UNIVERSITY OF CALGARY

PRESERVING ECOLOGICAL PROCESSES: A DECISION SUPPORT DOCUMENT FOR FOREST INSECT AND DISEASE MANAGEMENT IN JASPER NATIONAL PARK

by

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ABSTRACT

National Park managers recognise the importance of understanding and preserving ecological processes. In the first part of this thesis I review, analyse and present available data on insect and disease activity in order to identify knowledge gaps and increase understanding of these ecological processes in Jasper National Park. The result of this process showed that data were skewed to human use and transportation corridors, that point locations were limited especially for disease locations, and that there is very little baseline information regarding forest insect and disease activity in Jasper National Park. I make a recommendation to establish a research framework with several sub-recommendations indicating specific projects.

In the second part of this thesis I identify deficiencies in vegetation management relating to forest insects and diseases using a technique know as multiple accounts analysis (MAA). MAA provided an evaluation framework that assisted in evaluating the implications and relative merits of vegetation management actions. I evaluated vegetation management actions in terms of their consistency with the fundamental principles of Parks Canada (the criteria) using indicators I developed. In the results I identified improvements needed in vegetation management actions pertaining to ecological integrity – specifically in the area of setting and/or achieving ecological goals and in the incorporation of adaptive management. Improvement was needed in all areas indicating social values – especially communication with the public about insect and disease issues and attempts to understand public perceptions of management actions. I recommend continued development of relationships with adjacent land managers, the creation of a comprehensive forest insect and disease plan and the creation of a public information strategy. Several sub-recommendations are listed under each.

KEYWORDS: ecological processes, forest disturbance, forest diseases, forest insects, Jasper National Park, multiple accounts analysis, Parks Canada

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1.1 INTRODUCTION

Jasper National Park (JNP) is one of the largest national parks in North America, protecting critical portions of Canada's Rocky Mountain ecosystems. All national parks are governed by Parks Canada Policy which clearly directs managers within parks to "maintain ecosystems in as natural a state as possible" (Parks Canada 1994). Managers face the challenge of determining what is "natural," and of devising management plans that best ensure national parks meet this objective (Parks Canada 1997a). To ensure these management plans are executed, Warden Service specialists in each Park are appointed to oversee the aquatics, wildlife, and fire and vegetation programs to protect ecological integrity, increase safety, and minimize conflict with adjacent land managers.

General direction is provided to park managers by the principles and policies outlined in *Parks Canada Guiding Principles and Operational Policy* (1994)[i]. While this document provides guidance, implementation guidelines specific to each national park are not included. To remedy this problem in vegetation management, members of the mountain regional network created the *Vegetation Management Guideline for the Mountain Parks District* (Parks Canada 1997a). Although this guideline has not received official approval, it is being used by mountain park managers to guide vegetation management in the mountain national parks (A. Westhaver pers. comm).

The overall goal of the *Vegetation Management Guideline for the Mountain Parks District* is: "to maintain or restore the natural composition, structure and processes of vegetation representatives of the Rocky Mountain and Columbia Mountain Natural Regions." Specific goals are outlined for each type of natural disturbance. Regarding forest insects and diseases, the principal goal is: "to ensure the perpetuation of natural processes of vegetation...and to allow fluctuations of natural, dynamic populations of forest insects and diseases while considering the concerns of our neighbors." As a consequence of this 1997 guideline, JNP identified the need for a forest insect and disease management plan as one of three top priorities in vegetation management (A. Westhaver pers. comm.).

1.2 PURPOSE

The purpose of this thesis is to:

- provide current information on forest insects and diseases;
- review and assess forest insect and disease management; and
- recommend improvements to vegetation management in JNP as it relates to forest insects and diseases.

This thesis is a decision support document for park managers to use in conjunction with management plans for fire and non-native plants. It will be used by Jasper National Park to guide forest insect and disease management actions.

1.3 PROBLEM STATEMENT

The main message of *the Parks Canada Vegetation Management Guidelines for the Mountain Parks* states:

> "Parks Canada manages major vegetation disturbance processes so as to maintain or restore representative, native landscape biodiversity[ii] as closely as possible. Parks Canada pursues collaborative planning and partnering mechanisms with regional land managers that will strive to maintain and sustainably use native biodiversity of regional vegetation."

Realizing this vision at a park level means integrating local financial, political and scientific information into decisions affecting forest insects and diseases. In doing so, there are three main challenges for management in JNP. They are:

1. scientific certainty in decision-making;
2. conflicting management goals among adjacent managers; and
3. lack of funding to implement management strategies.

1.3.1 Scientific Certainty in Decision-Making

Parks Canada policy directs managers to maintain the natural composition of parks and the greater ecosystem. However, determining what is "natural" is complex for any manager faced with the issue of managing ecological processes (Goldstein 1999; Elliot 1994; Usher and Gardner 1988). One way of assessing what is natural is to conduct long-term studies and scientific research. However, very few studies have been conducted indicating the natural cycles of forest insects and diseases in JNP. This lack of information makes it difficult to speculate on historic patterns and potential activity of forest insects and diseases. It is a challenge for park managers to protect forest insect and disease activity as an ecological process when the functioning of that process is not understood.

1.3.2 Conflicting Management Goals Among Adjacent Land Managers

The primary forest insect and disease goal for the mountain district explicitly states that management will "consider the concerns of our neighbors" (Parks Canada 1997a). This is difficult for a number of reasons. Adjacent provincial land managers have different goals regarding the management of fire, forest insects and diseases. For example, Parks Canada and the Alberta Lands and Forest Service (ALFS) have conflicting viewpoints regarding the appropriate trade-offs between protecting the environment, providing jobs and sustaining an economically viable forestry industry (ideas – Mitchell 1995). Subsequently, ALFS and JNP differ in their approach to managing potential mountain pine beetle (*Dendroctonus ponderosae* Hopkins) infestations. Parks Canada's policy of minimal interference is of concern to ALFS, who fear an infestation of mountain pine beetle may establish in JNP and spread to adjacent forest management areas. Recent evidence of Mountain Pine Beetle activity in north Jasper National Park has intensified these fears. The science supporting Parks Canada and ALFS policy and the potential outcomes of implementing either policy has been a source of debate for several years. More importantly, at the root of the problem there exists a value-based conflict (Keeney 1992) resulting from different judgements about the ends to be achieved in forest management (Mitchell 1995). As a consequence addressing the concerns of neighbors is difficult.

1.3.3 Lack of funding to implement management strategies

Cutbacks, short-term grants and general lack of funding hinder the development of long term studies and research needed to increase understanding about forest insect and disease activity in JNP. Although Parks Canada's *National Business Plan* (Parks Canada 1995a) indicates that ensuring the ecological integrity of parks should be a priority, funds are not consistent or guaranteed. This lack of funding impedes scientific certainty in decisions, because managers must eliminate or cutback research programs, and gaps in the data remain. Although Parks Canada is committed to adopting ecosystem management as outlined in *Principles and Standards for Ecosystem-based Management for Parks Canada* (Parks Canada 1996b), this lack of funding and consequent lack of research impedes Parks Canada from advancing ecosystem management.

1.4 APPROACH

To approach these problems and to fulfill the purpose of this document, I first explored the background and setting for vegetation management in JNP, focusing on forest insects and diseases. This provides a context for the rest of the document. Next I reviewed, analyzed and presented the existing information on forest insects and diseases in Jasper National Park. This allowed me to identify gaps in the data and make recommendations for data improvement and future projects. I identified which agents should be considered a major concern, minor concern or not of concern at all. Specific methods are outlined in chapter 3. Next I defined deficiencies in vegetation management relating to forest insects, forest diseases and fire using a technique known as multiple accounts analysis. Recommendations to improve vegetation management as it relates to forest insect and diseases follows this analysis. Specific methods for the multiple accounts analysis are outlined in Chapter 4.

1.5 OBJECTIVES

This thesis:

1. **Reviews existing data and analyzes it for scientific certainty.**

   This entails a review of databases and literature pertaining to forest insect and disease ecology; Parks Canada Policy, Alberta Lands and Forest Policy, Decision-making theory, and Forest Insect and Disease management in National Parks. In carrying out this objective the potential and limitations of the data will be detailed.

2. **Summarizes historic conditions and agent occurrence information.**
   Completing this objective will provide park managers with a history of insect and disease occurrence in JNP based on available information. This task will also help identify gaps in the data and aid in making recommendations for future projects and the collection of baseline data. It will set the context for the rest of the document.
3. **Develops criteria to identify major and minor agents of disturbance and provides descriptions of species and their ecologies.**
   I identify major and minor insect and disease agents based on data collected for objective #2. This information is necessary to allow an understanding of which agents have historically occurred in JNP, and which may potentially occur in the future.
4. **Evaluates vegetation management actions in terms of forest insects and diseases. I evaluate the appropriateness of these actions in relation to the fundamental objectives of Parks Canada.**
   I analyze Parks Canada Policy to evaluate management actions. Precedents set previously (e.g. the *Banff National Park Forest Insect and Disease Management Plan* 1987) will be explored. Multiple Accounts Analysis will be used to determine the appropriateness of management actions in relation to the fundamental objectives of Parks Canada.
5. **Makes recommendations for forest insect and disease management.**
   I base this on the results of the multiple accounts analysis.
6. **Makes recommendations for implementation and general use of this thesis.**
   I base this on the results of the multiple accounts analysis and personal communications with key members of the Parks Canada Management community.

1.6 STUDY AREA

Jasper National Park is located in the province of Alberta, Canada (Figure 1). Jasper was established as a national park in 1907 and subsequently as a World Heritage Site under UNESCO.

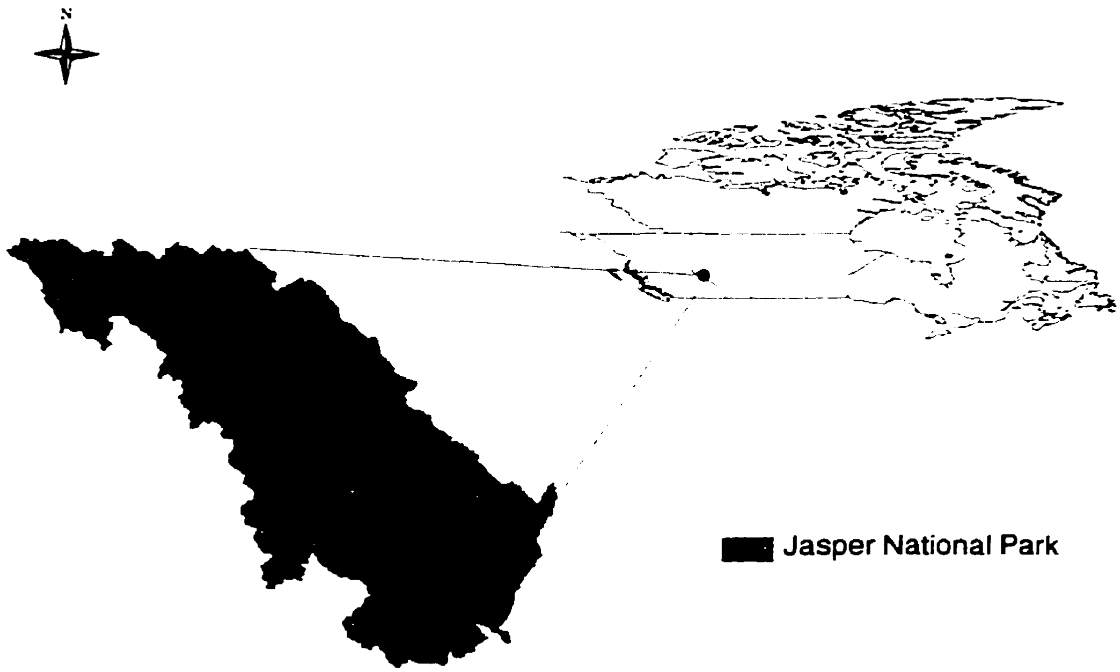

Figure 1. Study Area - Jasper National Park

In the *Guide's Guide* Parks Canada (1998) describes the geology and ecology of Jasper National Park. The landscape in JNP was shaped by glaciers. During the Pleistocene epoch, ice advanced and receded several times. The most recent advance occurred 25 000 years ago. Concentrations of ice submerged all but the highest peaks in the Rocky and Cariboo Mountains. In Jasper, tributary glaciers advanced out of valleys such as the Miette to feed into the massive Athabasca glacier. Glacial retreat occurred about 10 000 years ago in the Holocene. Meltwater deposited vast amounts of sediment throughout the valley, accounting for the sandy soil and rock flour that colors the lakes.

JNP is comprised of three ecoregions (Coen and Holland 1982): the Montane, Sub-alpine and Alpine. The zones are described by Parks Canada (and Canadian Heritage 1998). The Montane ecoregion occurs below about 1350 meters on the lower slopes and Valley bottoms of the Miette and Athabasca Valley. JNP is the northern limit for this ecoregion in Alberta. The Montane ecoregion represents only 7% of the park. It has the warmest and driest climate, is the most biologically productive and contains the greatest diversity of species and communities among the three ecoregions. The Montane ecoregion is comprised of a mosaic of forests, dominated by Lodgepole Pine (*Pinus contorta*), Douglas-fir (*Pseudotsugae menziesii*), White Spruce (*Picea glauca*) or Aspen (*Populus tremuloidis*) and by grasslands. Black Spruce (*Picea mariana*) forests tend to occur in wet muskeg areas. Lodgepole Pine are common, but are also widespread in the Sub-alpine ecoregion.

The Sub-alpine ecoregion typically ranges from 1350m to 2200 m. It is the largest ecoregion is Jasper, covering 58% of the park. The climate is cooler and wetter than the Montane ecoregion. Englemann Spruce (*Picea engelmannii*) and Subalpine Fir (*Abies lasiocarpa*) forests typify subalpine along with Lodgepole Pine. Small populations of whitebark pine (*Pinus albicaulis*) exist.

The Alpine ecoregion is above tree line, usually above 2200 m. Much of the alpine in JNP is rock and ice. The Alpine climate is severe - cold, wind-scoured and exposed. The growing season is short, however herbaceous meadows, dwarf shrub tundra and lichen tundra create a vegetation mosaic in this ecoregion. The pattern of this mosaic is often a reflection of snow pattern.

Jasper National Park is bordered on the north by the Willmore Wilderness Park (AB), to the west by Mount Robson Provincial Park (BC), Hamber Provincial Park (BC) and the Province of British Columbia, to the south by Banff National Park (AB), the White Goat Wilderness Area and Alberta; and on the east by the proposed Whitehorse Wildland Provincial Park and the province of Alberta, including the Foothills Model Forest (of which JNP is a part).

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[i] This document attempts to summarize direction from major Parks Canada documents such as the *National Parks Act*.

[ii] Freedman et al. (1994) defines biodiversity as "the richness of biological variation, ranging from within-species genetic variation, through subspecies and species, to communities, and the pattern and dynamics of all on the landscape." Parks Canada has adopted this definition.

CHAPTER 2 BACKGROUND AND SETTING

2.1 INTRODUCTION

This chapter provides a context for the analysis of insect and disease agent occurrence and their management in Jasper National Park. I summarize the effects of insects, disease and fire in this ecosystem, and provide a brief discussion of factors affecting the occurrence of these ecological processes. Fire is discussed here primarily because the same managers deal with both fire and forest insects and diseases. Fire management activities may affect the natural cycling of insect and disease populations. I do not attempt to draw explicit links between these processes. I mention fire for consistency between management documents and to allow for the integration of information about the relationship between fire and forest insects and diseases as it becomes available.

In this chapter I also explain how and why these processes are being managed in Jasper National Park. These processes are managed using a number of tools, including the use of Fire Management Units (FMUs). A discussion of FMUs and their relevance to forest insect and disease management is included at the end of the chapter.

2.2 NATURAL DISTURBANCES AS ECOLOGICAL PROCESSES

It is generally thought that diversity (age, species, genetic make-up) increases the stability of ecosystems (Stiling 1992). Stability can mean the ability of an ecosystem to resist change, or it can mean the ability of an ecosystem to rebound to its "original" configuration after disturbance (Stiling 1992). More accurately, diversity in ecosystems helps maintain "equilibrium," a dynamic process in which the level of stability fluctuates.

Ecological processes such as fire, and the activity of insects and disease are factors that disturb ecosystems to maintain diversity. For example, fire in a forest may cause short-term instability in a system, but increases the age and species diversity over the landscape in the long-term and reaches an equilibrium over time.

Key disturbance factors in Jasper National Park include windthrow, flooding, avalanches, fire, disease and insect activity. All are important in shaping the landscape. However, the scope of this document is limited to discussing the effects of insect and disease disturbance. Fire will also be discussed briefly for the reasons mentioned above. The presence or absence of fire may or may not affect the cycling of forest insects and diseases. The links between these processes have not been explicitly explored in the literature.

To protect an ecosystem, the disturbances that shape and maintain them must also be protected. The first step is to identify and understand what the important ecological processes are that maintain a given ecosystem. This is challenging, as the complex functioning of disturbances and their relationship to other natural processes may never be fully understood.

2.3 CLIMATE AND WEATHER AS INFLUENCES ON ECOLOGICAL PROCESSES

Climate and weather affect every component of the ecosystem including water, soil, vegetation, wildlife, and man (Fenton and Wallace 1987). Climate likely affects ecological processes such as fire (Johnson et al 1990; Johnson and Larson 1991) and the activity of forest insects and diseases. For example, climatic factors may have a direct influence on distribution and abundance of bark beetles (Scolyitdae) (Wood 1982). Temperature cycles likely affect the mortality, development, and emergence of Mountain Pine Beetle (*Dendroctonus ponderosae* Hopkins) (Bentz et al 1991, Safranyik and Linton 1991). Drought may stress trees and make them more susceptible to beetle attack (Wood 1982). Unfavorably high or low temperatures may cause cessation of beetle activity (Wood 1982). Safranyik (1978) and Safranyik and Linton (1991) found that mortality from cold is one of the major factors determining the distribution and abundance of Mountain Pine Beetle.

In the *Preliminary Fire Management Plan for Jasper National Park* (1987), Fenton and Wallace detailed a climatic history for JNP which is summarized here.

2.4 CLIMATE IN JASPER NATIONAL PARK

Jasper National Park's climate is variable. Physiographic differences make it difficult to classify the whole park as a climatic region. In general, Jasper is drier than areas to the west across the continental divide, but heavy precipitation events are more common than in any other Rocky Mountain Park (Janz and Storr 1977). Rainfall intensities are most severe in the eastern half of the park. Thunderstorm activity and the associated frequency of lightning ignition of forest fuels is low (Tande 1977). JNP falls into what is known as the "lightning fire shadow" cast by the continental divide (Heathcott 1999). Thunderstorm activity increases to the east and west, towards the foothills and continental divide respectively. Fire records since 1946 indicate that the number of reported fires attributed to lightning is higher in the mountain ranges southwest of Jasper townsite and in the Snake Indian Drainage than in the vicinity of the townsite. Generally, late afternoon thunderstorms occur from late May to September and reach a maximum in mid-July, but yearly patterns vary greatly. Less than 2.5% of all storms produce "dry strikes" ("lightning originating from clouds which do not produce precipitation at the ground or strikes that occur outside of the rain area").

2.5 INSECTS AND DISEASES IN FOREST ECOSYSTEMS

As the human population places greater demands on forest ecosystems, some insect and disease agents that compete with those needs are labeled as "pests" and subjected to management or control programs. However, insect and disease populations are important major ecological and natural components of forest ecosystems.

2.5.1 Diseases

The term disease refers to the outcome of pathogens on their hosts. However, for the purpose of this document, the term disease is also used as a colloquial term to refer to non-insect forest pathogens in Jasper National Park. This is done merely for consistency with other Parks Canada and Canadian Forest Service literature.

Manion (1981) outlined the influence of diseases in forest ecosystems. In undisturbed forests, diseases (or pathogens) and host populations have evolved a balanced relationship. Within a forest there may be genetic diversity, age diversity and species diversity. This means that forest populations are mosaics rather than uniform populations of plants all the same species, age or genetic make-up. Because of this, there are little or no selective pressures on pathogens to increase rapidly. In mosaics, widespread lethal diseases rarely develop, because there is no way for a large susceptible host population to develop. However, in some areas large susceptible populations do occur, and pathogen populations do shift to take advantage that population (see Needle Rusts in Chapter 3). Diseases break down weakened and less fit individual trees and other plants and facilitate succession.

2.5.2 Insects

Recycling and removing dead and dying trees and other plants is one of the forest's ecosystem's processes. Insects play a major role in this process (Wood 1982). For example, Wood (1982) provided details about beetles from the family Scolytidae that breed in broken, over-mature and dying woody plants. They are usually the first to attack stressed tissues, and their consumption of this material introduces or provides avenues for the entry of other disease-causing agents that accelerate the decomposition of dead or dying trees (Wood 1982). Wood speculated that this allows for more vigorous growth of the surviving plants in a forest community.

Some insects are responsible for more than the elimination of dead and dying trees. For example, an epidemic population of Mountain Pine may successfully attack and kill large areas of live trees. Large infestations of this kind act like other natural disturbances such as windthrow and fire to create mosaics of plant age and species. This mosaic on the landscape results in the decrease of widespread disease, and is good for several kinds of wildlife habitat (Spur and Barnes 1980).

2.6 FIRE IN FOREST ECOSYSTEMS

Fire is suspected as the dominant force in forest history in Jasper National (P. Achuff pers. comm). Spur and Barnes (1980) outlined the influence of forest fire in the ecosystem. Fire is an agent of regeneration and reproduction. Catastrophic fires kill existing stands and set the processes of regeneration in motion. It affects the reproductive adaptations of trees. Fire also reduces the amount of litter, sometimes baring the mineral soils and enhancing seedling establishment. Severe fires eliminate much tree, shrub and herbaceous competition, as well as woody debris, thereby causing the establishment of a new stand. Light surface fires reduce encroaching vegetation and reduce competition for soil moisture and nutrients. This may also result in an increase in the nutritional quality of the soil. Fires promote early stages of succession, whether by stand thinning, or total stand creation. Like other disturbances that create mosaic on the landscape, fire creates several different habitat types increasing the lands ability to support diverse species of wildlife.

2.7 FIRE HISTORY IN JASPER NATIONAL PARK

The best analysis of available information on fire history in Jasper National Park is provided by C.E. Van Wagner (1995) in his regressional analysis of Fire History for Banff, Jasper, and Kootenay National Parks. The timespan of the data set used for Jasper National Park is approximately 450 years. Results show that prior to 1735, a 55 year fire cycle existed (the time it takes for all of Jasper National Park to burn). A single large burn occurred throughout most of the forested area of the park in 1889. Between 1735 and 1915, a 150 year fire cycle was shown. The final 70 years of the data set showed very little burning. Records indicated that burns that are equal to a third or a fifth of the park have occurred once or twice per century. Van Wagner stipulates that the data was "not a tidy set," and that earlier than 1735 no confident analysis was possible. The data were taken as given, and "independent parties may reach different decisions based on subjective judgements about the data." He clearly states however that forests in Jasper National Park have been fire-free for five to seven decades (i.e. 1920-1995) for whatever reason. He suggests that the burned area has become disconnected from fire weather, and that the probable reasons may be change in the ignition regime, and or effectiveness of suppression, or both. However, although not stated by VanWagner, climate change must be considered as a factor affecting successional patterns and fire regimes over time.

2.8 THE RELATIONSHIP BETWEEN FIRE AND FOREST INSECTS AND DISEASES

As a major agent of disturbance, fire may also affect the activity of insect and disease agents (or vice versa). Studies exploring this link are very limited in the scientific literature. Wood (1982) suggested that fire may control and destroy broods in bark beetle infested trees, or may destroy broods under thin bark without burning the bark of the infested tree. However, he countered that trees slightly injured by fire that ordinarily would recover from their injuries are often highly attractive to bark beetles and may serve as a focal point for a developing epidemic. Spur and Barnes (1980) suggest a more circular pattern to the relationship between forest insects and fire. Fires may create dense, even-aged stands that are conducive to insect and disease outbreak. Such epidemics may create fuel conditions leading to intense and widespread fires. Fire may terminate this cycle leading to new even-aged stands that are for a time resistant to forest insects and diseases. However, this circular relationship was clearly hypothetical and unsupported with data collection. This theory is also in conflict with scientific studies suggesting that landscape altering fires are related to weather patterns (Johnson and Larson 1991).

2.9 MANAGING FIRE

Based on studies such as Van Wagner's, Parks Canada has adopted a fire management strategy to maintain and restore appropriate fire regimes (Parks Canada 1997a). Parks Canada also has a commitment to ensure adequate public protection and facility protection from fire (Parks Canada 1997a). For these reasons, Parks Canada develops fire management plans that detail actions Parks will take in meeting their goals and obligations.

The strategy used by Parks Canada is called "mixed fire restoration." This involves a mixture of fire suppression, fuel management, planned and random prescribed fire and moderate suppression. These techniques are further explained in the *Fire Management Handbook* (Parks Canada 1996c), the *Preliminary Fire Management Plan for Jasper National Park* (Fenton and Wallace 1987) and recent prescribed burn plans such as the *Brazeau Prescribed Burn Plan* (Parks Canada 1999).

In Jasper National Park, Fire Management Units (FMUs) have been developed to aid in directing and organizing fire management efforts. The boundaries of each Fire

Management Unit (FMU) coincide approximately with the boundaries of watersheds located therein.

2.10 MANAGING INSECTS AND DISEASES

Secondary to their primary goal of preserving natural processes and allowing fluctuation of forest insect and disease populations, Parks Canada's *Proposed Guidelines for Vegetation Management in the Mountain District* (1997a) state that they will consider the concerns of their neighbors in decisions regarding forest insects and diseases. The guideline also indicates that park managers will control, eliminate or prevent populations of non-native forest insects or diseases where practical. The primary objective of vegetation management is to let ecological processes function with as little interference as possible (1997a). Therefore, management actions are likely only justified in cases relating to non-native insects and diseases, or in cases where insect and disease activity in the park becomes a risk for adjacent land managers. When a risk is identified, JNP will determine if and how it will respond.

2.10.1 Management Actions

Currently, the main management activity carried out in JNP is monitoring. Yearly monitoring flights are flown with a member of the Canadian Forest Service to identify trees that have fading color or red tops (A. Westhaver pers. comm). These faded or red-topped trees may indicate mortality from insect or disease activity. Although aerial monitoring is an annual activity, it is not comprehensive or completely systematic. Areas where insect and disease activity is suspected are targeted. For example, the Smoky FMU is often targeted for monitoring flights because of its proximity to Mountain Pine Beetle pheromone traps in the Willmore Wilderness Area across the north boundary. If trees with fading color or red tops are identified, a ground survey may follow to investigate the cause of mortality (funds permitting). JNP also participates in non-native monitoring strategies like the Gypsy Moth program carried out by the Canadian Forest Service (Parks Canada 1997a). Every year ten traps are placed along the Athabasca River Valley to detect the non-native moth.

2.10.2 Managing for the Concerns of Adjacent Land Managers

Pro-active management actions like monitoring and sharing monitoring results is one way Parks Canada can maintain their commitment to minimal interference in ecological processes while considering the concerns of their neighbors. However, there are ways monitoring can be improved to be more effective to this end. For example, if adjacent land managers perceive a risk of a forest insect or disease infestation spreading from JNP, it is usually because there are similar host tree species in both JNP and adjacent areas in the Province of Alberta. One way to improve monitoring is to identify areas in JNP with similar tree species to those in adjacent provincial lands and focus monitoring efforts there.

2.10.3 Tree Species Common to JNP and the Province of Alberta

JNP is classified as the Rocky Mountain Natural Region (Achuff 1992). It consists of three natural subregions: the Montane, Sub-Alpine and Alpine (Achuff 1992). The area of the Province of Alberta surrounding JNP is generally made up of the Foothills Natural Region with two natural subregions: the Upper and Lower Foothills. The Foothills Natural Region is a transitional region between the Rocky Mountain Natural Region and the Boreal Forest Natural Region. An insect or disease population spreading from JNP to the Province of Alberta will likely pass into the Upper and Lower Foothills, beginning with the Upper Foothills. Table 1 shows tree species common in the Montane, Subalpine, Upper Foothills and Lower Foothills. The Alpine is omitted from this table as no host tree species occur there.

Table 1. List of Tree Species Common in the Montane, Subalpine, Upper Foothills and Lower Foothills Natural Subregions (Achuff 1992).

Montane	Subalpine	Upper Foothills	Lower Foothills
White Spruce *Picea glauca*		White Spruce *Picea glauca*	White Spruce *Picea glauca*
		Black Spruce *Picea mariana*	Black Spruce *Picea mariana*
Lodgepole Pine *Pinus contorta*	Lodgepole Pine *Pinus contorta*	Lodgepole Pine *Pinus contorta*	Lodgepole Pine *Pinus contorta*
		Balsam Fir *Abies balsamea*	Balsam Fir *Abies balsamea*
Aspen *Populus tremuloides*			Aspen *Populus tremuloides*
			Balsam Poplar *Populus balsamifera*
			Jack Pine *Pinus banksiana*
	Subalpine Fir *Abies lasiocarpa*	Subalpine Fir *Abies lasiocarpa*	
	Engelmann Spruce *Picea engelmannii*		Engelmann Spruce *Picea engelmannii*
Douglas-fir *Pseudotsugae menziesii*			
Limber Pine *Pinus flexilis*			

2.10.3 FMUs in Insect and Disease Management

In the above table I identify the location of tree species in the park similar to those in the Foothills Natural Regions. However, some areas of the park have more Alpine, Subalpine and/or Montane. This information could be more useful if the location of host tree populations were more specific. Therefore, I used the above information to determine what tree species in adjacent provincial lands corresponded to tree species in each Fire Management Unit (FMU) (Figure 2). To do this, I used a GIS exercise in which I overlaid vegetation management groups (Figure 3) throughout the park overtop of the map showing the FMU boundaries. From this exercise, two tables (Tables 2 and 3) showing the percentage of each vegetation group in each FMU were created.

