Applying Criteria and Indicators to Assess Ecological Integrity of a Boreal National Park and Adjoining Forest Management Units

by

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A CAUTION TO THE READER

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ABSTRACT

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Key Words: ecological integrity, criteria and indicators, Pukaskwa National Park, eastern boreal forest

Assessing and evaluating ecological integrity is a complex and often subjective task. However, recent legislative changes have forced ecosystem managers to develop more quantitative techniques to measure ecological integrity, particularly in Canada's national parks. Using a combination of measures for forest sustainability (Canadian Council of Forest Ministers Criteria and Indicators, 1995) and existing regional data sets, a suite of indicators have been structured into a hierarchical framework for monitoring broad-scale, ecological forces (referred to as "drivers of change"), as well as ecosystem, habitat and species dynamics for the Pukaskwa National Park ecosystem. The project's focus is on gaining a measurable understanding of the spatial and temporal aspects of the ecological integrity of the park and its broader ecosystem.

The indicators reveal that: (1) Pukaskwa National Park may be more unique than representative of the central boreal uplands, and (2) increasing human demand for natural resources, particularly timber, is playing a significant role in the ability of park management to maintain the park's ecological integrity. Road construction in the greater park ecosystem may play a significant role. These are important results that shape the park's management approach and priorities.

Continued use of this structural framework for ecological integrity will allow Pukaskwa National Park to be used as a benchmark for environmental change and contribute to the understanding required for mitigating such changes.

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INTRODUCTION

Over recent decades, resource managers have gone from species management, to habitat management, and currently, attempting to manage for entire ecosystems. However, understanding an ecosystem is mind-boggling and its level of complexity is beyond comprehension. As Egler (1977) stated: "ecosystems are not only more complex than we think, but more complex than we *can* think." Yet, this reality hasn't curbed expectations. Terms such as "enhancing biodiversity", "sustainable development" or "maintaining ecological integrity" have become common place in resource management goals, regardless of the complexity involved.

There has been increasing demand for land managers to provide a systematic means of evaluating the natural environment. The main thrust has been in the development of "indicators" as tools for ecosystem evaluation. Similar to more common and established economic indicators, a suite of ecological indicators intends to reflect the current state or condition of the environment. This has become even more acute with the legislated mandates of land managers for broad terms such as biodiversity, health, integrity and sustainability.

Parks Canada has mandated that National Parks in Canada consider *ecological integrity* first before any other planning principle. The purpose of this report is to evaluate the State of Pukaskwa National Park in terms of its ecological integrity. To accomplish this, there are 5 main objectives:

I. The development and assessment of a suite of terrestrial ecological indicators for Pukaskwa National Park.

II. An evaluation the "State of the Park" in terms of its terrestrial ecological integrity and how it is changing over time (temporal analysis).

III. The application of a common suite of indicators across administrative boundaries to begin monitoring the effects of two different management techniques (protection versus multi-use) on an ecosystem (spatial analysis).

IV. Enhance the understanding of indicators and their applicability and feasibility as a means of assessing ecological integrity for the park.

V. The creation of a structural framework to assist park managers in the ongoing assessment of the ecological integrity of Pukaskwa National Park.

I begin with a history of National Parks, the concept of ecological integrity, a history of Pukaskwa National Park, and the incorporation of a structural framework to assist in the evaluation of ecological integrity. I then apply a suite of indicators to summarize the "state of the park," including its limitations. This report will produce an evaluation of Pukaskwa National Park as a protected area.

LITERATURE REVIEW

LEGISLATION AND HISTORY OF NATIONAL PARKS

The first national park was established in Banff, Alberta, in 1885 as a means of stimulating tourism to the western mountain region of Canada (Bella, 1987). Recreation has been a major focus on the creation and maintenance of National Parks since the opening of Banff, and continues today.

In 1930, the Government of Canada passed the National Parks Act. This legislation set forth the purpose of national parks as: [Section 4 (General Purpose)]

> The National Parks of Canada are hereby dedicated to the people of Canada for their benefit, education and enjoyment, subject to this Act and the regulations, and the National Parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations.

Between the early 1950's and 1970's parks went through rapid expansion. Parks were developed to meet recreational needs of the people and included campgrounds, golf courses and ski hills (Dearden and Rollins, 1993). During the 1970's, park management began to reflect more concerns of the park environment, not only tourism. This change began with better understanding of species protection and the public's concern for the environment. By the 1980's, the language was changing. Concerns about fire management and the human/wildlife interface recognized parks as part of an ecosystem. Management began to recognize the protection of the park, included the protection of the ecosystem (Dearden and Rollins, 1993).

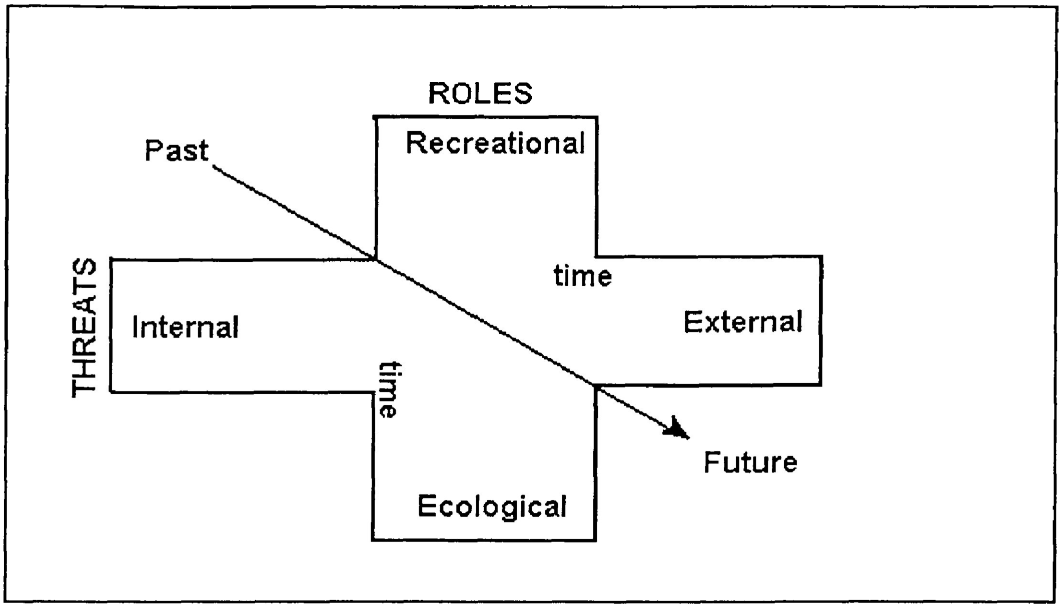


Figure 1. Changing emphasis in park roles over time (from Dearden and Rollins, 1993)

Management for park purposes differs markedly from that of other lands, where effort may be directed toward modifying or controlling nature, producing crops or extracting natural resources. Within national parks, effort is directed toward maintaining ecosystems in as natural a state as possible (Department of Canadian Heritage, 1994). This philosophy culminated with the amendment to the National Parks Act in 1988 to include the concept of ecological integrity as the first priority in management planning.

NATIONAL PARKS: ECOLOGICAL INTEGRITY

In 1988, the National Parks Act was amended to include "ecological integrity" as the primary goal in park management. Section 5 (1.2) of the National Parks Act states:

> Maintenance of ecological integrity through the protection of natural resources shall be the first priority when considering park zoning and visitor use in a management plan.

Many ecologists, including Parks Canada ecologists, define ecological integrity as a condition where the structure and function of an ecosystem are unimpaired by human induced stresses (Bouchard, 1997; Steedman, 1994; Woodley, 1993). Woodley (1993) defines ecological integrity as a state of ecosystem development that is optimized for its geographic location.

For national parks, this optimal state has been described as natural, naturally evolving, pristine, and untouched (Woodley, 1993). Park ecosystems with integrity do not exhibit the trends associated with stressed ecosystems (Woodley, 1993). Parks and protected areas are part of larger ecosystems and determinations of integrity in national parks must consider these larger ecosystems (Bouchard, 1997).

This concept of ecological integrity is intuitively appealing. It incorporates a sense of values including health, wholeness, persistence and stability. Yet, despite its appeal, conservation biologists and ecologists are having great difficulty in applying the concept in a practical way. (Geomatics, 1996).

First, parks seldom contain a complete or unaltered ecosystem. This, combined with increasing and cumulative stress from sources such as adjacent land use, downstream effects of air and water pollution, invasion by exotic species, visitor use and climate change can result in irreversible degradation of park ecosystems, the loss of biodiversity and impoverishment of gene pools (Department of Canadian Heritage, 1994). The inherent variability often makes it extremely difficult to separate the relative effects of natural and anthropogenic perturbations (De Leo and Levin, 1997).

Realizing that many stresses are global in nature, it becomes impossible to reach this state of “naturalness” where the influences of humans are not felt. Thus, ecological integrity becomes a directional goal for which ecologists and land-managers work towards, but may never achieve. In this way, no ecological system can have integrity.

Alternatively, Kimmins (1997b) makes the case that the words ecological integrity inherently implies a state or level of integrity. His position is that an ecosystem is any biological-physical system that exhibits the attributes of structure, function, complexity, interactions and interconnections of the sub-components, and change over time (Kimmins, 1997b). To say that an ecosystem has lost its integrity implies that it has lost the attributes of the system (Kimmins, 1997b). To suggest that an ecosystem lacks integrity is to require a change in the meaning of the words. Each individual ecosystem will have its own integrity, which is changed, but not lost, as natural processes or disturbances replace that condition with a new one, which in itself, has integrity (Kimmins, 1997b). Kimmins argues that there is only a loss of ecosystem integrity if the ecosystem processes are altered beyond the range that is characteristic for one of the seral stages of that ecosystem (Kimmins, 1997b). Therefore, by definition, an ecosystem has integrity.

So, on one hand, due to the limited ability to comprehend transboundary and cumulative effects, ecological integrity can never be achieved. Yet, on the other hand, by the word's own definition, each system maintains its own level of ecological integrity, and consequently is never lost. One of the problems of characterizing integrity is that ecosystems are not static -- they change over time due to purely natural factors and their changes are often erratic (or chaotic) and unpredictable (Noss, 1995). Thus, we are faced with the contradiction of perspective. Definitions and measures of ecosystem integrity from one perspective may complement, contradict, or be largely independent of those from other perspectives (e.g. temporal or spatial perspectives). Care must be taken to define the perspective used when making statements about ecosystem integrity and when making inferences about integrity from other perspectives (King, 1993). “Concepts of normalcy, constancy, variability and thus, ecosystem integrity are only meaningful with bounds set by the scale of observation” (King, 1993, p. 29). Therefore, a sound definition of integrity must be based within a site’s evolutionary and biogeographic context (Noss, 1995).

However, De Leo and Levin (1997) suggest that describing integrity must go beyond a biological perspective and recognize a human perspective, the ability of an ecosystem to continue to provide the services that humans expect (De Leo and Levin, 1997). For managed ecosystems, the ability to supply products such as food or timber may represent these services; for natural systems, valuations such as “wilderness” and “stability” may apply. Ecological integrity becomes a value for management of ecosystems within a human perspective.

Therefore within the context of ecological and human perspective, actually defining ecological integrity has become less relevant. A growing number of ecologists feel that it is much more useful to characterize the functional and structural aspects of ecosystems in order to provide a conceptual framework for assessing the impact of human activity on biological systems and to identify practical consequences stemming from this framework (Noss, 1995; De Leo and Levin, 1997).

Ecological integrity, like sustainability, is not an absolute concept. Ecological integrity is so complex that it cannot be measured directly (Noss, 1995; De Leo and Levin, 1997). What is required are a series of indicators at different spatial, temporal, and hierarchical levels of ecosystem organization (De Leo and Levin, 1997). Within a conceptual framework, these indicators should begin to characterize the functional and structural aspects of an ecosystem to assess the impact of human activity on biological systems (Noss, 1995). An indicator can be a statistic or parameter that, tracked over time, provides information on trends in the condition of a phenomenon and has significance extending beyond that associated with the properties of the statistic itself (Environment Canada, 1997). Attention should focus on the rates at which changes occur, understanding that certain changes are desirable, natural, and acceptable, while others are not (Botkin, 1990). Selecting indicators will be an evolutionary process. As our scientific knowledge of ecology and our experience with ecosystem management increase, we need to be open to the refinement of these indicators (Keddy et al., 1993).

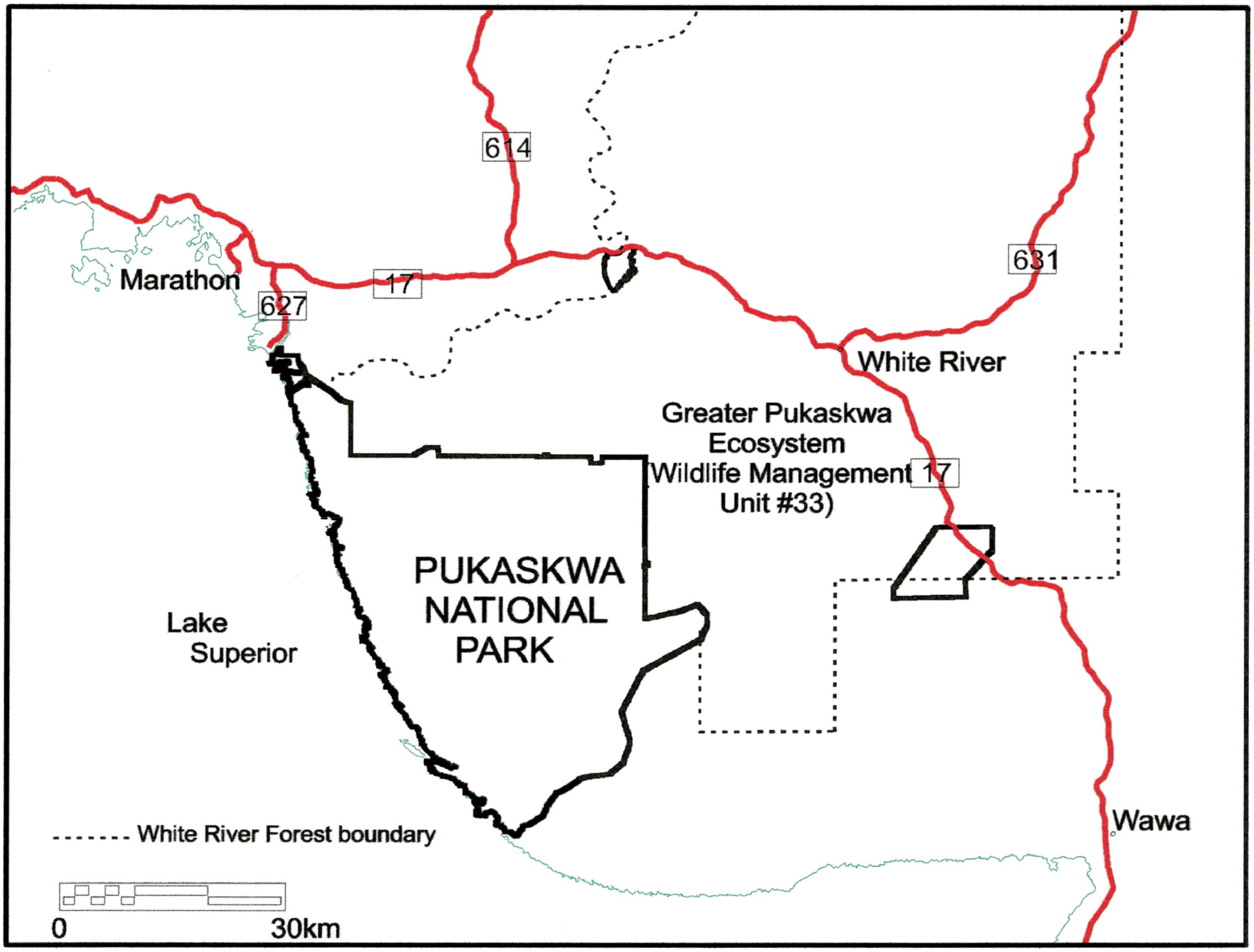
PUKASKWA NATIONAL PARK: HISTORY

Pukaskwa National Park is an 1878 square kilometer roadless area on the north-east coast of Lake Superior. It was established in 1978, to "protect a significant and representative part of the Central Boreal Uplands Region of Canada and the Great Lakes shoreline, and to encourage public understanding, appreciation, and enjoyment of its heritage so as to leave it unimpaired for this and future generations"(Department of Canadian Heritage, 1995, p.7).

The Central Boreal Uplands, as defined by Parks Canada, encompasses an area from northern Saskatchewan, through central Manitoba, northern Ontario and east into Quebec. The park occurs within the Abitibi Plains Ecoregion of the Boreal Shield Ecozone (Ecological Stratification Working Group, 1993). Hills (1961) classifies the park in Site Region 3E - Lake Abitibi, Site District 3E-4 - Tip Top Mountain. The park itself measures 1878 square kilometers along the north-east shore of Lake Superior. The park is relatively uniform uplands rising from 183.5 m along Lake Superior to 639.8 m at Tip Top Mountain.

Generally the soil in Pukaskwa is very course textured thin soils over bedrock on high, rolling hills (Duff et al., 1985). The lower valley slopes are covered by deep till and colluvium while the valley floors are covered by glacial and glaciofluvial deposits (Pukaskwa National Park, 1997). The park is within the transition zone from boreal forest in the north, dominated by black spruce, jack pine and white birch, to Great Lakes Forest in the south with occurrences of red maple, white pine and sugar maple. It is bordered by the Pic River at the north to the Pukaskwa River at the south. Lake Superior forms its western boundary and covers an area inland to Widgeon Lake. About

Figure 2. Location of Pukaskwa National Park, Ontario



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96% of the area is covered by vegetation, with the remaining 4% water. Lakes average 5 ha in size, with the largest (Birch L.) being 168 ha (Geomatics, 1996). The land base to the east is the White River Forest under licence to Domtar Inc., based in the town of White River. South of the park, the area is under licence to Clergue, a consortium of wood product companies based out of Wawa.

Until 1995, resource management practices tended to focus on internal park issues: visitor use, campgrounds, species populations. With the revision of the Park Management plan (1995) the focus changed to include an ecosystem approach to resource management(Department of Canadian Heritage, 1995). The goals and objectives of the PMP, specifically the goal of maintaining or enhancing ecological integrity, is implemented through the Ecosystem Conservation Plan (ECP) (Geomatics, 1996). The ECP is based on the ecosystem management principles identified by Grumbine's 10 characteristics of ecosystem management (Grumbine, 1994). One such characteristic is monitoring as a means of quantifying change within the ecosystem. Woodley (1993) describes two approaches to monitoring in national parks: threat-specific monitoring and ecosystem integrity monitoring. Threat-specific monitoring is derived from a known stress with either known or unknown effects. This normally involves hypothesis testing to decipher the relationship between the specific stressor and its effect. Ecological integrity monitoring is where the stress is unknown with either known or unknown effects. This type of monitoring includes a hierarchical approach to ecosystem monitoring and incorporates the principles of stress ecology, landscape ecology and conservation biology (Woodley, 1993). Both types of monitoring are critical to the understanding and protection of National Parks.

A critical component of ecosystem integrity monitoring is a suite of indicators that can be monitored and refined over time to quantitatively reflect and assess ecological integrity (Woodley, 1993). The ECP has identified 10 ecosystem categories with a total of 105 indicators as a means of assessing the ecological integrity of the park (Geomatics, 1996). Partnerships aside, the fiscal and human resources required to assess over 100 indicators are immense. Reducing the number of indicators is required to ensure that, first, they will meet the needs of the ecosystem conservation program to ensure that the goals of the park are being met, and second, not incur a cost that will prohibit continual reporting on the state of the park. With this in mind, it is critical to select effective indicators which will incorporate ecosystem principles, yet be repeatable and efficient.

Two principles of ecosystem monitoring are the spatial and temporal scales at which the attribute is assessed. The indicator cannot be static and must reflect change over time. Monitoring data has been collected in the Pukaskwa area for many years, and while they may not be the best indicators, they would be beneficial in their ability to reflect a changing ecosystem. Also, as much as possible, the indicator must move beyond the boundary of the park, and place the park within its spatial context. In this way, the park can act as a benchmark against different resource management techniques. By integrating with management programs of partner land management agencies, the park can maintain a collection of standard, consistent sets of data that will enable comparisons to be made across multi-scale geographical areas (Geomatics, 1996).

