Forest fires, woodland caribou and land use policies in northwestern Ontario (Rangifer tarandus)

Brian Frederick Kutas
Wilfrid Laurier University

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Forest Fires, Woodland Caribou and Land Use Policies in Northwestern Ontario

By

Brian Frederick Kutas
(Bachelor of Arts, Trent University, 1999)

THESIS
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ABSTRACT

Woodland caribou (*Rangifer tarandus caribou*) are a threatened species in Ontario's boreal forest. Caribou require habitat that supports appropriate forage, including large areas of lichen rich forests. This research examines two dynamics that influence woodland caribou habitat in northwestern Ontario. These dynamics are forest fires and land use policies. The effects of forest fires are assessed quantitatively at both the ecosite and landscape scales within Woodland Caribou Provincial Park. Land use policy and management activities are evaluated using a case study and a policy analysis of protected area and forest management approaches to woodland caribou conservation in this region.

Forest fires in Woodland Caribou Provincial Park exert tremendous influence on woodland caribou habitat. However, they vary significantly in their ecological effects and return intervals. Fire severity plays an important role in determining both structure and composition of forest communities, shaping forest openings, duff characteristics, and how terrestrial lichen (an important food source for woodland caribou) recolonize an area after a burn. Results show that the amount of terrestrial lichen able to regenerate varies depending upon canopy openness and duff accumulation on V30 sites within Woodland Caribou Provincial Park. The amount of area burned within the park (measured by decade) in the 20^{th} century varied dramatically from 319 ha in the 1950's to over 106,000 ha in the 1980's. These variations in site characteristics and stands of suitable ages have important implications for management and policy development. Forests suitable for woodland caribou habitat in this portion of Ontario are not in equilibrium. Land use policies intended to conserve caribou in this region must incorporate concepts of non-equilibrium forest dynamics.

Management and policy development related to the conservation of woodland caribou is largely absent in Ontario Parks, due to a lack of information and limited strategic vision. The Forest Division of the Ontario Ministry of Natural Resources is making significant strides towards sustainable management of forests, but silvicultural constraints imposed by the sustained yield paradigm are limiting the management prescriptions attempting to mimic natural disturbances. Fire management continues to be problematic in both jurisdictions, as the cost of ecologically oriented management remains very high. Moreover, concepts of non-equilibrium forest dynamics have not been integrated into any land use management prescription, further limiting forest fire management. Adaptive management that integrates the complexity of this ecosystem at multiple spatial and temporal scales is necessary for effective long-term conservation of woodland caribou habitat in northwestern Ontario.

"Learning is a long-term proposition that requires a ballast against short-term politics and objectives."

Lance Gunderson, 1999

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Woodland caribou (*Rangifer tarandus caribou*) are an area-sensitive threatened species that inhabits Canada's boreal forest (Harris, 1999). In Ontario, woodland caribou have experienced a dramatic recession of their historic range, which once extended south into the Great Lakes St. Lawrence forest region. Today, woodland caribou generally only exist to the north of the industrial boreal forest and in large protected areas such as Woodland Caribou Provincial Park (WCPP) (Schaefer, 2003). The reason for the reduction in range is due to over hunting, predation, and most importantly, habitat alteration by humans (Bergerud, 1974, 1985; Darby *et al.*, 1989; Pruitt, 1997; Racey and Armstrong, 2000). Woodland caribou are now considered a focal species for sustainable land use in Ontario's boreal forest (Darby *et al.*, 1989; Cumming, 1992; Duinker *et al.*, 1998b; Racey and Armstrong, 2000). The Ontario Ministry of Natural Resources (OMNR) considers the management and protection of this species to be a priority (Racey *et al.*, 1996a; Duinker *et al.*, 1998b), as they are an indicator of an ecologically intact Canadian boreal forest (Pruitt, 1997). The extirpation of caribou from this region indicates that land use management practices are not sustainable (OMNR, 2002b).

Woodland caribou are dependant upon a constant renewal of suitable habitat to be able to persist in a region (Schaefer and Pruitt, 1991; Cumming, 1992). This research focused on winter woodland caribou habitat, as habitat at this time of year is critical for survival. I have chosen to study winter woodland habitat because caribou congregate at this time of year, allowing for clear delineation of habitat. Delineating summer woodland caribou habitat is beyond the scope of this research, as caribou are highly dispersed at this time of year, making habitat classification difficult (Rettie and Messier, 2000; Gerrish pers. comm.). Areas considered to be high quality winter woodland caribou habitat in this region are coniferous, lichen rich forests on well-drained soils (Morash and Racey, 1990; Schaefer and Pruitt, 1991). These forests are important because terrestrial lichen, particularly *Cladina spp.*, are very important winter forage for caribou (Klein, 1982; Schaefer and Pruitt, 1991; Harris, 1992; Racey *et al.*, 1996a; Lance and Eastland, 2000; Johnson *et al.*, 2001).

1.1 Purpose

The purpose of this research was to examine issues related to conservation planning for woodland caribou in northwestern Ontario using a multidisciplinary approach. Examining and integrating the dynamics of woodland caribou management allowed me to delve into the complexity of resource management issues in this region. The two dynamics are:

1) ***Forest Fire*** - I have assessed the role of forest composition and structure at varying scales in relation to past fire events and its implication for woodland caribou management. I examined fire severity and its effects on winter caribou habitat in Woodland Caribou Provincial Park (primarily its effects on terrestrial lichen regeneration).
2) ***Land Use Management*** - I have evaluated policy and management approaches of the OMNR in this region, and how concepts of applied ecology have been incorporated into land use policy initiatives. I used the case study of *Rangifer* conservation and management to explore how concepts of ecosystem management (EM) are being employed at multiple spatial and temporal scales.

This research uses both quantitative and qualitative methods to examine the dynamics influencing woodland caribou conservation planning and habitat renewal. A multidisciplinary approach, incorporating ecological assessment policy analysis is used.

Ecological assessment and policy analysis research must be integrated to overcome management and planning impasses that result from disciplinary isolation (Van der Vink, 1997; Cortner, 2000; Ludwig *et al.*, 2001). More holistic ideas can be generated if science and policy assessment are combined in one study (Salwasser, 1993; Christensen *et al.*, 1996; Jensen *et al.*, 2001).

1.2 Study Area and Context

This study takes place in a region surrounding Woodland Caribou Provincial Park, which is located in northwestern Ontario between the town of Red Lake and the Manitoba border (Figure 1.1). The park was established to protect known woodland caribou habitat, and is a primarily upland representative landscape of the boreal ecosystem in Ontario (OMNR, 1986).

WCPP has a continental climate, and is highly influenced by prairie weather; this results in some of the lowest precipitation in Ontario. The summers are warm and dry; so that the landscape is particularly prone to forest fires (OMNR, 1986; Ehnes, 2000). This is evident with the abundance of fire-adapted species such as jack pine (*Pinus banksiana* Lamb.), which is common in this portion of the province (OMNR, 1986; Johnson, 1992; Ehnes, 2000; OMNR, 2002b).

The park is dominated by shallow soils and extensive bedrock outcrops. The predominant tree cover is jack pine, and to a lesser degree black spruce (*Picea mariana* Sarg.). In areas with deeper, richer soils, trembling aspen (*Populus tremuloides* Michx.) and paper birch (*Betula papyrifera* Marsh.) also make up a significant portion of the canopy (OMNR, 1986; Wepruk, 1986). Much of the park has experienced some form of disturbance by fire in the last century, with the most active forest fire decade being the 1980's.

This region's main economic engine is resource extraction, primarily forest harvesting (OMNR, 2002b). This is also the dominant land use management approach in the area. All areas south of the 51st parallel, excluding First Nation lands, settlements and provincial parks, are managed for this objective (Duinker *et al.*, 2001). The dominant form of forest harvesting is through clear-cutting, primarily jack pine and black spruce (Gordon *et al.*, 2001).

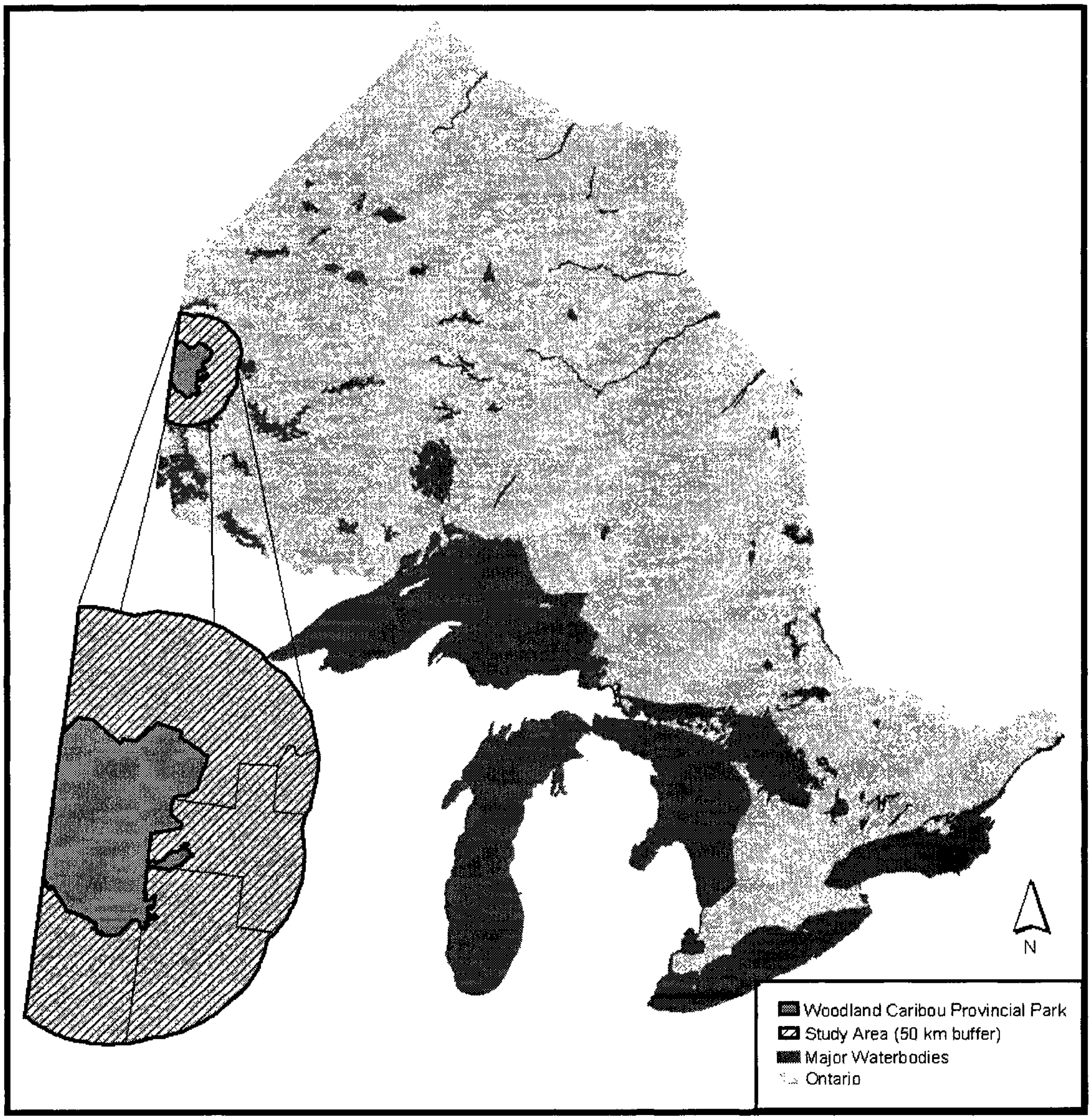

Figure 1.1: Woodland Caribou Provincial Park and the 50 km Buffer Study Area in the Ontario Context.

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1.3 Research Questions

1. How do variations in fire severity influence winter woodland caribou habitat?

2. Is there significant variation in the openness of known and potential caribou habitat, and how does this affect terrestrial lichen regeneration?

3. What are the past and present the land management approaches for conserving woodland caribou habitats in northwestern Ontario?

4. How is ecological science being integrated with land use policy in this region?

1.4 Objectives

By addressing these questions, I shall achieve two main objectives:

1.4.1 ACADEMIC

1. To conduct a multidisciplinary study of woodland caribou management issues, integrating knowledge from both the ecological and policy sciences.
2. Improve concepts of how policy and ecology influence one another in conservation planning.
3. Improve knowledge of the boreal forest ecosystem.

1.4.2 PRACTICAL

Beyond the realm of academe, this research will assist resource managers dealing with ecologically based landscape planning. It will assess how forest fires and policies influence management efforts of woodland caribou.

1.5 Thesis Approach

The quantitative and qualitative portions of this thesis are dealt with independently from this point until the end of the results section. This approach was used so that ideas and concepts could be developed and explored in detail. This results in four smaller chapters (two methods chapters and two results chapters). In the discussion and conclusion the ecological and land use policy sections are integrated to link concepts of how ecological and political dynamics interact. The integrated assessment of these dynamics gives a more holistic picture of the complex issues facing woodland caribou and resource managers in northwestern Ontario.

1.5.1 QUANTITATIVE SECTION

The quantitative section of this research explores the variable effects of forest fire severity on the regeneration of winter woodland caribou in WCPP. Fire severity was selected because lichen rich stands on shallow soils are born in fire (Schaefer and Pruitt, 1991; Johnson, 1992; Heinselman, 1996). Moreover, fire severity dictates the composition and structure of these forests (Johnson, 1981; Payette, 1992; Wang, 2002). To explore how fire has shaped these forests, I examine areas classified as suitable potential winter woodland caribou habitat at both the landscape and ecosite scales; ecosites are areas with relatively uniform topography, soil and hydrology, and chronosequence of vegetation (Uhlig and Wiltshire, 2001: 123). A typical ecosite in this region ranges from 100 m^2 to 10,000m^2. I used a multiscale assessment as understanding how ecosystems operate at multiple spatial scales improves management decisions (Heinselman, 1996; Elkie and Remple, 2001; Turner *et al.*, 2001; Wiens *et al.*, 2002).

1.5.1.1 Research Hypotheses

The hypotheses for the quantitative section of this research are:

1. *Ecosite Scale Assessment*

    a. Winter woodland caribou habitat varies in composition and structure at the ecosite scale.

    b. Age of forests is important in determining lichen abundance.

2. *Landscape Scale Assessment*

    a. Individual stands classified as high potential winter woodland caribou habitat vary in their structural openness.

    b. The amount of area burnt over time in WCPP is not in equilibrium.

1.5.2 QUALITATIVE SECTION

The qualitative section examines how the land use policy and management approaches have been developed for woodland caribou conservation in northwestern Ontario. I examine the approaches of both Ontario Parks and the Forest Division of the OMNR. These two branches are part of the Ministry of Natural Resources, but operate quite independently of one another, both in their organizational structure and management mandates. Ontario Parks is responsible for the management and development of provincial parks in the province, whereas the Forest Division is responsible for the management of lands allocated for forest harvesting in Ontario. Woodland caribou are far ranging species; they, along with other management issues, do not recognize arbitrary resource management boundaries. Therefore it is important to examine policy approaches of both branches of the OMNR.

1.6 Research Relevance

Past research on woodland caribou has focused on the spatial relationship of habitat patches and movement in relation to predators and disturbance (e.g., Rettie and Messier, 2000; Smith *et al.*, 2000; Schaefer *et al.*, 2001). The characteristics of forest fires, particularly the effects of fire severity on woodland caribou habitat, have not been explored in great detail. Potential future habitat is often characterized based on coarse scale vegetation classification and the age of the forest since last disturbance (FRI, etc), with fire severity being largely ignored. However, fire severity is relevant to woodland caribou, as it dictates the composition, structure and abundance of regenerating vegetation (Johnson, 1981; Payette, 1992; Schimmel and Granstorm, 1996; Turner *et al.*, 1999; Payette *et al.*, 2000; Wang, 2002).

Policy analysis related to woodland caribou in this region is extremely limited, with almost no research exploring the relationship between protected areas and lands managed for industrial forestry, and how this affects planning and management of this species at risk. Woodland caribou utilize both reserve lands and the industrial forests of northwestern Ontario; therefore research examining policies of both land management approaches is necessary.

This research draws on concepts and ideas from the biogeography, applied landscape ecology and conservation planning literature. It will contribute to the fields of conservation biology, resource management, and landscape ecology, by examining how policy approaches and fire characteristics interact and affect woodland caribou conservation planning efforts. Knowledge from this study may be used in other jurisdictions, where resource extraction interests and protected area agencies must work together to maintain populations of species at risk.

1.7 North American Focus

This research is focused on the North American context, as woodland caribou only exist in North America. Reindeer (*Rangifer tarandus*) in northern Europe are a very similar species, with similar habitat requirements (Harris, 1992; Kumpula *et al.*, 2000). I have limited comparison between the two regions, as most reindeer are semi-domesticated in Europe, making them a productive policy interest (Bostedt *et al.*, 2003). Moreover, the dynamics between woodland caribou and reindeer are quite different, as predation by carnivores such as wolves on reindeer is limited, as most predators have been extirpated. The significant difference in the incidence of forest fires (Suffling, 1992) further limits the potential for comparisons between northern Europe and northwestern Ontario.

2.0 LITERATURE REVIEW

2.1 Introduction

The objective of this chapter is to review literature relevant to woodland caribou habitat ecology and management. This review will explore three broad fields of study, which reciprocally influence one another in a dynamic fashion; the fields are: ecology, resource management and policy, and scale. First, fire ecology and management are important aspects, as the onset of forest fires, and their ecological effects determine both the amount and the quality of caribou habitat in this region (Schaefer and Pruitt, 1991). Second, land management plays an important role in species conservation, which influences the effectiveness of caribou management initiatives in northwestern Ontario (Noss and Cooperrider, 1994; Cortner and Moote, 1999; Clark *et al.*, 2000; Ludwig *et al.*, 2001). Finally, issues of scale are reviewed, as an understanding of scale affects both ecological phenomena and management decisions (Gibson *et al.*, 2000; Wiens *et al.*, 2002). An effective way to explore complex resource management issues is through a multi or interdisciplinary approach, drawing on numerous and diverse fields, allowing for a more holistic exploration of the issue at hand (Ewel, 2001; Ludwig *et al.*, 2001; Mitchell, 2002).

2.2 Woodland Caribou

Woodland caribou are members of the deer family (Cervidae), and live primarily in Canada's boreal forest (Pruitt, 1997). Caribou are habitat generalists that consume a wide variety of plants to sustain themselves throughout the year, and are widely dispersed (Cumming, 1992; Rettie and Messier, 2000). Caribou do however concentrate their range in the winter months, when many of them cluster together in small herds in areas with lakes and lichen-rich mature coniferous forests (Darby *et al.*, 1989). Woodland caribou consume a significant amount of lichen, both terrestrial, and when available, arboreal, primarily in winter months (Klein, 1982; Darby *et al.*, 1989; Johnson *et al.*, 2001). Lichens can make up as much as 60-70 percent of their diet during this ecologically critical time of year (Klein, 1982; Schaefer and Pruitt, 1991).

Caribou range throughout Ontario and the rest of North America has receded significantly since 1900 (Bergerud, 1974; Darby *et al.*, 1989). Historical caribou range once extended south to the French River region of Ontario, and caribou were once found in every province other than Prince Edward Island (Cumming, 1992). Today woodland caribou have been extirpated from both Nova Scotia and New Brunswick, and the continuous line of suitable habitat has been pushed north of 50 degrees latitude in Ontario (Figure 2.1) (Racey *et al.*, 1999; Cumming, 1992). Today the southern most caribou populations are found in a few large provincial parks in Ontario (e.g., Wabakimi and Woodland Caribou) (Cumming, 1998; Morash and Racey, 1990). This southern boundary is also the northern boundary of industrial forest harvesting in the province (Racey *et al.*, 1999), as caribou do not exist in recently cutover areas (Smith *et al.*, 2000). Effective conservation of caribou in the boreal forest would require restrictions on forest harvesting, which is undesirable for it (Cumming *et al.*, 1994; Pruitt, 1997).

Disturbance of forests by fire is an important dynamic for woodland caribou, as it destroys and renews habitat (Klein, 1982; Cumming and Beange, 1993). Most winter caribou habitat is in jack pine forests, which have their origins in fire (Morash and Racey, 1990; Johnson, 1992). Caribou will not return to fire altered habitat for long periods of time - at least 50 years, at which time the forests have reached a more mature state (Schaefer and Pruitt, 1991). Fritz *et al* (1993) discussed the cyclical use of a region by woodland caribou; in portions of northwestern Ontario caribou were largely absent for many decades, but as habitat became suitable, the occupancy by caribou increased. Caribou will continue to occupy such areas until another disturbance event.

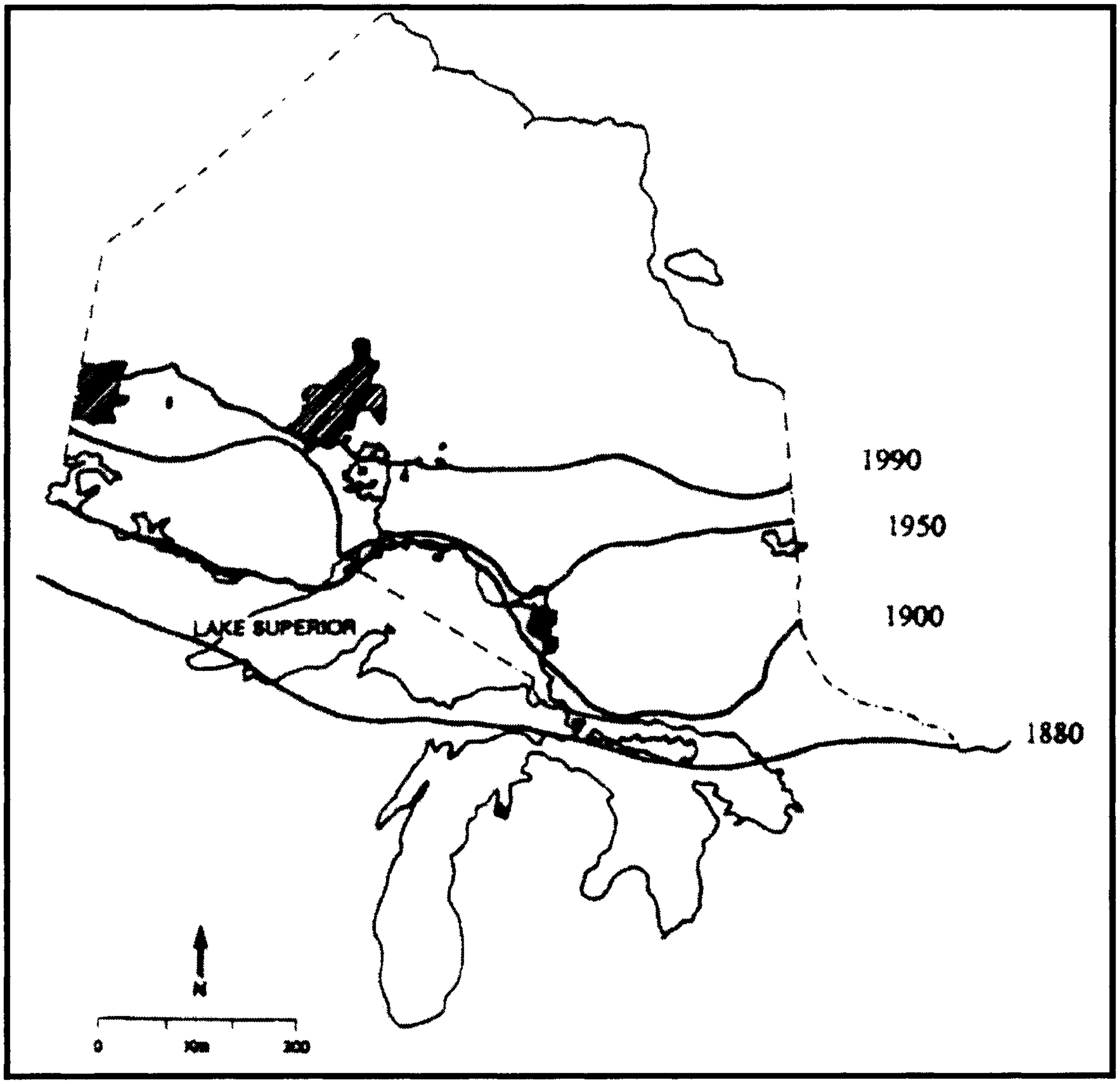


Figure 2.1: Range Recession of Continuous Woodland Caribou Habitat in Ontario
from Racey *et al.* 1999:5

2.3 Ecological Dynamics

The numerous ecological variables influencing the sustainability of woodland caribou in the boreal forest include predation, disease, and habitat alteration by fire (Bergerud, 1985; Racey *et al.*, 1999; Schaefer and Pruitt, 1991). For the purpose of this research I will only explore the issues related to fire.

2.3.1 FOREST FIRES

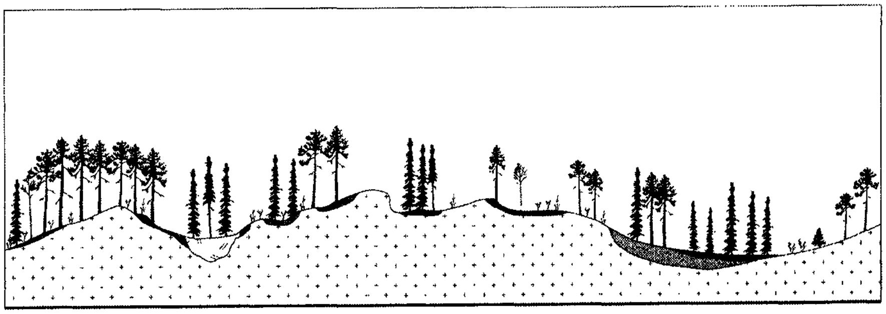
Most winter woodland caribou habitat in northwestern Ontario is in mature coniferous (primarily jack pine) forests on shallow or well-drained soils (Racey *et al.*, 1999). These communities were engendered by, and maintained by fire, and therefore disturbance by fire represents an important factor in the ecology and management of woodland caribou (Cumming, 1992; Schaefer and Pruitt, 1991). For the purpose of this research, I will characterize these habitats based on the Forest Ecosystem and Ecosite classification systems used for northwestern Ontario (Racey *et al.*, 1996b and Sims *et al.*, 1997). Winter habitat in mature jack pine forests, on shallow well drained soils are classified as Ecosite (ES) type 12 and Vegetation (V) type 30 (Figures 2.2 and 2.3) (Morash and Racey, 1990; Racey *et al.*, 1999).

Although fires may reduce the amount of caribou habitat in the short term with the alteration in habitat structure and the removal of lichen, forest fires are required to renew and maintain woodland caribou habitat over time (Klein, 1982; Webb, 1998). The absence of fire will lead to forests that are structurally and compositionally unfavorable to woodland caribou, as increasingly unsuitable and less fire tolerant species such as black spruce, and eventually balsam fir (*Abies balsamea* (L.) Mill.), trembling aspen and white spruce (*Picea glauca* (Moench) Voss) colonize the landscape (OMNR, 1986; Heinselman, 1996). These tree species, and their associated ground cover, do not favour winter foraging opportunities for caribou. (Klein, 1982; Schaefer and Pruitt, 1991).

Fire plays an important role in shaping plant communities in almost all terrestrial ecosystems in North America (Kilgore and Heinselman, 1990). Perhaps nowhere in North America is fire more important in shaping vegetation dynamics than in the boreal forest (Heinselman, 1973, 1981; Van Wagner, 1978; Bonan and Shugart, 1989; Payette, 1992;

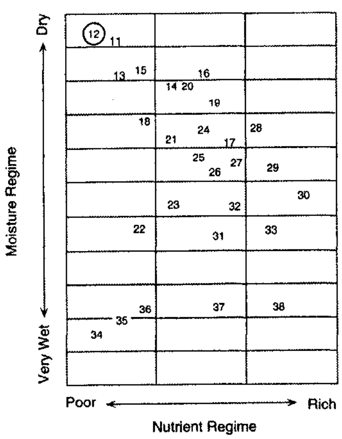
Suffling, 1995; Kimmins, 1997; Bergeron, 2000; McCarthy, 2001). Many species within the boreal forest are very well adapted to the onset of fire (Payette, 1992; Heinsleman, 1996; Bergeron, 2000); many boreal species such as jack pine with its serotinous cones, trembling aspen with their root suckering reproductive characteristics, black spruce with their lateral growth pattern, and fireweed (*Epilobium angustifolium* (L.)); have evolved with fire, and in many cases require the onset of fire to promote their regeneration (Johnson, 1992; Heinselman, 1996; Johnson *et al.*, 1998). The regeneration of plant species after fire will depend on the available seed sources, the intensity, severity and return interval of fires (Heinselman, 1981; Johnson, 1992; Schimmel and Granstorm, 1996; Greene *et al.*, 1999). Fire mobilizes nutrients, diversifies landscape mosaics, and perpetuates fire dependant species (Suffling, 1995; Ryan, 2002).

ES12 Black Spruce–Jack Pine: Very Shallow Soil



General Description

Overstory open and patchy to close-crowned. Dominated by black spruce and jack pine. Balsam fir and trembling aspen in patches. Shrub- and herb-poor. Soils very shallow (<20 cm) with bedrock outcrops. Bedrock frequently covered only by a shallow litter layer. Ground cover consists of bedrock, needle litter, lichen and feathermoss.



Soil Types
SS1, SS2, SS3, SS4, SS5
Mode of Deposition
bedrock, morainal
Humus Form
fibrimor, humifibrimor
Overstory
black spruce, jack pine, white birch
Shrubs/Trees (<10 m)
Vaccinium myrtilloides, Vaccinium angustifolium, Gaultheria hispidula, black spruce, balsam fir, *Linnaea borealis*
Herbs and Graminoids
Aralia nudicaulis, Cornus canadensis, Trientalis borealis, Clintonia borealis, Maianthemum canadense
Mosses and Lichens
Cladina mitis, Cladina rangiferina, Cladina stellaris, Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens, Dicranum polysetum

Comments

May occur as pure jack pine, pure black spruce or as a mixture. May cover small rock outcrops or extensive open bedrock areas. Forest cover may be patchy, with lichen-covered bedrock knobs and ridges. In addition to the characteristic V30, there may be small patches of a wide variety of other V-types, including V35–V38 where drainage is disrupted. White cedar may be locally abundant, especially in the Atikokan, Fort Frances and Dryden areas. Slow tree growth. S-types SS1 to SS4 are characteristic and dominant (>50% of polygon area), but inclusions of SS5, SS6 and SS9 are frequent.

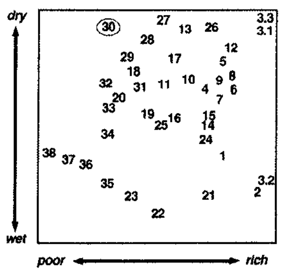
Figure 2.2:Description of Ecosite (ES)12 for Northwestern Ontario
from Racey *et al.*, 1996b: 48.

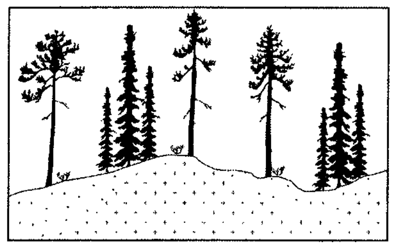
V30

Jack Pine - Black Spruce / Blueberry / Lichen

General Description (n=46)

Sparse jack pine and/or black spruce stands. The understory is open with scattered clumps of black spruce shrubs. *Vaccinium* spp. predominate in the herb / dwarf shrub layer. The forest floor is characterized by abundant lichen cover. Usually occurring on shallow, sandy or rocky sites.





Overstory Species

jack pine^{8}
black spruce^{6}
balsam fir^{1}

Common Understory Species

Shrubs: *Vaccinium angustifolium*, black spruce, *V. myrtilloides*

Herbs: *Maianthemum canadense*, *Melampyrum lineare*

Mosses: *Pleurozium schreberi*, *Dicranum polysetum*

Lichens: *Cladina rangiferina*, *C. mitis*, *C. stellaris*

Forest Floor Cover

Lichen: 48 Moss: 34 Conifer litter: 10 Bare rock: 9

Soil / Site Characteristics

Soil Groups:	(v shal)^{4}, (mod dp)^{3}, (dp d-f)^{2}
Thickness of Organic Layer:	[LFH] - (1-5)^{5}, (6-15)^{5}, (16-25)^{1}
Surface Texture :	c. loamy^{4}, c. sandy^{2}, f. sandy^{2}, non-soil^{2}, silty^{1}
C Texture (when present):	f. sandy^{5}, c. sandy^{3}, c. loamy^{1}
Moisture Regime / Drainage:	dry^{5}, fresh^{4} / rapid^{9}, well^{1}, poor^{1}
Mode of Deposition:	morainal^{5}, glaciofluvial^{4}, aeolian^{1}

Comments

Typically, **V30** describes poorly stocked stands on shallow soils over bedrock. However, soil conditions can vary from talus slopes and bare bedrock ("non-soils") to deep mineral soils; deep soils are more common in the west. *Ledum groenlandicum* and *Arctostaphylos uva-ursi* can be abundant as dwarf shrubs. The ground lichen flora is generally dominated by *Cladina* spp. but occasionally, especially in the west, *Stereocaulon* spp. can form significant cover. Some very poor mixedwood stands, most likely keying to **V18** and **V20**, could be comparable to the **V30** Type description.

Figure 2.3: Description of Vegetation (V) type 30 for Northwestern Ontario from Sims *et al.*, 1997: 65.

For the purpose of this literature review, I will focus on stand-replacing fires that kill trees, as these are the most common types of fires in this region, and most relevant to woodland caribou habitat management at the landscape level (Ehnes, 2000; Johnson, 1992; OMNR, 1986). Small-scale ground fires do occur, but do not make up a significant proportion of area burnt in this region (Ehnes, 2000; Johnson, 1992). Almost no literature was found exploring the effects of small, or low intensity ground fire on caribou habitat. However, low intensity surface fires have long been used to promote lichen abundance for reindeer foraging in the highly managed landscapes of northern Sweden (Hornberg *et al.*, 1999). This portion of this review will examine aspects of fire ecology that are relevant to woodland caribou management.

2.3.1.1 Fire Ignition

Most fires in the boreal forest are caused by either lightning or humans (Johnson, 1992; Li, 2000). Lightning is the dominant ignition source in more remote locations, whereas humans are the primary cause of fire in more developed areas (Johnson, 1992; Heinselman, 1996; Ryan, 2002). The effects of lightning-caused fire are more pronounced when they are accompanied by dry thunderstorms with little or no rain (Johnson, 1992). The absence of precipitation increases the likelihood of ignition and eventual fire spread (Ryan, 2002). Campers and others along transportation corridors (roads, railways and canoe routes in this region) do cause a significant number of fires (Heinselman, 1996). Human and lightning caused fires are common in the boreal forests of northwestern Ontario, with the Red Lake area, the field site for this research, having one of the highest number of lightning caused forest fires in Canada (OMNR, 1986; Johnson, 1992).

2.3.1.2 Fire Spread

Fuel characteristics determine both the rate, and how fires spread (Li, 2000). Mature forests with significant downed, dead trees will facilitate fire spread (Romme, 1982; USDA, 2000; Veblen, *et al.*, 2001). Highly heterogeneous landscapes do not facilitate rapid fire spread, as fuels often vary in their flammability, and connectedness (Turner *et al.*, 1989; Turner *et al.*, 1999; Cumming, 2001). Conifers are generally more flammable than deciduous trees, and facilitate both burning and spread (Johnson *et al.*, 1998; Wang, 2002). Wind is the dominant agent facilitating the spread of fire in the boreal, although fire also spreads by conduction and convection up slopes (Johnson, 1992).

Fires may spread through the canopy, surface and ground of forests; one fundamental variable to the spread of fire is fuel connectivity (Stocks, 1987a,b, 1989; Johnson, 1992; Kimmins, 1997). If no available fuel is in close proximity to a fire, the fire will not spread (Turner *et al.*, 1994; Miller and Urban, 2000).