FMU Map goes here

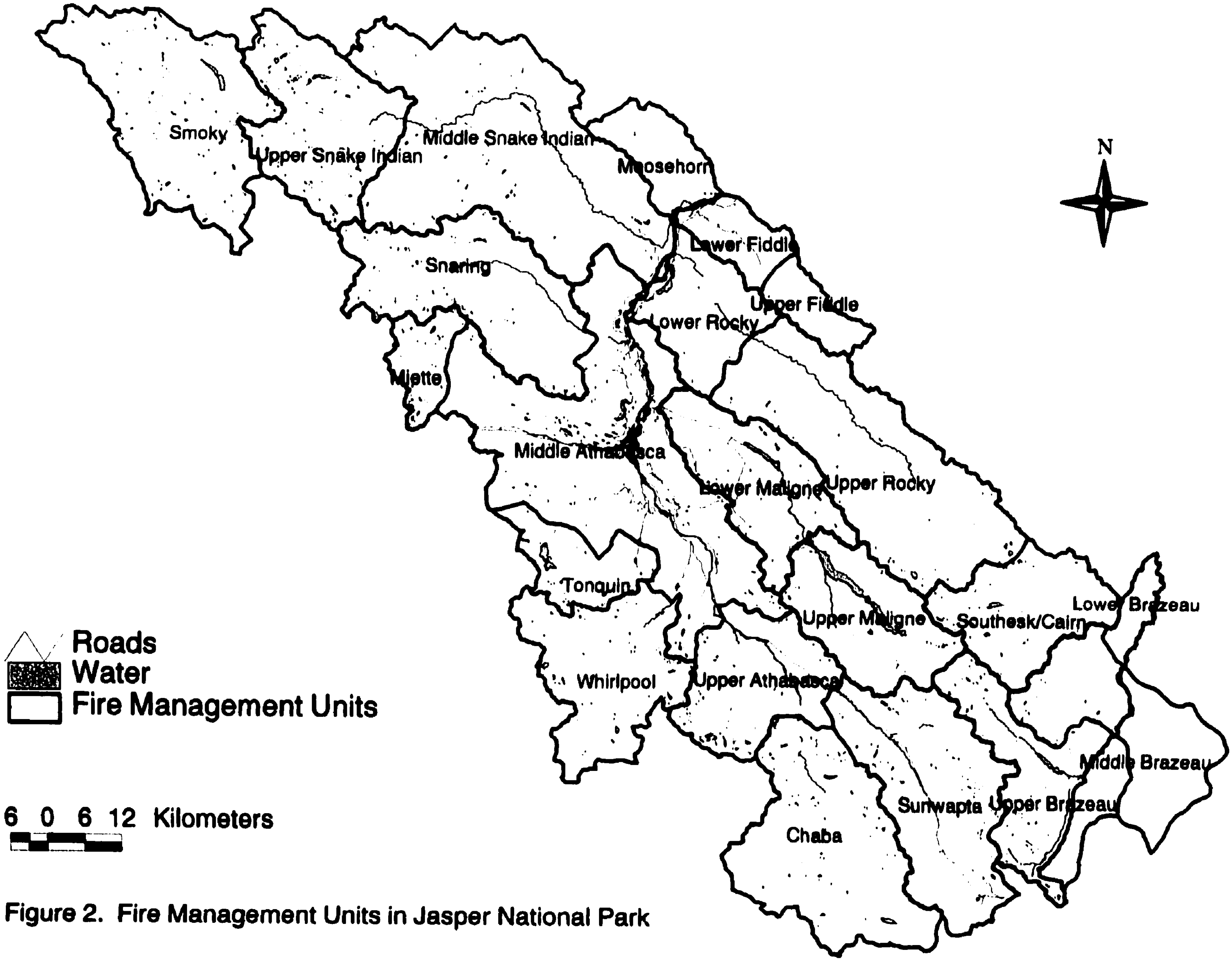

Figure 2. Fire Management Units in Jasper National Park

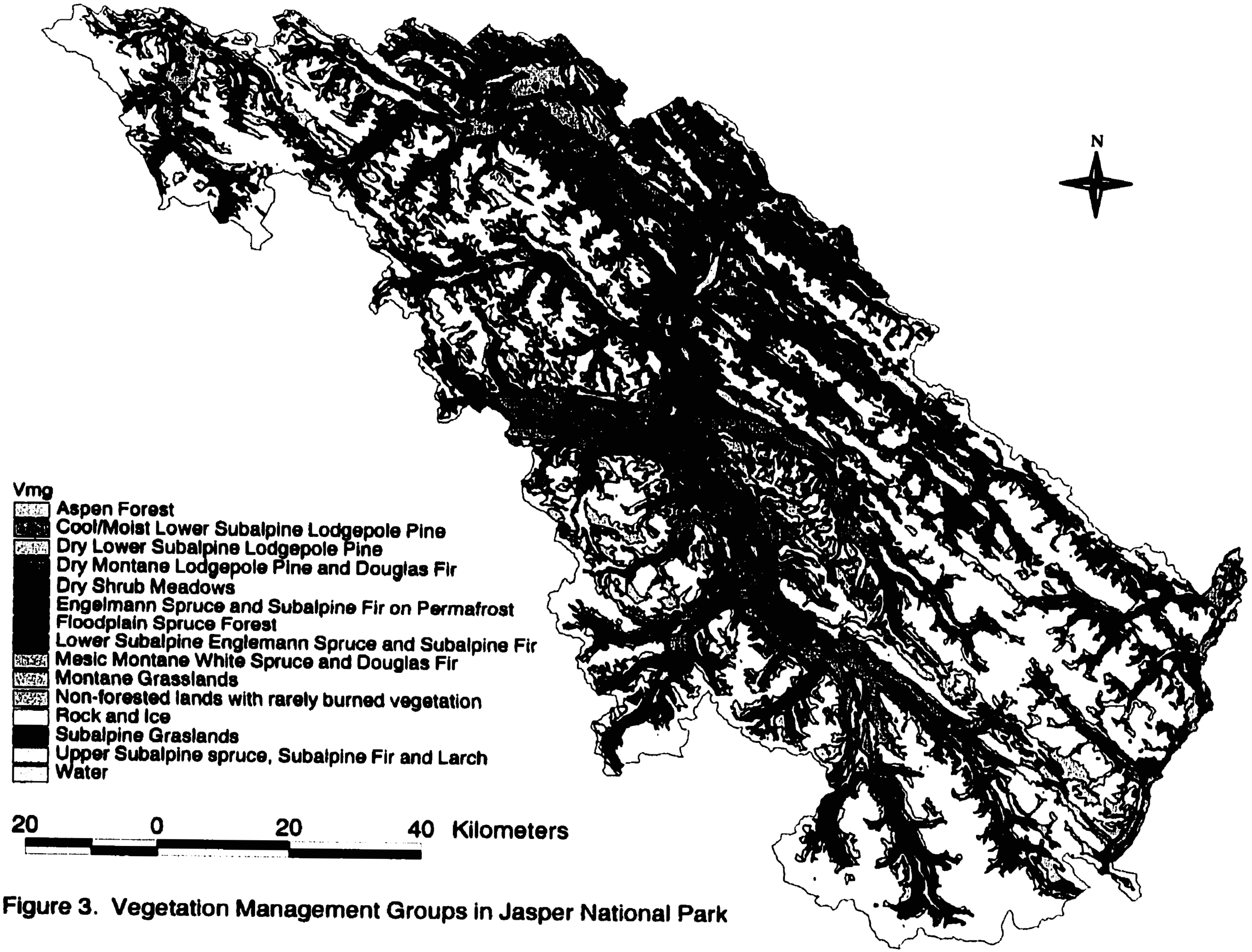

Figure 3. Vegetation Management Groups in Jasper National Park

Table 2. Percent Coverage of Vegetation Management Groups (VMGs) in the Upper Rocky, Whirlpool, Upper Athabasca, Upper Maligne, Southesk/Cairn, Chaba, Sunwapta, Upper Brazeau, Middle Brazeau, Lower Brazeau and Smoky FMUs

	Upper Rocky	**Whirlpool**	**Upper Athabasca**	**Upper Maligne**	**Southesk Cairn**	**Chaba**	**Sunwapta**	**Upper Brazeau**	**Middle Brazeau**	**Lower Brazeau**	**Smoky**
Total Area Km^2	927.6	542.7	439.9	450.4	418.3	771.5	702	528.2	517.9	76.8	779
Borders Alberta	Yes	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Dry Montane Lodgepole Pine and Douglas Fir % Cover	0.3	2.3	22.5	0	0	0	0	0	0	0	0
Dry Lower Subalpine Lodgepole Pine % Cover	5.2	1.5	6.7	1.2	4.4	4.4	5.1	2.6	2.8	25.4	3.2
Aspen Forest % Cover	0	0	0.5	0	0	0	0	0	0	0	0
Mesic Montane White Spruce % Cover	0.1	0.03	1	0	0	0	0	0	0	0	0
Cool/Moist Lower Subalpine Lodgepole Pine % Cover	3.9	5.3	16.9	4.4	2.2	4.7	5.5	5.2	1.6	41.5	9.3
Lower Subalpine Engelmann Spruce and Subalpine Fir % Cover	21.8	23	13.8	11.6	7.3	15.3	0.1	3.4	3.2	4.1	12.9
Floodplain Spruce Forest % Cover	1.6	0.2	1.1	0.3	1	0.6	0.7	0.5	1	2.9	0.4
Upper Subalpine Spruce, Subalpine Fir and Larch % Cover	13.1	15	14	13.9	9.8	8.7	14.4	7	3.8	2.1	12.9
Engelmann Spruce and Subalpine Fir % Cover	1.4	0	0	0.4	1.2	0	0	0.1	0.1	0	0
Montane Grasslands % Cover	0	0	0	0	0	0	0	0	0	0	0
Dry Shrub Meadows % Cover	1	0	0	0.5	3.8	0	0.7	2.1	1.8	0.9	0.1
Subalpine Grasslands % Cover	2.72	0	0.5	0.3	3	0	0.5	1.7	1.8	0	0
Non-forested lands with rarely burned vegetation % Cover	4.74	11.2	8.8	16.3	10.5	8.3	14.9	12.5	3.8	1.9	12.7
Water % Cover	0.3	0.6	1	4.8	0.6	0.5	0.3	0.7	0.2	0.5	0
Rock and Ice % Cover	43.4	43	30.6	46.1	56.4	57.6	49.6	40.6	23.8	20.7	47.7
Out of Park % Cover	0	0	0	0	0	0	0	23.7	56.1	0.2	0.1

Table 3: Percent Coverage of Vegetation Management Groups (VMGs) in the Upper Snake Indian, Middle Snake Indian, Moosehorn, Snaring, Lower Fiddle, Miette, Middle Athabasca, Lower Rocky, Upper Fiddle, Tonquin and Lower Maligne FMUs

	Upper Snake Indian	Middle Snake Indian	Moosehorn	Snaring	Lower Fiddle	Miette	Middle Athabasca	Lower Rocky	Upper Fiddle	Tonquin	Lower Maligne
Total Area Km^2	558.1	1273.8	208.1	667	153.4	143.7	1352.6	330.2	127.6	231.7	442.5
Borders Alberta	Yes	Yes	Yes	No	Yes	No	No	No	Yes	No	No
Dry Montane Lodgepole Pine and Douglas Fir % Cover	0	5.2	7.8	1.80.3	8.5	0	24.2	8	0	0	2.6
Dry Lower Subalpine Lodgepole Pine % Cover	7.9	8.5	10.2	8.2	11.5	0	3.6	11.1	12.7	0	9
Aspen Forest % Cover	0	1.1	0.5	0	2.8	0	1.3	3.0	0	0	3
Mesic Montane White Spruce % Cover	0	1.7	5.6	0.2	15.3	0	2.4	15	0	0	0.2
Cool/Moist Lower Subalpine Lodgepole Pine % Cover	1.9	14.5	12.2	3.8	3.4	1.1	12.4	3.92	1.6	1.9	14.7
Lower Subalpine Engelmann Spruce and Subalpine Fir % Cover	11.7	15.8	26.6	15.5	31	16.5	10.8	18.1	18.3	6.9	11.6
Floodplain Spruce Forest % Cover	0.4	1.2	2.3	0.1	0	0.7	1	2	0.3	0.7	0.9
Upper Subalpine Spruce, Subalpine Fir and Larch % Cover	14.3	11	2.5	18.1	2.2	26.4	13.4	7.3	10.4	24.6	16
Engelmann Spruce and Subalpine Fir % Cover	0.2	3.7	1.9	0.1	0	0	0	0.7	0	0	0
Montane Grasslands % Cover	0	0.1	3.6	0	0.4	0	0.8	2.7	0	0	0
Dry Shrub Meadows % Cover	0.2	4.3	1.5	0.3	0.7	0	0.2	1.4	2.9	0	0.3
Subalpine Grasslands % Cover	1	3.4	5.4	0.1	1.9	0	0.1	2.4	0.8	0	0.9
Non-forested lands with rarely burned vegetation % Cover	18.9	7.5	1.7	11.9	1.2	17.3	10.5	1.6	3.7	25.1	16.1
Water % Cover	0.2	0.4	2.1	0.3	1.2	0.9	1.4	5	0	2.5	1.3
Rock and Ice % Cover	42.1	21	15.9	40.6	16.9	37.3	17.8	20	45.9	38.3	27
Out of Park % Cover	0	0	0	0.2	0	0.1	0.1	0	0	0	0

Once these tables were created, I was able to identify where in each FMU there were host tree species similar to those in adjacent provincial lands. This information is used in the FMU descriptions below.

In the FMU descriptions I provide the percentage of each vegetation group present in that area in a table format. These tables were calculated from the same exercise used to derive Tables 2 and 3. The percentages were rounded up to the nearest whole number. Tables for each FMU were created for easy access to the information when referring to specific FMUs. Each FMU description contains a discussion of vegetation types (i.e. tree species) that are similar to those on lands adjacent to JNP. I indicate the proximity of the FMU to the continental divide and to major icefields. I discuss valley orientation, and the presence of the sub-natural regions of Alpine, Subalpine and Montane in each FMU. FMUs relatively close to Weldwood commercial timber operations are identified (Cardinal River Coals Ltd. 1999). These factors are included as it has been indicated by park managers (A. Westhaver pers. comm.) that this information will be useful in future speculations on the activity and management of insects and diseases in JNP. This information may also be important in speculating on future susceptibility and risk rating systems for insects and diseases (Shore and Safranyik 1992).

2.10.4 Fire Management Units

Descriptions of each FMU are provided below.

SMOKEY

The Smokey FMU is 779 km^2, located in the very northwestern tip of JNP. It is bordered to the west by Mount Robson Province Park (BC) and the Province of British Columbia. To the North is Willmore Wilderness Park in the Province of Alberta.

Tree species in JNP similar to those in the Willmore include Lodgepole Pine, Subalpine Fir and Englemann Spruce. Many of these tree species are divided by large tracts of alpine. In fact, roughly 48% of this FMU is comprised of rock and ice (Table 4). There are a number of large icefields and glaciers along the west boundary, including Resthaven Icefield, and the Chown, Swiftcurrent, Hargreaves, Mural, Coleman and Steppe Glaciers. The west boundary of the Smoky is right along the Continental Divide, although there are three lower subalpine passes that cross the divide into British Columbia. They are Bess Pass, Carcajou Pass, and Robson Pass. The major valley connecting the Smoky and Willmore Wilderness Park is the Smoky River Drainage. The major drainage in this FMU is the Smoky River, and its valley orientation is primarily north-south.

Table 4. Percent representation (area) of vegetation management groups in the Smoky FMU in JNP

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	3		Montane Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	9		Non-forested lands with rarely burned vegetation	15	13
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	13		Water	16	0
Floodplain Spruce Forest	7	0		Rock and Ice	17	48
Upper Subalpine Spruce, Subalpine Fir and Larch	8	13		Out of Park		0

UPPER SNAKE INDIAN

The Upper Snake Indian FMU is 558 km^2, located in the northeastern portion of JNP. It is bordered on the north by Willmore Wilderness Park, on the west by the Smoky FMU, on the southwest by Mount Robson Provincial Park (BC) and on the east by the Middle Snake Indian FMU. This FMU is about 42% rock and ice (Table 5). Further, about 19% is non-forested land. The majority of the remaining landscape is in the Subalpine Natural sub-region. Tree species common to the Subalpine and the Willmore Wilderness Park include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation in this FMU is primarily Northwest-Southeast. The west boundary of this FMU is on average about 24 kilometers east of the Continental Divide.

Table 5. Percent representation (area) of vegetation management groups in the Upper Snake FMU in JNP

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	8		Monatne Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	1
Cool/Moist Lower Subalpine Lodgepole Pine	5	2		Non-forested lands with rarely burned vegetation	15	19
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	12		Water	16	0
Floodplain Spruce Forest	7	0		Rock and Ice	17	42
Upper Subalpine Spruce, Subalpine Fir and Larch	8	14.34		Out of Park		0

MIDDLE SNAKE INDIAN

The Middle Snake Indian FMU is 1274 km^2, bordered to the north by Willmore Wilderness Provincial Park, to the west by the Upper Snake Indian FMU, to the south by the Snaring and Middle Athabasca FMU's, and to the east by the Lower Rocky and Moosehorn FMU's. This is a large FMU comprised of a number of vegetation types. Although rock and ice is significant on the landscape (21%) (Table 6), all three natural sub-regions can be found. Tree species in the Montane similar to those in Willmore Wilderness Park include White Spruce, Lodgepole Pine and Aspen. In the Subalpine (by far the dominant natural sub-region in this FMU), similar tree species include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation of the major drainage in this FMU is northwest-southeast. The west boundary of this FMU is on average about 48km west of the Continental Divide.

Table 6. Percent representation (area) of vegetation management groups in the Middle Snake Indian FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	5		Engelmann Spruce and Subalpine Fir	9	4
Dry Lower Subalpine Lodgepole Pine	2	9		Montane Grasslands	10	0
Aspen Forest	3	1		Dry Shrub Meadows	11	4
Mesic Montane White Spruce and Douglas Fir	4	2		Subalpine Grasslands	12	3
Cool/Moist Lower Subalpine Lodgepole Pine	5	15		Non-forested lands with rarely burned vegetation	15	8
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	16		Water	16	0
Floodplain Spruce Forest	7	1		Rock and Ice	17	21
Upper Subalpine Spruce, Subalpine Fir and Larch	8	11		Out of Park		0

MOOSEHORN

The Moosehorn is a small FMU (208 km^2) located in the northeast portion of JNP. It is bordered to the west by the Middle Snake Indian FMU, to the southwest by the Lower Fiddle FMU, and to the north and east by the Province of Alberta. About 16% of this FMU is rock and ice (Table 7). The rest of the landscape is comprised of all three natural sub-regions in JNP. Tree species in the Montane similar those in the Foothills Natural Region include White Spruce, Lodgepole Pine and Aspen. Tree species similar in the Subalpine include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. The predominant valley direction in this FMU is Northwest-Southeast. The main valleys connecting this FMU to the province are the Moosehorn and Athabasca River Valleys. The west boundary is located approximately 88 kilometers west of the Continental Divide. The Weldwood Forest Management Unit is located to the southwest.

Table 7. Percent representation (area) of vegetation management groups in the Moosehorn FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	8	Engelmann Spruce and Subalpine Fir	9	2
Dry Lower Subalpine Lodgepole Pine	2	10	Montane Grasslands	10	4
Aspen Forest	3	0	Dry Shrub Meadows	11	1
Mesic Montane White Spruce	4	6	Subalpine Grasslands	12	5
Cool/Moist Lower Subalpine Lodgepole Pine	5	12	Non-forested lands with rarely burned vegetation	15	2
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	27	Water	16	2
Floodplain Spruce Forest	7	2	Rock and Ice	17	16
Upper Subalpine Spruce, Subalpine Fir and Larch	8	3	Out of Park		0

SNARING

Snaring is a large FMU (667 km^2) located in the upper west half of Jasper National Park. It is bordered to the west by Mount Robson Provincial Park, to the north by the Upper and Middle Snake Indian FMU's, to the southwest by the Miette FMU and to the east and northeast by the Middle Athabasca FMU. The predominant feature on this landscape is rock and ice (41%)(Table 8). Another 12% is non-forested land. The remaining landscape is mostly sub-alpine. The west boundary of the Snaring FMU lies along the Continental Divide. This FMU does not border the Province of Alberta. Valley orientation is variable.

Table 8. Percent representation (area) of vegetation management groups in the Snaring FMU in Jasper National Park.

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	8	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0	Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	4	Non-forested lands with rarely burned vegetation	15	12
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	16	Water	16	0
Floodplain Spruce Forest	7	0	Rock and Ice	17	41
Upper Subalpine Spruce, Subalpine Fir and Larch	8	18	Out of Park		0

LOWER ROCKY

The Lower Rocky FMU is a medium sized FMU (330 km^2) located in the upper-middle east portion of Jasper National Park. It is bordered by the Middle Snake Indian FMU to the northwest, the Middle Athabasca FMU to the southwest, the Lower Maligne FMU to the south, the Upper Rocky to the southeast and the Lower Fiddle FMU to the northeast. This FMU does not border the Province of Alberta, although at its eastern most point it is only roughly 10 kilometers from the park border. This FMU is about 20% rock and ice (Table 9). The rest of the landscape is comprised of all three natural sub-regions in JNP. Montane tree species similar to the Foothills Natural Region include White Spruce and Lodgepole Pine. Subalpine tree species in this FMU similar to those in adjacent provincial lands include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. The most western tip of this FMU is approximately 36 kilometers from the Continental Divide. Valley orientation is primarily northwest-southeast.

Table 9. Percent representation (area) of vegetation management groups in the Lower Fiddle FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	8		Engelmann Spruce and Subalpine Fir	9	1
Dry Lower Subalpine Lodgepole Pine	2	11		Montane Grasslands	10	3
Aspen Forest	3	1		Dry Shrub Meadows	11	1
Mesic Montane White Spruce	4	15		Subalpine Grasslands	12	2
Cool/Moist Lower Subalpine Lodgepole Pine	5	4		Non-forested lands with rarely burned vegetation	15	2
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	18		Water	16	5
Floodplain Spruce Forest	7	2		Rock and Ice	17	20
Upper Subalpine Spruce, Subalpine Fir and Larch	8	7		Out of Park		0

LOWER FIDDLE

The Lower Fiddle is a small FMU (153 km^2) located on the northeast boundary of JNP. It's east boundary borders the Province of Alberta, The Upper Fiddle FMU is to the south, the Lower Rocky FMU is to the west, and the Moosehorn FMU is to the North. This FMU is about 17% rock and ice (Table 10). All three natural sub-regions are found here. Tree species in the Montane similar to the Foothills Natural Region include White Spruce, Lodgepole Pine and Aspen. Tree species similar in the Subalpine include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation is this FMU is dominantly northwest-southeast. The main valley connecting this FMU to the Province is the Athabasca River Valley. This FMU is approximately 68 km from the Continental Divide at its west boundary.

Table 10. Percent representation (area) of vegetation management groups in the Lower Fiddle FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	9	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	12	Montane Grasslands	10	0
Aspen Forest	3	3	Dry Shrub Meadows	11	1
Mesic Montane White Spruce	4	15	Subalpine Grasslands	12	2
Cool/Moist Lower Subalpine Lodgepole Pine	5	3	Non-forested lands with rarely burned vegetation	15	1
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	31	Water	16	1
Floodplain Spruce Forest	7	0	Rock and Ice	17	17
Upper Subalpine Spruce, Subalpine Fir and Larch	8	2	Out of Park		0

MIETTE

The Miette FMU is small (144 km^2) and is located on the west boundary of the Park. The Snaring FMU borders it to the north, and the Middle Athabasca FMU borders it to the southeast. The west boundary of this FMU sits along the Continental Divide. Approximately 38% of this FMU is rock and ice (Table 11). Another 17% is non-forested lands. The remaining landscape is primarily Subalpine. This FMU does not border the Province of Alberta, nor is it relatively close compared to other FMUs. However, tree species that are similar in the Subalpine include Lodgepole Pine, Subalpine Fir, and Engelmann Spruce.

Table 11. Percent representation (area) of vegetation management groups in the Miette FMU in Jasper National Park.

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	0	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0	Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	1	Non-forested lands with rarely burned vegetation	15	17
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	17	Water	16	1
Floodplain Spruce Forest	7	1	Rock and Ice	17	38
Upper Subalpine Spruce, Subalpine Fir and Larch	8	26	Out of Park		0

MIDDLE ATHABASCA

The Middle Athabasca is by far the largest FMU, spanning an area 1353 km ^{2}. It is located in the middle-west portion of the Park. Because of its size it is bordered by numerous FMUs: The Miette and the Snaring to the northwest, The Middle Snake Indian to the north, the Lower Rocky to the northeast, The Lower Maligne to the east, the Upper Maligne to the southeast, the Upper Athabasca to the south, and the Whirlpool and the Tonquin to the west. The west boundary of this FMU borders the Continental Divide. The largest percent of Montane can be found here (24%) (Table 12). Although this FMU does not border the Province of Alberta, there is very little terrain that breaks up the Montane along the valley floor of the Athabasca river all the way out to the Province. Tree species in the Montane that are similar to those in the in the Foothills Natural Region include White Spruce, Lodgepole Pine, and Aspen. There is also a significant amount of Subalpine in this area. Subalpine tree species similar to those in the Foothills include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation in this FMU varies.

Table 12. Percent representation (area) of vegetation management groups in the Middle Athabasca FMU in Jasper National Park.

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	24	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	4	Montane Grasslands	10	1
Aspen Forest	3	1	Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	2	Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	12	Non-forested lands with rarely burned vegetation	15	11
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	11	Water	16	1
Floodplain Spruce Forest	7	1	Rock and Ice	17	18
Upper Subalpine Spruce, Subalpine Fir and Larch	8	13	Out of Park		0

UPPER FIDDLE

The Upper Fiddle FMU is the second smallest FMU in Jasper National Park (128 km^2). It is bordered on the east by the province of Alberta, to the north by the Lower Fiddle FMU, and to the west by The Lower and Upper Rocky FMU. The west boundary of this FMU is approximately 66 kilometers from the Continental Divide. About 46% of this FMU is rock and ice (Table 13). The remaining landscape is mostly part of the Subalpine Natural Sub-region. Tree species common to the Subalpine and the Foothills Natural Region include White Spruce, Lodgepole Pine and Engelmann Spruce. The valley orientation in this FMU is northwest-southeast, with Fiddle Pass being the main valley exiting into the Province. The Weldwood Forest Management Area is located to the west of this FMU.

Table 13. percent representation (area) of vegetation management groups in the Upper Fiddle FMU in Jasper National Park.

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	13		Montane. Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	3
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	1
Cool/Moist Lower Subalpine Lodgepole Pine	5	2		Non-forested lands with rarely burned vegetation	15	4
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	18		Water	16	0
Floodplain Spruce Forest	7	0		Rock and Ice	17	46
Upper Subalpine Spruce, Subalpine Fir and Larch	8	10.4		Out of Park		0.01

TONQUIN

The Tonquin is a small FMU (232 km^2) bordered on the north and east by the Middle Athabasca FMU, on the south by the Whirlpool FMU and on the west by Mount Robson Provincial Park. The west boundary of the Tonquin sits along the Continental Divide. This FMU is about 38% rock and ice (Table 14). Another 25% is non-forested lands. The remaining landscape is predominantly Subalpine. The Tonquin does not border the Province of Alberta, nor is it close to an FMU that does. Valley orientation in the Tonquin is primarily northwest-southeast.

Table 14. Percent representation (area) of vegetation management groups in the Toquin FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	0		Montane Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	2		Non-forested lands with rarely burned vegetation	15	25
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	7		Water	16	3
Floodplain Spruce Forest	7	1		Rock and Ice	17	38
Upper Subalpine Spruce, Subalpine Fir and Larch	8	25		Out of Park		0

LOWER MALIGNE

The Lower Maligne FMU is medium-sized (443 km^2) located in the mid-eastern portion of the park. It is bordered on the north by the Lower Rocky FMU, on the north and west by the Middle Athabasca FMU, on the south by the Upper Maligne FMU and on the east by the Upper Rocky FMU. The west boundary of this FMU is located approximately 36 kilometers east of the Continental Divide. About 27% of this FMU is rock and ice (Table 15). The remaining landscape is comprised of all three natural subregions found in Jasper National Park. This FMU does not border the Province of Alberta. It is separated from the Province by the Upper Rocky FMU, which contains a number of mountain ranges and ridges running Northwest-Southeast. These ranges mostly impede any contiguous cover of vegetation from the Lower Maligne FMU to the Province. Valley orientation in this FMU is primarily Northwest-Southeast.

Table 15. Percent representation (area) of vegetation management groups in the Lower Maligne FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	3		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	9		Montane Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	1
Cool/Moist Lower Subalpine Lodgepole Pine	5	15		Non-forested lands with rarely burned vegetation	15	17
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	12		Water	16	1
Floodplain Spruce Forest	7	1		Rock and Ice	17	27
Upper Subalpine Spruce, Subalpine Fir and Larch	8	16		Out of Park		0

UPPER ROCKY

The Upper Rocky is a large FMU (928 km^2) locate on the mid-eastern border of Jasper National Park. It is bordered on the east by the Upper Fiddle FMU and the Province of Alberta (mainly Whitehorse Wildland Provincal Park), on the north by the Lower Rocky FMU, on the west by the Lower Maligne and Upper Maligne FMU's and on the south by the Southesk/Cairn FMU. The west boundary of this FMU is approximately 54 kilometers east of the Continental Divide. The Upper Rocky is about 43% rock and ice (Table 16), and the remaining landscape is primarily Subalpine. Tree species in the Subalpine here similar to those in Whitehorse Wildland Provincial Park and adjacent provincial lands are Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation is primarily northwest-southeast. Weldwood Forest Management Area lies directly west of Whitehorse Wildland Provincial Park.

Table 16. Percent representation (area) of vegetation management groups in the Upper Rocky FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	1
Dry Lower Subalpine Lodgepole Pine	2	5		Montane Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	1
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	3
Cool/Moist Lower Subalpine Lodgepole Pine	5	4		Non-forested lands with rarely burned vegetation	15	5
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	22		Water	16	0
Floodplain Spruce Forest	7	2		Rock and Ice	17	43
Upper Subalpine Spruce, Subalpine Fir and Larch	8	13		Out of Park		0

WHIRLPOOL

The Whirlpool FMU (543 km^2) is located in the mid-western portion of the park. It is bordered by the Tonquin FMU to the north, the Middle Athabasca FMU to the northeast, the Upper Athabasca to the southeast, the Province of BC to the west and southwest and Hamber Pronvincial Park to the southwest. The south and west boundary lie along the Continental Divide. About 43% of this FMU is rock and ice (Table 17). Another 11% is non-forested lands. The remaining landscape is predominantly Subalpine. This FMU does not border the Province of Alberta, nor does it border an FMU that does. Valley orientation is primarily northeast-southwest, with perpendicular tributary valleys.

Table 17. Percent representation (area) of vegetation management groups in the Whirlpool FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	1	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0	Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	5	Non-forested lands with rarely burned vegetation	15	11
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	23	Water	16	1
Floodplain Spruce Forest	7	0	Rock and Ice	17	43
Upper Subalpine Spruce, Subalpine Fir and Larch	8	15	Out of Park		0

UPPER ATHABASCA

The Upper Athabasca is a mid-sized FMU (440 km^2) located in the lower west portion of the Park. It is bordered by the Middle Athabasca FMU to the north, by the Whirlpool FMU to the northwest, by Hamber Provincial Park (BC) to the southwest, by the Chaba FMU to the southeast, and by the Sunwapta and Upper Maligne FMU's to the east. The southwest boundary of this FMU lies along the Continental Divide. This FMU is about 31% rock and ice, with another 9% being non-forested lands (Table 18). The remaining landscape is comprised mainly of Subalpine and some Montane. Although this FMU does not border the Province of Alberta, it is very close to Banff National Park and is one FMU away from adjacent provincial lands. Montane tree species similar to those adjacent lands include White Spruce and Lodgepole Pine. Tree species in similar in the Subalpine include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. The orientation of the main valley in this FMU is north-south.

Table 18. Percent representation (area) of vegetation management groups in the Upper Athabasca FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	5	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	7	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	1	Subalpine Grasslands	12	1
Cool/Moist Lower Subalpine Lodgepole Pine	5	17	Non-forested lands with rarely burned vegetation	15	9
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	14	Water	16	1
Floodplain Spruce Forest	7	0	Rock and Ice	17	31
Upper Subalpine Spruce, Subalpine Fir and Larch	8	14	Out of Park		0

UPPER MALIGNE

The Upper Maligne (450 km^2) is located south central portion of the Park. It is bordered by the following FMU's: the Lower Maligne to the northwest, the Upper Rocky to the northeast, the Upper Athabasca to the west, the Sunwapta to the southwest, the Upper Brazeau to the southeast, and the Southesk/Carin to the east. The west boundary of this FMU is approximately 44 kilometers from the Continental Divide. This FMU does not border the Province of Alberta, although it is next to two FMUs that do (Upper Rocky and Southesk/Cairn). In both of these FMUs vegetated areas are divided by mountain ranges and ridges oriented primarily Northwest-Southeast. About 46% of this FMU is rock and ice (Table 19) and another 16% is non-forested land. The remaining landscape is Subalpine.

Table 19. Percent representation (area) of vegetation management groups in the Upper Maligne FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	1	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	1
Mesic Montane White Spruce	4	0	Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	4	Non-forested lands with rarely burned vegetation	15	16
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	12	Water	16	5
Floodplain Spruce Forest	7	0	Rock and Ice	17	46
Upper Subalpine Spruce, Subalpine Fir and Larch	8	14	Out of Park		0

SOUTHESK/ CAIRN

Southesk/ Cairn (418 km^2) is located in the southeast portion of Jasper National Park. It is bordered to the northwest by the Upper Rocky FMU, to the south west by the Upper Maligne and Upper Brazeau FMU's, to the southeast by the Middle and Lower Brazeau FMU's and to the northeast by the Province of Alberta. The west boundary of this FMU is approximately 72 kilometers east of the Continental Divide. Southesk/Cairn is about 56% rock and ice (Table 20). Another 10% is non-forested lands. The remaining landscape is Subalpine. Tree species similar in the Subalpine and adjacent lands include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation in this FMU is predominantly northwest-southeast. The Weldwood Forest Management Area is located to the northeast.

Table 20. Percent representation of vegetation management groups in the Southesk/Cairn FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0	Engelmann Spruce and Subalpine Fir	9	1
Dry Lower Subalpine Lodgepole Pine	2	4	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	4
Mesic Montane White Spruce	4	0	Subalpine Grasslands	12	3
Cool/Moist Lower Subalpine Lodgepole Pine	5	2	Non-forested lands with rarely burned vegetation	15	10
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	7	Water	16	1
Floodplain Spruce Forest	7	1	Rock and Ice	17	56
Upper Subalpine Spruce, Subalpine Fir and Larch	8	10	Out of Park		0

CHABA

The Chaba FMU (771 km^2) is located in the southeast portion of the Park. It is bordered to the north by the Upper Athabasca FMU, to the east by the Sunwapta FMU, to the northwest by Hamber Provincial Park, and to the south and southwest by the Province of British Columbia. The western and southern boundary of the FMU lie along the Continental Divide. This FMU is 58% rock and ice (Table 21), with another 8% being non-forested lands. This FMU borders a large percent of the Columbia and Chaba Icefields. The remaining landscape is Subalpine. The Chaba does not border the Province of Alberta, although it borders the Sunwapta FMU that borders Banff National Park. Valley orientation is primarily north-south.

