A COMPARISON OF THE PRE-SETTLEMENT AND PRESENT DIVERSITY OF THE FORESTS OF CENTRAL ONTARIO

Paul Leadbitter©

A Graduate Thesis Submitted

In Partial Fulfillment of the Requirements

For the Degree of Master of Science in Forestry

Faculty of Forestry and the Forest Environment

Lakehead University

October 2000

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A Caution to the Reader

This M.Sc.F thesis has been through a semi-formal process of review and comment by at least two faculty members.

It is made available for loan by the faculty for the purpose of advancing the practice of professional and scientific forestry.

The reader should realize that opinions expressed in this document are the opinions and conclusions of the student and do not necessarily reflect the opinions of either the supervisor, the faculty or the University.

Abstract

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Key Words: Biodiversity, Great Lakes-St. Lawrence Forest Region, Crown Survey notes, pre-settlement forest, sub-divided township, non-subdivided township, working groups, hardwoods, softwoods, shade tolerance groupings, occurrence.

Original Crown Survey notes were used to infer the European pre-settlement forest diversity condition in the management units of Algonquin Park, French-Severn, Nipissing and Temagami in central Ontario, Canada. This diversity condition was then compared to the 1990 diversity of the forests as determined from forest resource inventory (FRI) maps. This study compared selected compositional proportions of the forest to identify potential changes that have occurred since 1890.

Ten sub-divided townships were randomly selected from Algonquin Park, French-Severn and Nipissing while all available non-sub-divided townships were used in the management unit of Temagami. The 1890 data represented the pre-settlement condition of the forest and acted as the baseline to which the 1990 data was compared. The 1890 data were derived from the original Crown Survey notes which were the forest cruise notes of the day, giving detailed descriptions of the forest cover including species composition, abundance, diameter at breast height and disturbances. The 1990 data were provided by the Ontario Ministry of Natural Resources in the form of FRI maps and spreadsheets. The data were sorted into working group proportions, hardwoods and softwoods, shade tolerance groupings and frequency of occurrence.

This study revealed that in terms of changes in working group proportions there have apparently been region wide increases in maple (*Acer spp.*), while balsam fir (*Abies balsamea*), hemlock (*Tsuga canadensis*) and the 'other conifer' group (larch (*Larix larcina*) and cedar (*Thuja occidentalis*)) have apparently decreased. This study revealed that there has been an apparent increase in the proportions of hardwoods in the region with a subsequent decrease in the proportion of softwoods. The analysis of shade tolerance groupings showed that there seems to have been an increase in the shade tolerant species while no large changes have occurred with the mid-tolerant species or the shade intolerant species. The regional comparison of frequency of occurrence of each species revealed that a total of nine of the fourteen species have apparent large changes.

This study has shown the usefulness of the Crown Survey notes in reconstructing the pre-settlement condition of these forests. These survey notes were easily available and could be simply converted to spreadsheet form. Future forest management plans should attempt to use these data as it will allow for more informed decision-making and will lead to a better understanding of original diversity conditions.

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1.0 INTRODUCTION

Biodiversity conservation is a priority in forest management in the 1990's. The protection of biodiversity is needed to ensure a healthy forest ecosystem and is required by Ontario's Crown Forest Sustainability Act (Ontario, 1994). Today, all forest management plans must consider and conserve the biodiversity of the forest landscape to ensure long term sustainable ecological and economic uses. One method that can help understand forest diversity is to use historical data to show what the forest looked like before European settlement and modern forestry practices altered the landscape.

Forest management planners need to know the diversity of the pre-settlement landscape in order to compare diversity in the modern forest landscape to these pre-settlement conditions. The original Crown Survey notes circa 1860 to 1920 give detailed, qualitative and quantitative descriptions of the pre-settlement forest landscape. Thus, these survey notes will be used for measuring forest diversity conditions before European settlement.

The Canadian Biodiversity Strategy (1995) defined biodiversity as the variability among living organisms from all sources and the ecological complexes of which they are a part, including diversity within species, between species and ecosystems. The concept of biodiversity is complex and is often broken down into components to help understand its importance (Table 1.0). Of particular interest to this study are the compositional components at the species and community or ecosystem levels. This study will look for apparent changes in compositional diversity within selected management units in the Great Lakes St. Lawrence Forest of central Ontario.