2.3.1.3 Fire Return Intervals

The return interval of fires will determine both the structure and composition of species within any given stand (Johnson, 1981; Romme, 1982; Heinselman, 1996; Turner *et al.*, 1994; Weir *et al.*, 2000). Forests that burn at short intervals after one another will favor species adapted to a short fire cycle, species such as jack pine (Johnson, 1992; Suffling, 1995; Lesieur *et al.*, 2002; Fule *et al.*, 2003). The average fire interval in northwestern Ontario in dry upland jack pine sites is less than 100 years (Ehnes, 2000), although there can be significant variation in forest ages (Schaefer and Pruitt, 1991). Since fires do not burn uniformly across the landscape, accurately aging large areas may be difficult and misleading (Johnson *et al.*, 1995; Fortin *et al.*, 1999). In areas that are less prone to extended dry weather, the fire return interval may be noticeably longer (Foster, 1983).

Since the 1890's, the return interval of fire has lengthened in much of the boreal forest due to the end of the little ice age (Lesieur *et al.*, 2002). The ecological implications are not well understood, beyond recognizing that the average forest age is older (Larsen, 1997; Weir *et al.*, 2000).

2.3.2 FIRE CHARACTERISTICS

The boreal forest has two primary types of stand replacing forest fires, wind driven and convective fires (Johnson, 1992). The effects on fuel consumption vary inversely with rate of spread; fast moving fires have relatively limited fuel consumption, whereas slow moving, convective fires consume considerably more fuel (Johnson and Miyanishi, 1995) (Figure 2.4).

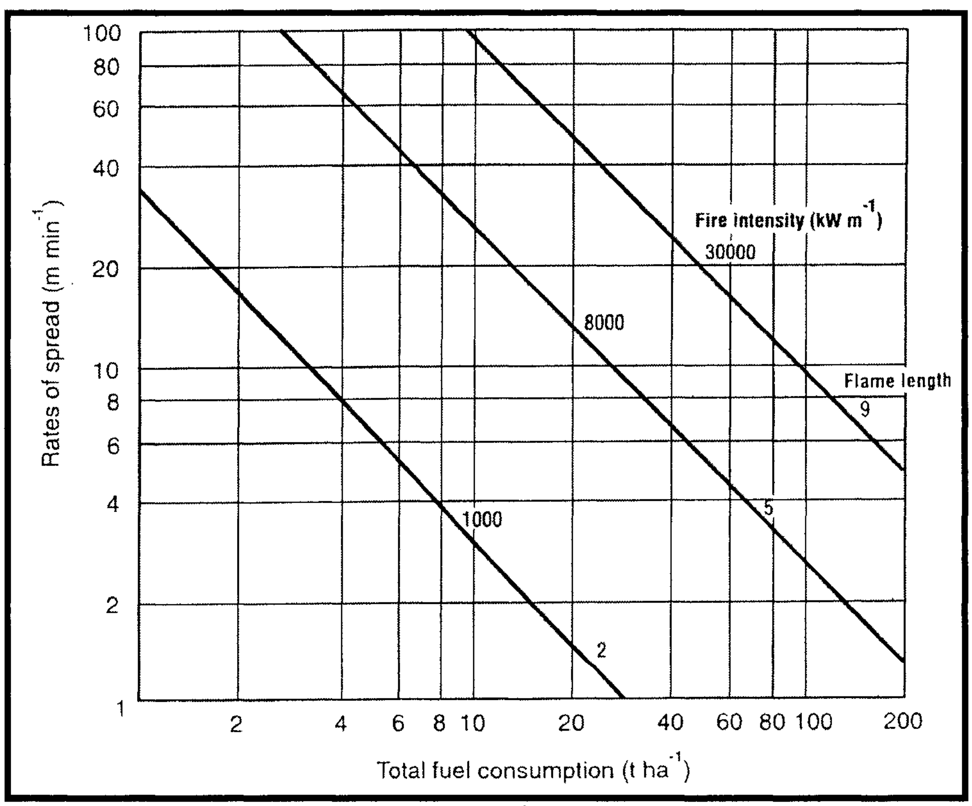


Figure 2.4: Rothermel and Anderson Fire Spread/Fuel Consumption Model.
Fire characteristics illustrating rate of spread (m/min) and total fuel consumption (*t*/ha) to fire intensity (kW/m) and flame length (m) (Rothermel and Anderson, 1966 cited in Johnson and Miyanishi, 1995: 273).

Wind driven fires move quickly across the landscape, and cover large areas. Many trees are killed, and the fires are often considered to be stand-replacing burns (Ehnes, 2000; Ryan, 2002). These fires are highly variable and may have limited ground fuel consumption (Miyanishi, 2001; Ryan, 2002). Wind driven fires generally result in an oblong shaped burn, with varying degrees of disturbance throughout the affected area (Romme, 1982; Li, 2000; McRea *et al.*, 2001b). These fires often leave many unburnt patches in the forest landscape, due to spotting ahead of the main fire front, and the variable influence of topography (Turner *et al.* 1994). Wind driven fires are much more common in the boreal, accounting for most of the area burnt in any given year (Johnson, 1992; Ontario Parks, 1998; McRea *et al.*, 2001).

Convective fires in comparison have relatively low rates of spread, but consume significantly more biomass (Johnson, 1992; Johnson and Miyanishi, 1995; Ryan, 2002). These fires have a more radial growth pattern (Ryan, 2002). Convective fires are less common, and require specific weather conditions to be maintained over time, usually associated with strong high-pressure systems, with low winds. Convective fires are much less understood than wind driven fires (Johnson, 1992).

The ecological effects of these two types of fire can vary dramatically (Johnson and Miyanishi, 1995; Ryan, 2002). From a tree death and regeneration perspective the effects may seem quite similar, as most trees are killed; but the similarities end there. The effects on ground vegetation, its composition and abundance will vary dramatically based on the characteristics of the fire (Johnson, 1981; Frelich and Reich, 1998; Lance and Eastland, 2000; Fule *et al.*, 2002). Tree and understory vegetation regeneration in fires with limited understory disturbance will favour less fire tolerant species such as trembling aspen (Heinselman, 1996; Payette *et al.*, 2000; Bergeron; 2000). More intense fires, where significant amounts of humus form (duff) have been burnt off will favor more fire tolerant species, such as jack pine, and other species able to withstand the harsh micro-climate site conditions (Johnson, 1981; Green *et al.*, 1999; Ryan, 2002; Wang, 2002).

2.3.2.1 Fire Severity Effects

Fire Severity can be defined as:

> The proportion of individual plant organisms and their propagules killed in a disturbance (Miller, 2000). It relates to the extent of mortality and survival of plant and animal life both aboveground and belowground and to loss of organic matter (Ryan, 2002). It is determined by heat released aboveground and belowground. Low severity disturbances will only slightly alter the biotic structure of a landscape (e.g. small insect outbreaks). Whereas, high severity disturbance will dramatically alter the biotic structure of a landscape, killing most plants and trees (e.g. large stand replacing forest fires) (Frelich, and Reich, 1998).

In areas where fire severity was high, and significant organic matter was removed, the regeneration of species will be quite variable, ranging from areas of pure jack pine in moderately severe burns, to areas with extreme disturbance, where the only plants to recolonize these areas will be robust pioneer species such as lichen (Whittle *et al.*, 1997; Lance and Eastland, 2000; Nguyen-Xuan *et al.*, 2000; Wang, 2002). More severe fires will remove more duff and limit regeneration of trees (Johnson, 1981,1992; Payette, 1992; Miyanishi, 2001). Severe fires can change a forest ecosystem from a closed canopy forest to an open canopy forest (Heinsleman, 1996; Payette *et al.*, 2000). In very severe burns, where little or no suitable seedbeds exist, species may not recolonize sites until long after the burn, as the nutrient capacity of the soils may be extremely low, and require long periods to recover to a stage where they can support any vegetation (Schaefer and Pruitt, 1991; Neary *et al.*, 1999).

2.3.2.2 Effects on Ground Vegetation

Fire's impact on ground vegetation and partially decomposed organic matter (duff) is particularly important for woodland caribou winter foraging opportunities, as the amount of organic matter on the ground determines the successional pathways of future colonization of preferred foraging species, specifically, terrestrial lichen (Racey *et al.*, 1996; Payette *et al.*, 2000; Pharo and Vitt, 2000; Sulyman and Coxson, 2001). The effects of fire can be quite variable depending on weather patterns leading up to the fire event (Bessie and Johnson, 1995; Beaty and Taylor, 2001; Kafka *et al.*, 2001; Miyanishi and Johnson, 2002). Depending on both the long and short-term weather patterns, the effect of fires on ground vegetation can vary dramatically, from nearly complete consumption of soil organic matter in certain areas, to almost no impact on the duff (Johnson, 1992; Miyanishi, 2001; Ryan, 2002). Disturbance at the ground layer will also depend on the characteristic of the fire (wind driven or convective), soil characteristics, topography, and fuel loading (Heinselman, 1981; Johnson, 1992; Chipman and Johnson, 2002; Ryan, 2002). For the purpose of this literature review, I will focus on the effects of fire on duff.

The amount of duff that will be consumed will be determined primarily by the dryness of the duff, represented by duff moisture code values (Miyanishi and Johnson, 2002). A high duff moisture code reading during the fire is needed to have significant duff consumption, with higher values needed to consume deeper duff layers (McRae *et al.*, 2001a; Miyanishi and Johnson, 2002). Convective fires traditionally consume more organic matter (Johnson, 1992; Ryan, 2002;), but forest fires are usually influenced by a combination of both convective and wind processes (Ryan, 2002). Duff consumption is somewhat separate from flame intensity, and the smoldering of ground litter and duff, through glowing combustion in fires will remove significant amounts of organic matter on the ground in severe burns (Miyanishi and Johnson, 2002). This level of detail in fire research is still in its infancy (Miyanishi pers. comm. 2002). The consumption of organic matter will leave areas with exposed mineral soils and rock outcrops (Johnson, 1981; Heinseleman, 1996).

The characteristics of burnt ground will largely determine the successional characteristics of future forest structure and composition (Greene *et al.*, 1999; Charron and Greene, 2002; Wang, 2002). Areas with a combination of mineral soil and thin organic matter will support a diversity of tree species, and are considered the favoured substrate for tree regeneration by forest managers (OMNR, 1997c; Green *et al.*, 1999); the more organic matter present, the more likely less fire tolerant species will regenerate (Brais *et al.*, 2000; Wang, 2002).

2.3.3 FIRE AND LICHEN

The likelihood that lichen will regenerate on any given site will depend on the site conditions and competition by other plants (Webb, 1998; Pharo and Vitt, 2000). The variability of lichen stands has been attributed to the type of disturbance, with age being only one factor in the successful recruitment of lichen (Webb, 1998; Pharo and Beattie, 2001; Sulyman and Coxson, 2001). Generally sites that have extremely poor nutrient capacities are the ones that will allow lichens to persist, as competition is limited (Ahti and Hepburn, 1967; Nguyen-Xuan *et al.*, 2000). Once canopy closure occurs, lichen will be limited, and will be succeeded by shade tolerant species such as red-stemmed feathermoss (*Pleurozium schreberi*) (Payette *et al.*, 2000; Sulyman and Coxson, 2001). When feathermoss mats replace lichens as the dominant ground cover, it is unlikely that lichen will be able to regenerate prior to another fire (Payette, 1992). Even fire may not be able to regenerate lichen communities, as the severity of burn will determine the suitability of post-fire sites (Webb, 1998; Neary *et al.*, 1999; Wang, 2002).

The effects of forest fires on lichen communities in the boreal forest are both detrimental and beneficial. In the short term after fire much of the lichen biomass will be removed through combustion (Schaefer and Pruitt, 1991; Harris, 1992). Although fires do limit lichen abundance, disturbance in the canopy and openings in the forest structure are necessary for the persistence of lichens, absence of fire will allow other plants to out compete lichen, and to shade out otherwise suitable habitats (Ahti and Hepburn, 1967; Johnson, 1981; Coxson and Marsh, 2001). In the lichen woodlands of the Northwest Territories and Quebec, relatively frequent fires are needed to maintain the openness of spruce stands to allow lichen mats to survive (Kershaw, 1985; Payette, 1992; Payette *et al.*, 2000). Similarly, the openness of jack pine barrens in the northern Great Lake region of the U.S. is also maintained by fire; fires are required for both the maintenance of openings and the composition of forest, in this case jack pine (Pregitzer and Saunders, 1999).

The regeneration of lichen after logging operations is becoming a consideration in silvicultural prescriptions (Holistedt and Harris, 1992; Miège *et al.*, 2001). Various techniques are being employed, including scarification and prescribed burns to reduce the organic matter in the soil (Harris, 1992). Short term (< 10 years) results have indicated that lichen will regenerate after forest harvesting (Holistedt and Harris, 1992). Long term results indicate that lichen are unlikely to remain on site in any abundance (Coxson and Marsh, 2001). The application of herbicides has also been considered to limit competing vegetation, but there are concerns that this form of treatment actually reduces lichen productivity, with particularly negative effects on species such as *Cladina rangiferina* (Newmaster *et al.*, 1999). The only known use of older cutovers by woodland caribou was near Armstrong, Ontario, where Racey *et al.* (1996a) found that in the early 1990's caribou were using a site harvested in the 1940's. The caribou appeared to be consuming terrestrial lichen (*Cladina spp.*); these lichens were growing on old roads and skid trails, where feathermoss mats had been removed at the time of the forest operation. In areas where the feathermoss mats were not completely removed, very thick feathermoss mats remained, almost completely out-competing the lichen. In northern Sweden, low intensity fire has historically been used to maintain the openness of sites for reindeer, though low stem density would make it undesirable for forest harvesting operations (Hornberg *et al.*, 1999).

2.3.4 FIRE MANAGEMENT

Since the 1940's, when technology allowed humans to effectively control fire, the dominant approach to forest fire management has been to suppress it (Heinselman, 1996; Agee, 1997; Ward *et al.*, 2002). As forest management activities intensify, there is increased interest in improving the effectiveness of fire suppression activities, to limit almost all fires to prescribed burns (Ridout and Botti, 2002). The primary reason for fire suppression is to preserve forests so they can be harvested; concern over private property and smoke pollution are also concerns (Heinselman, 1996; Butry *et al.*, 2001). The forest industry is critical to much of the northern Ontario's economy (Martell, 1994, 2001; Lees and Associates, 1998). Suppression efforts have extended the average fire return interval from approximately 100 years in northern Ontario, to over 600 years (Ward *et al.*, 2002).

Management of fire is changing slowly, with the recognition that it plays an integral role in maintaining ecosystems (Schullery, 1989; Agee, 1997; Hann and Bunnell, 2001). Using small-scale fires and disturbance emulation management approaches have become very popular in recent years (Adamowicz and Veeman, 1998; OMNR, 2002a; Armstrong *et al.*, 2003). This new approach to management will be quite controversial as most management prescriptions must fall within acceptable (economic) silvicultural prescriptions

(Kotar, 1997). Several authors suggest that approaching fire management from this perspective will limit options, and is unlikely to result in effective and ecologically sound management (Franklin *et al.*, 2000; McRae *et al.*, 2001b; Kuuluvainen, 2002). Fire's role in ecosystems has been altered quite dramatically by fire suppression activities throughout North America (Heinselman, 1996; Keane *et al.*, 2002; Woodley, 2002). Increasing fuel accumulation is a growing concern for resource and fire managers, as increased fuel loads will increase the likelihood of catastrophic fire (Hann and Bunnell, 2001; USDA, 2000). Measures are being taken to reduce fuel loads with small scale prescribed burning, how this will affect ecosystems is yet to be seen (Keane *et al.*, 2002). Forest fire management in Ontario is based on three fire management zones (Table 2.1 and Figure 2.5) (Ward *et al.*, 2002).

Table 2.1: Forest Fire Management Zones in Ontario.

Fire Management Zone	Management Action
Intensive	Suppress all fires except for prescribed burns.
Measured	Variable fire response depending on need, and threat to timber resources. Will suppress fires if suppression resources are available. May allow prescribed wildfire in large protected areas (e.g., Quetico Provincial Park).
Extensive	Let it burn, except where otherwise indicated (settlements, etc.)

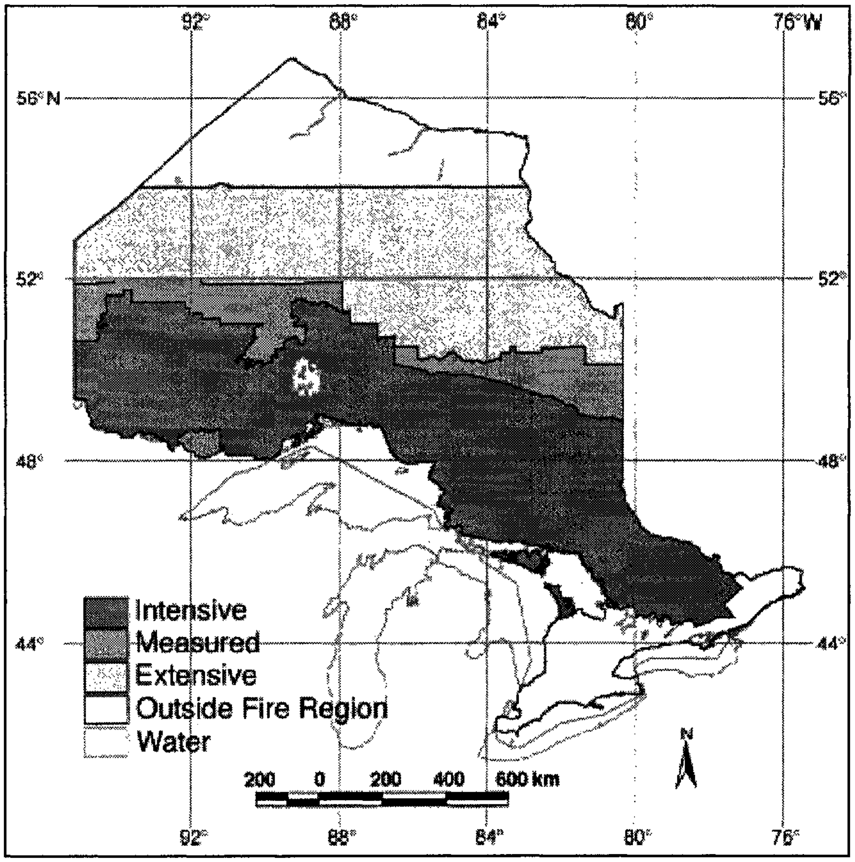


Figure 2.5: Forest Fire Management Zones in Ontario
(Ward *et al.*, 2002: 1469).

2.3.4.1 Fire Management and Protected Areas

The return of fire as a natural process in protected areas has long been a desirable objective, but remains operationally difficult (Canadian Parks Service, 1989; Woodley, 2002). The management of fire needs to be addressed in protected areas, as stand regeneration by other means such as harvesting is not an option for most parks (Murray, 1996; Frelich, 1993). Very few protected areas have a "let it burn" policy, Yellowstone National Park in 1988 allowed many fires to burn their course, but not without considerable public outcry (Schullery, 1989). From a long -term vegetation and ecosystem management perspective, these types of stand replacing fires may be in the best interest of the protected area (Romme, 1982; Romme and Despain, 1989; Ontario Parks, 1998).

Protected areas at both the national and provincial level have been very conservative in their approach to fire management. The most common form of management is to have relatively small natural burn zones at the heart of the protected area, with large buffers within the reserve to protect economic interests adjacent to parks (Heathcott and Crofts, 1997; Ontario Parks, 1998). Small prescribed burns are also used, often to reduce fuel loads, and to prevent larger fires (Ontario Parks, 1998; USDA, 2000). Most parks' fire programs in Canada remain the jurisdiction of provincial and territorial resource management agencies (Manitoba Conservation, 1998; Ontario Parks, 1998; OMNR, 2002b). Fire management in protected areas has been simplistic, due in part to a general lack of understanding of specific ecosystems variables, and strategic management direction (Johnson and Miyanishi, 1995 and 2001; Murray, 1996; Richards *et al.*, 1999; Possingham, 2001). More staffing and resources need to be invested in fire management programs, as this process represents one of the most important ecological variables in many ecosystems (Kutas *et al.*, 2002). This may be difficult, due to a lack of public appetite for such a costly investment (Woodley, 2002).

2.4 Land Use Management Dynamics

The management of land in North America has traditionally been focused on the development of resources and economic prosperity (Epp, 2000). Little attention was paid to the ecological consequences of such activities (Hessing and Howlett, 1997; Dale *et al.*, 2000; Lawson *et al.*, 2001). Land management and their associated policies are critically important to the conservation of biodiversity and the management of ecosystems, as these management paradigms often frame our knowledge, and give general direction to research (Salwasser, 1993; Bean, 1997; Goldstein, 1999; Gordon *et al.*, 2001; Ludwig *et al.*, 2001). If biodiversity and ecosystems are to be effectively managed, a broader research approach must be taken, looking beyond disciplinary boundaries and exploring multiple aspects of resource management (Franklin 1993; Brewer, 1999). This section of this review will focus on three of the more relevant approaches to land management influencing woodland caribou: protected area management, forest management, and the evolving concepts of ecosystem-based management (Euler, 1998).

2.4.1 PROTECTED AREA MANAGEMENT

Protected areas in North America have long been viewed as the likely savior of threatened ecosystems and biodiversity conservation (Dearden and Rollins, 2002; Noss and Scott, 1997; Noss and Cooperrider, 1994). Most remote protected areas have limited development, and preserve naturally evolving ecosystems (Meffe and Carrol, 1997). All protected areas are not equal; many reserves located in close proximity to large population centres have numerous stressors and are usually quite small - less than 1000 ha (Shafer, 1995; Zorn *et al.*, 2001). These parks require active management to maintain viable ecosystems and prevent infiltration of exotic species such as Garlic Mustard (*Alliaria petiolata*), and reduce the impacts of native species that have limited predation (e.g. white tailed deer (*Odocoileus virginanus*) and other species (Parks Canada Agency, 2000; Noss *et al.*, 2002; Woodley, 2002). Large reserves far away from urban centres can also face numerous management issues. These reserves often have low visitation, are not in the public eye, and funding is often in short supply, which limits management options (Eagles, 1998; Kutas *et al.*, 2002).

Although the guiding principle of many protected area agencies is to maintain some form of ecological integrity (EI) or naturalness, many parks were designated in another era, when concepts of EI had not yet been proposed, making effective EI management difficult (Noss, 1995; Promaine and Rempel, 1999; McNamee, 2002). Reserves such as Yellowstone and Banff National Parks, and Algonquin Provincial Park were initially established to promote tourism and other development opportunities in more remote parts of the continent in the 19th century (Killan, 1993; McNamee, 2002). Little thought was given to the future impacts of resource development that would occur around once remote protected areas (Noss and Cooperrider, 1994). Today, with the encroachment of resource extraction activities adjacent to reserves, threats to ecosystems are increasing within reserves (Buechner *et al.*, 1992; Nelson, 1993; Heinselman, 1996).

Much of the protected area academic and government literature has focused on the benefits of having an extensive reserve systems in place; a general theme of conservation biology, is that the more land or water under protected areas management, the better (Noss and Cooperrider, 1994; Margules and Pressey, 2000). In recent years, there has been growing criticism and concern of how protected areas have been established and managed (e.g. Pressey *et al.*, 1993 Eagles, 1998; Nudds *et al.*, 1998; Margules and Pressey, 2000; Kutas *et al.*, 2002). Few concepts of how ecosystems evolve over time within reserves have been explored, with most research focusing on very short time intervals. The important effects of disturbance and landscape evolution and persistence would likely not fit well within the current approach to park management (White, 1987; Baker, 1992; Cumming *et al.*, 1996). With limited funding allocated to various management agencies, large protected area systems with numerous reserves are improperly managed, and face serious threats both from within and outside the reserves (Woodley *et al.*, 1998; Margules and Pressey, 2000; Lambeck and Hobbs, 2002).

Ecosystem-based management has emerged as an important consideration in protected area management, as most reserves are now seen as experiencing considerable threats from activities beyond their boundaries (Nelson, 1993; Landres *et al.*, 1998; Slocombe and Dearden, 2002). Parks Canada has been particularly outspoken in their commitment to ecosystem-based management, and has identified it as a key component in their quest for managing for EI (Parks Canada Agency, 2000). Effective implementation of ecosystem-based management objectives, as identified by Grumbine (1997), has been limited (Wilson, 2001b); most research and management activities that result in lasting changes occur on very small scales (Lambeck and Hobbs, 2002).

Contemporary critiques of protected areas have identified more pressing issues of how existing reserves and reserve systems have evolved throughout the 20th century. There is now growing concern that many protected areas, particularly large parks, were primarily established out of political convenience, and in regions that were deemed undesirable for extractive resource interests, making the ecological merit of any one reserve debatable (Norton, 1999; Margules and Pressey, 2000). This is likely the case for many protected areas in Ontario (Priddle, 1982; Lee Kam, 1993; Duinker *et al.*, 1998b), and therefore should be considered critically important when undertaking any type of ecological or policy assessment of protected areas in this jurisdiction. For this reason, I will limit my discussion of protected area theory and management. For a more detailed assessment of protected area management, readers are encouraged to review Noss and Cooperider (1994); Meffe and Carroll (1997); and Dearden and Rollins (2002).

Forest and ecosystem management have considerably more influence than protected area management on the viability of woodland caribou (Euler, 1998). In the case of northern Ontario, protected area management is very much nested within these land use approaches (Duinker *et al.*, 1998b; Cumming and Beange, 1993).

2.4.2 FOREST MANAGEMENT

Forest management and land use policies related to the extraction of timber have long influenced land use planning in North America (Epp, 2000), with forestry interests playing a very important role in the allocation of land throughout Canada (Killan, 1993; Wilson, 2001a). Traditionally, the focus of forest management has been the extraction of wood fibre in the most economically effective manner possible (Duinker *et al.*, 1998a; Oliver *et al.*, 1999). This type of management has resulted in large areas of North America being cleared of virgin timber; the Great Lakes region, the southeastern United States and the Pacific Northwest are all examples of this form of resources extraction (Noss and Cooperrider, 1994; Perry, 1999). Today, areas once deemed undesirable for large scale and economical forestry practices are being exploited. One of these regions is the boreal forest of northwestern Ontario, where the high quality fibre from black spruce makes fibre for newsprint and paper products. Larger trees such as jack pine are also harvested. This northward extension of forestry has put increasing pressure on organisms and ecosystems in this region (Cumming and Beange, 1993; Pruitt, 1997).

Forestry practices have evolved significantly from the time of pure extraction (Ontario Forest Policy Panel, 1993), where little concern was paid to the regeneration of forests, or the importance of other organisms living within these ecosystems (Duinker *et al.*, 2001; Perry, 1999). Numerous forest management paradigms have been used in North America since this time of pure of resource extraction. Currently more environmentally sensitive approaches that include ecosystem-based and landscape management are being used (Duinker *et al.*, 2001; Bassillie, 2002; OMNR. 2002b). The approach to forest management may change overtime, but the focus on accessing timber still remains.

2.4.2.1 Planning in a Forestry Environment

Land use planning in regions where forestry is an important economic interest dominates the management of land; this has been the case for well over two centuries in North America (Baskent and Yolasigmaz, 1999; Epp, 2000). This is primarily due to the seemingly endless supply of this renewable resource, which covers much of the continent, and historically, all of the settled regions in Ontario (Epp, 2000). Land use planning exercises have been somewhat imbalanced due to the influence of productive interests (forest extraction) versus non-productive interests (preservationists) (Priddle, 1982; Hessing and Howlett, 1997).

In northern and central Ontario the forest industry plays a critical role in the economies of the regions, and therefore has significant influence over policy (Lawson *et al.*, 2000; Duinker *et al.*, 2001). Many communities in northern Ontario are almost exclusively economically based on the extraction of forest resources (Lees and Associates, 1998; Martell, 2001). This dependence on forest resources, and the simplicity of economies in the region, has significantly limited the policy alternatives that have been explored. All land use policies in this region are framed within the context of forest management (Lawson *et al.*, 2001).

Traditional forest management activities in Ontario have been very insensitive to the ecological requirements of forest ecosystems (Duinker *et al.*, 1998a). Little attention has been paid to alternative management prescriptions that would limit the supply of timber to local mills (Priddle, 1982; Lawson *et al.*, 2001). Sustained yield is the dominant form of forest management in Ontario, in which most of the forestry estate is slated to be harvested in the future. The idea behind sustained yield is that no more can be harvested than is regenerated in a given time period (OMNR, 1994, 1997; Gordon *et al.*, 2000; Duinker *et al.*, 2001). This form of management imposes significant restrictions on policy decisions and directions, as there can be no net loss of forest productivity over time. The designation of protected areas, and forests lost to fire, wind and insect damage, place increasing constraints on the forest industry (Oliver *et al.*, 1999). Minimizing these perceived adverse effects is in the best interest of the forest industry (Oliver *et al.*, 1999; Martell, 2001). Limiting forest productivity (flow of forest products) is not only a difficult political "sell"; in many forestry circles it is simply unacceptable (Wood, 2000).

Forest ecosystems are inherently complex, and present an interesting dilemma for society. They provide important resources, which support both local and global economies, yet, at the same time, they are critical components needed for the conservation of biodiversity and carbon sequestration, along with many other ecosystem functions (Perry, 1998; Spies and Turner, 1999). Balancing these seemingly conflicting and contradictory interests presents a formidable challenge for resource managers responsible for equitable land allocation (Mitchell, 2002). Since the late 1980's, ecosystem-based management has become an increasingly important consideration in forest planning decisions (Perry and Maghembe, 1989; Hunter, 1993; Ontario Environmental Assessment Board, 1994); with concepts of forest and land use sustainability coming to the forefront of forest management (Kohm and Franklin 1997). A diversity of approaches are being explored to minimize the adverse effects of the forest industry on forest biodiversity, ecosystem functions and processes (Kohm and Franklin 1997; Duinker *et al.*, 2001). Various guidelines and regulations have been devised to maintain selected non-forest product species within the landscape (Potvin *et al.*, 2000; OMNR, 2002b). Numerous species, particularly those of economic value, are being used as indicators of forest health (McLaren *et al.*, 1998; Perry, 1998; Simberloff, 1998). This approach appears to work well, although there is a significant bias towards promoting habitat for species that complement desirable silvicultural prescriptions, and have economic value (Rempel *et al.*, 1997). Species that limit the economic potential of forest harvesting are given considerably less attention (Cumming *et al.* 1996; Montegomery and Brown, 1992).

The beneficial impacts of ecosystem-based forest management have been quite variable, as traditional power structures remain (Song and M'Gonigle. 2001; Wilson, 2001b). True ecosystem-based management prescriptions have been slow to follow due to the separation of economic, ecological and societal interests (Endter-Wada *et al.*, 1998; Lindenmayer *et al.*, 2000).

Forest management approaches continue to avoid taking into consideration the complexities of forest ecosystems (Bunnell and Huggard, 1999; Quinby, 2001). Forest management is still very much dominated by economics and sustained yield concepts, as noted by Gordon *et al.* (2001):

> …complexity has largely been ignored in the development of forest management systems, most of which are based on a superficial knowledge of successional processes, some historical successes, and a good understanding of growth and yield. (66).

The effects of forest management, including those undertaken since the 1990's, have had adverse effects on numerous wildlife species, particularly those requiring large areas of mature forests (Pruitt, 1997; Cumming, 1998). Woodland caribou numbers and densities continue to decline significantly due to the forest harvesting methods being used throughout their range (Pruitt, 1997; James 1999).

More recently, large-scale initiatives have been undertaken to promote a more realistic pattern of disturbance by harvesting in a way that emulates fire patterns (usually larger cut blocks), with lower edge to interior area ratios (Attiwill, 1994; OMNR, 2002b). It is hoped that by emulating fire patterns and size, that this silvicultural technique will improve future habitat of species requiring large mature forests, such as woodland caribou. This method of harvesting has been criticized, as it only addresses one aspect of fire emulation (pattern) (Gordon, 1996; Franklin *et al.*, 2000; McRae *et al.*, 2001b). Successful implementation of emulation techniques will take considerably more research and clever silvicultural practices, if natural characteristics, including biodiversity protection, are to be viable (Niemela, 1999; Simberloff, 1999; Seymour *et al.*, 2002). Larger scale, and longer-term research and management initiatives will have to be taken for humans to begin to understand the complexities of forest ecosystems (Lindenmayer, 1999). Management prescriptions that do not necessarily favor the most economically and aesthetically pleasing options will also have to be explored (Kimmins, 1999; Leadbitter *et al.*, 2002).

2.4.3 ECOSYSTEM MANAGEMENT

Ecosystem management or ecosystem-based management (EM) is an evolving research and management paradigm that attempts to integrate and understand the complexities of ecosystems, by looking at the "big picture" (Francis, 1993; Mitchell, 2002). EM is a land (and potentially water) management framework that promotes a holistic view of all resources within an ecosystem. The desire is to protect and perpetuate complex ecosystem functions, structures, and compositions within a given landscape (Dale *et al.*, 2000). This may include sustaining viable populations of endemic species and maintaining disturbance regimes (such as fire and insect outbreaks) and sustaining other ecosystem processes (such as water filtration and CO_2 sequestration), so that a region can evolve in a sustainable fashion while maintaining a predetermined state of ecological integrity (Noss and Cooperrider, 1994; Grumbine, 1997; Slocombe, 1998a; Woodley *et al.*, 1998; Yaffee, 1999). Humans should be considered a critical component of ecosystems, as they exert tremendous influence over almost every system on earth (Endter-Wada *et al.*, 1998; Mitchell, 2002).

Yellowstone National Park in the United States was an early testing ground for EM concepts, where large and far ranging animals such as the grizzly bear (*Ursus arctos horribilis*) were coming under increasing threats from activities beyond the boundaries of this reserve, necessitating an approach that operated at a broader scale (Agee and Johnson, 1988; Noss and Cooperrider, 1994). Threats to this ecosystem continue today, with many of the initial issues remaining unresolved (Glick and Clark, 1998; Noss *et al.*, 2002).

The ecosystem approach looks at the complexity of parts, both social and biophysical, within a given system and how they interact (Slocombe, 1998b), and attempts to be holistic in nature (Mitchell, 2002). EM is not a new idea; Leopold (1949) proposed similar ideas long ago. EM has evolved out of integrated resource management and watershed planning, with strong influences from the protected area planning and management literature (Slocombe, 1993; Noss and Cooperrider, 1994). This holistic form of management is needed due to a deficiency in the way sustained yield and multiple-use management systems have approached resources in the past (Seymour and Hunter, 1999). Information is fundamental to the success or failure of EM; if this type of management is to be successful, a tremendous amount of research is needed to understand the complexities of even the simplest ecosystem (Perry, 1998; Dale *et al.*, 2000).

Success of EM is primarily based on the ability of planners and managers to recognize the need for shared knowledge, the behavioral tendencies, the value systems of stakeholders, and the ability to understand the benefits of both short and long-term plans (Brunner and Clark, 1997; Yaffee, 1997). EM is a complicated approach to land management, with many skeptics (e.g., Fitzsimmons, 1996), as many people have embraced various facets of EM, with little consensus on direction of land use strategies (Yaffee, 1999; Wilson, 2001b). Although there is widespread acceptance of the term (Wilson, 2001b), lack of specifics and clear definitions of terms and concepts have hindered its implementation (Salswasser, 1994; Simberloff, 1999).

Grumbine (1994) proposed ten key themes of EM (Figure 2.6), which appear to have stood the test of time, and have been widely accepted as the vital characteristics of successful EM planning approaches (Mitchell, 2002).

1. Hierarchical Context	6. Adaptive Management
2. Ecological Boundaries	7. Interagency Cooperation
3. Ecological Integrity	8. Organizational Change
4. Data Collection	9. Humans Embedded in Nature
5. Monitoring	10. Values

Figure 2.6: Grumbine's Ten Themes of Ecosystem Management.

The appealing characteristic of EM is that it incorporates a diversity of ideas into a holistic planning framework (Grumbine, 1997). Understanding how ecosystems operate over both space and time may be beyond our comprehension; ecosystem-scale research projects are extremely expensive and somewhat intangible, and as a result, are very rare (Carpenter, 1996; Schindler, 1998). Unfortunately, small spatial and short temporal scale research projects may not be able to be replicate the complexities of actual ecosystems, as indicated by Schindler:

> Unless they (experiments) can be cleverly designed to mimic major ecosystem processes and community composition, smaller-scale experiments often give highly replicable but spurious answers. Problems with appropriate scaling are difficult to deduce without direct comparisons to whole-ecosystem experiments. ...Accurate management decisions cannot be made with confidence unless ecosystem scales are studied (1998, 323).