Table 21. Percent representation (area) of vegetation management groups in the Chaba FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	4		Montane Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	0
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	5		Non-forested lands with rarely burned vegetation	15	8
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	15		Water	16	0
Floodplain Spruce Forest	7	1		Rock and Ice	17	58
Upper Subalpine Spruce, Subalpine Fir and Larch	8	9		Out of Park		0

SUNWAPTA

The Sunwapta FMU (702 km^2) is located in the south central portion of Jasper National Park. It is bordered to the north by the Upper Athabasca and Upper Maligne FMUs, to the west by the Chaba FMU, to the east by the Upper Brazeau FMU and to the south by Banff National Park. This FMU is very close to the Continental Divide, and almost touches it on its southwest tip. The Sunwapta is 59% rock and ice, with another 15% non-forested lands (Table 22). The southwestern tip borders the Columbia Icefields. The remaining landscape is Subalpine. Subalpine species that are similar in both the Sunwapta and provincial lands adjacent to Banff National Park include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation is primarily north-south.

Table 22. Percent representation (area) of vegetation management groups in the Sunwapta FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	5	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	1
Mesic Montane White Spruce	4	0	Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	6	Non-forested lands with rarely burned vegetation	15	15
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	0	Water	16	0
Floodplain Spruce Forest	7	1	Rock and Ice	17	50
Upper Subalpine Spruce, Subalpine Fir and Larch	8	14	Out of Park		0

UPPER BRAZEAU

The Upper Brazeau (528 km^2) is located in the south portion of Jasper National Park, and extends partly into the Province of Alberta and the White Goat Wilderness Area. It is bordered on the west by the Sunwapta FMU, to the northwest by the Upper Maligne FMU, to the northeast by the Southesk/Cairn FMU, to the east by the Middle Brazeau FMU, and to the south by the remainder of the White Goat Wilderness Area and the Province of Alberta. The west border of this FMU is approximately 40 kilometers from the Continental Divide. The Upper Brazeau is about 40% rock and ice Another 13% is non-forested lands (Table 23). The remaining landscape is Subalpine. Tree species common to both the Subalpine in this region and the Province of Alberta and White Goat Wilderness Park include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation is northwest-southeast.

Table 23. Percent representation (area) of vegetation management groups in the Upper Brazeau FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage	Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0	Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	3	Montane Grasslands	10	0
Aspen Forest	3	0	Dry Shrub Meadows	11	2
Mesic Montane White Spruce	4	0	Subalpine Grasslands	12	2
Cool/Moist Lower Subalpine Lodgepole Pine	5	5	Non-forested lands with rarely burned vegetation	15	13
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	3	Water	16	1
Floodplain Spruce Forest	7	0	Rock and Ice	17	41
Upper Subalpine Spruce, Subalpine Fir and Larch	8	7	Out of Park		24

MIDDLE BRAZEAU

The Middle Brazeau (518 km^2) is located in the southeast portion of the Park, and over half of the total area of this FMU occurs outside of Jasper National Park in the Province of Alberta. It is bordered on the north by the Southesk/Cairn FMU, to the south and east by the Province of Alberta and to the west by the Upper Brazeau FMU. The west boundary of this FMU is approximately 44 kilometers from the Continental Divide. The Middle Brazeau is 24% rock and ice (Table 24). The remaining landscape is primarily Subalpine. Subalpine tree species similar to those in adjacent provincial lands include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Valley orientation is variable.

Table 24. Percent representation (area) of vegetation management groups in the Middle Brazeau FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	3		Montane Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	2
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	2
Cool/Moist Lower Subalpine Lodgepole Pine	5	2		Non-forested lands with rarely burned vegetation	15	4
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	3		Water	16	0
Floodplain Spruce Forest	7	1		Rock and Ice	17	24
Upper Subalpine Spruce, Subalpine Fir and Larch	8	4		Out of Park		56

LOWER BRAZEAU

The Lower Brazeau is the smallest FMU (77 km^2) in Jasper National Park, located on the very southeastern tip. It borders the Middle Brazeau FMU and the Province of Alberta. The west boundary of the Lower Brazeau is about 58 kilometers from the Continental Divide. This FMU is about 21% rock and ice (Table 25). The remaining land is Subalpine. Subalpine tree species similar to those in the adjacent provincial lands include Lodgepole Pine, Subalpine Fir and Engelmann Spruce. Weldwood Forest Management area is located to the northeast.

Table 25. Percent representation of vegetation management groups in the Lower Brazeau FMU in Jasper National Park

Vegetation Management Groups	#	% Coverage		Vegetation Management Groups	#	% Coverage
Dry Montane Lodgepole Pine and Douglas Fir	1	0		Engelmann Spruce and Subalpine Fir	9	0
Dry Lower Subalpine Lodgepole Pine	2	25		Montane Grasslands	10	0
Aspen Forest	3	0		Dry Shrub Meadows	11	1
Mesic Montane White Spruce	4	0		Subalpine Grasslands	12	0
Cool/Moist Lower Subalpine Lodgepole Pine	5	42		Non-forested lands with rarely burned vegetation	15	2
Lower Subalpine Engelmann Spruce and Subalpine Fir	6	4		Water	16	1
Floodplain Spruce Forest	7	3		Rock and Ice	17	21
Upper Subalpine Spruce, Subalpine Fir and Larch	8	2		Out of Park		0

3.1 INTRODUCTION

This chapter provides a review and analysis of existing information on forest insects and diseases affecting tree species in Jasper National Park. First I discuss the methods. Following that I have divided forest insects and diseases into 3 categories: major agents of concern; minor agents of concern; and agents not of concern. I mapped major and minor insect locations using ArcInfo, then provided descriptions of each agent's ecology and their activity in this region. A discussion follows.

3.2 METHODS

3.2.1 Background

The database used in this project was largely compiled from the Forest Insect and Disease Survey (FIDS) section of the Canadian Forest Service (Parks Canada 1994b) from surveys conducted between 1940 and 1994. According to the *Report on Database of Historic Records for Insect and Disease Conditions in Jasper, Waterton Lakes, Kootenay, Yoho, Glacier and Mt. Revelstoke National Parks* by Dianne Szlabey (Parks Canada 1994b), the majority of information in the database comes from collections made in the late 1940's and early 1950's. At that time the emphasis was on recording species type and their location. This was done through the use of enclosure slips. The Canadian Forest Service began entering the enclosure slip information into a database (FIDSINFOBASE) in the 1960's. However, in the 1960's rangers stopped filling out enclosure slips as often and began recording observations in notebooks and summarising this information in regional annual reports. By the end of the 1970's, the majority of emphasis was switched to species having potential economic impact. I augmented the data (from Szlabey) with written summaries of insect and disease activity that incorporates other sources of information (Brandt 1997; Parks Canada 1996b; Brandt et al 1996; Paulson 1995; Brandt 1995).

3.2.2 Limitations of Database

The limitations of the database are as follows:

1. The locations of insects and diseases appear to occur most often in areas that are/were most travelled. The locations have not been randomly located, and when looking at the distributions maps it is obvious the data were skewed to transportation corridors.
2. As outlined by Szlabey (1994), there were inconsistencies in the data collection process, resulting in problems with uniformity in the data.
3. Locations were given in eastings and northings. After converting the data to GIS point data, the locations are only accurate to 1 kilometer. This level of accuracy is listed as an M class precision in the Nature Conservancy Biological Conservation Data (The Nature Conservancy 1988).
4. The data describes which species may have historically occurred in the park. However, it likely does not represent the historical distribution of the agent. For example, a disease many only show up as having 2 point locations on the entire map of JNP. However, it is unlikely a given disease only affected two geographical points.
5. The Szlabey report on the database is only current until 1994. Point locations of agents after that time are not included in the historical distribution. For example, work on Douglas Fir Beetle by Lisa Paulson (1995) does not show up as point locations in this database.

3.2.3 Database Analysis

I converted the database from a dbase file into Microsoft Access format and reformatted it into alphabetical listings making it easier to use. The eastings and northings (Universal Transverse Mercator Grid coordinates) were converted into grid coordinates compatible with the geographic information system, ArcInfo (GIS). The watershed data were missing from the digital copy of the database, and therefore were re-entered using the hard copy that accompanied it.

After selecting major and minor agents of concern (process outlined below), I created tables of each in Arcview. Based on these tables I developed distribution maps overlaid by fire management units for each major and minor insect. The information provided on the maps was augmented by written histories. There was no point location data available for Forest Tent Caterpillar (*Malacosoma distria*) and Lodgepole Pine Beetle (*Dendroctonus murryanae*).

Distribution maps were not created for diseases. The point data for diseases were so limited it did not warrant mapping polygons. I discuss point data for diseases in written histories below.

3.2.4 Major and Minor Insect and Disease Selection

Using personal correspondence, literature reviews, and information gained through a four month directed study, I devised a flow chart for dividing agents into three categories. Each agent listed in the database (including those flagged by D. Szlabey and the Canadian Forest Service) were grouped in one of the following three categories:

- Major agents of concern
- Minor agents of concern
- Agents not of concern

Dividing the agents into categories made the data easier to handle.

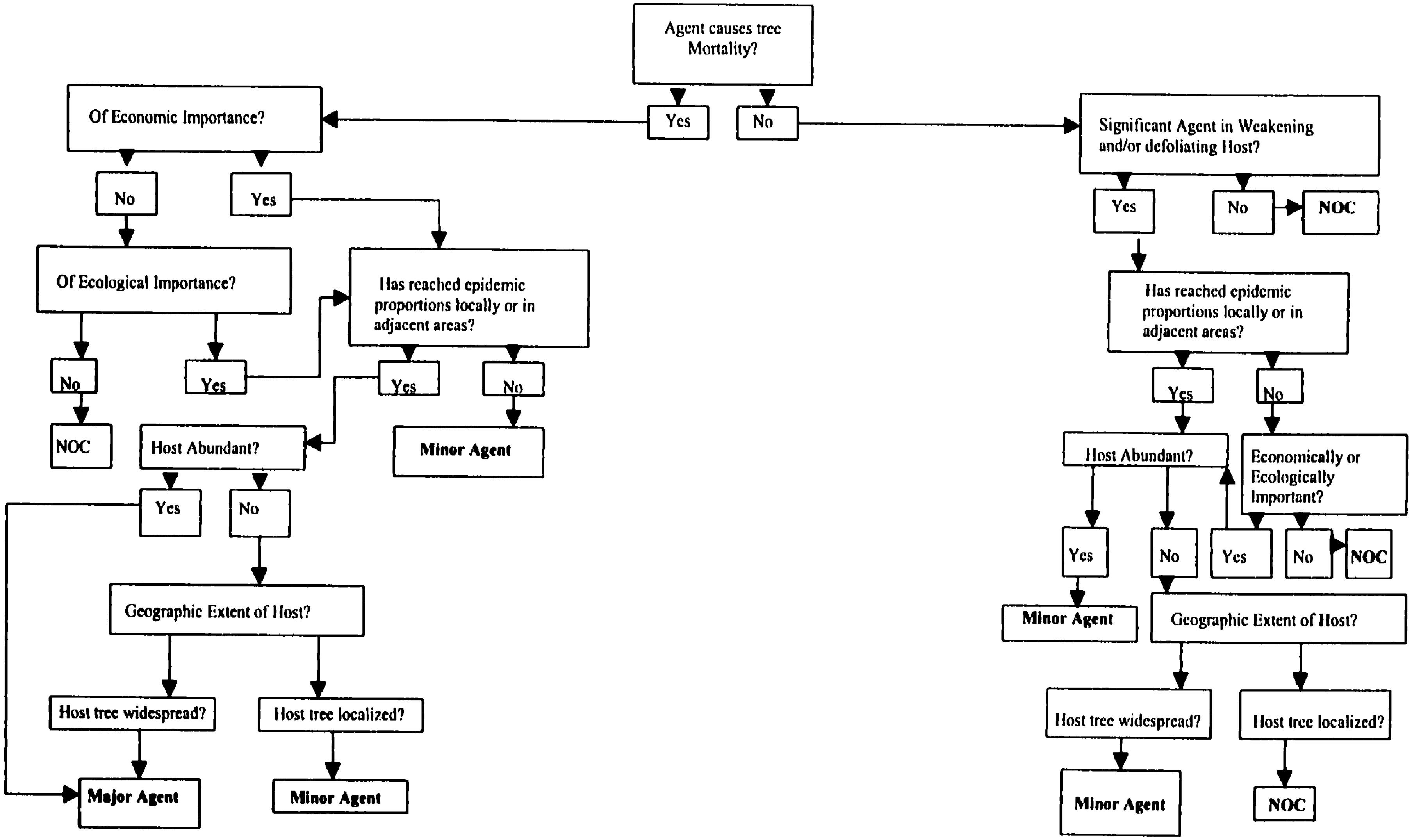

Figure 4. Flow chart used to group agents into the categories 'agents of major concern', agents of minor concern' and 'agents not of concern' (NOC)

The flow chart is complex, and it was important during its development to clearly define each of the criteria:

Tree Mortality:	Tree dies as a result of agent attack
Economic Importance:	Agent attacks timber species harvested by adjacent land managers (e.g. Lodgepole Pine, White Spruce, Black Spruce, Balsam and Subalpine Fir).
Ecological Importance:	Agent threatens or has the potential to threaten, extirpate or seriously modify elements of ecosystem processes in Jasper National Park. (e.g. White Pine Blister Rust causes extensive mortality in limited White Bark Pine Communities in Jasper National Park (P. Achuff pers. comm.).
Host Abundant :	Host tree species common throughout park. (See tables 2 and 3 in chapter 2)
Geographic Extent of host:	Host tree widespread or localised. (See distribution of vegetation management groups in FMUs, Table 2 in chapter 2).
NOC	Agent Not of Concern
Weakening/defoliating	Agent removes enough vegetation or in other ways harms the host to the point where the host can not fully recover to a healthy state akin to a tree of similar age in similar climate that has not been attacked. This may heighten the risk of the host being attacked by other agents (e.g. warren collar root weevil activity causes major entry ways for Armillaria).

Non-native agent:	Agent historically not part of natural cycling of the biota. Agent introduced from other parts of the world into JNP.
Major Agent:	Agent of economic or ecological importance, has reached epidemic proportions locally or in adjacent areas, and host is abundant, continuous or can be attacked by aggressive mechanism of agent spread.
Minor Agent:	Agent is significant in weakening or defoliating the host, has reached epidemic proportions locally or in surrounding areas, and/or is economically or ecologically significant, and/or where host is abundant, continuous or can be attacked by aggressive mechanism of agent spread.
Epidemic:	Because of the lack of information on population sizes in this document, "epidemic" refers to a visible increase in trees attacked over time (T. Shore pers. comm.). Further definition will need to be on a per species basis. For example Mountain Pine Beetle epidemics will be defined differently from Armillaria Root Rot.

The flow chart was reviewed in many drafts by the supervisory committee for this project and by vegetation specialists in the park.

3.2.5 Limitations of Flow Chart and Assumptions of Use

While efforts were made to review other agents that were flagged by the Canadian Forest Service or in the written historical accounts by Dianne Szlabey, there is still a chance that agents of concern may have been missed. Firstly, I have minimised this risk having this document reviewed by other insect, disease and vegetation management specialists (Tuesday November 2 1999).

Secondly, I recognise the defining criteria for the flow chart may generate some discussion. For example, the chosen definition of epidemic may be disputed. However, communication with experts in the field has been conducted to alleviate some of this uncertainty (T. Shore pers. comm.). Therefore, the flow chart should be used as a tool, and should not supplant decision-making based on all the available facts.

3.2.6 Species Descriptions and Ecology

Ives and Wong (1988) and Hiratsuka (1987) provide almost all of the species descriptions and ecology, unless otherwise stated. These books contain the best general information on species descriptions, ecology and distribution. This is a working document, based on the best available information on each agent in an easy format for managers to access.

3.3 RESULTS

3.3.1 Dividing Agents Into Categories

This is the list of agents by category: major, minor and agents not of concern.

Major Insects:

1. *Choristoneura fumiferana* (Spruce Budworm) - need to confirm location of adjacent infestations
2. *Dendroctonus ponderosae* (Mountain Pine Beetle)
3. *Dendroctonus pseudotsugae* (Douglas Fir Beetle)
4. *Dendroctonus rufipennis* (Spruce Beetle) - need to confirm adjacent infestations
5. *Coleotechnites starki - Used to be Recurvia starki* (Lodgepole Pine Needleminer)

Minor Insects

1. *Acleris variana* (Eastern Blackheaded budworm)
2. *Dendroctonus murryana* (Lodgepole Pine Beetle)
3. *Pikonema alaskenis* (Yellowheaded Spruce Sawfly)
4. *Pikonema dommockii* (Greenheaded Spruce Sawfly)
5. *Adelges cooleyi* (Cooley Spruce Gall Adelgid)
6. *Pristiphora erichsonii* (Larch Sawfly)
7. *Hylobius warreni* (Warren Root Collar Weevil)
8. *Ips pini* (Pine Engraver)
9. *Oligonychus ununguis* (Spruce Spider Mite)
10. *Malacosoma disstria* (Forest Tent Catepillar)
11. *Phyllocnistis populiella* (Aspen Serpentine Leaf Miner)
12. *Epinotia sp.* (Aspen Leaf Roller)

Major Diseases

1. *Arceuthobium americanum* (Lodgepole pine dwarf mistletoe)
2. *Armillaria mellea* (Armillaria root rot)

Minor Diseases

1. Needle Casts
2. Leaf Spot diseases
3. Western Gall Rusts
4. Needle Rusts
5. Blights
6. Others

Non-native species of concern

1. *Cronartium ribicola* (White Pine Blister Rust)
2. *Lymantria dispar* (Gypsy Moth)
3. *Fenusa dohrnii* (European Alder Leaf Minor)
4. *Profenusa thomsoni* (Ambermarked Birch Leafminor)
5. *Anaplophora glabripennis* (Asian Long-horned beetle)

I handled major agents of concern that are not native separately because Parks Canada's objective for alien species differ from objectives for native species. The objective for non-native species is to prevent their introduction or to eradicate them (Parks Canada 1997a).

3.3.2 Agent Ecology and Activity in Jasper National Park

The importance of Forest Insects and Diseases was outlined in Chapter 3. In this section I discussed each major, minor, and non-native major agent. I provided a description of the ecology of the agent, along with a brief summary of that agent's activity in Jasper National Park. At times there are differences in the level of detail regarding the activity of each agent. This is purely a result of the different levels of data available for this exercise. Some agents (i.e. those that are of potential economic concern to the Province of Alberta) have more information available than others. In cases where data were really limited, information from the Province at large was used to provide at least some information on the regional activity of that agent.

3.3.3 Major Insects

The Major Insects in Jasper National Park are listed below.

SPRUCE BUDWORM

***Choristoneura fumiferana* Clemens: Order Lepidoptera, Family Tortricidae**

Species Description and Ecology

Taken/adapted from Ives and Wong 1988 unless otherwise referenced

Spruce Budworm prefers mature Balsam Fir as a host, but has been known to cause severe outbreaks in White Spruce stands, as has been the case in Jasper National Park (Szlabey 1994).

The lifecycle of this insect is one year, including six larval instars. The second larval instar emerges from hibernation in late April or May. These larvae are yellowish and have dark brown heads and thoracic shields. They mine needles, unopened buds, or male flowers and feed within expanding shoots. Mature larvae are 18-24 mm in length and have black heads and reddish bodies that are lighter in color on the sides. The thoracic shield is brown and is separated from the head by a whitish band. There are two rows of whitish spots along the back. The larvae usually web two or three shoots together to form a feeding tunnel. Pupae are formed among the foliage in June and are attached to the silk lining of the feeding tunnel by the cremaster. Adults emerge in late June or July. They have a wingspan of about 20 mm and are variable in color. The fore wings are usually dull gray with bands and spots of brown, and the hind wings are light gray. The eggs are green and are deposited in clusters of about 20 on the needles of the host tree. The eggs hatch in about 10 days, and the tiny larvae disperse among the foliage on silken threads. The first-instar larvae spin hibernacula under bark scales and molt to the second instar without feeding. The adult moths emerge from July to mid-August and are about 13 mm long, with a 15-25 mm wingspan (Unger 1995). They fly mainly at dusk, and egg masses can be found under host needles from late July to mid-August (Unger 1995).

As the damaged foliage of the host tree dies, it assumes a reddish color. As heavy rains or winter snowfalls wash the dead foliage, the extent of damage becomes apparent. Short periods of defoliation causes a decrease in radial increment, but prolonged outbreaks cause severe branch and ultimately tree mortality. Additional tree mortality may be caused by secondary pests such as bark beetles due to the stresses associated with defoliation (Unger 1995).

Activity in Jasper National Park (Figure 5)

Populations of Spruce Budworm generally increased in the province of Alberta between the years of 1994 and 1996 (Brandt 1997; Brandt et al 1996; Brandt 1995). However, available information suggests that there have been no recent outbreaks of Spruce Budworm in Jasper National Park. Historically, Spruce Budworm has occurred in the Whirlpool, Upper Athabasca, Middle Athabasca, Lower Maligne and Lower Fiddle FMUs.

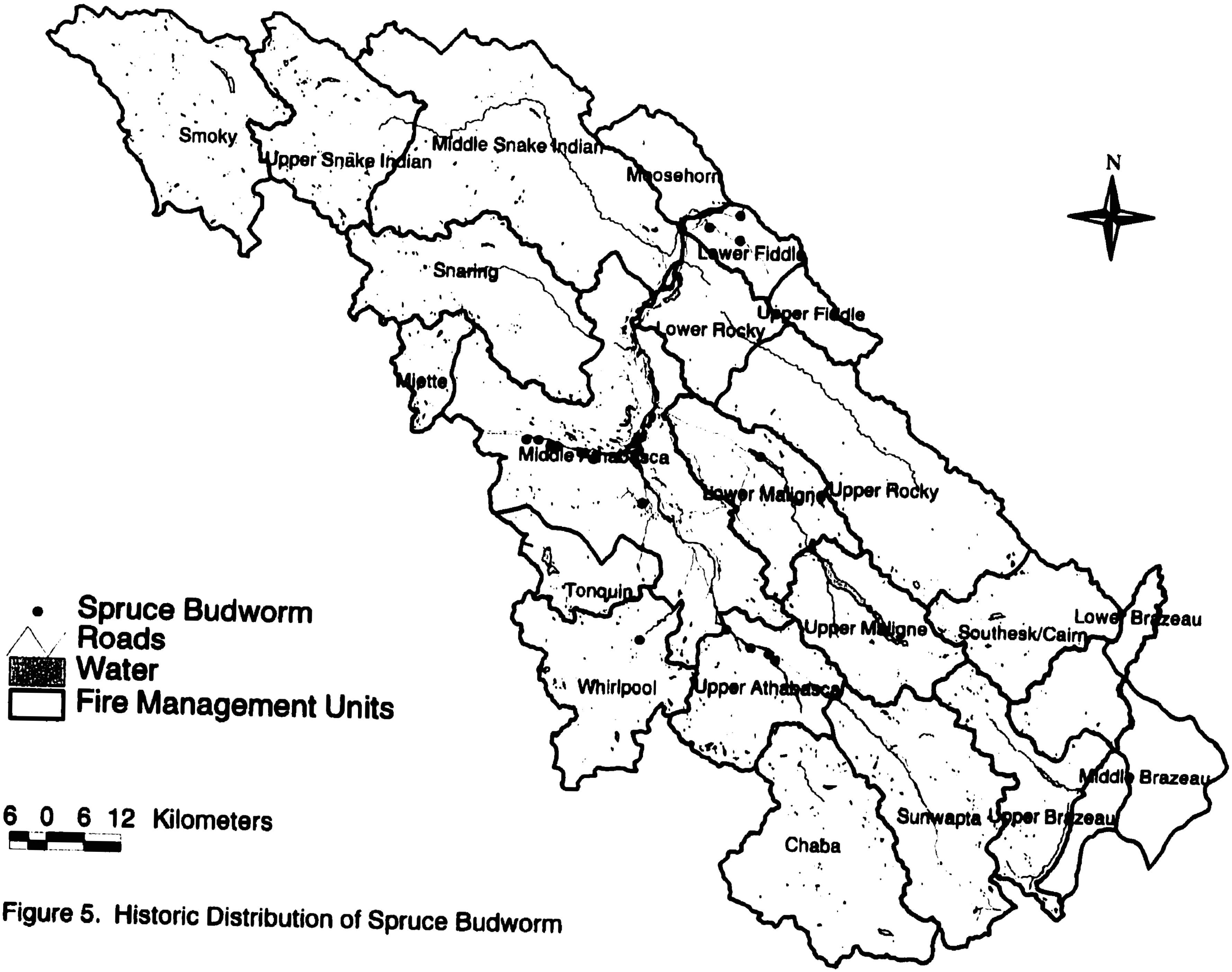

Figure 5. Historic Distribution of Spruce Budworm

MOUNTAIN PINE BEETLE

Dendroctonus ponderosae Hopkins: Order Coleoptera, Family Scolytidae

Species Description and Ecology

Taken/adapted from Ives and Wong 1988 and Unger 1993

The Mountain Pine Beetle is known to the forestry industry as one of the most destructive pests in Western Canada. Although it attacks a variety of pine species, the host of concern in Jasper National Park is Lodgepole Pine (*Pinus contorta*).

Mountain Pine Beetle normally have one generation a year, although this can vary due to temperature and elevation. For example, in warmer climates that have been know to experience two broods per year, whereas colder climates may only experience one brood every two years. The adults range from 3.7 to 7.5 mm in length. Young adults are light to creamy tan in color, changing to black as they reach full maturity. Beetle flights usually occur throughout July and August, usually peaking in mid-July. The female excavates long vertical galleries, often with a crook at the base, in the inner bark and secrete pheromones that attract the males. The white eggs are deposited singly in groups of niches excavated on alternate sides of the gallery as it is being constructed. The larvae are white, legless grubs with brown heads, and they bore lateral galleries. The larvae overwinter in the galleries and resume feeding in the spring. The pupae are white and exarate and rest in pupal chanbers.

Mountain Pine Beetle attacks the larger trees in the stand first. Successful attack usually results in the death of the tree due partly to the girdling effect of the larval galleries and partly to the blue stain fungi that the beetles carry. The fungal mycelia quickly proliferate throughout the sapwood, plugging the vessels. Foliage discoloration usually occurs in the spring of the year following attack.

Activity in Jasper National Park (Figure 6)

1986 aerial surveys over the park indicate no infestations, however, small infestations were mapped in adjacent Mt. Robson Provincial Park (Szlabey 1994).

1988 all suspect or beetle attacked trees were removed form Mt. Robson Provincial Park. Still no evidence of mountain pine beetle in JNP (Szlabey 1994).

1991 ground surveys were made in JNP, but no tree mortality was attributed to the mountain pine beetle (Szlabey 1994).

1992 Mountain Pine Beetle attacks were reported at Chown Creek in JNP. However, this was never confirmed (Szlabey 1994).

1993 Mountain Pine Beetle attacks occurred at two of 12 pheromone trapped trees: in the Whirlpool River Valley and in the Miette River Valley. Neither of these attacks were successful (Szlabey 1994).

1996 -1997 aerial surveys conducted by Jasper National Park. No evidence of Mountain Pine Beetle attack (A. Westhaver pers. comm.).

1998 aerial survey of north JNP. No evidence of Mountain Pine Beetle Activity recorded (Unger 1998).

1999 Mountain Pine Beetle attacked trees found in the Smoky Fire Management Unit. Approximately 50 trees were identified as 'suspicious' from the air in September. Later ground surveys identified Mountain Pine Beetle as the cause of Mortality.

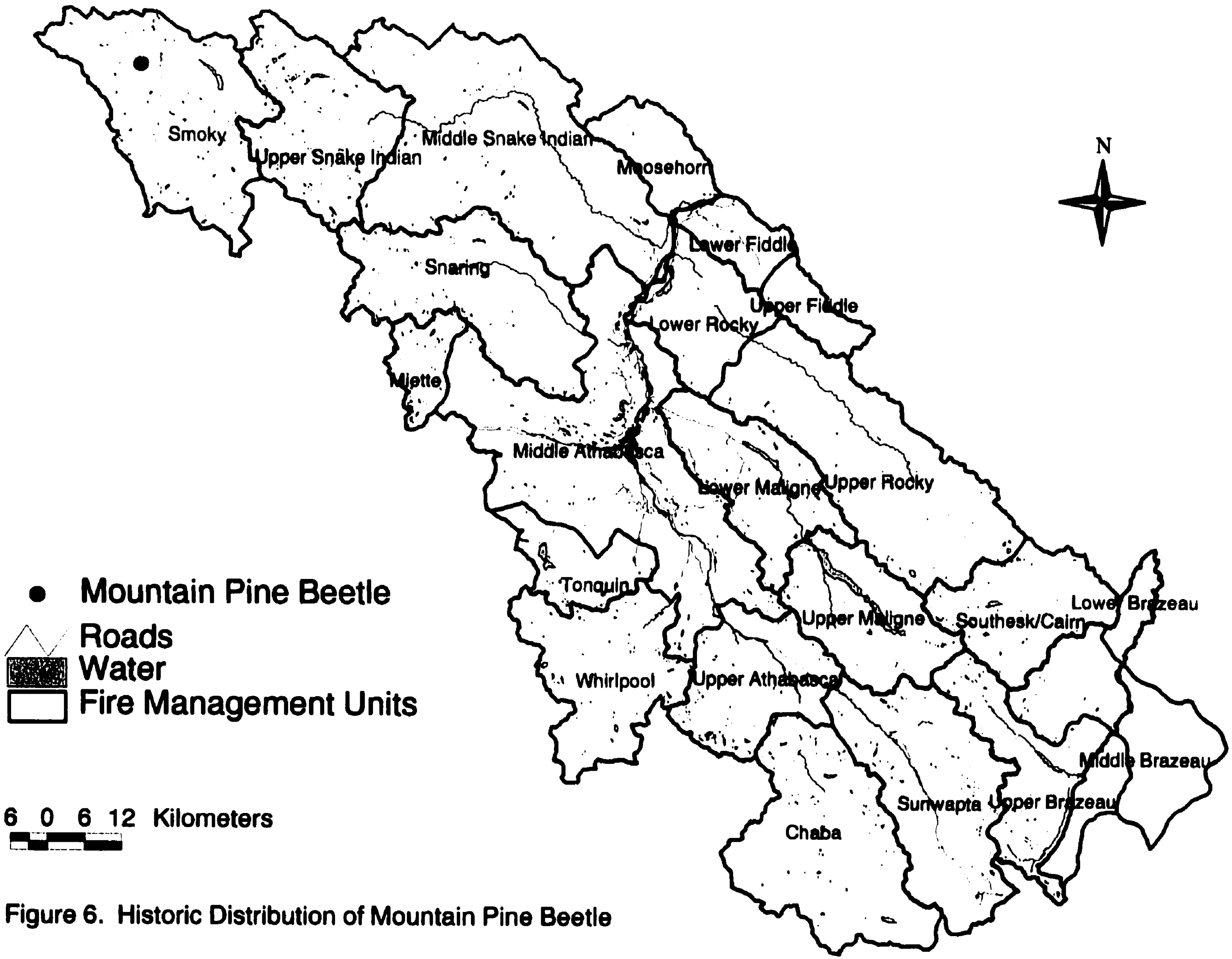

Figure 6. Historic Distribution of Mountain Pine Beetle

DOUGLAS-FIR BEETLE

***Dendroctonus pseudotsugae* Hopkins: Order Coleoptera, Family Scolytidae**

Species Description and Ecology

Taken/Adapted from Ives and Wong 1988 and Humphreys 1995

Douglas-fir Beetle attacks primarily Douglas-fir (*Pseudotsuga menziesii*), with Western Larch (*Larix occidentalis*) being attacked on occasion in some regions. In Jasper National Park, Douglas-fir is the primary host.

The lifecycle of the Douglas-fir Beetle is one year, although 2 broods may be produced within that year. Adult beetles measure 4 to 7 mm long, and typically fly and attack susceptible trees in the spring. The major flight period usually occurs in May and June. The female Douglas-fir Beetle chews through the outer bark and constructs her egg galleries in the inner bark. There she lays a brood of 10-36 eggs which are elliptical, pearly white and 1 to 1.2 mm long. These eggs are laid alternately along the sides of the gallery. The male follows behind the female ridding the gallery of frass. Later he will plug the entrance when the brood has been laid. Eggs hatch in about 2 weeks and the young larvae bore away from the egg gallery. The larvae feed for about 2 or 3 months until the winter prevents them from continuing. A few weeks later the larvae become young adults. The Douglas-fir beetle primarily overwinters as young adults or mature larvae. Young adults emerge through a circular hole they bore to the surface in the spring.

Although the Douglas-fir beetle prefers hosts such as felled trees, stumps and windfall, if the right conditions exist for a population to increase to epidemic proportions, live trees may be attacked and subsequently killed. Discoloration of tree foliage is one indication of attack, although this may not occur until a year after. Confirmation of attack may be obtained by removing the bark and observing gallery patterns.