The utilization of indicators in monitoring forest condition is becoming more prominent with government commitment to forest sustainability. The Canadian Council of Forest Ministers (CCFM) made a commitment in the Canadian National Forest

Strategy to "maintain and enhance the long-term health of our forest ecosystems for the benefit of all living things, both nationally and globally, while providing environmental, economic, social and cultural opportunities for the benefit of present and future generations" (CCFM, 1995). This commitment was furthered at the 1992 United Nations conference on Environment and Development (UNCED) in Rio de Janeiro, where the importance of sustainable forest management was recognized (CCFM, 1995). These commitments led to the development of criteria and indicators of sustainable forest management (CCFM, 1995) and these indicators are intended to provide information on trends or changes in the status of forests and related values over time. The criteria for forest sustainability have been included in the Ontario Forest Management Planning Manual (1997) and included within the Canadian Standards Association Sustainable Forest Management System (Z-808-96). Thus, the utilization of indicators is becoming more apparent and has become an important tool in the evolution of the assessment of forest sustainability.

There are 6 forest management criteria which have been identified within the CCFM and the Ontario FMPM:

1. Conservation of biological diversity
2. Maintenance and enhancement of forest ecosystem condition and productivity
3. Conservation of soil and water resources
4. Forest ecosystem contributions to global ecological cycles
5. Multiple benefits to society
6. Accepting society's responsibility for sustainable development

The CCFM suggests 83 indicators to assess the 6 criteria as measures of forest sustainability. No single criterion is a measure of sustainability on its own, but together they can highlight trends or changes in the status of forests and forest management over time (CCFM, 1997). In this way, ecosystem assessment of sustainability on Crown forests is similar to that of ecological integrity on Park lands: the use of indicators as a measure of the state of the forest condition. Therefore applying a similar set of indicators in the park as those being incorporated outside the park would allow for a meta-analysis where spatial comparisons are made across administrative boundaries. Obviously, management goals are different, as are some of the indicators. However, there is significant overlap in two criteria: conservation of biological diversity, and the maintenance and enhancement of forest ecosystem condition and productivity.

By assessing biodiversity with a similar suite of indicators across districts with different management goals, we can begin to evaluate the impact of management on the indicators. Just as important that we ask "What are the effects of timber harvesting on biodiversity?", we should ask "What are the effects of <u>not</u> timber harvesting on biodiversity?". In this way, the park can begin to act as a benchmark or control for the impact of harvesting on the ecosystem. It can also assist in evaluating whether parks and protected areas can maintain biodiversity. It is important that indicators have this degree of commonality, thus comparing "apples to apples". Therefore, by filtering the ECP indicators through the CCFM indicators, the park will be able to assess ecological integrity in terms of forest biodiversity and ecosystem condition within the park and in relation to the surrounding ecosystem.

This approach may help re-evaluate the ECP indicators to a manageable number, both humanly and fiscally. Although this approach reduces the number of indicators of the ECP, assessing the park ecosystem remains a complex and multifaceted issue. It is useful to develop a compartmentalized framework or model that simplifies the components and helps clarify their interrelationships (McKenney et al., 1994). Within a conceptual framework, these indicators should begin to characterize the functional and structural aspects of an ecosystem to assess the impact of human activity on biological systems (Noss, 1995). A structural framework is key to selecting indicators, thus revealing how and where ecosystem attributes change.

PUKASKWA NATIONAL PARK: FOREST INTEGRITY, FRAMEWORK

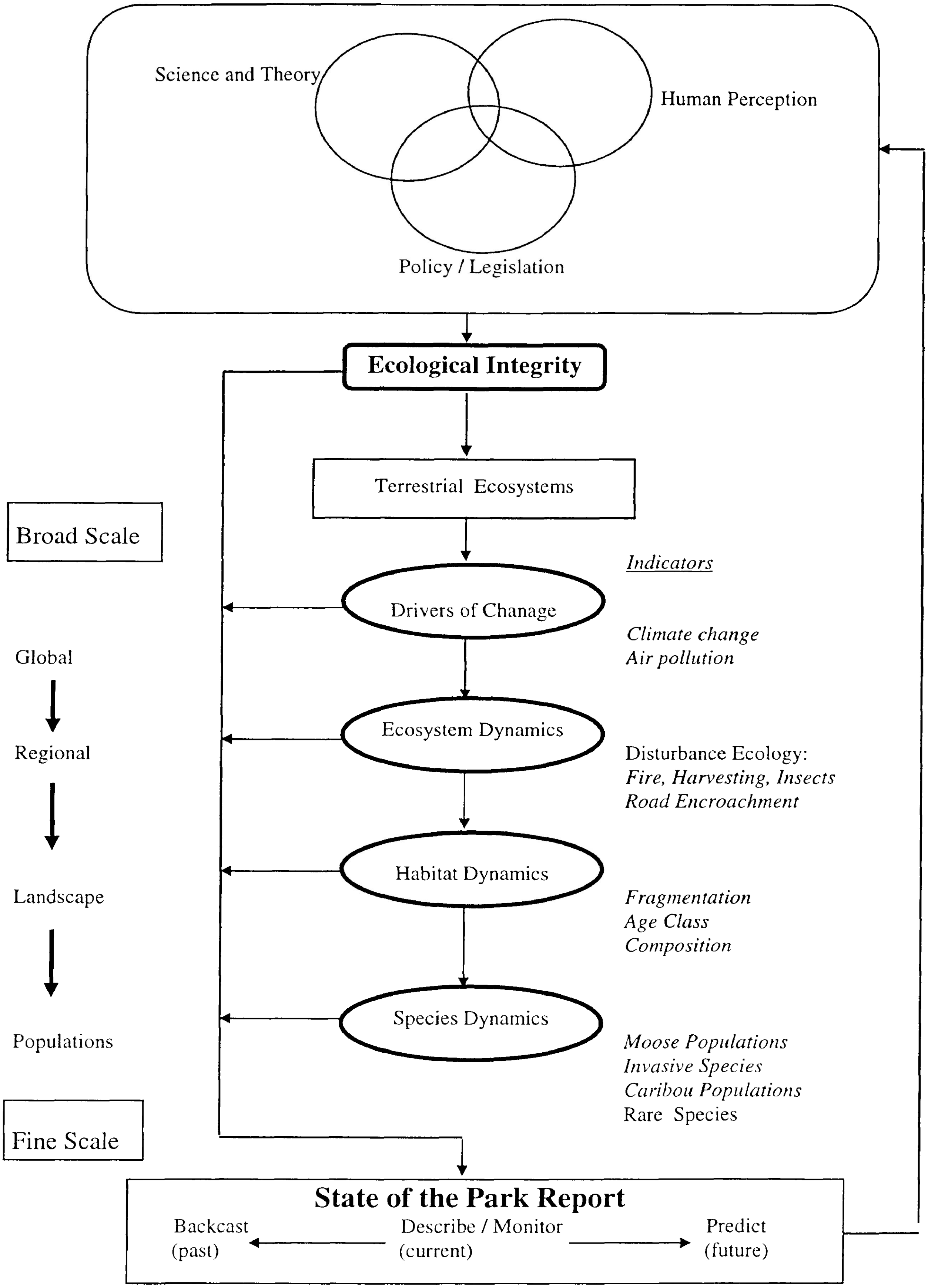
The purpose of the framework is to direct park management towards its desired value. The objective of the analysis is to reflect the condition or state of the park and how it is changing over time. This state of the park report is akin to a report card on how park management reflects upon park values. This, in combination with human attitudes, influences how the park is managed, both in terms of science and policy. It develops into a feedback loop of adaptive management, with ongoing assessment and adjustment.

To better understand the state of the park, a series of indicators at various scales of influence are required. Concepts such as hierarchical context, ecological boundaries, monitoring, data collection and adaptive management must be considered in selecting indicators. However, assessing integrity is as much a reflection of the human perceptions and policy as it is science. Data availability and budgetary constraints also influence indicator selection. Undoubtedly, assessing integrity will be an evolutionary process. As data become available, and ecosystem understanding increases, ecosystem assessment will be improved. Together, these indicators reflect the "state" of the park. A summary of quantifiable measures will continue to influence the perception, science and policy surrounding ecological integrity. Unlike Environment Canada's State of the Environment reporting, this state of the park does not quantify societal response, or human activity for each indicator. It restricts its reporting to the current condition of the park with some interpretation of the effects.

This framework classifies the park forest ecosystem into four hierarchical scales of influence ranging from broad to fine scales. These are: drivers of change, ecosystem dynamics, habitat dynamics, and species dynamics.

Drivers of change are macro-scale contributions to understanding the state of the park. They are characterized by their transboundary, multi source and level of

Figure 3. Framework for Assessing Terrestrial Integrity for Pukaskwa National Park



influence. Its broad-scale influence "drives" the ecosystem. While there are numerous macro-scale influences such as latitude and altitude, changes at this scale are extremely limited. Measurable changes for Pukaskwa National Park include climate change and air quality.

The drivers of change have the most direct influence on the next level, ecosystem dynamics (e.g., regional scale impacts to disturbance cycles in the boreal forest). Such indicators include fire cycles and spruce budworm cycles in Pukaskwa National Park. Another major influence at the ecosystem scale is the forest road network. Although more accurately a driver of change, the road network density concern is on a scale of the greater Pukaskwa region.

It is the physical disturbance on the landscape that most influences habitat dynamics of the park and areas surrounding the park. Habitat concerns include forest fragmentation, age class distribution, and forest composition. Another measure of habitat dynamics is the impact of disturbance (particularly roads or human corridors) which influence the level of invasive or non-native species into the area. Many are incidental and non-spreading, but a few invasive species can have serious repercussions regarding habitat survival (i.e., purple loosestrife in wetlands).

What is often most influenced by habitat is species dynamics. These are often the most common level of data collected and have short response times to change. Moose (*Alces alces*) populations, caribou (*Rangiferous tundrus*) populations, endangered species and genetics are species level indicators which measure change. They are often most influences by changes in habitat dynamics and normally respond to other pressures.

Together these types of indicators attempt to reflect the state of the park. Certainly there are more effective indicators, but these have the ability to reveal change as they have already been measured for a number of years.

INDICATORS

DRIVERS OF CHANGE: CLIMATE CHANGE

Climate change has had a major effect on the structure of biotic communities (Noss and Cooperrider, 1994). Climate change links a multitude of phenomena, including: climatic instability, atmospheric dust, jet stream movements, El Nino effects, shift in vegetation zones, increased soil erosion, fire frequency, and species extinctions (Forman, 1995).

Climate has changed continuously, at one rate or another, throughout the history of the earth. One of the most important climate induced forces shaping the biodiversity of North America has been the periodic advances and retreats of continental glaciers in relatively recent times from the Pleistocene to the present (Noss and Cooperrider, 1994). Climates have usually changed slowly in the past. However, human influence appears to be accelerating climate change. Increasing concentrations of carbon dioxide into the atmosphere, due to the burning of fossil fuels, trap energy radiating from the earth. These gases are commonly referred to as "greenhouse gases". Global atmospheric CO_2 concentrations increased by 3.8% between 1985 and 1994 (Environment Canada, 1996). In Canada, temperatures have also been rising steadily since the 1970's (Environment Canada, 1996). Simulation studies of expected changes in species ranges and changes in ecosystem dynamics have indicated that rapidly changing climatic conditions could significantly thwart natural-area protection efforts at a global scale (Haplin, 1997).

Concern has been expressed that if global temperatures continue to rise there may be contraction in the forests, extinction of species, and increased biological invasions (Forman, 1995; Vitousek et al, 1996). At greatest risk is the boreal forests. Loh (1996) states that 2/3 of the boreal forests are likely to be affected by climate change, and 25-40% of which are expected to disappear altogether, mainly through fire and pest attack (Loh, 1996). With Pukaskwa National Park at the southern extent of the boreal forest, the consequences could be dramatic.

The Canadian Forest Service has expressed concern that climate change can influence the range of tree species and affect the growth and productivity of forests including disturbances such as fire and drought and thus is, a major factor in determining the sustainability of Canada's forests (CFS, 1997).

Weather data has been collected within the greater Pukaskwa area from 1888 to 1975 in White River. Beginning in 1953, weather data has been collected in Marathon, and since 1985, in Pukaskwa National Park. Both the Marathon and Pukaskwa stations are administered by Atmospheric Environment Services (AES) branch of Environment Canada, through remote collection networks. Pukaskwa National Park administers two other stations, one at Otter Cove, the other at Soldier Mountain, primarily for fire weather data collection. Temperature at the AES stations has been tabulated into mean monthly temperatures. These means were then averaged to give the mean annual temperature for each year for White River (1888-1975), Marathon (1953-1982) and Pukaskwa (1985-1991).

Amongst these three stations, there is substantial evidence of the coastal effect of Lake Superior between the two near coast stations (Pukaskwa and Marathon) and the interior station at White River. Although there are many factors which influence weather, including topography, latitude and altitude, the predominantly westerly winds off Lake Superior regulate the temperature along the coast (Findlay, 1973). This regulatory condition provides for cooler summers and warmer winters in Marathon and along the coast of Lake Superior. This coastal area is approximately 4°C warmer and moves inland approximately 14 km (Findlay, 1973).

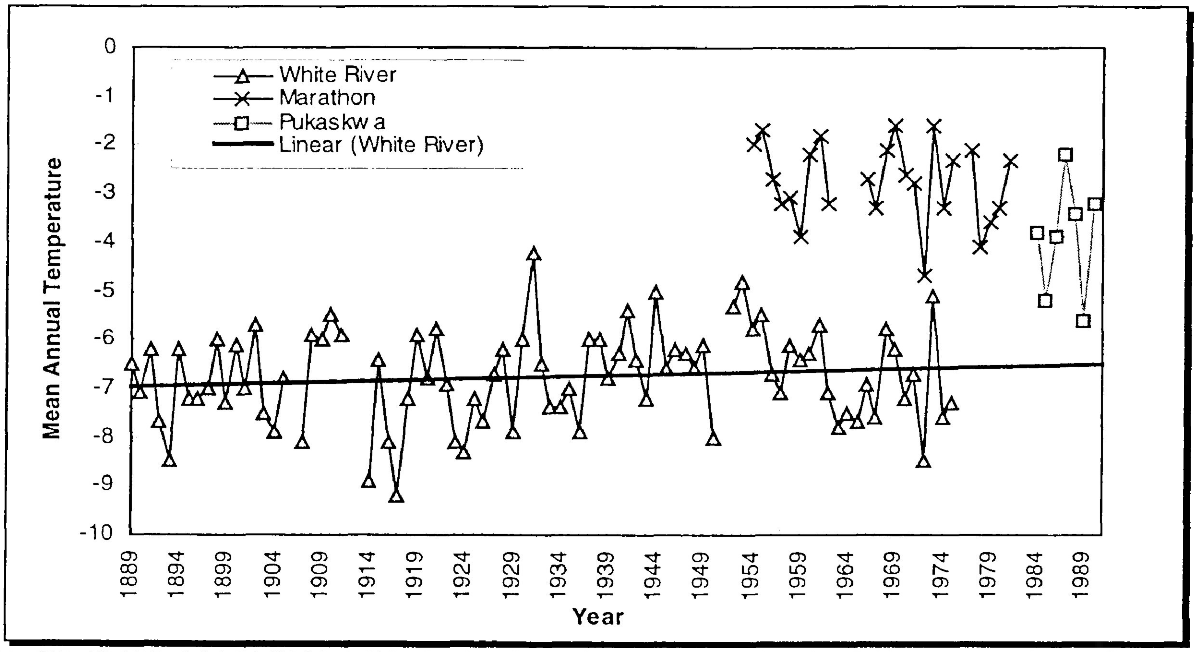


Figure 4. Mean annual temperatures for White River, Marathon and Pukaskwa National Park.

Over the course of >100 years of weather collection, there has apparently been a slight rise in annual temperature (ca. 0.5° C) based mostly on White River data. It is expected that although the White River station and the coastal station vary due to the coastal effect, the overall change and difference between the two should remain constant due to their proximity to one another.

There are a few extremes in the climate data but most records fall within one standard deviation of the mean. From this it is difficult to assume that the temperature in this region is rising within the park ecosystem. However, this should not act as evidence to contradict the effects of increased CO_2 emissions into the atmosphere. Future monitoring will assist in detecting climatic instability.

Although it is not within the park's control, it is essential to monitor the climate in this area, particularly due to its proximity in the southern limit of the boreal forest where impacts could be most acute.

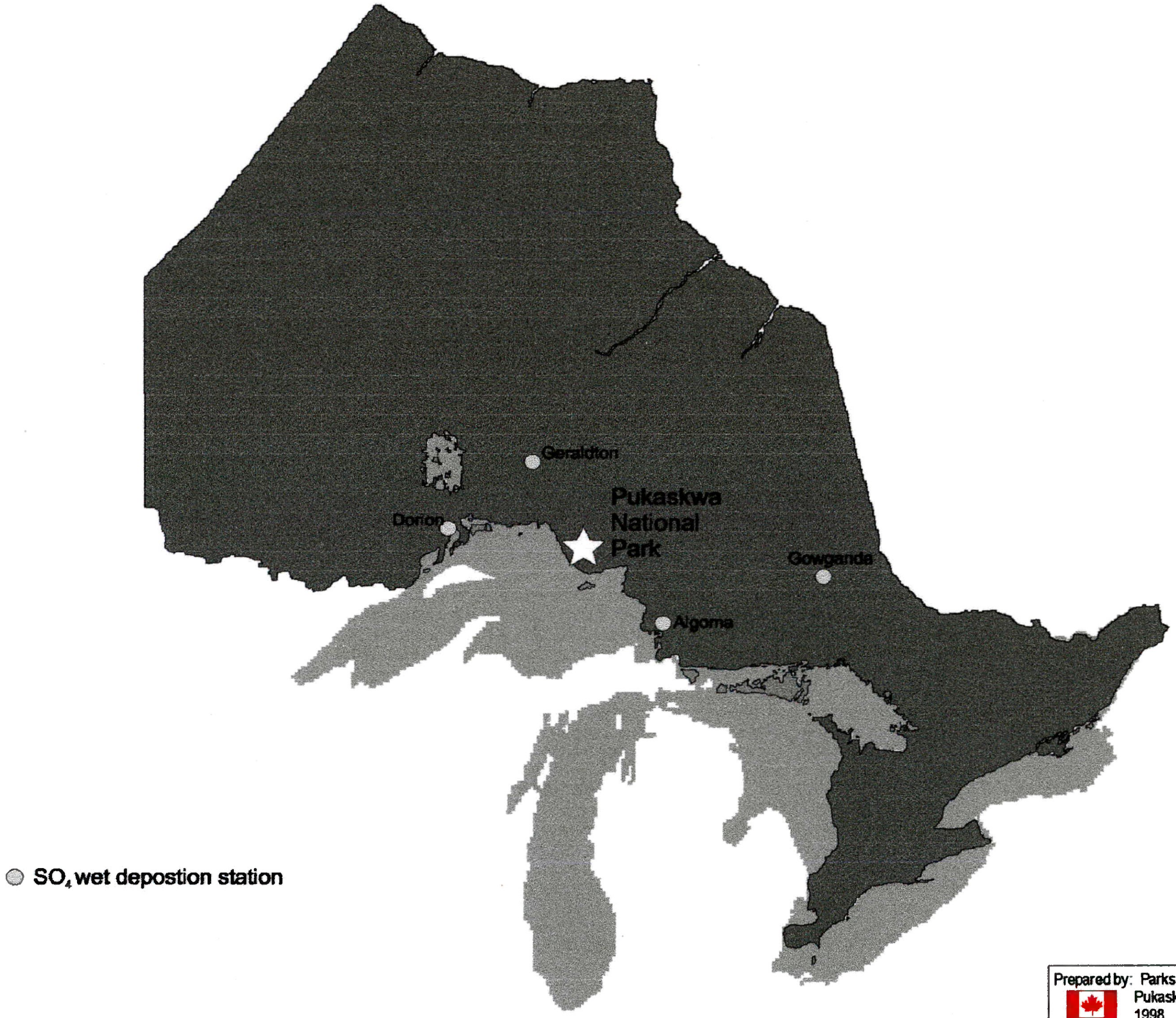
DRIVERS OF CHANGE: SPATIAL TRENDS IN WET SULPHATE DEPOSITION IN NORTHERN ONTARIO

In the past, people assumed that the atmosphere was so vast that materials released into the air would be widely dispersed and their effects would be minimal (Noss and Cooperrider, 1994). However, emissions from the combustion of fossil fuels of nitrogen oxides (NO_x), sulpher dioxide (SO_2), heavy metals, and organic contaminants combine with moisture in the atmosphere to produce nitric and sulfuric acid. This acidic moisture may be transported great distances before being deposited as rain, fog, snow, or dust (Moyle and Leidy, 1992). The effects are not "minimal".