EM attempts to balance two fundamental concepts within its planning domain. These include understanding the importance of science, which informs the planning process; and recognizing the values of various stakeholders (Christensen *et al.*, 1996; Grumbine, 1997).

2.4.3.1 Science and Ecosystem Management

Scientific understanding of how ecosystems function is considered a primary requirement for effective EM (Dale *et al.*, 2000). Unfortunately, our understanding of ecosystems at multiple scales is still quite limited (Spies and Turner, 1999; Dale *et al.*, 2000; Woodley, 2002). Science should play an important role in EM (Meffe and Viederman, 1995), and research will have to accommodate a diversity of interests and approaches to be truly effective (Franklin, 1997). Both scientists and resource managers must recognize the limits of their knowledge (Holling and Meffe, 1996; De Leo and Levin, 1997; Gunderson, 1999). Many ecosystem properties operate at scales that cannot yet be measured (Romme *et al.*, 1998; Suffling and Perera, In press). An important aspect of science's contribution to ecosystem management is the desire to maintain the resiliency of ecosystems (Gunderson, 2000; Carpenter and Gunderson, 2001). Resiliency of an ecosystem was first proposed by Holling (1973), and is considered important as ecosystems that are resilient can withstand alterations by disturbance without changing system states (Gunderson, 1999).

Ecosystem management and conservation biology may be an overarching theme in ecology related research, but very rarely is this research conducted in a strategic fashion that would limit the impact that humans have on ecosystems (Woodwell, 2002). This strategic approach to management may be difficult for scientists who pride themselves on objectivity, as such a strategy would imply some form of bias or value (Brunner and Clark, 1997; Ludwig *et al.*, 2001). But as Costanza (2000) noted, a strategic vision is fundamental to sustainability:

> The most critical task facing humanity today is the creation of a shared vision of a sustainable and desirable society, one that can provide permanent prosperity within the biophysical constraints of the real world in a way that is fair and equitable to all of humanity, to other species, and to future generations.

2.4.3.2 Values and Ecosystem Management

Science does play an important role in ecologically-oriented approaches to management (Francis, 1993; Noss and Cooperrider, 1994; Meffe and Viederman, 1995), however EM will unlikely be effective based on science alone (Yaffee, 1997; Brunner and Clark, 1999). Beyond the understanding of the scientific nature of non-human components in ecosystems, there must also be a much greater understanding of the social complexities and dynamics that will both decide and be affected by EM decisions regarding natural resources (Kotar, 1997; Chavas, 2000). Grumbine (1997) found that:

> People make commitments based on values as much if not more so than on facts and logic. As managers learn to accept the role of human values explicitly, the success of ecosystem management will become more likely (46).

Understanding and managing the values of society are inherently complex and often contradictory. These values play a key role in EM, as they direct ideas and policies (Grumbine, 1997; Slocombe, 1998a). The recognition of these values is critical to any planning process, and should not be underestimated (Grumbine, 1997). In addition, they must often work in the face of conflict and uncertainty (Mitchell, 2002; Suffling and Perera, In Press).

2.4.4 UNCERTAINTY AND ADAPTIVE MANAGEMENT

Ecosystem management is a large scale and long-term undertaking; our knowledge is incomplete and will have to evolve as new information becomes available (Light, 2001; Slocombe, 1998a). Uncertainty in complex systems requires management and implementation approaches that can cope with ever-changing environments. Adaptive management is one approach that can be applied to a complex system like boreal forest management and planning. This approach is attractive and necessary, due to the uncertainty of how the bio-physical and socio-economic systems operate, and how they may evolve in the future (McLain and Lee, 1996; Walters, 1997; Gunderson, 1999; Stankey *et al.*, 2003). An adaptive management process will allow practitioners of the policy to implement this strategy so that it best reflects the local idiosyncrasies (Mitchell, 1997; Yaffee, 1999). Adaptive management will also allow all people in the planning and implementation process to learn from examples, experiments, and hopefully mistakes through feedback mechanisms (Nudds, 2000).

Researching future alternatives and possible end results is another attractive aspect of adaptive management, and may provide more relevant information for decision makers, while at the same time reducing uncertainties in both the research and planning processes (Gray, 2000). Adaptive management is not a simple task, people must be willing to accept that all theories investigated and plans implemented may not work (Gunderson, 1999). Adaptive management can be a very expensive process that will take a significant amount of time to implement, but the focus should not solely be on the end product, it should be on the process of achieving the end goal (Gray, 2000; Duinker *et al.*, 1998b).

> In most planning exercises, implementation is likely to be gradual or, if rapid, will often fail to achieve all targets, particularly those landscapes with economic potential. In these cases, the planning process should loop back periodically, so that progress can be updated, new ideas selected as appropriate, and implementation reconsidered (Margules, and Pressey, 2000: 249).

This is particularly relevant for the boreal forest, where the majority of current values place short-term economic gains ahead of long-term sustainability (Pruitt, 1997; Dellert, 2000; Lawson *et al.*, 2001).

2.5 Scale

Issues facing land use managers invariably occur at multiple scales (Lembeck and Hobbs 2002; Bunnell and Huggard, 1999). Scale related problems are important when dealing with both ecological phenomena and policy developments, and have come to the forefront of ecological and landscape research (Turner, 1989; Wiens, 1989; Forman, 1995; Turner *et al.*, 2001; Meadowcroft, 2002; Suffling and Perera, In press). Ecological phenomena may change according to the spatial and temporal scale at which they are measured, making scale a particularly relevant variable when posing research questions or management options (Delcourt *et al.*, 1983; Levin, 1992; Wiens *et al.*, 2002). Scale can however present many complex and contradictory issues for managing natural resources over space and time (Bunnell and Huggard, 1999; Haufler *et al.*, 1999; Gibson *et al.*, 2000; Schneider, 2001); effective management prescriptions at one scale do not necessarily result in lasting or effective management prescriptions at other scales (Haufler *et al.*, 1999; Haila, 2002).

Scale can be defined as "*The spatial or temporal dimension of an object of process, characterized by both grain and extent.*" (Turner *et al.*, 2001: 29). Important to understanding scale is the understanding of hierarchy. Hierarchy in landscape ecology is a way of categorizing ecosystems into functional units (Urban *et al.*, 1987); it allows scientists to view ecological phenomena at various levels of organization (Forman, 1995). Another concept that can assist ecologists and resource managers in addressing questions of scale is domains of scale (Wiens, 1989). Domains refer to regions of the scale spectrum in which scale dependency in some ecological systems may have discrete boundaries, creating regions of the spectrum in which process-pattern relationships are constant regardless of scale (Wiens, 1989).

Scale-related research is gaining greater prominence in ecology and resource management, as landscape ecology and planning become an important part of resource decision-making (Turner *et al.*, 2001; Wiens *et al.*, 2002; Wu and Hobbs, 2002). Resource management decisions occur at multiple spatial and temporal scales. Spatial and temporal dynamics in landscape ecology are linked as patterns and processes influence one another over both space and time (Turner, 1989; Spies and Turner, 1999). Larger spatial scale dynamics will evolve more slowly; reciprocally, slower moving dynamics may need to be observed at larger scales to be detected (Figure 2.7) (Turner and Dale, 1998). The shifting mosaic of habitats, and the organisms that occupy them over time, determine the characteristics of ecosystems, and how they will continue to evolve based on their structural and compositional legacies (Swetnam *et al.*, 1999; Foster *et al.*, 2003).

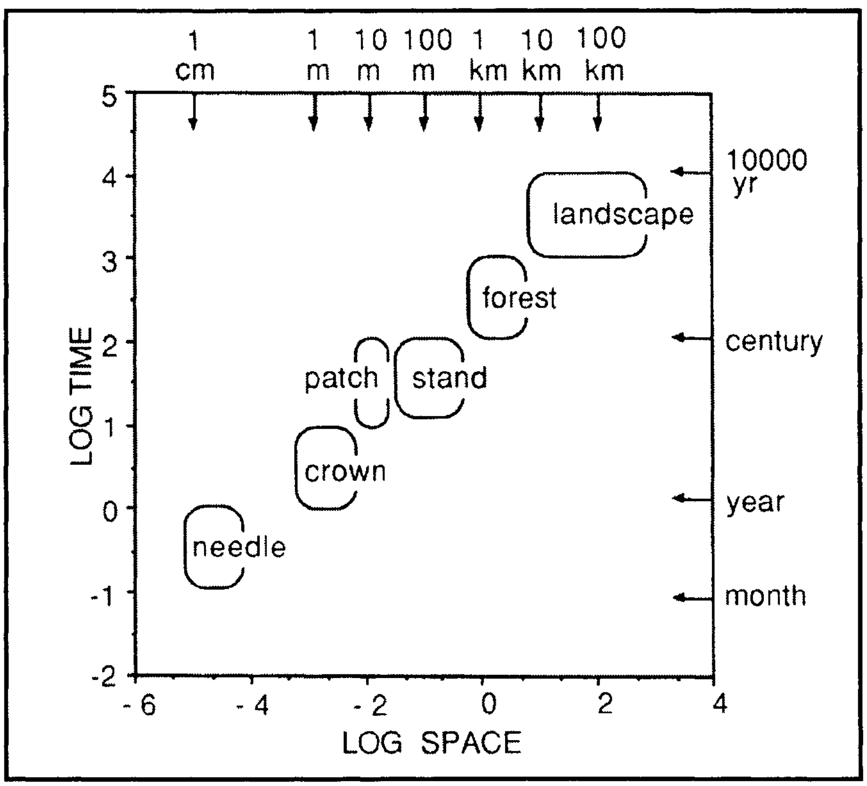


Figure 2.7: Relationship Between Spatial and Temporal Scale in the Boreal Forest (Holling 1992: 452).

2.5.1 SPATIAL SCALE

Spatial scale is an important aspect of landscape ecology and planning as the both the grain and extent of measurements must be determined prior to undertaking research. The grain refers to level of detail, whereas the extent refers to the total area that is being observed or analyzed (Dungan *et al.* 2002). Grain and extent set the lower and upper limits of resolution in a given study, meaning that patterns cannot be detected at finer or coarser scales than the grain and extent of the data (Turner *et al.*, 2001; Dungan *et al.* 2002). Spatial scale can be examined at several hierarchical levels, such as patch, stand, region and landscape (Bunnell and Huggard, 1999). Ecological phenomena such as forest fires occur at multiple scales, which are quite different from forest harvesting activities, which are managed at only one scale (Elkie and Rempel, 2001). Three categories exist in which spatial scale related issues can arise: 1) the *phenomenon* being studied such as the spatial structure of vegetation and the processes that affect it; 2) the *sampling* units used to study the phenomenon, for example the size of the quadrats used to study vegetation; and 3) the *analysis* of the data, used to draw conclusions about the phenomenon (Dungan *et al.* 2002: 627). These three categories all provide potential sources of researcher-induced bias, as well as potential sources of dissention among researchers undertaking similar studies.

Spatial scale is particularly relevant to caribou management, as this species requires large areas of undisturbed boreal forest, that are made up of a complex mosaic of forest patches, wetlands, lakeshores and exposed rock ridges (Darby *et al.*, 1989; Schaefer and Pruitt, 1991; Schaefer, 1998; Racey *et al.*, 1999). Research and management of this species requires an understanding of many complex spatial variables, such as the size of management unit, juxtaposition of habitat patches, patch and landscape shapes (James, 1999; Spies and Turner, 1999; White *et al.*, 1999).

Determining the scale at which to conduct research and to manage organisms is an ongoing issue in conservation biology (Kotilar and Wiens, 1990; Wiens *et al.*, 2002). Traditional forms of land management in Ontario have occurred at relatively narrow spatial scales and in isolated contexts (Spies and Turner, 1999; Francis, 2000; Duinker *et al.*, 2001). This form of decision-making looks inward towards the defined management unit (Franklin, 1993), isolating decisions from one another (Brunckhorst and Rollings, 1999). Quinby (2001) noted in his study of old-growth forests in northern Ontario that the representation of selected areas to be protected or harvested depended upon the scale at which management prescriptions were made; although the overstorey composition was similar in various stands, the understory and future conditions of the forests were likely to be quite different.

Protected areas are also managed on a limited spatial scale, often with little consideration of resources or activities beyond their boundaries; the exception to this phenomenon is the exclusion of forest fires for the protection of timber resources outside of parks (e.g., Heathcott and Crofts, 1997). This relatively small-scale, inward looking approach has limited the management options (Skibicki, 1995; Theberge and Theberge, 2002). This approach to land management may be particularly risky for woodland caribou as resource extraction activities occurring adjacent to known caribou habitat do affect the viability of this species, as management prescriptions in one region do have spillover effects on other management units (Cumming, 1992; James, 1999).

2.5.2 TEMPORAL SCALE

Temporal scale is a much more abstract concept, as it is difficult to detect change and measure ecological phenomena over long time periods (Turner and Dale, 1998; White *et* *al.*, 1999). As a result, the study of issues related to temporal dynamics has been given significantly less attention in the literature in comparison to spatial scale (Gordon *et al.*, 2001). Addressing variation of ecological phenomena over time is significantly more challenging, as most research projects rarely extend beyond a few years, making long-term research imperative for effective resource management (Turner *et al.*, 2003). Temporal scale issues permeate all aspects of resource management, and have been called the invisible present (Gordon *et al.*, 2001). Time is critical to deciding the rotation age of a forest stand and its implications on economic and ecological values. It is also relevant when deciding what timescale to design and manage protected areas on (Scott *et al.*, 1999; Oliver *et al.*, 1999; Margules and Pressey, 2000). Clearly, temporal dynamics are complex and require significant attention (White *et al.*, 1999; Schneider, 2000). In some cases paleoecology may assist in this regard, but understanding the dynamics over time remains a significant obstacle in both landscape ecology and planning (Delcourt *et al.* 1983; Wiens 1989; Turner *et al.* 2001; Mitchell, 2002). Spatio-temporal simulation modelling is attempting to address the potential change in ecosystem structure over time, but many generalizations and assumptions have to be made in order for most models to function effectively (Mladenoff and He 1999; Armstrong *et al.*, 2003), limiting their direct application and effectiveness in resource management (Gutzwiller, 2002).

Varying the timescale to be used in ecological studies and management can dramatically alter the processes observed, and can determine the range of patterns and processes that can be detected (Wiens, 1989; Turner *et al.* 2001). Ecosystems evolve over long periods of time, and demonstrate lasting impressions from past disturbance events (Heinselman, 1996; Foster *et al.*, 2003). As Romme *et al.* (1998) noted, the impacts of a disturbance will depend on its size and/or severity; these impacts will vary depending on the scale and phenomena being measured, with few universal rules, as context is of paramount importance.

Policies also come and go in very short succession, often dictated by political bias and the need for expediency in planning processes (Yaffee, 1997; Courtner and Moote, 1999; Clark, 2002; Mitchell, 2002). The understanding of long-term ecological dynamics may not be desirable in planning processes focused on resource extraction, as the complexity of issues related to temporal dynamics would not likely fit into economic models (Wood, 2000; Hall *et al.*, 2001). However, in the case of Ontario, this may be improving somewhat (Francis, 2000). The tremendous uncertainty in long-term planning makes the development of long-term policies difficult (Lee, 1993; Noss and Cooperrider, 1994; Gordon and Cole, 1994; Stankey *et al.*, 2003), requiring a truly adaptive management process (Gunderson, 1999; Light, 2001). Planning with the uncertainty of long-term ecological dynamics in mind, historical variability may be used to frame research, but as ecosystems are constantly evolving this is a moving target (Johnson and Miyanishi, 1995; Landres *et al.*, 1999). The change in forest fire frequency in the boreal since the little ice age is a good example (Larsen, 1997; Suffling and Speller, 1998; Lesieur *et al.*, 2002).

2.6 Overview of Ideas

Woodland caribou are far ranging species that require large areas of boreal forest (Cumming, 1992). Their primary winter habitat is mature jack pine forests; to perpetuate these forests, and their associated habitats, large natural fire regimes are necessary (Schaefer and Pruitt; Heinselman, 1996). Fires however have undesirable effects on forest harvesting operations in this region (Martell, 1994). Small prescribed burns improve potential habitat (Ahti and Hepburn, 1967; Harris, 1992), but do not replicate the large and stochastic nature of natural fires (McRea *et al.*, 2001). Forest harvesting has been promoted as an alternative to forest fire, although there is little empirical evidence that supports their similarities (Gordon, 1996; Franklin *et al.*, 2000). Moreover, the ecological effect of forest disturbances occurs at multiple spatial and temporal scales, all of which influence the dynamics of woodland caribou habitat (Schaefer and Pruitt, 1991; Lindenmayer, 1999). An adaptive ecosystem approach, operating at the landscape level, is needed to conserve this species (Euler, 1998).

3.0 QUANTITATIVE METHODS

3.1 Ecosite Scale Assessment

One hundred and sixty random plots were generated in Kernel derived polygons ($p = 95\%$) using ArcView (Hooge and Eichenlaub, 1997). The Kernel polygons were based on point location of GPS collared woodland caribou winter distribution within Red Lake and Kenora districts, in the WCPP region (OMNR, 2002) (Figure 3.1). The Kernel polygons delineate areas within and directly adjacent to WCPP where there is known winter woodland caribou occupancy. Of the 160 random points, 141 accessible plots were inventoried using Ontario Parks' Rapid Assessment Plot (RAP) method (based on the northwestern Ontario Forest Ecosystem Classification; Racey *et al.*, 1996b and Sims *et al.*, 1997). One hundred and twelve of the 141 ecosites were classified as ES12/V30 sites (Racey *et al.*, 1996b; Sims *et al.*, 1997). These were selected based on the importance of open jack pine forests for winter woodland caribou use, and the likely presence of terrestrial lichen (Wepruk, 1986; Darby *et al.*, 1989; Morash and Racey, 1990; Schaefer and Pruitt, 1991; Kenkel *et al.*, 1998).

Age since last disturbance was determined by sampling three mature jack pine (where available), using an increment borer, and measuring age of tree at breast height in the field (Luckai, 2001). When no jack pines were present, the species and age of the three closest (to the randomly generated point) canopy trees were inventoried (Luckai, 2001). The mean age of these trees was used to determine the age of the stand. Presence and characteristics (depth in mm) of the duff on site were also assessed in relation to the last disturbance. Four duff depth samples of were measured two metres from the randomly generated point in each cardinal direction. Depth of duff was calculated by averaging the four duff depths. High duff accumulation below the ground vegetation/ground cover would indicate either abundant duff accumulation prior to past fire events, or low severity of ground fires, or both (Johnson, 1992; Payette *et al.*, 2000; Miyanishi and Johnson, 2002; Ryan, 2002).

A Principal Components Analysis (PCA) (multivariate ordination technique) was used to determine pattern of ground vegetation gradients in relation to age and humus characteristics (Johnson, 1981; Manley, 1994; Kenkel *et al.*, 1998; Bergeron, 2000; Townend, 2002). The variables used in the PCA are humus form depth (mm); percent of ground covered by lichen and feathermoss; canopy cover (percent), and age of the stand in years. PCA was selected as this is a common ordination technique used to explore variations in multivariate data (e.g., Johnson, 1981; Kenkel *et al.*, 1998). In addition, age of canopy was plotted against percent ground cover of both lichen and feathermoss, and least squares regression was calculated for each (Zar, 1999).

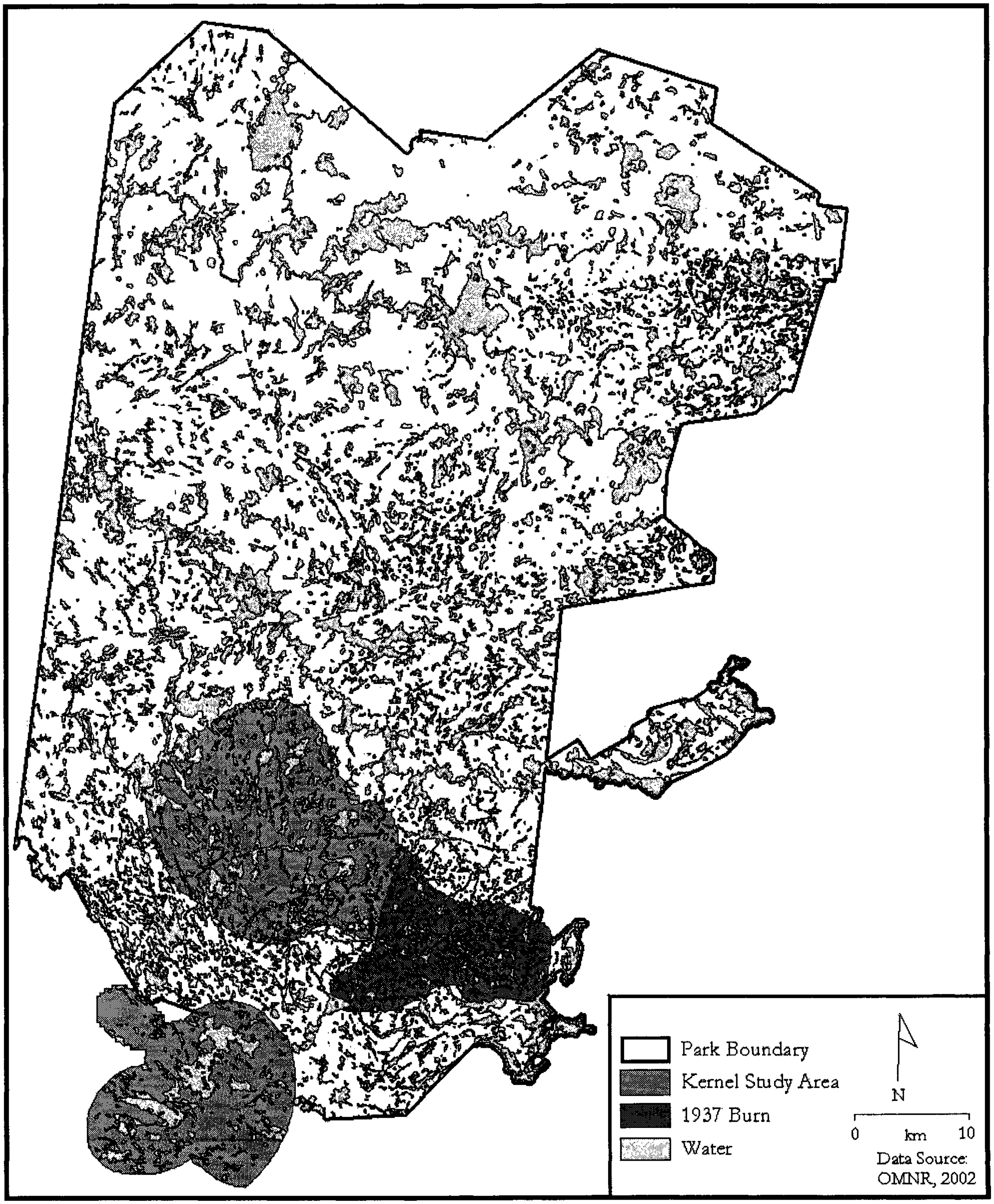


Figure 3.1: Location of Rapid Assessment Plot Study Areas. Study areas were based on woodland caribou home range assessment and a 1937 burn within Woodland Caribou Provincial Park.

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3.2 Landscape Scale Assessment

The purpose of this portion of the study was to compare the forest structure (openness) of four areas that burned during the 1930s within WCPP. As mentioned above, terrestrial lichens (primarily *Cladina spp.*) are very important winter forage for woodland caribou (Klein, 1982; Darby *et al.*, 1989; Schaefer and Pruitt, 1991; Kumpula, 2001). Forests with more openings (clearings on suitable substrates) have the potential to support more lichen than do closed canopy forests (Ahti and Hepburn, 1967; Kenkel *et al.*, 1998; Payette *et al.*, 2000).

OMNR's forest fire coverage (from the Natural Resources Values Information System (NRVIS), OMNR's GIS database coverage) for Ontario was clipped to the WCPP boundary in ArcView; the area for each of the 1930 burns in the coverage was calculated in m^2 and hectares. This GIS coverage delineates fires 40 ha and larger in Ontario (Bilbey and Lipsett-Moore pers. comm.). The coverages primarily delineate the outline of the burnt areas. The uniformity of fires in this landscape (Ehnes, 2000) makes the coverage a useful and apparently accurate GIS/mapping data source in this context. The amount of area burned between 1900 and 1996 was also calculated for the park for each decade.

Landscape scale study areas were selected based on areas that should become available winter habitat within this decade (2000-2010). Optimal woodland caribou habitat in this region occurs when forests with appropriate structure and composition are between 50 and 90 years old (Schaefer and Pruitt, 1991; Morash and Racey, 1990; Racey *et al.*, 1999). These sites were selected to provide resource managers with the most current information to aid in management decisions.

Three 1930 fire polygons were clipped based on the existing NRVIS woodland caribou habitat mosaic layer. Areas supporting inappropriate soils and vegetation, as well as those recently burned (<60 years old), were removed, leaving three polygons. As the NRVIS layer did not include all areas burnt in the 1930s (personal observation while inventorying sites within WCPP), one additional polygon was delineated in ArcView by air photo interpretation of 1983 air photos, ground truthing, and RAP methods described above (5 sample plots). These four clipped polygons, delineating four individual fires during the 1930's, became the focus of this portion of this research (landscape scale study areas) (Figure 3.2). These were selected as they were the only remaining potential caribou habitat within WCPP that are on appropriate soils and the correct age. Each burn polygon was named for ease of reference, the names are: North, Mid, Wrist, and South (Figure 3.2).

Digital Ontario Ministry of Natural Resources 1983 air photographs (images) (1:15,840) were individually georeferenced. Using Patch Analyst 2.2, each individual burn was partitioned into a lattice composed of 5-ha hexagons (Elkie *et al.*, 1999). Within the four study areas, using ArcView, the 5-ha hexagons were randomly selected throughout the burn polygon, so that 20% of each individual burn was sampled. The individual images were then clipped using a mask based on the random sample of hexagon shapefiles (ArcView Image Analysis) (ESRI, 2000). The digital air photos were converted into grids using ArcView Spatial Analyst 1.0 and then reclassified into Boolean images using spectral image clustering and reclassification (Verbyla and Chang, 1997). The images were classified into 64 classes on a gray scale between 0 and 255. The forest openings and rock clearings (spectral value of 178 - 255) = 1, the remaining features (spectral value 0-178) = 0, or no data. As all air photos have different spectral reflectance values, the minimum range for forest openings values was between 178 and 191.

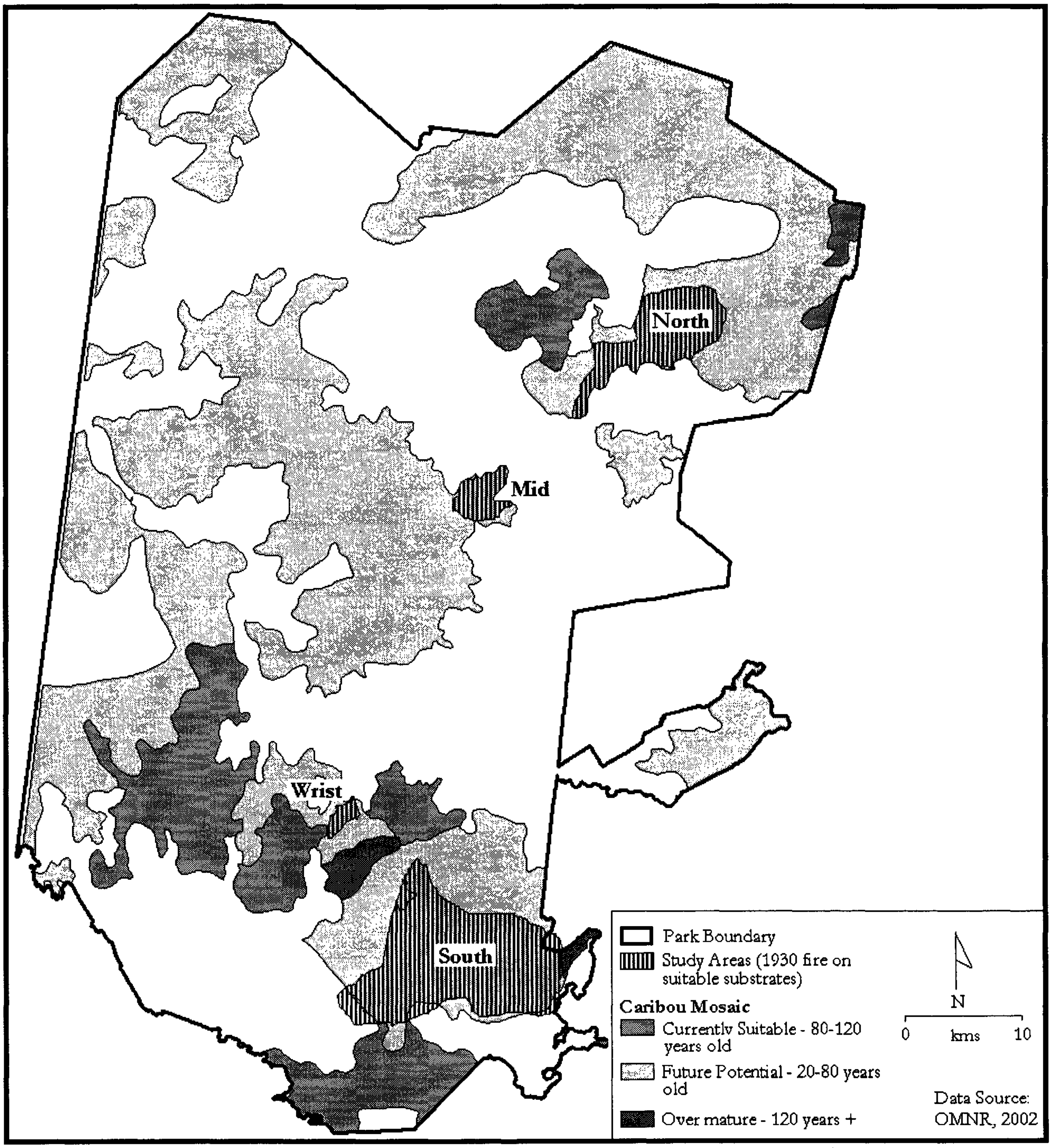

Figure 3.2: Landscape Scale Study Areas and the NW Ontario Caribou Mosaic within Woodland Caribou Provincial Park. Caribou mosaic classification is based on OMNR descriptions.

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The reclassified grids were then converted into shapefiles and were merged together based on the extent of the individual burns. The areas in m^2 of the forest openings were then calculated for each of the 5-ha hexagons in each of the 1930 burns. This was repeated for each of the four fires assessed.

A Levene's test for homogeneity of variance was conducted. As the samples had unequal variances, a non-parametric Kruskal-Wallis H test was used to compare the amount of forest openings (m^2) between the 1930 burns. Individual Mann-Whitney U tests were then used to compare the amount of forest openings (m^2) between each of the 1930 fires (Zar, 1999).

4.0 QUANTITATIVE RESULTS

4.1 Ecosite Scale Assessment

Of the 141 Rapid Assessment Plots inventoried, 79% (112) were ES12/V30 sites. These sites were underlain by very shallow soils or bedrock (FEC soil type = SS1-SS3). Canopy coverage varied from 0 to 100%; the age of the plots ranged from 53 to 157 years old. Ground cover ranged from bare bedrock, to lichen rich mats, to thick feathermoss mats (primarily *Pleurozium schreberi*). The lichen cover ranged from 0 to 80%, whereas feathermoss ranged from 0 to 100%, depending on site characteristics; the most common terrestrial lichens were *Cladina mitis, C. rangiferina* and *C. stellaris.* The most common understory woody-stemmed plants were velvetleaf blueberry (*Vaccinium myrtilloides* Michx.) and black spruce saplings. Green alder (*Alnus crispa* (Ait.) Pursh) and common juniper (*Juniperus communis* L.Var. depressa Pursh) also were present on many sites.

The principal components analysis revealed distinct variations among the V30 sites (Figure 4.1). The sites were grouped based on the accumulation of humus form and ground cover characteristics, which were dominated by either feathermoss or lichen species. Principal Component 1 was a gradient from almost no humus form accumulation, to areas with abundant humus form development (161 mm). The sites ranged from open jack pine sites with abundant *Cladina spp.*, to closed canopy jack pine stands with up to a 30% black spruce component, dominated by feathermoss ground cover. Principal component 2 was an age gradient, from young to old (53 - 157 years old). The principal component axis 1 and 2 accounted for 82 percent of the variation of the PCs (58 and 24 % respectively); they were delineated based on eigenvalue assessment.

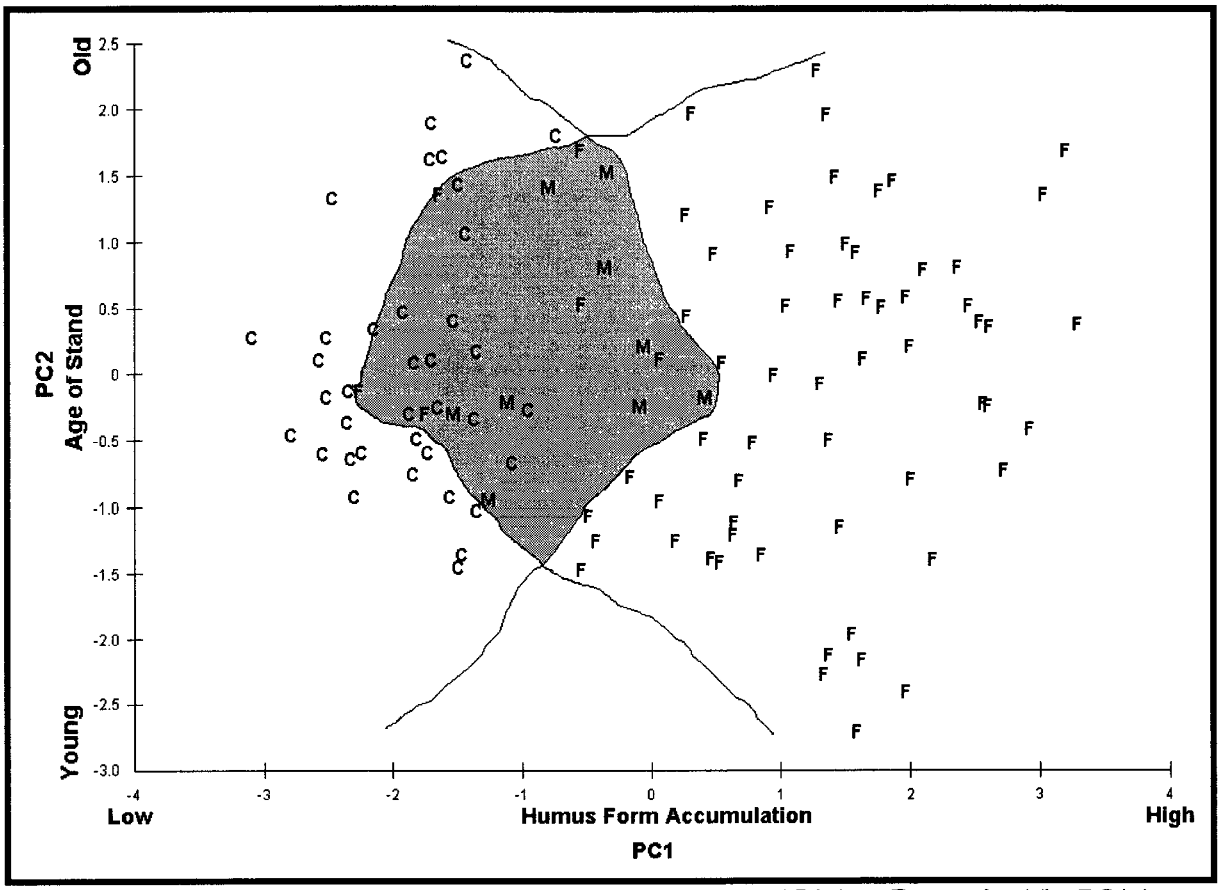

Figure 4.1: Principal Components Analysis of Feathermoss and Lichen Dynamic. The PCA is based on feathermoss (F) or lichen (C) dominance of ground cover on V30 sites in WCPP. The shaded region is a transition area where (M) denotes mixed amounts of lichen and feathermoss, ranging between 60/40 and 40/60 percent of total ground cover.