Activity in Jasper National Park (Figure 7)

1991 A Douglas-fir beetle outbreak was discovered in at 10 sites in Jasper National Park (Paulson 1995).

1992 The outbreak expanded to 30 sites that were located primarily in the Middle Athabasca Fire Management Unit.

1993 Outbreak expanded to 55 sites in the same FMUs.

1994-
1995 Outbreak continued to expand (Brandt 1995 and Brandt et al 1996). While the number of infested areas remained unchanged, the number of dead trees increased.

1998 The Jasper National Park Forest Health monitoring flight in September done in conjunction with Leo Unger of the Pacific Forestry Centre (Canadian Forest Service) revealed recent tree mortality due to Douglas-fir beetle after a two year period where no new mortality was detected. However a thorough investigation of previous sites was not conducted, and should be during the next monitoring flight.

Figure 7. Historic Distribution of Douglas-fir Beetle

SPRUCE BEETLE

***Dendroctonus rufipennis:* Order Coleoptera, Family Scolytidae**

Species Description and Ecology

Adapted from Ives and Wong 1988 unless otherwise stated

Spruce Beetle is the most destructive agent in mature spruce in British Columbia and is a major agent throughout western North America (Furniss and Carolin 1977).

Adults are a robust, cylindrical beetle about 6 mm long, dark brown to black in color with fine dense hair. Spruce Beetles have one, two or three year life cycles, depending on local climatic conditions. Adults attack both Englemann and White Spruce in the spring by boring through the bark low on the bole and then tunneling upward along the bark-sapwood boundary. Galleries are about 8 mm wide. An attack is detected by the presence of coarse frass at the tree base; pitch tubes are rarely present (Cottrell 1978). Attacks usually girdle the tree and kill it. Virtually all outbreaks originate from disturbances such as blowdown, road clearing or logging in which dying or recently downed trees are initially attacked thus permitting a population buildup. Larger diameter trees are preferred (Furniss and Carolin 1977)

Activity in Jasper National Park (Figure 8)

Spruce Beetle is distributed throughout British Columbia, the Yukon (Humphreys and Safranyik 1993) and Northern Alberta (Brandt 1995). Historically, Spruce Beetle has occurred within Jasper National Park in the Middle Athabasca Fire Management Unit.

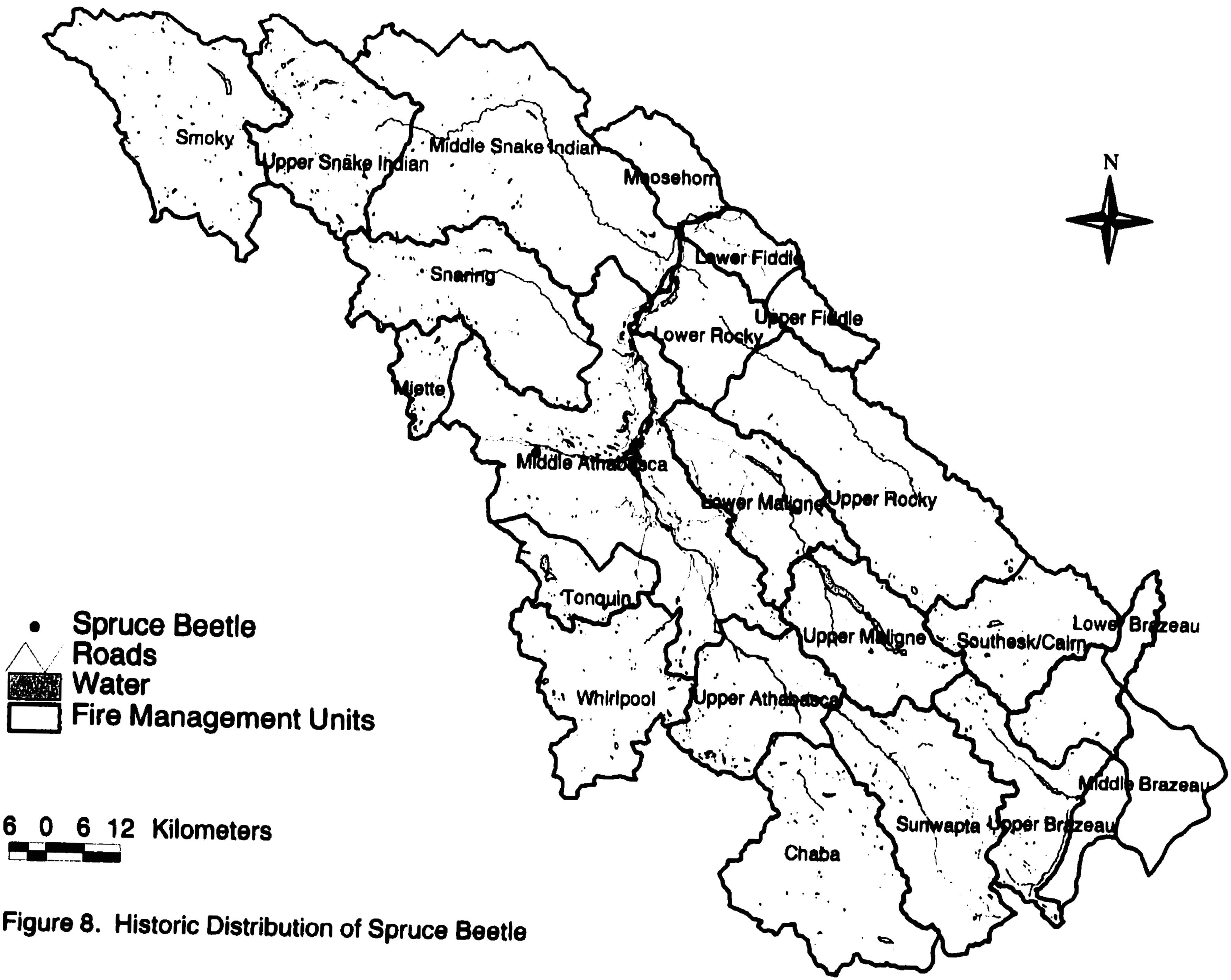

Figure 8. Historic Distribution of Spruce Beetle

LODGEPOLE PINE NEEDLEMINER
Coleotechnites starki
***A.K.A. Recurvia Starki* Freeman: Order Lepidoptera, Family Gelechiidae**

Species Description and Ecology
Taken directly from Ives and Wong 1988 unless otherwise cited

The Lodgepole Pine Needleminer normally has a 2 year lifecycle in which it overwinters in the second and fourth instar. Pupation occurs in the mined needles during June of the second year, and the small gray moths emerge from early July to August. Populations are synchronised, so that adults are present only in even-numbered years. The moths have a wingspan of 12-14 mm, and the fore wings are variously marked in black. Eggs are usually deposited in old mines. The newly hatched larvae mine into the tips of new needles in Late August or early September and overwinter there. The larvae transfer to a fresh needle in June or July of the following summer, having completely destroyed the contents of the first needle. Mining of these needles is completed by the following May, when a third needle is attacked. These needles are also completely mined by the time larval development is completed in June. Early-instar larvae are lemon yellow to light orange in color, with light brown thoracic and anal shields and heads. The larvae get progressively darker with each molt, and mature larvae are brownish with dark brown or black shields and heads.

Lodgepole Pine Needleminor damage causes discoloration of the mined segment. The major effects are reduction of annual growth increment and discoloration that has an aesthetic impact (Petty and Ives 1971). Annual incremental loss of heavily infested stands has ranged between 20 and 75%.

Activity in Jasper National Park (Figure 9)
Lodgepole Needleminer has some of the best historical records of activity for Jasper National Park.

1948 a light to severe outbreak was noted for an area approximately 22.5 kilometers (14 miles from the townsite on the Mount Edith Cavell Road. The total infested area was never calculated.

1949 light damage was reported in several areas. In the vicinity of tangle creek near the headwaters of the Sunwapta river, an infestation extended throughout the upper Sunwapta and Athabasca valleys, northwestward to the confluence of the Whirlpool and Athabasca River. "Beyond this point the forest on the valley floor was virtually unaffected, although the infestation continued along the higher slopes to the vicinity of Whistlers creek in the west and around Signal Mountain to the lower end of Medicine Lake in the east. The infestation continued to spread into the tributary valleys: "...It followed the Astoria river to a point due west of Cavell Lake, extended up to the Whirlpool River to Moab Lake and also along the Athabasca River to its junction with the Chaba River." Although the infestation was generally light, the infestation became more severe in the area 1.6 kilomenters (1 mile) south of Poboktan Creek and extending northward almost to Athabasca Falls and southward up the Athabasca and Sunwapta Rivers.

1950 noticeable discoloration of attacked trees and the infestation increased in size in some areas of the Upper Athabasca River Valley. There were "trees noticeably browned from Poboktan Creek north to the junction of Whirlpool and Athabasca rivers. Up to 50% [of the] needles were mined in this area." The infestation did not spread south, but did extend to Henry House, located 16 kilometers down the Athabasca River from the townsite. "The infestation extended to three miles west of Geikie and to the east along the maligne River as far as the lower end of Maligne Lake. By 1951, the infestation had increased in two areas: at " Poboktan Creek and on Mount Edith Cavell Road, populations of approximately 30 and 33 larvae per branch tip respectively; in the latter area the greatest population in 1950 was 9.4 larvae per branch tip."

1951 the infestation had increased in two areas: at "Poboktan Creek and on Mount Edith Cavell Road, populations of approximately 30 and 33 larvae per branch tip respectively."

1952 meduim to heavy infestations "remained above the 5000 foot level at Poboktan Creek and on Mount Edith Cavell Road." Light infestations below that level and in previously mentioned areas persisted between 1951 and 1952.

1953 a medium population was recorded in the Whirlpool and Astoria River Valleys. Populations were recorded as light in Poboktan Creek and in the Miette Valley

1954 populations persisted throughout throughout much of the Athabasca Valley "from the base of Catacomb Mountain to just north of Jasper townsite." Although most trees were lightly attacked, medium to severe attacks were recorded between Caledonia and Hibernia Lakes and on the lower slopes of Mount Edith Cavell between the Astoria and Whirlpool Rivers.

1955 the infestation had tapered off, with pine stands showing little or no needle miner damage.

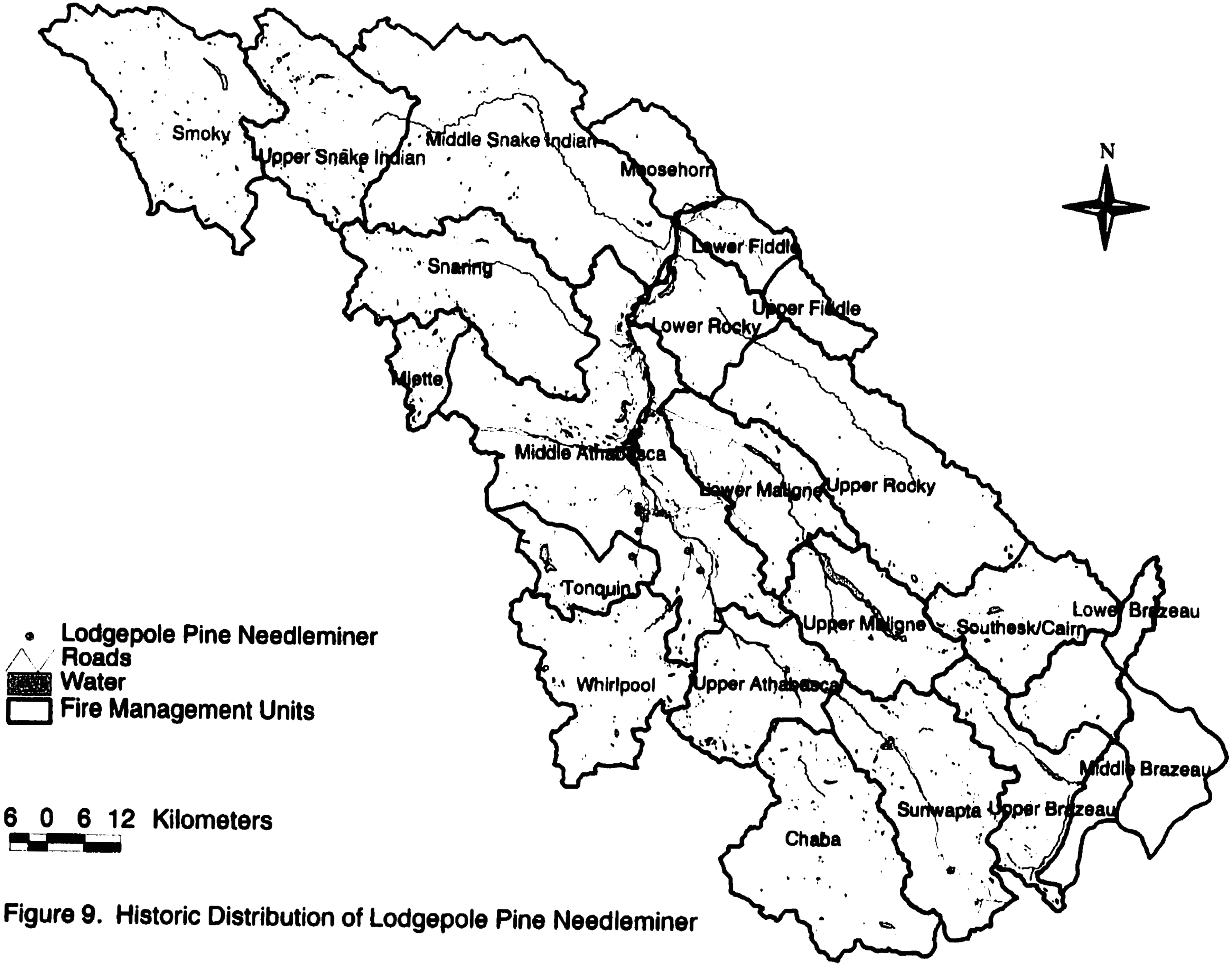

Figure 9. Historic Distribution of Lodgepole Pine Needleminer

3.3.3 Minor Insects

EASTERN BLACKHEADED BUDWORM
Acleris variana: **Order Lepidoptera, Family Tortricidae**

Species Description and Ecology
Taken from Ives and Wong 1988

The Eastern Blackheaded Budworm (*Acleris variana*) and the Spruce Budworm (*Choristoneura fumiferana*) are the most common budworms in this region. Like the Spruce Budworm, *Acleris variana* feeds on a variety of hosts including balsam fir, white spruce, and black spruce. This budworm has not caused severe damage in the prairie provinces.

Acleris variana overwinters as an egg laid singly on the undersurface of the needles. The lifecycle is one year. Eggs hatch in June, and the young larvae feed in the developing shoot and have dark brown or black heads and a green or yellowish body. Full grown larvae are 11-15 mm long. The head color varies from reddish brown to dark brown or black. The thoracic shield is mainly dark brown or black, and the body is light green. Adults emerge in August. They have a wingspan of about 20 mm, and are variable in coloration. The forewings are usually gray or dark gray with light bands, but may also be ocherous or reddish with yellowish bands. The hind wings are dark gray.

Activity in Jasper National Park (Figure 10)

1957 light infestations in Jasper National Park (Szlabey 1994).

1968 severe damage to new spruce buds along the Celestine Lake Road attributed to *Acleris variana*

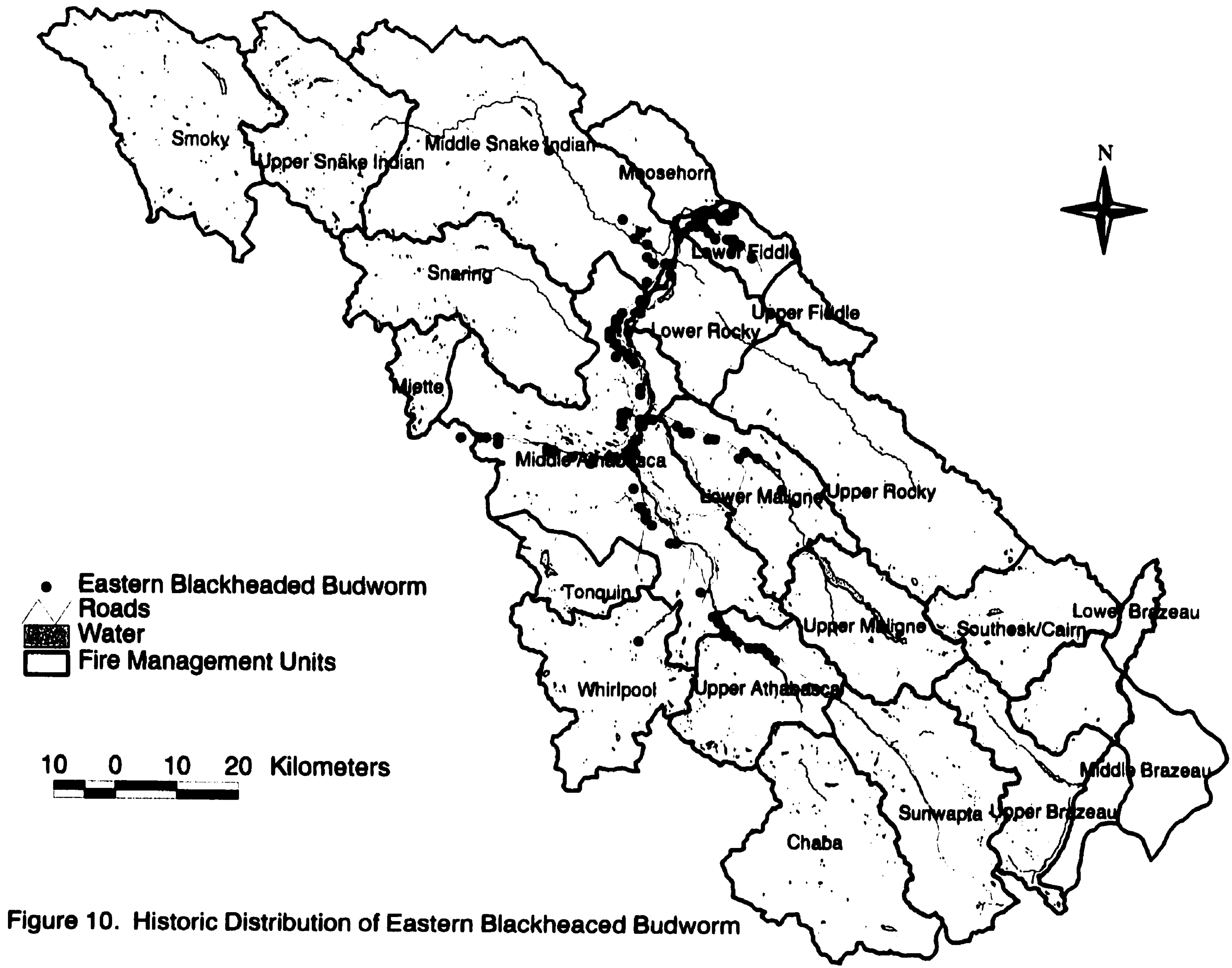

Figure 10. Historic Distribution of Eastern Blackheaced Budworm

Lodgepole Pine Beetle

***Dendroctonus murrayanae* Hopkins: Order Coleoptera, Family Scolitidae**

Species Description and Ecology

Taken from Ives and Wong 1988

The Lodgepole Pine Beetle attacks the lower bole and root crown of primarily overmature of weakened lodgepole pine or jack pine, causing localised infestations. The overwintering adults are between 5.0 and 7.5 mm long. They emerge in June attack the root crown or lower bole of the tree, causing pitch tubes to form. Following successful attack, the adults construct irregular vertical galleries. Groups of eggs are laid in pockets excavated off the main galleries and separated from them by packed frass. The larvae feed laterally in groups, then turn up or down to form broad, L-shaped tunnels. There is one generation annually.

Activity in Jasper National Park

Dendroctonus murrayanae Hopkins has been found in the following locations (Szlabey 1994):

1952 4 mile lodge road (Middle Athabasca Fire Management Unit)

1956 Watch Tower Basin Road (Lower Maligne Fire Management Unit)

1956 Miette Campgrounds (Lower Fiddle Fire Management Unit

1959 Jasper Park Lodge (Middle Athabasca Fire Management Unit)

1964 Opposite Grizzly Creek (Sunwapta Fire Management Unit)

1966 Mount Edith Cavell Road, 0.9 miles from the junction with 93a (Middle Athabasca Fire Management Unit)

1980 Whistler Campground, Mt. Edith Cavell Road (Middle Athabasca Fire Management Unit)

1983 Athabasca view point (Middle Athabasca Fire Management Unit)

1984 Lake Annette (Middle Athabasca Fire Management Unit)

1994 Several infested trees found in the park

YELLOWHEADED SPRUCE SAWFLY

Pikonema alaskensis: **Order Hymenoptera, Family Tenthredinidae**

Species Description and Ecology

Taken from Ives and Wong 1988 unless otherwise cited

The Yellowheaded Spruce Sawfly is the most destructive of the sawflys, attacking Englemann, White and Black Spruce.

The Yellowheaded Spruce Sawfly has one generation per year and overwinters as larvae in soil-encrusted cocoons beneath the trees. [The adults] emerge from the soil between late May and mid-June. Eggs are deposited singly in the base of the new needles. The larvae at first feed on the new foliage, then move to the older foliage. They have yellowish brown heads and shiny olive green bodies with paired longitudinal grayish green dorsal and subdorsal lines. There is also a single grayish green line below the spiracles. They attain a length of 16-20 mm when fully grown.

The affected branches are almost entirely devoid of foliage, and during a heavy attack most of the trees foliage may be devoured. Repeated heavy attacks may kill the trees or severely retard both height and radial growth.

Activity in Jasper National Park (Figure 11)

1967 White Spruce was severely defoliated at the Celestine Lake turnoff from Highway 16 (Middle Snake Indian Fire Management Unit)

1969 White Spruce was severely defoliated at the Celestine Lake turnoff from Highway 16 (Middle Athabasca Fire Management Unit)

1973 planted Spruce that had been manipulated for park purposes were severely defoliated in portions of the park.

1988 light moderate and severe defoliation of roadside Spruce regeneration occurred in the park.

1989 light and moderate defoliation was noted on Highway 93 between Athabasca Falls and Jasper Townsite (Middle Athabasca Fire Management Unit)

1990 light to moderate defoliation was again reported on Spruce regeneration along the majority of major highways.

Extensive point locations were recorded for *Pikonema alaskensis*. All 152 point locations were recorded in the Middle Athabasca FMU.

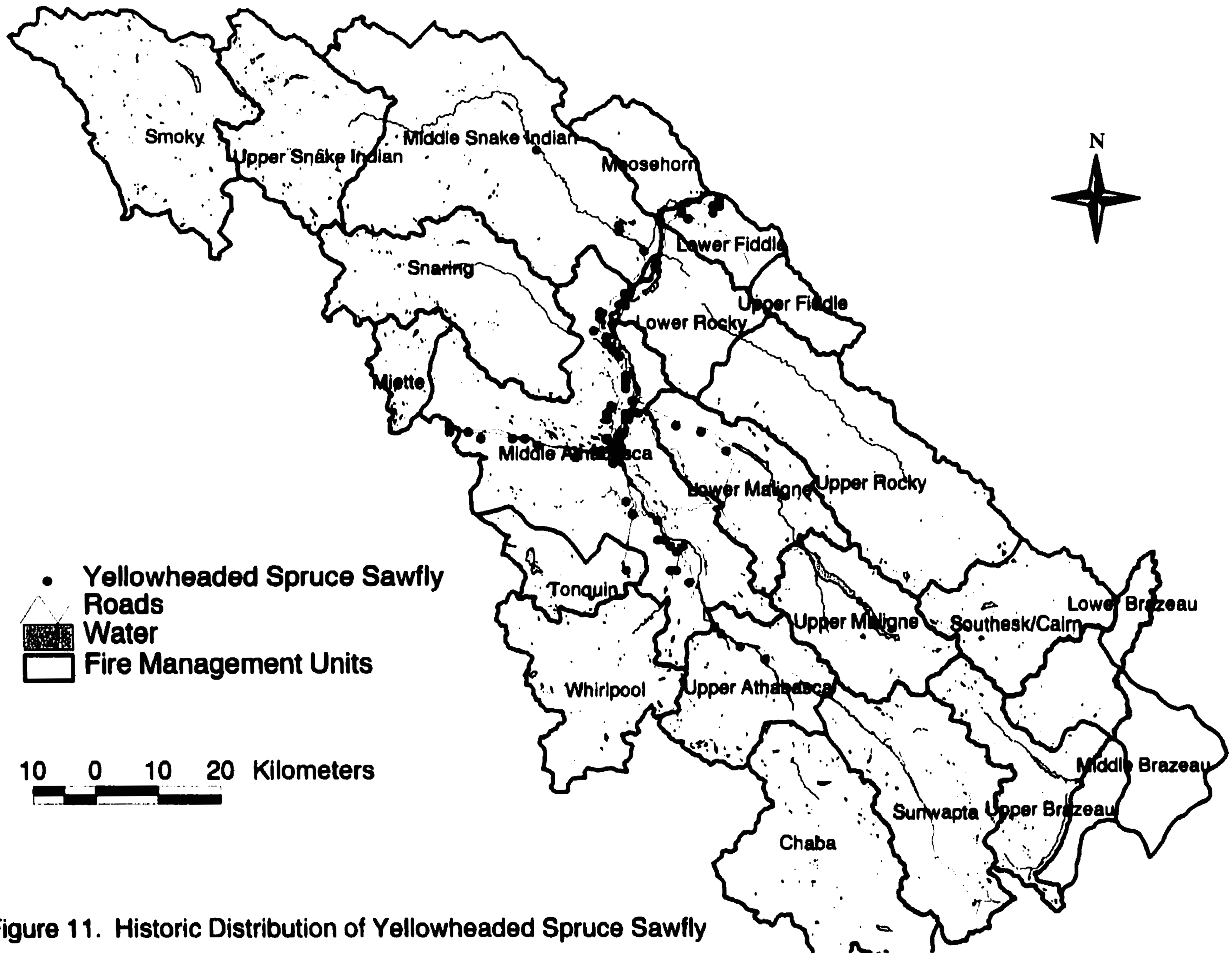

Figure 11. Historic Distribution of Yellowheaded Spruce Sawfly

GREENHEADED SPRUCE SAWFLY

***Pikonema dommockii:* Order Hymenoptera, Family Tenthredinidae**

Species Description and Ecology

Taken from Ives and Wong 1988.

The Greenheaded Spruce Sawfly is often found with the Yellowheaded Spruce Sawfly (*Pikonema alakenis)* but is not as common and usually of minor importance. The lifecycle of *P. dommockii* resembles that of *P. alaskenis*. There is one generation per year, and the larvae overwinter in soil-crusted cocoons beneath the trees. The adults emerge between late May and mid-June. Eggs are deposited singly in the base of the new needles. The larvae feed on the new foliage first, and then move on to the old foliage. The larvae have green heads and green bodies with whitish green stripes. They are approximately 20 mm long when fully grown.

Activity in Jasper National Park (Figure 12)

Occurences of *Pikonema dommockii* are well documented in the database. This agent has primarily attacked white spruce in numerous watersheds which correspond to the Miette , Middle Athabasca, Snaring, Middle Snake Indian, Lower Athabasca, Lower Maligne, Sunwapta, Lower and Upper Rocky and the Whirlpool Fire Management Units.

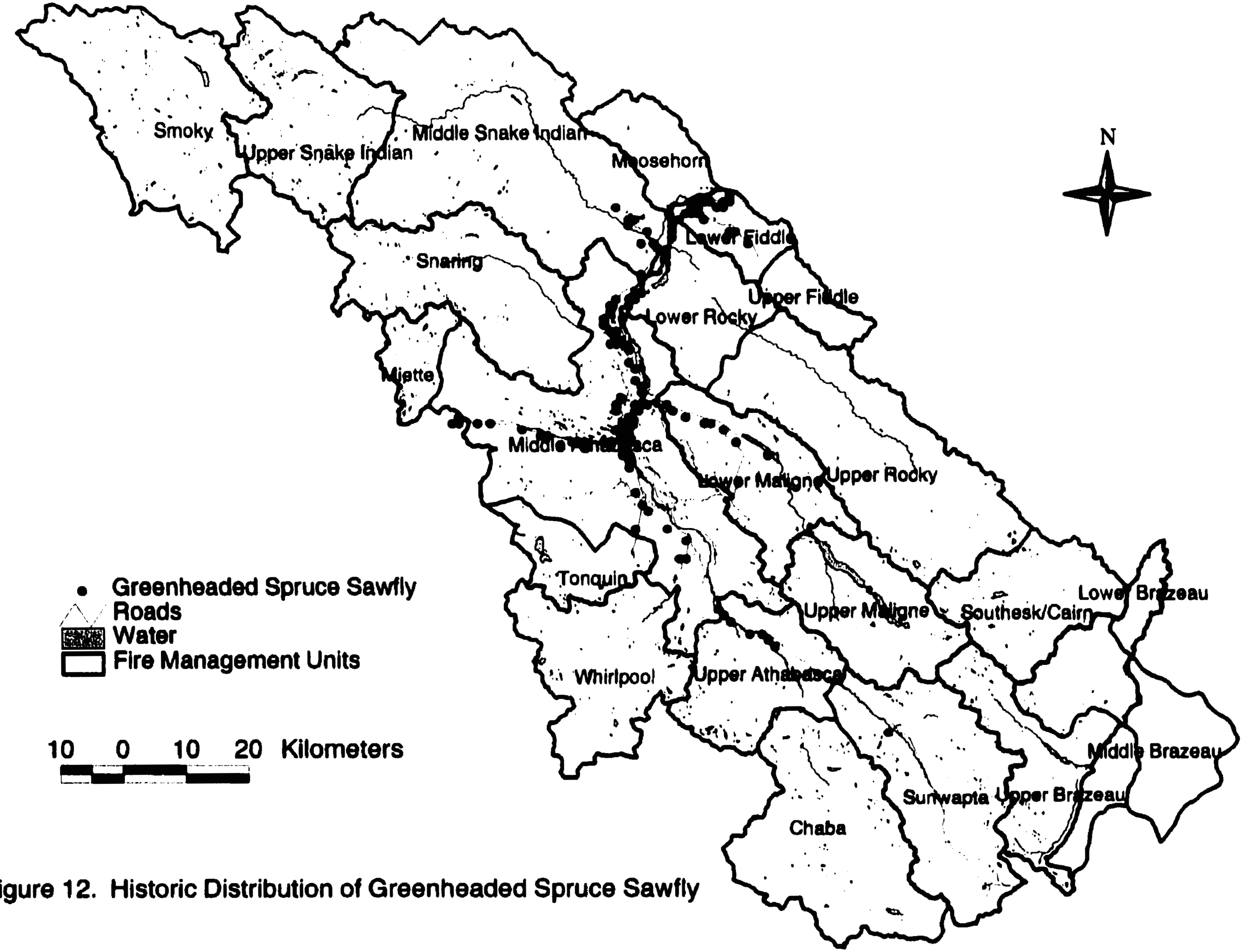

Figure 12. Historic Distribution of Greenheaded Spruce Sawfly

COOLEY SPRUCE GALL ADELGID

***Adelges cooleyi:* Order Homoptera, Family Adelgidae**

Species Description and Ecology

Taken from Ives and Wong 1988

Adelges cooleyi attacks several species of spruce throughout Canada, but is more abundant in the west where it's alternate host, Douglas Fir is present. Gall causing adelgids have complex life cycles involving sexual and asexual reproduction. *Adelges cooleyi* is a host alternating species, and requires two years to complete its lifecycle. "The flocculent stage on Douglas-fir produces both winged and wingless parthenogenetic females in the spring. The wingless females remain on the Douglas Fir, but the winged females migrate to spruce in the summer, where they lay eggs that develop into small wingless male and female aphids. After mating, each female lays a single egg at a node, between the twig and old bud scales. Female nymphs hatching from these eggs feed on the needles for a while, then migrate to the stem just below a bud, where they overwinter. Development is complete in the spring, and their feeding stimulates gall formation. Each adult female lays about 200 eggs. Nymphs hatching form these eggs migrate to the elongating new growth, where the galls are formed. The galls of *Adelges cooleyi* are typically elongate and pineapple shaped and may cause the shoot to curl if only one side is attacked. Gall formation does not cause a marked reduction in needle length on the gall. The winged parthenogenetic females emerging from the galls migrate to Douglas-fir to lay their eggs. The nymphs hatching from those eggs overwinter on the lower surface of the new foliage. There is also a wingless parthenogenetic form of *Adleges cooley* that causes flocculence on spruce and is capable of reproducing itself without an alternate host. It is not clear if galls are produced under these conditions, but what appear to be *Adelges cooleyi* galls have been found in areas where no Douglas-fir is present." The galls formed by these adelgids usually kill the affected shoots, although vigorous shoots may survive. The dead galls persist on the trees for several years. The health of the tree is usually not adversely affected unless the infestation is over a prolonged period.

Activity in Jasper National Park (Figure 13)

1965 large populations of *Adelges cooleyi* on Douglas-fir were noted along the Athabasca River between Athabasca Falls and Celestine Lake (Szlabey 1994).