Of Canada's total land area, about 4 million square kilometers, or 43%, is highly sensitive to acid rain (Environment Canada, 1996). This is primarily a concern on the boreal shield, including Pukaskwa National Park, where shallow soils and extensive granite bedrock have little ability to neutralize acidic pollutants. The effects on aquatic ecosystems in boreal environments have been well documented. Paralleling the concern over the effects of acid rain on aquatic ecosystems is concern over its effects on forests. "There is no doubt that acidic precipitation has a direct adverse effect on vegetation, including damage to the cuticle, interference with guard cells, disturbance of metabolism and poisoning of cells, interference with reproduction, accelerated foliar leaching, alteration of mycorrhizal and nitrogen-fixing associations, alteration of host-parasite relations, and increases in susceptibility to other stresses" (Tamm and Cowling, 1976, from Kimmins, 1997a). Environment Canada (1996) found that acid precipitation has caused the dieback and deterioration of white birch in eastern Canada.

There has not been any data collected on the amount or concentration of acidic precipitation in Pukaskwa National Park. However, beginning in the early 1980's, Environment Canada has collected precipitation characteristics, including concentrations of wet sulphate deposition, the leading component of acid rain. The amount of wet sulphate deposition (kg/ha/year) was collected at a number of stations surrounding the park: Dorion (north, coast), Geralton (north, interior), Gowganda (east), and Algoma (south) (Figure 5). Although not directly in Pukaskwa, the data does identify the long term trend of sulphate deposition on a regional scale.

Figure 5. Wet sulphite collection centres near Pukaskwa National Park: Dorion, Geraldton, Gowganda, and Algoma



*data supplied by Atmospheric Environment Service, Environment Canada, Downsview Ontario Canada

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The data analyzed the total amount of wet sulphate deposition in kg/ha/year in relation to the total amount of precipitation. This standardizes the values to assess actual change in the amount of wet sulphate deposition in relation to the total volume of rainfall. Seasonal breakdowns were not incorporated, but may be valuable if further attention is warranted in acid rain effects, particularly acid shock in the spring.

The results of this indicator reflect the environmental condition, but not the effects, of acid precipitation in the Greater Pukaskwa Ecosystem. There was an average 10 year data set for each of the four stations, and on average the amount of wet sulphate deposition proportional to the amount of rain has been decreasing over the 10 year period by approximately 1% per year, totaling 11.25% over the 10 year period.

The amount of wet sulphate deposition in Geralton station increased by 8% over a 9 year period from 10.84 kg/ha in 1984 to 11.17 kg/ha in 1992 (Figure 6). Geralton averaged 70.5 cm of precipitation per year and 8.76 kg/ha/year of wet sulphate deposition.

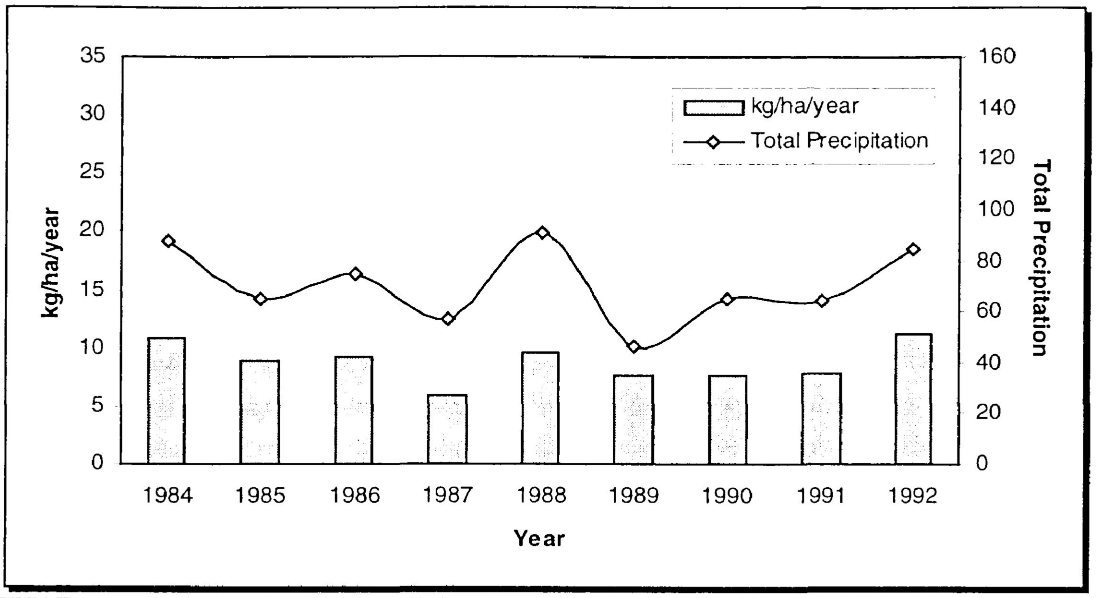


Figure 6. Wet Sulphate deposition and total precipitation, Geralton, Ontario, 1985-1994.

The amount of wet sulphate deposition in Dorion station decreased by 12% over a 10 year period from 11.04 kg/ha in 1981 to 10.6 kg/ha in 1991 (no data for 1989). Dorion averaged 74 cm of precipitation per year and 11.07 kg/ha/year of wet sulphate deposition (Figure 7).

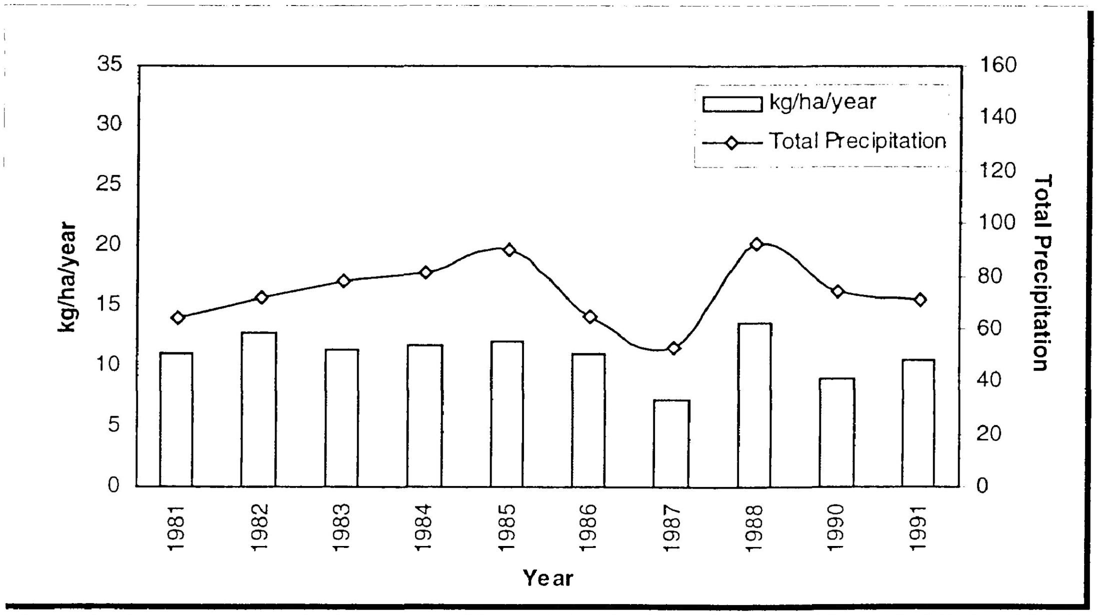


Figure 7. Wet Sulphate deposition and total precipitation, Dorion, Ontario, 1985-1994.

The amount of wet sulphate deposition in Gowganda station decreased by 36% over an 10 year period from 23.21 kg/ha in 1981 to 16.21 kg/ha in 1990 (Figure 8). The majority of that decrease was after 1981 where the amount of wet sulphate decreased from 23.21 kg/ha to 12.34 kg/ha in 1982. Between 1982 and 1990, there was an 8% decrease in wet sulphate. Gowganda averaged 70 cm of precipitation per year and 15.1 kg/ha/year of wet sulphate deposition.

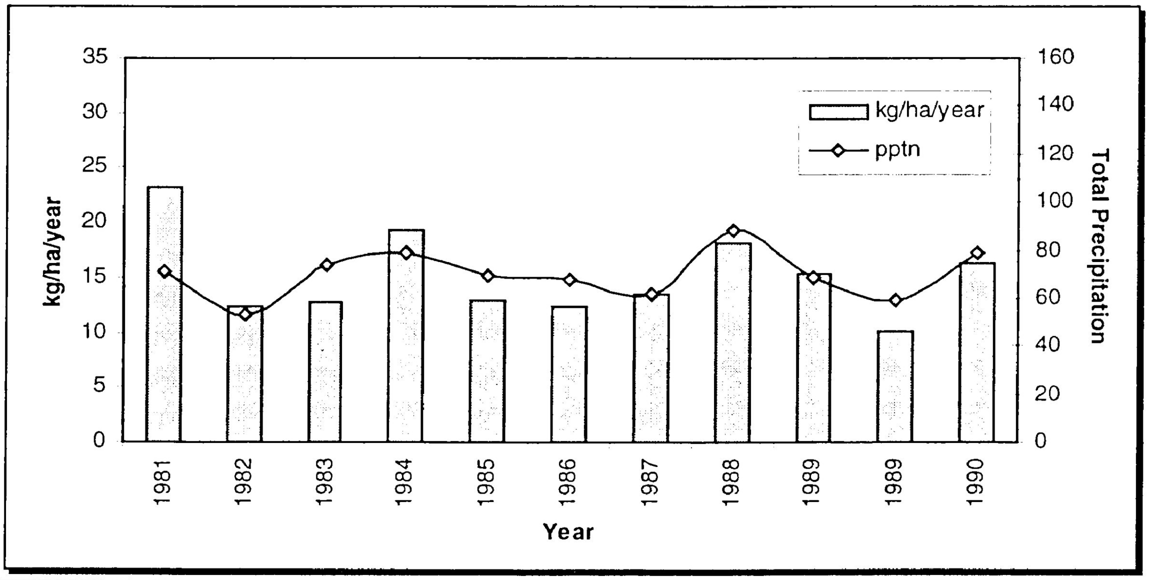


Figure 8. Wet Sulphate deposition and total precipitation, Gowganda, Ontario, 1985-1994.

The amount of wet sulphate deposition in Algoma station decreased by 33% over a 10 year period from 31.2 kg/ha in 1985 to 17.34 kg/ha in 1994 (Figure 9). Algoma averaged 127.3 cm of precipitation per year and 23.2 kg/ha/year of wet sulphate deposition.

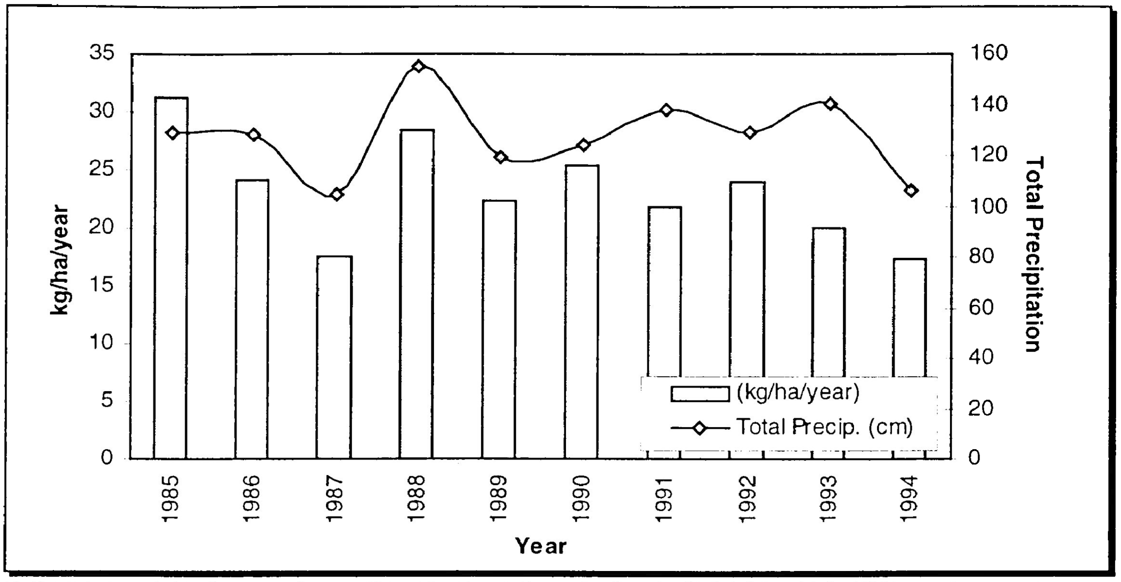


Figure 9. Wet Sulphate deposition and total precipitation, Algoma, Ontario, 1985-1994.

In the early 1980's, the Aquatic Effects Group, established under the Canada/U.S. Memorandum of Understanding on acid rain, determined that sites experiencing 20 kg/ha/year or more, of wet sulphate deposition were experiencing acidification damage (Environment Canada, 1997). Between 1980 and 1994, the area of eastern Canada receiving more than 20 kg/ha/year of wet sulphate deposition has been decreasing. In 1980, Environment Canada found that 700,000 square kilometers of eastern Canada received more than 20 kg/ha/year. 1993 results found that less than 300,000 square kilometers of eastern Canada received that much wet sulphate deposition.

Part of that area includes the Algoma district north of Sault Ste. Marie, south of Pukaskwa National Park. For 8 of the 10 years monitored, Algoma received greater than 20 kg/ha/year. This is likely due to the proximity to industrial steel production in Sault Ste. Marie.

The three other stations surrounding Pukaskwa National Park fell below the critical limits set by the Aquatics Effects Group in all but one of the 30 sampling station years. It should also be noted that the amount of wet sulphate in Geralton is not declining as the other stations, but remains fairly stable.

It is expected that the concentration of wet sulphate deposition in Pukaskwa National Park is similar to the surrounding communities, particularly Geralton and Dorion. If Dorion and Geralton serve as guides, Pukaskwa is estimated to be receiving 8 to 14 kg/ha/year of wet sulphate deposition within average precipitation volumes. The average precipitation is slightly higher (1983-1991, mean 84 cm), consequently the total volume of SO_4 would likely be higher, but not to the levels observed in Algoma.

With these results, one would be lead to believe that the amount of wet sulphate deposition is decreasing, and the park is not within the area of concern as set by Aquatic Effects Group. However, the shallow soils and acidic bedrock of Pukaskwa make the area more sensitive to lower amounts of acidic precipitation. This is particularly evident in the aquatic ecosystems where acidification is the "primary cause for some lakes being totally devoid of fish life" (Schiefer and Fellbaum, 1996). In 1990, the Inland Waters Directorate of Environment Canada assessed the sensitivity of lakes in Pukaskwa to acidification. "Of the 59 lakes investigated, 32 were classified as having extreme sensitivity and 23 had moderate sensitivity to acidification. 41 of the 59 lakes had acidity levels below the water quality guideline (pH 6.5) for the protection of aquatic life, and 20 of those had pH levels below the biotic threshold of pH 6.0 " (McCrea et al., 1990). Even low concentrations of wet sulphate deposition may have a negative effect on the park ecosystem.

Optimistically, wet sulphate deposition is decreasing, despite continual industrial output and human resource consumption. Although Pukaskwa National Park does not receive the critical limit of 20 kg/ha/year set by the Aquatic Effects Group, the park appears to be sensitive to low concentrations of acidic precipitation. The current levels entering the park, estimated between 8 kg/ha/year to 14 kg/ha/year, may have a negative impact on the aquatic system. The effects of acid precipitation on the terrestrial ecosystem in Pukaskwa National Park remain unknown. However, due to its sensitivity, it may be necessary to further decrease sulphate levels further if the park ecosystem is to withstand the effects of acid precipitation.

ECOSYSTEM DYNAMICS: DISTURBANCE ECOLOGY

Landscape dynamics throughout much of the world tend to be a function of exogenous and endogenous processes or disturbances which result in a dynamic pattern of communities at different stages of development (Forman, 1997). Many landscapes tend to be in a state of continual flux and non-equilibrium as a result of fluctuating disturbance regimes and scale effects between disturbances and landscapes (Methven and Feunekes, nodate; Botkin, 1990; Noss and Cooperrider, 1994). Accepting the overall control of climate on biological and physical processes, the inherent pattern of vegetation type in Pukaskwa is controlled by topographic and edaphic features through such attributes as elevation, aspect, texture, moisture regime and nutrient availability (Lopoukhine, 1989). Superimposed on this inherent pattern is an induced pattern of age classes created by natural and human-caused disturbances, such as forest fire, insects, and timber harvesting. Equally, pattern is created at a fine scale by gaps representing the microheterogeneity or microhabitats within a community (Forman, 1995).

The ecosystem dynamics evaluates three indicators of landscape level disturbance forces within the Pukaskwa National Park ecosystem: fire, spruce budworm (*Choristoneura fumiferana*), and harvesting.

Fire

Vegetation management decisions at Pukaskwa National Park are based within the Vegetation Management Plan (Lopoukhine, 1989). Fire dominating succession models (e.g., Kayll, 1968), have been adopted into the Vegetation Management Plan (Lopoukhine, 1989) and the Park Management Plan (1995). The Vegetation Plan states that to maintain the ecosystem in a healthy natural state, a fire return interval of 75 (+/-50) years is required (Lopoukhine, 1989). With the park measuring 1878 km^2, an average of 2500 ha / year must burn to achieve a 75 year return interval.

Early records of planned and accidental Native burning along the coastline for blueberry propagation and creating favourable moose habitat have been recorded in early European histories (Marsh, 1976). In 1823, J.J. Bigsby, while traveling near Pukaskwa noted that "the Indians burn large tracks of pine barrens in order to favour the growth of very useful autumnal fruits"(Marsh, 1976). However, it is difficult, if not impossible to estimate the extent to which native burning occurred.

By the 1900's, fire was discouraged within the province. The fire history for Pukaskwa National Park has been mapped back to the 1920's. Excluding fire from the landscape has been the objective of both provincial and federal land managers throughout Ontario. However, due to the remote and roadless character of the future park, fire suppression had limited effect until the inclusion of advanced techniques of the 1960's. Between 1920 and 1960, there was approximately 5 large fires (>1000 ha) within the current park boundary. The 1936 burn from Brush Creek to the Bremner River was a particularly large fire covering an area of over 47000 ha. (Figure 10). Within the Greater Pukaskwa Ecosystem there have been 6 large fires since 1923 (Domtar Inc., 1998). Two of the fires occurred in the 1920's, and one was the same 1936 Pukaskwa burn. The three remaining fires were in 1954 (2 fires measuring 31900 ha) and 1976, a 500 ha railway fire. The remaining fires have been small (<100 ha) (Domtar Inc., 1998).

However, since the 1960's, fire has had a limited role on landscape disturbance with 21 fires covering 55 ha between 1957 and 1997 in Pukaskwa National Park (Figure 10). In order to encourage fire as a disturbance agent within Pukaskwa National Park, 1998 saw the first "prescribed burn", with a 23 ha understory white pine (*Pinus strobus*) burn near the south end of the park.

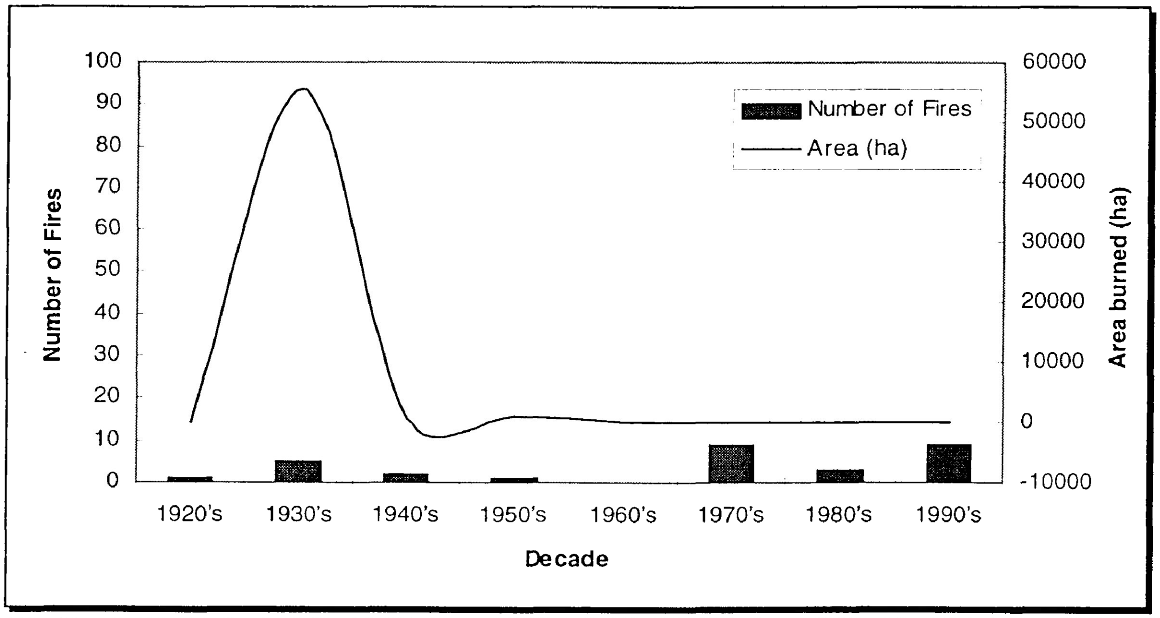


Figure 10. Number of fires and area burned for Pukaskwa National Park, by decade, 1920-1990.