4.2 Landscape Scale Assessment

The area burnt in the 1900s (organized by decade) varied from 319 ha in the 1950s, to over 106,000 ha in the 1980s (Figure 4.2). During the 1930s nearly 50,000 ha burnt within the park.

To compare the median openness of each of the 1930 burns, a non-parametric Kruskal-Wallis H test was conducted as the assumptions for ANOVA were not met (unequal variances). These results indicated that there was a significant difference between at least two of the samples ($p<0.00001$) (Figure 4.3). The Wrist study site had the highest average forest opening (12380m²), whereas the South study site had the lowest (3168m²) (Table 4.1).

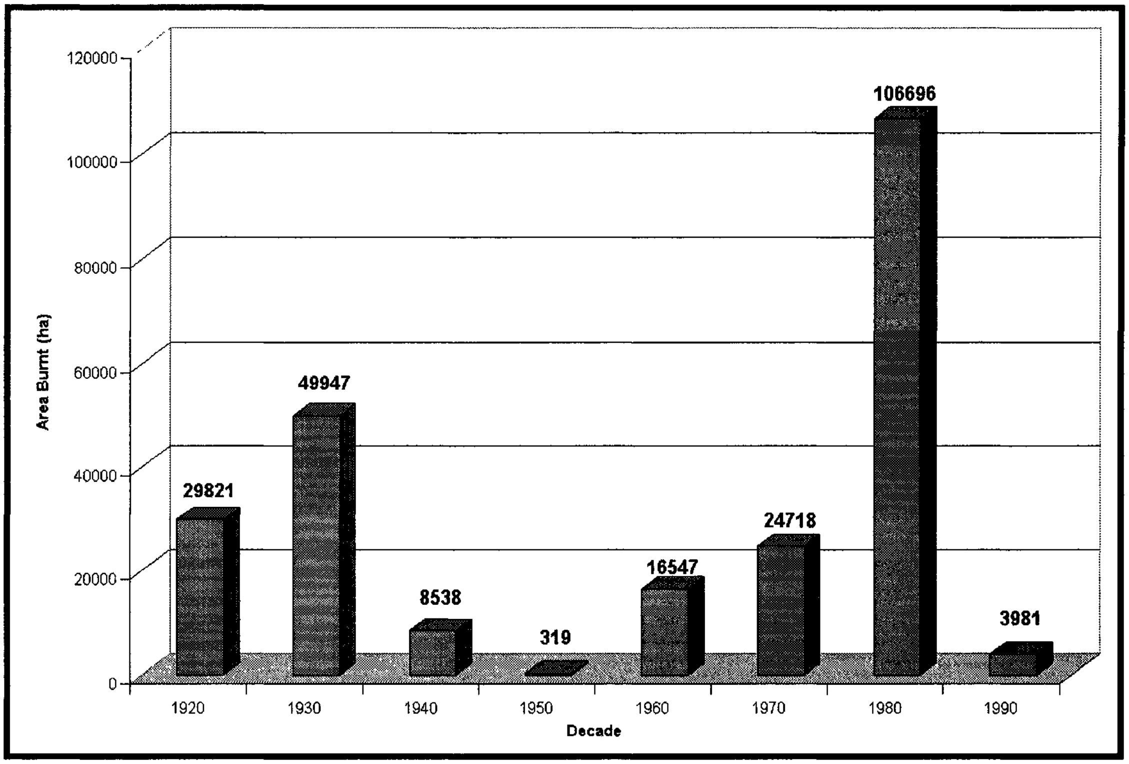

Figure 4.2: Area burnt by decade in Woodland Caribou Provincial Park during the 1900s.

Table 4.1: Variation in Mean Forest Openings and Area of Landscape Scale Study Sites.

Study Site	N (# of 5 ha hexagons)	Mean Area of Forest Openings (m²)	Area of Study Sites (m²)
North	168	6380	42,000,000
Mid	53	3556	13,250,000
Wrist	13	12380	3,250,000
South	448	3168	112,000,000
Total	682	N/A	170,500,000

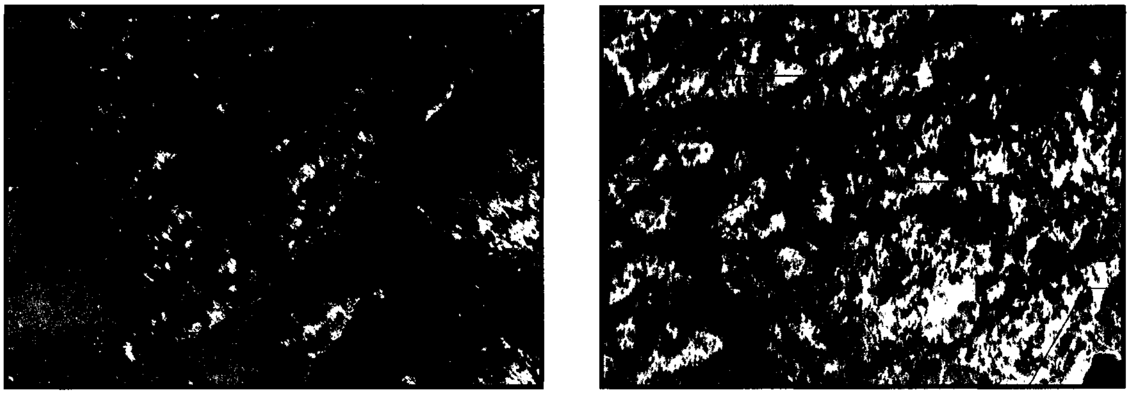

Figure 4.3: Variation in the Openness of V30 Sites in WCPP. An example of the differences in the forest openings on two different sites burnt in the 1930s. The site on the left is adjacent to Burntrock Lake (South study site), and has abundant feathermoss growing over bedrock. The site on the right is adjacent to Wrist Lake (Wrist study site), and is very open with abundant terrestrial lichen. The hexagons are the 5 ha used in this analysis. The scale of the photos is 1:15,840.

Individual Mann-Whitney U tests were conducted between each study area. Significant differences were found in the openness of forests (area m^2), between the Wrist and South, North and South, Wrist and Mid, and North and Mid study sites (Table 4.2).

Table 4.2: Comparison of Mean Openness of Landscape Scale Study Sites. P-values from the Mann-Whitney U tests. Significant values have been italicized. (when $p < 0.0083$).

	North	Mid	Wrist
North	-------	--------	-------
Mid	*<0.001*	-------	-------
Wrist	0.0087	*<0.001*	-------
South	*<0.00001*	0.1459	*<0.00001*

There was very weak negative relationship between stand age and lichen abundance (R^2 = 0.05). Conversely, there was a very weak positive relationship between stand age and feathermoss abundance (R^2 = 0.06) (Figure 4.4). The R^2 values are not the same, as the abundance of ground cover does not total 100 percent.

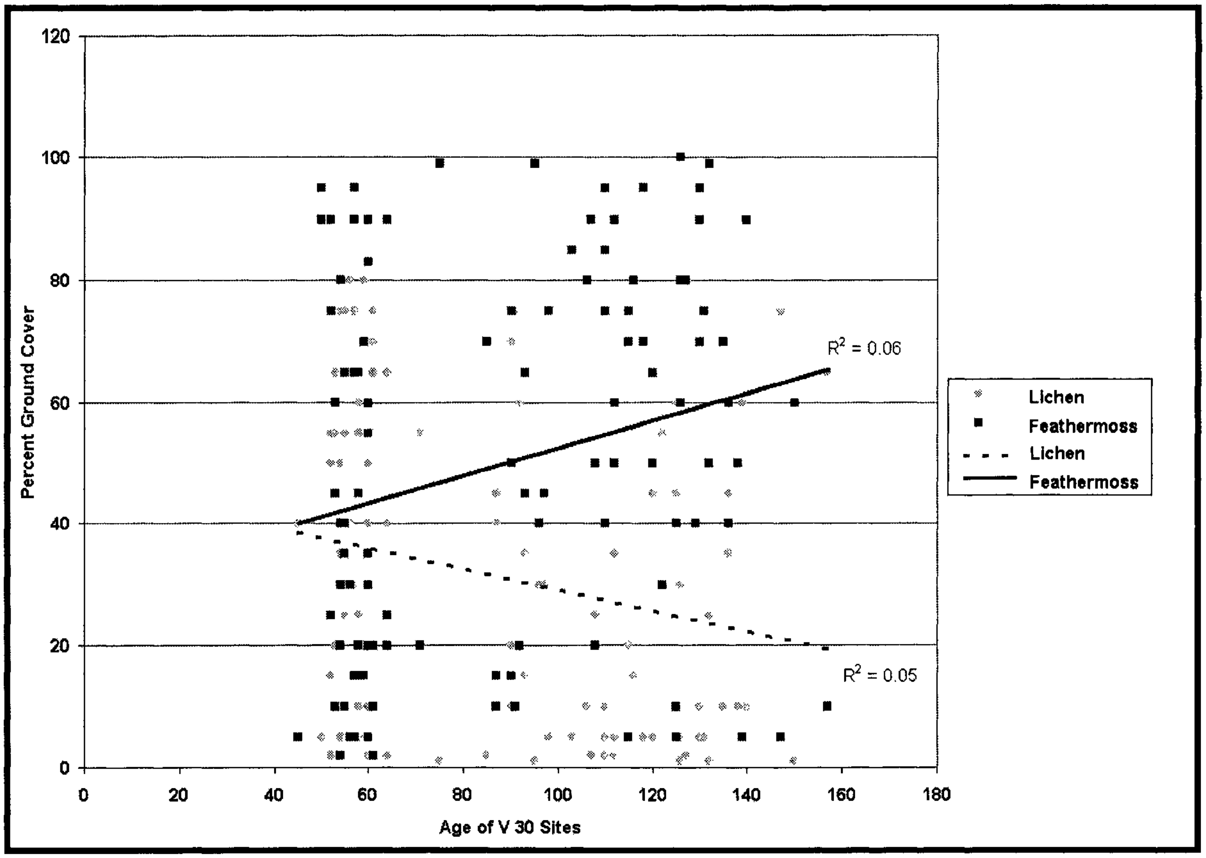

Figure 4.4: Lack of Relationship Between Ground Cover and Stand Age of V30 Sites in WCPP.

5.0 QUALITATIVE METHODS

5.1 Policy Evaluation – Case Study

Both Ontario Parks and the Forest Division of the OMNR (hereafter Ontario Parks and Forest Division) have identified ecosystem management as an important component of land use policy and management activities, as it provides direction and a holistic framework in which to operate (Duinker *et al.*, 2001; OMNR, 2002b; Ontario Parks, 2003b). Land use policy is an integral part of woodland caribou planning and management (Landres *et al.*, 1998; Armstrong, 1998; Duinker *et al.*, 1998; Cartwright, 2001; Clark, 2002). However, policy analysis is a complex undertaking, wrought with subtleties and intricate dynamics at play (Hessing and Howlett, 1997). As Clark *et al.* (2000) stated:

> Policy is more than formal mechanisms such as legislation or government action, and it includes the informal, collective, and often unconscious actions of many people and institutions (682).

Thus, this evaluation uses two different approaches to provide a more holistic perspective of land use policy issues related to woodland caribou conservation planning. The two sections are:

1. *Historic Assessment, Current Developments and Description Case Study.*
2. *Policy Analysis.*

1. Historic Assessment, Current Developments and Description Case Study

A case study of policy approaches of Ontario Parks and industrial forest management interests (Forest Division and forest management companies, e.g. Weyerhaeuser) related to woodland caribou planning and management was conducted. This case study examines policy approaches within an identified study area, which includes a 50 km wide buffer surrounding WCPP (Figure 5.1) (Feagin *et al.*, 1991; Pal, 1992, 1997; Neuman, 1997; Clark, 2002). This area was selected because existing OMNR data of GPS collared caribou indicate that woodland caribou inhabiting WCPP travel within this area in their natural home range. I did not want to select a larger area, as caribou are not found more than 50 km south of WCPP (Racey and Armstrong, 2000; Schaefer, 2003; Gerrish pers. comm). Moreover, this region encompasses a sufficiently large but somewhat manageable area (1.94 million ha).

I examined established policy and management guidelines related to resource, land and woodland caribou management; I used grey literature to support concepts and to clarify ambiguities. Multiple sources were used for this assessment, including:

-Formal policy, such as the Crown Forest Sustainability Act.
-Management Prescriptions, such as forest management plans for FMUs within the identified buffer zones.
-GIS data, primarily from the NRVIS database, including the caribou mosaic, road network patterns, and harvesting blocks.
-OMNR grey literature, such as the Interim Management Statement for WCPP

The analysis gives a short historical context starting in the 1980's (a more detailed historic context can be found in the literature review) - the decade when Woodland Caribou Provincial Park was established and concepts of EM were starting to take hold in North America (OMNR, 1986; Agee and Johnson, 1988; Noss and Cooperrider, 1994). I then described and critically evaluated how policy approaches have been developed and are being implemented, and what this means for woodland caribou, and their ability to persist in this region.

The decision to omit information from Manitoba was a difficult one, but due to the sporadic nature and rudimentary quality of available data, Manitoba was not examined in great detail.

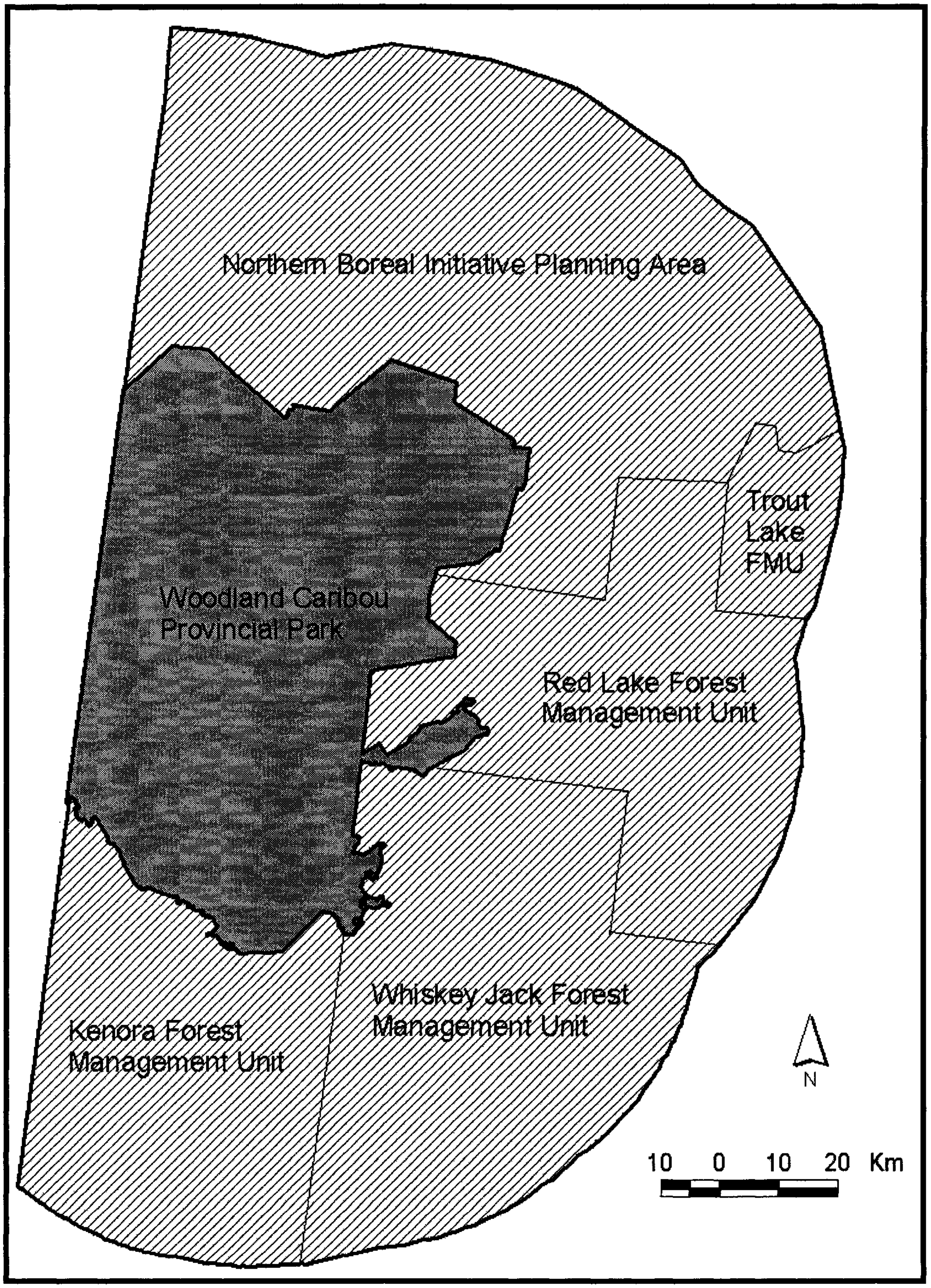

Figure 5.1: Woodland Caribou Provincial Park Within the 50 km Buffer Study Area. WCPP and adjacent forest management units and a portion of the Northern Boreal Initiative planning area.

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5.2 Policy Analysis

This analysis examined, when possible, policy approaches taken by Ontario Parks and the Forest Division, relating to woodland caribou conservation planning in northwestern Ontario. I have used content evaluation of formal legislation, management guidelines, and internal government literature from the Ontario government, to assess how these two branches of the OMNR have embraced concepts of EM, and have integrated them in resource planning and management of woodland caribou in this region (Hogwood and Gunn, 1984; Hessing and Howlett, 1997; Cortner and Moote, 1999). This analysis used a focused criteria and indicator system for its assessment, similar to that used by the OMNR in assessing the sustainability of forest management practices (Pal, 1992; Mrosek, 2001; OMNR, 2002). This analysis examined policy approaches at the operational/management level of land use planning; linkages with higher-level policy were also discussed, but is not be the primary focus of this research.

The criteria that have been selected for this analysis are the goals outlined by Christensen *et al.* (1996), in *The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management.* These criteria were selected based on their applicability to the woodland caribou conservation issues, the sensibility for ecological assessment and widespread use and acceptance of these goals (Jensen *et al.*, 2001). Moreover, these four criteria are useful for woodland caribou conservation planning assessment, as they are succinct, making them a manageable set of criteria for this evaluation. The criteria are:

1. Defining Sustainable Goals and Objectives
2. Reconciling Spatial Scales
3. Reconciling Temporal Scales
4. Making Systems Adaptable and Accountable

A scoring system is used to compare and evaluate how these four criteria have been adopted and integrated into land use policy approaches by the Forest Division and Ontario

Parks. The indicators are selected based on concepts of EM outlined in academic and professional literature related to themes in conservation biology and planning, forest management, species at risk management and landscape ecology. Each indicator is posed as a question; an index ranging between 1 and 5 was used (Table 5.1).

Table 5.1: Rationale for Scoring Used in Policy Analysis.

Score	Rationale
1	No mention of the concept or related ideas to the indicator(s).
2	Acknowledgement of concept, but no proposed strategy or action developed.
3	Acknowledgement of concept with proposed management strategies.
4	Acknowledgement of concept with established policy and/or management related to indicator.
5	Establishment of policy related to indicator with demonstrated management result (e.g., defined scale for spatial planning).

The *Defining Sustainable Goals and Objectives* criterion is considered the most important of the four criteria, as plans and policy approaches without this fundamental criterion cannot effectively implement the remainder of the criteria (Mitchell, 1997; Chavas, 2000; Possingham, 2001). No hierarchy or rank of importance for the remaining criteria is used, as the other indicators are considered to be of equal value. Citations and rationale are provided to clarify concepts and the basis for the indicators selected for this analysis. The sum of each indicator was not tabulated, as changing the weight of each indicator would change the total score for each policy assessed. A breakdown of the criteria and associated indicators are outlined in tables 5.2 - 5.5.

The documents that were assessed for the Forest Division are:

1. Racey, G., A. Harris, L. Gerrish, T. Armstrong, J. McNichol, and J. Baker. 1999. *Forest Management Guidelines for the Conservation of Woodland Caribou: A Landscape Approach.* Version 1.0 Draft. Ontario Ministry of Natural Resources, Thunder Bay, Ontario.

2. Ontario Ministry of Natural Resources. 2002a. *Forest Management Guide for Natural Disturbance Pattern Emulation.* Toronto, Queen's Printer.

And for Ontario Parks:

1. Ontario Ministry of Natural Resources. 1992. *Ontario Provincial Parks: Planning and Management Policies.* Toronto, Queen's Printer.

2. Ontario Parks. 1997. *Ontario's Parks and Protected Areas: A Framework & Action Plan.* Toronto, Queen's Printer.

3. Ontario Parks. 2000. *Woodland Caribou Provincial Park Interim Management Statement.* Red Lake, Queen's Printer.

Table 5.2: Criterion 1, Defining Sustainable Goals and Objectives and the three indicators related to woodland caribou conservation planning.

	Indicator 1	Indicator 2	Indicator 3
Defining Sustainable Goals and Objectives	Are goals and objectives (G & O) clearly stated and defined in policy or management prescription(s)?	Are the G & O dynamic, and do they represent a range of values?	Are G & O based on science and an understanding of social values, and not solely on assumptions or philosophies?
Indicator Concept Citations	Christensen *et al.*, 1996; Franklin, 1997; Mitchell, 1997; Possingham, 2001	Pal, 1997; Franklin, 1997; Clark, 2002	Grumbine, 1994, 1997; Lautenschlager, 1998; Margules and Pressey, 2000; Nazir, 2001
Rationale	The first step in resolving resource and environmental management issues is to envision what a sustainable and equitable future will look like (Mitchell, 1997: 285). This can only be achieved with clearly defined goals and objectives (Christensen *et al.*, 1996). Clearly stated goals and objectives based on scientific principles and recognized social values are necessary if sustainable resource management initiatives are to be effectively implemented (Salwasser, 1993; Franklin, 1997; Lautenschlager, 1998; Cortner, 2000; Hall *et al.*, 2001).		

Table 5.3: **Criterion 2, Reconciling Spatial Scales** and the three indicators related to woodland caribou conservation planning.

	Indicator 1	Indicator 2	Indicator 3
Reconciling Spatial Scales	Do policies reflect the need for large contiguous areas, incorporating linkages with other management jurisdictions?	Do policies clearly state what spatial scale the intended management prescription pertains to?	Do policies acknowledge other phenomena (e.g. forest harvesting and fires) operating at other scales that may affect caribou management?
Indicator Concept Citations	Cumming, 1992, 1998; Wiens *et al.*, 2002	Spies and Turner, 1999; White *et al.*, 1999; Meadowcroft, 2002; Wiens, *et al.*, 2002	Franklin, 1993; Quinby, 2001; Turner *et al.*, 2001
Rationale	Woodland caribou are highly nomadic creatures requiring both winter and summer ranges, and because they use dispersion as a predator avoidance technique (Darby *et al.*, 1989; Cumming, 1992), large spatial scales must be incorporated into policy, planning and management of this species. Small residual patches within a largely disturbed landscape, with limited connectivity to other habitats, are unlikely to support area sensitive species (Noss and Cooperrider, 1994; James, 1999; Wiens *et al.*, 2002). Not recognizing scale related issues in management simplifies complexity, resulting in missed opportunities for sustainable management (Franklin, 1997; Bunnell and Huggard, 1999).		

Table 5.4: Criterion 3, Reconciling Temporal Scales and the three indicators related to woodland caribou conservation planning.

	Indicator 1	Indicator 2	Indicator 3
Reconciling Temporal Scales	Do policies or management plans (P & M) incorporate concepts of long term planning, extending beyond 20 years?	Do P & M recognize the time required for woodland caribou habitat needs (i.e. planning and management for 50 –200 years)?	Have P & M acknowledged and incorporated the concept of non-equilibrium patch dynamics in this region?
Indicator Concept Citations	Meadowcroft, 2002; Yaffee, 1997; White *et al.*, 1999; Pruitt, 1997	Schafer and Pruitt, 1991; Noss and Cooperrider, 1994; Spies and Turner, 1999; Wiens, *et al.*, 2002	Johnson, 1992; Heinselman, 1996; Spies and Turner, 1999; White *et al.*, 1999; Ryan, 2002; Armstrong *et al.*, 2003
Rationale	Long term policies and management prescriptions are rare, as tremendous uncertainty exists in what the future may hold (Mitchell, 1997; Meadowcroft, 2002). Planning and management cycles are often dictated by political direction, cycles and objectives (Yaffee, 1997). Concepts of non-equilibrium patch dynamics are important as the effects of disturbances exhibit tremendous variation, resulting in diverse, non-renewing patch and landscape characteristics (Baker, 1989; Sprugel, 1991; Shinneman and Baker, 1997; Spies and Turner, 1999; Turner *et al.* 2001; Perry, 2002; Armstrong *et al.*, 2003; Suffling and Perera in press).		

Table 5.5: Criterion 4, Making Systems Adaptable and Accountable and the three indicators related to woodland caribou conservation planning

	Indicator 1	Indicator 2	Indicator 3
Making Systems Adaptable and Accountable	Is there a recognized adaptive management framework in which P & M are nested within, and has this system been used?	Are P & M accountable for missed opportunities?	Are there formal policy instruments to take remedial action to rectify or improve problem areas?
Indicator Concept Citations	Lee, 1993; Gunderson *et al.*, 1995; Light, 2001	Mitchell, 1997; Christensen, 1997; Stankey *et al.*, 2003	Noss and Cooperrider, 1994; Yaffee, 1997; Possingham, 2001; Stankey *et al.*, 2003
Rationale	Most of the boreal forest is poorly understood (Pruitt, 1997; Schindler, 1998a), with few long-term studies. Woodland caribou are particularly poorly understood (Cumming, 1992). With such tremendous uncertainty, and limited knowledge, all policies and management decisions should be considered as experiments (Gunderson, 1999; Nudds, 2000; Light, 2001). Policies must also be accountable, as implementation of well-intentioned policy directions often do not result in substantive actions (Noss and Cooperrider, 1994; Yaffee, 1997; Possingham, 2001; Stankey *et al.*, 2003).		

6.0 QUALITATIVE RESULTS

6.1 Introduction

This case study presents the results of an evaluation of woodland caribou management in both the forestry environment and Woodland Caribou Provincial Park. The WCPP region has long been recognized as an important area that supports woodland caribou habitat (Simkin, 1965; Ahti and Hepburn, 1967; OMNR, 1986). This area is part of the central boreal uplands, and in Ontario, is part of Hill's site region 4S. It is dominated by large fairly homogeneous stands of even-aged forests that have resulted from large forest fires that dominate landscape evolution in this region (Ehnes, 2000; Perrea *et al.*, 2001). The dominant tree cover in this region is jack pine: it covers 80% of WCPP (OMNR, 1986; OMNR, 2002b). Areas that are suitable for winter woodland caribou occur primarily on dry upland sites dominated by jack pine and black spruce (Darby *et al.*,1989). These stands tend to be poorly stocked, and have many forest openings, allowing sufficient light to penetrate to the forest floor, supporting terrestrial lichen (Harris, 1992; Gollat, 2000).

6.2 The Developing Woodland Caribou Management Issue

Protecting woodland caribou has been a concern in this region for over 25 years. In 1978, woodland caribou range extended south to Cliff Lake (approx. 175 km south of Red Lake) (Brousseau, 1979; Racey and Armstrong, 2000). At this time there were very few protection measures for caribou. Formal planning incorporating protected areas began in the late 1970's in this region, and continued into the 1980's at which time the Strategic Land Use Planning process (SLUP) began (EPP, 2000). Through the SLUP process two land management approaches were developed that influenced caribou conservation efforts in this region. Forest management, which is now starting to consider the protection of this species through forest management planning processes; and provincial parks, namely WCPP which was established to protect woodland caribou in this region. The establishment of WCPP was influenced by the development of adjacent Atikaki Provincial Park in Manitoba (Atikaki Coalition, 1974; OMNR, 1986).

Since the late 1970's continuous woodland caribou occupancy has receded north by about 200 kilometers (Schaefer, 2003). Today small remnant populations are found near Ear Falls, but most caribou populations, which are considered viable, are found considerably further north, or in areas such as WCPP (Racey and Armstrong, 2000). The continuous push north of forest harvesting and the constraints imposed by forest fires have considerably reduced the region's supply of land suitable for woodland caribou occupancy. This is likely to continue with the expansion of forest harvesting into the Northern Boreal Initiative planning area. Within WCPP alone, more than 106,000 ha burned in the 1980's, making these areas unsuitable for woodland caribou for at least the next 50 years. This limited supply of habitat is the key threat to the preservation of woodland caribou and the resource managers responsible for their persistence.

6.3 Changing Land and Forest Management

The 1980s were a time of reflection and change for land management in Ontario. The Strategic Land Use Planning process (SLUP) was coming to an end, with very few significant (large wilderness class) new protected areas established (Killan, 1993). There was an even greater focus on intensified timber extraction in the province at that time (Priddle, 1982; Killan, 1993; Epp, 2000). By the latter half of the 1980's, significant pressure on the provincial government forced politicians and the forest industry to take stock of the state of the natural forest resources in Ontario (Duinker *et al.*, 2001). This was the Integrated

Resource Management (IRM) period in Ontario's forest management history (Lawson *et al.*, 2001). IRM brought new stakeholder and resource interests to the forest policy development table; some of these include, tourism, fish and wildlife, and environmental interests (Epp, 2000; Duinker *et al.*, 2001). The integrated approach to management appealed to a broader group of policy actors than pure sustained yield, but there was growing concern that IRM was still very much dominated by fibre extraction interests (Euler and Epp, 2000). Decisions were still based on the concepts of growth and yield, with little attention paid to developing more holistic management (Noss and Cooperrider, 1994; Oliver *et al.*, 1999).

During the 1980's and into the early 1990's new ideas were developed and put into practice, which led to ecosystem-based management (Agee and Johnson, 1988; Noss and Cooperrider, 1994). As new approaches were being explored, forestry operations were increasing in intensity and productivity as the industry embraced new technologies, allowing for increased use of resources (Euler and Epp, 2000). The limitations of the IRM approach became increasingly evident (Howlett and Rayner, 2001). Ideas of EM began to shape how policy developers and resource managers approached forest resource issues (Epp, 2000; Duinker *et al.*, 2001). Ontario was no exception to the change in forest management ideals. Forest management in the province was going through a tumultuous time; there was increasing pressure from other interest groups to change the way forest management was approached (Priddle, 1982; Lawson *et al.*, 2001). These new ideas lead to the establishment of the Class Environmental Assessment of Timber Management on Crown Lands, which eventually resulted in the development of the current provincial Act that directs the management of timber on Crown lands, the Crown Forest Sustainability Act (Duinker *et al.*, 2001).

Leading the change in direction in Ontario were the landmark recommendation set out in the *Diversity* report, prepared by the Ontario Forest Policy Panel (1993). This group of diverse stakeholders effectively took the pulse of Ontario, and identified what direction the province should follow with regard to forest policy and management. Many of the recommendations outlined in this report became the basis for forest policy direction in Ontario (Euler and Epp, 2000). The panel recommended that forest policy and management be more holistic and able to adapt to the changing values of both the citizens of Ontario and the global community (Ontario Forest Policy Panel, 1993). This would mean adopting both ecosystem and adaptive management concepts as leading direction in forest land use in Ontario.

6.4 Forest Management of Woodland Caribou

Forest policies and management practices have dramatic effects on woodland caribou (Pruitt, 1997; Racey and Armstrong, 2000). In Ontario's boreal forest there are no formal policies directly related to the conservation of woodland caribou. There is interest in developing formal and binding policy, but lack of consensus between stakeholders has limited its development and implementation (Armstrong, 1998; Basillie pers. comm.)

The Crown Forest Sustainability Act (CFSA) and the Policy Framework for Sustainable Forests are enabling legislation that set the direction for all policy and management development for forestry practices on Crown land in Ontario. Both pieces of legislation have identified ecosystem-based management as a fundamental principle leading the direction in sustainable forest management in the province (Armstrong, 1998; OMNR, 2002b).

The CFSA and the associated EM initiatives are based on the following principles:

1. Large healthy, diverse and productive Crown forests and their associated ecological processes and biological diversity should be conserved.

2. The long term health and vigor of Crown forests should be provided for by using forest practices that, within the limits of silvicultural requirements emulate natural disturbances and landscape patterns while minimizing adverse effects on plant and animal life, water, soil, air and social and economic values, including recreational values and heritage values. 1994, c. 25, s. 2(3).

Moving away from the traditional sustained yield paradigm is a significant departure for policy makers in Ontario. Forest policy now identifies other forest values as an integral part of sustainable forestry (Franklin, 1997; Adamowicz and Veeman, 1998; Lawson *et al.*, 2001). No upper level policy documents explicitly cite woodland caribou as a policy priority, but selected wildlife species have been identified as indicators of their ecosystem, where special management approaches are necessary for sustainable forest management. The woodland caribou is one of these featured species for the boreal region of Ontario (McLaren *et al.*, 1998; OMNR, 1999).

6.4.1 OPERATIONAL SCALE OF WOODLAND CARIBOU MANAGEMENT

Forest policy sets the general direction for forest management activities, but management prescriptions on the ground are the decisions that will have the greatest effect on woodland caribou management (Howlett and Rayner, 2001). To carry out the direction set forth by the CFSA, operational management prescriptions are made in the management planning process for forestry activities on Crown land (OMNR, 2002b). These management plans are developed for 20 years, they are both reviewed and updated every five years (OMNR, 1997a). The five year review period is likely to be extended to 10 years with 2 five year operational periods (OMNR, 2002c). This change is in the process of being implemented through the Environmental Assessment (EA) review process (OMNR, 2002c). Forest management planning is primarily a process to ensure that forest resources are used and regenerated in a cost effective and efficient manner, while limiting waste (e.g., the reduction in timber productivity). The forest management plan is the guiding document that sets out the direction for forest harvesting, and other resource protection within a forest management unit (FMU). This is achieved by a sustainable forest management license agreement between the province and a forest management company (i.e Weyerhaeuser). Forest management plans are regulated and directed by selected guidelines and regulations that are meant to promote forest regeneration and protection of the environment (OMNR, 2002b).