Records indicate the presence of *Adelges cooleyi* throughout the park for the past four decades, especially in Fire Management Units Miette, Whirlpool, Middle Athabasca, Lower Athabasca, Snaring, Middle Snake Indian, Lower Rocky, Upper Maligne, and Lower Fiddle.

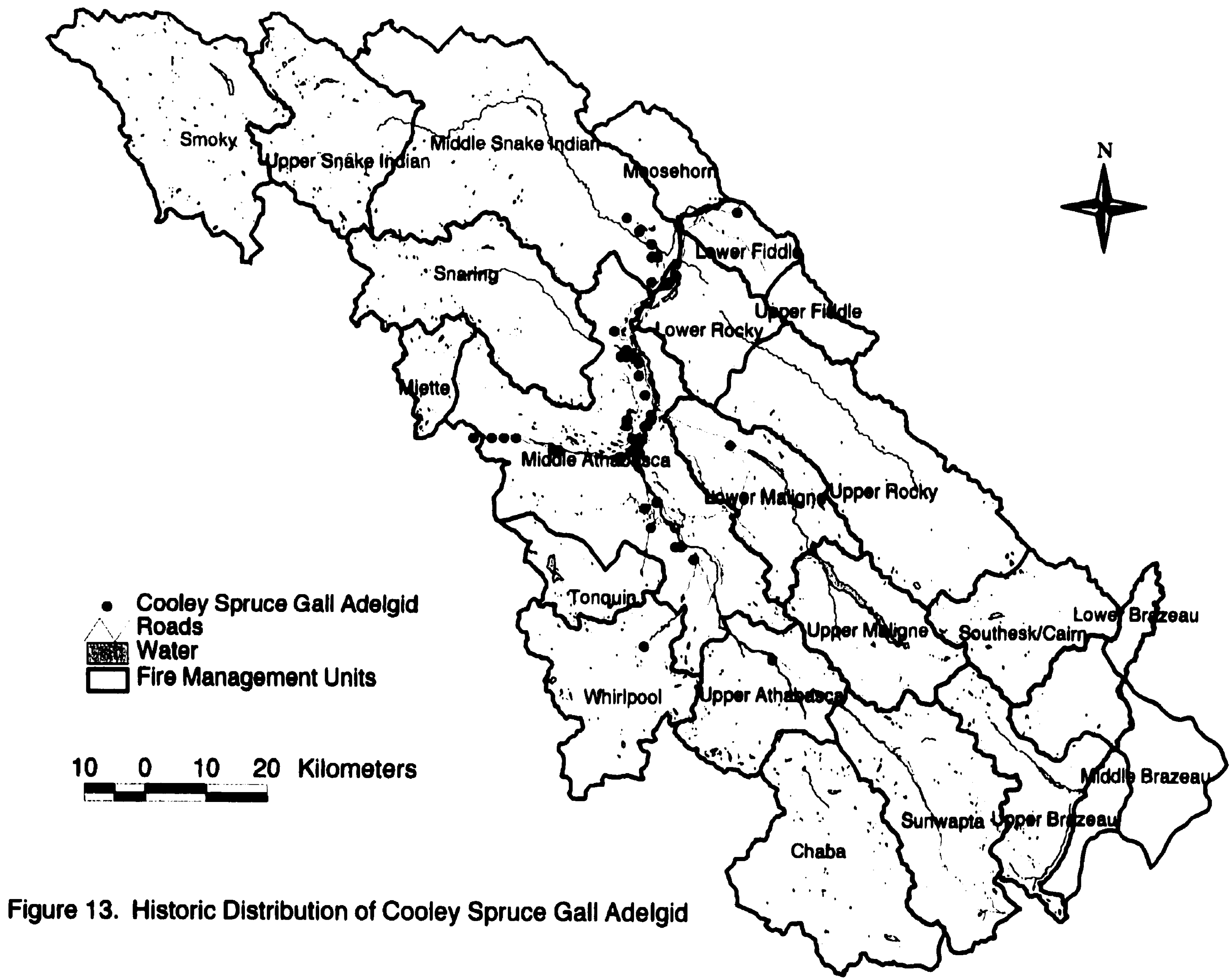

Figure 13. Historic Distribution of Cooley Spruce Gall Adelgid

LARCH SAWFLY

***Pristiphora erichsonii* Hartig: Order Hymenoptera, Family Tenthredinidae**

Adapted from Ives and Wong 1988

Species Description and Ecology

Taken directly from Ives and Wong 1988

The Larch Sawfly attacks tamarack and other Larches. It is credited with killing most of the merchantable tamarack in this country. Outbreaks in Eastern Canada were most severe. A parasite (*Olesicampe benefactor* Hinz) was introduced in Manitoba from Europe in 1961, and has since been distributed to other areas in Canada. It appears to be keeping the numbers of larch sawfly under control. Localised infestations have been noted recently in the prairie provinces, but these have not been near any of the release areas.

The Larch Sawfly normally has one generation per year; occasionally there is a partial second generation. Females lay viable eggs without mating. A small percentage of males occurs, but it is not known if they mate. The larch sawfly overwinters as larva in a tough leathery cocoon spun in moss or duff. During wet weather the larvae will spin cocoons near the surface, but during dry spells the larvae burrow down to find moisture before spinning cocoons. Cocoons spun by male larvae and by females containing the newly introduced parasite are noticeably smaller than those spun by unparasitized female larvae. Adults emerge from cocoons over a prolonged period beginning in late May or early June; consequently, some larvae complete development before the last adults have emerged. The female is about 10mm long and is predominantly black with an orange band around the abdomen and orange or yellowish markings on the legs. The eggs are laid in slits cut into the elongating shoot by the female's ovipositor, which usually causes the shoot to curl. The eggs are completely hidden when first laid, but after imbibing moisture they swell, showing their glistening surfaces. Larvae have three pairs of thoracic legs and seven pairs of abdominal prolegs. The young larvae are pale green with brownish or black heads. They cut notches in the sides of the needles at first, but soon eat the whole needle. The larvae are gregarious and feed in colonies, especially during the early instars. The colonies tend to mingle or break up as the larvae grow older, particularly during severe infestations, and it is not unusual to find older larvae feeding in small colonies or individually. Mature larvae are about 16 mm long and have black heads. The upper part of the body is grayish green, and the lower part is lighter green. The period required for individual larvae to complete feeding varies with temperature but usually ranges from 3 to 4 weeks.

Larch sawfly causes moderate to severe defoliation. This causes a marked reduction in length of the needles and in radial increment the following year. Prolonged defoliation will cause twig and branch mortality and may eventually kill the tree, although the trees can generally withstand a surprising amount of defoliation without succumbing. Even trees that have lost most of their branches may eventually recover if the outbreak subsides and growth conditions are favourable.

Activity in Jasper National Park (Figure 14)

1956-79 Small infestation present in a small isolated stand of tamarack along the Miette Hotsprings road (Lower Fiddle Fire Management Unit).

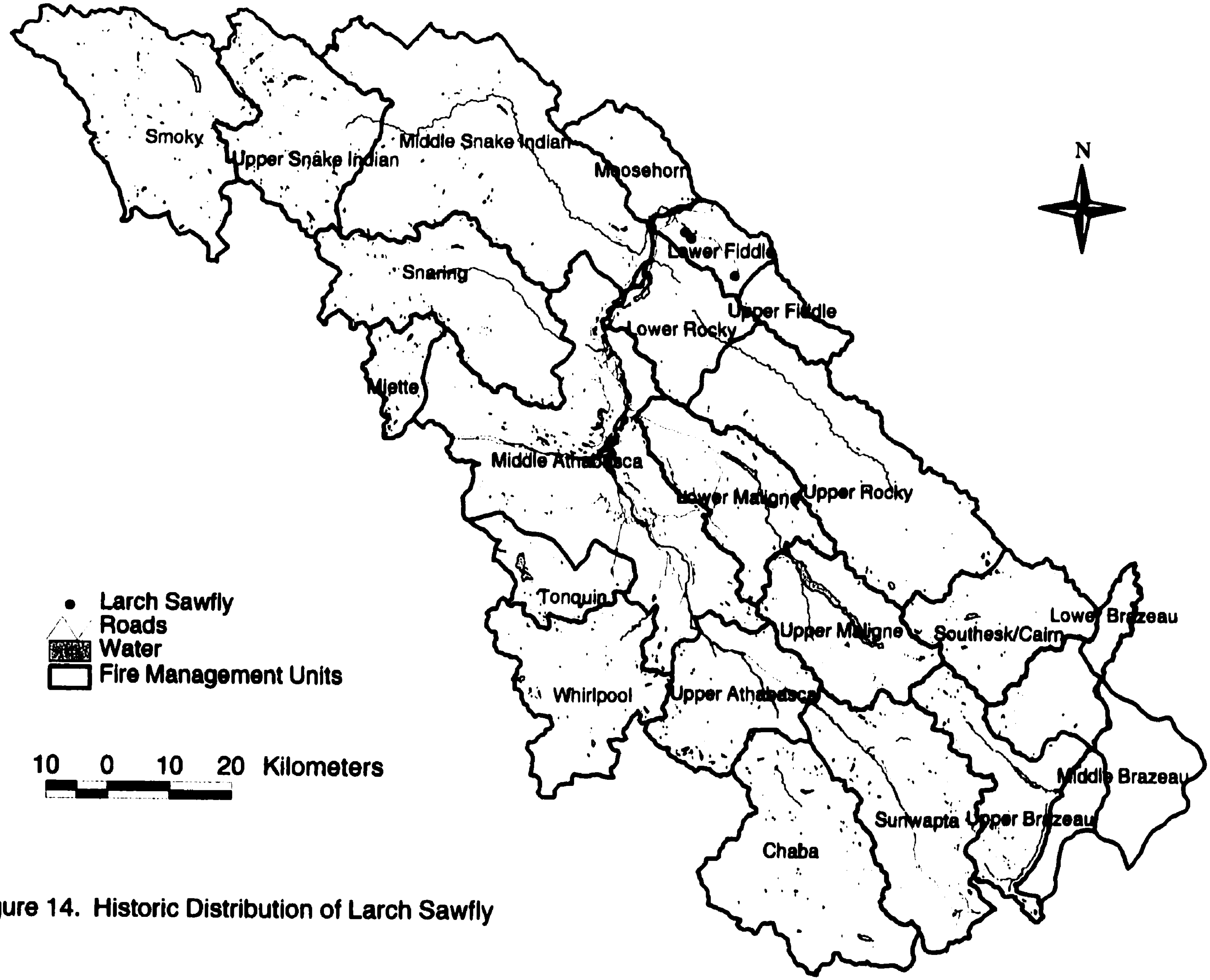

Figure 14. Historic Distribution of Larch Sawfly

WARREN ROOT COLLAR WEEVIL

Hylobius warreni Wood: Order Coleoptera, Family Cuiculionidae

Species Description and Ecology
Taken from Ives and Wong 1988

The Warren Root Collar Weevil feeds on white spruce, jack pine, lodgepole pine and several other coniferous species. Rates of infestation vary but are usually greatest on moist or wet sites.

The Warren Root Collar Weevil has a 2-year life cycle, and the adults live and lay eggs for as long as 4 years. They are stout-bodied weevils, 12-15 mm in length. The basic body colour is dark brown or black; it is covered with white or pale yellow hairs or scales that form irregular spots on the elytra and give the body a grayish appearance. The adults have rudimentary hind wings and cannot fly. They feed on the host needles or on the bark of twigs and small roots. The larvae are whitish, legless grubs with brown heads. They feed in the bark and cambial area of the host tree at or below the duff surface, causing copious flows of resin. Roots or basal stems over 25mm in diameter are tunneled by the larvae. These tunnels often girdle small trees. Last-instar larvae (up to 20 mm in length) form cells near the base of the tree in which to pupate. The exarate pupae are creamy-whit in color and are about the same size as the adults.

Hylobius warreni feeding sometimes kills young trees and is one of the most significant entry courts for root rot and other disease organisms on older trees. Young trees that die during the winter have a bleached appearance in early spring, while the foliage on those dying at other times of the year usually turns a reddish brown. Repeated attacks on mature trees, in addition to providing entrance courts for disease, cause a small but significant loss in height and radial increment.

Activity in Jasper National Park (Figure 15)

Hylobius warreni has been located in the Athabasca and Sunwapta FMU's (Szlabey 1994). Its distribution is suspected to be more widespread than is indicated by only 5 point locations in the database (only one point had GIS coordinates) (Pers. Comm

Unger). It was generally noted throughout the prairie region (including JNP) in 1994 and 1995 (Brandt 1995 and 1996).

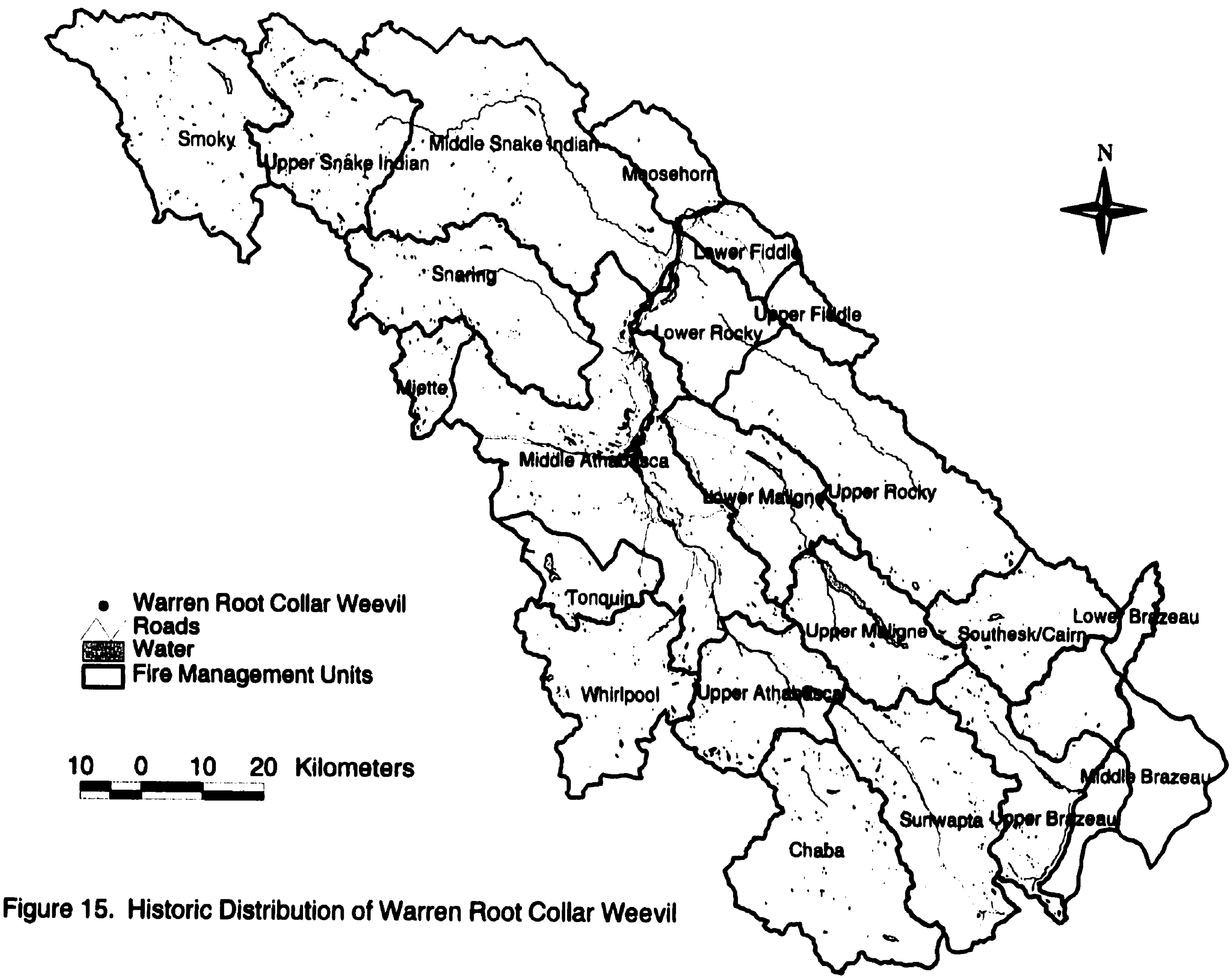

Figure 15. Historic Distribution of Warren Root Collar Weevil

PINE ENGRAVER

Ips pini Say: Order Coleoptera, Family Scoytidae

Species description and ecology
Taken from Ives and Wong

Ips pini is the most abundant *Ips* species in this region. It is widely distributed through North America, where it attacks most species of pine and occasionally spruce. Infestations are normally confined to dead wood, but the insect is capable of successfully attacking apparently healthy trees, especially during periods of spring drought. These attacks are usually limited to small trees or to the tops of larger ones and are particularly likely to occur if large amounts of slash or windfall are present. Infestations in live trees are usually short lived.

All *Ips* species that are common in this area have four spines on each side of the elytral declivity and range in colour from light brown to almost black, depending upon age. Pine Engraver adults are intermediate in size, measuring 3.5-4.5mm in length. Their galleries normally follow the grain but may run in any direction in heavy infestations on fallen trees. Young adults feed on the phloem tissue for several weeks, then emerge from the bark in September or October and hibernate in the duff. Immature stages remaining in the bark rarely survive the harsh winter temperatures in prairie provinces.

Hibernating adults become active in early spring. Males cut entrance holes through the bark, then construct nuptial chambers large enough to accommodate several females. Successful males mate with the females that have joined them. The females then begin constructing galleries in the phloem. These galleries initially radiate out from the nuptial chambers but later tend to follow the grain of the wood. Eggs are deposited in niches cut at intervals along these galleries. Larvae tend to feed at right angles to the egg galleries, enlarging their galleries as they grow. Their feeding is mainly in the phloem. Females are known to emerge from the bark after laying their first batch of eggs. Many of these females establish a second, smaller brood.

Activity in Jasper National Park (Figure 16)

Historically, Pine Engraver has occurred in the following FMU's: Middle Athabasca (from 1952-1990), Upper Athabasca (1984), Tonquin (1952-1954), and the Lower Maligne (1952) and the Middle Snake Indian (1958). More recently, infestations have been noted on the Pyramid Lake Benchlands (Personal Observations 1998) in the Middle Athabasca FMU.

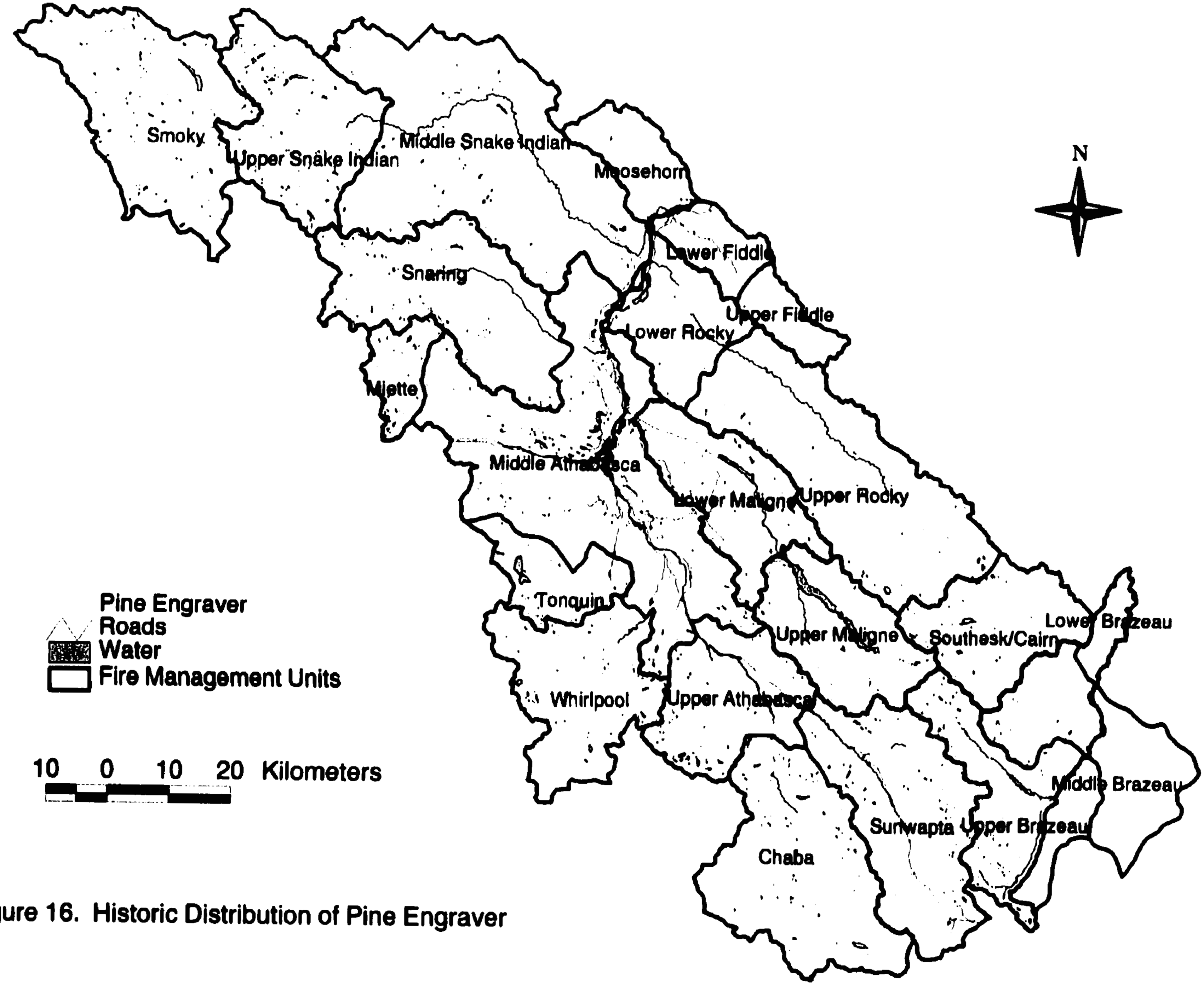

Figure 16. Historic Distribution of Pine Engraver

SPRUCE SPIDER MITE

***Oligonychus ununguis* Jacobi: Order Acarina, Family Tetranychidae**

Species Description and Ecology

Taken from Ives and Wong 1988

The Spruce Spider Mite is widely distributed in North America, attacking predominantly its primary host spruce and occasionally Balsam Fir, Douglas Fir and others.

The Spruce Spider Mite has several generations per year and over-winters in the egg stage on the host tree. The over-wintering eggs hatch in May or early June depending upon the weather, and the young larvae start feeding by sucking sap from the needles and young shoots. The newly hatched larvae are pinkish but change to green after they have fed on the foliage. They are oval is shape and have three pairs of legs. The larvae feed for about 3 days and then molt to the nymphal stage, which resembles the larval stage except that the nymphs are larger and have four pairs of legs. Young nymphs are dark green but they become dark green in the second nymphal instar. After feeding for about 6 days, the nymphs transform into adults, which are similar to the late-instar nymphs but are larger. Colour varies from dark green to dark brown. Females are about 0.5mm long and are larger than the males. They are therefore difficult to see except under magnification. The mites spin webbing wherever they go, and their feeding causes discoloration of the foliage. Both of these symptoms are indicative of mite damage, but checking the foliage with a hand lens of tapping the branches over a sheet of white paper are the best methods for confirming the presence of mites. The mites can be seen with the naked eye as minute moving dots on the white paper. Each female may live for about 1 month and is capable of laying 40-50 eggs. These eggs develop into adults in 2-3 weeks depending upon the weather, and six or more generations may occur during the summer. Hot, dry conditions appear to favour survival, and tremendously high populations may build up by late summer. Deposition of over-wintering eggs starts in early September and continues until a hard frost continues.

The mites weaken the trees by sucking the sap from the foliage, often causing it to desiccate and drop prematurely. This insidious damage often goes unnoticed, and the tree may be seriously weakened before the problem is recognised. The premature loss of foliage may kill twigs, especially in shaded areas, and may lead to the death of entire branches if the infestation persists. Extremely severe infestations may ultimately kill the trees, especially during periods of drought.

Activity in Jasper National Park (Figure 17)

Szlabey 1994

1957 moderate to heavy infestations occurred on a few trees and hedges in Jasper Townsite

1958 light infestations again present

1960 moderately heavy infestations of Spruce Spider Mite occurred on the grounds of Jasper Park Lodge; although populations in Jasper townsite had increased from 1960, damage was light.

1964 light infestations in Jasper, Radium and Banff

Present light infestations around townsite and in valley bottoms (A. Westhaver pers. Comm., N. Wilson a.h.s.).

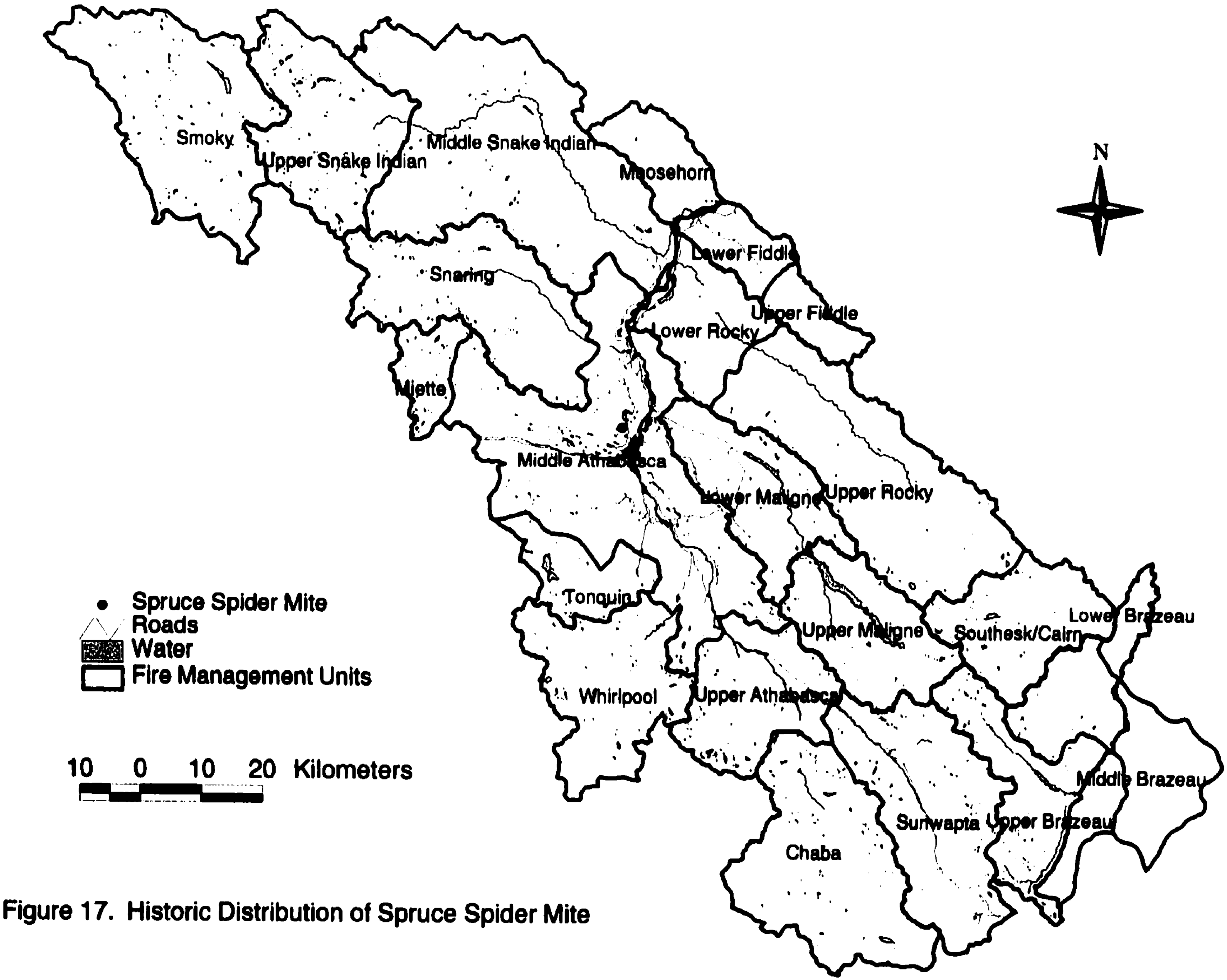

Figure 17. Historic Distribution of Spruce Spider Mite

Forest Tent Caterpillar

Malacosoma disstria Huber: Order Lepidoptera, Family Lasiocampidae

Species Description and Ecology

Taken from Ives and Wong 1988

The Forest Tent Caterpillar is a severe defoliator of aspen. Outbreaks typically last 4 or 5 years, but some persist for several more years. The average period between the 1st years of severe defoliation at any given location is about 10 years, with a range of 6 – 16 years. This means that there is nearly always an outbreak in progress somewhere within the prairie provinces. Light defoliation has little effect on tree growth. Two or more years of moderate to severe defoliation, however, causes a severe reduction in radial growth and may cause considerable branch and twig mortality. Normally there is very little tree mortality directly attributable to defoliation, even when the trees are completely stripped of foliage, because the trees refoliate and produce enough new leaves to carry on essential photosynthesis.

The Forest Tent Caterpillar has one generation per year. The young larvae hatch early in the spring, usually more or less coincident with the flushing of the aspen foliage. They are black and hairy and are about 3 mm long. If the foliage has not flushed the larvae will mine the buds. The larvae are gregarious, and although they do not form a tent they spin a trail of silk wherever they go. When not feeding they rest in a mass on a silken mat spun on the trunk or larger branches. There are five larval instars. Mature larvae are about 45-55 mm long and are covered with conspicuous silky hairs. They have broad, bluish lateral bands on the body and a dorsal band that has conspicuous white or creamy keyhole-shaped marking on a predominantly brownish black background. There are broken orange and brown lateral lines on each edge of the dorsal band. Five of 6 weeks after hatching form the egg, the mature larvae form silken cocoons that contain a powdery yellow substance. The cocoons are spun between aspen leaves if the stand is not completely defoliated but may be spun in almost any available site if the trees are stripped of foliage. The larvae pupate soon after cocoons are spun, and the stout-bodied moths emerge about 10 days later. The moths live only a few days and are light yellow to buff brown in colour with two oblique dark bands on the fore wings. They have a wingspan of 35-45 mm. The female deposits her eggs around a small twig in a band that usually contains between 150 and 200 eggs. The number may be as small as 100 or as great as 300, however, depending on the vigor of the female. The eggs are covered with a frothy substance called spumaline, which is brown in colour. Weak females often deposit egg bands that become fully developed larvae about a month after the eggs are laid, but the larvae do not normally emerge until the following spring.

Activity in Jasper National Park

1961 light to moderate defoliation from forest tent caterpillar was note north of the Jasper Townsite (Middle Athabasca Fire Management Unit).

Forest tent caterpillar has been active in parts of the province in 1994, 1995 and 1996, when populations increased by 40%) (Brandt 1995; 1996; 1997). However, recent activity in Jasper National Park has not been noted.

ASPEN SERPENTINE LEAFMINER

***Phyllocnistis populiella* Chambers: Order Lepidoptera, Family Gracillariidae**

Species Description and Ecology

Taken from Ives and Wong 1988

Several small moth larvae mine the leaves of aspen. The Aspen Serpentine Leafminer, *Phyllocnistis populiella* Chambers, forms serpentine mines in the upper and lower surfaces of trembling aspen leaves. Similar mines are sometimes found on other tree species, but these are probably caused by related but undescribed species. The aspen serpentine leafminer has one generation per year and overwinters in the adult stage. The tiny, mainly whitish moths have a wingspan of about 5 mm and emerge from hibernation more or less coincident with the flushing of trembling aspen foliage. They feed on nectar produced by glands near the base of some of the young trembling aspen leaves. Eggs are laid on both the upper and lower surfaces of the leaves, although the majority are on the upper surface. The young larva enters the leaf by chewing its way through the bottom of the egg. The larvae have four instars. The first three instars have sickle-shaped mandibles and consume only epidermal cells, without breaking the cuticle. The larvae meander back and forth in the leaf, leaving a streak of frass. The are 3-6 mm long when fully grown. Fourth-instar larvae have no functioning mouth parts. They spin silken cells within the mines, in which pupation occurs. Adults emerge in late July or early August. They are active for several weeks before they disappear, presumably to hibernate in the duff.

The leaf miners have little adverse effect on the host trees. The mining of the leaf tissue causes the leaves to dry out and turn brown, however, and may lead to premature leaf drop, especially during severe infestations.

Activity in Jasper National Park (Figure 18)

1957 heavy infestation on Yellowhead Pass in the park; in an area extending 3 miles along the valley, ined. (Middle Athabasca FMU).

1960 heavy infestation from Athabasca Falls (Middle Athabasca FMU) to approximately 10 miles north of Jasper Townsite, westward along the Miette Valley to Geikie (Middle Athabasca and Tonquin

FMU's) and eastward to Maligne Canyon (Lower Maligne FMU). Moderate infestation surrounded the heavy infestation extending north to the Fiddle River Bridge and east to Medicine Lake (Lower Maligne FMU).