Undoubtedly, fire plays a tremendous role in the boreal forest dynamics. For Pukaskwa National Park, there has been a total of 30 fire starts over the past 75 years (1923-1998), or an average of 4 fires per decade. Forest fires had their greatest influence in 1936, when over 47,000 ha were burned in one fire along the north end of the park. From this, one could believe that there are few fires with the park, and that they tend to be large in terms of area burned. Also, there is no compelling evidence that fire suppression has altered the vegetation dynmaics within the park at this point.

Spruce Budworm

Vegetation in terms of structure, composition, and distribution is greatly influenced by insects within the boreal forest (Poitevin et al., 1989). The spruce budworm is considered by many to be the most significant of the biotic disturbances in the boreal forest (Urquizo et al., 1998). Epidemic predation by the spruce budworm is a biological process triggered by a combination of climatic conditions and high proportions of mature fir and spruce in the overstory (Methven and Feunekes, nodate). This process becomes a cyclical pattern of fir mortality followed by fir recruitment from abundant regeneration and has supported these forests (Morin, 1994). The entire park is and has been susceptible to budworm infestations and is a predominant disturbance factor for the Greater Pukaskwa Ecosystem.

Insect monitoring in Ontario has been done through the Forest Insect and Disease Survey (FIDS) of Forestry Canada. The first recorded infestation of spruce budworm to the area was during the 1920-1930's, originating near Ontario/Quebec boundary moving south and westward (Turner, 1950). Budworm cycled again from 1967 to 1997 throughout Ontario with 18.8 million ha defoliated in 1980 (peak year). Spruce budworm defoliation from Wawa District, which includes Pukaskwa National Park, has declined sharply since a 1992, when 1,621,297 ha were defoiliated to virtually no defoliation in 1997 (Figure 11).

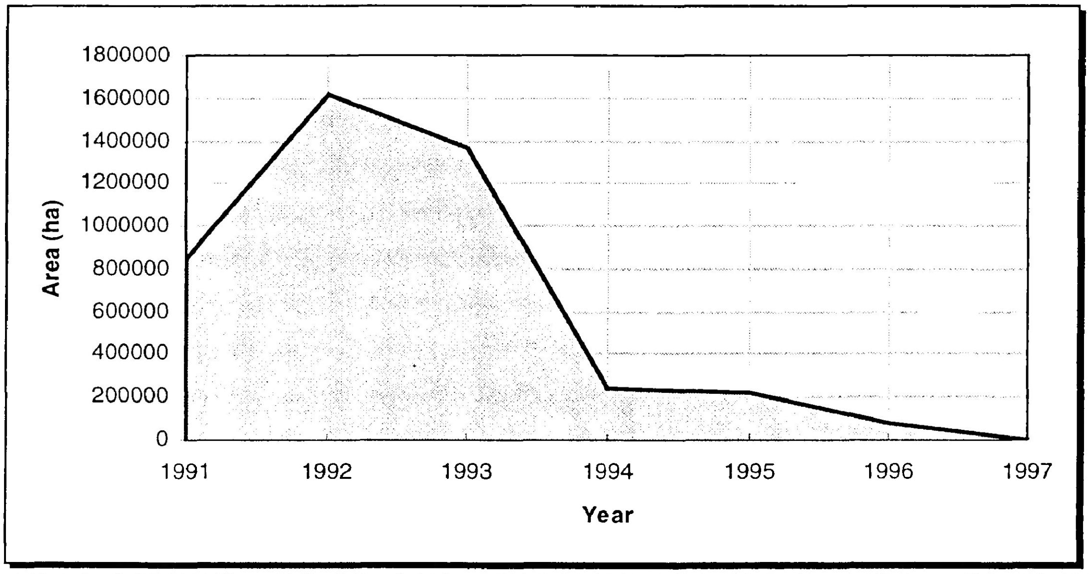


Figure 11. Area of Moderate to Severe Spruce Budworm Damage for the Wawa district, 1991-1997.

Successional studies following spruce budworm infestations in Minnesota found that budworm reduced the basal area of the host species (balsam fir) by 48% (Batzer and Popp, 1985). Consequently, the overstory converted to an earlier successional stage of predominantly aspen and white birch

(Batzer and Popp, 1985).

Harvesting

Commercial harvesting first began in the Pukaskwa National Park area in 1904, one mile inland from Pukaskwa Depot. It was a selective white pine logging operation that ceased in 1910.

In 1917, the Lake Superior Paper Company began logging the Pukaskwa River area. Operations centered around Imogene Cove but gradually moved inland along both the east and west tributaries of the Pukaskwa River. Logging crews were contracted to cut white spruce and balsam fir in prescribed areas (Marsh, 1976). When the operation ceased in 1930, the cut area extended 20 miles up the west branch and 16 miles up the east branch.

The next period of harvesting in the Pukaskwa area occurred in 1937 along the White River. This was a salvage logging operation throughout the areas covered by the 1936 fire. In 1945, a smaller harvesting operation began in from Oiseau Bay to gather construction materials, chiefly pine, for the new mill in Marathon.

Outside of the park, in 1960, logging began near the current location of Obatanga Provincial Park. The focus was largely on black spruce and worked from Obatanga towards Pokei Lake. This operation ceased in 1980 (Domtar Inc., 1998).

Generally, all harvesting in the region was limited by transportation and proximity to a sawmill. However, in 1977, Domtar Inc. established a new sawmill in the town of White River. The opening of the White River sawmill witnessed an explosion of harvesting over the past 20 years (Figure 12). Technological advancement, both in the mill and in the woodland increased the area harvested from approximately 1000 ha/ year to over 3000 ha/ year for the White River Forest Management Area. Harvesting accounts for 2/3 of the total disturbance between 1988 and 1993 (Domtar Inc., 1998). Until 1995, the softwood timber was the only target within the White River forest. Hardwoods were ignored until 1995 with a new strandboard mill in Wawa.

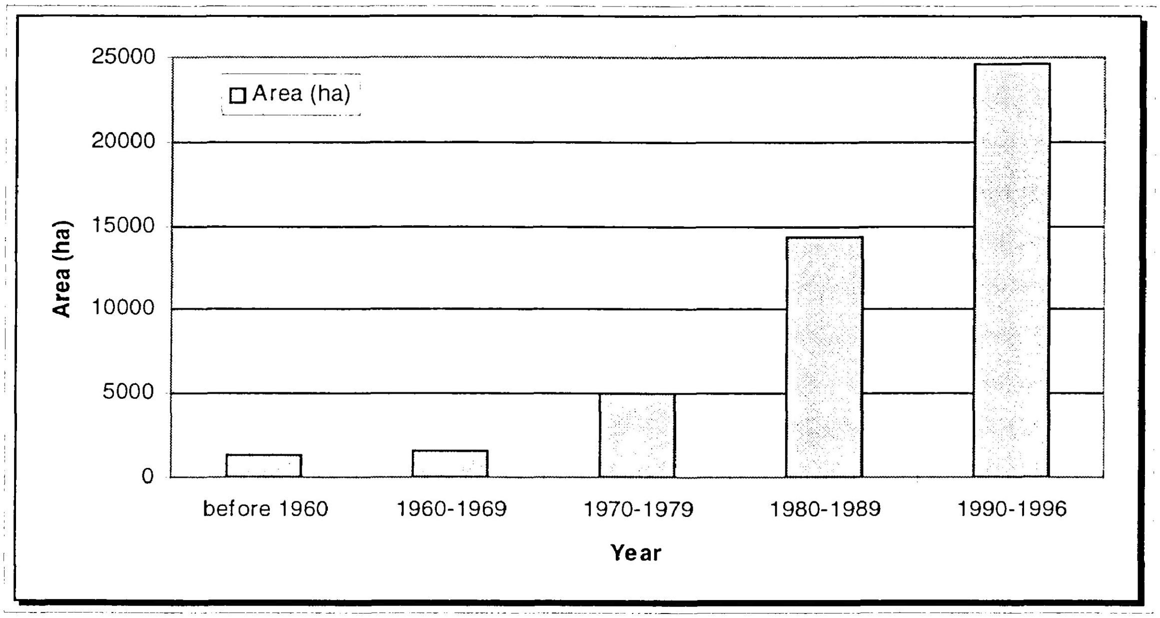


Figure 12. Area harvested within the White River Forest (ha) up to 1996.

The data reveals that spruce budworm has the largest influence on disturbance dynamics of the Greater Pukaskwa Ecosystem. However, its influence is confined largely to the mature balsam fir composition. Pine and spruce is largely being "disturbed" by harvesting. Fire had its largest influence during the 1930's and has a marginal role over the past 60 years.

It is hypothesized that due to the temperate effect of Lake Superior its increased moisture and precipitation, the fire cycle is longer than the 75 (+/-50) years predicted in the Vegetation Management Plan (Lopoukhine, 1989). Yet the role of forest disturbance remains complex. Fire may be limited in terms of starts, but can be large in terms of area burned. Nested within this is re-occuring spruce budworm infestations. Unfortunately, with the limited length of data, it remains difficult to estimate the role fire plays on the landscape. This being stated, similar landscapes have been studied to understand the level of disturbance in the boreal forest. Bergeron and Debuc (1989), who studied succession in the Abitibi region of northwestern Quebec, found an abundance of birch (*Betula payrifera*) in a post 200 year fire cycle with a decrease in jack pine and white spruce. The Abitibi forest composition results in a post 200 year fire cycle forest is similar to that of Pukaskwa's forest composition. This is not to say that fire cannot occur, but those that do, would be either limited in size by the deciduous vegetation cover. This being said, at some point, due to accumulated horizontal structure, periodic large fires can errupt (as the 1936 burn). Therefore, fires may tend to be infrequent in number, with the majority being limited in growth with periodic large scale disturbances. Overall, there is no complelling evidence that supports a fire return interval of 75 years (+/- 50 years) estimated by Lopoukhine in the Vegetation Management Plan (1989).

Assumptions that vegetation communities follow a deterministic and directional pathway structured by finely regulated autogenic feedback mechanisms have become questioned (Christensen, 1988). More ecologists are recognizing that, even under similar abiotic conditions, chance factors play a considerable role in patterns of succession (Kimmins, 1997a; Bergeron and Dubuc, 1989; Christensen, 1988). Natural disturbances of various sorts play an integral role in the long-term maintenance of virtually all ecosystems. It is this multi-directional successional pathway that forms the basis for the ecosystem structure in Pukaskwa.

ECOSYSTEM DYNAMICS: AREA AND SPATIAL DISTRIBUTION OF ROADS WITHIN THE GREATER PUKASKWA NATIONAL PARK ECOSYSTEM BETWEEN 1984 AND 1994

Roads are increasingly recognized as one of the greatest negative impacts to the ecological integrity of any natural ecosystem (Forman, 1995; Schonewald-Cox and Buechner, 1992; Noss and Cooperrider, 1994). Forman identifies five ecologically significant functions of roads, including conduit, barrier (or filter), habitat, source and sink in forested landscapes (1995). The impacts of roads include: habitat loss, the introduction of non-native species, increased human use/access and its potential for poaching, unauthorized access and use, plus the physical dissection of the regional landscape (Forman, 1997). Studies on black bear (*Ursus americanus*) (Broady and Pelton, 1989), wolf (*Canis lupus*) (Mech et al., 1988), moose (Rempel et al., 1997) and caribou (Cumming et al., 1996) reveal population density and distribution changes due to the increased development of roads into forested areas. Current research within the Greater Pukaskwa Ecosystem is finding similar results. As part of the Pukaskwa Predator Prey Process Project (P5), the development and use of roads within the White River forest is the leading cause of wolf mortality. With road development increasing, the number of moralities and the impact to wolf pack structure will increase as well.

Cumulatively, Forman's (1995) ecologically significant functions of roads constitute a leading threat to biodiversity (Noss and Cooperrider, 1994). Until the opening of the Domtar mill in White River in 1978, the number of roads surrounding Pukaskwa was limited. However, with harvesting areas expanding from White River west towards the park, the threat to the park's ecological integrity is increasing.

Satellite imagery was acquired from 1984 and 1994 for the park and the greater park ecosystem. The image was classified into 17 spectral bands including roads. Although not perfect, the image does identify primary, secondary and most tertiary roads in the study area. Thus, there may be some roads not identified due to the smoothing of the satellite image or misclassification of the pixel on the image.

The area of roads were calculated in GIS (SPANS^{TM}). Calculating roads from a remote sensing image requires some estimation and is not designed to measure actual area of road as it is to measure trend in road growth. Roads are classified where the majority of the pixel represents that signal, or reflection. This resulted in a disjointed road network when some pixels did not reflect a road due to a majority reflection of something else. However, enough road pixels were reflected that allowed the GIS to "connect the dots" and vectorize the road map, essentially, making it into a line (not a raster).

The area was grouped into 2 km wide buffers from the park boundary out to 16 km. The study area in this case is encompassed by Highway 17 and Lake Superior. Sixteen kilometers is the closest length to Highway 17 and this is used as the maximum concentric buffer away from the park.

The results show an increase in the total area of roads and that the proximity of these roads is getting closer to the park boundary between 1984 and 1994 (Figure 13). The total area of road within 16 km of the park boundary increased from 4.29 km^2 in 1984 to 12.83 km^2 in 1994. The majority of this road area was out from the north-east corner of the park boundary towards the town of White River (Figure 14). With an average road width of 6 m, this area equates to 715 km (4.29 km^2 / 0.006 km)of road within 16 km of the park boundary in 1984, to over 2136 km of roads in 1994. Again, these number should the trend in road development, not the absolute area of roads.

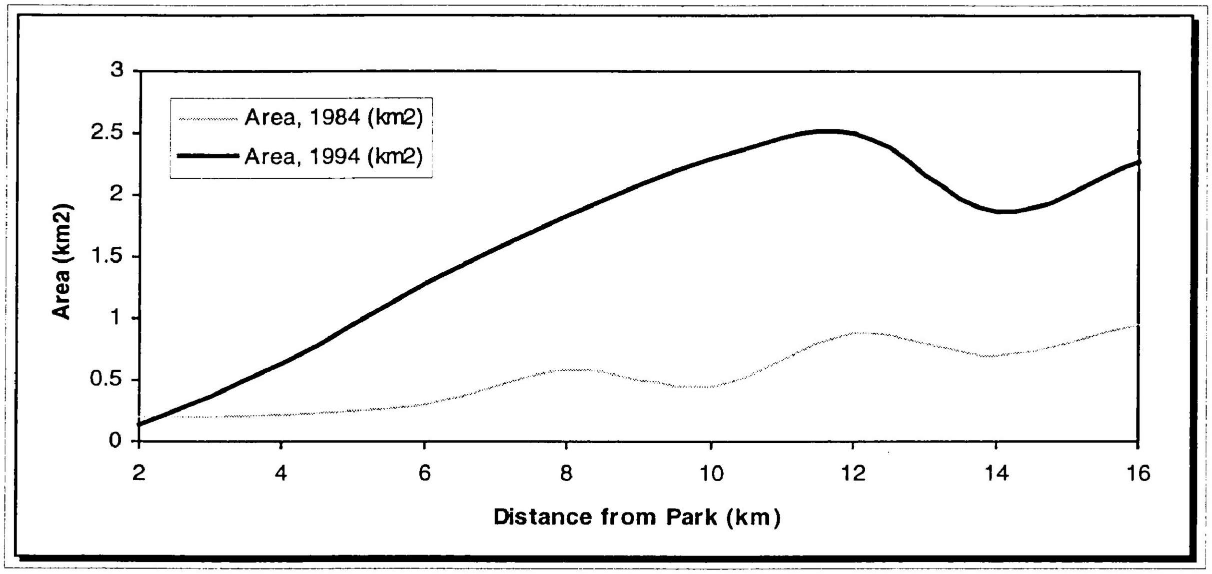
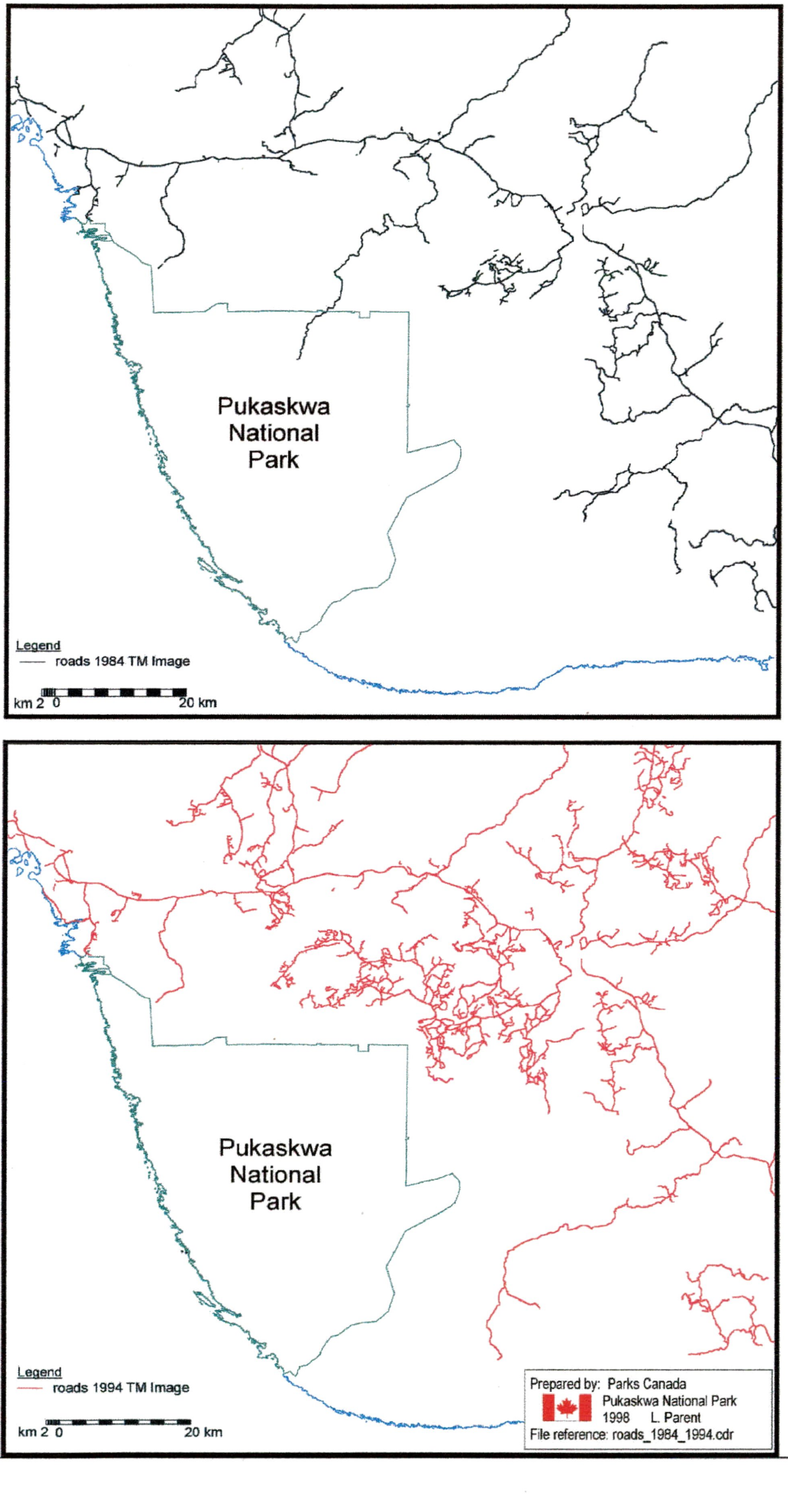


Figure 13. Area of road in proximity to Pukaskwa National Park, from Landsat TM 1984 and 1994 (km^2)

Figure 14. Distribution of roads within the Greater Pukaskwa Ecosystem from Landsat TM data, 1984 and 1994.



Road construction is done for the extraction of timber throughout the White River forest. The satellite image data reveals how road construction has nearly tripled within 16 km of the park between 1984 and 1994. This trend has been continuing and the upcoming plan (1998-2018) for the White River forest will create substantial road construction within 2 km of the park. This type of development may have direct detrimental impacts to the wolf, caribou and black bear populations.

This impact is evident in the Greater Pukaskwa Ecosystem. As part of the P5, Krizan (1997) studied the influence of roads on habitat use and spatial distribution of wolves. Krizan found that the wolves utilized the roads when available and unless near waste disposal sites, roads had little effect on wolf population distribution. However, over the three year study, "road caused mortality from collision and access was responsible for the death of 12 individuals from the five study packs representing 70.6% of the known moralities" (Krizan, 1997). This number may be increasing. Forshner (pers. com., 1998) found that over a one year period (1997), she found 9 wolf mortalities, all directly related to road development. Although results of the study are not final, it would appear that road caused mortality represents a significant factor in wolf survival throughout the region.