6.4.2 NORTHWESTERN ONTARIO WOODLAND CARIBOU MANAGEMENT

To guide forest management plans in the conservation of woodland caribou, two informal strategies have been developed for this region: 1. *Towards a Strategy for Caribou Habitat Management in Northwestern Ontario* (Greig and Duinker, 1997), and 2. *A Management Framework for Woodland Caribou Conservation in Northwestern Ontario* (OMNR, 1999). Both of these documents identify directions that the OMNR should take to manage woodland caribou in Ontario. The general consensus is that there should not be a further recession of woodland caribou in northwestern Ontario, and that caribou management must fit within the silvicultural constraints of economical forest harvesting (Greig and Duinker, 1997; Racey *et al.*, 1999). A caribou line (southern extent of current woodland caribou population in this portion of the province) has been identified as the benchmark for maintaining caribou populations. This is to be accomplished through the caribou mosaic of planned disturbances through forest harvesting (Armstrong *et al.*, 1998; Racey *et al.*, 1999; Gollat, 2000). The caribou mosaic approach has partitioned the landscape into harvesting blocks based on the stand age, these stands are to be renewed when the stands reach between 80-100 years of age (Figure 6.1) (Gollat, 2000). Both strategies have identified two key guidelines to direct woodland caribou planning and management. The forest management planning process on Crown lands uses two management guidelines that directly affect caribou conservation planning. They are:

1: *Forest Management Guidelines for the Conservation of Woodland Caribou: A Landscape Approach Version 1.0 Final Draft* (Hereafter Caribou Guidelines)

2: *Forest Management Guide for Natural Disturbance Pattern Emulation* (Hereafter Emulation Guidelines)

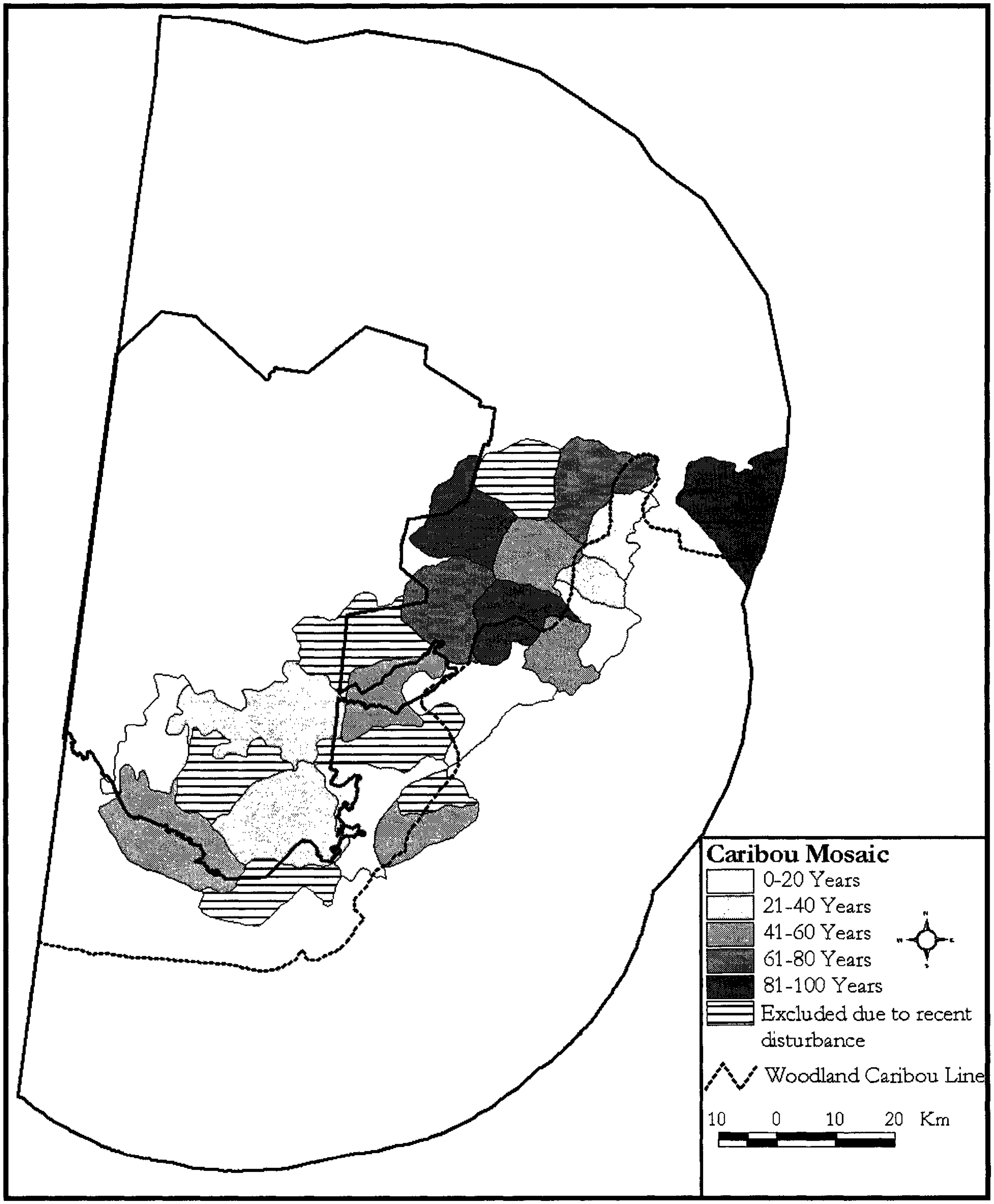

Figure 6.1 Current Caribou Line and Planned Disturbance Mosaic in the WCPP Study Area Context. Disturbance Mosaic is based on 20 year management planning.

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Forest Management Guidelines for the Conservation of Woodland Caribou: A Landscape Approach Version 1.0 Final Draft – Summary

The woodland caribou guidelines indicate that current forest management harvesting practices (small clearcuts and relatively short rotation periods (60–80 years)) are inappropriate for maintaining caribou within the managed forest landscape. The desire is to avoid further range reduction of woodland caribou within northwestern Ontario. Forest management plans should incorporate large spatial scales (potentially even larger that current FMUs), and much longer temporal scales of planning (appox. 100 years) in management prescriptions. Long term planning should also consider the allocation of winter habitat in the next forest rotation. Fire can be used when economically feasible, but caribou habitat should be a priority when protecting forest resources through suppression efforts, particularly winter, migration and calving sites. Wood flow is unlikely to be negatively affected by these guideline, but some adjustments may have to be made to ensure habitat suitability and connectivity, especially in the short-term. The guidelines indicate that caribou management must be nested within an adaptive management framework, as our knowledge of woodland caribou is not complete. Management practices must still fall within the silvicultural framework of existing forest management for this region. These guidelines are to work in concert with the Forest Management Guide for Natural Disturbance Pattern Emulation, which will direct harvesting patterns.

Forest Management Guide for Natural Disturbance Pattern Emulation - Summary

The emulation of fire pattern through harvesting techniques in the boreal forest has become a dominant forest management paradigm (Attiwill, 1994; Adamowicz and Veeman, 1998). This concept is founded on the principle that by emulating the pattern of natural disturbance (forest fires), the function and associated ecosystem values will also be mimicked and maintained to an acceptably sustainable level. This management approach addresses the deficiency of smaller block type clearcuts, and the adverse effects of high edge to area ratios of cutovers, which primarily promotes habitat suitable for edge adapted species (white tail deer, brown-headed cowbird, etc). The larger cut size is more natural than the current maximum 260 ha. This guide indicates that clearcuts may be as large as 10,000 ha. Clearcuts of this size are more representative of the size of fire disturbances in the boreal forest, and may promote large uniformly aged stands for species such as woodland caribou. Larger clearcuts must be separated by larger residual patches, and cannot be harvested prior to the 3 metre green-up or 20 years post harvest criteria. The more natural shape of harvesting leaves residual (insular) patches and peninsulas within clearcut areas, to provide shelter for organisms, and to potentially provide linked corridors across cutovers between uncut areas within the managed forest. Prescribed fire should be used as often as possible to better emulate the effects of fire.

6.5 Protected Area Management and Woodland Caribou

Formal protection of woodland caribou came into existence in 1929, when hunting of woodland caribou was outlawed in Ontario (Darby *et al.*, 1989). At that time there were no protected areas set aside for woodland caribou conservation, although Quetico Provincial Park was in existence at this time, and caribou inhabited the region (Heinselman, 1996). Early wildlife managers and researchers identified an area around Irregular Lake (currently within the WCPP boundary) as an important year round area that supported woodland caribou (Simkin, 1965). This region was recognized as having high woodland caribou populations and was jointly set aside as a Caribou Game Preserve in 1957, along with an area that crossed the Manitoba border (Sandilands and Gagnon, 1982). This region was then identified as a potential provincial park, and became a Provincial Park Reserve in 1967 (Sandilands and Gagnon,1982). At this time there was the possibility of setting aside an area within this region as a national park (OMNR, 1986). Further protected area development did not occur until the late 1970's and into the 1980's when resource assessments were conducted as part of the SLUP process. During the 1980's, management prescriptions were applied to large sections of the boreal forest in Ontario through the SLUP planning process (including the West Patricia Land Use Planning Process). In the 1980's two large protected areas in northwestern Ontario were identified as provincial park candidates that were to be established as reserves protecting woodland caribou habitat; these reserves were Wabakimi Provincial Park (155,000 ha at the time of establishment) located northwest of Lake Nipigon and WCPP (Lee Kam, 1993; Killan, 1993). For the purpose of this research I only explore policy developments related to WCPP. Once it was determined that the park area had low mineral potential and only small areas of productive forest would be lost, the region was designated as a 450,000 ha boreal wilderness park under the Provincial Parks Act (Sandilands and Gagnon, 1982; OMNR, 1986).

Significant amounts of background information were collected prior to the park's establishment in 1983. Most of the data was related to rare plant communities (Brunton, 1986), and fisheries (Wepruk, 1986b). Woodland caribou surveys were conducted in both the 1970's and 80's as moose (*Alces alces*) densities were being determined (OMNR, 1986). Wepruk (1986a) conducted a formal assessment of woodland caribou population and potential habitat; habitat potential was last evaluated in 1991 by C.M. Consultants (Harris *et al.*, 2001). During the 1990's almost no research or formal assessment was conducted on woodland caribou or their habitat within the park.

Ontario provincial parks are directed by the Provincial Parks Act, which is not discussed, as this act gives very general direction to strategic planning, and makes no reference to species at risk, and only passing reference to the concept of nature protection in parks (Eagles, 1993; Wilkinson, 2002). More explicit direction for Ontario provincial parks is provided by *Ontario Provincial Parks: Planning and Management Policies* (also known as the Blue Book) (OMNR, 1992).

Provincial parks are categorized according to a provincial park classification system; parks can be classified as: Wilderness, Nature Reserve, Historical, Natural Environment, Waterway and Recreation parks (OMNR, 1992; Priddle, 1993). Woodland Caribou Provincial Park is a Wilderness class provincial park.

> Wilderness parks are substantial areas where the forces of nature are permitted to function freely and where visitors travel by non-mechanized means and experience expansive solitude, challenge and personal integration with nature (OMNR, 1992: 15).

Many management prescriptions are based on a zoning system; the zones within a Wilderness class provincial park can be any combination of the following: wilderness, nature reserves, historic, and access zones (Priddle, 1993). The designation of park zones is completed through the management planning process.

Ontario Parks has developed strategies beyond the Blue Book, including: *Ontario's Parks & Protected Areas: A Framework and Action Plan* (OMNR, 1997). This strategy builds on concepts developed in the Blue Book, and identifies both EM and adaptive management as integral parts of Ontario Parks' strategy for protected area planning and development. This strategy was part of the Lands for Life (LFL) planning process which is now part of Ontario's Living Legacy (OLL), a land use planning process to complete a system of protected areas in Ontario, while providing greater certainty for resource extraction interests (Francis, 2000). The Convention on Biological Diversity is also recognized by the Ontario government (OMNR, 1997).

6.5.1 WOODLAND CARIBOU PROVINCIAL PARK

Although Woodland Caribou Provincial Park has existed for 20 years, a park management plan has not yet been developed for the area. A formal park management planning process is underway and should be completed by 2005; this process will identify priorities and general management direction for the park. An Interim Management Statement (2000) has been published which recognizes woodland caribou as a priority species that should be protected. The statement recognizes forest fire as a very important landscape dynamic, since the region's forest ecosystems have evolved with fire (OMNR, 2000). Fire and vegetation management plans are planned as future developments (D. Gilmore, pers. comm). Until the management planning process is complete, no zoning, and therefore no specific planning or management actions can be taken, beyond what is outlined in the Provincial Park's Act (enforcement of basic regulations and the maintenance of infrastructure).

An interim fire management strategy is in the process of being developed for WCPP; the draft strategy has identified a buffer zone within the park perimeter as a no burn zone, to protect forest resources outside the park. Another mosaic approach is to be used, to protect the maximum amount of woodland caribou habitat over the next 20 years (D. Gilmore pers. comm.). This research will contribute to these concepts and potentially how the mosaic will be planned.

Ontario has a recovery team (through the Committee on Endangered Wildlife in Canada (COSEWIC)) for woodland caribou that is developing a strategy for woodland caribou conservation (Lipsett-Moore, pers com). The team includes members from Ontario Parks, however, the only fulltime staff member of WCPP, the park superintendent, is not a member of the recovery team. The strategy developed by this team will feed into provincial conservation initiatives and the new federal species at risk legislation. The new federal species at risk legislation (SARA) has no capacity for enforcement, or implementation of any strategy (Ontario Parks, 2003), so this will not be discussed in great detail. A new Environmental Assessment (EA) policy is being developed to facilitate management and planning of species at risk and forest fire management (Ontario Parks, 2003b). This EA has not yet been implemented; therefore an assessment of its efficacy is not yet possible.

Policy development in Ontario provincial parks is much less structured than in the forest management sector of the OMNR. This is not due to the lack of complexity, or need for better management practices; it is likely due to limited human and financial resources.

6.6 Policy Analysis Results

The policy analysis section examines how the Forest Division and Ontario Parks have approached selected criteria of ecosystem management. An index of indicators is used to evaluate whether or not selected concepts of EM are being integrated into land use policy approaches.

6.6.1 DEFINING SUSTAINABLE GOALS AND OBJECTIVES

Based on all indicators within this criterion, the Forest Division is doing a better job at defining sustainable goals and objectives of EM compared with Ontario Parks (Table 6.1). Ontario Parks received a low score largely because they failed to clearly define goals and objectives (Table 6.1). However, at the local (i.e. management planning) level, Ontario Parks did achieve moderate success at defining goals and objectives of EM. None of the policy and management approaches had dynamic goals, nor did they represent a wide range of values.

6.6.2 RECONCILING SPATIAL SCALES

The *Forest Management Guidelines for the Conservation of Woodland Caribou* addressed issues of spatial scale, which resulted in the highest score of all policies analyzed (Table 6.2). These guidelines incorporated many concepts of spatial planning and management. The remaining policy approaches only make passing reference to spatial scale related issues. Ontario Parks has no formal policy related to woodland caribou management, therefore it cannot address issues related to this species, resulting in very low scores.

6.6.3 RECONCILING TEMPORAL SCALES

None of the policy approaches used by either Ontario Parks or the Forest Division scored exceptionally high on this criterion; one exception was the *Forest Management Guidelines for the Conservation of Woodland Caribou*, which did moderately well as it addresses the need for long-term planning (Table 6.3). All of the policy approaches failed to acknowledge or incorporate the concept of non-equilibrium patch dynamics in this region (Table 6.3), which dramatically lowered the final scores.

6.6.4 MAKING SYSTEMS ADAPTABLE AND ACCOUNTABLE

All policy approaches scored particularly low on this final criterion (Table 6.4). Although *Forest Management Guidelines for the Conservation of Woodland Caribou*, *Forest Management Guide for Natural Disturbance Pattern Emulation*, and *Ontario's Parks & Protected Areas: A Framework & Action Plan* mention the desire to integrate adaptive management into policy and management decisions, no framework exists. None of the policy approaches make any reference to being accountable for missed opportunities (Table 6.4). Similarly, none of the policy approaches indicate how or if remedial action can be taken to rectify or improve problem areas (Table 6.4).

Table 6.1: Results of the Policy Analysis for the Defining Sustainable Goals and Objectives Criterion.

Defining Sustainable Goals and Objectives	Affiliation	1: Are goals and objectives (G & O) clearly stated and defined?					2: Are the G & O dynamic, and represent a range of values?					3: Are G & O based on science and an understanding of social values?				
		+ -					+				-	+				-
Score		5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Forest Management Guidelines for the Conservation of Woodland Caribou	Forest Division		4							2				3		
Forest Management Guide for Natural Disturbance Pattern Emulation	Forest Division		4							2					2	
Ontario Provincial Parks: Planning and Management Policies	Ontario Parks				2					2					2	
Ontario's Parks & Protected Areas: A Framework & Action Plan	Ontario Parks				2					2				3		
Woodland Caribou Provincial Park Interim Management Statement	Ontario Parks		4							2					2	

Table 6.2: Results of the Policy Analysis for the Reconciling Spatial Scales Criterion.

Reconciling Spatial Scales	Affiliation	Do policies reflect the need for large contiguous areas, incorporating linkages with other management jurisdictions?					Do policies clearly state what spatial scale the intended management prescription pertains to?					Do policies acknowledge other phenomena (e.g. forest harvesting and fires) operating at other scales that may affect caribou management				
		+				-	+				-	+				-
Score		5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Forest Management Guidelines for the Conservation of Woodland Caribou	Forest Division		4					4						3		
Forest Management Guide for Natural Disturbance Pattern Emulation	Forest Division				2				3							1
Ontario Provincial Parks: Planning and Management Policies	Ontario Parks				2					2		N/A				
Ontario's Parks & Protected Areas: A Framework & Action Plan	Ontario Parks				2					2		N/A				
Woodland Caribou Provincial Park Interim Management Statement	Ontario Parks			3				4							2	

Table 6.3: Results of the Policy Analysis for the Reconciling Temporal Scales Criterion.

Reconciling Temporal Scales	Affiliation	Do policies or management plans (P & M) incorporate concepts of long term planning, extending beyond 20 years?					Do (P & M) recognize the time required for woodland caribou habitat needs, (i.e. planning and management for 50 –200 years)?					Have (P & M) acknowledged and incorporated the concept of non-equilibrium patch dynamics in this region?				
		+				-	+				-	+				-
Score		5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Forest Management Guidelines for the Conservation of Woodland Caribou	Forest Division	5							3							1
Forest Management Guide for Natural Disturbance Pattern Emulation	Forest Division				2					2						1
Ontario Provincial Parks: Planning and Management Policies	Ontario Parks		4							2						1
Ontario's Parks & Protected Areas: A Framework & Action Plan	Ontario Parks		4							2						1
Woodland Caribou Provincial Park Interim Management Statement	Ontario Parks			3						2						1

Table 6.4: Results of the Policy Analysis for the Making Systems Adaptable and Accountable Criterion.

Making Systems Adaptable and Accountable	Affiliation	Is there a recognized adaptive management framework in which (P & M) are nested within, and has system been used?					Are (P & M) accountable for missed opportunities?					Are there formal policy instruments to take remedial action to rectify or improve problem areas?				
		+				-	+				-	+				-
Score		5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Forest Management Guidelines for the Conservation of Woodland Caribou	Forest Division				2						1					1
Forest Management Guide for Natural Disturbance Pattern Emulation	Forest Division					1					1					1
Ontario Provincial Parks: Planning and Management Policies	Ontario Parks					1					1					1
Ontario's Parks & Protected Areas: A Framework & Action Plan	Ontario Parks				2						1					1
Woodland Caribou Provincial Park Interim Management Statement	Ontario Parks					1					1					1

7.0 DISCUSSION

7.1 Ecosite Assessment

At the ecosite scale, the ES12/V30 plots exhibit variation with respect to forest structure and composition of species on these sites. Forests with more openings and lower stem densities had less humus form development and more terrestrial lichen on site. Conversely, sites with thicker humus form development over bedrock were associated with greater canopy closure, more feathermoss, and less lichen (Johnson, 1981; Payette *et al.*, 2000). This variation at the ecosite scale has important implications for woodland caribou in this region, as they are dependant on terrestrial lichen as an important food source (Klein, 1982; Schaefer and Pruitt, 1991; Johnson *et al.*, 2001).

The lichen abundance can be attributed to the openness of stands, which varies depending on humus form depth. Lichen did not exist in abundance under closed or nearly closed canopies, even though suitable overstorey trees (jack pine) and substrate (shallow soil or bedrock) were present. Humus form accumulation appears to be the controlling factor in the feathermoss-lichen dynamic (Nguyen-Xuan *et al.*, 2000; Payette *et al.*, 2000). Where humus form (>2 cm depth) is present over bedrock, there is little or no terrestrial lichen. These sites have higher tree stem densities and greater canopy closure, limiting lichen regeneration. In WCPP, open woodlands (with extensive exposed bedrock outcrops) appear to be necessary to support abundant lichen over long periods of time (Johnson, 1981; Schaefer and Pruitt, 1991; Sulyman and Coxson, 2001). Sites with relatively deep humus form development on bedrock or shallow, well-drained sites did not support abundant lichen (Payette *et al.*, 2000).

In forest of the ages studied (53-157 years after fire), lichen was found in abundance at all ages on open sites. The characteristics of these lichen stands can be attributed to the characteristics of past forest fire events (Johnson, 1981; Payette, 1992), as fires dictate aboveground site characteristics, as well as which seeds or rhizomes survive after the disturbance (Johnson, 1981, 1992; Payette, 1992; Heinselman, 1996; Miller, 2000).

7.2 Regeneration of Jack Pine Forests After Fire

How a boreal jack pine forest regenerates after a forest fire will depend on fire severity (Ryan, 2002; Wang, 2002). Fire severity determines both the structure and composition of these forests (Johnson, 1981; Payette, 1992; Turner *et al.*, 1999; Payette *et al.*, 2000; Wang, 2002). Severe fires, or fire events with short return intervals, will consume more organic matter (including humus form) than low severity fires (Johnson, 1992; Payette, 1992; Miyanishi, 2001; Ryan, 2002).

Humus form is critical in northern forests, especially in shallow soil environments, where it becomes much of the soil. Humus form is often the entire nutrient capital for many forests on V30 sites (OMNR, 1997c; Green, *et al.*, 1999; Prescott *et al.*, 2000; Gordon *et al.*, 2001). Areas with little or no humus after a fire have limited ability to support trees, as growing conditions are too severe. Few trees are able to effectively regenerate with almost no soil to retain moisture (Kimmins, 1997). This leads to extreme fluctuations in microclimate site conditions (extreme drought and significant frost damage), making germination and survival of vascular plants very difficult (Kimmins, 1997; Green *et al.*, 1999; Prescott *et al.*, 2000). Low seedling densities result in low tree densities in mature forests, often with many forest openings or gaps (Figure 7.1) (Johnson, 1992; Heinselman, 1996; Turner *et al.*, 1999; Ryan, 2002). These forest openings become ideal habitat for species that can withstand these harsh environments and require abundant sun light, such as *Cladina rangiferina*, an important food source for woodland caribou.

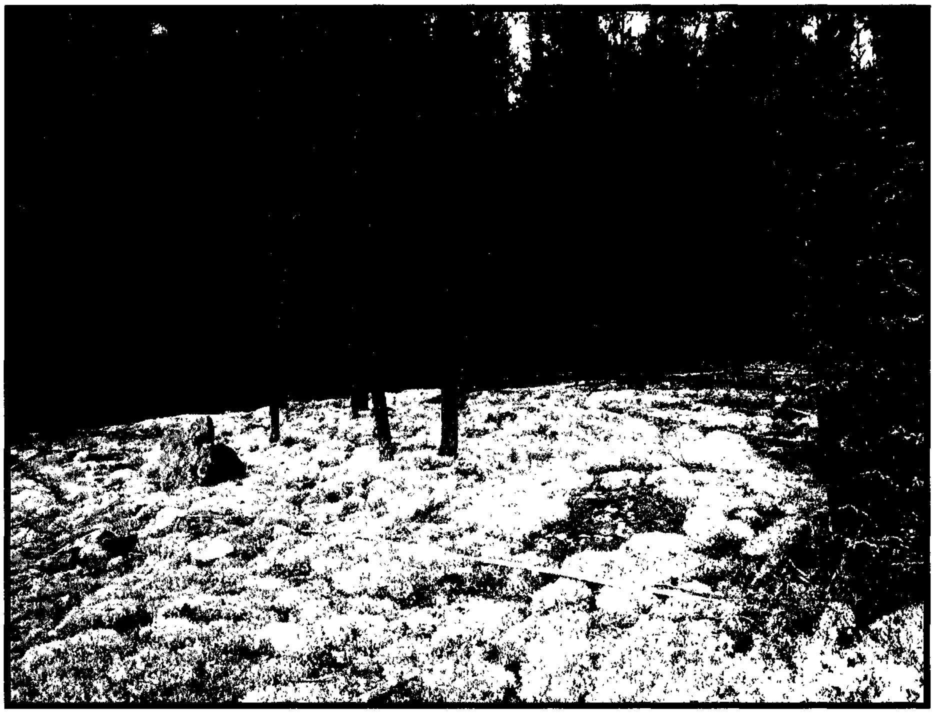

Figure 7.1: Openness of Lichen Rich Ecosites. These are examples of open jack pine forests growing in a bedrock dominated ecosystems. The top photo shows a forest opening where *Cladina rangiferina* is the dominant ground cover; the bottom photo is an example of jack pine growing on bedrock. Stems are relegated to cracks in the bedrock and in depressions where humus form provides rooting foundation and nutrients. All stems are of the same cohort; the smaller ones have been limited in size due very harsh growing conditions.

Limiting duff accumulation will depend upon forest fire severity. Stand replacing fires that burn through the canopy and consume aboveground biomass will not necessarily consume duff (Miyanishi and Johnson, 2002; Ryan, 2002). The remaining unconsumed duff may not be abundant, but the effects on the variation in the density of stem regeneration on V30 sites after fire are dramatic. Areas with even thin layers of burnt duff on site are very favorable substrates for jack pine regeneration, especially compared to bedrock (Greene *et al.*, 1999). Tree regeneration and density on sites with greater amounts of unburnt or partially burnt duff will be more abundant, as this offers a suitable seedbed (Kimmins, 1997; Prescott *et al.*, 2000).

Humus forms will develop over time as forests mature; forests with more canopy cover will have more litter fall, contributing to greater amounts of potential humus form development (Miyanishi, 2001). Areas with low stem density and forest openings will accumulate humus form much more slowly, which in turn will influence the characteristics of future forest fires and how forests regenerate in the future.

The effects of humus form will have a lasting legacy on forest regeneration and site characteristics (Kimmins, 1997; Prescott *et al.*, 2000). The legacy of humus form development on a site will determine how a stand regenerates, and the amount of terrestrial lichen on site. The stand legacy will also influence future disturbance events, as stand density and composition will determine fuel type, abundance and pattern of future fires (Ryan, 2002).

7.3 Landscape Assessment

The variation of shallow soil jack pine forests was not only an ecosite scale phenomena (Figure 7.2). The four 1930 fires showed significant variation in the openness of the forests studied. The North and Wrist sites had a higher average amount of forest openings than the Mid and South study sites. The greater average size of forest openings in the North and Wrist sites mean that sun dependant species such as *Cladina spp.* will likely be able to persists for longer time periods and in greater abundance (over time) than areas such as the Mid and South study areas. Forests at the landscape scale that have smaller forest openings will support lichen, but lichen regeneration and abundance will occur at an earlier successional state than forest with large canopy openings (Johnson, 1981; Payette *et al.*, 2000). Larger forest opening may also favor woodland caribou foraging opportunities, as average snow depths are shallower due to wind, allowing easier access to lichen in the critical late winter months (Schaefer and Pruitt, 1991; Johnson *et al.*, 2001).

The effects of forest fires within WCPP do not only vary with stand composition and structure. The amount of area burned over time also varies tremendously. During the 20th century there was dramatic variation in the amount of area burned, measured by the amount of area burned in each decade. Almost no fires burned during the 1950s (319 ha), whereas a large portion of the park burned during the 1980s (106,696 ha). This extreme fluctuation in fire size will make prescribed fire within the park challenging; burning small areas (<2000 ha) each year may be manageable (Reilly pers comm.) but this would limit fire size to a maximum of 20,000 ha per decade. This is far smaller than the largest area by fire decade in the 20th century. Moreover, most large fires burned a considerable amount of area outside of the park (at least as much as was burnt in the park). By limiting the amount of area burned, resource managers are limiting the amount of potential caribou habitat. How woodland caribou respond to this extreme variation in habitat availability over time is beyond the scope of this research. However, some interesting points can be made about lichen regeneration in a non-equilibrating fire environment.

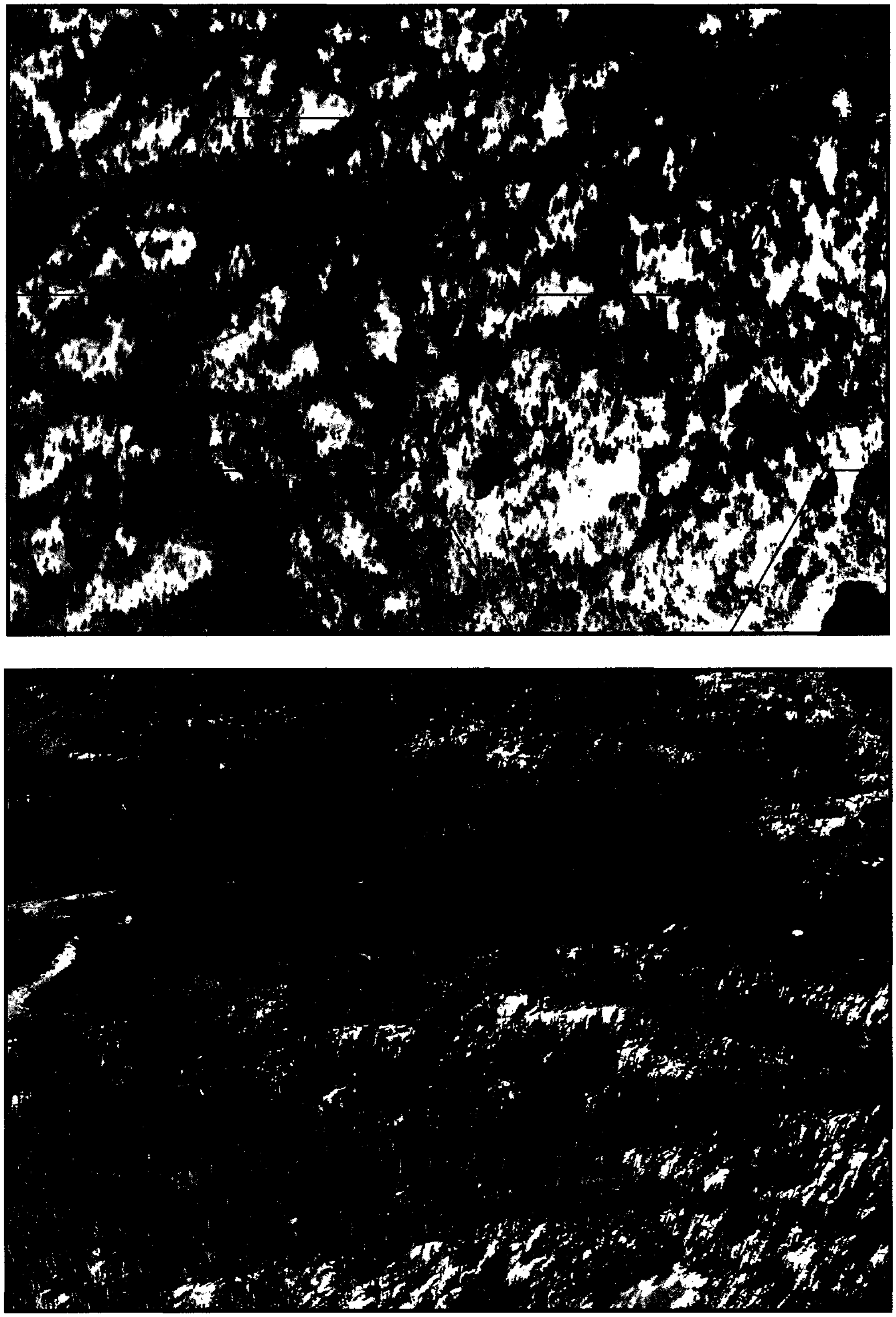

Figure 7.2: Variability in Landscape Scale Forest Openings. Landscape views of open jack pine sites in Woodland Caribou Provincial Park; the photo on the top is a very open area with abundant lichen (the polygons are 5 ha hexagons); the bottom photo shows the variability of forest openings in this region.

7.3.1 TERRESTRIAL LICHEN DYNAMICS OVER TIME

Terrestrial lichens are well adapted to surviving periodic disturbance by fire, and can persist in harsh environments (Johnson, 1981; Kershaw, 1985; Webb, 1998). The onset of fire can actually improve habitat for terrestrial lichen by opening up closed canopies and limiting competing species such as feathermoss and shrubs which will shade out lichen when they become dominant (Ahti and Hepburn, 1967; Schaefer and Pruitt, 1991; Payette *et al.*, 2000; Coxson and Marsh, 2001).

On average, forests with smaller canopy openings had higher percentages of lichen cover in young stands (50-70 years) than young stands with expansive forest openings. This is likely due to the effects of fire severity; where more lichen biomass was combusted in more severe fires, resulting in a longer regeneration time (Heinselman, 1996; Payette *et al.*, 2000). This however changes quite dramatically as these forests begin to age, when stands become dominated by feathermoss and black spruce. Stands with smaller forest openings begin to succeed to forests with greater overall canopy closure than stands with larger canopy openings. Black spruce begin to fill in the canopy gaps, and feathermoss (primarily *Pleurozium schreberi*) becomes the dominant ground cover at an earlier successional stage than in forests with larger average forest openings, limiting shade intolerant species (Figure 7.3) (Johnson, 1992; Sulyman and Coxson, 2001; Miyanishi and Johnson, 2002). The resulting lack of light, and the ability of feathermoss to out-compete lichen, changes the dynamics and the amount of lichen in these forests, transforming these forests from lichen rich to feathermoss rich forests (Payette, *et al.*, 2000; Coxson and Marsh, 2001). (Figure 7.4).

Figure 7.3: Black Spruce Regeneration. Regenerating black spruce and feathermoss in a once open V30 jack pine (bare stems in foreground) stand on Wrist Lake. Notice the vigorous growth of black spruce saplings, shading out potential lichen habitat.

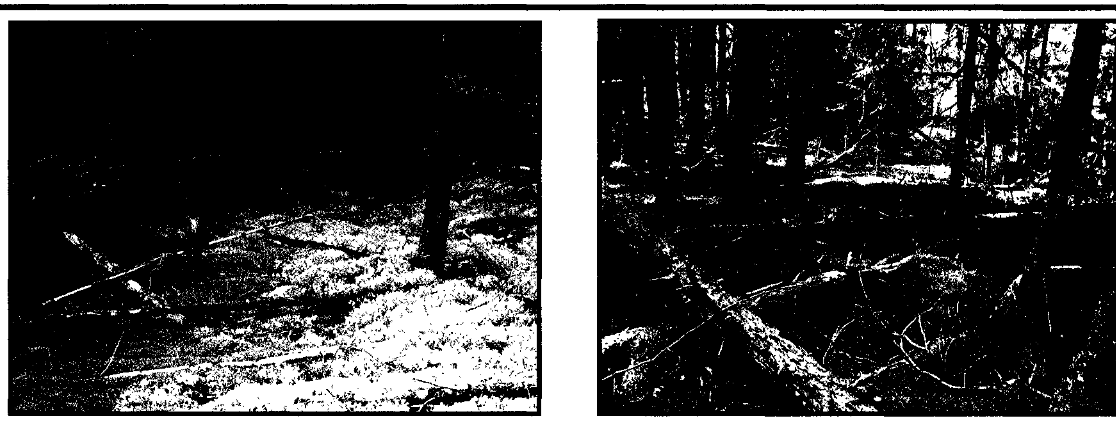

Figure 7.4: Succession of Ground Cover in V30 Stands. The photo on the left shows the competition for ground cover in a 62 year old V30 site, the forest opening is to the right of this picture (where the lichen is), whereas the closed canopy forest is to the left. (where the feathermoss is growing). The photo on the right shows the dominance of feathermoss in a 127 year old shaded V30 site. Feathermoss was found growing over lichen in this stand.

In forest with larger openings, and less humus form, terrestrial lichens are able to persist for much longer (Johnson, 1981; Schaefer and Pruitt, 1991). The harsh microclimate of these larger forest openings limits the encroachment of feathermoss and black spruce (Payette, 1992; Heinselman, 1996). The openness allows lichens to persist in this landscape until these stands are very old for this region (>150 years). The average fire return interval for this portion of the country is less than 100 years (Ehnes, 2000). The longer than average return interval of fire events in this region may be attributed to lack of fuel, and poor fuel connectivity (Heinselman, 1996; Turner *et al.*, 1989; Ryan, 2002) or just by chance.

7.4 Importance for Woodland Caribou

The pronounced variation in the mean amount of forest openings, and resulting lichen regeneration in these V30 sites is important for caribou persistence in this region. Woodland caribou must respond to available forage (lichen), by accessing forests with different attributes (lichen abundance) at different ages. In regions with low severity fires (smaller forest openings, greater amount of humus form), caribou likely access these stands/landscapes at an earlier successional stage (50-80 years old), when lichen is most abundant. In areas where fires were more severe (greater forest openings, less humus form accumulation) caribou can access these stands at later successional stages, as these stands will continue to support lichen until they are much older (>150 years old) (Schaefer and Pruitt, 1991; Sulyman and Coxson, 2001). This dynamic availability of lichen at different forest ages is very important for caribou, as the forest fire return intervals are not in equilibrium (Sprugel, 1991; Shinneman and Baker, 1997; Armstrong *et al.*, 2003). This means that there is not a sustained yield of lichen rich stands for caribou forage in any one area. When fires are small or infrequent such as in the 1950s, or when fires are not severe, the result will be less lichen over time. To make up for this lichen deficit, older stands that experienced more severe burns in the past, which are generally more open, and large fires (e.g., 1980s) must provide foraging opportunities when lichen availability is limited elsewhere.