Table 1.0. Examples of levels and components of biodiversity as described by Nigh et al. 1992 and as used in this study.

Levels of Biodiversity	Components of Biodiversity Compositional	Structural	Functional
Genetic	Genes/alleles	Genetic structure	Evolution
Species	Number of species	Species distribution and abundance	Trophic levels
Community or Ecosystem	Number of communities or Ecosystems	Habitat structure, community distribution and abundance	Ecosystem processes

Biodiversity studies have traditionally focused on the current condition of ecosystems with little consideration of pre-settlement diversity conditions. However, Botkin (1990) pointed out that changing ecosystems could only be understood if we have baseline surveys of their status and continue to monitor their condition over time. Studying the pre-settlement condition of Ontario's forests is an important part of our understanding of today's forest structure (Stabb, 1996). With a better understanding of how forest structure has changed over the last century, forest managers can make better-informed decisions regarding forest ecosystems today.

Study Objectives

The primary goal of this research project is to compare European pre-settlement measures of compositional landscape diversity along original Crown Survey lines in four management units in central Ontario to similar measurements from the current forest.

These measures of diversity include:

1) Working group proportions;
2) The relative abundance of hardwoods vs. softwoods;
3) Shade tolerance group proportions;
4) Each species frequency of occurrence.

These comparisons will look for apparent compositional changes that have occurred in the selected management units and will provide a better understanding of how the forest has changed since 1890. The goals of this project will be achieved when planners are able to use these measures as part of the planning process.

Crown Survey Notes

In Canada, in contrast to many old-world countries, it is possible to reconstruct the original conditions of the pre-settlement forest by studying early records made by Crown Surveyors. In most parts of Europe, centuries of gradual forest clearing, exploitation and management have made it almost impossible to reconstruct the nature of the original vegetation communities (Whitney, 1987). However in Canada, industrial development of the wilderness occurred at a much faster rate in a relatively shorter time period. Thus, in Canada it is possible to attempt a reconstruction of these pre-settlement forests using the Crown Survey notes.

In Ontario's early history, Crown Land Surveyors were contracted by the government to perform exploration surveys and layout survey control lines, known as meridians and base lines (Sebert, 1980). These surveys were required for mapping purposes and to mark out the basic survey fabric from which new townships and townsites were established (Weaver, 1968). Survey lines were established using a uniform method and a relatively uniform size, but due to the limitations of the survey equipment the lengths of the survey lines were not always the same. However, for the purposes of this study these inconsistencies are not important because each township is compared to itself over two periods of time.

Before 1792, Crown Surveys were often inaccurate and inadequate which caused many settlement problems. Because of the inadequacies of these early surveys the Surveyor General, acting under the authority of the Lieutenant Governor, appointed all surveyors. In 1849 legislation was passed establishing the qualifications needed for any surveyor candidate. Candidates had to be at least twenty-one years of age and were required to serve a three-year apprenticeship under an established surveyor (Lambert, 1967).

After 1849, when a survey was needed the Crown Lands Department would hire a qualified surveyor and give him specific instructions. For example, Provincial Land Surveyor (PLS) Walter Beatty was engaged to survey the Seventh Baseline, located north of Lake Superior. He was instructed to employ twenty men and take them and his supplies to "Lake Neepigon" and begin the survey. He was further instructed to explore the country on each side of the survey line for fifteen miles, noting the character of the country as well as the kind of timber in order of its relative abundance. He was also to note all marshes, swamps, burns and meadows, all lakes, ponds and rivers and the relative depth and quality of the water (Lambert, 1967). Lambert also concluded that detailed instructions appear to have been the rule and were usually carried out to the letter. This idea of the surveyors listing the tree species in order of relative abundance is of critical importance to this study as it was one of the basic assumptions I used when extracting the forest data form the survey notes.

