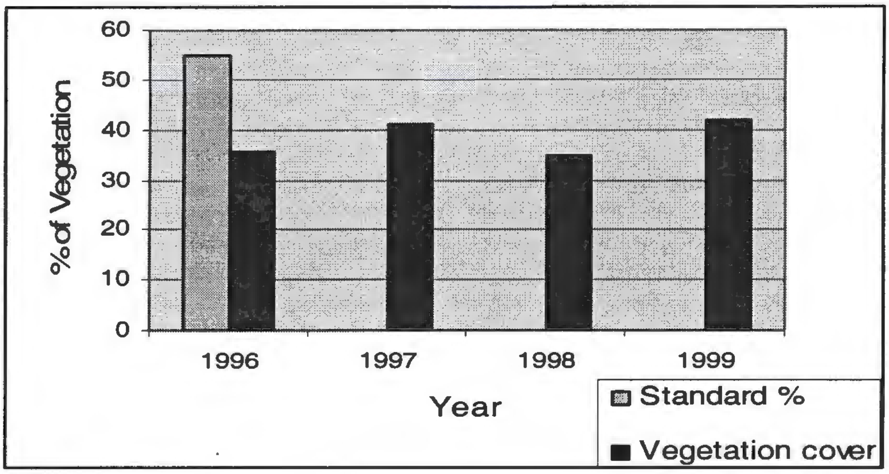


A. Robson Pass



B. Chalet

Fig. 22: Vegetation cover by location



Falls of the Pool

5.4 Summary

The above data on trail width, trail depth, proliferation of social trails, and vegetation cover all indicate towards a gradual deterioration of trail-specific resource conditions along the Berg Lake trail. Trail data show that width in many locations has increased, but depth is not a major problem. Trail depth in Kinney Lake and Emperor Hill has exceeded the standard. Trails are more damaged in the Whitehorn and Emperor Hill areas, which can be attributed to high visitor traffic and the fragile characteristic of the alpine environment. Other environmental factors such as surface runoff, freeze-thaw cycle, and natural erosion are equally responsible for this degradation.

Trail width seems to be sensitive in Kinney Lake, Emperor Hill, and Berg Lake areas. The high number of day hikers, especially up to the Kinney Lake area seems to be responsible for the degradation. In this area trail width and depth both exceed the standard. Similarly, data also show that trail proliferation is an issue that needs to be urgently dealt with at Whitehorn campground. Vegetation cover in the three transects show that, except in the Berg Lake Chalet area, cover has not declined significantly.

Chapter 6: Discussion

A cross-sectional analysis of the Berg Lake trail reveals several potential factors contributing to trail degradation. Environmental factors and the lack of a proper management strategy to mitigate the existing problems are the two main reasons. The trail monitoring system that has been implemented since 1996 has several problems. First, the total number of trail plots is too few. The inclusion of only 12 monitoring plots, which were selected arbitrarily, does not adequately represent the trail conditions. Second, the emphasis on only 2 indicators, i. e., trail depth and trail width, is ineffective. The existing indicators fail to establish the cause and effect relationship between use and environmental factors, and the magnitude and extent of trail degradation. Since 1996, visitor use has been declining; however, trail impacts seem to be increasing in frequency and intensity. Third, some campgrounds are severely impacted, as indicated by the high frequency of root exposure and soil compaction, and suggest that monitoring of campground is essential as well.

The trail impact analysis focused on two main indicators, trail width and depth, at selected sites. The park management has selected other indicators such as water quality, campground crowd, trail traffic, tents outside designated camps, and vegetation cover; however, data on these aspects do not exist. Analysis of trail depth and width, and vegetation cover (on selected transects) were based on data collected over the last six years. It is questionable if the current trail monitoring has helped park management in deciding when and how to implement mitigation strategies. The state of the trails, as indicated by the data collected, may thus have nothing to do with park manager's decision on trail repairs and closures. Indeed, many trail sections were reconstructed to provide safe access to hikers, but the decision to repair trails have been based on intuition rather than what the indicators suggest.