7.5 Land Use Policy Assessment

The development of policy related to the conservation of woodland caribou in Ontario has been very limited. Although Ontario Parks and the Forest Division have expressed interest in developing policy, no formal policy has yet been developed. This is the case, despite the fact that woodland caribou have been considered a species at risk for over 25 years. Establishing large protected areas such as Woodland Caribou Provincial Park was an important step towards conserving this species, but the lack of management within the protected area and encroaching forest harvesting activities increase uncertainties regarding species persistence in this region.

7.5.1 FOREST MANAGEMENT AND WOODLAND CARIBOU

The Forest Division has made great strides in addressing other forest values not directly tied to fibre extraction (Adamowicz and Veeman, 1998; Duinker *et al.*, 2001, Balsillie, 2002). Some of these advances are related to habitat considerations for other valued organisms such as moose and fish, and their habitats (Remple *et al.*, 1997; Francis, 2000). These values have economic value (are harvestable), and are able to fit within the silvicultural constraints of economic forest harvesting. The strategies that have been developed for woodland caribou conservation give some direction for caribou conservation, but are primarily descriptive in nature (e.g., Greig and Duinker, 1997; OMNR, 1999). These have yet to be tested or put into practice; therefore it is difficult to assess their potential efficacy.

Two forest management guidelines have been developed, which direct land use activities that affect woodland caribou habitat. These forest management guidelines appear promising, as they incorporate new ideas of ecosystem and adaptive management, but significant challenges in implementation remain (OMNR, 2002b).

7.5.1.1 Forest Management Guidelines for the Conservation of Woodland Caribou

The Caribou Guidelines appear to be a substantive move on the part of the Forest Division to address the issue of woodland caribou range recession due to forest harvesting activities. Even though these guidelines are still in the draft stages (final draft, version 1.1), many of the concepts are being implemented through the forest management planning process and the implementation of the caribou mosaic (Armstrong, 1998; Racey and Armstrong, 2000; Gerrish and Lipsett-Moore pers. comm.). These guidelines consistently outscored all other policy approaches (1.Forest Management Guide for Natural Disturbance Pattern Emulation, 2. Ontario Provincial Parks: Planning and Management Policies, 3. Ontario's Parks & Protected Areas: A Framework & Action Plan, and 4. Woodland Caribou Provincial Park Interim Management Statement) evaluated in this study. The guidelines have clear objectives, and acknowledge the limitations of small scale and short term planning in conservation efforts for this species. An adaptive management approach to management is also encouraged.

Reconciling spatial and temporal scale related issues is the greatest challenge in the implementation of these guidelines. Planning on the regional scale (larger than individual FMUs) will be very difficult as the management of wood flow is currently based on FMU boundaries (OMNR, 2002b). This is important for woodland caribou, as they are far a ranging species (Darby *et al.*, 1989; Racey *et al.*, 1999). Restricting harvesting in one FMU to protect caribou habitat will not be an easy political "sell", and will cause local, if not regional, economic concerns (Barrett *et al.*, 1998). The cost of planning at the regional level, in cooperation with operational plans, will be very high and complex (Margules and Pressey, 2000; Possingham, 2001). No example of this scale of management with operational plans exists in Ontario.

Temporal scale issues will be the most difficult to address as they are often abstract, and may not become apparent until management regimes have been put into place (including regional timber access rights) (White *et al.*, 1999; Gordon *et al.*, 2001). Resource extraction interests will demand guaranteed long-term resource access rights, to ensure profitable returns on planning and infrastructure investments (Loehle *et al.*, 2002). By granting long-term resource access, opportunities for adaptive management are compromised (Yaffee, 1999; Light, 2001). This is particularly relevant in caribou management, as the area required to maintain a viable woodland caribou population in this region is not known (Schaefer pers comm.). Current caribou population numbers (which are not known) may be unsustainably low, resulting in future extirpation. The ability of woodland caribou to reoccupy an area after forest harvesting is also not known. There have been very few examples of woodland caribou using cutover areas after harvesting (Darby *et al.*, 1989; Racey *et al.*, 1996; Racey and Armstrong, 2000). Therefore the current approach to management is not guaranteed to be effective at conserving woodland caribou.

The Caribou Guidelines were developed on the premise of adaptive management, as so little is known about this animal and their habitat requirements. Management prescriptions are based on the best available knowledge and are considered to be experimental. The concept of adaptive management is an attractive option for resource managers in Ontario as all management prescription should be dynamic and reflect new knowledge (Nudds, 2000). Adaptive management will be difficult, as no adaptive management system exists within the OMNR (Baker, 2000); this is compounded by the fact that there is insufficient monitoring and scientific research in this region (Nudds *et al.*, 1998; Kutas *et al.*, 2002; Lipsett-Moore, 2002). There is concern that an adaptive management framework is too complex and costly to implement in practical application (MacDonald *et al.*, 1999). As Stankey *et al.* (2003) noted, if a system designed for adaptive management is too difficult to implement, the system will remain rigid, limiting options and preventing mitigative actions.

Small-scale, informal monitoring systems and changes to policies and management prescriptions do occur, but cannot be considered to be truly adaptive (Gunderson, 1999; Baker, 2000; Stankey *et al.*, 2003), as these approaches are ad hoc. The real challenge in implementing an adaptive management framework for woodland caribou conservation is the length of time necessary to regenerate caribou habitat after a disturbance (at least 50 years). Based on this planning horizon, the effects of management prescriptions made today cannot be fully evaluated until well into the future. It is unknown whether adaptive management can work on this long time horizon or this large spatial scale (Stankey *et al.*, 2003).

7.5.1.2 Forest Management Guide for Natural Disturbance Pattern Emulation

Pattern emulation forest harvesting is meant to mimic the shape and size of forest fires, and potentially their ecological effects. This forest management concept is an interesting idea with some ecological merit (Franklin *et al.*, 2000; McRea *et al.*, 2000b). This form of forest harvesting has become the dominant silvicultural prescription in Canada's boreal forest (Adamowicz and Veeman, 1998). Increasing the size of cut blocks will minimize edge effects, and will better approximate the size and potential pattern of natural disturbances such as forest fires (Niemela, 1999; McRea *et al.*, 2000b). However, this perspective on forest fire characteristics and their ecological effects is simplistic (Gordon, 1996; Franklin *et al.*, 2000).

The Pattern Emulation Guidelines (PEG) recognizes the differences between forest fires and forest harvesting, and acknowledge their limitations. The biggest difference between the two processes is that forest fires are primarily a chemical form of disturbance, with physical impacts, whereas clear cutting is dominantly a mechanical process (Gordon, 1996; McRea *et al.*, 2000b; OMNR, 2002a). The chemical changes in soil pH due to ash accumulation and cation exchange generally leads to higher pH after fire, whereas in forest harvesting operations, this does not occur (Kimmins, 1997; Johnston and Elliott, 1998; Prescott *et al.*, 2000; Simard *et al.*, 2001). This change in the timing and availability of soil nutrients and soil pH may have long-term ecological effects on stand characteristics (Simard *et al.*, 2001). The PEG have not addressed the differing ecological effects of these two disturbance processes. Forest fires are highly variable disturbance agents, with diverse ecological effects depending on the severity of the fire events (Johnson, 1992; Turner *et al.*, 1999; Ryan, 2002; Wang, 2002; this study). The variability of clear cutting and their ecological effects do not reflect the range of scales at which fires operate (Franklin *et al.*, 2000; Elkie and Remple, 2001). Disturbance severity is purposefully limited to promote productive tree regeneration (OMNR, 1997c). Although the desire of these guidelines is to emulate the pattern of fire disturbance, the variable effects of disturbance severity are not emulated (Figure 7.5).

Tree regeneration after a disturbance is an important part of sustainable forest management (OMNR, 2002b). If site conditions are inappropriate (lack of nutrients), tree regeneration will be compromised; therefore, sites with sufficient nutrient capitals are required for sustainable forest management (Kimmins, 1997; OMNR, 1997c; Whittle *et al.*, 1997). The Forest Division has acknowledged in the *Forest Management Guidelines for the Protection of the Physical Environment* (Physical Environment Guide) how they would like to emulate disturbance severity. This is clearly stated in the Physical Environment Guide, where the authors state:

> Site damage must be viewed in context with effects of natural disturbances (e.g., wildfire, windthrow, erosion) on ecosystem form and function. Natural disturbance regimes and their effects are highly variable and it is important that effects of human disturbance stay within the range of natural variability. Although some natural disturbances are severe, the intent of our human activities is to emulate less catastrophic disturbance effects (i.e., although some severe natural disturbance events can reduce site productivity, the goal of forest management is to maintain site productivity) (OMNR, 1997c: 2).

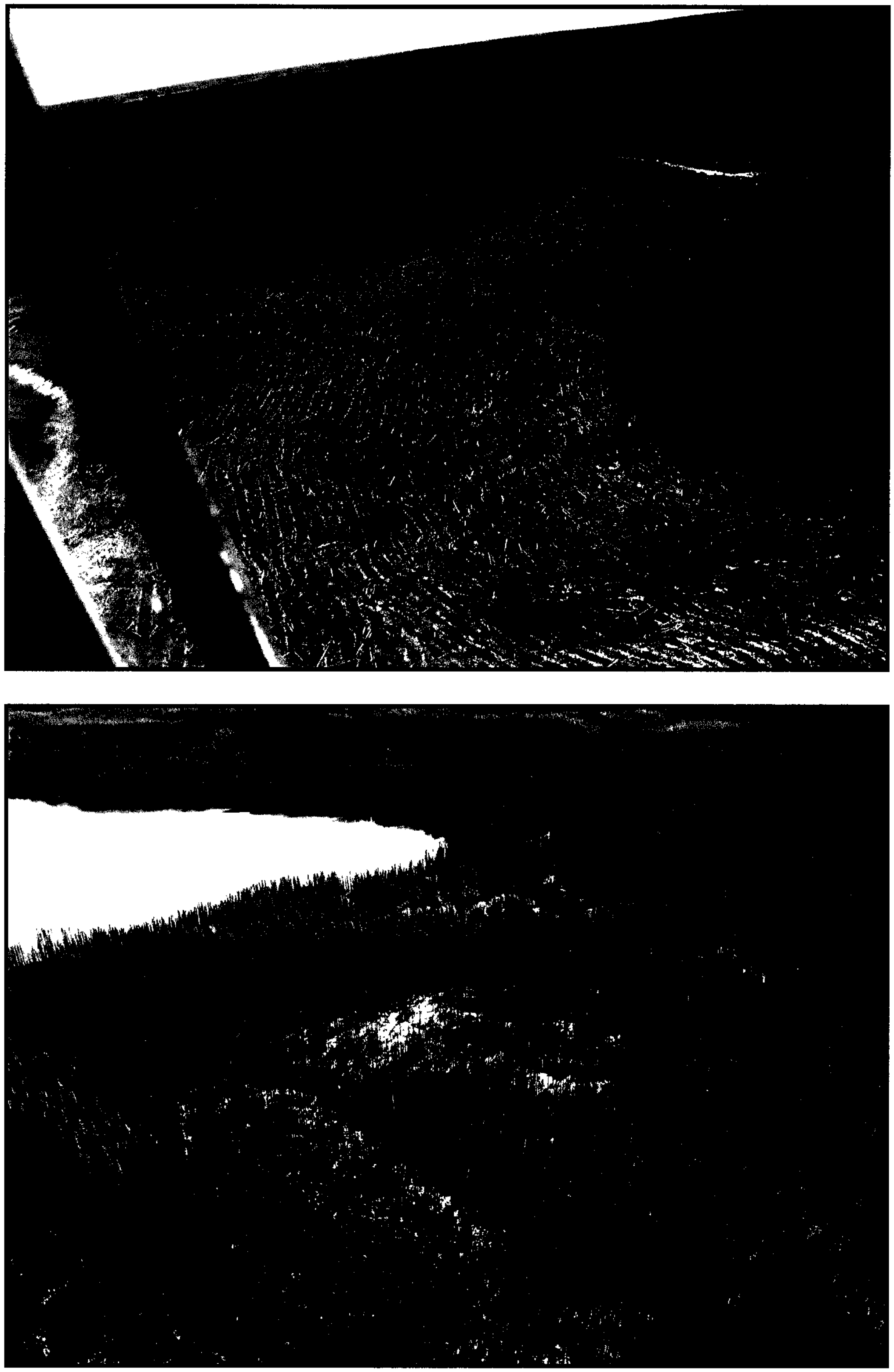

Figure 7.5: Landscape Disturbances Northeast of WCPP. These two disturbances are directly adjacent to one another. The top photo shows the uniformity of a cutover in the region, whereas the bottom photo shows the variability of an area that burned in 2002.

The maintenance of site productivity for trees dramatically alters the ecological characteristics (amount of humus form and the regeneration of both tree and understorey plants) of sites harvested, compared with the effects of fire (McRea *et al.*, 2000a; Nguyen-Xuan *et al.*, 2000; Wang, 2002). Numerous studies have found significant differences between the effects of forest harvesting and the effects of fire. Carlton (2000) stated that the regeneration of understorey plants was much more vigorous in areas harvested using clear cutting methods compared to sites that were burnt. Similar findings were found by Hearnden *et al*, (1992) in their assessment of post logged conifer sites, where hardwoods such as trembling aspen regenerated in greater abundance than in similar burnt areas. When cutovers regenerate excessive broad leaf species the application of herbicides, such as glyphosate is used to limit competing plant regeneration (Campbell *et al.*, 2001). These herbicides have dramatic negative effects on *Cladina spp.* (limiting caribou forage) (Newmaster *et al.*, 1999). The effects of clear cutting on bryophytes and lichens are also significantly different than in burnt areas, as the amount of ground vegetation and cover (particularly duff) that is disturbed varies significantly (Nguyen-Xuan *et al.*, 2000; Ehnes and Keenan, 2002). These differences pose challenges for site regeneration that will be suitable for woodland caribou winter habitat. The objective of maintaining site productivity for trees compromises the ecological characteristics of naturally disturbed sites.

7.5.2 IMPLICATIONS FOR WOODLAND CARIBOU

Forest regeneration using clear cutting under the PEG has important implications for woodland caribou management. The regenerating forest composition and structure in clear cuts does not emulate the effects of fire. Sites after forest harvesting are richer in soil nutrients, with more humus form, as well as greater competition from plants such as trembling aspen, herbs and feathermoss. All of these site regeneration characteristics are diametrically opposed to the site conditions needed for significant terrestrial lichen regeneration (poor nutrient capacity soils, limited competition and open canopy). These differences limit potentially high quality winter woodland caribou habitat, as lichen biomass will be reduced. The amount of lichen likely to regenerate in cutovers will be dramatically less than in areas disturbed by fire. Therefore, the PEG may emulate the shape and approximate size of fires (Niemela, 1999; Suffling and Perera, In press), but when it comes to woodland caribou habitat requirements, these guidelines do little to improve or maintain lichen forage for woodland caribou in their winter habitats.

7.6 Protected Area Management and Woodland Caribou

Large protected areas such as Woodland Caribou and Wabakimi Provincial Parks have been established in northwestern Ontario to protect woodland caribou (Duinker *et al.*, 1998b). Both parks are very large, totaling 450,000 and 892,000 ha respectively. Resource managers and policy makers see these parks as protected woodland caribou habitat; however, they are not directly managed for the conservation of woodland caribou, as neither park has a management plan. The lack of management plans (policy development) may be a result of lack of interest on the part of the bureaucratic organization, in this case Ontario Parks (Pal, 1997; Kernaghan and Siegel, 1999). Research on woodland caribou is now beginning to occur in both parks. I will only discuss issues related to WCPP, as this is the focus of this research, although ideas and findings likely equally apply to Wabakimi.

The policies affiliated with Ontario Parks tended to score lower in the policy assessment compared with policy affiliated with the Forest Division. The distinction between the policy approaches is that the Forest Division policies had much clearer objectives when it came to conservation practices. Moreover, the lack of policy development by Ontario Parks with regard to management of large boreal protected areas limited their score. The lack of explicit policy direction can be attributed to two challenges facing Ontario Parks. These are:

1. Lack of Information.
2. Lack of Clear Strategic Vision.

1.) Lack of Information: The absence of original research related to the conservation of woodland caribou and fire management in protected areas has limited the ability of Ontario Parks to form substantive policies (Kutas *et al.*, 2002; Lipsett-Moore, 2002).

This is a significant issue for Ontario Parks. Provincial parks in northern Ontario are not well studied (Kutas *et al.*, 2002; Lipsett-Moore, 2002; Kingston, McGrath, Gilmore pers. comm.). Purposeful and strategic research and monitoring programs do not exist in most protected areas in northern Ontario. Most large protected areas are only now collecting the most basic information for general management planning purposes (Gilmore, Kingston pers. comm.)

Ontario Parks appears to have a southern Ontario focus, as much of the research budget is allocated to protected areas in this portion of the province (e.g., Jalava *et al.*, 2002; Mallaney, 2002). This may be due to the high concentration of people in this region, and a general awareness of the limited amount of protected land in this portion of the province. Although the amount of protected land in northwestern Ontario far exceeds that of south/central Ontario, clearly the budgets are not based on the size of the protected area. This is very problematic for research and monitoring of these large northern parks, as access and field research is much more costly, due to their remoteness and lack of roads in the parks. This results in parks with little or no data to assist in the formulation of policies and management prescriptions.

WCPP does not have specific management plans for species at risk or forest fires, resulting in an ad hoc approach to management. This is problematic, as policies from other jurisdictions, notably forestry interests, become the default policy in these parks (e.g., Caribou Guidelines). This poses significant challenges, as management objectives may differ considerably. The development of the caribou mosaic for planned disturbances in Red Lake District, which extends from the forest management land base into WCPP, exemplifies the problem. By applying the caribou mosaic for planned disturbances to WCPP, the efficacy of the park's management is determined by forestry practices outside the park. This form of "command and control" management makes conservation practices "brittle" (Holling and Meffe, 1996; Francis, 2000). If any one part of the system fails to achieve its goals, then the management system (in this case, maintenance of woodland caribou within the region) fails, possibly resulting in the demise of woodland caribou.

The current caribou mosaic that extends into the park is also problematic, as this management prescription attempts to dictate the size, spatial extent, and timing of disturbances within the WCPP. As noted in the *Landscape Assessment* section of this thesis, fire size and severity are highly variable, and not in equilibrium. This means that the current caribou mosaic cannot be applied to WCPP, as humans do not posses the capabilities to manage fire (the only acceptable disturbance with the park) over this large an area (Agee, 1997; Martell, 2001; Woodley, 2002). Moreover, a single fire, burning with the right conditions, could burn this entire area (with remnant unburned patches) (McRea *et al.*, 2000b).

2.) Lack of Clear Strategic Vision: Ontario Parks has a dual mandate, to both protect important natural heritage values and to provide recreation opportunities to the residents of Ontario and beyond (OMNR, 1992). This mandate is necessarily broad, but more specific and needed policies related to the protection of ecological integrity are needed (Wilkinson and Eagles, 2001). The management of far ranging organisms such as woodland caribou, and ecosystem processes such as forest fires, do not exist for this region. Both of these management policies would require clear and long term strategic planning.

The lack of a clear strategic vision in government agencies is an institutional problem (Dovers, 2001). Bureaucracies are often not meant to have clear strategic visions, and are meant to manage and mitigate issues (Goodin, 1996; Borins, 2000; Possingham, 2001). The lack of a strategic, long term vision, with clear goals and objectives, is common in the protected area domain (Possingham, 2001). Too often strategies are short term and focused on delaying the inevitable, such as species extinction, catastrophic fire, etc. (Possingham, 2001). This approach to management does not bode well for complex issues requiring long term, careful, operational planning, issues like fire management and woodland caribou conservation. Developing plans and strategies that are not tested or implemented further complicates these inevitable problems (Searle, 2000).

A clear strategic vision is necessary to address complex resource and environmental issues (Chavas, 2000; Mitchell, 2002). Without a clear vision, Ontario Parks will continue to face significant challenges into the future. Many protected areas in northwestern Ontario have only been in existence for two decades. At the time of establishment, many issues were not well understood, and have been ignored for too long. Now that industrial activities are encroaching on areas once deemed as perpetual wilderness areas (notably the Northern Boreal Initiative Planning area), parks must reevaluate, and establish clear strategies, if species such as woodland caribou are to be protected.

7.6.1 IMPLICATIONS FOR WOODLAND CARIBOU

Resource managers have traditionally seen protected areas in northwestern Ontario as "protected caribou habitat". Although resource extraction activities are not permitted within these areas, caribou persistence is not guaranteed. Resource extraction activities beyond the park boundary, lack of information, and fire management issues within WCPP have increased the complexity and uncertainty of this issue. A clear understanding of best management practices may not be possible, due to the lack of information and strategies. Woodland caribou management must be dealt with at multiple spatial and temporal scales in order to understand and potentially manage this far ranging species. Not investing in even basic research in this region will severely limit the potential for effective woodland caribou management, as effective policies cannot be developed in the absence of knowledge (Yaffee, 1997; Gunderson, 1999; Possingham, 2001; Lipsett-Moore, 2002).

7.7 Ecosystem Management and Woodland Caribou

Ecosystem management has been identified by both the Forest Division and Ontario Parks as a desirable management framework in which to operate (OMNR, 2002b; Ontario Parks, 2003a). Although the Forest Division and Ontario Parks have conceptually embraced concepts of EM, based on the goals outlined by Christensen *et al.* (1996) used in this assessment, both branches of the OMNR face significant challenges in implementing EM objectives.

Management prescriptions and policies that reflect the dynamic, and often unpredictable nature of the boreal forest have not been embraced. Both branches of the OMNR have only superficially reconciled issues of scale. Management of large areas (>500,000 ha), with clear operational plans still eludes the OMNR. The Forest Division has made greater advancements in their EM initiatives compared with Ontario Parks. Important research has been conducted on forest dynamics in the forestry environment (e.g., Kenkel *et al.*, 1998). The biggest limitation to forest ecosystem dynamic research in this region is that it is constrained by the economics of silvicultural reality (OMNR, 2002a,b). This means that forest fire, the major driver of ecosystem renewal, is almost always excluded from all research and management prescriptions.

Information and an understanding of ecosystem dynamics are fundamental components of EM (Salwasser, 1993; Christensen *et al.*, 1996; Noss and Scott, 1997; Christensen, 1997; Kohm and Franklin, 1997; Jensen *et al.*, 2001). This does not bode well for Ontario Parks, as information on ecosystem dynamics (including woodland caribou) is nearly absent. If this information vacuum persists, Ontario Parks will not be able to effectively comment on, or contribute to EM initiatives. This will result in the maintenance of the status quo, where the Forest Division dictates land management in this region.

Temporal scale issues are beyond the scope of most management systems currently used in this region. Most of these systems were developed based on the concept of ecosystem equilibrium, which does not reflect the dynamic nature of the boreal ecosystem (Baker, 1989; Suffling and Speller, 1998; Turner *et al.*, 2001; Armstrong *et al.*, 2003). An example of this is the zoning system within Ontario Parks, which was not developed to reflect the dynamic nature of this fire prone ecosystem. To address the issue of an ever-changing ecosystem, a comprehensive monitoring program should be initiated to understand change (Spies and Turner, 1999).

Sustained yield at any scale does not reflect a dynamic ecosystem where spatial extent and forest characteristics (structure and composition) of landscapes are not in equilibrium. However, sustained yield, long term planning, and resource allocation are important components of forest management (Oliver *et al*, 1999; Loehle *et al.*, 2002). This need for resource certainty limits the adaptability of forest management systems (Stankey *et al.*, 2003). EM cannot be implemented if a system is not adaptable (Christensen *et al.*, 1996), thus, learning will have to occur to facilitate EM (Gunderson, 1999).

EM is a costly and complex undertaking (Franklin, 1997). Protected areas and forestry interests will have to develop a system where clear strategies are developed for integrated information collection, monitoring, and adaptable management practices, to ensure woodland caribou habitat viability in this region.

7.8 Summary

Forest fires are a critical factor in landscape evolution in the boreal forest, and play an integral role in determining the characteristics of woodland caribou habitat. Resource managers must address the complex nature of forest fires and incorporate them into policy and management planning decisions. Policy development must be highly adaptable in this context, as the effects of forest fires can vary dramatically. The ecological ramifications of rigid policies or incremental change will result in lost opportunities and mismanagement. Woodland caribou are vulnerable in this region, as they are at the southern limit of their current range. Pressures from forest harvesting, and the inevitable onset of fire, require active and adaptive management (Woodley, 2002).

The highly variable nature of forest fires will be a challenge for existing management systems, as dramatic changes in woodland caribou habitat availability, due to the onset of fire, can occur in a short period of time (less than a decade). This periodic, but rapid change resulting from forest fires is a natural phenomenon in fire prone landscapes (Romme, 1982; Heinselman, 1996; McRea *et al.*, 2000b; Fule *et al.*, 2003). Attempting to suppress this ecological process will have significant ecological ramifications in the future by severely limiting the amount of future caribou habitat.

An equally challenging endeavor will be attempting to improve forest management practices so that they are more sustainable, and better reflect the dynamic nature of forest fires. Maintaining a set severity of disturbance for productive tree regeneration will do little to maintain winter woodland caribou habitat in northwestern Ontario. Although severe disturbances may decrease tree productivity of forests in the boreal, the productivity and long term sustainability of woodland caribou is dependant upon these periodic severe fires.

Ecosystem management ideals will have little benefit on conservation of woodland caribou, as long as they remain in the conceptual realm. Without the development of applicable management prescriptions, which are tested and monitored, ecosystem management will simply remain a game of semantics (Noss and Cooperrider, 1994; Fitzsimmons, 1996).

8.0 CONCLUSIONS AND RECOMMENDATIONS

Woodland caribou habitat and forest fires are inextricably linked in northwestern Ontario. The variable effects of fire severity determine the composition, structure and abundance of winter woodland caribou habitat in this region. Policy and management decisions made to conserve woodland caribou must also incorporate the variability of fire, and the dynamic nature of these habitats. In protected areas, fires dictate the quantity, quality and timing of suitable winter habitats. Protected area policies must reflect an understanding all of these variables, if they are to direct management of caribou. In areas managed for forest harvesting, where fire pattern emulation is the dominant management technique used to renew caribou habitat, the differences between fire regenerated stands and human regenerated forests have important implications for woodland caribou's ability to recolonize an area after harvesting. Not addressing the fire management issue will result in lost opportunities and the increased probability of further woodland caribou decline.

8.1 Woodland Caribou Provincial Park Management

Setting aside land in protected areas does not guarantee the protection of species or ecosystems, as threats from beyond their boundaries, such as habitat fragmentation and alteration, make active monitoring, assessment and management a necessity for conservation efforts (Margules and Pressey, 2000; Woodley, 2002). This portion of the boreal forest exemplifies these issues and needs, as forest harvesting adjacent to WCPP, and forest fires within the park, play an important role in shaping terrestrial ecosystems (Johnson, 1992; Payette, 1992; Heinselman, 1996; Franklin, 1997). Threats to protected areas are not only from beyond their borders; significant threats also exist within Ontario Parks themselves. The most prominent threats include a lack of information, limited clear strategic vision, and the limited active management of complex ecosystems within WCPP. These three challenges threaten woodland caribou persistence in this region, as there is very little management of these animals or their habitat in Ontario Parks. Protected areas must reflect stresses outside their boundaries and take mitigative action to ensure the maintenance of these ecosystems within their boundaries.

The boreal ecosystem is dynamic, and representative examples may be difficult to maintain as landscapes exhibit tremendous variation depending on their successional state (Payette, 1992; Cumming *et al.*, 1996; Fortin *et al.*, 1999). To date, the variable nature of forest fires and their important ecological effects have not been adequately integrated into land use policy and management prescriptions. WCPP and Ontario Parks have not addressed fire management effectively, which threatens fire-adapted ecosystems in protected areas (Kilgore and Heinselman, 1990; Agee, 1997; Johnson and Miyanishi, 2001; Kutas *et al.*, 2002). Forest fires should no longer be perceived as a binary event (simply burnt or not burnt), as burnt forests exhibit tremendous variation, depending on the severity of forest fires (Turner *et al.*, 1999; Kafka *et al.*, 2001; Wang, 2002). Complete fire suppression in this region is unlikely, and for the reasons mentioned previously, is undesirable. Many of the terrestrial environments in WCPP are fire-adapted ecosystems, and any type of vegetation or fire management plan must address this. WCPP is unique in this regard, as it is one of the most fire driven ecosystems in Ontario Parks' system of protected areas. Fire and species at risk management plans should reflect this uniqueness, and the importance of variable fire characteristics (including fire severity) in this ecosystem.

If high quality woodland caribou habitat is to be maintained, clearly articulated management objectives must be developed; these in turn should be supported by ongoing research, and monitoring (Lindenmayer, 1999; Turner *et al.*, 2003). Active management and restoration of degraded ecosystems through prescribed burning for example should also be considered (Agee, 1997; Margules and Pressey, 2000; Possingham, 2001; Woodley, 2002). Policies and progressive management prescriptions may have to be developed somewhat independantly by entrepreneurial bureaucrats (Kernaghan and Siegel, 1999, Borins, 2000), if formal policy developments continue to be elusive.

Not investing in substantive research and monitoring programs limits what management programs Ontario Parks can initiate. With limited knowledge of the ecosystems that Ontario Parks is responsible for managing, only the most basic policy and management decisions can be made. When larger or more complex planning initiatives are undertaken (e.g., Ontario's Living Legacy), or during future landscape level planning initiatives for the conservation of woodland caribou, Ontario Parks will not be able to contribute.

8.2 Forest Management Practices and Woodland Caribou

The Forest Division is taking important steps to develop more ecologically oriented management practices. However, implementation of these practices is occurring at an extremely slow rate. The delay in the development of substantive policies and management practices pose significant threats to woodland caribou. The most pronounced threat is the continued attrition of caribou habitat, which is altered by forest harvesting. The northward expansion of harvesting is limiting current woodland caribou habitat in this region. The long-term response of caribou to these large-scale human land alterations is still unknown. Resource managers of this generation will not know if their management prescriptions will be able to sustain woodland caribou. Thus a precautionary approach to management should be utilized (Mitchell, 2002).

The Northern Boreal Initiative will further constrain options for sustainable caribou conservation. If forest harvesting continues north of WCPP, existing populations within the park may be compromised, as this large protected area will become an island of protection. The effects on metapopulation dynamics and genetic exchange with other caribou may also be compromised (Noss and Cooperrider, 1994).

8.2.1 ACCEPTING FIRE

The desire for near complete fire suppression in the managed forest is having remarkable consequences on how ecosystems evolve (Kilgore and Heinselman, 1990; Noss and Cooperrider, 1994; Heinselman, 1996; Agee, 1997; Kirwan and Shugart, 2000; Keane *et al.*, 2002). Not reflecting the variable nature of fires in forest management prescriptions by selectively choosing which aspects of fire are desirable (shape and size), threatens the long-term viability of woodland caribou and other organisms dependant on fire-regenerated ecosystems (Pruitt, 1997; Hobson and Schieck, 1999; McRea *et al.*, 2001b) Recognizing the stochastic character of fire driven ecosystems, and incorporating these characteristics in policy and management decisions will not be easy or cheap. But if sustainability of these ecosystems is the measure of sustainable forest management, then the cost of forestry may have to increase and account for the habitat needs of organisms such as woodland caribou.

8.2.2 IMPLEMENTING WOODLAND CARIBOU POLICY

The Caribou Guidelines are impressive; they outline the need for landscape level planning over multiple forest rotations, and conceptually embrace adaptive management. These conceptual ideas are an important first step, but implementation continues to be elusive. Although conceptually progressive, the Caribou Guidelines in concert with the Pattern Emulation Guidelines are very much framed within a traditional forest management paradigm (sustained yield). The overriding influence of silvicultural constraints will limit the potential of these guidelines. By managing complex, dynamic ecosystems within the bounds of the sustained yield paradigm, concepts of non-equilibrium ecosystem dynamics are completely ignored (Dellert, 2000). This does not bode well for sustainable management, as the boreal forest is a non-equilibrating system, which requires periodic large and severe disturbances (Johnson, 1992; Heinselman, 1996; McRea *et al.*, 2001b). Shifting away from the sustained yield system will be very challenging, as the forest industry and all the communities based on this industry are dependant upon continued access to fibre (Ontario Forest Policy Panel, 1993; Lee and Associates, 1999; Oliver *et al.*, 1999).

8.2.3 THE IMPORTANCE OF FORESTRY

Much of northwestern Ontario's economy is based on the forest industry (Wightman and Wightman, 1997; OMNR, 2002b). Limiting forest resource development in this region will require more than a shift in values, it will require a complete social and economic transformation. The cost of this transformation would be immense, if not impossible, given the current situation. Policies limiting productive interests are unlikely to change dramatically, unless they are forced to change, with no other option (Hessing and Howlett, 1997).

Although I have been critical of the forestry practices throughout this research, I do not see substantial changes in forestry practices until a majority of society recognizes the need for a dramatic change in consumption patterns. I also feel like somewhat of a hypocrite, as I criticize land management practices from the largest, persistent clear cut in the province (southern Ontario). When I move to northern Ontario, I know I want to live in a community with a strong forest sector as they provide the tax base for schools, hospitals and libraries. Currently there do not appear to be many other options. Although the number of jobs has decreased in the forest sector (Lawson *et al.*, 2001), alternatives do not offer viable options for sustainable livelihoods in this region. If substantive change is to occur, all residents of Ontario will have to recognize the implications of their consumptive decisions. Forests are harvested as a result of existing and growing demands for fibre-based products. Limiting consumption of these products will increase the likelihood of woodland caribou survival in Ontario.

8.3 Future Prospects

The management of forest dwelling woodland caribou is inherently complex, and presents an interesting dilemma for resource managers. Woodland caribou are considered to be an indicator of an ecologically intact, mature boreal forest ecosystem, yet their habitats are dynamic and prone to disturbances such as forest fires (Schaefer and Pruitt, 1991; Pruitt, 1997; McLaren *et al.*, 1998), resulting in contradictory short and long term management objectives. Balancing these seemingly opposing management objectives will be challenging, and will require exploration, learning, and most importantly an ability to adapt (Gunderson, 1999). Woodland caribou appear to be a good indicator of an ecologically intact boreal forest in this region; however, a sequence of indicators should be identified for all successional stages of boreal forest development.

Policy developed for woodland caribou conservation is largely absent in Ontario as protection of habitat will affect resource interests in this region. Woodland caribou conservation (large scale management, over millions of hectares) will be very costly for resource interests, as it would require significant land use restrictions (Cumming *et al.*, 1994; Pruitt, 1997; Hann and Bunnell, 2001). Moreover, woodland caribou have limited direct monetary value, as they cannot be hunted. The large-scale and long-term research needed to understand how caribou react to fire, harvesting and predation will be very costly. A project on woodland caribou dynamics in British Columbia has been ongoing for 5 years, with a budget of at least $800,000 per year (Walshe, pers comm.). This project is only beginning to understand some of these dynamics, and will likely have to both broaden its scope, and focus on how specific variables (e.g., fire) influence other dynamics.

Woodland Caribou Provincial Park and environs is a spectacular boreal landscape, where the forces of nature have persisted with relatively limited human intervention. This park should be viewed as an exciting opportunity for discovery and learning. Many of the challenges faced by more southern, and developed protected areas are not yet a concern here, notably large human populations nearby. This relative freedom could allow resource managers and academics to explore and better understand the dynamics of forest fires and how they influence fire dependant species such as woodland caribou on a grand scale. WCPP's proximity to other large protected areas in Manitoba, and undeveloped areas to the north, broaden opportunities for landscape level research projects.