Many ecologists believe that the early land surveys represent the most reliable source of information on pre-settlement forest composition because they represent a systematic sample of vegetation (Noss 1985). Noss (1985) also stated that pre-settlement forest systems were relatively ancient and stable, and provided a baseline against which to measure the vicissitudes of humanized landscapes. These early survey notes provided a snapshot in time of selected measures of landscape diversity composition in Ontario's original forests along specific survey lines.

Few other sources of information exist for a reconstruction of Ontario's forests. Bromley (1935) discussed reconstruction techniques of forests and pointed out that land surveyor's records have been most commonly used. Bourdo (1956) stated that surveyor records possess the advantage of having been written *in situ* according to a pre-determined plan. Thus they constitute an unbiased sample of vegetation communities and can be used for both quantitative as well as qualitative analysis (Bourdo, 1956).

Because the Crown Surveys are considered a reasonably standardized method of sampling, Noss (1985) pointed out that survey records could be statistically compared with each other and to equivalent samples from modern vegetation. Thus survey records are useful for:

1) Identifying and mapping plant communities and species distributions;
2) Relating the vegetation to physical factors of the environment;
3) Comparing the pre-settlement condition to the present, managed one;
4) Providing guidelines for natural area inventory and management. (Noss, 1985).

The use and usefulness of Crown Survey records and in the United States, General Land Office survey records (GLO) have been well documented. Schwartz (1994) used GLO survey records as the basis of a database to determine the abundance and distribution of major tree species in northern Florida. Lorimer (1977) analyzed species composition, successional status and frequency of large-scale disturbance in northeastern Maine using witness trees that were derived from GLO records. Deelen et al. (1996) compared past and present forest conditions in two deer yards using GLO records as the basis of the past forest condition. Abrams and McCay (1995) and Abrams and Ruffner (1995) used witness tree data extracted from the GLO surveys to analyze vegetation-site relationships of witness trees in pre-settlement West Virginia and Pennsylvania respectively. Weunscher and Valiunas (1967), Bromely (1935), Nelson (1957), Palik and Pregitzer (1992) all used GLO records for reconstruction of original forest conditions in Missouri, Southern New England, Georgia and lower Michigan, respectively. Whitney (1987) used GLO records to trace the ecological history of the Great Lakes Forest of Michigan. Barrett et al. (1995) examined relationships between soils and pre-settlement forest in Michigan using GLO records as a starting point. Siccama (1971) used the original land surveys to compare past and modern forests in Northern Vermont.

Historical data have been widely used in the United States, however the instances of their use in Canada are limited. Clarke (1969) used Crown Survey notes to estimate the composition of the forest of North Dumfries Township in southern Ontario, Canada. Davis (1986) also used Crown Survey records to examine evolving landscape productivities in four townships in southern Ontario, Canada. Heidenreich (1973) described a procedure for mapping the vegetation of Simcoe County using Ontario land surveys. Pile (1969) also described methods of analyzing original vegetation using land survey records. These authors have demonstrated the value of historical data for reconstructing forest composition in Canada. However, my study is the first attempt to use this approach in such a large region and the first to use four management units in central Ontario. The value of this historical data is high and will lead to a better understanding of historical diversity.

2.0 METHODS

Study Areas

The study was conducted in four management units (MU) in central Ontario within the Great Lakes St. Lawrence Forest Region (Hosie, 1990). These management units were Algonquin Park, Nipissing, French-Severn (a.k.a. Parry Sound) and Temagami. With the exception of the Algonquin dome in Algonquin Park, the geologic characteristics of this region are relatively similar. In either case, the geology and geomorphology of the region have been discussed in detail by McCann (1987) and Rowe (1972).

The Algonquin Park, Nipissing and French-Severn study areas are each made up of 10 sub-divided townships (Figs 2.1, 2.2 and 2.3), while the Temagami sample area is made up of 65 non-sub-divided townships (Figure 2.4). The differences between the townships and their selection are discussed in detail in the next section. In total the database consists of approximately 7000 kilometers of survey lines.