1962 numerous from Athabasca Falls to the Snaring River (Middle Athabasca FMU), from the junction of the Athabasca and Miette Rivers up the Miette Valley to the park boundary (Middle Athabasca and Miette FMUs), and from the mouth of the Maligne River up the Maligne Valley for 8miles (Lower Maligne FMU).

1964 Moderate infestations near the town of Jasper (Middle Athabasca FMU)

Point locations for aspen serpentine leaf miner have historically been recorded in the following FMU's: The Middle Athabasca, the Miette, the Middle Snake Indian, The Lower Maligne, the Lower Fiddle, and the Tonquin.

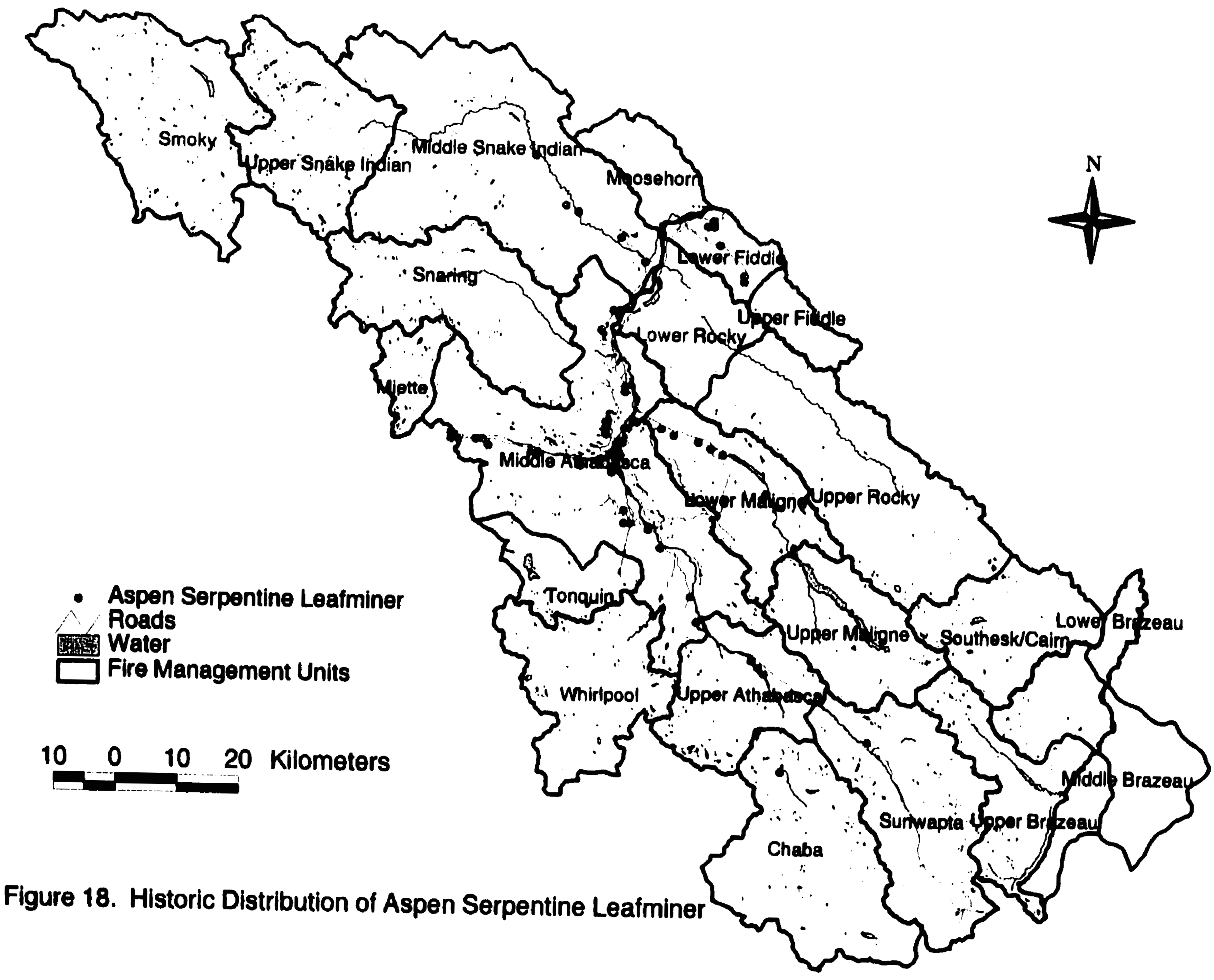

Figure 18. Historic Distribution of Aspen Serpentine Leafminer

ASPEN LEAF ROLLERS

Epinotia species: **Order Lepidoptera, Family Torticidae**

Species Description and Ecology

Adapted from Ives and Wong 1988

Several species of *Epinotia* have been noted in Jasper National Park, including *Epinotia solandriana* Linnaeus. The lifecycles of these Aspen Leaf Rollers are not fully understood. It is known that they overwinter as eggs. The larvae have yellowish brown heads marked with black or dark brown and have creamy coloured bodies. The thoracic shield is yellow to yellowish brown, sometimes with brown edges. The anal plate is pale, and the large setal basis may be the body colour or light brown.

Damage from the Aspen Leaf Roller caused the leaves to roll-up, but often little damage is done to the tree.

Activity in Jasper National Park (Figure 19)

Almost all recordings of *Epinotia* activity have been in the Middle Athabasca FMU.

Occasionally the genus has been recorded in the Lower Fiddle and Lower Maligne FMU.

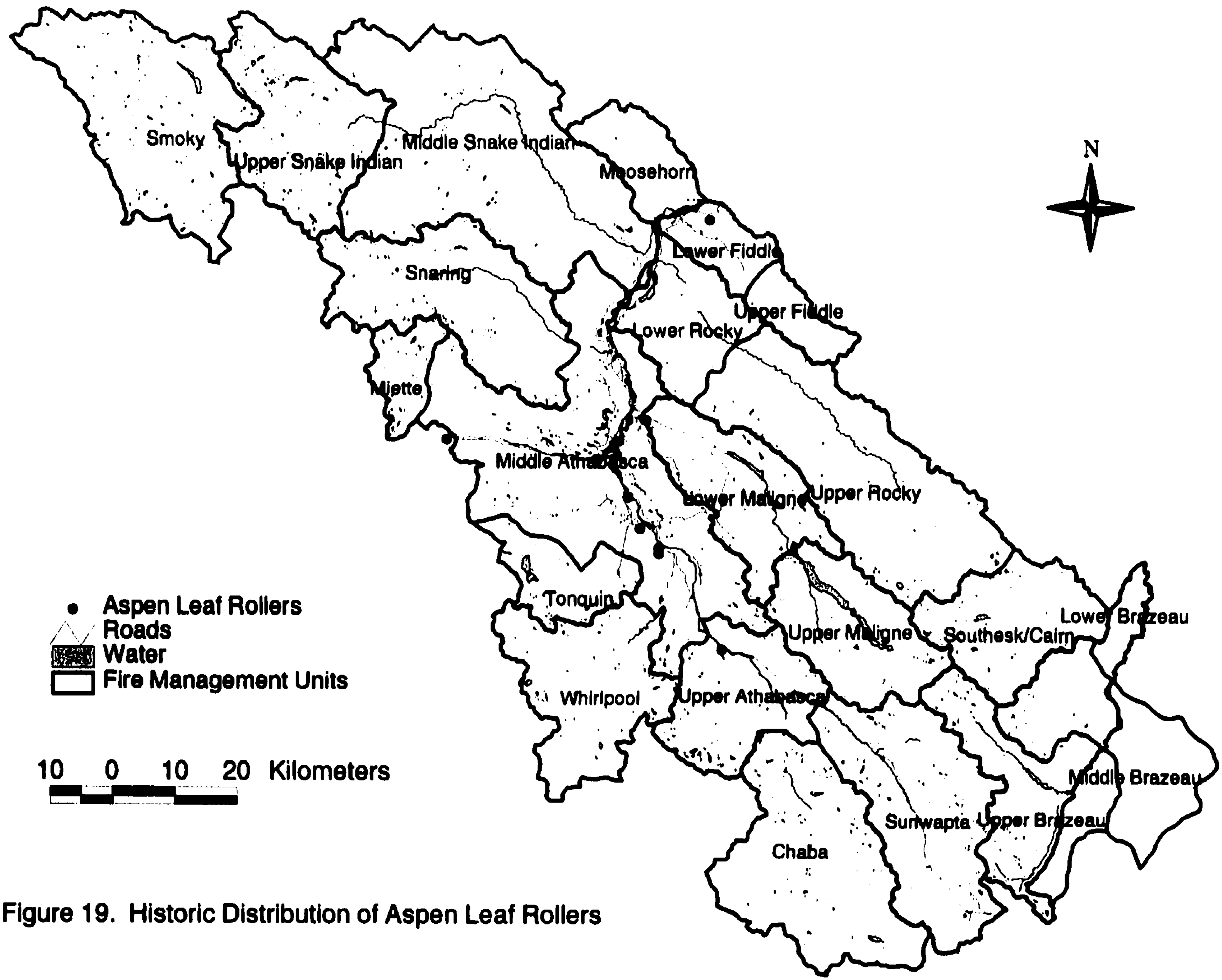

Figure 19. Historic Distribution of Aspen Leaf Rollers

3.3.5 Major Diseases

Two major diseases have been recorded in Jasper National Park: *Arceuthobium americanum* (Lodgepole pine dwarf mistletoe) and *Armillaria mellea* (Armillaria root rot).

Lodgepole Pine Dwarf Mistletoe

***Arceuthobium americanum:* Family Loranthaceae**

Species Description and Ecology
Taken from Hiratsuka 1987

Lodgepole Pine Dwarf Mistletoe is a parasitic flowering plant belonging to the family Loaranthaceae. The two main hosts are Lodgepole Pine and Jack Pine, although it occasionally attacks other species.

The most conspicuous symptom of dwarf mistletoe infection is the production of witches brooms. The size and shape of the brooms vary depending on the host species and the age and position of the infection. Witches' brooms on jack pine tend to be much larger and more open than those on lodgepole pine. Infected branches are usually twisted and produce spindle-shaped swellings. Dwarf Mistletoe is dioecious (having separate male and female plants). Aerial shoots of dwarf mistletoe are greenish yellow and up to 10cm long and consist of branch segments with reduced scale-like leaves. Depending on the sex of the plant, they produce male or female flowers during late spring or early summer. After pollination, berries are produced on female plants in the summer and remain on the plant for about a year before they ripen. When aerial shoots become nonfunctional, they fall off and leave basal cups, which stay for several years. The basal cups are connected to the endophytic system of the dwarf mistletoe in the pine tissue and are important diagnostic features of Dwarf Mistletoe, because witches' brooms and swellings of the stem can also result from many other causes and fresh aerial shoots are often absent.

The single, large seed in a berry is forcefully discharged during mid-August to mid-September. The speed of discharge has been measured at approximately 25 m/s, and the seed has been known to fly up to 15m. The seed is surrounded by a hygroscopic, sticky material called viscin that enables it to adhere to the surface on which it lands. When seeds land on susceptible host tissue they overwinter, germinate in May or June, and penetrate the host. Young twigs are most susceptible. It takes about 3 to 5 years before the infection produces aerial shoots. Flower and seed production usually begins 1 to 2 years after the shoots first appear.

These diseases cause the largest amount of annual loss in merchantable Lodgepole and Jack Pines in the prairie provinces. Heavily infected young trees will not reach merchantable size. Dwarf Mistletoe not only causes mortality but also reduces growth by about one-third. Dwarf Mistletoe is particularly damaging to immature stands up to 50 years old. The unsightly appearance of the infected trees due to brooming is also a serious concern in townsites and parks.

Activity in Jasper National Park

(Szlabey 1994)

1952 severe infection in Jasper near townsite (Middle Athabasca FMU)

1959 extensive infections on lodgepole pine 10 miles south of Jasper (Middle Athabasca FMU)

1965 approximately 60 percent of the lodgepole pine in four separate and well-defined areas in Jasper Townsite were infected with this mistletoe (Middle Athabasca FMU)

1972 severe mortality occurred in pine stands north of Athabasca Falls and along the Jasper Airfield (Middle Athabasca FMU)

1988 caused considerable mortality in the vicinity of Jasper townsite and south of Jasper townsite and south of Jasper townsite along Highway 93 between Athabasca Falls and Jasper.

1995 extensive infestations recorded in Jasper National Park (Brandt 1995).

ARMILLARIA ROOT ROT
Armillaria ostoyae

Species Description and Ecology
Taken from Hiratsuka 1987

Armillaria was originally considered a single species (*Armillaria mellea*) but is now suspected to be made up of many distinct species of *Armillaria*. The main species causing mortality of conifers in the prairie provinces is now *A. ostoyae.* It is also present on aspen in Northern Alberta.

This disease has been reported from most areas of the world and is common in the prairie provinces. Some of the typical symptoms of Armillaria Root Rot are abrupt or gradual reduction in growth, bright reddish brown or yellowish discoloration of foliage over the whole tree, and resinosis around the root cooler. White, radiating mycelial fans formed between the bark and wood around the base of the infected trees are typical signs. Dark brown or black fungal strands called rhizomorphs or shoestrings are also formed on decayed wood or in the soil surrounding the diseased roots. In the fall, fruiting bodies (known as honey mushrooms) may be formed on diseased trees. The mushrooms are honey-yellow to brown, have annular rings, and are edible. In larger trees, the diseases causes spongy root and butt rot with numerous fine, black zone lines.

The disease cycle is not completely known. Infection of living trees probably occurs mainly by rhizomorphs and by root contacts or root grafts. Rhizomorphs are usually found on diseased tissue but are known to extend up to 10 m in the soil behind infected host plants. Spores produced on sporophores (mushrooms), which disperse to dead stumps or other dead woody material, may also play some role in dissemination of the disease.

Small infected trees are usually killed quickly; large trees may have reduced growth but keep growing for a long time in spite of the presence of the fungus in the root system or as butt rot. Often it is difficult to assess the true impact of this disease because it tends to kill trees already weakened by unfavourable environmental conditions, insects and other diseases. This disease is especially important in plantations or highly managed stands because it tends to kill young trees in groups and thus created undesirable gaps in well-spaced stands.

Activity in Jasper National Park

In 1987, lodgepole pine mortality caused by Armillaria Root Rot occurred at several locations in the park (Szlabey 1994). In 1994 and 1995, Armillaria infection centers found throughout most of the prairie provinces.

3.3.6 Minor Diseases

There is a multitude of minor diseases in Jasper National Park. Many of these diseases can be classified into general groups such as needle casts, blights or rusts. Many of these diseases are difficult to identify to a species level without the help of experts. To make the ecology section for minor diseases manageable and more user-friendly, minor disease ecology and historical occurrences will be discussed under general headings.

NEEDLE CASTS

Species Description and Ecology
Adapted from Hiratsuka 1987

Needle casts and other needle diseases can be found on pine, spruce and fir in Jasper National Park. Needle casts is the term used for a group of needle diseases caused by fungi belonging to the class Ascomycetes. Distribution of needle casts on spruce is widely distributed in the prairie provinces. On pine, distribution and abundance vary from year to year. The distribution of needle diseases on fir is not well understood in Jasper National Park.

Various patterns of discoloration, death and casting of needles are the most common symptoms of this group of diseases. It is often difficult to tell which species is the causative agent. Positive identification can be accomplished only when mature asci or ascospores are present and can be examined microscopically (although a few species exhibit specific symptoms and can be identified easily).

Windborne ascospores produced on second or third-year needles infect current-year needles in the spring or early summer. Symptoms may not show until late summer or fall. Mature fruiting bodies are usually produced during the winter and sporulate during the spring.

None of the needle rusts kill large trees or affect their health significantly unless heavy and repeated infections occur over successive years. Extensive defoliation can reduce the vigor of small trees and affect tree growth and shape in general.

Activity in Jasper National Park

Szlabey (1994)

1954 *Hypodermella montivaga* (Petrak) (needle cast of lodgepole pine) occurred in epidemic proportions in Jasper National Park. Found frequently in areas that sustained attack by lodgepole pine needleminer. Affected areas include pole-sized trees in Poboktan Creek and Mt.

Edith Cavell areas.

1955 *Hypodermella montivaga* (Petrak) epidemic in same areas as last year.

1964 *Hendersonia pinicola* caused heavy damage to lodgepole pine in extended areas of the park.

1966 *Elytroderma deformans* (Weir) Darker (needle cast on pine) present in light to severe infestation South of Jasper townsite to Athabasca Falls.

1966 *Hypodermella concolor, Hypodermella montana, Lophodermium pinastri and Gloeeocoryneum* cinereum caused severe damage to lodgepole pine at the west end of Maligne Lake.

1967 *Elytroderma deformans* (Weir) Darker caused considerable needle drop in the vicinity of Athabasca Falls.

1971 *Elytroderma deformans* (Weir) Darker – high infections were noted between Jasper townsite and Athabasca Falls

1973 *Hendersonia pinicola* – a pocket of severe infection was recorded at mile 17 on the Celestine Lake Road.

1984 *Lophodermella concolor* [Dearn.] Darker – moderate to severe infestations occurred on many Individual trees

1995 *Lophodermella concolor* [Dearn.] Darker was observed in the Rocky Mountain National Parks and in the Eastern Slopes Region, but at much reduced levels over those seen in the last several years.

LEAF SPOT DISEASES ON ASPEN AND POPLAR

Species Descriptions and Ecology
Taken from Hiratsuka 1987

No detailed distribution data are available for each leaf spot disease in the prairie provinces. The main hosts are aspen (*Populus tremuloides*)and balsam poplar (*Populus balsamifera*). There are some conspicuous symptoms for each leaf spot disease, but microscopic examination of spores (mostly conidia) is required for accurate diagnosis of most species.

In general, airborne ascospores are produced on overwintered dead leaves in spring and initiate infections on newly formed leaves. Conidia can repeat infections during the growing season.

Infections are often heavy and cause premature shedding of leaves; however, leaf spot diseases seldom significantly affect the health of trees unless repeated severe infections occur.

Activity in Jasper National Park

1990 *Marssonina populi (*Lib) Magn. Noted at several locations throughout Jasper National Park

1994 *Marssonina populi (*Lib) Magn. And *Marssonina tremuloides* Kleb. – severe damage noted near Hinton and in Jasper National Park (Brandt 1995). Light to moderately infected trees throughout The park (Gates 1995).

WESTERN GALL RUSTS

Species Descriptions and Ecology
Taken from Hiratsuka 1987

Western Gall Rust on Pine is caused by the fungus *Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka. This rust is found across Canada. The major host in Jasper National Park is lodgepole pine.

Conspicuous perennial globose galls are produced on the stems of hard pines. During May to July powdery, orange-yellow spores are produced on the surface of the galls. Very young galls are sometimes spindle-shaped swellings produced by another pine stem rust, comandra blister rust (*C. comandrae* Pk.).

This rust has an autoecious cycle, meaning it is capable of infecting pine directly without going to an alternate host. Spores produced on the galls from the end of May to July become airborne and infect the green tissue of young shoots. Small galls appear a few months after infection but do not produce spores until the year following infection. Galls grow each year and produce spores every spring for many years, unless the gall tissue dies with the stem or sori are inactivated by mycoparasites.

Main stem galls often kill small trees, but small active galls usually increase annually in size and produce spores each spring for many years without killing the trees. Trees with main stem galls tend to be deformed and easy to break at the gall. Branch galls on large trees do not affect the vigor of trees significantly. This disease tends to be intensified in highly managed young pine forests probably because of the pine-to-pine life cycle, the high susceptibility of vigorously growing shoots, and the perennial nature of active galls, which serve as inoculum sources.

Activity in Jasper National Park

1972 *Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka jack pine regeneration was severely infected along the Whirlpool River fire access road.

1994 *Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka - Common on pines throughout region (Brandt 1995).

1995 *Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka – high incidence of this disease observed in Jasper National Park

NEEDLE RUSTS

Species Description and Ecology
Adapted from Hiratsuka

There are numerous species of needle rusts occurring on pine, spruce and fir. On pine, the rust fungus is *Coleosporium asterum* (Diet.) Syd. The main host in this area is lodgepole pine, but the fungus is known in all the prairie provinces and the Northwest Territories. Eight needle rusts are known on spruce in the prairie provinces, but the most prevelant species are *Chrysomyxa ledicola* lagh. and *Chrysomyxa ledi* d By. There are six species of needle rust common on fir in the region, although the distribution of each species is not well known.

Symptoms of infection range depending on the host species and the pathogen causing the symptoms.

Coleosporium asterum (Diet.) Syd infection on lodgepole pine is recognized easily by the orange-yellow aeciospores produced in whitish cylindrical columns (peridermia) on second-year needles. Infected needles are often older and paler in color and drop prematurely. Pustules of powdery, yellow urediniospores are produced on the lower side of leaves of alternate hosts, and smooth, raised orange-red telia appear later in the growing season. Infections on pine are initiated on first-year needles in late summer by basidiospores produced on alternate hosts (asters and goldenrods). The rust overwinters in infected needles and produces spermogonia and aecia the next spring. Aeciospores are disseminated by wind and infect leaves of alternate hosts. Urediniospores are then produced that can reinfect alternate hosts. Later in the season, teliospores develop on the alternate hosts and germinate to produce basidiospores.

Chrysomyxa ledicola lagh. and *Chrysomyxa ledi* d (By) infection on spruce results in a slight discoloration of the needles. On the needles may be found small, dot-like sexual fruiting structures (spermogonia), which produce spermatia, and cup-or tongue-shaped structures (aecia), which produce powdery, orange-yellow aeciospores. Infected needles drop prematurely. Positions of the spermogonia on the needles (subcuticular or subepidermal) and size of aeciospores are important characteristics for species identification. Powdery, orange spores (aeciospores) produced on spruce needles infect young leaves of the alternate host, *Ledum sp.p*, in the spring. Small infected areas develop on the leaves of *Ledum* spp. in the fall. After the fungus overwinters, waxy mound-like spore structures (telia) are formed. Upon germination of teliospores, fragile basidiospores are formed and become windborne. They may infect young needles of spruce. Later orange pustules (uredinia) are formed on the same leaves of *Ledum* spp., and powdery, orange spores (urediniospores) produced in them can re-infect leaves of *Ledum* spp.

On fir, infected needles are often chlorotic or discolored (yellow, brown) or become chlorotic and shed prematurely. Small, dot-like spermogonia and yellowish-orange or white cup-shaped aecia with powdery aeciospores are produced on the undersides of needles. *Melampsorella caryophyllacearum* causes conspicuous witches' broom symptoms similar to yellow witches' broom of spruce. The typical disease cycle of a fir needle rust, exemplified by *Pucciniastrum epilobii*, is as follows. The pathogen overwinters in cushion-shaped fruiting bodies (telia) on dead leaves of fireweed. In the spring, teliospores germinate to produce fragile, windborne basidiospores. They infect newly produced fir needles. In a few weeks minute, dot-like sexual fruiting structures (spermogonia) are produced. They are followed by cup-shaped aecia containing powdery, yellow aeciospores. These spores infect leaves of fireweed and produce a repeating spore state (uredinia) with powdery spores (urediniospores); later, cushion-shaped, dark-colored telia are formed. Disease cycles of other needle rusts of fir are similar to that of *Pucciniastrum epilobii.*

Generally, these diseases do not cause significant damage. However, infection by needle rusts can occasionally be very heavy, and all or most of the current year needles to be dropped prematurely. Repeated heavy infections may cause a reduction in the growth of small trees. One species, *Pucciniastrum epilobii* can inhibit the growth of young alpine fir in years of heavy infection

Activity in Jasper National Park

(Szlabey 1994)

1972 *Chrysomyxa ledicola and Chrysomyxa ledi* (needle rusts on spruce) – severe infections Recorded at Maligne Canyon and Medicine Lake

1973 *Chrysomyxa ledicola and Chrysomyxa ledi* – moderate to severe infections along Maligne Lake Road

1990 *Chrysomyxa ledicola* (Pk.) – severe needle discoloration evident along Mt. Edith Cavell Road

1994 *Chrysomyxa ledicola* (Pk.) – severe needle discoloration evident along Mt. Edith Cavell Road The primary species involved in *Lophodermella concolor* [Dearn.] Darker, although other species are of note including *Elytroderma deformans* (Weir) Darker and *Davisomycella ampla* (Davis) Darker (Gates 1995).

Aspen and Poplar Leaf and Twig Blight

Species Description and Ecology
Taken from Hiratsuka, 1987

Two very similar leaf and twig blight diseases are caused by closely related fungal pahtogens: *Ventura maclaris* (Fr.) E. Muller on aspen and *Ventura populina* (Vuill.) Fabric., on balsam poplar. The two diseases are distributed widely throughout the praire provinces and other parts of th northen North America.

Blackening and wilting of young shoots and leaves are typical symptoms of the two diseases. Tips of the blackened shoots often bend back, producing the shepherds crook symptom. On older leaves brownish black, irregularly shaped spots appear. Typical conidia are produced on infected leaves and young shoots an permit positive identification of the diseases.

Ascospores and conidia produced on dead overwintered tissues are dispersed by the wind and infect newly formed shoots and leaves in the spring. Conidia are produced on the blackened part of stems and leaves develop fully and reinfect young leaves. Once leaves develop fully and harden, no new infections seem to occur. Later in the fall and during the winter, the perfect stage of the fungi (perithicia with ascospores) begins to form on dead infected tissues.

When most of the tender shoots of young trees are attacked, the trees are disfigured and growth is severely affected. Infection on larger trees is rare and does not siginifcantly affect their growth.

Activity in Jasper National Park

1994 Most areas of Jasper National Park affected by *Venturia macularis*. Infections were moderate to severe in many areas (Gates 1995)

1998 Twig Blights of aspen and poplar widespread in Northern Alberta (Ranasinghe et al 1998)

3.3.4 Non-native agents of concern

Parks Canada aims to identify, eliminate or control non-native forest insect and disease populations (Parks Canada 1997a). They following are considered agents of concern for Jasper National Park.

WHITE PINE BLISTER RUST
***Cronartium ribicola* J.C. Fisch**

Species Description and Ecology
Taken from Hiratsuka 1987

White Pine Blister Rust is caused by the rust fungus *Cronartuim ribicola* J.C. Fisch. This fungus is the most destructive disease of white pines in North America, Europe and Asia. In the Prairie Provinces the hosts of this fungus are Whitebark Pine (*Pinus albicaulis* Engelm.) and limber pine (*Pinus flexilis* James) at high elevations in the Rocky Mountains. Alternate hosts are many species of gooseberry and currant belonging to the genus *Ribes*. The rust occurs on alternate hosts beyond the range of infected pines.

Elongated cankers girdle the stem and eventually kill the tree beyond the cankers, thus causing spiketop or flagging symptoms. On alternate hosts, dome-shaped uredinia, containing urediniospores, and column-shaped uredinia or column-shaped telia of *C. ribicola*.

Fragile, windborne spores (basidiospores) produced on alternate host plants initiate the infections of pine through the needles, and then it grow into the stems. Elongated cankers develop, and one to several years after infection spermogonia with sweet droplets containing sexual spores (spermatia) are produced; later, aecia break through the bark. Powdery, orange-yellow aeciospores are released from the blisters. The aeciospores are windborne and infect alternate hosts but are incapable of reinfecting pine. Within a few weeks, small dome-shaped, spore-producing uredinia are formed, and urediniospores produced in them can reinfect alternate host leaves. Later, clumnar or hair-like structures called telia are produced that consist of aggregations of teliospores. Basidiospores are produced upon germination of teliospores.

White Pine Blister Rust kills white pines of all ages and sizes. Limber and whitebark pines in the Rocky Mountains are heavily infected.

Activity in Jasper National Park

It is likely that all whitebark pine in Jasper National Park are infected with this fungus (Pers. Comm Achuff).

1970 Mortality of whitebark pine reported at Mount Edith Cavell and near Athabasca Falls (Szlabey 1994).

1974 Mortality of regeneration whitebark pine was noted along Mount Edith Cavell and Geraldine Tower Roads (Szlabey 1994).

GYPSY MOTH

Lymantria dispar (Linnaeus): Order Lepidoptera

Species Description and Ecology
Taken from Ives and Wong 1988

The gypsy moth was introduced into North America in the 19^{th} century and is gradually spreading westward. It will feed on almost any species of tree or shrub.

Gypsy moth overwinters in the egg stage. Adults of both sexes have wings, but only the males fly. The males have whitish fore wings marked with dark wavy lines. The larvae are very hairy and reach a length of 30-65 mm when fully grown. The body is yellowish brown and densely mottled with black and has a middorsal row of blue and red tubercles.

Gypsy moth may become a major defoliator if it establishes in this area.

Activity in Jasper National Park
Gypsy moth has not been detected in Jasper National Park to date. Jasper continues to participate in the Gypsy moth monitoring program with the Canadian Forest Service. Approximately 10 pheromone traps are placed in the park each year in an attempt to detect the moth.

EUROPEAN ALDER LEAFMINER

***Fenusa dohrnii* (Tischbein) Order Hymenoptera, Family Tenthredinidae**

Species Description and Ecology

Taken from Ives and Wong 1988

The European Alder Leafminer is an introduced insect that is now widely distributed in Canada. It likely has a similar lifecycle to that of the birch leafminer, *Funusa puilla* (Lepeletier). These insects usually have two generations per year in the prairie province, but may have a partial third generation if the frost-free period is long and the weather is unusually warm. This Leafminer overwinters as a prepupal larva in a small cocoon beneath the trees. The adults emerge in late May. They are small black sawflies with yellowish brown legs and re 2.5-3.5 mm long. The females lay their eggs in slits cut in the upper surface of young leaves, usually towards the middle of the leaf. The larvae feed on the leaf tissue between the two epidermal layers. Several larvae may feed together within on mine. The larvae have four feeding instars and a fifth nonfeeding instar. Fully fed fourth-instar larvae have brown heads and creamy-white bodies and are 5.3-6.5 mm long. They have claws on the thoracic legs and can be recognised by the midventral black marks on the three thoracic segments and first abdominal segment. The second generation develops 45-50 days after the first. Oviposition is still concentrated on the young leaves, so that most mines are in the periphery of the crown.

Activity in Jasper National Park

1988 light to moderate infestations common in the Park.

AMBERMARKED BIRCH LEAFMINER

Profenusa thomsoni (Konow): Order Hymenoptera, Family Tenthredinidae

Species Description and Ecology

Taken from Ives and Wong 1988

The Ambermarked Birch Leafminor was first described in Europe, and now has holarctic distribution. It has one generation per year and overwinters as a prepupal larva in a tiny cocoon spun in the soil beneath the trees. The parthenogenetic females emerge in July. They are small black sawflies with white legs. Eggs are laid in slits along the veiwns in the basal and central area of the upper surface of the leaves. The larvae have five feeding instars and a sixth nonfeeding instar. They have light-colored heads and creamy-white bodies and are about 7 mm long when fully grown. There are no claws on the thoracic legs. There is a conspicuous midventral light-colored patch on the prothorax and a much smaller, dark midventral path on each of the other two thoracic segments. Mines of several larvae usually coalesce and contain conspicuous frass. The mining causes the leaves to dry out and turn brown. This does not seriously affect the health of the tree unless the mining is unusually severe, but the annual increment may be reduced slightly.

Activity in Jasper National Park

1994 Moderate to severe defoliation along most road side stands of Mountain birch between Jasper Townsite and the east gate

ASIAN LONG-HORNED BEETLE
***Anaplophora glabripennis* (Motchulsky)**

Species Description and Ecology
Adapted from Humphreys et al 1998

The Asian Long-Horned beetle is a serious pest of hardwood trees in China, and in 1997 was detected at various locations in North America. In British Columbia and Ontario, the interceptions have been associated with wood packing material.

In its native range, this insect may have a one or two-year lifecycle. It has the ability to overwinter as an egg, larva or pupa. The eggs hatch in 11 days in June-July if the cycle is one year, and September-October if it is a two-year cycle. Early larval instars feed in the phloem. Late 4th instars move into the xylem. In the early spring, mature larvae pupate in the wood. Adults begin emerging in May, and populations peak in July. These beetles fly for about 2-3 days to feed and mate. The females make grooves in host tree branches to lay eggs.

Adults feed on the leaves and bark of trees causing considerable damage. This insect attacks and kills healthy trees. They prefer to attack the shoots of host trees causing the young shoots of host trees causing the young shoots to wither and die. The female chews round or lip-shaped grooves on branches in preparation for laying eggs. Young larvae feed in the sappy, green inner bark causing the bark to become concave. Mature larvae bore into the heartwood of the tree, and created large winding galleries in the inner wood, eventually killing the host. Emerging adults chew their way out of the wood creating large, circular exit holes and heavy, coarse wood fibres on the ground.

Acitvity in Jasper National Park
There is no evidence that this species is established in Canada. However, the detection signifies a potential threat to all hardwood species.