What is harder to predict is the countless indirect effects of roads, such as within pack dynamics, predator-prey relations, spatial distributions, and habitat re-characterization. This impact is exemplified with the rate at which these roads are being constructed and productive land base is being lost. The latest forest license plan does not contain a long-term road strategy for this area. Roads are built within every 5 year work schedule but little effort is placed on road de-commissioning or abandonment strategies.

The result will further dissect the park from the surrounding forested area and expand the ecologically significant factors of roads. For example, if human access continues to effect the mortality of wolves (as per Krizan, 1997), it is unlikely that Pukaskwa is large enough to support a sustained wolf population. Reduction in roads and road density is beneficial to the ecological functioning of the park ecosystem.

HABITAT DYNAMICS: QUANTIFYING LANDSCAPE FRAGMENTATION

Here I define fragmentation as the process that converts large areas of relatively uniform vegetation into a landscape mosaic of small patches of vegetation of different age classes, and into a mosaic of small patches of wildlife habitat potential (Kimmins, 1997b; Forman, 1995; Primack, 1993). Fragmentation is caused by natural processes as well as human activities (Forman, 1995; CCFM, 1997). Soil type, disturbance pattern, and water bodies, are just a few of the constraints to homogeneity in terms of forest patch size, age class or wildlife habitat potential. It is separate from dissection which subdivides an area with equal-width lines (e.g. roads, powerlines, railways) (Forman, 1995).

Fragmentation is often referred to as one of the most detrimental impacts to a functioning ecosystem (Meffe and Carroll, 1994). It has been shown to have major alterations in hydrologic regimes, mineral nutrient cycles, radiation balance, wind patterns, soil patterns and has resulted in changing species patterns(Forman, 1995; Meffe and Carroll, 1994). It can effect species movement, connectivity and isolation (Forman, 1995). This, in turn, can impact the number of edge species, number of exotic species, nest predation, and extinction rate while decreasing the characteristic for the dispersal of interior specialists, large home range, species and metapopulation dynamics (Forman, 1995; Hanski, 1997).

However, as much as fragmentation can be detrimental to a functioning ecosystem, it is also critical to the systems viability. Disturbance such as forest fire create the mosaic that *is* the boreal forest. Disturbance creates the structural habitat diversity which is vital to wildlife diversity (Meffe and Carroll, 1994). Therefore, in many ways, fragmentation is essential to the forest dynamics.

Meffe and Carroll hypothesize that there are distinctions between human caused fragmentation and naturally patchy landscapes, the former negative and the later, positive (Meffe and Carroll, 1994). Yet it is difficult to separate the two. Quantifying fragmentation attempts to understand what is there, not what is absent. If fragmentation is the breaking up of a landscape into smaller components, then the source of the disturbance is not the main concern.

Therefore, there must always be some degree of fragmentation - both human and natural in origin. What is more critical is understanding the spatial and temporal dynamics of the landscape. We must focus our attention on the rates at which changes occur, understanding that changes are desirable, natural, and acceptable, while others are not (Botkin, 1990).

The Ecosystem Conservation Plan (ECP) for Pukaskwa National Park has expressed concern for the level of fragmentation in and around the park (Geomatics, 1996). It has been recommended as an indicator of the forest integrity for Pukaskwa National Park (Geomatics, 1996). The level of fragmentation is also recognized as an indicator of ecosystem diversity in the Canadian Standards Association (CAN/CSA-

Z808-96 Appendix A2.1.1.4). In this way, Pukaskwa will be able to contrast the natural level of fragmentation of the park with those areas seeking CSA registration. The level of fragmentation will be different based on a variety of site conditions (e.g. cover type, disturbance regime, soil type). It would not be unexpected to find that fragmentation differs between two areas, even areas adjacent to one another. Of greater relevance is the temporal dynamics of fragmentation and the rate of change between one geographical area and another.

The purpose of this indicator is to assess the level of forest fragmentation and how the fragmentation compares a protected forest (Pukaskwa National Park) to a forest management area (White River and Wawa Crown Forest).

Fragmentation generally increases with patch number, density, and total boundary length in the landscape while average patch size, total interior habitat, and connectivity normally decreases.(Forman, 1995, p.408).

To quantify the landscape characteristics, two Landsat satellite images were acquired from Pukaskwa National Park. The satellite image classification was conducted at Lakehead University CARIS. Landcover maps were derived from Landsat Satellite Thematic Mapper imagery for 1984 and 1991 with an update of the cutovers in 1994. Both images were coded to 1:50,000 NTS mapsheets to spatial error of 25 m. Landsat TM channels 3,4,5 for June, 1991 were used for the classification (Runesson, 1995). This image was updated in 1994 to reveal cutovers to that date. This 1994 update did not reclassify the entire image, yet for this study it will be assumed that there were no significant changes in the landscape characteristics other than harvested areas.

Using the two raster images, I used Fragstats (Mcgarigal and Marks, 1993) to quantify the patch structure. Fragstats quantifies the areal extent and spatial distribution of patches (i.e. polygons on a map coverage) within a landscape.

The Landsat TM image classification produced 16 classes (Table 1). These were reclassified to 7 different classes (conifer, deciduous, mixed, other [wetlands etc.], water, cutovers and clouds). Due to the size of the image, a 72m pixel size was used for analyzing the images.

Table 1. Remote sensing classifications for the Greater Pukaskwa Ecosystem, 1984, 1994

Conifer > 80%, 76-100% crown closure
Conifer > 80%, 51-75% crown closure
Conifer > 80%, 25-50% crown closure
Deciduous > 80%, 51-75% crown closure
Mixed Conifer >50%, 25-50% cc
Mixed Deciduous >50%, 25-50% cc
Non-productive lands
Cutovers
Roads
Water
Wetlands/deciduous non-productive
Inert (rock, sand, bare soil)
Railroad
Hydro
Urban
Cloud

Number of Patches, Patch Density

The total number of patches within the park increased slightly, from 7243 to 8366 (+ 16 %) while the number of patches outside the park has increased from 18397 to 23806 (+ 29 %). The patch density (# of patches / 100 ha) is a better estimate of the patch difference. With the park density increased from 3.9 in 1984 to 4.6 in 1994, whereas the area outside the park increased 3.7 patches per 100 ha in 1984 to 4.9 patches in 1994. (Figure 15 and 16).

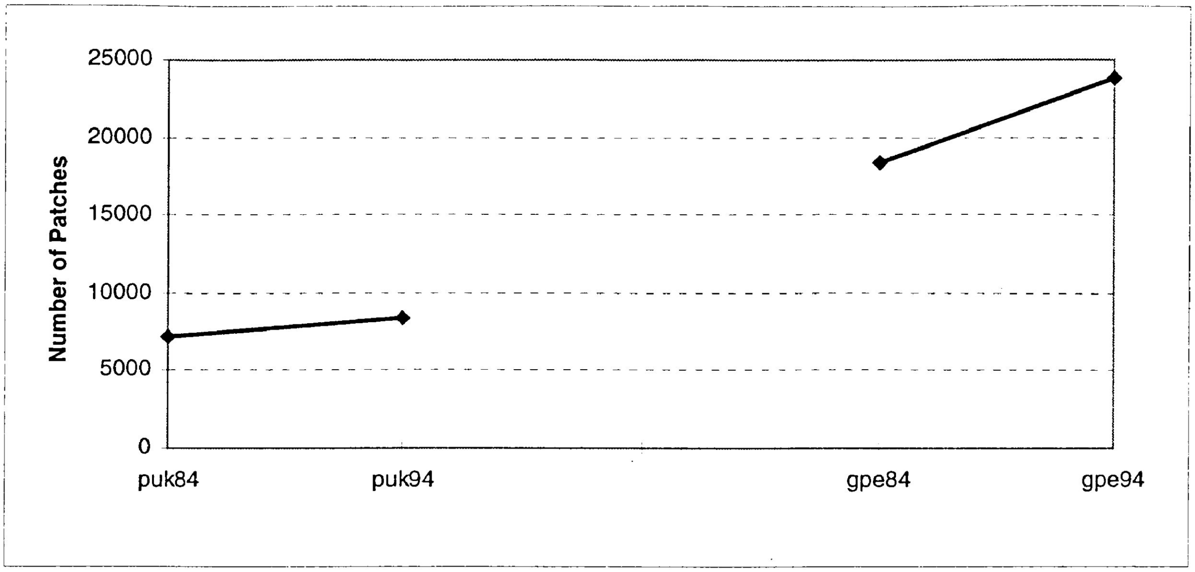


Figure 15. Number of Patches in Pukaskwa National Park and the Greater Pukaskwa Ecosystem, 1984-1994.

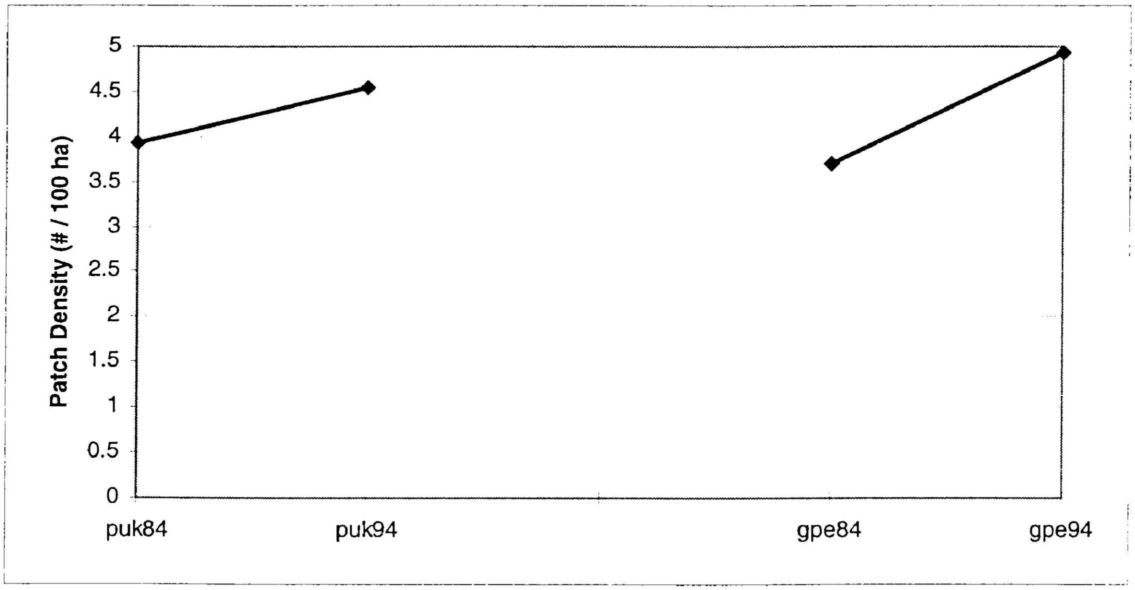


Figure 16. Patch Density, Pukaskwa National Park and the Greater Pukaskwa Ecosystem 1984-1994.

Patch Size

The mean patch size has decreased throughout the entire study area. The mean patch size in the park has decreased from 25.4 ha to 22.0 ha while the area surrounding the park patch size decreased from 27.0 ha to 20.2 ha. The standard deviation for these patch sizes also declined, but is much higher outside the park. (Figure 17)

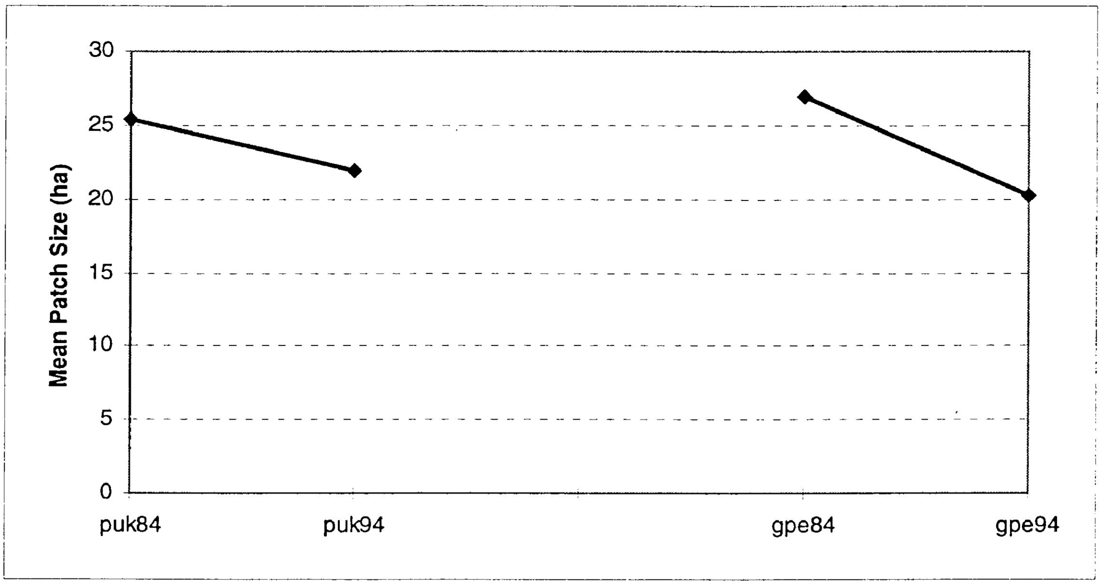


Figure 17. Mean Patch Size (ha), Pukaskwa National Park and Greater Pukaskwa Ecosystem

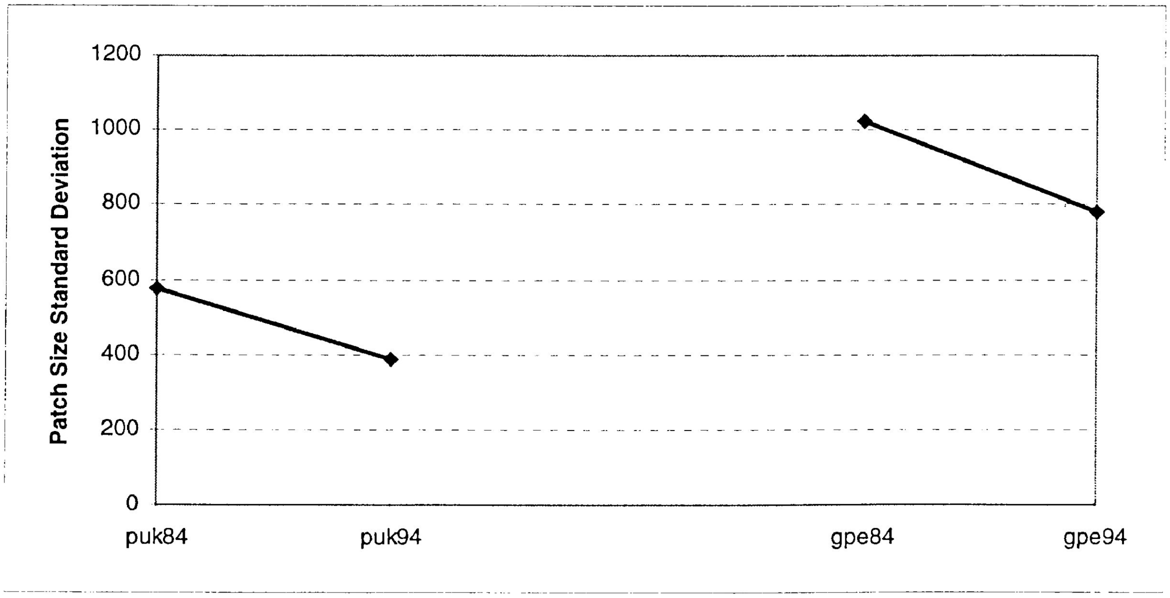


Figure 18. Patch Size Standard Deviation, Pukaskwa National Park and Greater Pukaskwa Ecosystem

Edge Density

The edge density was expressed as a measure of meters per hectare. The edge density increased in Pukaskwa National Park from 58.491m/ha to 62.496m/ha, a 6.8% increase. The area surrounding the park rose from 59.127m/ha to 66.743m/ha, a 12.9% increase in edge density.

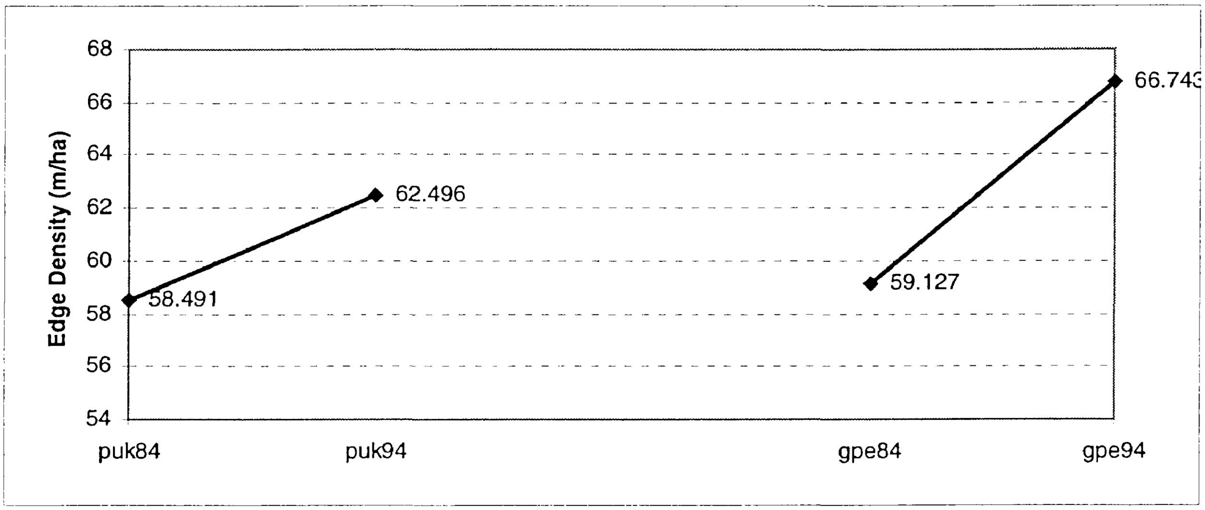


Figure 19. Edge Density (m/ha) for Pukaskwa National Park and the Greater Pukaskwa Ecosystem

Core Area

The core area is measured by defining the interior of patches. The interior was set at areas greater than or equal to 100 m where micro-climatic conditions (e.g., humidity, light) shift to interior forest conditions (Rempel et al., 1997). The core area density increased in both the Park and the Park landscape. In the park the number of core areas per 100 hectares decreased from 3.494 to 3.665, an increase of 4.9% from 1984 to 1994. Outside the park area, the number of core areas per 100 hectares went from 3.562 to

4.024, a 13% increase. The total core area in each of these landscape has decreased by 4694.6 ha within the park (-5%) and by 28844.3 ha outside the park (-12%).

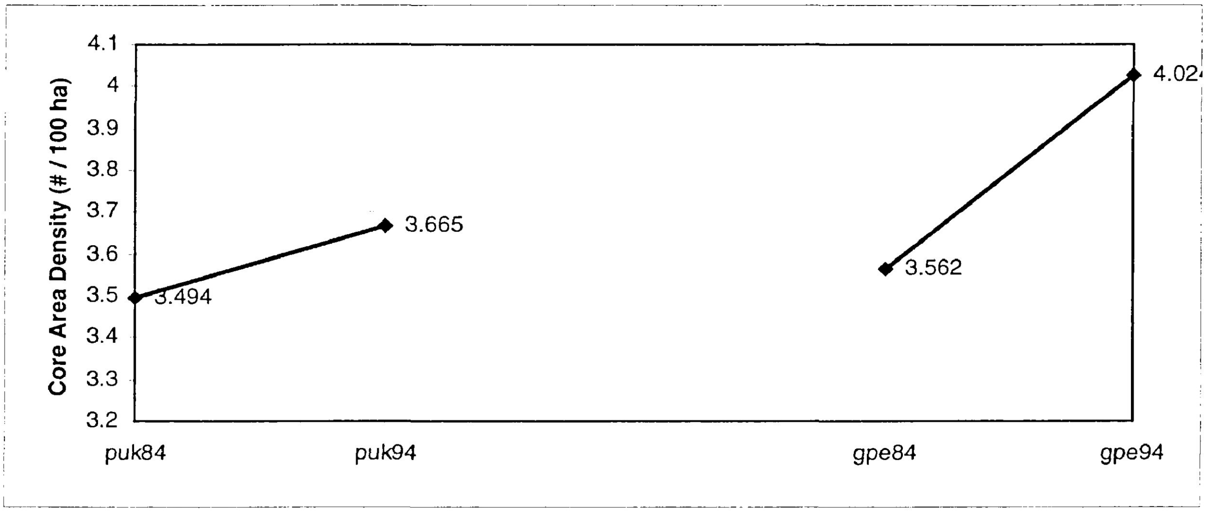


Figure 20. Core Area Density (#/100 ha), Pukaskwa National Park and Greater Park Ecosystem

Analysis

Ten years may not be conclusive to derive definitive conclusions about the change in patch structure over the greater Pukaskwa ecosystem. This being stated, it is interesting to note that the indices reveal a similar trend showing that both areas attain some degree of fragmentation across the landscape and are likely subject to similar forces. It is also worthy to note that the decrease in total core area decreases, while density increases. Thus there are a greater number of core areas, yet the area of those cores is decreasing. Using Forman's characteristics of fragmentation, the Park and the Park landscape has become more fragmented between 1984 and 1994. Between these years, there was a substantial spruce budworm (Choristoneura fumiferana [Clemens]) epidemic that effected much of the area (Forest Insect and Disease Survey, 1997). That, plus the lack of forest fires, subjected the area to similar landscape level forces. It is noted, however, that fragmentation is occurring at a slightly higher rate outside the park, particularly in terms of edge density and total core area. This may be a result of the increased harvesting activity in the White River forest, particularly post-1990. Following the Moose Management guidelines, harvest blocks were smaller, irregular shaped patches. This type of cutting is intended to increase the amount of edge favoured by moose. The result would be an increase in forest fragmentation, different from that that of an uncut area such as Pukaskwa.