One of the objectives of trail monitoring is to provide inputs to decisions on park management; however, discussion with Mt. Robson Provincial Park management revealed that limited use of available data has been made in day-to day operations. The purpose of a trail monitoring is to protect resources and develop guidelines for trail management. Available trail literature suggests that a variety of trail impact indicators need to be monitored on a continuous basis. These indicators can be grouped into three categories: (1) environmental, (2) user related, and (3) managerial. Environmental indicators include information on trail-specific topographical features and impact variables, including number of informal trails, trail width, trail incision, tread conditions, trail grade, trail alignment, root exposure, bedrock exposure, soil type and texture, soil compaction, soil moisture, muddiness, and trail braiding (Marion, 1994). Use-related information includes density of hiking traffic, party size, group composition, campground densities, and other use types. Managerial information includes aspects that show certain preventive or remedial measures introduced to resolve existing or any potential trail impacts. These may include culverts, water bars, boardwalks, and other maintenance features.

It is inappropriate to focus on only two indicators. Some monitoring plots are no longer on the main trail while a few plots are on reconstructed/rehabilitated areas, making previous data invalid. Data from these plots have to be treated as baseline (post rehabilitation).

It is crucial to upgrade the current trail monitoring system in Berg Lake. There were complains of insufficient toilets and improperly placed bear poles. There are also problems associated with the profusion of informal trails which are created because hikers wander around (to collect firewood, explore viewpoints, or answer nature's call) carelessly. As already stated, some resource impairment after visitation is inevitable; however, excessive resource degradation and the proliferation of user-created trails and campsites are considered unacceptable, especially in backcountry areas (Leung and Marion, 2000). The Berg Lake trail campgrounds, especially at Whitehorn, are severely degraded due to the development of unnecessary social trails. In addition, seepage from outhouses is also believed to have occurred on some campgrounds, and particularly at Whitehorn. This could become a public health hazard. Tent-pads are placed haphazardly in some campgrounds; for example, in Marmot Basin tent-pads are scattered over a large area, thus necessitating the need for informal trails, and contributing to overall reduction in vegetation cover. Literature on backcountry camping impacts suggests that concentration of tent-pads is preferable than dispersal (Hammitt and Cole, 1998; Marion, 1994). This could not only help reduce the development of undesired trails, but would also facilitate efficient and effective monitoring.

Some trail plots have become obsolete. Trail plots 7 and 8 are located on hardened site, where chances of soil compaction are negligible. Selecting such sites may be useful to illustrate the effectiveness of hardened (natural or artificial) areas. The existing Berg Lake trail monitoring methods are not precise enough. For example, data on trail depth is based on measurement of the deepest section of the trail surface. Marion (2002), has introduced a new system in which depth measurements show the total loss of trail surface area. According to this method, several depth measurements are taken across a line perpendicular to the trail, and values are averaged.

One of the main problems in trail data collection is the subjective judgment of the person taking the measurement. The park personnel responsible for collecting data have not received any formal training in trail measurements and monitoring, which is why data are highly inconsistent. Detail written instructions help resolve this; however, trained personnel is necessary if an effective monitoring is to be conducted. Educating the park rangers about the procedures, techniques, and application of indicators is important. Similarly, estimating vegetation cover in three discretely selected transects (near the shelters) is inadequate to illustrate whether or not visitor use causes vegetation impacts. Several plots need to be established in and around heavily used campgrounds, and a quantitative measure of plant diversity and density should be included.

Existing literature indicate that trail degradation is highly influenced by levels of use (Hammitt and Cole 1998; Leung and Marion, 2000); however, the current data structure and the few number of monitoring plots do not provide any conclusive evidence to support the above statement. Trail width in some plots exceeds the acceptable limit of the standard set by the park. This information, however, is subject to speculation, although in general trail width in backcountry areas increase as use levels increase (Hammitt and Cole, 1998). Running water on ruts created by hikers further compounds soil erosion problems. The freeze-thaw cycle also contributes to soil erosion. When a trail becomes muddy, visitors avoid the muddy section by circumventing the trail, and in the process enlarge the impacted area. Leung and Marion (1999), in their study of trails in Great Smoky Mountain National Park (GSMNP), USA found that circumventing muddy sections of the trail is a major factor contributing to trail width. This was the case at Plot 1 where due to muddiness hikers had left the main trail tread and created a second tread. This can be prevented if drainage dips and water bars are placed appropriately to provide adequate drainage and keep the trail surface dry. Drainage dips are angled trenches which are dug across the tread, and a berm is created on the down slope to divert water off the trail. The water bar works in the same way. It is made with either wood or rocks embedded in the down slope berm to reduce erosion and standing water. Both of these techniques require constant maintenance to clear drainage channels and reinforce berms, as blocked channels could further lead surface runoff and erosion (Leung and Marion, 1999).