3.4 DISCUSSION

Dianne Szlabey (1994) has done a remarkable job of collating available data on insects and diseases in Jasper National Park, and her work has been invaluable to this project. The database she compiled aided greatly in the identification of agents to be divided into major and minor agents of concern, making the information more useful to managers. It also provided point locations of insects and diseases, and allowed for speculation about which agents historically occurred in this area. However, the data that has been available historically is not necessarily a strong representation of agent presence and distribution. For example, the point locations provided are severely skewed to human travel and transportation corridors. The point locations for disease occurrences are so limited, it does not warrant mapping them. To augment this problem, there has been very little baseline data collected by Jasper National Park or the Canadian Forest Service to improve the information in the database. Likely due to lack of funds, research is focused on agents with potential economic repercussions, and has moved away from a holistic understanding of insect and disease functions in Jasper National Park.

In Chapter 5, recommendations aim to improve the quality of data and level of knowledge about insects and diseases in Jasper National Park. They are a result of the database analysis and assessment of information availability.

4.1 INTRODUCTION

In this chapter I used Multiple Accounts Analysis (MAA) to determine whether or not current vegetation management actions are consistent with the fundamental principles of Parks Canada. MAA provides a framework for this evaluation. It involves three basic steps: the specifications of evaluative criteria, the assessment of management actions under these criteria, and the presentation and interpretation of the results (Province of British Columbia 1993).

MAA explicitly recognises that not all benefits and costs can be expressed in dollar terms. It is an appropriate method for analysing management actions in the national parks, where many of the values do not have a dollar figure attached to them (i.e. ecological integrity).

In the remainder of this chapter, I detail the methods used in the MAA, and explain each component involved. This chapter summarises the results and includes a discussion of the analysis.

4.2 METHODS

For this MAA I created a matrix that is broken down into two major components: criteria and management actions (Table 26). Due to their broad nature, the criteria are further broken down into indicators. Each indicator is accompanied by a scale that will be used to rate management actions.

Table 26. An example of the MAA summary matrix adapted for the evaluation of vegetation management actions in Jasper National Park

	Criteria 1		Criteria 2		Criteria 3	
	Indicator 1 Scale 0-4	**Indicator 2** Scale 0-3	**Indicator 1** Scale 0-3	**Indicator 2** Scale 0-4	**Indicator 1** Scale 0-4	**Indicator 2** Scale 0-3
Management Action 1						
Management Action 2						
Management Action 3						

The development of criteria, indicators and scales, and management actions is outlined below.

4.2.1 Criteria Development

Criteria development was guided by the *Crown Corporations Multiple Accounts Guideline* (Province of British Columbia 1993) and a literature review of relevant Parks Canada Policy (Parks Canada 1997a; 1996b; 1995b and 1994a) and decision-making tools (Thompson 1997; Mitchell 1995; Parks Canada 1996a; Chechile and Carlisle 1991; Duffy-Armstrong 1979).

The fundamental principles of Parks Canada served as the criteria by which management actions were evaluated. To ensure that the chosen criteria were appropriate, a key informant interview was conducted with seven members of the Jasper Warden Service and Ecosystem Secretariat (Robson 1993 and Tremblay 1982). A list of participants is located in Appendix A. Each participant was asked to weight and evaluate the criteria. The results of this process (Appendix B) were incorporated into the MAA.

4.2.2 Weighting the Criteria

At a group meeting of vegetation specialists (November 2, 1999), participants indicated that a weighting system should be established for the criteria in this analysis. The group suggested that ecological integrity should carry more weight than social values and resource considerations, and that social values should carry more weight than resource considerations.

4.2.3 Indicator Development

I developed indicators and their accompanying scales from the same policy and literature review outlined under section 4.2.1.

4.2.4 Validation of the Criteria and Indicators

Once the criteria, indicators and scales were developed, they were reviewed at a group meeting of vegetation specialists in the Mountain District (Tuesday November 2 1999)(participants listed in Appendix A). The general method used for this process was the key informant interview, but was done in a group setting. Participants were given a handout showing the matrix, the numbered scales associated with the indicators, and a number of specific questions (Appendix B). The participants were allowed to make comments in confidence during the written exercise, and then were allowed a chance to comment further during the ensuing discussion. Participants provided detailed comments on the usefulness, appropriateness and potential accuracy of the outlined criteria, indicators and numbered scales. This method was the most realistic for this project. Several attempts were made to set up individual interviews or acquire information. This was generally unsuccessful. Requesting an hour of time at the Parks Canada Western Region Fire and Vegetation meeting provided a captive audience and produced feedback that was very helpful in tailoring the Multiple Accounts Analysis to this project.

Comments that were repeated more than twice were incorporated into the analysis. If any comments stated that some part of the process was unclear, a revision was made to clarify that section. Several points worthy of discussion were raised, and will be addressed later.

4.2.5 Management Action Development

I distilled the management actions evaluated in the MAA from the proposed *Vegetation Management Guideline for the Mountain District* (Parks Canada 1997). For the purposes of this MAA, action oriented statements were extracted and included in the MAA as management actions. The management actions for fire, insects and diseases were evaluated in the MAA matrix in the order they appear in the document.

4.2.6 Analysis

Ratings were assigned to each management action under each indicator based on the scales I developed. Overall, the more points assigned, the more favourable the rating. For example, on a scale of 0-4 the most favourable rating would be a 4. If the indicator was not relevant to the management action, it was assigned a rating of NR (not relevant).

Once all the ratings were assigned, each column was tallied. These tallied scores are located in the row titled 'Score' in Table 27. Next, the highest potential score of all relevant ratings in each column were tallied (i.e. values of 'NR' were not counted in this tally). Theses scores are located in the row titled 'Highest Potential Score'. I calculated a percentage from these two scores by dividing the 'score' by the 'highest potential score'. Percentages were rounded to the nearest integer and are found in the row titled 'percent score of indicator.' These percent scores represent how the group of management actions rated proportionately under each indicator. Finally, I wanted to know how the group of management actions rated proportionately under each criteria. I totalled both the scores and highest potential scores for each criteria. The total of the scores was divided by the total of highest potential scores providing a percentage, located in the section titled 'Percent Score for Each Criteria'.

4.2.7 Validation of Analysis

To test the accuracy of my analysis, it was reviewed by the Park Fire and Vegetation Specialist Alan Westhaver, the Park Fire and Vegetation Warden Rick Kubian and the Park Conservation Biologist Peter Achuff. Inconsistencies and errors were corrected.

4.2.8 Assumptions and Limitations of the Analysis

A number of assumptions preface this analysis. Firstly, this is a relative process. It is appropriate for the level of management it is directed toward (fire and vegetation management at the park level), but should not be considered a statistically valid exercise.

Secondly, management actions were evaluated as isolated entities. It is recognized that on any particular project, a number of the actions may be taken at once to ensure all of the criteria were addressed. However, this exercise is useful in showing how the vegetation management actions rated proportionately.

4.2.9 Recommendations

Recommendations were provided based on the results of the analysis. They are located in Chapter 5.

4.3 MULTIPLE ACCOUNTS ANALYSIS COMPONENTS

The following is a description of the criteria, indicators and scales I developed for the MAA.

4.3.1 Criteria

Parks Canada has three fundamental accountabilities to Parliament and the Canadian people: 1) ecological and commemorative integrity; 2) service to clients and 3) wise and efficient use of funds (Parks Canada 1995). For the purpose of this analysis, these accountabilities will be grouped under three criteria headings: ecological integrity, social values and resource considerations. Each of these criteria will be discussed below.

Ecological Integrity

The preservation of ecological (and cultural) integrity is the first objective of National Parks in Canada (Parks Canada 1994;1995a). Ecological integrity is defined as: "The condition of an ecosystem where the structure and function of the ecosystem are unimpaired by stresses induced by human activity and are likely to persist." (Parks Canada 1994). Parks Canada's National Business Plan (1995b) states that "...ensuring the ecological integrity of parks and sites is a fundamental value and imperative for Parks Canada," and objectives are being set to improve the state of ecological integrity. Protecting ecological integrity (and cultural integrity) should take precedence in acquiring, managing and administering heritage places and programs in every application of their policies and guiding principles (Parks Canada 1996).

In reality, national parks are not always managed with ecological integrity as the number one objective. Shortages in funding and pressure from adjacent land managers are two of the many factors that contribute to this problem. This was illustrated when I asked a group of seven managers within Jasper National Parks to weight ecological integrity against eight other criteria. Participant's answers ranged from 13 – 55% in terms of the importance they placed on ecological integrity in management decisions in JNP. (Appendix B).

Although this was not a statistically valid exercise, it does indicate that the value of ecological integrity, or the relative weight it is given in decision-making processes is not uniform, even among park managers.

Social Values

The protection of social values is an important objective of Parks Canada. National Parks are "dedicated to the people of Canada for their benefit, education and enjoyment...and shall be maintained and made use of so as to leave them unimpaired for the enjoyment and use of future generations." Parks Canada also has a shared responsibility in an international heritage agenda (Parks Canada 1994a), and therefore must also consider the international community in decisions that effect the cultural and ecological integrity of World Heritage Sites (Parks Canada 1994a). Parks Canada has a responsibility to consider the social values of park visitors, the Canadian Public, and the international community in making management decisions.

Resource Considerations

Resource considerations of both Jasper National Park and adjacent land managers will be evaluated in this analysis. The first consideration is the program resources within Jasper National Park. Program resources include funding for operational activities, people and specialized equipment to do the work and funding to conduct related monitoring and research. The second consideration is the potential effects of the management actions taken in Jasper National Park on the economic resources of adjacent land managers (i.e. merchantable timber).

Although the availability of program resources are rarely mentioned in Parks Canada Policy outside of the National Business Plan, these considerations have a significant impact on management decisions and on the implementation of prescribed management actions. Parks Canada's National Business Plan (1995b) states that Parks Canada should be "...ensuring the ecological integrity of parks and sites is a fundamental value and imperative for Parks Canada." Again protecting Ecological Integrity should take precedence in acquiring, managing and administering heritage places and programs in every application of their policies and guiding principles, including the allocation of program resources (Parks Canada 1996b).

The consideration of resources is not limited to Jasper National Park. Parks Canada has mandated themselves to consider the concerns of adjacent land managers (Parks Canada 1997a). In doing so, Parks must consider the affect their management decisions have on the resources of their neighbors.

4.3.2 Indicators

INDICATORS ASSESSING MANAGEMENT EFFORTS IN ECOLOGICAL INTEGRITY

I developed five indicators of whether or not management actions are working toward ecological integrity. These indicators are not direct measures of the ecological integrity of specific systems, but have been used to assess if management actions are aimed at contributing information to that end. They are: Scientific Information Adequacy; Ecological Goals; Precautionary Principle; Adaptive Management; Communication with Adjacent Land Managers; and Co-operation with Adjacent Land Managers. These indicators and their rating scales are discussed below.

Adequacy of Scientific Information

Parks Canada is directed to adopt an ecosystem-based approach to management (Parks Canada 1996). To do so, adequate scientific information is required to make sound decisions. I used the following scale to assign a rating to each management action:

0 No data or applicable literature available to inform management decisions

1 Data or applicable literature exist outside the park and have been extrapolated to inform management actions

2 Data and/or applicable literature for Jasper National Park exist, but is sparse or incomplete with no monitoring program to inform management decisions

3 Data for Jasper National Park exist, is sparse or incomplete but research is being conducted to increase understanding and monitoring programs are being established; relevant literature from external sources is available.

4 Reliable or definitive baseline data exist. A monitoring program is current and continues to inform and modify management actions

Ecological Goals

The Overall Goal for insect and disease management in the Mountain Parks is "to ensure the perpetuation of natural processes of vegetation disturbance ...and allow the fluctuations of natural, dynamic populations of forest insects and diseases..." (Parks Canada 1997a). I used this scale to evaluate whether or not current management actions are contributing to specific, ecological goals.

0 Current management action has not been established to contribute to a specific ecological goal.

1 Management action contributes to the broad ecological goals and strategies for fire and insect and disease management outlined by the *Vegetation Management Plan for the Mountain District* (1997). It is not derived from specific ecological goals or strategies.

2 Management action is derived from specific ecological goals or strategies outlined in the *Vegetation Management Plan for the Mountain District* (1997), or a related document (i.e. a Forest Insect and Disease Plan).

Adaptive Management

Resource managers rarely have all the required information and understanding before making decisions regarding ecosystems (Mitchell 1995). In striving toward ecosystem management, the approach taken must be "adaptive". This means that when a management action is taken, the results are monitored, evaluated and the manager is provided with feedback to guide future management decisions. Closely related to adaptive management is the concept of the precautionary principle. The use of the precautionary principle in management decisions is stressed in Parks Canada Policy relating to Ecosystem Management. Ecosystem Management acknowledges "the complexity of ecosystems and our relatively poor understanding of them, which will necessitate an adaptive approach to resource management and social policy and the adoption of the precautionary principle: erring on the side of caution when considering management options" (Parks Canada 1996).

The degree to which adaptive management and the precautionary principle are applied are indicators of whether or not there is an attempt to move toward an ecosystem management approach. Parks Canada is mandated to take this direction. I use the following scale to evaluate management actions for adaptive management:

0 No monitoring, evaluation or feedback is occurring. Precautionary principle is not applied.

1 Monitoring program established, but no evaluation or feedback. Precautionary principle is not applied.

2 Monitoring Program established, some evaluation but no feedback into management decisions. Precautionary Principle is applied.

3 Monitoring Program established, evaluation occurring, feedback into management decisions.

Co-operation and Communication with Adjacent Land Managers

National Parks share boundaries with a number of different agencies ranging from provincial parks, to provincial crown land, to private landowners, to resource extraction leaseholds. Each of these jurisdictions has a management agenda, and often goals and objectives differ between agencies. Ecosystems are not confined to within National Park boundaries. In the larger picture, resource and environmental problems can rarely be treated in isolation. This means that some degree of co-operation between adjacent land managers is necessary for the survival of the greater ecosystem. Co-operating with adjacent land managers is an important part of ecosystem management. This does not mean compromising the values of the national parks, but working together to create positive relationships, develop monitoring programs, share information, create understanding and work towards sustainable use of natural resources surrounding the national parks. Ideally, this means being up front with respective agendas.

I developed two indicators here. The first evaluates the level of communication between Parks Canada and other agencies, which has obvious importance to the ecosystem management process. The scale is as follows:

0	No interagency communication, or very little only when problems arise
1	Ad hoc, infrequent formal interagency communications; no formal minutes or publicised results; Communication may be restricted to field level contacts
2	Ad hoc, infrequent formal interagency communications; results of meetings recorded and distributed; regular informal communication at field levels; managerial contacts when issues arise
3	Regular formal interagency meetings and communications at field and management levels; results of meetings formally recorded and distributed; open exchange of data, monitoring results and discussion of issues and prevention

The second scale evaluated the amount of co-operation between Parks Canada and other agencies in sharing information, recognizing individual and common goals and collaboration (i.e. on monitoring, fire management etc). The scale is as follows:

0	No exchange of information; no recognition of individual or common goals; no collaboration
1	Uni-directional or partial exchange of information; recognition of individual goals; no recognition of common goals, minor inter-agency collaboration
2	Occasional mutual exchange of information, recognition of individual and common goals, minor inter-agency collaboration
3	Consistent mutual exchange of information, recognition of individual and common goals, Significant inter-agency collaboration

Indicators Addressing the Management of Social Values

I developed three indicators to assess whether social values were being assessed. They are Public Perceptions, Communications and Visitor Experience.

Public Perceptions

Although not clearly defined as a driving force for management in Parks Canada Policy, public perception is still an important driving force in the decision-making of Park Managers. The public may be considered everyone from park visitors, to organized groups such as Environmental Non-Government Organizations. As more attention is placed on the management of national parks, the reaction of the public may play a serious role in actions taken by park managers. If the public perceives that Parks Canada is acting outside of their mandate or policies, a range of actions could stem from these perceptions. These actions may range from public pressure for certain management actions, to lawsuits regarding National Park commitment to mandate and/or policy. In the past, public pressures in insect and disease management have ceased insect control activities in Kootenay National Park (R. Walker pers. comm).

It is difficult to evaluate how the public perceives park management for numerous reasons. Firstly, who is the public that Jasper National Park is accountable to? Is it the people of Alberta, some of whom share borders with Jasper National Park? Is it the people of Canada, who theoretically own the park through tax dollar contributions and legislation? Or, is it the international community, to whom Jasper National Park has a responsibility to as a steward of a world heritage site? In some ways, Jasper National Park is accountable to them all. How can public perceptions be evaluated at all three levels? How can the fact that not all of the public will share the same perceptions be reconciled? These questions are difficult to answer, and finding an answer is outside of the scope of this document. However, it is still important to consider the reaction of the public in decisions regarding fire, forest insects and diseases. The purpose of this indicator is to evaluate whether or not an attempt is being made to understand public perceptions at this decision making level, recognizing that park managers may be limited in their ability to do so. I developed the following scale.

0 Management action does not consider public perception/reaction, or management actions are likely unknown to public

1 Management action taken in response to public reaction.

2 Management action aims to seek out and improve public perception.

Communications

How the public perceives management actions in JNP is often affected by the communication they receive. In adhering to the Principles and Standards for ecosystem-based management, Parks Canada should "fully engage the human community (greater than the residents of the ecosystem) of the ecosystem in question, in understanding of ecosystem dynamics and in decision-making at all scales." (Parks Canada 1996). To assess communications, I used the following scale:

0 Communication to the public about management actions non-existent

1 Communication to the public about management action exists, but are general reactive

2 Communication to the public about management actions exists and is consistent, but is general and not issue specific

3 Specific communication mechanisms have been developed and information about management actions is being delivered to the public

4 Specific communication mechanisms have been developed, information about management actions is being delivered to the public and an effective opportunity for public to provide feedback into the process exists.

Visitor Experience

National Parks are mandated to consider the experience of the visitor (Parks Canada 1994). Some vegetation management practices may affect the visitor experience. For example, actions such as trail closures and alterations to the landscape through fire and other ecological processes may have an effect on the enjoyment of those travelling through the park. Large tracts of trees killed by an insect or disease is another may affect the aesthetic experience of the visitor. Therefore, it is important to consider visitor experience in decision-making. However, it is important to realize that 'value' is relative to each person's experience, and the relative nature of assigning 'value' limits the importance of this indicator. I developed this scale.

0 Management action has a known negative effect on visitor experience
1 Management action has a negative effect on visitor experience that can be mitigated
2 Management action has no effect on visitor experience
3 Management action has a possible positive effect on visitor experience
4 Management action has a known positive effect on visitor experience

INDICATORS OF RESOURCE CONSIDERATIONS

The availability of program resources has a great impact on what management actions can be implemented. Management actions may also have economic implications for adjacent lands. The safety and liability of certain actions (i.e. a prescribed burn) is also closely tied to economic considerations, and will also be included in this section.

I used four indicators to evaluate how management's consideration of resources. The indicators are: Parks Canada Considerations; Adjacent Land Manager Considerations; Short term liability; and Long term liability. They are described as follows:

<u>Parks Canada Considerations</u>

The National Business Plan and individual Park bussiness plans direct funding to actions relating to ecosystems and research or studies (Parks Canada 1995). At the individual park level, the allocation of resources is largely dependant on the priorities placed on projects by upper management (anonymous pers. comm.). Although management plans and actions are established, resources to implement the plans are not always available. Resources include not only adequate funding, but adequate staffing and the allocation of time needed to carry out management actions. With this indicator and respective scale I evaluate the feasibility of management actions under current resource allocation conditions.

0 Program resources for management actions resources not allocated in annual operating budget or special projects in the Parks Canada or Jasper National Park Business plan

1 Program resources for management action allocated under Parks Canada National Business plan; receives minimal or no resource assistance from the Jasper National Park Budget for general activity in this field

2 Program resources for management action resources allocated under Parks Canada Business Plan, and receives partial resource assistance from the Jasper National Park Budget for dedicated action

3 Management action resources allocated under Parks Canada Business Plan, and receives full resource assistance from the Jasper National Park Budget for dedicated action

Considerations for Adjacent Land Managers:

> "Integrated programs of co-operative ecosystem-based management amongst park managers and their neighbours are crucial to protect park ecosystems, maintain regional biodiversity and ultimately sustain ecosystems" (Parks Service 1992).

The Mountain Parks have directed themselves to consider the concerns of adjacent land managers when making decisions about fire and vegetation issues, including forest insects and diseases (1997a). In doing so, the consideration given these neighbours becomes an indicator of the integrity of the management decision. I use the following scale in this assessment:

0 Management action has a known negative effect on adjacent land owners

1 Management action has a possible negative effect on adjacent land owners

2 Management action has no effect on adjacent land owners

3 Management action has a possible positive effect on adjacent land owners

4 Management action has a known positive effect on adjacent land owners

Liability:

Liability is linked to resource considerations. Ultimately, poor choices around liability lead to economic repercussions. Liability may be considered on a short term or a long term scale. For example, an action like prescribed burning may exhibit higher elements of risk in the short term, but in the long term may decrease liability by reducing the spread of small fires across the fire break into the townsite. For that reason, I divided liability into the following two scales:

Liability – short term

0 Management action is inherently risky; injury to the public/public land possible

1 Management action is inherently risky; injury to public/public land unlikely

2 Management action has no known effect on public or public land

3 Management action likely to increase public safety or the safety of public land

4 Management action known to increase public safety or the safety of public land

Liability – long term

0 Management action is inherently risky; injury to public/public land possible

1 Management action is inherently risky; injury to public/public land unlikely

2 Management action has no known effect on public or public land

3 Management action likely to increase public safety or the safety of public land

4 Management action known to increase public safety or the safety of public land

4.4 RESULTS AND DISCUSSION

The results (Table 27) show that proportionately, resource considerations scored the highest, while ecological integrity scored considerably low at 56% and social values scored even lower at 29%. This likely exemplifies the reality of vegetation management in Jasper National Park. However, vegetation managers in the Mountain District agree that emphasis should be put strongly on ecological integrity, and that social values should be emphasised more than resource considerations (November 2, 1999). Therefore, there appears to be a disparity between the way vegetation is managed, and the way vegetation specialists believe it should be managed. Below is a discussion of the results of each criteria.

4.4.1 Ecological Integrity

The percentage of 56% reflects proportionately how management actions scored using this criteria. This percentage seems high in light of the database analysis and assessment of available data in Chapter 3. The score may be high because many of the management actions did not relate to Ecological Integrity. If zeros were assigned instead of 'NR' under each indicator, the percentage would have been significantly lower. Fore example, the indicator 'scientific information adequacy' attained a percentage of 63%, but only 8 out of the 16 management actions required scientific information to be gathered. It may even be likely that the management actions that are related to ecological integrity were created with data availability in mind.

Some indicators rated significantly higher than others. The indicators 'communication and co-operation with adjacent land managers' rated high relative to indicators like

	ECOLOGICAL INTEGRI[T]			
	Scientific Information Adequacy 0-4	Ecological Goals 0-2	Adaptive Management 0-3	Communi[ty] With Adj[acent] Land Man[agers] 0-3
ACTIONS				
1. The average cost of planned and random ignition prescribed fires within the district will be less than $100/ha	NR	0	NR	NR
2. The fire assessment system is applied to all wildfires within the district to ensure fire suppression funds are used in a cost effective manor	NR	0	NR	NR
3. Key forest insect and diseases are monitored annually; databases are updated and integrated into GIS	3	2	3	NR
4. Annual monitoring results are shared with other agencies	NR	0	NR	3
5. Provide as much notice as possible of prescribed fires that may affect clients. Prevent any loss of property from prescribed or wildfire	NR	0	NR	3
6. Develop interagency fire co-operation plans in support of the Canada/Alberta agreement, the Canada/British Columbia agreement, and the Banff Bow Valley study	NR	0	NR	3
7. Faculties, communities and adjacent lands are protected from unwanted fire	NR	0	NR	NR
8. Active fuel reduction programs are underway on public and private lands and is supported by dedicated and cost sharing funding	2	1	0	1
9. Clients support or participate in the fire management program	NR	0	NR	1
10. Non-native forest insect and disease populations are identified or controlled through continued participation in the gypsy moth program, annual mountain pine beetle monitoring, evaluation of Douglas-fir beetle and white bark pine blister rust infestations and threat to susceptible species; occurrences of non-native forest insect and disease species (i.e. larch case bearer, satin moth, gypsy moth, balsam wooley adelgid) highlighted in database and reporting procedures.	3	2	3	3
11. An active role is taken in interagency forest health groups (i.e. AB-BC interagency forest health workshop)	NR	0	NR	3
12. Within the mountain district, high intensity (stand replacement) and low intensity (understory, grass, shrub) planned prescribed burns are carried out within the next five year period	2	2	0	1
13. The cumulated area burned by all fires falls within the acceptable range of fire cycles at the end of the planning period for various vegetation groups and eco-regions	2	2	0	1
14. Increased understanding of the ecological role of forest insect and diseases gained by the analysis of GIS layers for landscape/successional effects of forest insect and diseases	3	2	3	3
15. Fire management achieves a landscape mosaic resulting in natural range of forest insect and disease populations fluctuations	2	2	0	1
16. Improved knowledge of non-traditional forest insect and disease species (i.e. non-pest) with baseline inventories begun by 1998.	3	2	2	3
Score	20	15	11	23
Highest Potential Score	32	36	24	36
Percent score of indicator	63	42	46	64
Total Percent Score for each criteria = **Total of all Indicator Scores for each criteria/Total of potential Scores**	90/161 = 56%			

Table 27. Results of the Multiple Accounts Analysis used to evaluate the c

Y		SOCIAL VALUES			RESOURCE CONSIDERATIONS			
ation cent gers	Co-operation with Adjacent Land Managers 0-3	Public Perceptions 0-2	Communications 0-4	Visitor Experience 0-4	Parks Canada Considerations 0-3	Considerations for A.L.M 0-4	Liability - Short Term 0-4	Liability - Long Term 0-4
	NR	0	NR	NR	3	NR	NR	NR
	NR	0	NR	NR	3	NR	NR	NR
	NR	0	0	2	2	3	NR	2
	1	0	0	2	2	3	NR	2
	3	2	1	3	3	3	3	NR
	3	0	1	2	3	2	NR	4
	NR	2	1	4	3	4	4	4
	2	1	1	1	3	2	1	3
	NR	2	1	2	2	2	1	3
	2	0	0	2	1	3	NR	NR
	2	0	1	2	3	3	NR	NR
	1	0	0	1	3	3	1	3
	1	0	0	1	3	3	1	3
	2	0	0	2	1	3	NR	NR
	1	0	0	2	1	3	NR	NR
	3	0	0	2	1	3	NR	NR
	21	7	6	28	35	40	11	21
	33	32	56	56	48	56	24	32
	64	22	11	50	73	71	46	66
		41/144 = 29%			107/160 = 67%			

onsistency of vegetation management actions with the fundamental principles of Parks Canada

'ecological goals' and 'adaptive management'. Low scores under 'adaptive management' are of concern, as adaptive management and the use of the precautionary principle is important when there is not adequate scientific information to make a decision with any certainty.

Overall, the percentage assigned to the criteria 'Ecological Integrity' needs to be increased. The major shortfalls in management efforts toward ecological integrity are the lack of emphasis on ecological goals (and the achievement of existing ecological goals) and adaptive management. It has been established that National Parks are directed to adopt an ecosystem-based management system. To maintain ecological integrity of its parks, Parks Canada is mandated to adopt an ecosystem-based management approach for directing policy and activities (Parks Canada 1996b). Ecosystem Management means acknowledging "the complexity of ecosystems and our relatively poor understanding of them, which will necessitate an adaptive approach to resource management and social policy and the adoption of the precautionary principle: erring on the side of caution when considering management options" (Parks Canada 1996b). Parks Canada is directed to utilise ecosystem management which considers the human use of resources to be secondary in importance to the primary goal of maintaining ecological integrity. The National Parks Act (Parks Canada 1994a) emphasises this by mandating that the protection of ecological integrity take precedence in acquiring, managing and administering heritage places and programs. Fundamental to this is adaptive management, the use of the precautionary principle and the establishment of specific ecological goals. To attain ecological goals, often a level of scientific information adequacy is required, and therefore improvement in this area is needed.

4.2.1 Social Values

Social values scored proportionately low in this analysis. The indicator 'Communications' scored the lowest (11%), indicating that communication with the public needs significant improvement. Closely linked to communication is 'public perception', which also scored a low percentage at 23%. These scores indicate that very little is being done to assess public perception, or to educate the public about the course of action being taken in vegetation management. General attempts are made to this end, but are often reactive. To achieve ecosystem management, ultimately the co-operation of the public will be a necessity. This can not be achieved without adequate communication and a willingness to investigate how the public perceives management actions.

Visitor experience was the third indicator of social values. The analysis suggested it is likely that there is no major impact on visitor experience attributable to vegetation management. This indicator scored relatively high compared to 'public perception' and 'communications'. Negative visitor experiences may be mitigated by increasing communication about the vegetation management program. For example, an area burned in a prescribed fire may lose some of its aesthetic appeal to a hiker in the area, but an increased understanding of the ecological value of that fire may serve to mitigate a negative response.

On the whole, this analysis indicates that a significant increase in the consideration of social values is needed in vegetation management.

4.4.3 Resource Considerations

Overall, resources considerations rated significantly higher than ecological integrity and social values. No real need for improvement seems necessary in this category, as it already receives emphasis over criteria that are the prime directives of National Parks. No recommendations will be made for the improvement of resource considerations, as efforts at this point should focus improving actions that work toward ecological integrity and on increasing the consideration of social values.

4.5 RECOMMENDATIONS

Recommendations from this analysis can be found in Chapter 5.

CHAPTER 5 RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

In this chapter, I summarise the gaps and program deficiencies identified in chapters 3 and 4. Based on these gaps and deficiencies, and as outlined in the objectives in Chapter 1, I make recommendations for forest insect and disease management and for the implementation and general use of this thesis. I finish this chapter with a conclusion for this thesis.

5.2 RECOMMENDATIONS

5.2.1 Knowledge Gaps and Recommendations from Chapter 3

In Chapter 3 I identify the following as weaknesses in the data:

- The data in the database are skewed to human use and transportation corridors.
- The point locations provided in the database are very limited. For example, there is very little location information for diseases.
- There is very little baseline data on insects and diseases in JNP that could be used in the future to assess changes (i.e. patterns and species composition).

The following recommendation and sub-recommendations would improve data availability and use.

1. Establish a research framework for assessing and evaluating insect and disease activity in JNP. Collect, then evaluate baseline data to reduce scientific uncertainty.

Available information on forest insects, disease and fire in Jasper National Park requires improvement. Information could be strengthened through scientific research and through taking inventories and establishing a monitoring program. It is the responsibility of park managers to ensure that the framework for a strong research and monitoring program is put in place. This of course depends largely on funds available and the amount of support from upper management. Still, the establishment of a framework would allow projects to be identified and prioritised ahead of time. Too often research and monitoring is left up to other agencies or universities. These agencies are valuable partners in this venture, and should be encouraged to continue doing projects that supports this framework. An established framework would help identify research opportunities that contribute to the conservation goals of Jasper National Park.

This framework should:

- detail appropriate research and annual monitoring projects;
- prioritise those projects; and
- identify the resources that will be used to implement projects (i.e funds and manpower);

These points are broken down into sub-recommendations below:

1a. Detail appropriate research and monitoring projects

The following are recommendations for specified research and operational monitoring.

➢ Create Susceptibility and Risk Rating Systems for major insects in JNP.

One of the main motivations for forest insect and disease management in JNP is the commitment to consider adjacent land managers in decisions that may affect them. One way to do this while maintaining the commitment to minimal interference in ecological processes, is to anticipate the location and quantify the potential for future epidemic activity by creating susceptibility and risk rating systems for the major insects of concern. Examples of these types of models exist, but none are specific to the climate, and biotic conditions found in JNP. Shore and Safranyik (1992) outline a method for creating a susceptibility and rating system for Mountain Pine Beetle in British Columbia. To use this system, baseline data specific to Jasper ecoregions needs to be collected.

➢ Collect baseline data for susceptibility and risk rating systems

Using the Shore and Safranyik (1992) model as a guide, the following information is needed to use their model:

- percentage of susceptible host tree species (in basal area);
- average age of the host tree species in study area;
- density of stands in stems per hectare;

- longitude and latitude of study area; and
- elevation of host tree species in study area.
- size of insect population adjacent to study area and
- proximity of insect infestation adjacent to study area.

The Shore and Safranyik (1992) report outlines assumptions and limitations in using their model. In the event that JNP wishes to model susceptibility and risk, experts in the field (i.e. Canadian Forest Service, Universities) should be consulted. Models will need to be tailored to individual insects and appropriate climatic variables will need to be defined.

➢ Develop a consistent monitoring program to assess insect and disease activity

Monitoring efforts in the Smoky have been successful in identifying the presence of Mountain Pine Beetle. However, consistent monitoring of major insects throughout JNP is needed. Due to the size of the study area (JNP), initial monitoring efforts should be conducted by air. Aerial routes should be established in each FMU along Vegetation Management Groups containing tree species utilised by major insects. Once a potential area of major insect activity is identified, then a ground investigation is warranted.