Although it is difficult to make definitive conclusions, there is a trend in the level of fragmentation that should be of concern to park management. Operations adjacent to the park boundary have been intensifying over the past 5 years and will continue over the next 20 years. This may have noticeable impacts on the fragmentation of the park in terms of the patch size and core area. If this occurs, there may be unrealized effects on wildlife populations in and around the park (e.g. F. Burrows thesis (in press) - moose movements outside the park to access cutovers).

With the incorporation of natural disturbance cut patterns utilized within the White River forest, the level of fragmentation may be more observable in terms of patch size and density, rather than edge density and core area. Natural disturbance patterns used in this area tend to be larger in size than those used for moose management.

HABITAT DYNAMICS: FOREST AGE CLASS DISTRIBUTION FOR PUKASKWA NATIONAL PARK AND THE WHITE RIVER FOREST

Forest age is often considered an important indicator of the well being of the forest. In disturbance dependent systems, such as the boreal ecosystem, disturbance is reflected within the age class structure. Van Wagner's age distribution model states that the boreal forest should reflect a negative exponential age class distribution, with high proportions of young regeneration and less and less old growth (Van Wagner, 1978). This theory would reflect substantial disturbance with a disturbance return interval at a constant rate. Other age distributions, such as an even distribution, would be more desirable for timber companies as it would maintain a constant supply of wood. Again, this model, which is limited both spatially and temporally, can reveal forest age dynamics. Forest age is important as it relates to habitat preferences for many wildlife species.

For this indicator, two administrative units were quantified: Pukaskwa National Park (1878 km^2), and the adjacent White River Forest (ca. 4000 km^2). My objective was to determine the current age class distribution for both Pukaskwa National Park, and the adjacent White River forest.

Data regarding tree age in Pukaskwa National Park is limited to the 1977 biophysical report (Gimbresky et al., 1977). That report groups the dominant tree species into 5 age classes, representing early through old growth forests. No stand replacing disturbance occurred since that study so the age class distribution from the 1977 report was used by adding 20 years to each age class, resulting in 5 age classes: 0-44, 45-64, 64-

95, 95-115, and 115+ years of age. I used the same 5 classes for the White River Forest based on 1994 data from Domtar Inc.

For Pukaskwa National Park, the highest proportion of trees were aged over 115 years (34%). For the White River forest, the largest proportion were in the 65 to 95 age class (34%). The White River forest has a much higher proportion of younger stands (20%) than that of the park which had none (0%). The White River forest has less than 15% of its forest in the 115 + year class.

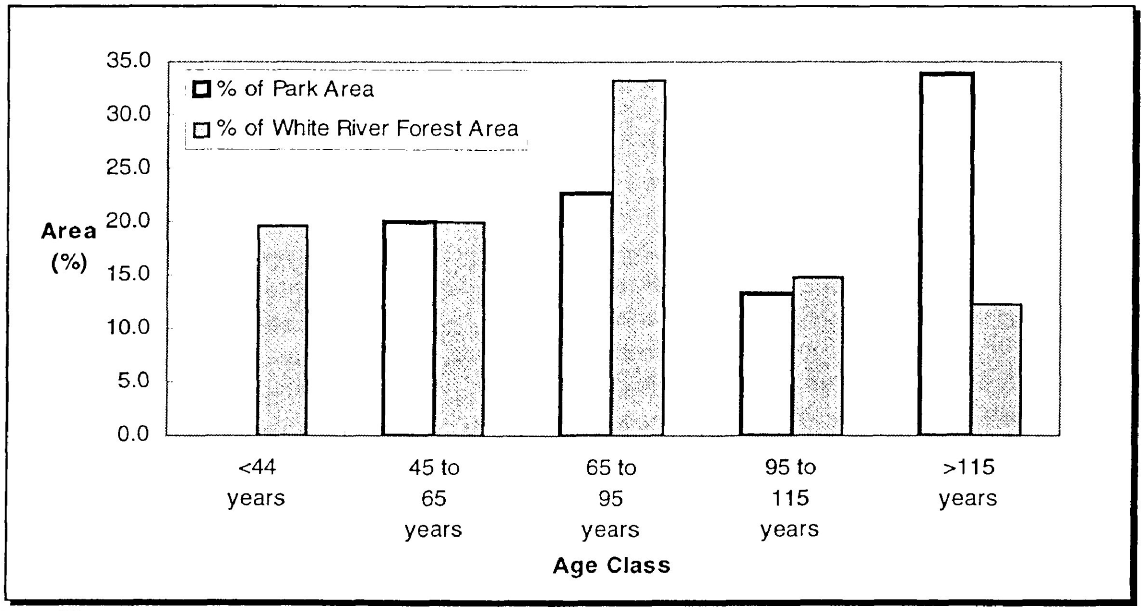


Figure 21. Age class distribution for Pukaskwa National Park and the White River forest.

The mature forest (115+ years) and limited number of complete stands under 44 years of age in the park is most likely a result of the limited stand replacing disturbance within the park. Spruce budworm, while a major force in the forest composition, has not completely eliminated stands. In this way, the influence of budworm on age class distribution is difficult to interpret. This indicator was limited to assessing the age structure of the dominant canopy for each stand.

Stand replacing fire has had a much more dramatic influence on the age structure of the park. The 1936 fire of 47,000 ha in Pukaskwa National Park accounted for the rise in the 45-65 year age class. The 65 to 95 age class was also a result of past large scale, stand replacing disturbances in 1931 and 1924.

Within the White River forest, harvesting, and re-generation has allowed for the opportunity of young growth while reducing the area of older forests. The White River forest more closely resembles an even distribution for harvested forests with a predictable supply of mature forests. Pukaskwa, however, reveals a much more mature forest and very much skewed to the older age class.

Age class distribution and its resulting patch mosaic across the landscape is one of the most important factors in maintaining sustainability. Clearly, there is a spatial difference between age class distribution between Pukaskwa National Park and the White River Forest. Pukaskwa lacks any regenerating stands less than 44 years of age, and has an abundance of older forests over 115 years. The White River forest contains a fair amount of young stands and substantially less older forest. With few stand replacing fires across each unit since the 1950's, forest harvesting and renewal is likely the principle factor in the differing age class distributions. It would then be reasonable to propose that wildlife species preferring young stands would prefer the White River forest, whereas, species preferring older stands would prefer Pukaskwa.

HABITAT DYNAMICS: OVERSTORY FOREST COMPOSITION CHANGE WITHIN THE GREATER PUKASKWA AREA

The purpose of Pukaskwa National Park, in the context of vegetation, will be to "ensure continued representivity of the boreal forest with emphasis inland on boreal mixed-wood ecosystems" (Park Management Plan, 1995). Yet exactly what type and how much of the boreal mixed-wood should be represented must be considered within the context of natural succession. Succession is a process of change in ecosystem structure, function and composition over time (Kimmins, 1997a). This indicator quantifies broad-scale composition of the park and the Greater Park Ecosystem and begins to measure compositional change.

Although it is recognized that the vertical structure of the forest is essential to understanding succession on the stand level, field collection is costly and has yet to be established. However, on the landscape level, satellite imagery can classify the overstory species for the Greater Pukaskwa Ecosystem as a measure of horizontal structure succession. This indicator focus is on compositional change of the dominant overstory canopy for the Greater Pukaskwa Ecosystem.

Landsat TM imagery from 1984 and 1994 was acquired and classified by Lakehead University CARIS. Both the 1984 and 1994 images covered an area including Pukaskwa and the surrounding area from Marathon to Wawa. Two areas were analyzed separately for each image: the park, not including Lake Superior, and the surrounding area out to Highway 17 including large portions of the White River and Wawa Forests. The total area covers approximately 6805 km^2, with approximately one third representing the park.

Both images were originally grouped into 17 classes. Eleven of the 17 classes were grouped into 6 compositional classes: conifer (>80%), deciduous (>80%), mixedwood (<80%), non-productive lands (including wetlands), cutovers, and roads. The remaining six of the 17 classes were not included due to the class absence of any overstory composition and had minor changes over the two images. These classes included water (7.5%); plus railway, urban areas, hydro, clouds, and bare rock.

The park and the area surrounding the park are similar in that they contain over 40% conifer and approximately 20% mixedwood. However, the area of hardwood over the two landscapes are different. Pukaskwa contains an area of over 22% hardwood, while the adjacent land mass is slightly under 8%. The area surrounding the park also contains larger proportions of cutovers (2.72% in 1984, and 3.81% in 1994), and a 4% greater area than the park is classified as non-productive (14%) (Figure 22).

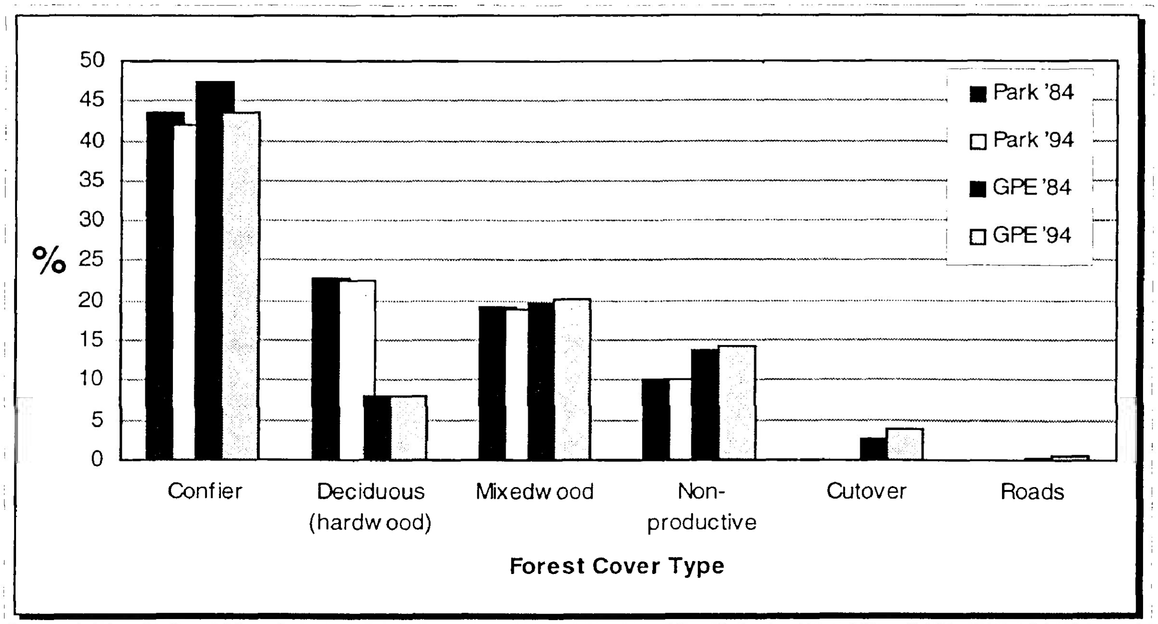


Figure 22. Forest Composition, Pukaskwa National Park and Greater Pukaskwa Ecosystem, 1984-1994.

Note: "GPE" refers to the Greater Pukaskwa Ecosystem EXCLUDING the area of Pukaskwa National Park.

Temporally, neither the park landscape or the area surrounding the park has changed substantially. The 1984 image reflects 99.98% similar as the 1994 image. The area surrounding the park correlates at 99.88% reflecting very slight overall change over the 10 year period. The largest decline in the area surrounding the park is the 4% decline in conifer forests. Also of note is the 1% increase in cutovers and the near doubling of land classified as roads from 0.3% to 0.55%.

Table 2. Forest Composition, 1984 to 1994 for Pukaskwa National Park and the Greater Pukaskwa Ecosystem.

	Park '84	Park '94	GPE '84	GPE '94
Conifer	43.42	41.91	47.42	43.58
Deciduous (hardwood)	22.69	22.61	7.96	7.96
Mixedwood	19.15	19.02	19.72	20.12
Non-productive	10.17	10.13	13.82	14.25
Cutover	0	0	2.72	3.81
Roads	0.01	0.01	0.3	0.55
Other	4.56	6.32	8.06	9.73

Note: "GPE" refers to the Greater Pukaskwa Ecosystem EXCLUDING the area of Pukaskwa National Park.

The temporal variation over the 10 year period revealed very little change. The largest disturbance was the spruce budworm infestation from the mid 1980's to the mid 1990's (Forestry Canada, 1997). It is likely that the budworm had a consistent impact on both the park and the area surrounding the park, reducing balsam fir and white spruce throughout Pukaskwa and the Greater Pukaskwa Ecosystem. Combined with the relative absence of fire, harvesting is the only disturbance difference between the two areas. Softwood harvesting resulted in a 3.84% reduction of conifer cover outside the park.

It is evident that, in terms of overstory composition, the greatest difference between Pukaskwa National Park and the surrounding landscape is the higher proportion of hardwood forest in the Park. This relative abundance of hardwood species will have associated relationships in terms of species dynamics (i.e. moose) and also disturbance dynamics (i.e. fire size). The question of why hardwood species are so abundant in Pukaskwa National Park is important, and may be related to its proximity to Lake Superior. As revealed in Findlay's climate study of Pukaskwa National Park (1973), the coastal influence of Lake Superior extends approximately 14 kilometers. This not only regulates temperature extremes, but provides higher humidities. With cooler temperatures and higher humidities, it would be reasonable to believe that the fire would be less predominant within this coastal affected area than in areas further away from Lake Superior. This factor may be limiting fire size. This would lead to dieback in fire dependent species such as pine and spruce dieback creating "gaps", succeeded by shade-intolerant species such as white birch and trembling aspen. The gap distribution of vegetation less prone to fire and the increased moisture is likely increasing the fire cycle longer than the 75 (+/-50) years predicted in the Vegetation Management Plan (Lopoukhine, 1989). Based on the nature of the disturbance cycle and overstory composition, the fire return interval may be as great as 200 years. This is supported by Bergeron and Debuc (1989) who studied succession in the Abitibi region of northwestern Quebec. They found an abundance of birch (*Betula payrifera*) in a post 200 year fire cycle with a decrease in jack pine and white spruce. The Abitibi forest composition results in a post 200 year fire cycle forest is similar to that of Pukaskwa's forest composition. This is not to say that fire cannot occur, but those that do would be limited in size by the deciduous vegetation cover creating smaller burned areas than those experienced in predominantly conifer forests. Therefore, the return interval for the entire park would be considerably longer than the 75 year (+/- 50 years) return interval estimated by Lopoukhine in the Vegetation Management Plan (1989).

One could argue that fire suppression and not Lake Superior is the cause of the difference in overstory composition. This would be a reasonable assumption except that the hardwood area is localized to within a coastal strip (~14 km) and not further inland. It is also unlikely that suppression response time and effectiveness is better within the park than outside the park, particularly due to its inaccessibility. This is not to say that fire cannot occur within the coastal area of Pukaskwa National Park, but those that do, would be limited in size by the deciduous vegetation cover creating smaller burned areas than those experienced in predominantly conifer forests.

Further inland, the lake effect is reduced. Higher summer temperatures and less humidity would create enhanced opportunities for fire ignition and size and consequently a overstory composition comprised more toward fire dependent vegetation, particularly pine and spruce. Consequently, it is the White River forest that is predominantly conifer.

Thus, the hardwood composition differences between Pukaskwa National Park and its surrounding landscape may be relatively unaffected by fire suppression and, in essence, be "natural". The trend that may arise over time is the spatial differences in conifer composition. The majority of the area surrounding the park is administered by Domtar Inc., which operates a sawmill in White River. The Domtar mill requires 400,000 m^3 of wood annually to maintain efficient operations (Domtar Inc., 1998). That supply will be maintained over the next 20 years. Using the Strategic Forest Management Model (SFMM), after the year 2018 until 2058, Domtar estimates operations will not be able to meet its required volume for softwoods. This should alter the overstory composition by further reducing conifer overstory. Appropriate tree planting to maintain conifer forests would likely alleviate this situation in the future.

Pukaskwa National Park is at a crossroads. It is likely that the coastal section of the park will maintain a small disturbance forest replacement cycle, known more as “gap” dynamics. It is the interior areas, which coincides with the park boundary that are of a greater concern due to its increased fire potential. In order to maintain conifer composition in this forest, active fire management is required.

Natural disturbances of various sorts play an integral role in the long-term maintenance of virtually all ecosystems. It is this multi-directional successional pathway that forms the basis for the habitat structure in Pukaskwa. In terms of overstory composition, Pukaskwa National Park is different than its surrounding landscape. There is a consistently higher proportion of deciduous hardwood forest within Pukaskwa National Park in comparison to its surrounding landscape. This is likely due the temperate effect of Lake Superior which has lengthened the fire return interval near the coast eliminating much of the fire dependent boreal softwoods.

There has been very little change between the two images (1984 and 1994). Spruce budworm will continue to be a major influence across the entire landscape. However, fire and harvesting will be the large scale disturbance agents which will likely further differentiate the composition of the park and the surrounding area.

SPECIES DYNAMICS: OCCURRENCE OF INVASIVE SPECIES IN PUKASKWA NATIONAL PARK

Exotic species are generally referred to as species that are beyond their native range (Meffe and Carroll, 1994; Primack, 1993). White et al. (1993) separate exotic species in two groups: invasive and alien. Invasive refers to a plant that has moved into a habitat and reproduced so aggressively that it has displaced some of the original components of the vegetative community, whereas alien refers to a plant that did not originally occur in an area where it is now established, but which arrived as a direct or indirect result of human activity (White et al., 1993).

These species are a concern because they can alter the natural character of the ecosystem (White et al., 1993). Primack (1993) outlines three major forces in the transportation of species: European colonization, horticulture and agriculture, and accidental transport. All three of these methods play a role in the introduction of new species at Pukaskwa National Park.

In Pukaskwa National Park, the history of exotic species coincides with the arrival of loggers and the community at Pukaskwa Depot, near the mouth of the Pukaskwa River. Other concentrations of exotics are found in similar disturbed areas such as the White River, Otter Cove and the present Park Administration Building.

According to White et al.'s (1993) survey of invasive plants in Canada, of the 526 vascular plant species found within Pukaskwa National Park, 46 or 8.74% are considered alien (Appendix A). This is considerably less that the 27% of the flora surveyed in Ontario that are classified as alien (White et al., 1993). Although considered alien, the species in Pukaskwa do not appear to have a detrimental impact on the forest condition. Only Reed Canary Grass (*Phalaris arundinacea*) is considered a "Principal Invasive Alien" by to White et al (1993). It is found in wetland areas, although it's distribution and spread rate is unknown in Pukaskwa.

Following closure of operations at Pukaskwa Depot in 1930, the rate of introductions slowed. However, some of the species, particularly feed species, survive (Timothy, Alfalfa, etc.). Since construction of the Pic River bridge into the park in the 1980's, numerous other species have been transported (dandelion, various grasses, daisy, etc.). These species are slowly being unintentionally spread along the Coastal Hiking Trail between Hattie Cove and the North Swallow River.

Of future concern is the impact of harvesting roads encroaching on the park boundary. This could allow a greater number of exotic species access to remote areas of the park backcountry.

SPECIES DYNAMICS: MOOSE POPULATION DENSITIES WITHIN THE GREATER PUKASKWA ECOSYSTEM

The moose is Ontario's largest mammal. It has maintained a symbolic stature of "north" and "wilderness" as well as maintaining a high economic value in terms of hunting. With this status, it has a long history of monitoring and consideration in the provisions of a multi-use landbase. The essence of this concern about effective moose management led to the creation of timber harvesting guidelines to ensure that their habitat is respected and enhanced to encourage greater moose densities (OMNR, 1988).