Soil in the Berg Lake trail corridor is relatively wet, and is prone to hiker-induced compaction. Surface runoff is a problem particularly on steep slopes. Some trail plots were located under a dense canopy cover with low sunlight penetration. After the thawing of the snow on trail, trail surface becomes wet and muddy. In such a situation, hiking induces further soil-erosion and compaction, eventually leading to increased trail width. In the Emperor Hill and Whitehorn areas (Plots 5 & 6), trail surface erosion were caused by the steep gradient of the slope (see Appendix: Plates i and j). In addition, accumulated water along the bottom of a trail on a steep slope causes visitors to avoid such areas. In Great Smoky Mountain National Park, Marion (1994) observed that the muddiest trail in the flat land area could not sustain heavy traffic during the wet periods, as heavy traffic led to excessive muddiness and trail widening. Along the Berg Lake trail, Plot 4 exhibits similar problems. Hikers also tend to avoid rocky areas due to slippery conditions. This prompts them to go off-trail, which not only widens the trail, but is also a first step toward establishing an informal trail.

The Mt. Robson Park staff reported the likelihood of water contamination in nearby streams and lakes in Whitehorn and Marmot Basin (Chris Zimmerman, Park Ranger, pers.

Comm., 2002). During heavy rain, water seeps through the Marmot toilet, and eventually drains into Berg Lake. This is a problem in many backcountry areas (Hammitt and Cole, 1998), and is an issue if backcountry users depend on local streams and rivers for drinking water. Park management needs to monitor water quality in these areas before any incident occurs. Monitoring water quality has not been a priority in Mt. Robson Provincial Park.

Many sections of the Berg Lake trail were reconstructed in 2001, as part of a regular trail maintenance scheme. Data on trail width and depth from some plots suggest that maintenance was a factor in contributing to trail width and depth. Despite the fact that repairs alter the trail surface greatly, data on trail depth and width has been collected as a routine task, without any sense of purpose or goal. Reduction in visitor numbers since 1996 has not translated into reduction in trail and campground impacts. Park staff reported that much damage occurs during late spring when school groups visit the park. Lack of trail and campground etiquette among school students is reported to be an issue.

The present study illustrates that visitor use levels and impacts have an inverse relationship. In other words, even with low levels of use, trail impacts have not diminished but have tended to increase in frequency and intensity of damage. This supports the findings of other researches that amount of use is not the only factor that contribute to resource degradation (Cole, 1990; Hammitt and Cole, 1998; Leung and Marion, 2000; Marion, 1994). One plausible explanation for this is the fragile environmental characteristics of Mt. Robson, which is susceptible even to low levels of use. Periodic trail maintenance has kept the problem to a minimum. This implies that the current monitoring system requires a dramatic improvement, both in the number of indicators and the number of plots to be monitored.

Mount Robson Provincial Park should be commended for initiating a trail monitoring study, as there are hardly any comparable studies conducted in Canada's parks and protected areas. There are structural issues, such as the lack of research funding and manpower, not just in BC Parks but in Canada as a whole. Thus, it can be argued that given the lack of financial resources and trained personnel who would be able to conduct a more detailed and accurate impact assessment, it is doubtful if improvements in monitoring system only would be of any practical use. A systematic basis for monitoring should be developed and applied to make visitor regulations and control of ecological damage more science-based rather than intuition-based.

Chapter 7: Conclusions and Recommendations

The main objective of this research was to examine the utility and effectiveness of trail monitoring system implemented in the Berg Lake trail corridor in Mount Robson Provincial Park. Four main aspects were covered including analysis of trail width, depth, vegetation cover, and profusion of informal trails. This research revealed the weaknesses of implementing a monitoring system without fully understanding the utility and purpose of ecological monitoring. Lack of a comprehensive monitoring, and improper and inadequate site selections were major weaknesses of the existing monitoring system. It is understandable that such a system will hardly enable park management to do a good job in resource protection and enhancement of visitor satisfaction. In order to make judicious trail and visitor management decisions, selection of indicators and sites are essential to improve the resource conditions in Mount Robson Provincial Park.