Monitoring every FMU would provide the most complete information. However, this would require considerable time and resources. If one of the main motivators for managing insects in JNP is the concern of adjacent land managers, then monitoring efforts should be focused in FMUs that border the Province of Alberta or Alberta Provincial Parks. Table 28 shows major insect activity in FMUs that border Alberta:

Table 28. Major Insect Activity in FMUs that border the Province of Alberta

	Spruce Budworm	Mountain Pine Beetle	Douglas-Fir Beetle	Spruce Beetle	Lodgepole Pine Needleminer
Upper Rocky					
Southesk/Cairn					
Sunwapta					x
Upper Brazeau					
Middle Brazeau					
Lower Brazeau					
Smoky		x			
Upper Snake Indian					
Middle Snake Indian					
Moosehorn					
Lower Fiddle	x				
Upper Fiddle					

This table indicates that at the very least monitoring efforts should be focused in the Lower Fiddle, Smoky and Sunwapta FMUs. However, the lack of non-skewed data in the database means that relying on this information alone to focus monitoring efforts is limited. Therefore, it is necessary to combine all the information put forth in this document to provide the best guide to monitoring given the current level of information. Table 29 summarises each FMUs proximity to the province of Alberta, the historic presence of major insects in each FMU, and the percentage of each Vegetation Management Group (VMG) containing major insect host tree species in each FMU. Arbitrary points are applied under each column and tallied in the column titled "Monitoring priority: High/Med/Low". From this simple exercise, monitoring priorities are established for each FMU in Jasper National Park. These priorities are also summarised in Figure 20. From this exercise, I determined that the FMUs with the highest monitoring priority are the Smoky, Moosehorn, Lower Fiddle, Middle Athabasca, Upper Athabasca and Lower Brazeau.

Once the susceptibility and risk rating systems are in place, results from them could be used to identify potential forest insect and disease activity in each FMU. This information should be used to update the current monitoring strategy.

➢ <u>Input all new information into the database</u>

Host trees affected by major insects located during monitoring flights should be recorded as GIS co-ordinates and inputted into the database. Other recent work, like L. Paulson's work on Douglas-Fir Beetle should also be added into the database.

➢ <u>Collect data/conduct paleoecology research that would provide information on the historic cylcling of insect and disease activity</u>

An example of projects such as this one can be found in Kootenay National Park where core samples of lake sediments are being taken and investigated for historic presence of bark beetles (R. Walker pers. Comm.). JNP would benefit from more research projects such as this one.

Table 29. Matrix used to establish monitoring priorities in Jasper National Park

FMU	Adjacent To Alberta?	Spruce Budworm Present?	% VMG with host species	Mountain Pine Beetle Present?	% VMG with host species	Douglas-Fir Beetle Present?	% VMG with host species	Spruce Beetle Present?	% VMG with host species	Lodgepole Pine Needleminer Present?	% VMG with host species	Monitoring Priority High/Med/Low
Upper Rocky	Yes (5)	No (0)	0 (0)	No (0)	9 (1)	No (0)	0 (0)	No (0)	38 (3)	No	9 (1)	Med (10)
Whirlpool	No (0)	Yes (5)	0 (0)	No (0)	9 (1)	No (0)	2 (1)	No (0)	38 (3)	Yes	9 (1)	Med (11)
Upper Athabasca	No (0)	Yes (5)	1 (1)	No (0)	46 (3)	No (0)	23 (1)	No (0)	30 (3)	Yes	46 (3)	High (16)
Upper Maligne	No (0)	No (0)	0 (0)	No (0)	6 (1)	No (0)	0 (0)	No (0)	26 (1)	No	6 (1)	Low (3)
Southesk/Cairn	Yes (5)	No (0)	0 (0)	No (0)	7 (1)	No (0)	0 (0)	No (0)	19 (1)	No	7 (1)	Med (8)
Chaba	No (0)	No (0)	0 (0)	No (0)	9 (1)	No (0)	0 (0)	No (0)	25 (1)	No	9 (1)	Low (3)
Sunwapta	Yes (5)	No (0)	0 (0)	No (0)	11 (1)	No (0)	0 (0)	No (0)	15 (1)	Yes	11 (1)	Med (8)
Upper Brazeau	Yes (5)	No (0)	0 (0)	No (0)	8 (1)	No (0)	0 (0)	No (0)	11 (1)	No	8 (1)	Med (8)
Middle Brazeau	Yes (5)	No (0)	0 (0)	No (0)	4 (1)	No (0)	0 (0)	No (0)	8 (1)	No	4 (1)	Med (8)
Lower Brazeau	Yes (5)	No (0)	0 (0)	No (0)	67 (5)	No (0)	0 (0)	No (0)	0 (0)	No	67 (5)	High (15)
Smoky	Yes (5)	No (0)	0 (0)	Yes (5)	13 (1)	No (0)	0 (0)	No (0)	26 (1)	No	13 (1)	High (13)
Upper Snake Indian	Yes (5)	No (0)	0 (0)	No (0)	10 (1)	No (0)	0 (0)	No (0)	27 (1)	No	10 (1)	Med (8)
Middle Snake Indian	Yes (5)	No (0)	2 (1)	No (0)	28 (1)	No (0)	5 (1)	No (0)	33 (3)	No	28 (1)	Med (12)
Moosehorn	Yes (5)	No (0)	6 (1)	No (0)	30 (3)	No (0)	8 (1)	No (0)	39 (3)	No	30 (3)	High (16)
Snaring	No (0)	No (0)	0 (0)	No (0)	14 (1)	No (0)	2 (1)	No (0)	34 (3)	No	14 (1)	Med (6)
Lower Fiddle	Yes (5)	Yes (5)	15 (1)	No (0)	24 (1)	No (0)	9 (1)	No (0)	49 (3)	No	24 (1)	High (17)
Miette	No (0)	No (0)	0 (0)	No (0)	1 (1)	No (0)	0 (0)	No (0)	44 (3)	No	1 (1)	Low (5)
Middle Athabasca	No (0)	Yes (5)	2 (1)	No (0)	40 (3)	Yes (5)	24 (1)	Yes (5)	28 (1)	Yes	40 (3)	High (24)
Lower Rocky	No (0)	No (0)	15 (1)	No (0)	23 (1)	No (0)	8 (1)	No (0)	43 (1)	No	23 (1)	Low (5)
Upper Fiddle	Yes (5)	No (0)	0 (0)	No (0)	14 (1)	No (0)	0 (0)	No (0)	29 (1)	No	14 (1)	Med (8)
Tonquin	No (0)	No (0)	0 (0)	No (0)	2 (1)	No (0)	0 (0)	No (0)	32 (3)	Yes	2 (1)	Low (5)
Lower Maligne	No (0)	Yes (5)	0 (0)	No (0)	41 (3)	No (0)	0 (0)	No (0)	29 (1)	No	41 (3)	Med (12)

Legend:

Points for Adjacent to Alberta:

Yes	5
No	0

Points for Percentages of VMGs:

0	0
1 – 29%	1
30% - 49%	3
50% - higher	5

Points for Agent Present :

Present	5
Not Present	0

Total Points Used to Prioritise Monitoring:

Low	0 – 5
Medium	6 -12
High	13

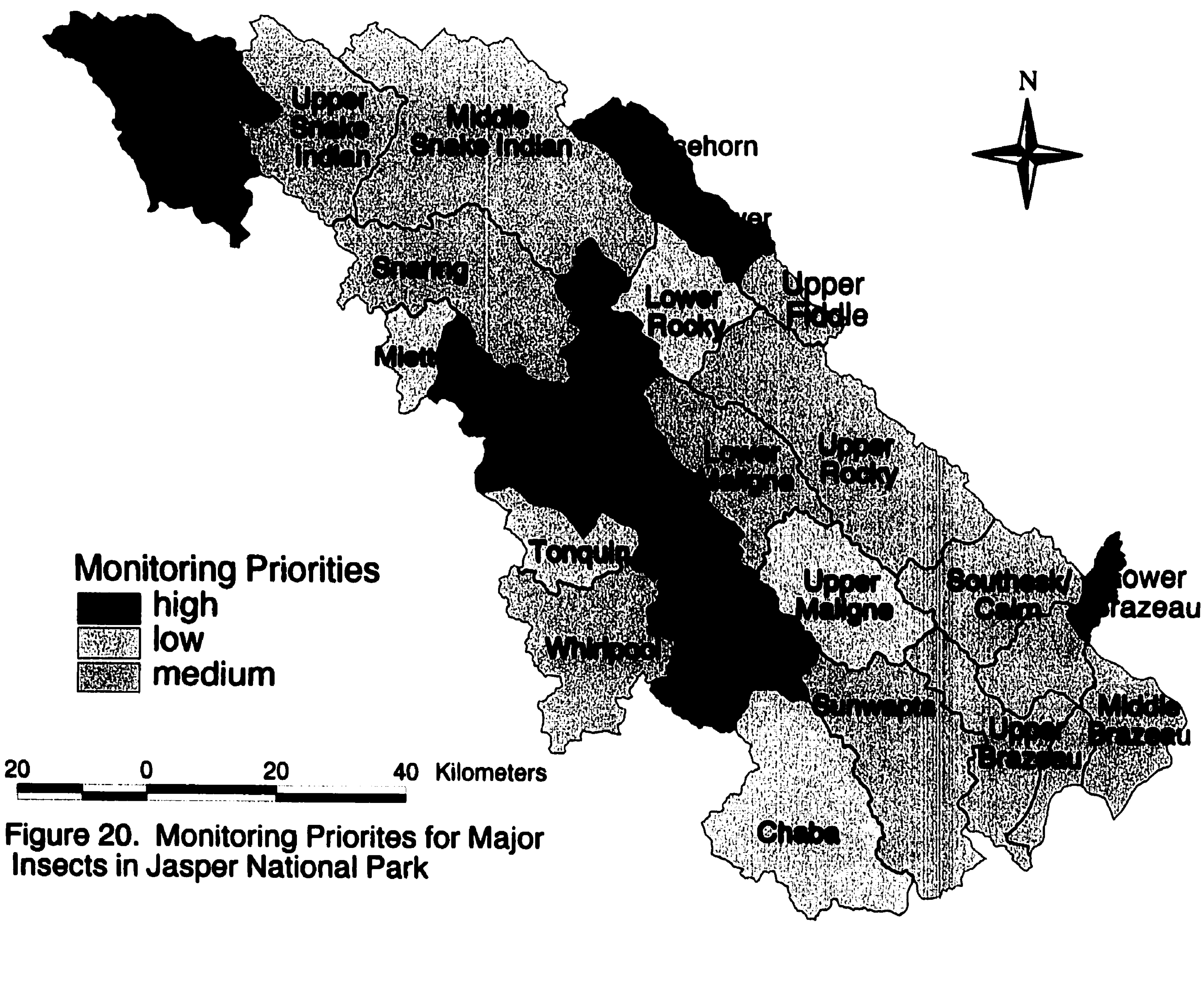

Figure 20. Monitoring Priorites for Major Insects in Jasper National Park

➢ Collect baseline data indicating the relationship between fire and insects and diseases in JNP

In JNP, fire is considered the dominant agent of disturbance. The fact that there is a relationship between fire and the activity of forest insect and diseases is often alluded to (Parks Canada 1997a). However, there is very little literature to indicate exactly what that relationship is. In JNP there is no information on record regarding the relationship between fire and insect and disease activity. As a starting point, observations could easily be recorded before, during and after a prescribed fire. These types of studies could be done in conjunction with a university and/or the Foothills Model Forest and could be on-going to document the activity of agents in the area over a number of years.

➢ Actively seek researchers to fill in research gaps in JNP

By identifying research gaps and research questions, JNP is in the position to facilitate outside researchers in contributing to the knowledge of insects and diseases.

1b. Prioritise Projects

Projects should be prioritised to aid managers in the allocation of program resources. Projects could be implemented in the following order:

- Develop a consistent monitoring program to assess insect and disease activity

This should happen first to address some of the immediate concerns of adjacent land managers (i.e. concerns outlined in Chapter 1 about Mountain Pine Beetle).

- Collect baseline data for susceptibility and risk rating systems
- Create susceptibility and risk rating systems for major Insects
- Conduct studies on the historic cycles of insects and diseases in JNP
- Collect baseline data indicating the relationship between fire and insect/disease activity

1c. Identify program resources used in projects

The following sub-recommendations would aid in the implementation of future projects:

➢ Integrate programs

Funds and other program resource shortages may be alleviated in part by the integration with some programs in other departments or within the Warden Service. For example, backcountry 'kits' could be created for backcountry wardens and trail crew. In the event they encounter an injured tree, these kits could used to assess the tree for insect damage and to bring back samples. Helicopter time could also be shared between departments depending on where the flight is intended. The fire crew could potentially participate in forest insect and disease projects during slow times. These ideas would require further discussion with the heads of each department.

➢ Consult with experts

Experts will be needed to carry out some projects. For example, susceptibility and risk rating will likely require input from researchers in the Canadian Forest Service or from a University. In the past, monitoring flights and ground investigations of dead or dying trees have been assisted by technicians from the Canadian Forest Service. Their continued participation lends credibility to JNP's program, although this may be difficult in light of recent changes in CFS mandates and the elimination of most forest insect and disease activities from the CFS program. New funds are needed to contract experts to facilitate the Parks Canada program.

5.2.2 Knowledge Gaps, Program Deficiencies and Recommendations from Chapter 4

In Chapter 4 I identify the following knowledge gaps and program deficiencies in insect and disease management:

- Management actions relating to ecological integrity need improvement – specifically in the area of setting and/or achieving ecological goals and in the incorporation of adaptive management.
- Management actions relating to social values need improvement in all areas – especially communications with the public and the assessment of public perceptions about forest insect and disease issues.

The following recommendations aim to improve management relating to ecological integrity and social values.

2. **Continue to improve relationships with adjacent land managers**

JNP is part of a larger ecosystem that is managed by several agencies (i.e. Parks Canada, Alberta Lands and Forest Service, Foothills Model Forest and Weldwood Forest Management Area). To ensure the survival of the greater ecosystem, good working relationships need to be maintained between agencies. JNP already participates in interagency forest health workshops, and shares monitoring information with adjacent land managers. Their continued participation indicates that JNP acknowledges the concerns of their neighbours while maintaining their commitment of minimal interference in ecological processes is essential. An additional project that would contribute to good relations and be a useful tool to the agencies involved would be the development of a regional map of major insect activity.

➢ Develop an annual regional map of major insect activity

An annual map showing agent activity in JNP and adjacent lands would be a useful tool in inter-agency meetings and would help to prioritise monitoring. This may be a project where funds could be pooled between agencies to produce a map that is useful for all agencies. It would involve the co-operation of the British Columbia Forest Service, Alberta Lands and Forest Service, the Mountain District National Parks, Foothills Model Forest and timber companies with adjacent forest management areas.

3. **Create a Forest Insect and Disease Management Plan**

This thesis provides information that should be incorporated into a comprehensive Forest Insect and Disease Plan or Strategy. Additionally, the plan or strategy should:

➢ Define Ecological Goals

The results of the multiple accounts analysis showed management actions scored low in terms of identifying and executing ecological goals. Although an overall goal is listed in the *Vegetation Management Guidelines for the Mountain District* (Parks Canada 1997a), the setting of more specific operational ecological goals would make it easier for park managers to formulate research questions. These research questions could then be entered into the research framework (Recommendation 1).

Ecological goals could be set by Forest Management Unit. For example, in the Smoky FMU ecological goals could pertain to Mountain Pine Beetle populations. In the Middle Athabasca FMU, ecological goals could relate to Spruce Budworm populations.

➢ Detail responses to potential forest insect and disease infestations

The plan should outline how JNP will respond in the event of a major agent infestation (i.e. JNP will let the infestation run its course, while monitoring its progression). These pre-determined responses should be made clear to adjacent land managers.

➢ Devise a way to manage adaptively

Management actions rated low for 'adaptive management' in the multiple accounts analysis. Effective management means there must be a way to feedback the results of research and monitoring into decision-making.

4. Create a Public Information Strategy

Communication around vegetation management issues requires improvement. To move toward ecosystem-management, eventually the co-operation of the public and associated stakeholders will be necessary. An attempt should be made to assess how the public perceives management actions, and how communication about management actions can be improved. Key messages about ecological processes should be developed. A public information strategy detailing actions taken in specific situations may be one way of improving the amount and quality of information received by the public.

➢ Consult the experts

There are many in-house experts on communication in Parks Canada who would provide valuable insight in creating a public information strategy. These people should be used as a resource.

5.3 IMPLEMENTATION

Implementation depends largely on the program resources available. Using the priority list, projects should be implemented as resources become available. More resources may come available as awareness about the economic, ecological and social importance of projects grow. Efforts to create awareness would be valuable to this end.

5.4 CONCLUSION

In this thesis, I provided current information on insect and disease activity in Jasper National Park by collating insect and disease ecologies and utilising a database to identify agent activity. During this process I identified problems and limitations in the database and made recommendations for improvement. The main recommendation was to establish a research framework that will identify and document insect and disease activity in Jasper National Park. Following this, I reviewed and assessed forest insect and disease management using multiple accounts analysis. In this analysis I evaluated the consistency of vegetation management actions (affecting forest insects and diseases) with the fundamental principles of Parks Canada. This analysis showed that more management efforts are required in maintaining ecological integrity, and in understanding and assessing social values. I recommended continued improvement of relationships with adjacent land managers, the creation of a comprehensive forest insect and disease plan, and the creation of a public information strategy.

Throughout this thesis I maintain that Parks Canada's primary directive is the preservation of ecological processes. All of the recommendations presented here adhere to Parks Canada's commitment to minimal interference in ecosystem functioning. I do not intend this document to be used in any way that compromises this commitment. National Parks are a place where the value and protection of ecological disturbance processes should be the focus of management, and should remain a priority. This document should be used to ensure this happens in forest insect and disease management in Jasper National Park.

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Shore, Terry. January 29 1999. PhD, Canadian Forest Service, Pacific Forestry Center, Victoria.

Walker, Robert. May 22, 1998. Fire and Vegetation Specialist, Lake Louise, Yoho and Kootenay National Parks.

Westhaver, Alan. Throughout project. Fire and Vegetation Specialist, Jasper National Park. Parks Canada.

Woodley, Stephen. February 3 1999. Federal Forest Officer. Parks Canada.

APPENDIX A

List of Participants in initial Key Informant Interview
Jasper Warden Service and Ecosystem Secretariat:
(printed with permission of participants)

Achuff, Peter. Conservation Biologist, Ecosystem Secretariat, Jasper National Park.

Cardiff, Shawn. Environmental Assessment Specialist, Ecosystem Secretariat, Jasper National Park

Hodgins, Doug. Ecosystem Planning Manager. Ecosystem Secretariat, Jasper National Park.

Kolesch, Alex. Land Use Specialist, Ecosystem Secretariat, Jasper National Park.

Kubian, Rick. Fire and Vegetation Warden. Warden Service. Jasper National Park.

McLeod, Andrew. Development Officer, Jasper National Park.

Westhaver, Alan. Fire and Vegetation Specialist, Warden Service, Jasper National Park.

List of Participants at the November 2, 1999 Western Regional Meeting, Calgary
(printed with permission of the participants)

Achuff, Peter. Conservation Biologist. Ecosystem Secretariat. Jasper National Park.

Dolan, Bill. Chief Park Warden. Warden Service, Waterton Lakes National Park.

Heathcott, Mark. Fire Management Officer. Western Region. Parks Canada.

LaBoucane, Tim. Fire and Vegetation Specialist. Warden Service. Mt. Revelstoke/Glacier National Park.

Pengally, Ian. Fire and Vegetation Specialist, Warden Service, Banff National Park.

Schwanke, Randall. Fire and Vegetation Specialist, Warden Service, Waterton Lakes National Park.

Smith, Janice. Communications. Waterton Lakes National Park.

Walker, Robert. Fire and Vegetation Specialist. Warden Service. Lake Louise, Yoho and Kootenay National Parks.

Westhaver, Alan. Fire and Vegetation Specialist, Warden Service, Jasper National Park.

APPENDIX B

Western Region Fire and Vegetation Meeting
November 2, 1999
Key Informant Questions for Project Input
Forest Insect and Disease Management in Jasper National Park

Name/ Park:

Please answer the following questions with regards to the attached list of criteria and indicators:

1. Do you prefer a numbered scale for the evaluation, or a low/medium/high scale?
2. Please read through the numbered rating systems. Are there other indicators under each criteria that have been left out? Is there something you would change? Please comment in the margin.
3. Please provide your comments on Multiple Accounts Analysis below. How can it be helpful to you? What could be improved?

Criteria and Indicators for Multiple Accounts Analysis

<u>Ecological Integrity:</u>
Scientific Certainty

0 No data available to inform management decisions
1 Data exists for areas outside the park and has been extrapolated to inform management actions
2 Data for Jasper National Park exists, but is sparse or incomplete with no monitoring program to inform management decisions
3 Data for Jasper National Park exists, is sparse or incomplete but research is being conducted to increase understanding and monitoring programs are being established
4 Strong Baseline data exists and a monitoring program is current and continues to inform management actions

Precautionary Principle: erring on the side of caution when considering management decisions

0 Management action certain to negatively affect the ecological integrity of considered area
1 Management action likely to negatively affect the ecological integrity of the considered area
2 Affects of management action on ecological integrity unknown
3 Management action likely to positively affect the ecological integrity of the considered area

4 Management action certain to positively affect the ecological integrity of the considered area

*If management action has no effect on ecological integrity, rate it from 2-4 depending on whether that area needs more positive action or not.

Ecosystem Management:

Adaptive Management

0 No monitoring, evaluation or feedback is occurring
1 Monitoring program established, but no evaluation or feedback
2 Monitoring Program established, some evaluation but no feedback into management decisions
3 Monitoring Program established, evaluation occurring, feedback into management decisions

Cooperation with adjacent land managers

0 No interagency communication
1 Ad hoc, less formal interagency communications; no formal minutes or publicized results; no agreement of ecosystem boundary or community being managed; No common management goals agreed upon
2 Ad hoc, less formal interagency communications; results of meetings recorded and distributed, informal recognition of ecosystem boundary or community being managed; No common management goals agreed upon
3 Formal interagency meetings and communications; results of meetings formally recorded and distributed, formal agreement of ecosystem boundary or community being managed, Common management goals agreed upon

Public Perceptions:

Public Perceptions

0 Management actions are made outside the mandate of Jasper National Park and Parks Canada; Communication to public about management actions non-existent
1 Management actions are within mandate/policy; communication to public about management actions non-existent
2 Management actions are within mandate/policy, communication to the public about management action exists
3 Management actions are within mandate/policy, communication to the public about management actions exists and is consistent
4 Management actions are within mandate/policy, communication to the public about management actions exists and is consistent; an effective opportunity for public to provide feedback into the process exists

Economic Considerations:
Parks Canada

0 Management action not feasible within budget
1 Management action not feasible within budget, but goes ahead with limited resources
2 Management action feasible within budget, but receives middle-low priority
3 Management action feasible with budget, and receives high priority

Out of Parks

0 Management action has a known negative effect on adjacent land owners
1 Management action has a possible negative effect on adjacent land owners
2 Management action has no effect on adjacent land owners
3 Management action has a possible positive effect on adjacent land owners
4 Management action has a known positive effect on adjacent land owners

Service to Clients:
Visitor Experience

0 Management action has a known negative effect on visitor experience
1 Management action has a possible negative effect on visitor experience
2 Management action has no effect on visitor experience
3 Management action has a possible positive effect on visitor experience
4 Management action has a know positive effect on visitor experience

Liability:

Short term safety
0 Management action is inherently risky; injury to public possible
1 Management action is inherently risky; injury to public unlikely
2 Management action has no immediate effect on public
3 Management action likely to increase public safety
4 Management action known to increase public safety

Long term safety

0 Management action is inherently risky; injury to public possible
1 Management action is inherently risky; injury to public unlikely
2 Management action has no immediate effect on public
3 Management action likely to increase public safety
4 Management action likely to increase public safety

Western Region MAA input Results
November 2, 1999

Comments on Ecological Integrity Section:

Scientific Certainty:

- Change "scientific certainty" to "scientific information adequacy." Certainty is not the same as adequacy
- 1 and 2 are not mutually exclusive
- There is some duplication between scientific certainty and adaptive management section
- What are the standards to assess data strength? What are the standards to assess results of analysis or recommendations based on data?
- Too complicated! Simplify!
- A 3rd ecological factor is possible. Create a scale where at one end is: "the named action has a pervasive ecological impact on all/most park ecosystems" and at the other end is: "Action has no implications for park or regional ecosystems."
- Number 0 under scientific certainty should read " No data or applicable literature…"
- Using the word "area" here may be a red herring here. In all cases the area should be flexible to fit the specific issue.
- Number 4 under scientific certainty should read "reliable or definitive baseline data…" instead of "strong baseline data…."
- Some possible indicators of Ecological Integrity might be: Are viable populations of native flora and fauna being maintained? Are ecological processes functioning? (i.e. fire, predator/prey relationships/connectivity of habitats for wildlife/insects and diseases?
- Should be moved to ecosystem management – not measures of E.I.

Precautionary Principle:

- Precautionary principle deals with certainty (overlap).
- Precautionary principle: if the effects of a management action on ecological integrity are unknown, is there a testable hypothesis?
- If effects of management action on ecological integrity is unknown, then it should get the same rating as if certain negative effects are likely to occur. I.e. if you don't know, don't do it.
- What about neutral impact?
- Should be moved to ecosystem management – not measure of Ecological Integrity.

Comments on Ecosystem Management:

Adaptive Management:

- Section Good
- Checkmark for section (Good)
- Ecosystem management includes many of the other headings. It is a way of doing business which includes science, social and economic elements

Co-operation with Adjacent Land Managers:

- Too much is being lumped here. Split communication and common goals
- Add one more level (between 2 and 3): field level acceptance but not formal management level
- Under # 3, include "common management goals agreed upon at all levels"
- Checkmark for section (good).
- "Good"
- Is "no interagency communication" worse than adversarial communications? Is it worse than agreeing to disagree?
- Change "less formal" to "little formal"

Comments on Public Perceptions

- Separate communications from perception of mandate
- Provide definition and assumptions when using the phrase "outside the mandate of JNP)
- Too much lumped together – separate communications from policy
- Not sure what you're trying to get at with the management aspect of this?
- This continuum with respect to communication is pretty good
- You may want to consider separate indicators for communication to visitors as opposed to those outside the park (usually non-existent). May also want to separate out communication indicators relative to visitors (relates to public support versus other government agencies we work with i.e. partners and landowners (relates to more effective working with others).
- Not sure how "actions outside the mandate" is the most important factor in public perception of the management.
- What does it mean when management actions are within mandate/policy?
- This section is good – include it.
- Under # 0, add "or disjointed" on the end.
- Split policy and communication

Comments on Economic Considerations Section

- May want to call this section "resource considerations" – includes money, people, equipment, time and how they are allocated

Parks Canada:

- May want to revise wording: i.e. for # 0: "resources to implement action are provided in the Park Business plan
- Would use word "funded" instead of feasible.
- The word "priority" may be a red herring. The key is: Is this it resourced?
- It is not possible to for a management action to be not feasible under the budget, but to go ahead with limited resources. One is not possible without the other.
- There is a wide range of management actions from following literature, to field monitoring with varying periodicity, to active management operations, which have very different budget costs. What kind or cost of management action?

Out of Parks:

- Distinguishing between 0 an 1, and between 3 and 4 may be splitting hairs?
- This is leaseholders and concessionaires?
- Adjacent land owners could be a heterogeneous group with differing land management goals and thus differing positive or negative effects. Effects on neighbors are more than just economic?

<u>Comments on Service to Clients:</u>

Visitor Experience:

- Visitor experience is a heterogeneous mix. May need to evaluate specific aspects or types of visitor experience
- Is distinguishing between 0 and 1, and 3 and 4 splitting hairs?
- Important section – include.
- Add "or unknown" at end of #0 so that it reads "management action has a known negative effect of visitor experience, or the effect is unknown.

<u>Comments on Liability Section:</u>

- Need to define "management action" what are the risks to public or staff doing the work?
- Safety and Economic Considerations may be linked
- Should this section include liabilities for more than human values? Or is that adequately captured under "precautionary principle."

Short Term Safety:

- Splitting hairs again between 0 and 1, and 3 and 4.
- Is there room for an indicator which reads "no known effect"

Long Term Safety:

- Add indicators here: How informed/involved/supportive are park managers regarding field level actions/programs? Create scale where at one end might have "not informed/involved or supportive" and at the other end "Managers informed, active advocates of programs"

General Comments

- Need to identify user of this matrix and level of detail appropriate for that user.
- Public Perception, communications and visitor experience are linked in ways that this MAA does not capture. Perceptions and experience are based, in part, on the communications that they have been exposed to . I con not decide whether to lump them under the headings "social" and communications, or whether to expand them.
- In a general sense, it seems to me that there are three basic criteria here: Ecological Integrity, Social Values and Economic Considerations. All the others could be feathered into one of this three. The relative weight of all these factors is critical to the process, but the most difficult part (in terms of a meaningful approach). I would suggest that their weight be: Ecological Integrity (50%), Social Values (20-40%) and Economic Considerations (10-30%).
- May want to lump economic considerations and liability in some way.
- Adaptive management may relate to experimental design
- Under the actions listed in the chart (from the vegetation management plan 1997), there are a lot of actions that are "talk" and not "action".
- It is not always possible to recognize the concerns of adjacent land managers.
- May want to lump the criteria under 3 headings: Ecological Integrity, Social, and Economic. Parks clearly states some of these should be weighted higher, i.e. ecological integrity gets higher priority than social and economic. Would put ecosystem management with Ecological Integrity. Would put Service to clients, liability and public perceptions together under social category. Would make public perceptions an indicator.
- Service to clients appears to deal largely with visitors and potentially could deal with "the public" as a whole that we are accountable to. I think you need a fundamental principle that relates to how effectively we working with other decision makers who can potentially leverage our efforts or create barriers, i.e. landowners, regional/provincial government etc.
- Few of the actions listed in the chart relate to communication except notification of management actions. For example, education (long term support) and awareness programs). Communications are part of protection relative to public understanding and support and management understanding and support.
- Would like to see weighting of categories, and linking of fundamental principles together. Ecological integrity should weight high, service to clients should be low, ecosystem management should be high, economic considerations should be low, public perceptions should be nil.
- Criteria are good and can be applied. Ranking/number system good. Reflects well on management actions. There should be more weighting on ecological integrity – it is

the mandate of Parks Canada. Compress short and long term liability into one. Closer alignment of service to clients and public perceptions.

- Add extra criteria on chart – Is it funded?
- I see value in having each manager put a % breakdown of importance on various categories of indicators.
- With respect to Mountain Pine Beetle we have to choose between two requirements of the Act 1988 regarding Ecological Integrity and the direction of policy (1994) which acknowledges we may take actions to protect neighboring lands. If we are unwilling to fund and implement a pine beetle control program, should we allow ALFS or the forestry industry the opportunity to complete a project proposal and submit an environmental assessment for pine beetle control. Would such and E.A. pass and proceed? Should Parks implement pine beetle control in return for other favors by the province such as changes to wolf hunting regulations, reintroduction of bison in parks, fire use plans in provincial protected area adjacent to parks. Who should be at the table, who should broker a scratch you back/scratch mine negotiations?

Other park goals to consider: wilderness recreation and solitude and lack of industrial activity in remote areas. What about tourism based goals (i.e. not logging in front country area on a scenic landscape

APPENDIX C

THE UNIVERSITY OF CALGARY

INTER-OFFICE

TO: Micki Wilson

FROM: Prof. Thomas L. Harper
Environmental Design Ethics Committee

DATE: 1998-04-17

Re: YOUR APPLICATION FOR EVDS ETHICS COMMITTEE APPROVAL

Thank you for your research proposal and request for review by the EVDS Ethics Comittee.

We have reviewed your application to conduct human subject research dealing with "A Forest Insect Management Plan for Jasper National Park" and find that it is acceptable from an ethics perspective. In making our recommendation, we are satisfied that the anonymity and confidentiality of the respondents has been adequately protected, risks and benefits of the research have been clearly stated, the respondent's legal rights have not been limited, respondents may withdraw at any time, and the security and eventual destruction of the data has been adequately addressed.

You should note that the approval of this research by the ethics committee does not imply that your research design or analytic techniques are acceptable from an academic perspective. It simply means that in the Committee's judgement, the human subjects will not be harmed by the proposed research.

Should you require the University of Calgary to issue a certificate of Institutional Ethics Review, you should request that we forward your application, with our evaluation to the Joint Faculties Research Ethics Committee (Office of the Vice-President Research, Karen McDermid) for review and direct response.

Thomas Harper

CAMPUS MAIL

cc: Dr. Nigel Shrive, Joint Faculties Research Ethics Committee
c/o Karen McDermid, A131