Past management decisions have identified the park as "protected caribou habitat", with little regard to the quality of this habitat, or the duration/suitability of potential habitats in the future. Woodland caribou will be best managed when decisions are made based on research and an understanding of the ecosystem in which they live. This can only be achieved if we examine and understand controlling variables of woodland caribou habitat, such as forest fires, and how their dynamics operate at multiple spatial and temporal scales (Wiens *et al.*, 2002).

8.4 Recommendations

The management of highly dispersed animals with dynamic habitat requirements, such as woodland caribou, is challenging. In order to effectively manage these ecosystems and the organisms that live within them, a sound understanding of variables that influence their sustainability is required (Franklin, 1993). The following are recommendations for future research and management of woodland caribou within WCPP and environs.

1. Invest in the development of a vegetation management plan that examines current vegetation distribution, composition and structure. This plan should account for variability of vegetation characteristics in the future. This is critical if resource managers within the OMNR are ever to seriously model future woodland caribou habitat. In addition, the vegetation management plan should address lichen abundance and dynamics. This will require further research, as current FEC/ELC frameworks may be insufficient to characterize and quantify this important variable in caribou habitat management.

2. Develop a forest fire management plan. This plan should be primarily based on clearly stated management objectives, which should include woodland caribou habitat requirements. It should also recognize that WCPP is a very fire driven landscape, and fire suppression should be only one of several management prescriptions.

3. As woodland caribou winter habitat occurs in a diversity of stand ages (50 –150 years), resource managers should resist the tendency to assume all suitable conifer stands meeting this age criterion are appropriate habitat. As mentioned throughout this study, in many cases stands that appear to meet the age and vegetation composition criteria exhibit considerable variation in lichen abundance, therefore making some sites unsuitable. Areas that have been identified as current or potential future habitat should be examined in greater detail.

4. Develop a large-scale woodland caribou habitat project, which investigates the effects of fire, forest harvesting, predator- prey interactions, and ungulate parasite interactions. This project should be developed in conjunction with key stakeholders, including:

   -Ontario Parks
   -Manitoba government
   -Manitoba Model Forest
   -First Nations
   -the forest industry
   -other interested parties

This should be an ongoing project, and should not be directed solely to fit within silvicultural guidelines, as this limits ideas and options, many of which may not be compatible with Ontario Parks' mandate.

5. All woodland caribou research, management, and planning should be nested within an adaptive management framework, as much of the understanding of caribou habitat dynamics is still in its infancy. Attempts should be made to make this truly adaptive, as other adaptive management projects have failed due to their lack of flexibility, unwillingness to learn, and the dominance of a few influential stakeholders (Gunderson, 1999; Light, 2001; Stankey *et al.*, 2003).

9.0 REFERENCES

Adamowicz, W.L. and T.S. Veeman. 1998. Forest policy and the environment: Changing paradigms. *Canadian Public Policy*, XXIV Sup. 2: S51-S61.

Agee, J.K. 1997. Fire Management for the 21st Century. In *Creating a Forestry for the 21st Century*, K.A. Kohm and J.F. Franklin, eds. Washington, Island Press: 191-202.

Agee, J.K. and D.R. Johnson. 1988. *Ecosystem Management for Parks and Wilderness.* Seattle, University of Washington Press.

Ahti, T. and R.L.Hepburn. 1967. *Preliminary Studies on Woodland Caribou Range, Especially on lichen Stands in Ontario.* Research Report # 74. Department of Lands and Forests.

Armstrong, E.R. 1998. Integration of woodland caribou habitat management and forest management in northern Ontario. *Rangifer.* Special Issue No. 10: 221-230.

Armstrong, G.W., V.L. Adamowicz, J. A. Beck, Jr., S.G. Cumming and F.K.A. Schmiegelow. 2003. Coarse filter ecosystem management in a nonequilibrating forest. *Forest Science*, 49: 215-223.

Armstrong, I., G. Swant and H.R. Timmerman. 1998. Developing a woodland caribou habitat mosaic on the Ogoki-Nakina north forests in northwestern Ontario. *Rangifer.* Special Issue No. 10: 235-240.

Atikaki Coalition. 1974. Atikaki: A proposal for a viable Manitoba-Ontario wilderness area east of Lake Winnipeg.

Attiwill, P. M. 1994. The disturbance of forest ecosystems: the ecological basis for conservation management. *Forest Ecology and Management,* 63: 247-300.

Baker, J.A. 2000. Landscape ecology and adaptive Management. In *Ecology of a Managed Terrestrial Landscape: Patterns and Processes of Forest Landscapes in Ontario.* A.H. Perera, D.L. Euler, and I.D. Thompson eds. Vancouver, UBC Press: 310-322.

Baker, W.L. 1989. Landscape ecology and nature reserve design in the Boundary Waters Canoe Area, Minnesota. *Ecology*, 70: 23-35.

Baker, W.L. 1992. The landscape ecology of large disturbances in the design and management of nature reserves. *Landscape Ecology, 7*: 181-194.

Balsillie, D. 2002. Forward. In *State of the Forest Report 2001.* Toronto, Queen's Printer.

Barrett, T.M., J.K. Gilles, and L.S. Davis. 1998 Economic and fragmentation effects of clearcut restrictions. *Forest Science*, 44: 569-577.

Baskent, E.Z., and H.A, Yolasigmaz. 1999. Forest landscape revisited. *Environmental*

Management, 24: 437-448.

Bean, M.J. 1997. A policy perspective on biodiversity protection and ecosystem management. In *The Ecological Basis of Conservation,* S.T.A. Pickett, R.S. Ostfeld, M. Shachak, and G.E. Likens, eds. New York, Chapman and Hall: 23-28.

Beaty, R. M., and A. H. Taylor. 2001. Spatial and temporal variation of fire regimes in a mixed conifer forest landscape, Southern Cascades, California, USA. *Journal of Biogeography,* 28: 955-966.

Bergeron .Y. 2000. Species and stand dynamics in the mixed-woods of Quebec Southern Boreal Forest. *Ecology* 81: 1500–1516.

Bergerud, A.T. 1974. Decline of caribou in North America following settlement. *Journal of Wildlife Management*, 38: 757-770.

Bergerud, A.T. 1985. Antipredator strategies of caribou: dispersion along shorelines. *Canadian Journal of Zoology*, 63: 1324-1329.

Bessie, W.C. and E.A. Johnson, 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. *Ecology*, 76: 747-762.

Bonan, G. B., and H. H. Shugart. 1989. Environmental factors and ecological processes in boreal Forest. *Annual Review of Ecology and Systematics,* 20: 1-28.

Borins, S. 2000. Loose cannons and rule breakers, or enterprising leaders? Some evidence about innovative public managers. *Public Administration Review.* 60: 498-507.

Bostedt, G., P.J. Parks, M. Boman. 2003. Integrated natural resource management in northern Sweden: An application to forestry and reindeer husbandry. *Land Economics* 79: 149-159.

Brais, S., P. David, and R. Ouimet. 2000. Impacts of wildfire severity and salvage harvesting on the nutrient balance of jack pine and black spruce boreal stands. *Forest Ecology and Management*, 137: 231-243.

Brousseau, C. 1979. *Trends in the woodland caribou (Rangifer tarandus_ population in the Cliff Lake Area of the Dryden District 1972-1978*. Unpublished OMNR document.

Brewer, G.D. 1999. The challenges of interdisciplinarity. *Policy Sciences*, 32: 327-337.

Brunckhorst, D.J., and N.M. Rollings. 1999. Linking ecological and social function of landscapes: Influencing resource governance. *Natural Areas Journal*, 19: 57-64.

Brunton, D.F. 1986. *A Reconnaissance Life Science Inventory of Woodland Caribou Park.* Technical report #2 OMNR, Red Lake District.

Brunner, R.D., and T.W. Clark. 1997. A Practice-based approach to ecosystem management. *Conservation Biology.* 11: 48-58.

Bunnell, F.L. and D.J. Huggard. 1999. Biodiversity across spatial and temporal scales: problems and opportunities. *Forest Ecology and Management,* 115: 113-126.

Buechner, M., C. Schonewald-Cox, R. Sauvajot, and B.A. Wilcox. 1992. Cross-boundary issues for national parks: what works "on the ground". *Environmental Management,* 16: 799-809.

Butry, D.T., D.E. Mercer, J.P. Prestemon, J.M. Pye, and T.P. Holmes. 2001. What is the price of catastrophic wildfire? *Journal of Forestry*: 9-17.

C.M. Consultants. 1991. *Woodland Caribou Habitat Potential: 1990-2010*, Red Lake District.

Campbell, R.A., J.E. Wood, D.G. Thompson, and E. Iskra. 2001. Site preparation – chemical. In *Regenerating the Canadian Forest, Principles and Practices for Ontario.* R.G. Wagner and S.J. Colombo eds. Markham, Fitzhenry & Whiteside Limited: 221-242.

Canadian Park Service. 1989. *Keepers of the flame: implementing fire management in the Canadian Parks Service.* Ottawa.

Carpenter, S.R. 1996. Microcosm experiments have limited relevance for community and ecosystem ecology. *Ecology,* 77: 677-680.

Carpenter, S.R. and L. Gunderson. 2001. Coping with collapse: Ecological and social dynamics of ecosystem management. *BioScience,* 51: 451 457.

Cartwright, J. 2001. Does our government really want to protect endangered species? *Policy Options,* June: 39-42.

Charron, I., and D.F. Greene. 2002. Post-wildfire seedbeds and tree establishment in the southern mixedwood boreal forest. *Canadian Journal of Forest Research,* 32: 1607-1615.

Chavas, J-P. 2000. Ecosystem valuation under uncertainty and irreversibility. *Ecosystems,* 3: 11-15.

Chipman, S.J. and E.A. Johnson. 2002. Understory vascular plant species diversity in the mixedwood boreal forest of western Canada. *Ecological Applications,* 12: 588-601.

Christensen, N.L. 1997. Implementing ecosystem management: Where do we go from here? In *Ecosystem Management, Applications for Sustainable Forest and Wildlife Resources.* M.S. Boyce and A. Haney eds. New Haven, Yale University Press: 325-342.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R.Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, R.G. Woodmansee. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. *Ecological Applications*, 6: 665-691.

Clark, T.W. 2002. *The Policy Process.* New Haven, Yale University Press.

Clark, T.W., N. Mazur, S.J. Cork, S. Dovers and R. Harding. 2000. Koala conservation policy process: Appraisal and recommendations. *Conservation Biology*, 14: 681-690.

Cortner, H.J. 2000. Making science relevant to environmental policy. *Environmental Science & Policy,* 3: 21-30.

Cortner, H.J., and M.A. Moote. 1999. *The Politics of Ecosystem Management.* Island Press, Washington.

Costanza, R. 2000. Visions of alternative (unpredictable) futures and their use in policy analysis. *Conservation Ecology,* 4. [online] URL: ttp://www.consecol.org/vol4/iss1/art5

Coxson, D.S. and J. Marsh. 2001. Lichen chronosequences (postfire and postharvest) in lodgepole pine (*pinus contorta*) forests of northern interior British Columbia. *Canadian Journal of Botany*, 79: 1449-1464.

Cumming. H.G. 1992. Woodland caribou: facts for forest managers. *The Forestry Chronicle*, 68: 481-491.

Cumming, H.G. 1998. Status of woodland caribou in Ontario: 1996. *Rangifer*, 10: 99-104.

Cumming. H.G. and D.B. Beange. 1993. Survival of woodland caribou in commercial forests of northern Ontario. *The Forestry Chronicle*, 59: 579-588.

Cumming, S.G. 2001. Forest type and wildfire in the Alberta boreal mixedwood: What do fires burn? *Ecological Applications*, 11: 97-110.

Cumming, S.G., P. Burton, S. Prahacs, and M. Garland. 1994. Potential conflicts between timber supply and habitat protection in the boreal mixedwood of Alberta, Canada: A simulation study. *Forest Ecology and Management.* 68: 281–302.

Cumming, S.G., P.J. Burton, and B. Klinkenberg. 1996. Boreal mixedwood forests may have no "representative" areas: some implication for reserve design. *Ecography*, 19: 162-180.

Dale, V.H., S. Brown, R.A. Haeuber, N.T. Hobbs, N. Huntly, R.J. Naiman, W.E. Riebsmae, M.G. Turner, and T.J. Valone. 2000. Ecological principles and guidelines for managing the use of land. *Ecological Applications*, 10: 639-670.

Darby, W.R., H.R. Timmermann, J.B.Snider, K.F. Abraham, R.A. Stefanski, and C.S. Johnson. 1989. *Woodland Caribou in Ontario, Background to a Policy*. Queen's Printer. Ontario Ministry of Natural Resources.

Dearden, P., and R. Rollins. 2002. *Parks and Protected Areas in Canada,* 2nd Edition. Oxford University Press, Oxford and Toronto.

Delcourt, H. R., P. A. Delcourt, and T. Webb III. 1983. Dynamic plant ecology: The spectrum of vegetational change in space and time. *Quaternary Science Reviews,* 1: 153-175.

De Leo, G. A., and S. Levin. 1997. The multifaceted aspects of ecosystem integrity. *Conservation Ecology*, 1. [online] URL: http://www.consecol.org/vol1/iss1/art3.

Dellert, L.H. 2000. Sustained yield: Why has it failed to achieve sustainability? In *The Wealth of Forests.* C. Tollefson ed. Vancouver, UBC Press: 255-277.

Dover, S. 2001. *Institutional Sustainability.* TELA, Australia Conservation Foundation. Available online at: www. acfonline. org. au/ publications/ tela/ intro. htm

Duinker, P.N., S. Nilsson, and M.E. Chipeta. 1998a. Forestry for sustainable development and global fibre supply. *Unasylva*, 49: 3-10.

Duinker, P.N., T.R. Armstrong, B.T. Hyer, and B. Peterson. 1998b. Using caribou knowledge in expanding the Wabakimi protected area. *Rangifer*, 10: 183-193.

Duinker, P.N., A, Harris, G. Munro, and M. Innes. 2001. Policy on forest regeneration in Ontario: Recent trends and future prospects. In *Regenerating the Canadian Forest, Principles and Practices for Ontario.* R.G. Wagner and S.J. Colombo eds. Markham, Fitzhenry & Whiteside Limited: 43-59.

Dungan, J.L., S. Citron-Pousty, M. Dale, M.-J. Fortin, A. Jakomulska, P. Legendre, M. Miriti, M. Rosenberg. 2002. A balanced view of scaling in spatial statistical analysis. *Ecography*, 25: 626-640.

Eagles, P.F.J. 1993. Parks legislation in Canada. In *Parks and protected areas in Canada,* 2nd Edition P. Dearden and R. Rollins eds. Oxford and Toronto, Oxford University Press: 57-74.

Eagles, P.F.J. 1998. Ecotourism and parks: Do or die. In *Changing Parks.* J.S. Marsh and B.W. Hodgins eds. Toronto: Natural Heritage/Natural History Inc: 261-278.

Eagles, P. 2002. Environmental Management. In *Parks and Protected Areas in Canada.* P. Dearden and R. Rollins, eds. Don Mills, Oxford University Press: 265-294.

Ehnes, J.W. 2000. *What Does a Large Wildfire Disturb and What Does It Leave in the Eastern Two-Thirds of the Manitoba Model Forest?* Winnipeg, Ecostem Ltd.

Ehnes, J. and V. Keenan. 2002. Implementing wildfire-based timber harvest guidelines in southeastern Manitoba. *The Forestry Chronicle.* 78: 680-685.

Elkie, P.C. and R.S. Rempel. 2001. Detecting scales of pattern in boreal forest landscapes.

Forest Ecology and Management, 147: 253-261.

Elkie, P.C. R.S. Rempel, and A.P. Carr. 1999. *Patch Analyst User's Manual: A Tool for Quantifying Landscape Structure.* NWST Technical Manual TM-002. Toronto, Queen's Printer.

Endter-Wada, J., D. Blahna, R. Krannich and M.Brunson. 1998. A framework for understanding social science contribution to ecosystem management. *Ecological Applications*, 8: 891-904.

Epp, A.E. 2000. Ontario forests and forest policy before the era of sustainable forestry. In *Ecology of Managed Terrestrial Landscape - Patterns and Processes of Forest Landscapes in Ontario*, A.H. Perera, D.L. Euler, and I.D. Thompson eds. Vancouver, UBC Press: 237-275.

ESRI. 2000. *Using ArcView Image Analysis.* California, Environmental Systems Research Institute, Inc.

Euler, D.L. 1998. Will ecosystem management supply woodland caribou habitat in northwestern Ontario? *Rangifer*, Special issues No. 10: 25-32.

Euler, D.L. and A.E. Epp. 2000. A new foundation for Ontario forest policy for the 21st century. In *Ecology of Managed Terrestrial Landscape - Patterns and Processes of Forest Landscapes in Ontario*, A.H. Perera, D.L. Euler, and I.D. Thompson eds. Vancouver, UBC Press: 276-294.

Ewel, K.C. 2001. Natural resource management: The need for interdisciplinary collaboration. *Ecosystems*, 4: 716–722.

Farrar, J.L. 1995. *Trees in Canada.* Markham, Fitzhenry and Whitesite Limited and the Canadian Forest Service.

Fitzsimmons. A.K. 1996. Sound policy or smoke and mirrors: does ecosystem management make sense? *Water Resources Bulletin*, 32: 217-227.

Forman, R.T.T. 1995. *Land Mosaics, the Ecology of Landscapes and Regions.* Cambridge, U.K, Cambridge University Press.

Fortin, M., S. Payette, and K. Marineau. 1999. Spatial vegetation diversity index along a postfire successional gradient in the northern boreal forest. *Ecoscience,* 6: 204-213.

Foster, D., F. Swanson, J. Aber, N. Brokaw, D. Tilman and A. Knapp. 2003. The importance of land-use legacies to ecology and conservation. *Bioscience*, 53: 77-88.

Foster, D.R. 1983. The history and pattern of fire in the boreal forest of southeastern Labrador. *Canadian Journal of Botany,* 61: 2459-2471.

Foster, D.R. 1985. Vegetation development following fire in *Picea Mariana* (Black Spruce)-

Pleurozium forests in southeastern Labrador, Canada. *Journal of Ecology*, 73: 517- 534.

Francis, G. 1993. Ecosystem management. *Natural Resources Journal*, 33: 315-345.

Francis, G. 2000. Strategic Planning at the Landscape Level. In *Ecology of a Managed Terrestrial Landscape: Patterns and Processes of Forest Landscapes in Ontario.* A.H. Perera, D.L. Euler, and I.D. Thompson eds. Vancouver, UBC Press: 295-309.

Franklin, J.F. 1993. Preserving biodiversity: species, ecosystems, or landscapes? *Ecological Applications,* 3: 202-205.

Franklin, J.F. 1997. Ecosystem management: An overview, In *Ecosystem Management, Applications for Sustainable Forest and Wildlife Resources.* M.S. Boyce and A. Haney eds. New Haven, Yale University Press: 21-53.

Franklin, J., D. Perry, R. Noss, D. Montgomery and C. Frissell. 2000. *Simplified Forest Management to Achieve Watershed and Forest Health: A Critique.* Seattle, National Wildlife Federation.

Frelich, L.E. 1993. Fire policy in the BWCAW: Discussion of some ecological issues. *BWCA Wilderness News.* Publisher Unknown.

Frelich, L.E. and P.B. Reich. 1998. Disturbance severity and threshold responses in the boreal forest. *Conservation Ecology*, 2. [online]. Http://www.consecol.org/vol2/iss2/art7: accessed on 03/02/2003.

Fritz, R., Suffling, R. and Younger, A.T. 1993. The influence of the fur trade, famine and forest fires on moose and woodland caribou populations in northwestern Ontario from 1786 to 1911. *Environmental Management.* 17: 477-489.

Fule, P. Z., W. W. Covington, M. M. Moore, T. A. Heinlein, and A. E. M. Waltz. 2002. Natural variability in forests of the Grand Canyon, USA. *Journal of Biogeography,* 29: 31-47.

Fule, P. Z., J.E. Crouse, T.A. Heinlein, M.M. Moore, W.W. Covington and G. Verkamp. 2003. Mixed-severity fire regime in a high-elevation forest of Grand Canyon, Arizona, USA. *Landscape Ecology*, 18: 465-486.

Gale, F. P. 2000. Economic specialization versus ecological diversification: the trade policy implications of taking the ecosystem approach seriously. *Ecological Economics*, 34: 285-292.

Gibson, C.C., E. Ostrom, T.K. Ahn. 2000. The concept of scale and the human dimensions of global change: a survey. *Ecological Economics*, 32: 217-239.

Glick, D.A., and T.W. Clark. 1998. Overcoming boundaries: The Greater Yellowstone

Ecosystem. In *Stewardship Across Boundaries,* R.L. Knight and P.B. Landres, eds. Washington D.C: Island Press: 237-256.

Gollat, R. 2000. *A Habitat Management Strategy for the Conservation of Woodland Caribou on the Armstrong Forest.* Unpublished OMNR document.

Goodin, R.E. 1996. Institutions and their design. In *The theory of institutional design.* R.E. Goodin, ed. Cambridge: Cambridge University Press.

Goldstein, P.Z. 1999. Functional ecosystems and biodiversity buzzwords. *Conservation Biology*, 13: 247-255.

Gordon, A.G. 1996. The sweep of the boreal in time and space, from forest formations to genes, and implications for management. *The Forestry Chronicle*, 72: 19–30.

Gordon, A.M., and W.G. Cole. 1994. Long-Term *Ecological Research Program Strategic Plan.* Forest Research Information Paper No. 115. Ontario Forest Research Institute.

Gordon, A.M., C. Chourmouzis, and A.G. Gordon. 2000. Nutrient inputs in litterfall and rainwater fluxes in 27-year-old red, black and white spruce plantations in central Ontario, Canada. *Forest Ecology Management.* 138: 65-78.

Gordon, A.M., D.M. Morris, and A.G. Gordon. 2001. In *Regenerating the Canadian Forest, Principles and Practices for Ontario.* R.G. Wagner and S.J. Colombo eds. Markham, Fitzhenry & Whiteside Limited: 63-90.

Gray, A. N. 2000. Adaptive ecosystem management in the Pacific Northwest: a case study from coastal Oregon. *Conservation Ecology*, 4. [online] URL: http://www.consecol.org/vol4/iss2/art6

Greene, D.F., J.C. Zasada, l. Sirois, S. Kneeshaw, H.Morin, I. Charron, and M.J. Simard. 1999. A review of the regeneration dynamics of North American boreal forest tree species. *Canadian Journal of Forest Research*, 29: 824-839.

Greig, L. and P. Duinker. 1997. *Towards a Strategy for Caribou Habitat Management in Northwestern Ontario.* Final Report of the Northwest Region Caribou strategy Advisor Panel. Queen's Printer.

Grumbine, R.E. 1994. What is ecosystem management? *Conservation Biology*, 8: 27-38.

Grumbine, R.E. 1997. Reflections on "what is ecosystem management?" *Conservation Biology*, 11: 41-47.

Gunderson, L. 1999. Resilience, flexibility and adaptive management - - antidotes for spurious certitude? *Conservation Ecology*, 3. [online] URL: http://www.consecol.org/vol3/iss1/art7

Gunderson, L.H. 2000. Ecological resilience – in theory and application. *Annual Review of*

Ecology and Systematics, 31: 425-439.

Gutzwiller, K.J. (ed.) 2002. *Applying Landscape Ecology in Biological Conservation.* New York: Springer.

Haila, Y. 2002. Scaling environmental issues: problems and paradoxes. *Landscape and Urban Planning,* 61: 59–69.

Hall, C., D. Lindenberger, R. Kummel, T. Kroeger and W. Eichhorn. 2001. The need to reintegrate the natural sciences with economics. *BioScience*, 51: 663-673.

Hann, W.J. and D.L. Bunnell. 2001. Fire and land management planning and implementation across multiple scales. *International Journal of Wildland Fire*, 10: 389–403.

Harris, A. 1992. *Post-logging regeneration of reindeer lichens (Cladina spp.), as related to woodland caribou winter habitat.* Technical Report # 69, Northwestern Ontario Boreal Forest Management. Ontario Ministry of Natural Resources.

Harris, A. 1999. *Report on the Status of Woodland Caribou in Ontario.* Prepared for the Committee on the Status of Species at Risk in Ontario. Thunder Bay, Northern Bioscience.

Harris, A., R. Foster, and M. Jones. 2001. *Life Science Inventory: Woodland Caribou Signature Site.* Thunder Bay, Northern Bioscience.

Haufler, J.B., T. Crow, and D. Wilcove. 1999. Scale considerations for ecosystem management. In *Ecological Stewardship: A Common Reference for Ecosystem Management*, R.C. Szaro, N.C. Johnson, W.T. Sexton and A.J. Malk eds. Oxford: Elsevier Science Ltd: 331-343.

Hearnden, K.W., S.V. Millson, and W.C. Wilson. 1992. *A Report on the Status of Forest Regeneration: Ontario Independent Forest Audit.* Ontario Ministry of Natural Resources. Sault Ste. Marie, Ontario.

Heathcott, M. and M. Crofts. 1997. *Pukaskwa National Park Forest Fire Management Plan.* Department of Canadian Heritage, Parks Canada.

Heinselman, M. L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. *Quaternary Research*, 3: 329-382.

Heinselman, M. L. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystem. In *Fire Regimes and Ecosystem Properties* H. A. Mooney, T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners eds. Honolulu, Hawaii. United States Forest Service: 7-57.

Heinselman, M. 1996. *The Boundary Waters Wilderness Ecosystem.* Minneapolis, University of Minnesota Press.

Hessing, M. and M. Howlett. 1997. *Canadian Natural Resource and Environmental Policy.* Vancouver, UBC Press.

Hobbs, R. 1997. Future landscapes and the future of landscape ecology. *Landscape and Urban Planning*, 37: 1-9.

Hobson, K.A and J. Schieck. 1999. Changes in bird communities in boreal mixedwood forest: harvest and wildfire effects over 30 years. *Ecological Applications*, 9: 849-863.

Hogwood, B.W. and L.A. Gunn. 1984. *Policy Analysis for the Real World.* New York, Oxford University Press.

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4: 1-23.

Holling, C.S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. *Ecological Monographs*, 62: 447-502.

Holling, C.S., and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology*, 10: 328-337.

Holistedt, C. and A. Harris. 1992. *Critical Silvics of Reindeer Lichen as Related to Vegetation Management.* Technical Note # 17, Northwestern Ontario Boreal Forest Management. Thunder Bay, Ontario Ministry of Natural Resources.

Hooge, P. N. and B. Eichenlaub. 1997. *Animal Movement Extension to ArcView. ver. 1.1.* Anchorage, AK, Alaska Biological Science Center, U.S. Geological Survey.

Hornberg, G., L. Ostland, O. Zackrisson, and I. Bergman. 1999. The genesis of two *Picea-Cladina* forest in northern Sweden. *Journal of Ecology*, 87: 800-814.

Howlett, M. and J. Rayner. 2001. The business and government nexus: Principal elements and dynamics of the Canadian forest policy regime. In *Canadian Forest Policy,* M. Howlett, ed. Toronto, University of Toronto Press: 23-64.

Hunter, M.L. 1993. Natural fire regimes as spatial models for managing boreal forests. *Biological Conservation*, 65: 115-120.

Jalava, J.V., J.L. Riley, A.E. Zammit, P.J. Sorrill, T. Holden and J. Henson. 2002. Big picture applications of bioregional planning in Ontario. In *Ecological Integrity and Protected Areas*, proceedings of the Parks Research Forum of Ontario. J. Porter and J.G. Nelson eds. Waterloo, Heritage Resources Centre: 25-35.

James, A.R.C. 1999. *Effects of Industrial Development on the Predator-Pray Relationship between Wolves and Caribou in Northeastern Alberta.* Unpublished Ph.D. dissertation, Department of Biological Sciences. Edmonton, University of Alberta.

Jensen, M.E., N.L. Christensen Jr., and P. S. Bourgeron. 2001. An Overview of Ecological Assessment Principles and Applications. In *A Guidebook for Integrated Ecological Assessments.* M.E. Jensen and P.S. Bourgeron, eds. New York, Springer-Verlag: 13-28.

Johnson, C.J., K.L. Parker and D.C. Heard. 2001. Foraging across a variable landscape: behavioral decisions made by woodland caribou at multiple spatial scales. *Oecologia*, 127: 590-602.

Johnson, E.A. 1981. Vegetation Organization and Dynamics of Lichen Woodland Communities in the Northwest Territories, Canada. *Ecology*, 62: 200-215.

Johnson, E.A. 1992. *Fire and Vegetation Dynamic: Studies from the North American Boreal Forests.* Cambridge, Cambridge University Press.

Johnson, E.A. and K. Miyanishi. 1995. The need for consideration of fire behavior and effects in prescribed burning. *Restoration Ecology*, 3: 271-278.

Johnson, E.A., K. Miyanishi, R.J. Bridge. 2001. Wildfire regime in the boreal forest and the idea of suppression and fuel buildup. *Conservation Biology*, 15: 1554-1557.

Johnson, E.A., K. Miyanishi, and J.M.H. Weir. 1995. Old-growth, disturbance, and ecosystem management. *Canadian Journal of Botany*, 73: 918-925.

Johnson, E. A., K. Miyanishi, and J. M. H. Weir. 1998. Wildfires in the western Canadian boreal forest: Landscape patterns and ecosystem management. *Journal of Vegetation Science,* 9: 603-610.

Johnston, M. and J. Elliott. 1998. The effect of fire severity on ash, and plant and soil nutrient levels following experimental burning in a boreal mixedwood stand. *Canadian Journal Soil Science*, 78: 35–44.

Kafka, V., S. Gauthier, and Y. Bergeron. 2001. Fire impacts and crowning in the boreal forest: study of a large wildfire in western Quebec. *International Journal of Wildland Fire*, 10: 119-127.

Keane, R.E., K.C. Ryan, T.T. Veblen, C.D. Allen, J. Logan, B. Hawkes. 2002. *Cascading Effects of Fire Exclusion in Rocky Mountain Ecosystems: a Literature Review.* General Technical Report RMRS-GTR-91. Colorado, USDA Forest Service.

Kenkel, N.C., P.R. Watson and P. Uhlig. 1998. *Modelling Landscape-Level Vegetation Dynamics in the Boreal Forests of Northwestern Ontario.* Forest Research Report No. 148. Toronto, Queen's Printer.

Kernaghan, K. and D.T. Siegel. 1999. *Public Administration in Canada: A Text*, (4th edition). Scarborough: Nelson.

Kershaw, K.A. 1985. *Physiological ecology of lichens.* Cambridge, Massachusetts, Cambridge

University Press.

Kilgore, B.M., and M.L. Heinselman. 1990. Fire in wilderness ecosystems. In *Wilderness Management 2nd Edition.* J.C. Hendee, G.H. Stankey and R.C. Lucas, eds. Colorado, North American Press: 214-239.

Killan, G. 1993. *Protected Places: A History of Ontario's Provincial Parks System.* Toronto, Dundurn Press.

Kimmins, J.P. 1997. *Forest Ecology*, 2nd Edition. Upper Saddle River, New Jersey, Prentice Hall.

Kimmins, J.P. 1999. Biodiversity, beauty and the "beast": Are beautiful forests sustainable, are sustainable forests beautiful, and is "small" always ecologically desirable? *The Forestry Chronicle,* 75: 955-959.

Kirwan, J.L. and H.H. Shugart. 2000. Vegetation and two indicies of fire on the Delmarva Peninsula. *Journal of the Torrey Botanical Society*, 127: 44-50.

Klein, D.R. 1982. Fire, lichens, and caribou. *Journal of Range Management*, 35: 390-395.

Kohm, K.A. and J.F. Franklin. 1997. *Creating a Forestry for the 21st Century.* Washington D.C., Island Press.

Kotar, J. 1997. Silviculture and ecosystem management. In *Ecosystem Management, Applications for Sustainable Forest and Wildlife Resources* M.S, Boyce and A, Haney eds. New Haven, Yale University Press: 265-275.

Kotliar, N.B., and J.A. Wiens. 1990. Multiple scales of patchiness and patch structure: a hierarchical framework for the study of heterogeneity. *Oikos*, 59: 253-260.

Kumpula, J., A. Colpaert, M. Nieminen. 2000. Condition, potential recovery rate and productivity of lichen (*Cladina. spp.*) ranges in the Finnish reindeer management area. *Arctic*, 53: 152-160.

Kumpula, J. 2001. Winter grazing of reindeer in woodland lichen pasture: Effect of lichen availability on the condition of reindeer. *Small Ruminant Research*: 39: 121-130.

Kutas, B., H. Doran, K. Hung, S. Janetos, D. Strath, R. Suffling, and B. Woodman. 2002. Management in a planning vacuum: Co-operation in the Quetico - BWCA - Voyageurs International Boundary Region. *Environments*, 30: 31-43.

Kuuluvainen, T. 2002. Natural variability of forests as a reference for restoring and managing biological diversity in boreal Fennoscandia. *Silva Fennica*, 36: 97-125.

Lambeck, R.J. and R.J. Hobbs. 2002. Landscape and regional planning for conservation: Issues and practicalities. In *Applying Landscape Ecology in Biological Conservation*, K.J. Gutzwiller, ed. New York, Springer: 360-380.

Lance, A.N. and W.G. Eastland. 2000. *A Guide to Evaluating Forest Stands as Terrestrial Lichen Forage Habitat for Caribou.* Prince George, British Columbia. Industrial Forestry Services Ltd.

Landres, P.B., S. Marsh, L. Merigliano, D. Ritter and A. Norman. 1998. Boundary effects of wilderness and other natural areas. In *Stewardship Across Boundaries* R.L. Knight and P.B. Landres, eds. Washington D.C.: Island Press: 117-139.

Landres, P.B., P. Morgan and F.J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. *Ecological Applications*, 9: 1179-1188.

Larsen, C.P.S. 1997. Spatial and temporal variations in boreal forest fire frequency in northern Alberta. *Journal of Biogeography*, 24: 663-673.

Lautenschlager, R.A. 1998. From Rhetoric to Reality: Using specific environmental concerns to identify critical sustainability issues. *Ecosystems*, 1: 176-182.

Lawson, J., Levy, M, and L.A. Sandberg. 2001. Perpetual revenues and the delights of the primitive: Change, continuity, and forest policy regimes in Ontario. In *Canadian Forest Policy,* M. Howlett, ed. Toronto, University of Toronto Press: 279-315.

Leadbitter, P., D. Euler, and B. Naylor. 2002. A comparison of historical and current forest cover in selected areas of the Great Lakes-St. Lawrence Forest of central Ontario. *The Forestry Chronicle*, 78: 522-529.

Lee Kam, R. 1993. Wabakimi Provincial Park: A case study of boundary delineation. In *Size and Integrity Standards for Natural Heritage Areas in Ontari*o, *Proceedings from a Seminar* S.F. Poser, W.J.Crins and T.J. Beechey, eds. Huntsville, Ontario Ministry of Natural Resources, Queen's Printer: 65-83.

Lee, K.N., 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Washington, DC, Island Press.

Lees, W.L and Associates. 1998. *The Economic Contribution of the Primary Forest Products Industry to Northwestern Ontario.* Commissioned by the Northwest Forest Network. Thunder Bay, Ontario.

Leopold, A. 1949. *A Sand County Almanac.* New York, Oxford University Press.

Lesieur, D., S. Gauthier, and Y. Bergeron. 2002. Fire frequency and vegetation dynamics for the south-central boreal forest of Quebec, Canada. *Canadian Journal of Forest Research*, 32: 1996-2009.

Levin, S.A. 1992. The problem of pattern and scale in ecology. *Ecology,* 73: 1943-1967.

Li, C. 2000. Fire regimes and their simulation: with reference to Ontario. In *Ecology of a Managed Terrestrial Landscape: Patterns and Processes of Forest Landscapes in Ontario.* A.H.

Perera, D.L. Euler, and I.D. Thompson eds. Vancouver, UBC Press: 115-140.

Light, S.S. 2001. Adaptive ecosystem assessment and management: The path of last resort. In *A Guidebook for Integrated Ecological Assessments*, M.E. Jensen and P.S. Bourgeron eds. New York: Springer: 55-68.

Lindenmayer, D.B. 1999. Future directions for biodiversity conservation in managed forests: indicator species, impact studies and monitoring programs. *Forest Ecology and Management*, 115: 277-287.