The Berg Lake trail monitoring data indicates that trail width is a major problem; data indicated that trail width continue to increase at several locations. For example, trail plots 1-3 and 5-8 have exceeded the minimum standard set by the Park management. The physical condition of the trail is fairly acceptable to many visitors (based on informal discussion with some visitors and Park Rangers). Emperor Hill, Whitehorn, and Kinney Lake are problem areas in terms of amount of degradation caused by visitor activities. Plots 1, 2, 5 and 9 exhibit severely incised trail surface. Due to high levels of soil compaction, root and bedrock exposures are also common in several areas.

Analysis of vegetation cover in the three transects indicate that loss of vegetation cover as a result of human trampling is not a major issue. Vegetation cover remains within the standards, except in the Berg Lake Chalet area, where cover has reduced slightly. During the field survey, soil compaction, root exposure, and amount of bare ground were found to be significant problems in all campgrounds. The Berg Lake Chalet and Whitehorn campgrounds are especially impacted. These areas are not included for monitoring, which further show that the current monitoring system needs to be improved to include areas that have high use levels. Overcrowding in campgrounds has been reported too.

Visitor numbers on the Berg Lake trail was high before the implementation of the quota system in 1996. Because of the quota system, campground use has now been regulated to evenly distribute its use across all campgrounds. However, due to locational factors and scenic attraction, visitor pressure is concentrated on the Berg Lake and Whitehorn campgrounds. As indicated earlier, Berg Lake is the final destination for the majority of hikers. The Whitehorn Campground is located mid-way, and receives hiker from both directions (to and from Berg Lake). Thus, campground monitoring must be initiated at these locations. Data also show that visitor use level is decreasing, indicating that the camping quota system may have resulted in the displacement of some backcountry users.

The factors that contribute to trails impacts include use-level, environmental and managerial factors. Visitor behavior, experience in backcountry hiking, duration of stay, season, and group-size are important variables to consider when examining the relationship between use and impacts. Available data on use level and impacts do not allow establishing any firm relationship between the two. Indicators need to be evaluated from time to time, and park managers should consider alternative approaches to curb the problem.

Analysis of trail data points to several issues. The most important is the indication that data are inconsistent, depending on who collects it and when it is collected. Measuring techniques need to be refined, and park staff must undergo formal training on monitoring procedures. Mt. Robson Provincial Park should be commended for their efforts in trail monitoring. However, if ecological monitoring of the trails and campgrounds are deemed important by park management, then resources must be set aside for training. This is an important consideration for BC Parks.

7.1 Recommendations

Recognizing the structural limitations of funding and technical experts to overcome the existing problem of the Berg Lake trail monitoring, the following is recommended:

- include additional indicators such as root exposure, running water, bedrock exposure, and trail alignment in the existing trail monitoring;
- establish a monitoring system for other trails, e. g., Mt. Fitz William;
- develop a campground monitoring system, with focus on vegetation cover, network of informal trails, and crowding;
- monitor water quality at Whitehorn and Berg Lake;
- reconfigure tent pads in Falls of the Pool and Whitehorn to reduce informal social trails;
- relocate the outhouse on Marmot Basin to a safer site where the potential for seepage is low;
- educate and train the park rangers in monitoring techniques and procedures, so that a more effective monitoring system can be implemented;
- install water dips, water bars, and culverts where required;
- revise the indicator standard based on current conditions;

- educate park managers about the value of a sound monitoring system; and
- ensure Park managers can implement their decisions regarding visitor regulation and trail and campground maintenance based on the monitoring data.

7.2 Suggestions for future research

It is suggested that a social survey (visitor survey) to examine visitors' perception of resource conditions along the Berg Lake trail be conducted. Establishing a basis for visitor survey and social monitoring, with a view to understand visitor's perception of crowding and their recreational satisfaction, is needed as well. A study of visitor impacts on wildlife, especially adjacent to the Berg Lake trail corridor might shed light on potential conflicts between recreation and wildlife conservation. Finally, an experimental trampling study that illustrates the relationship between use levels and amount of impacts should be initiated.

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Appendix (contd.)