Of all the indicator selections, research into indicator species is by far the most active (McLaren et al., 1998; Welsh and Lougheed, 1996; D'Eon and Watt, 1994). As an indicator, moose is best associated with two distinct habitat types: upland conifer, small tree, at the landscape level, and mixedwood, shrub, at the landscape level (McLaren et al., 1998). Moose is an edge dependent species, and as such, cannot represent the entire spectrum of species in the park. What is most beneficial of an indicator such as moose for Pukaskwa is the temporal and spatial database. Moose have been monitored in Pukaskwa and Ontario since the 1970's and this provides for beneficial spatial and temporal comparisons for Pukaskwa and the surrounding landscape.

Pukaskwa has monitored moose populations since the early 1970's using a variety of survey methods. In 1986, staff at Pukaskwa National Park began to coordinate surveys with the Ontario Ministry of Natural Resources utilizing Gasaway et al.'s method for estimating moose populations (1986) (Wade, 1994). The same survey method has been employed for every survey since 1986 (1990, 1993, 1996). To increase comparison accuracy, I only analyzed those surveys conducted with the same field methodology. The Ontario Ministry of Natural Resources conducted similar moose surveys for Wildlife Unit #33 since 1984 and has estimated during intervening years. Using moose density for the two units (#33 and PNP), this indicator can begin to show population trends over a thirteen year period. The data for surveys was obtained from Pukaskwa National Park moose monitoring reports (Wade, 1996), and data sheets from Gord Eason, Wildlife Biologist with the Ontario Ministry of Natural Resources, Wawa, Ontario.

Since the early 1980's, moose within Wildlife Unit #33 revealed a increasing density up to 1994 where it has stabalized at 0.29 moose per square kilometer. During 4 moose surveys in Pukaskwa have shown a declining population density from approximately 0.2 moose/km^2 to just over 0.1 moose/km^2 in 1996 (Figure 23).

The data reveals that the population density of moose are stable in WU#33, while the Pukaskwa population has declined to nearly one third of the surrounding landscape. There could be a number of factors contributing to this decrease in moose density in the park. Hutchison et al. (1987) reviewed ten such factors relating to moose populations and distributions, including: immigration, reproduction, hunting, illegal hunting, predation, interspecific competition, climate, diseases and parasites, food availability, and emigration. Peek (1980) summarized these factors into two basic models which ultimately regulate moose populations; ungulate/habitat and ungulate/predator.

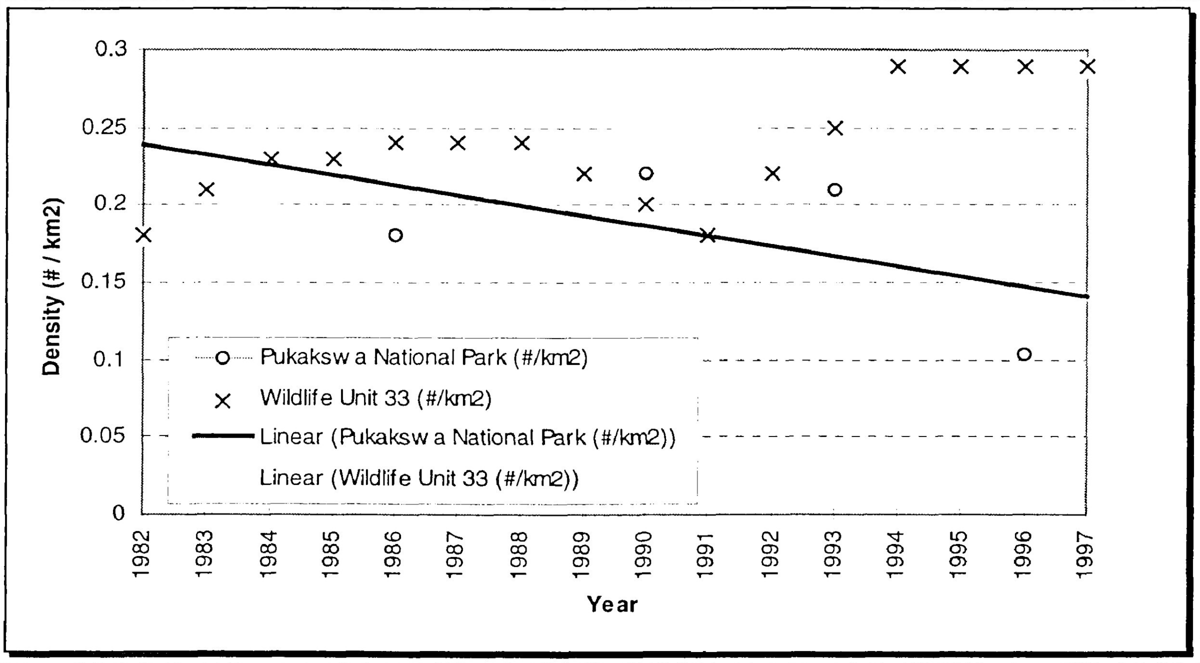


Figure 23_. Moose densities for Pukaskwa National Park and Wildlife Management Unit 33.

In the park there are generally two moose predators: wolves and humans. Bergerud et al.(1983), suggested that predation was the limiting factor in moose populations within Pukaskwa National Park. Thompson and Peterson (1988) disagreed with Bergerud et al.'s findings, finding omissions of other limiting factors such as food, weather and cohort vulnerability. During the five year study on the moose-wolf-caribou-landscape dynamics within Pukaskwa (known as the P5, 1994-1999) it appears that wolf predation is playing a minor role in regulating moose populations within Pukaskwa. In fact, results from the study have found that while predation on moose does occur, waste disposal sites and possibly beaver (*Castor canadensis*) are the principle food sources for wolf populations throughout the Greater Pukaskwa Ecosystem (Forshner, pers. com.).

The other source of predation is human. However, Pukaskwa's inaccessible landbase and illegal aircraft access provide for no known hunting occurrences in the park since its establishment in 1978. On the other hand, WU#33 provides for the opportunity for 45 moose tags to be harvested, plus Aboriginal harvesting. Hunting alone would give reason to believe that if predation was the limiting factor on moose populations, moose densities would be higher in the park. Yet, this is not the case. The number of moose is *decreasing in the park* while the hunted population remains stable.

The second factor in what may be what is limiting the moose density, is the moose/habitat relationship. Moose prefer to diet on early young browse (Hunter, 1990). There is no disturbance factor in Pukaskwa which has created a significant patch opening since the Birch Lake fire in 1956. However, WU#33 has experienced a continually increasing amount of harvesting creating numerous patch openings. Simply put, expansive clearcuts are great for moose (Hunter, 1990). This lack of preferred habitat in the park may be the most logical explanation of the lower moose densities within the park. The P5 is suggesting this, as radio-collared moose are most commonly found in the cutovers outside the park (Burrows, pers. com.). Increasing habitat suitability, or openings, through intervention (r.e. moose management guidelines, OMNR, 1988) outside the park appears to allow for a hunted population to remain stable. The limited openings produced by major disturbances within the park over the past 40 years has contributed to the decrease in population density despite the absence of hunting. This differs from other findings which found that where hunting occurs, moose management guidelines creating openings alone are not sufficient for increasing moose density (Rempel et al., 1997).

Despite this decline in moose densities throughout the park, this should not be taken as indication of failure of park management actions. Increasing species populations on limited spatial and temporal scales cannot be the goal when managing for an ecosystem. Moose cannot be considered the primary indicator for species response. Moose are a good indicator of small, upland conifer and mixedwood shrub at the landscape level (McLaren et al., 1998). What this indicator may imply, is a reduction of small upland conifer and mixedwood shrub with Pukaskwa National Park. Care must be given to ensure that the effective species are monitored which best reflect the full range of habitat structure and values of Pukaskwa National Park.

SPECIES DYNAMICS: THREATENED SPECIES MONITORING: RESULTS OF A 17 YEAR SURVEY OF PITCHER'S THISTLE (CIRSIUM PITCHERI), PUKASKWA NATIONAL PARK, ONTARIO.

Pitcher's Thistle (*Cirsium pitcheri* (Torr.)) is endemic to the Great Lakes shoreline (White et al., 1983). The majority of its population is found along the eastern shore of Lake Michigan and the western shore of Lake Huron in open sandy environments (Gleeson and Cronquist, 1963). Mosquin (1990) suggests that the plant is an early successor into sandy environments, and that periodic disturbance is vital to its survival. However, the plant is susceptible to white tailed deer (*Odocoileus virginianus*) browsing (Phillips and Maun, 1996) and human development and trampling (D'Ulisse and Maun, 1996).

C. pitcheri is considered rare in Ontario (White et al., 1983), and in 1988, was classified as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Keddy, 1987). The Pukaskwa plants are a periphery population, with no other records on the north shore of Lake Superior. Their presence in Pukaskwa is likely a result of seed migration by water currents or possibly human movements within Lake Superior (Parks Canada, 1986).

The cooling influence of Lake Superior provides suitable habitat for many arctic-alpine species including Franklin's Lady Slipper (*Cypripedium passerinum* Rich.) and Northern Twayblade (*Listera borealis* Morong.). Although there are numerous sandy environments along the north shore of Lake Superior, *C. pitcheri* plants are found only in one area at Oiseau Bay, 30 km south of the park entrance at Hattie Cove. The plants are protected from direct human interference by low fences around the colonies with notification signs informing visitors of the plants' importance.

When Pukaskwa National Park was established in 1978, efforts were made to begin a monitoring program for some of the unique flora of the park. The original study design was produced by C. Keddy in 1982, and later re-visited by T. Mosquin (1990). In

1981, park staff began to annually monitor *C. pitcheri* found along Oiseau Bay in two areas approximately 200 meters apart (Creek Beach and Crescent Beach).

Methods for monitoring *C. pitcheri* are outlined in the Rare Plant Management Plan for Pukaskwa National Park (Parks Canada, 1986). The survey is a total count, at 1.25 m intervals (Reside, 1991). Individual plants are pegged and numbered as per their life cycle, i.e. seedling (first year), rosettes (>1 year, non-flowering), and flowering plants plus the growing environment (sandy, woody debris, etc.) in which the plant is found. Successional changes to the surrounding environment and other associated species are also recorded.

Mosquin (1990) found that the methodology for counting flowering plants and rosettes had been altered slightly between 1981 and 1985. As a result, he applied a conversion factor to the 1981-5 data, by analyzing the ratio of single to multiple stemmed plants among rosettes in 1986, 1987 and 1990 (Mosquin, 1990).

Descriptive statistics such as mean and standard deviation have been applied to the results to reveal trends in the data over the 16 year period.

Over 16 years the data indicates a mean total population of 401.7 plants along the two beaches within Pukaskwa National Park (Figure 24). There is a standard deviation of 182.9. Numbers ranged from 760 to 153 in 1985 and 1991 respectively. In 1986, a beaver dam upstream from the thistle colony burst releasing a substantial volume of water (Sahanatien, 1985). This forced the re-routing of the creek near its mouth destroying 63% of the thistle population (Sahanatien, 1985). Between 1986-91, the population remained low (<300 total population) until 1991 with a population of 153 individuals. Since 1991 the population has rebounded to a high of 497 in 1996.

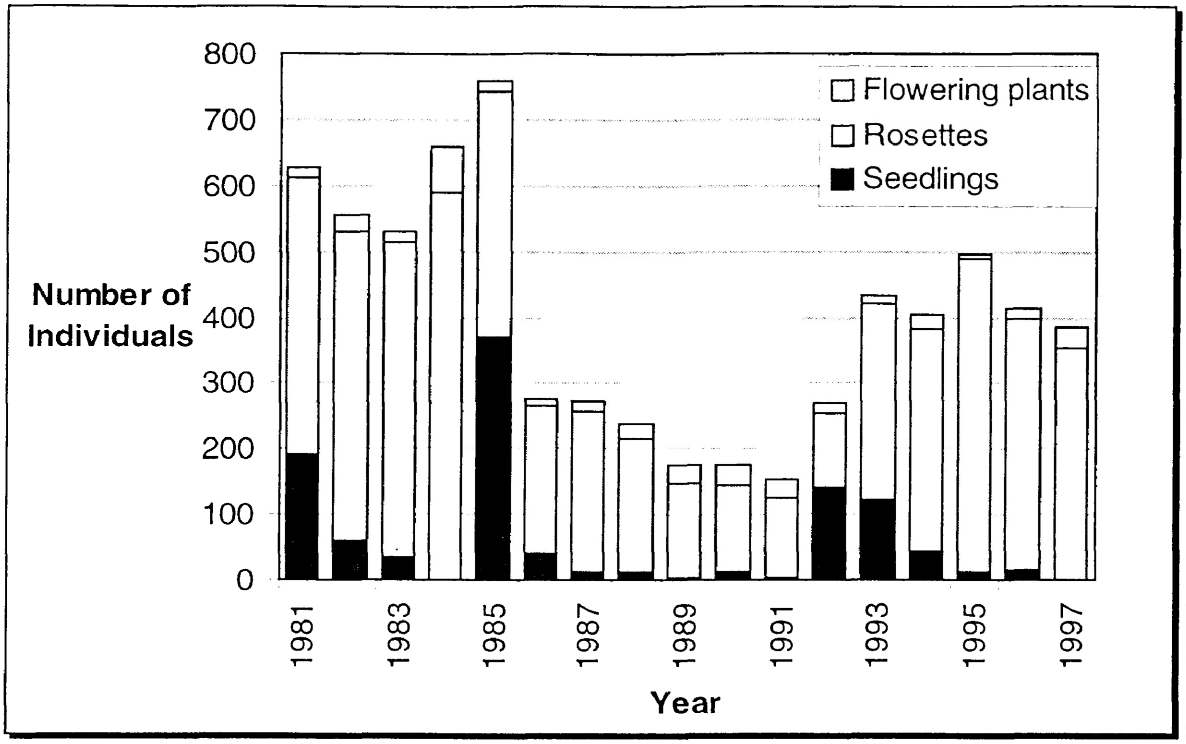


Figure 24_. Pitcher's Thistle populations, Pukaskwa National Park, 1981-1997

C. pitcheri appears to have survived the catastrophic impact to its habitat in 1986. As suggested by Mosquin (1990), periodic disturbance may actually assist the survival of the plant by reducing the encroachment of later successional species. Since 1986, however, the re-routing of the creek into Oiseau Bay has reduced the annual level of disturbance at the site (Mosquin, 1990). The population near Creek Beach (the larger of the two concentrations), is no longer influenced by deposition or periodic water fluctuations. With this lack of disturbance, Mosquin suggested that the population would have difficulty competing with other encroaching vegetation (Mosquin, 1990). However, the total plant population has actually increased since 1991, initiated by a higher number of seedlings in 1992. Reside (1992) suggests that the cool weather and moist conditions that were prevalent during the summer months of 1992 may have contributed to the higher germination rate. Thus, the favourable growing conditions of 1992 may have propagated enough seedlings to give the population a reprieve from succeeding vegetation. It is too early to detect whether succession will eventually limit the *C. pitcheri* population.

The *C. pitcheri* population at Pukaskwa National Park remains unthreatened by human development and trampling and deer browsing as found in the Pinery Provincial Park on Lake Huron (Phillips and Maun, 1996; D'Ulisse and Maun, 1996). *C. pitcheri* is within a Special Preservation Zone within Pukaskwa National Park, free from development or human activity. At this point in time, white-tailed deer do not consistently inhabit Pukaskwa National Park.

The effect of species isolation remains a long term concern, particularly in this peripheral population. *C. pitcheri* has not been found anywhere else on the north shore of Lake Superior, and because of genetic drift, the isolation and smaller size of peripheral populations generally lead to less genetic variation than in central populations (Lesica and Allendorf, 1995).

Based on data collected since 1981, the population of *C. pitcheri* at Oiseau Bay, in Pukaskwa National Park appears to remain viable with an average of over 400 individual plants. The current population has rebounded significantly from a 1992 population of 153 individual plants. Continued natural disturbance will be vital to the survival of this species. However, due to succession and possible genetic isolation, it remains difficult to predict the long term status of this species in Pukaskwa.

SPECIES DYNAMICS: CARIBOU POPULATIONS, PUKASKWA NATIONAL PARK 1972 - 1996

One of the unique characteristics of Pukaskwa National Park is the presence of Woodland Caribou. Whereas the range for caribou populations in Ontario have advanced northward, a small, disjunct population survives along the coast of Lake Superior (Bergerud, 1974). Bergerud believes that due to range destruction and overhunting, caribou populations have all but been eliminated south of Lake Nipigon (Bergerud, 1974). Pukaskwa's relative remoteness has enabled it to maintain the southern most naturally occurring concentration of Woodland Caribou distribution in Ontario (Ahti and Hepburn, 1967). In 1984, the species was listed as "vulnerable" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 1996).

Under the direction of Dr. Tom Bergured, the Canadian Wildlife Service and eventually, Parks Canada, the caribou have been studied since 1972. This has lead to a number of wildlife debates, particularly the "Bergerud hypothesis". Essentially, Bergured found that the caribou in Pukaskwa are concentrated along the coast of Lake Superior (Bergerud, 1984). He felt that caribou dispersed to the coast as a predator avoidance strategy from wolves in the winter(Bergerud et al., 1983). The shallower snow depths along the coast enables the caribou to evade wolf predation. Bergured et al.(1983) hypothesized that moose would also migrate to the coast in the winter. This would attract wolves to the coastal areas which would lead the wolf to prey on the available caribou due to the higher success rates than predation on moose (Bergerud et al., 1983). Bergerud (1989) warned that unless predator control was enacted, the caribou population would be extirpated from Pukaskwa within 25 years. Thus, in his opinion, the caribou in Pukaskwa are predator regulated, yet there was no evidence to substantiate this claim.

This did lead to park managers to question inter-relationship study between the moose, wolf and caribou and their habitat through the Greater Pukaskwa Ecosystem, and developed into the Pukaskwa Predator Prey Process Project (P5). Initiated in 1993 as a 5 year study, its objectives included analysis of the movements of these three species to further test Bergerud's hypothesis.

Since 1972 the Canadian Wildlife Service and Parks Canada have surveyed the woodland caribou population along the coast of Pukaskwa National Park from the Pic River to the Pukaskwa River. Between 1972 and 1983, the caribou were surveyed annually. From 1983 to 1997, they were surveyed biannually with additional counts in 1990 and 1996, totaling 21 separate counts. Over the 25 year study period, there was a mean average of 18.43 caribou with a standard deviation of 6.25 (Figure 25). The range varies from 31 in 1979 to 6 in 1995.

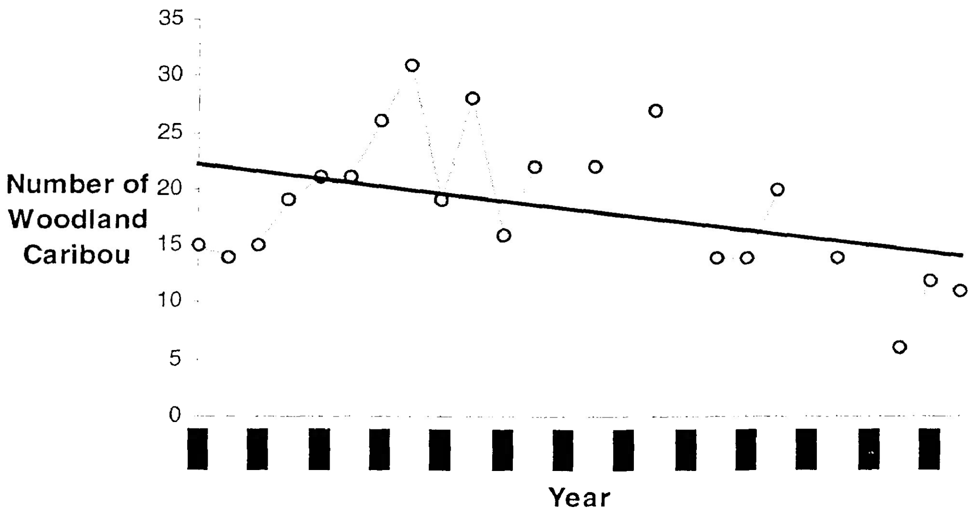


Figure 25. Caribou populations, Pukaskwa National Park, 1972-1997.

The caribou population of Pukaskwa National Park is low. Of concern to park managers is the fate of the caribou: will the caribou survive, or will they dissipate, not to predation - but to genetic inbreeding. Recent work has some grounds for optimism. Wade (1997) speculates that there may be some genetic exchange with populations outside the park. The caribou in Pukaskwa may be a deme in a metapopulation. After 3 years of telemetry data collection, Wade found that one male in particular wintered in the south end of the park, and every summer migrated along the coast north of Marathon. Although not conclusive, it does indicate that caribou are capable of movements towards other known caribou populations (Pic Island).