Lippke, B., and J. Bishop. 1999. The economic perspective. In *Maintaining Biodiversity in Forest Ecosystems,* M.L. Hunter Jr. (ed). Cambridge, Cambridge University Press: 597-638.

Lipsett-Moore, G. 2002. Ecological integrity in parks and protected areas in australia: concepts an reality. In *Ecological Integrity and Protected Areas*, proceedings of the Parks Research Forum of Ontario. J. Porter and J.G. Nelson eds. Waterloo, Heritage Resources Centre: 37-45.

Loehle, C., J.C. MacCracken, D. Runde and L. Hicks. 2002. Forest management at landscape scales: solving the problems. *Journal of Forestry*, Summer: 25-33.

Luckai, F. 2001. *Forest Measurements Field Manual.* Lakehead University, Faculty of Forestry and the Forest Environment, Thunder Bay, Ontario.

Ludwig, D., Mangel, M., and B. Haddad. 2001. Ecology, conservation, and public policy. *Annual Review of Ecology and Systematics,* 32: 481-517.

Mallany, S. 2002. A natural resource strategy for the Ontario Ministry of Natural Resources, Southcentral Region. In *Ecological Integrity and Protected Areas*, proceedings of the Parks Research Forum of Ontario. J. Porter and J.G. Nelson eds. Waterloo, Heritage Resources Centre: 169-175.

Manitoba Conservation. 1998. *Fire Program Policy.* Winnipeg, Manitoba, Manitoba Conservation.

Manley, B.F.J. 1994. *Multivariate Statistical Methods: A Primer.* 2nd Edition. New York, Chapman Hall.

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. *Nature*, 405: 243-253.

Martell, D.L. 1994. The impact of fire on timber supply in Ontario. *The Forestry Chronicle*, 70: 164-173.

Martell, D.L. 2001. Forest fire management. In *Forest Fires: Behavior and Ecological Effects,* E.A. Johnson and K Miyanishi, eds. San Diego, Academic Press, 527-584.

MacDonald G.B., J. Fraser, P. Gray. 1999. *Adaptive management forum: linking management and science to achieve ecological Sustainability.* Queen's Printer. Toronto.

McCarthy, J. 2001 Gap dynamics of forest trees: a review with particular attention to boreal forests. *Environmental Reviews* 9: 1-59.

McLaren, M.A., I.D. Thompson and J.A. Baker. 1998. Selection of vertebrate wildlife indicators for monitoring sustainable forest management in Ontario. *The Forestry Chronicle*, 74: 241-248.

McLain, R.J., and R.G. Lee. 1996. Adaptive management: promises and pitfalls. *Environmental Management*, 20: 437-448.

McNamee, K. 2002. From wild spaces to endangered spaces. In *Parks and protected areas in Canada,* 2nd Edition P. Dearden and R. Rollins eds. Oxford and Toronto, Oxford University Press: 21-50.

McRae, D.J., M.G. Weber and P.C. Ward. 2001a. Site preperation – prescribed fire. In *Regenerating the Canadian Forest, Principles and Practices for Ontario,* R.G. Wagner and S.J. Colombo eds. Markham, Ontario. Fitzhenry & Whiteside Limited: 201-219.

McRae, D.J., L.C. Duchesne, B. Freedman, T.J. Lynham, and S. Woodley. 2001b. Comparisons between wildfire and forest harvesting and their implications in forest management. *Environmental Reviews*, 9: 223-260.

Meadowcroft, J. 2002. Politics and scale: some implications for environmental governance *Landscape and Urban Planning*, 61: 169–179.

Meffe, G.K, and C.R. Carroll. 1997. *Principles of Conservation Biology.* Sunderland, Sinauer Associated, Inc.

Meffe, G., and S .Viederman. 1995. Combining science and policy in conservation biology. *Wildlife Society Bulletin,* 23: 327–32

Miège, D.J., H.M. Armleder, M.J. Waterhouse, T. Goward. 2001. *A Pilot Study of Silvicultural Systems for Northern Caribou Winter Range Lichen Response,* Working paper # 56. British Columbia Ministry of Forests Research Program.

Miller, C., and D. L. Urban. 2000. Connectivity of forest fuels and surface fire regimes. *Landscape Ecology* 15: 145-154.

Miller, M. 2000. Fire Autecology. In *Wildland fire in ecosystems: effects of fire on flora.* J.K. Brown and J.K. Smith eds. Gen.Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 9-34

Mitchell, B. 1997. *Resources and Environmental Management.* Harlow, Prentice Hall.

Mitchell, B. 2002. *Resources and Environmental Management*, 2nd Ed. Harlow, Prentice Hall.

Miyanishi, K. 2001. Duff Consumption. In *Forest Fires: Behavior and Ecological Effects,* E.A. Johnson and K Miyanishi, eds. San Diego, Academic Press: 437-476.

Miyanishi, K. and E.A. Johnson. 2002. Process and patterns of duff consumption in the mixedwood boreal forest. *Canadian Journal of Forest Research*, 32: 1285-1295.

Mladenoff D.J. and H.S. He. 1999. Design, behavior and application of LANDIS, an object-oriented model of forest landscape disturbance and succession. In *Spatial Modeling of Forest Landscape Change: Approaches and Applications*, Mladenoff, D.J. and W.L. Baker, eds. Cambridge, U.K., Cambridge University Press: 125-162.

Morash, P.R. and G.D. Racey. 1990. *The northwestern Ontario forest ecosystem classification as a descriptor of woodland caribou (Rangifer tarandus caribou) range.* Technical Report # 55, Northwestern Ontario Forest Technology Development Unit. Ontario Ministry of Natural Resources.

Montegomery, C., and G.M. Brown. 1992. Economics of species preservation; the Spotted Owl case. *Contemporary Policy Issues*, X: 1-12.

Murray, M.P. 1996. Natural processes wilderness management unrealized. *Natural Areas Journal*, 16: 55-61.

Nazir, M. 2001. Future forest policies in Canada. *The Forestry Chronicle,* 77: 127-128

Neary, D.G., C.C. Klopatek, L.F. Debano, P.F. Folliott. 1999. Fire effects on belowground sustainability: a review and synthesis. *Forest Ecology and Management*, 122: 51-71.

Nelson, G. 1993. Beyond parks and protected areas: From public lands and private stewardship to landscape planning and management. In *Parks and protected areas in Canada,* 2nd Edition P. Dearden and R. Rollins eds. Toronto, Oxford University Press: 45-56.

Neuman, W.L. 1997. *Social Research Methods*, 3rd Edition. Needham Heights, MA. Allyn and Bacon.

Newmaster, S.G., F.W. Bell, and D.H. Vitt. 1999. The effects of glyphosate and triclopyr on common bryophytes and lichens in northwestern Ontario. *Canadian Journal of Forest Research*, 29: 1101-1111.

Nguyen-Xuan, T., Y. Bergeron, D. Simard, J. W. Fyles, and D. Paré. 2000. The importance of forest floor disturbance in the early regeneration patterns of the boreal forest of western and central Quebec: a wildfire versus logging comparison. *Canadian Journal of Forest Research*, 30: 1353-1364.

Niemela, J. 1999. Management in Relation to disturbance in the boreal forest. *Forest Ecology and Management*, 115: 127-134.

Norton, D. 1999. Forest Reserves. In *Maintaining Biodiversity in Forest Ecosystems,* M.L. Hunter

Jr. ed. Cambridge, Cambridge University Press: 525-555.

Noss, R.F. 1995. *Maintaining Ecological Integrity in Representative Reserve Networks*. Toronto, World Wildlife Fund.

Noss, R.F. and A.Y. Cooperrider. 1994. *Saving Nature's Legacy: Protecting and Restoring Biodiversity*, Washington, Island Press.

Noss, R.F. and J.M. Scott. 1997. Ecosystem protection and restoration: The core of ecosystem management. In *Ecosystem Management, Applications for Sustainable Forest and Wildlife Resources* M.S. Boyce & A. Haney, eds. New Haven, Yale University Press: 239-264.

Noss, R.F., C. Carroll, K. Vance-Borland, and G. Wuerthner. 2002. A multicriteria assessment of irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. *Conservation Biology*, 16: 895-908.

Nudds, T.D. 1999. Adaptive management and the conservation of biodiversity. In *Practical Approaches to the Conservation of Biological Diversity.* R.K. Baydack, H. Campa, and J.B. Haufler eds. Washington D.C., Island Press: 179-193.

Nudds, T.D., C.P. Henschel, J. Kerr, D. Currie, L. Fahrig, S. Koh, and C.G. McLauglin. 1998. Protected areas network: Assessment of Ontario's 'Nature's Best' action plan and recommendations. In *Parks and Protected Areas in Ontario,* J.G. Nelson, K. Van Osch, T.J. Beechey, W.R. Stephenson and J. Marsh, eds. Heritage Resources Centre, University of Waterloo: 363-372.

Oliver, C., M. Boydak, G, Segura, and B, Bare. 1999. Forest organization, management and policy. In *Maintaining Biodiversity in Forest Ecosystems*, M.L. Hunter Jr., ed. Cambridge Massachusetts, Cambridge University Press: 556-596.

Ontario Environmental Assessment Board. 1994. *Reasons for Decisions and Decisions - Class Environmental Assessment by the Ministry of Natural Resources for Timber Management on Crown Lands in Ontario.* Ontario Environmental Assessment Board.

Ontario Forest Policy Panel. 1993. *Diversity: Forests, People, Communities – A Comprehensive Forest Policy Framework for Ontario.* Toronto, Queen's Printer.

Ontario Parks. 1997. *Ontario's Parks and Protected Areas: A Framework & Action Plan.* Toronto, Queen's Printer.

Ontario Parks. 1998a. *Protection of Vulnerable, Threatened and Endangered Species in Parks -* Policy. Toronto, Queen's Printer.

Ontario Parks. 1998b. *Quetico Provincial Park Fire Management Plan.* Toronto, Queen's Printer.

Ontario Parks. 2000. *Woodland Caribou Provincial Park Interim Management Statement.* Red Lake, Queen's Printer.

Ontario Parks. 2003a. *A Class Environmental Assessment for Provincial Parks and Conservation Reserves.* Toronto, Queen's Printer.

Ontario Parks. 2003b. *Ontario Parks Homepage.* Available online at: www.ontarioparks.com . Last accessed 11/01/03.

Ontario Ministry of Natural Resources. 1986. *Woodland Caribou Provincial Park: Background Information.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 1992. *Ontario Provincial Parks: Planning and Management Policies.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 1994. *Crown Forest Sustainability Act, 1994.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 1995. *Policy Framework for Sustainable Forests.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 1997a. *A Guide to Forest Management Planning.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 1997b. *Forest Management Planning Manual for Ontario's Crown Forests.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 1997c. *Forest Management Guidelines for the Protection of the Physical Environment.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 1999. *A Management Framework for Woodland Caribou Conservation in Northwestern Ontario.* Unpublished OMNR document.

Ontario Ministry of Natural Resources. 2002a. *Forest Management Guide for Natural Disturbance Pattern Emulation.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 2002b. *State of the Forest Report 2001.* Toronto, Queen's Printer.

Ontario Ministry of Natural Resources. 2002c. *A Review by the Ministry of Natural Resources Regarding the Class Environmental Assessment for Timber Management on Crown Lands in Ontario.* Toronto, Queen's Printer.

Pal, L.A. 1992. *Public Policy Analysis: An Introduction.* Scarborough, Nelson.

Pal, L.A. 1997. *Beyond Policy Analysis.* Scarborough, Nelson.

Parks Canada. 2002. *Pukaskwa National Park Fire Management Program.* [online]: http://www.parkscanada.gc.ca/pn-np/on/pukaskwa/natcul/natcul2e_E.asp. Last accessed 03/03/03.

Parks Canada Agency. 2000. *Unimpaired for Future Generations*? Protecting Ecological Integrity with Canada's National Parks. Vol. II, Setting a New Direction for Canada's National Parks. Report of the Panel on Ecological Integrity of Canada's National Parks. Ottawa, ON.

Payette, S. 1992. Fire as a controlling process in the North American boreal forest. In *A Systems Analysis of the Global Boreal Forest,* H.H. Shugart, R. Leemans and G.B. Bonan, eds. New York, Cambridge University Press: 144-169.

Payette, S., N. Bhiry, A. Delwaide and M. Simard. 2000. Origin of the lichen woodlands at its southern range limit in eastern Canada: the catastrophic impact of insect defoliators and fire on the spruce-moss forest. *Canadian Journal of Forest Research*, 30: 288-305.

Perry D.A. 1998. The scientific basis of forestry. *Annual Review of Ecology and Systematics.* 29: 435-466.

Perry, D.A. and J. Maghembe. 1989. Ecosystem concepts and current trends in forest management time for reappraisal. *Forest Ecology and Management,* 26: 123-140.

Pharo, E.J., and A.J. Beattie. 2001. Management forest types as a surrogate for vascular plant, bryophyte and lichen diversity. *Australian Journal of Botany*, 49: 23-30.

Pharo, E.J., and D.H. Vitt. 2000. Local variation in bryophyte and macro-lichen cover and diversity in Montane forests of western Canada. *The Bryologist,* 103: 455-466.

Prescott, C.E., D.G. Maynard, and R. Laiho. 2000. Humus in northern forests: friend or foe? *Forest Ecology and Management* 133: 23-36.

Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright and P.H. Williams. 1993. Beyond opportunism: Key principles for systematic reserve selection. *Trends in Ecology and Evolution*, 8: 124-128.

Priddle, G.B. 1982. Parks and land use planning in northern Ontario. *Environments*, 14: 47-51.

Promaine, A. and R.S. Rempel. 1999. Applying criteria and indicators to assess ecological integrity in a boreal national park and adjacent forest management units. In *Science and Management: Sustaining the Boreal Forest.* T.S. Veeman, D.W. Smith, B.G. Purdy, F.J. Salkie and G.A. Larkin, eds. Edmonton, Sustainable Forest Management Network: 532-537.

Possingham, H.P. 2001. *The Business of Biodiversity: Applying decision theory principles to nature conservation.* TELA, Australia Conservation Foundation. Available online at: www. acfonline. org. au/ publications/ tela/ intro.html

Potvin, F., Belanger, L., and Lowell, K. 2000. Marten habitat selection in a clearcut boreal landscape. *Conservation Biology*, 14: 844-857.

Pregitzer, K.S. and S.C. Saunders. 1999. Jack pine barrens of the northern Great Lake region. In *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*, R.C. Anderson, J.S. Fralish, and J. M. Baskin, eds. New York, Cambridge University Press: 343-361.

Pruitt, W.O. 1997. Threats to woodland caribou and the Taiga. *Global Biodiversity*, 7: 25-31.

Quinby, P. A. 2001. Scale of ecological representation: A case study of old-growth forest conservation in Temagami, Ontario, Canada. *Natural Areas Journal,* 21: 216-228.

Racey, G.D. and T. Armstrong. 2000. Woodland caribou range occupancy in northwestern Ontario: past and present. *Rangifer*, Special Issues No. 12: 173-183.

Racey, G., A. Harris, and R.F. Foster. 1996a. *Caribou winter habitat in the new forest: lessons from Lucy Lake.* Ontario Ministry of Natural Resources. Northwest Science and Technology, Thunder Bay Ontario. TR-103.

Racey, G.D., A.G. Harris, J.K. Jeglum, R.F. Foster, and G.M. Wickware. 1996b. *Terrestrial and wetland ecosites of Northwestern Ontario.* OMNR. Northwest Science and Technology. Field Guide FG-02.

Racey, G., A. Harris, L. Gerrish, T. Armstrong, J. McNichol, and J. Baker. 1999. *Forest Management Guidelines for the Conservation of Woodland Caribou: A Landscape Approach.* Version 1.0 Draft. Ontario Ministry of Natural Resources, Thunder Bay.

Rempel, R.S., P.C. Elkie, A.R. Rodgers, M.J. Gluck. 1997. Timber management and natural-disturbance effects on moose habitat: Landscape evaluation. *Journal of Wildlife Management*, 61: 517-524.

Rettie, W.J. and F. Messier. 2000. Hierarchical habitat selection by woodland caribou: its relationship to limiting factors. *Ecography*, 23: 466-478.

Richards, S.A., H.P. Possingham, and J. Tizard. 1999. Optimal fire management for maintaining community diversity. *Ecological Applications*, 9: 880-892.

Ridout, D.B. and S.J. Botti. 2002. Blueprint for fire planning. *Journal of Forestry*, 100: 36-41.

Romme, W.H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. *Ecological Monographs*, 52: 199-221.

Romme, W.H., and D.G. Despain. 1989. Historical perspectives on the Yellowstone fires of 1988. *BioScience*, 39: 695-699.

Romme, W.H., E.H. Everham, L.E. Frelich, M.A. Moritz and S.E. Sparks. 1998. Are large, infrequent disturbances qualitatively different from small frequent disturbances? *Ecosystems*, 1: 524-534.

Ryan, K.C. 2002. Dynamic interactions between forest structure and fire behavior in boreal ecosystems. *Silva Fennica*, 36: 13-39.

Salwasser, H. 1993. Sustainability needs more than better science. *Ecological Applications*, 3: 587-593.

Salwasser, H. 1994. Ecosystem management, can it sustain diversity and productivity? *Journal of Forestry*. August: 6-10.

Sandilands, B.A. and P.R. Gagnon. 1982. *Woodland Caribou Provincial Park Proposal: A summary of Recommendation Arising out of the West Patricia Land Use Plan.* Red Lake. Unpublished OMNR document.

Schaefer, J.A. 1998. Incorporating spatial scale into ecological studies of *Rangifer. Rangifer,* 10: 259-260.

Schaefer, J.A. 2003. Long-term range recession and the persistence of caribou in the Taiga. *Conservation Biology*, 17: 1435-1439.

Schaefer, J.A. and W.O. Pruitt, Jr. 1991. Fire and woodland caribou in southeastern Manitoba. *Wildlife Monographs*, 116: 1-39.

Schaefer, J.A, A. M. Veitch, F.H. Harrington, W.K. Brown, J.B. Theberge, and S.N. Luttich. 2001. Fuzzy structure and spatial dynamics of a declining woodland caribou population. *Oecologia*, 126: 507-514.

Schimmel, J. and A. Granstorm. 1996. Fire severities and vegetation response in the boreal Swedish forest. *Ecology*, 77: 1436-1450.

Schimmel, J. and A. Granstorm. 1997. Fuel succession and fire behavior in the Swedish boreal forest *Canadian Journal of Forest Research*, 27: 1207-1216.

Schindler, D. W. 1998. Replication versus realism: The need for ecosystem-scale experiments. *Ecosystems* 1: 323-334.

Schneider, D. C. 2001. The rise of the concept of scale in ecology. *BioScience,* 51: 545-553.

Schullery, P. 1989. The fires and fire policy. *Bioscience*, 39: 686-699.

Searle, D.R. 2000. *Phantom Parks: The Struggle to Save Canada's National Parks.* Toronto, Key Porter Books.

Seymour, R.S. and M.L. Hunter, Jr. 1999. Principles of ecological forestry. In *Maintaining Biodiversity in Forest Ecosystems.* M.L. Hunter Jr., ed. Cambridge, Massachusetts, Cambridge University Press: 22-61.

Simard, D.G., J.W. Fyles, D. Paré, and T. Nguyen. 2001. Impacts of clearcut harvesting and wildfire on soil nutrient status in the Quebec boreal forest. *Canadian. Journal of Soil Science*, 81: 229–237.

Simberloff, D. 1998. Flagships, keystone and umbrella species: Is single species management passé in the landscape era? *Biological Conservation*, 83: 247-257.

Simberloff, D. 1999. The role of science in the preservation of forest biodiversity. *Forest Ecology and Management*, 115: 101-111.

Simkin, D.W. 1965. *A Preliminary report of the woodland caribou study in Ontario.* Department of Lands and Forests. Section Report No. 59.

Sims, R.A., W.D. Towill, K.A. Baldwin, P Uhlig, and G.M. Wickware. 1997. *Field Guide to the Forest Ecosystem Classification for Northwestern Ontario.* OMNR. Northwest Science and Technology. Thunder Bay, Ontario. Field Guide FG-03.

Shafer, C.L. 1995. Values and shortcomings of small reserves. *BioScience*, 45(2): 80-88.

Shinneman, D.J. and W.L. Baker, 1997. Nonequilibrium dynamics between catastrophic disturbances and old-growth forests in ponderosa pine landscapes of the Black Hills. *Conservation Biology*, 11: 1276-1288.

Skibicki, A. J. 1995. *Preliminary Boundary Analysis of the Greater Pukaskwa National Park Ecosystem Using the ABC Resource Survey Approach.* Occasional Paper No. 6. Heritage Resources Centre, University of Waterloo and Parks Canada, Waterloo, Ontario.

Slocombe, D.S. 1993. Implementing ecosystem-based management. *BioScience*, 43: 612-622.

Slocombe, D.S. 1998a. Defining goals and criteria for ecosystem-based management. *Environmental Management*, 22: 483-493.

Slocombe, D.S. 1998b. Lessons from experience with ecosystem-based management. *Landscape and Urban Planning*, 40: 31-39.

Slocombe, D.S. and P. Dearden. 2002. Protected areas and ecosystem-based management. In *Parks and Protected Areas in Canada 2nd Edition,* P. Dearden and R. Rollins eds., Don Mills, Oxford University Press: 295-320.

Smith, K.G., E.J. Ficht, D. Hobson, T.C. Sorensen and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. *Canadian Journal of Zoology*, 78: 1433-1440.

Song, S.J., and R.M. M'Gonigle. 2001. Science, power, and system dynamics: the political economy of conservation biology. *Conservation Biology*, 15: 980-989.

Spies, T.A., and M.G. Turner. 1999. Dynamic forest mosaics. In *Maintaining Biodiversity in*

Forest Ecosystems. M.L. Hunter Jr. ed. Cambridge, Massachusetts, Cambridge University Press: 95-160.

Sprugel, D.G. 1991. Disturbance, Equilibrium, and Environmental Variability: What is 'Natural' Vegetation in a Changing Environment? *Biological Conservation*, 58; 1-18.

Stankey, G.H., B.T. Bormann, C. Ryan, B. Shindler, V. Sturtevant, R.N. Clark, and C. Philpot. 2003. Adaptive management and the northwest forest plan: Rhetoric and reality. *Journal of Forestry*: 40-46.

Stocks, B. J. 1987a. Fire potential in the spruce budworm-damaged forests of Ontario. *The Forestry Chronicle:* 8-14.

Stocks, B.J. 1987b. Fire behavior in immature jack pine. *Canadian Journal of Forest Research*, 17: 80-86.

Stocks, B.J. 1989. Fire behavior in mature jack pine. *Canadian Journal of Forest Research*, 19: 783-790.

Suffling, R. 1992. Climate change and boreal forest fires in Fennoscandia and central Canada. In *Greenhouse-Impact on Cold Climate Ecosystems and Landscapes.* M.M. Boer and E.A. Koster, eds. Cremlingen-Destedt, Germany: 111-132.

Suffling, R. 1995. Can disturbance determine vegetation distribution during climate warming?: A boreal test. *Journal of Biogeography*, 22: 501-508.

Suffling, R. and D. Speller. 1998. The fire roller coaster in Canadian boreal forests. In *Decoding Canada's Past: Climate Variations and Biodiversity Change During the Past Millennium.* D.C. McIver and R.E. Meyer eds. Downsview. Atmospheric Environment Service, Environment Canada: 19-26.

Suffling, R. and A.H. Perera. In Press. Concepts and approaches in characterizing natural forest disturbance regimes. In *Emulating Natural Forest Landscape Disturbances: Concepts and Applications.* A.H. Perera, L.J. Buse, and M.G. Weber, eds. New York, Columbia University Press.

Suffling, R., C. Lihou, and Y. Morand. 1988. Control of landscape diversity by catastrophic disturbance: A theory and a case study of fire in a Canadian boreal forest. *Environmental Management*, 12: 73-78.

Sulyman, R.S. and D.S. Coxson. 2001. Microsite displacement of terrestrial lichens by feather moss mats in late seral pine-lichen woodlands of north-central British Columbia. *The Bryologist,* 104: 505-516.

Swetnam, T.W., C.D. Allen, and J.L. Betancourt. 1999. Applied historical ecology: using the past to manage the future. *Ecological Applications*, 9: 1189-1206.

Theberge, J., and J. Theberge. 2002. Application of ecological concepts to the management of protected areas. In *Parks and Protected Areas in Canada* 2nd edition. P. Dearden and R. Rollins eds. Don Mills, Oxford University Press: 70-96.

Townend, J. 2002. *Practical Statistics for Environmental and Biological Scientists.* New York, John Wiley & Sons, LTD.

Turner, M. G. 1989. Landscape ecology: The effects of pattern on process. *Annual Review of Ecology and Systematics*, 20: 171-197.

Turner, M.G., S.L. Collins, A.L. Lugo, J.J. Magnuson, T.S. Rupp, and F.J. Swanson. 2003. Disturbance dynamics and ecological response: the contribution of long-term ecological research. *BioScience*, 53: 46-56.

Turner, M. G., and V. H. Dale. 1998. Comparing large, infrequent disturbances: What have we learned? *Ecosystems*, 1: 493-496.

Turner, M.G., W.H. Romme, and R.H. Gardner. 1999. Prefire heterogeneity, fire severity, and early postfire plant reestablishment in sub-alpine forests of Yellowstone National Park, Wyoming. *International Journal of Wildland Fire*, 9: 21-36.

Turner M. G., R. H. Gardner, and R. V. O'Neill. 2001. *Landscape Ecology: in Theory and Practice.* Springer-Verlag, New York.

Turner, M. G., R. H. Gardner, V. H. Dale, and R. V. O'Neill. 1989. Predicting the spread of disturbance across heterogeneous landscapes. *Oikos*, 55: 121-129.

Turner M.G., W.W. Hargrove, R.H.Gardner, and W.H. Romme. 1994. Effects of fire on landscape heterogeneity in Yellowstone National Park, Wyoming. *Journal of Vegetation Science* 5: 731–742.

Turner, M. G., W. H. Romme, R. H. Gardner, and W. H. Hargrove. 1997. Effects of fire size and pattern on early succession in Yellowstone National Park. *Ecological Monographs,* 67: 411-433.

Uhlig, P.W.C. and B. Wiltshire. 2001. Ecosystem classification and forest regeneration. In *Regenerating the Canadian Forest, Principles and Practices for Ontario.* R.G. Wagner and S.J. Colombo eds. Markham, Fitzhenry & Whiteside Limited: 119-140.

Urban, D.L., O'Neill, R.V. and H.H. Shugart Jr. 1987. Landscape ecology: A hierarchical perspective can help scientist understand spatial patterns. *BioScience,* 37: 119-127.

USDA. 2000. *Boundary Waters Canoe Area Wilderness - Fuel Treatment.* Milwaukee, USDA Forest Service.

Van der Vink, G.E., 1997. Scientifically illiterate vs. politically clueless. *Science* 276: 1175.

Van Wagner C.E. 1978. Age-class distribution and the forest fire cycle. *Canadian Journal of Forest Research* 18: 818–820.

Veblen, T. T., D. Kulakowski, K. S. Eisenhart, and W.L. Baker. 2001. Subalpine forest damage from a severe windstorm in northern Colorado. *Canadian Journal of Forest Research*, 31: 2089-2097.

Verbyla, D.L. and K. Chang. 1997. *Processing Digital Images in Geographic Information Systems.* Santa Fe, Onward Press.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology* [online]1. http://www.consecol.org/vol1/iss2/art1

Wang, G.G. 2002. Fire severity in relation to canopy composition within burned boreal mixedwood stands. *Forest Ecology and Management*, 163: 85–92.

Ward. P.C., A.G. Tithecott, and B.M. Wotton. 2001. Reply – A re-examination of the effects of fire suppression in the boreal forest. *Canadian Journal of Forest Research,* 31: 1467-1480.

Webb, E.T. 1998. Survival, persistence, and regeneration of the reindeer lichens, *Cladina stellaris, C. rangiferina,*and *C. mitis* following clearcut logging and forest fire in northwestern Ontario. *Rangifer*, 10: 41–47.

Weir, J.M.H., E.A. Johnson and K. Miyanishi. 2000. Fire frequency and the spatial age mosaic of the mixedwood boreal forest in western Canada. *Ecological Applications*, 10: 1162-1177.

Wepruk , R, 1986. *Woodland Caribou Investigations of Woodland Caribou Provincial Park, 1985.* Ministry of Natural Resources, Red Lake District.

White, P.S. 1987. Natural disturbance, patch dynamics, and landscape pattern in natural areas. *Natural Areas Journal*, 7: 14-22.

White, P. S., and S. T. A. Pickett. 1985. The Ecology of Natural Disturbance and Patch Dynamics. Orlando, Academic Press.

White, P.S., J. Harrod, W. H. Romme, and J. Betancourt. 1999. Disturbance and temporal dynamics, In *Ecological Stewardship: A Common Reference for Ecosystem Management*, R.C. Szaro, N.C. Johnson, W.T. Sexton and A.J. Malk eds. Oxford: Elsevier Science Ltd: 313-330.

Whittle, C.A., L.C. Duchesne, and T. Needham. 1997. The impact of broadcast burning and fire severity on species composition and abundance of surface vegetation in a jack pine (*pinus banksiana*) clear cut. *Forest Ecology and Management*, 94: 141-148.

Wiens, J.A. 1989. Spatial scaling in ecology. *Functional Ecology,* 3: 385-397.

Wiens, J.A., B. Van Horne, and B.R. Noon. 2002. Integrating landscape structure and scale into natural resource management. In *Integrating Landscape Ecology into Natural Resource Management*, J. Liu and W.M Taylor eds. New York, Cambridge University Press: 23-66.

Wightman, W.R. and N.M. Wightman. 1997. *The Land Between: Northwestern Ontario Resource Development, 1800 to the 1990s.* Toronto, University of Toronto Press.

Wilkinson, C.J.A. 2002. *Biodiversity Conservation in Ontario: An Examination of Legislation and Government Policy.* Ph.D. thesis, Department of Geography, University of Waterloo.

Wilkinson, C.J.A. and P.F.J. Eagles. 2001. Strengthening the conservation of biodiversity: Reforming Ontario's Provincial Parks Act, *Natural Areas Journal*, 21: 329-336.

Wilson, J. 2001a. Experimentation on a leash: forest land use planning in the 1990s. In *In search of sustainability: British Columbia forest policy in the 1990s.* M. Howlett, J. Wilson B. Cashore, G. Hoberg, J. Rayner. eds Vancouver. UBC Press: 31-60.

Wilson, J. 2001b. Talking the talk and walking the walk: reflections on the early influence of ecosystem management ideas. In *Canadian Forest Policy.* M. Howlett ed. Toronto, University of Toronto Press: 94-126.

Wood. P.M. 2000. *Biodiversity and democracy.* Vancouver, UBC Press.

Woodley, S. 2002. Planning and managing for ecological integrity. In *Parks and Protected Areas in Canada* 2nd Edition. P. Dearden and R. Rollins eds. Don Mills, Oxford University Press: 97-114

Woodley, S., G. Forbes, and A. Skibicki. 1998. *State of the Greater Fundy Ecosystem.* [online]: http://www.unb.ca/web/forestry/centers/cwru/soe/title.htm

Woodwell, G.M. 2002. On purpose in science, conservation and government. *Ambio*, 31: 432-436.

Yaffee, S.L. 1997. Why environmental policy nightmares recur. *Conservation Biology*, 11: 328-337.

Yaffee, S.L. 1999. Three faces of ecosystem management. *Conservation Biology*, 13: 713-725.

Zar, J.H. 1999. *Biostatistical Analysis, 4th edition.* New Jersey, Prentice Hall.

Zorn, P., W. Stephenson, and P. Grigoriev. 2001. An ecosystem program assessment process for Ontario National Parks. *Conservation Biology*, 15: 353-362.

10.0 APPENDIX

Glossary of Terms

ANNUAL ALLOWABLE CUT (AAC)– The volume of wood that may be harvested in a given region per year.

AREA OF THE UNDERTAKING (AOU) - The region within the geographic boundaries of the area of the undertaking (sensu environmental assessment) is all land and water within forest management unit boundary lines. The northern boundary is generally the northern limit of current commercial timber operations; the southern boundary is generally the limit of the forest on Crown Land (Figure 10.1) (OMNR, 2002b: 6-10).

Figure 10.1: The AOU in Ontario (shaded region)

DISTURBANCE – A relatively discrete event that disrupts the structure of an ecosystem, community, or population and changes the resource availability or physical environment (White and Pickett, 1985). Disturbances may be either biotic (insects, pathogens, herbivory, etc) or abiotic (fire, wind, drought, avalanche, and others); they may be either natural or human induced (Perera *et al.*, 2000). The influence of disturbance events is dependent on both the spatial and temporal scale of the event (Tuner *et al.*, 2001; Suffling and Perera, In Press).

DISTURBANCE INTENSITY - The force of the disturbance event; it can be measured quantitatively (e.g. energy released from the flame of a forest fire, or the velocity of wind) (Johnson, 1992).

DISTURBANCE LEGACY - The influence of one or more disturbance events, and how they affect communities from individuals to landscapes of a given period of time. A specific disturbance event on a particular community or patch may influence both succeeding disturbance events and the sequence of succeeding disturbance events (Heinselman, 1996; Foster *et al.*, 2003).

DISTURBANCE SEVERITY - The proportion of individual plant organisms and their propagules killed in a disturbance. Low severity disturbances will only slightly alter the biotic structure of a landscape (e.g. small insect outbreaks). High severity disturbance will dramatically alter the biotic structure of a landscape, killing most plants and trees (e.g. large stand replacing forest fires) (Frelich and Reich, 1998).

ECOSITE – Areas with relatively uniform topography, soil and hydrology, and chronosequence of vegetation. Scale of 1:50,000 - 1: 10,000 (Uhlig and Wiltshire, 2001: 123).

ECOSYSTEM MANAGEMENT (EM) – Ecosystem management is a land (and potentially water) management framework that promotes a holistic view of all resources within an ecosystem. The desire is to protect and perpetuate complex ecosystem functions, structures and compositions within a given landscape (Noss and Cooperrider, 1994; Christensen *et al.*, 1996; Franklin, 1997; Grumbine, 1997; Woodley *et al.*, 1998; Yaffee, 1999). EM must consider humans as an integral part of the an ecosystem (Grumbine, 1997; Franklin, 1997). As ecosystem boundaries are often intangible and difficult to define, properly managing an area within a defined boundary is often impossible, since influences beyond the confines of a land parcel almost always influence activities within it (Woodley *et al.*, 1998).

FOREST MANAGEMENT UNIT (FMU)- All or part of a Crown forest that has been designated as a management unit for the purposes of the Crown Forest Sustainability Act (OMNR, 2002b: 6-15).

FOREST RESOURCE INVENTORY (FRI) A resource inventory conducted for each management unit on average every twenty years. The FRI divides the area into a number of components, such as water, non-forested, non-productive forest, and productive forest; and further classifies each component by ownership/land use categories. The FRI provides descriptive information about the timber resource on each management unit (e.g., stand age, stand height, species composition, stocking level) in the form of interpreted aerial photographs, forest stand maps and a set of standard inventory ledgers referred to as reports (OMNR, 2002b: 6-13).

NORTHERN BOREAL INITIATIVE (NBI) - An ongoing land use planning process to develop forest resources in cooperation with First Nations north of the current AOU. This initiative is subject to Environmental Assessment approval.

POLICY – A course of action or inaction chosen by public authorities to address a given problem or an interrelated set of problems (Pal, 1997).

POLICY APPROACH - A policy direction taken by a government agency relating to a specific subject. This may be observed through supporting policy documents, management regulations and guidelines (Hogwood and Gunn, 1984; Hessing and Howlett, 1997; Clark *et al.*, 2000; Clark, 2002).

SCALE - The spatial or temporal dimension of an object or process, characterized by both grain and extent (Turner *et al.*, 2001: 29)

WOODLAND CARIBOU PROVINCIAL PARK (WCPP) - A 450,000 ha wilderness provincial park in northwestern Ontario, which represents a boreal upland ecosystem. The park was established to protect known woodland caribou habitat in this region of Ontario (OMNR, 1986).