Trail development over time

g. Plot 5-1996

h. Plot 5-2002

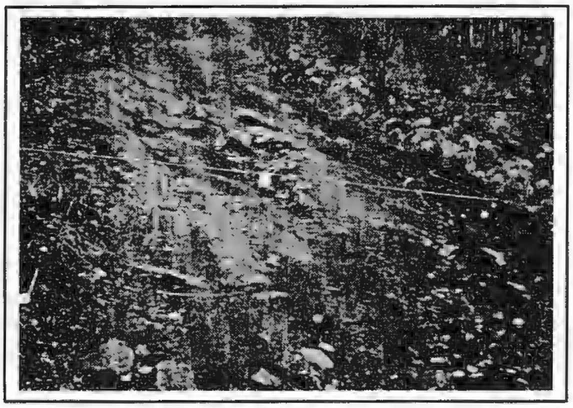
i. Plot 6-1996

j. Plot 6-2002

k. Plot 7-1996

l. Plot 7-2002

Appendix (contd.)



m. Plot 8-1996

n. Plot 8-2002

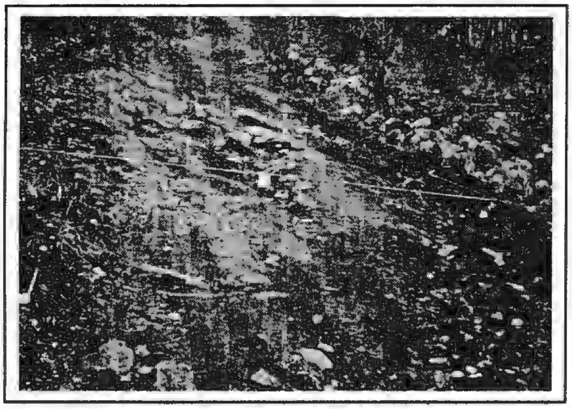
o. Plot 9-1996

p. Plot 9-2002

q. Plot -1996

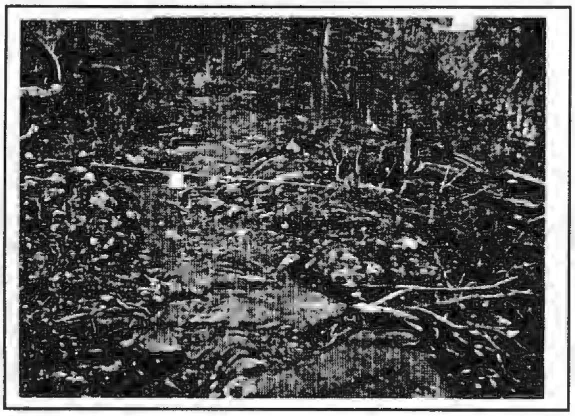
r. Plot 11-2002

Appendix (contd.)

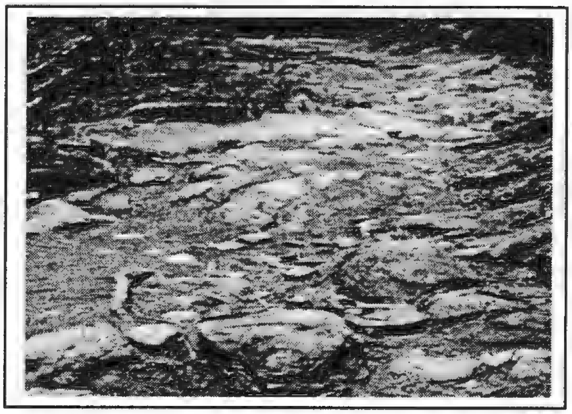


m. Plot 8-1996

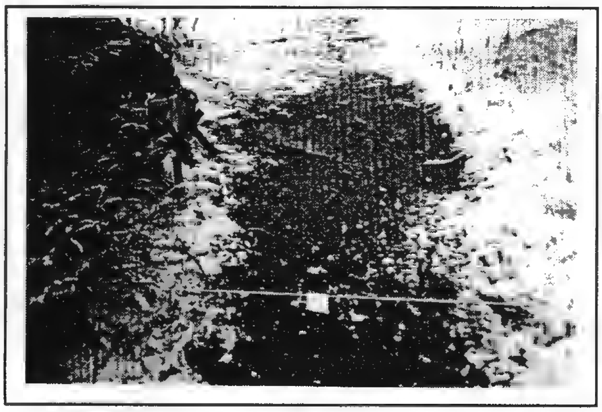
n. Plot 8-2002



o. Plot 9-1996



p. Plot 9-2002



q. Plot -1996

r. Plot 11-2002