The second reason for optimism of the caribou's survival is the accuracy of the population estimates. The park has always conducted population surveys along the coast. As the surrounding landscape becomes more accessible, incidental sightings of caribou are more frequent. It is possible that the caribou are not limited to the coast as previously assumed, and there may be a greater population inland. There remains little evidence at this time to substantiate Bergerud's claim of a predator regulated caribou population. Early results from the P5 indicate little interaction between wolves and caribou within Pukaskwa.

DISCUSSION

This report establishes a structured framework to reflect Pukaskwa National Park's ecological integrity and contribute to the state of the park reporting. By integrating a hierarchical approach with available data, management direction and external initiatives, this report attempts to best reflect the spatial and temporal change throughout the Greater Pukaskwa Ecosystem. In doing this, it is working to answer the fundamental question for all protected areas: is the park protecting what it was established to protect? More simply, is the park, as a protected area, doing "it's job?"

Drivers of Change

It must be recognized that the ultimate "driver of change" will be continual growth in human consumption and population (Noss and Cooperrider, 1994). Humans have altered and are continuing to alter the ecosystem at alarming rates. What is most alarming is the rate of change for which this population explosion and demand is occurring. This will be the ultimate indicator by which all ecosystems will receive the largest threat (Noss and Cooperrider, 1994). Until society begins to get a handle on this, protected areas will merely be delaying the inevitable; a breakdown in the ecosystem construct, which will more be a sum of the parts that we want it to be, than what it is for itself.

Beyond the temporal scope of plate tectonics, uplift and erosion and glaciation, is climatic instability. Current theory suggests that increases in CO_2 and other "greenhouse gases" are rapidly changing the climatic dynamics. It is predicted that temperatures will rise and may dramatically alter the southern boreal forest. Current data for the Pukaskwa area reveals a 0.5 ° C rise in temperature over the past 120 years. Although this reveals a minor change in temperatures, climatic instability is foreseen as a future problem with 25-40% of the boreal forests predicted to disappear altogether in the near future (Loh, 1996).

Local scale spatial patterns in climate reveal interesting and important aspects of Pukaskwa National Park. Re-enforcing Findlay (1973) report, the coastal area is considerably warmer than the interior by about 4°C. This does not indicate a "stress" or problem, but dramatically alters the assumptions made about Pukaskwa as representative example of the boreal forest. At the broadest of scales, Pukaskwa receives a critically different input into the system. In this way, putting the park in its proper context is important when looking at the greater ecosystem.

The other broad scale influence is air quality, particularly acidic precipitation. Stations located across northern Ontario have measured the wet sulphate deposition over the past 15 years. Although Pukaskwa National Park falls below the provincially established critical limit of 20 kg/ha/year, it is likely that the shallow soils negate any buffering capacity of the ecosystem. Aquatic research over the past 10 years (McCrea, in press) reveals highly stressed rivers within Pukaskwa, despite being below the supposed critical limit. The effects of wet sulphate deposition on Pukaskwa's terrestrial ecosystem have not been studied in detail, but eastern forest communities are experiencing enormous stress on the vegetation, including a reduction in nitrogen fixation in the soil and inhibit germination (Barbour et al., 1987).

Ecosystem Dynamics

An understanding of disturbance regimes is essential to understanding biodiversity conservation. Three large scale disturbance forces were reviewed in this report: forest fire, spruce budworm, and timber harvesting. An additional indicator, road development, was reviewed as it disturbed the landscape, but, although directly associated with timber harvesting, it differs in that roads physically convert the ground cover and create increased human access.

Undoubtedly, fire plays a tremendous role in the boreal forest dynamics. For Pukaskwa National Park, there has been a total of 30 fire starts over the past 75 years (1923-1998), or an average of 4 fires per decade. Forest fires had their greatest influence in 1936, when over 47,000 ha were burned in one fire along the north end of the park. Whereas fire has and continues to be present within the park, with the limited number of starts, and the relatively short data set, it is difficult to estimate the significance of fire in forest development. It does appear however, that although fire occurs relatively infrequently, it has the potential to be large in terms of area.

The most influential insect disturbance is the spruce budworm. Budworm infestations occur throughout the Greater Pukaskwa Ecosystem (600,000 ha) reducing the balsam fir composition of the forest. This forms a basis for a gap phase disturbance cycle as shade intolerant species (including balsam fir and white birch) quickly recolonize small canopy opening gaps in the forest. The Pukaskwa and White River forests were last infested in the late 1980's and has since subsided. It would appear that Pukaskwa's disturbance characteristics result from infrequent burns establishing a broad level of disturbance, driven by spruce budworm throughout.

Increasingly, harvesting is occurring in the lands surrounding the park as the primary large scale disturbance factor. Although harvesting has occurred in the past, it was limited to large river corridors and was selective in nature. Current practices are much more extensive, with large clearcuts and efficient mechanization. Harvesting in the White River forest surrounding the park is rising exponentially since the 1960's, and is encroaching rapidly toward the park boundary. Future wood supply deficits will compound this problem.

What is most concerning is the encroachment of roads towards the park. Greater needs to maintain wood supply have pushed logging further away from the mill creating more roads to access more timber. Moreso than the cutting, the roads will pose the greatest threat to the viability of much of the Pukaskwa Ecosystem. For example, road accessibility is either directly or indirectly the principle cause of wolf mortality throughout the greater ecosystem.

Habitat Dynamics

The landcover mosaic was quantified using satellite imagery and FRAGSTATS, a software package developed to analyze landscape structure. Age class interspersion is increasing both within and outside the park, although at a slightly higher pace outside the park. Both landscapes were influenced by spruce budworm which would contribute the increase in age-class interspersion. The increased harvesting activity over the 10 year period likely resulted in the slightly higher degree of interspersion outside of the park.

Pukaskwa's mature forest (115+ years) and relative infrequent occurrence of any stands under 44 years of age is most likely a result of the limited stand replacing disturbance within the park. The 1936 fire of 47,000 ha in Pukaskwa National Park accounted for the rise in the 45-65 year age class. The 65 to 95 age class was also a result of past large scale, stand replacing disturbances in 1931 and 1924.

Within the White River forest, harvesting, and re-generation has encouraged young growth while reducing the area of older forests. The White River forest most resembles an "even" distribution for harvested forests with a predictable supply of mature forests. Pukaskwa however, reveals a much more mature forest, and is skewed to older age classes.

The composition of the park and the White River forest has remained fairly constant over a 10 year period (1984-1994). Pukaskwa, however, contains a much higher proportion of hardwoods than the White River forest. There is no reason to believe that this is not normal within the park. A higher fire return interval of the Pukaskwa forest should reveal a higher proportion of hardwood species. Again, this results in spatial differences between Pukaskwa and its surrounding landscape.

Pukaskwa is fortunate to have limited road access. For the most of the park access is only through river corridors and coastal routes. With the exception of the development of Pukaskwa Depot between 1917 and 1930, invasive flora and fauna have remained relatively low. Forty-six non-aggressive invasive species have been identified within the park, centered about the Pukaskwa Depot area at the south end of the park and the Park Administration office and campground at the north end. Only Reed-Canary grass (*Phalaris arundinacea*) is considered moderately aggressive, yet its sightings are few.

Species Dynamics

Moose population densities have been assessed since the mid-1980's both in and outside of the park. Moose maintain a social and economic importance and have a long monitoring history throughout Northern Ontario. However, moose densities within the park are less than half of what they are in the surrounding landscape. Moose are best an indicator for small, upland conifer and mixedwood shrub at the landscape level (McLaren et al., 1998). The lower moose densities imply a lower availability of their preferred habitat.

Woodland Caribou have been the most studied species in the Park. The population is estimated to be very small, between 15 and 30 individuals. Caribou have been migrating north for over 100 years and are not found very far south of Lake Nipigon. The Pukaskwa population may be somewhat of an anomaly, but it is difficult to predict their fate in terms of genetic isolation.

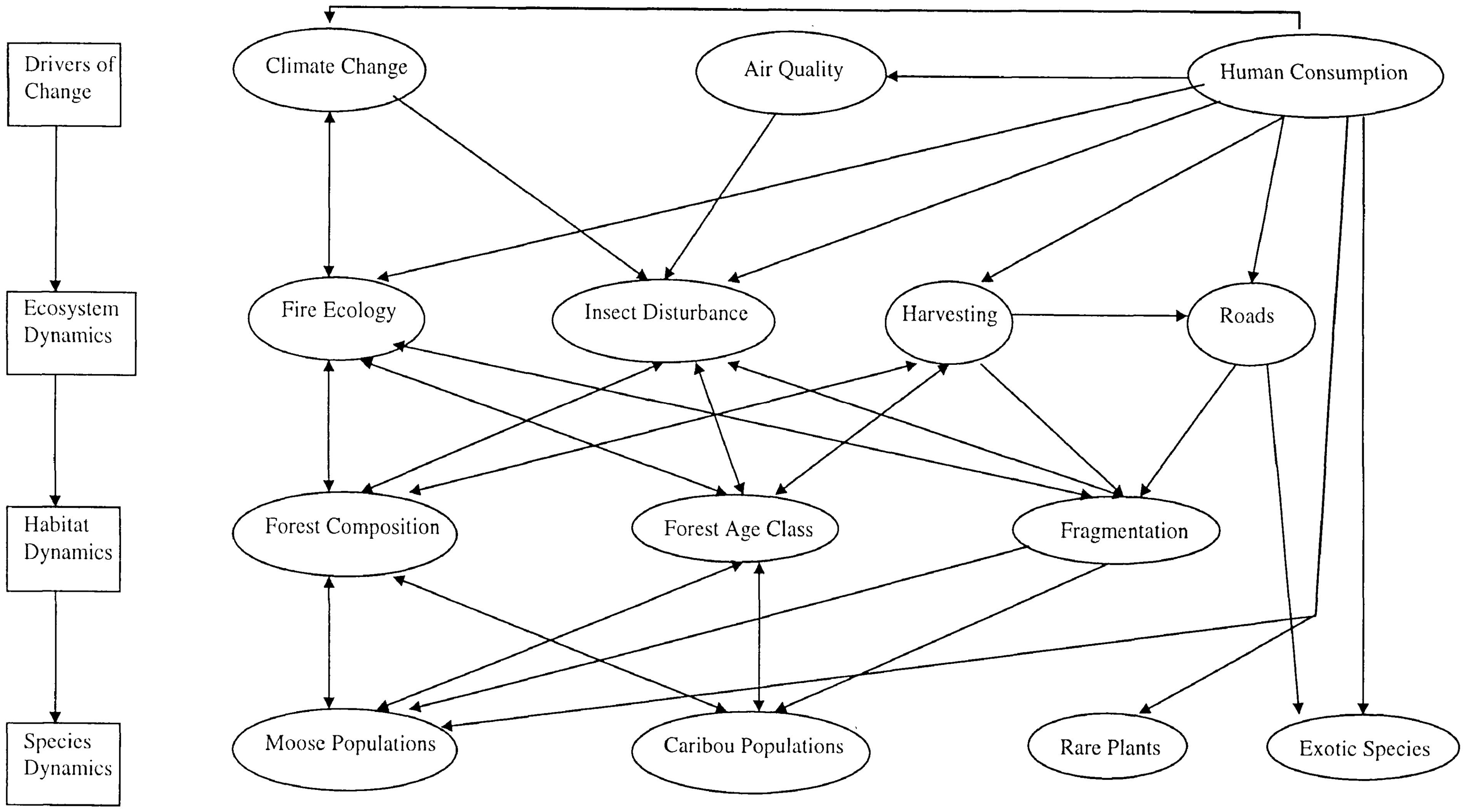
For 17 years, staff have been monitoring its only COSEWIC listed species, the Pitcher's Thistle (*Cirsium pitcheri*). A southern disjunct, the plant likely seeded itself in Pukaskwa via water or human movements around Lake Superior. Over the past 17 years the population has remained with over 400 individuals, despite its near removal in 1985 when an upstream beaver dam burst and removed much of the current habitat. Currently, there biggest threat is dune succession, yet there is no reason to believe it won't survive.

Linkages

Through this heirachical framework, relationships to link the various indicators begin to emerge (Figure 26). The linkages for these indicators also reflect that the ecosystem is not solely "top-down", but in many ways, "bottom-up". Although that relationship is recognized, it has yet to be fully explored in this context.

The most isolated of the indicators is the rare species (Pitcher's Thistle). Initially, is difficult to argue that this is a key indicator of the terrestrial integrity of the Greater Pukaskwa Ecosystem. While it may be true, the fact that it is considered "threatened" in Canada, bestows it a special consideration in park management, more for political justifications than ecological ones. However, beyond the political responsibility of monitoring rare plants, the question becomes; what ecological function could cause the thistle to dissappear? Secondly, is that change in function ecologically significant? At this point it is difficult to determine, but it is this type of questioning which alters the monitoring from what was earlier termed "ecological integrity monitoring" to "threat-specific monitoring". Continued monitoring allows for a baseline of population dynamics.

Figure 26. Linkages for Indicators of Terrestrial Ecosystem Integrity - Pukaskwa National Park



Alternately, human consumption is often overlooked (overwhelmed) as having a significant bearing on the ability of the park management to adequately protect the ecosystem. Although often recognized intuitively, it is not just a driver of change, it is *the* driver of change in ecosystem management. Park and forest management is merely an attempt to redue the impacts of human consumption. The difficultly is that the results of human consumption are so all encompassing that it is impossible to understand or even predict what is "natural" and what is not.

It is important to note that not all relationships are explored, but only those for which indicator data exists. Key omissions include alternate species with different spatial habitat requirements such as species at the stand and forest level. Also, species at different trophic levels, particularly omnivores and carnivores.

CONCLUSION

> We tend to think of national parks as pristine areas, protected from outside influences by their boundaries. The reality is very different. Parks are affected by previous land management practices such as forest harvest, insect control, dams and fire control. Even more remote areas are influenced by pollutants and climate change. In addition, most southern parks have development including roads, transportation and communication corridors, and buildings to accommodate visitors and park management. (State of the Parks, 1997 Report)

In many ways, this generic statement from the 1997 State of the Parks Report applies directly to Pukaskwa National Park. Administrative boundaries and good intentions are not enough to protect Pukaskwa. Wise management has maintained much of the original character of the park by limiting internal development such as roads and buildings. However, with better understanding of ecosystem functions, we are beginning to understand that protecting a park does not protect necessarily protect its contents.

This report is the first investigation into how the park is changing over time. It also the first time much of Pukaskwa has been directly compared within its greater ecosystem. From this spatial-temporal relationship, it is becoming clear that the assumptions made about the park within the context of a "central boreal uplands", are not wholly accurate. The effect Lake Superior has on the terrestrial ecosystem, from climate to species populations, may characterize Pukaskwa as more unique than representative. In fact, it may be more than just the effect of Lake Superior. Cumming et al. (1996), states that there may not be such a thing as a "representative" area of the boreal mixedwood ecosystem. Thus, to define Pukaskwa as a representative portion of the Central Boreal Uplands, may be impossible. The assumptions made about the park have been based on its assumed representativeness and have to be re-analyzed: habitat quality will remain low; moose, wolf and caribou populations will remain low; fire will play a major role in forest development, but it will occur infrequently; gap dynamics will structure the forest and insects will be the principle disturbance agent. It may be more accurate to consider Pukaskwa a portion of a boreal coastal zone rather than the boreal uplands area.

Kimmins (1997a) defines an ecosystem as any biological-physical system that exhibits the attributes of structure, function, complexity, interactions/interconnection of the sub-components, and change over time. Kimmins argues that every system, by definition, has integrity. In this way, integrity is in a constant state of flux, and it is more human perception than hard science that allocates the level of integrity for a particular geographic location. Yet, if as Kimmins states that there is only a loss of integrity when the ecosystem processes are altered beyond the range that is characteristic of that system, one indicator in particular stands out: roads. Roads have altered the ecosystem beyond the range that is characteristic for the seral stages of any system. There is no analogy to roads in the natural ecosystem. The greater the number and density of roads, the greater the impact on ecological processes, hence the integrity is diminished.

These indicators are not only an evaluation of the integrity of an ecosystem, but ones which are a component to examine the sustainability of a forest prescribed within the criteria and indicators of sustainable forest management (CCFM, 1996). The indicators examined in this paper fell within criteria's 1 and 2; biodiversity conservation, and the maintenance of forest health and productivity. Based on these two criteria, the question becomes; is the forest sustainable? Similar to examining integrity, it is a matter of perspective. The obvious difference between the two areas is the level of forest harvesting within the White River forest. This does have effects on age class, fragmentation, composition, and moose populations. Yet whether this is positive or negative is a matter of perception. This is mainly limited to a lack of data to understand what is acceptable and what is not. Again, as with integrity, it would likely be safe to say that roads (not an indicator according to the CCFM) are a cause of concern as they have the potential to have the greatest threat to sustainability of the forest ecosystem.

Other indicators reveal trends which assist in characterizing the State of the Park. Together, they reveal to us under what condition and trend the park system is operating. To amalgamate the indicators, or rank the park beyond this would be presumptuous as it would imply a state of equilibrium or a steady state ecosystem. The paradox is that Pukaskwa National Park is an area set a side to protect an ecosystem that must change. We must focus our attention on the rates at which changes occur, understanding that certain changes are natural, desirable, and acceptable, while others are not (Botkin, 1990).

As with any ecological study, this one is limited by scale, both space and time. It is difficult to ascertain a true measure of change with a system that has developed for thousands of years, with 10 to 100 years of data. What this type of project hopes to initiate is an on-going monitoring system to better understand the future trends in the Greater Pukaskwa Ecosystem.

Spatially, one has to questions Pukaskwa's size. If Pukaskwa is not an accurate representation of the Central Boreal Uplands, would size matter? Cummings et al., (1996) estimate that an adequate representative site would have to be 50 times greater than the largest disturbance measured. With the largest fire measured at 47,000 ha in

1936, Pukaskwa would have to be over 12.5 times its current size to 23,500 km^2. It would seem highly unlikely that this will occur. What it does reveal, however, is the difficulty in assessing and reporting on an ecosystem when you only have a small portion of it, particularly with respect to large scale processes.

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Appendix: Invasivel Flora Species of Pukaskwa National Park

Invasive species defined as per White et al.(1993). Cross referenced using Gleeson and Conquist (1963), Manual of Vascular Plants of Northeastern United States and Adjacent Canada
* specimen located in the Park herbarium

	Common Name	Scientific Name
	Quack grass	*Elymus repens*
*	Giant Redtop	*Agrostis gigantea*
	Redtop	*Agrostis stolonifera*
*	Sea Lymegrass	*Elymus arenarius*
	Reed Canary Grass	*Phalaris arundinacea*
	Timothy	*Phelum pratense*
*	Canada Bluegrass	*Poa compressa*
*	Kentucky Bluegrass	*Poa pratensis*
*	Sedge spp.	*Carex muricata*
*	Wild Chives	*Allium schoeoprasum*
	Tall Nettle	*Urtica dioica*
	Sheep Sorrel or Sourdock	*Rumex acetosella*
	Curled Dock	*Rumex crispus*
	Lamb's Quarters or Pigweed	*Chenopodium album*
	Mouse-ear Chickweed	*Cerastium fontanum*
*	Bladder Campion	*Silene vulgaris*
	Slender Starwort	*Stellaria graminea*
	Common Chickweed	*Stellaria media*
	Common Buttercup	*Ranunculus acris*
	Beaked Wintercress	*Barbarea orthoceros*
*	Common Wintercress	*Barbarea vulgaris*
	Wormseed Mustard	*Erysimum cheiranthoides*
*	Wood or Upland Strawberry	*Fragaria vesca*
	Wild Raspberry	*Rubus strigosus* or *idaeus*
	Alfafa	*Medicago sativa*
	Yellow Clover	*Melilotus officinalis*
	Alsike Clover	*Trifolium hybridum*
	Red Clover	*Trifolium pratense*
	White Clover	*Trifolium rapens*
	Tufted Vetch	*Vicia cracca*
*	Hemp Nettle	*Galeopsis tetrahit*
*	Heal-all	*Prunella vulgaris*
	Butter-and-eggs or Toadflax	*Linaria vulgaris*
*	Thyme-leaved Speedwell	*Veronica serpyllifolia*
*	Common Plantain	*Plantago major*
*	Northern Yarrow	*Achillea millefoleum*
*	Ox eye Daisy	*Leucanthemum vulgare*
*	Canada Thistle	*Cirsium arvense*
	Daisy Fleabane	*Erigeron strigosus*
	Common Fleabane	*Erigeron philadelphicus*
	Common Cudweed	*Gnaphalium uliginosum*
	King Devil	*Hieracium floribundum*

Handsome Hawkweed	*Hieracium umbellatum*
Pineapple Weed	*Matricaria matricarioides*
Common Sowthistle	*Sonchus uliginosus*
Common Dandelion	*Taraxacum officinale*