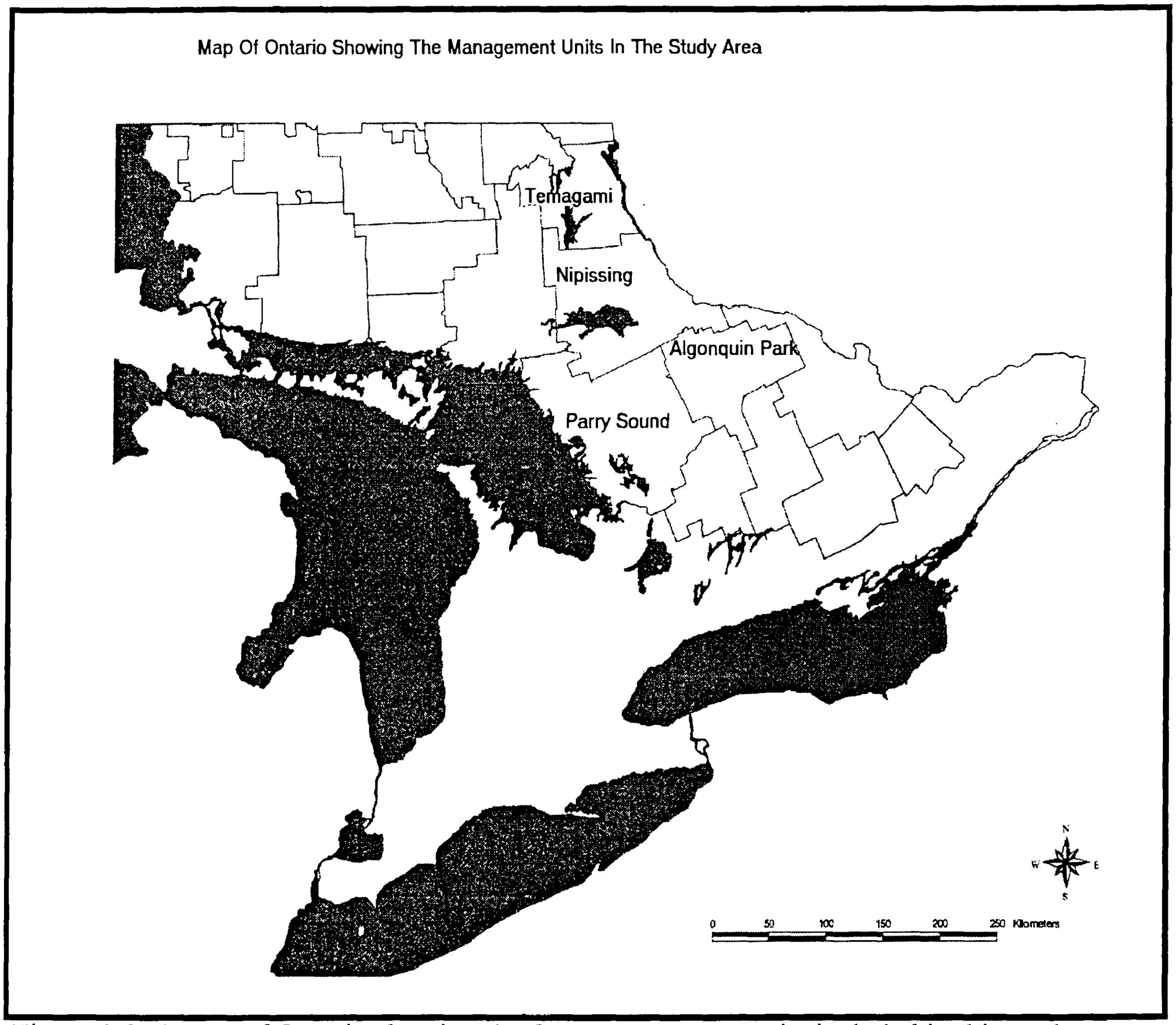

Figure 2.0 A map of Ontario showing the four management units included in this study of historical biodiversity. Note: Parry Sound is also called French-Severn.

Algonquin Park

The Algonquin Park management unit is located in central Ontario (Figure 2.0) in the Great Lakes-St. Lawrence Forest Region. Figure 2.1 shows the location of the ten sub-divided townships in Algonquin Park which make up the study area.

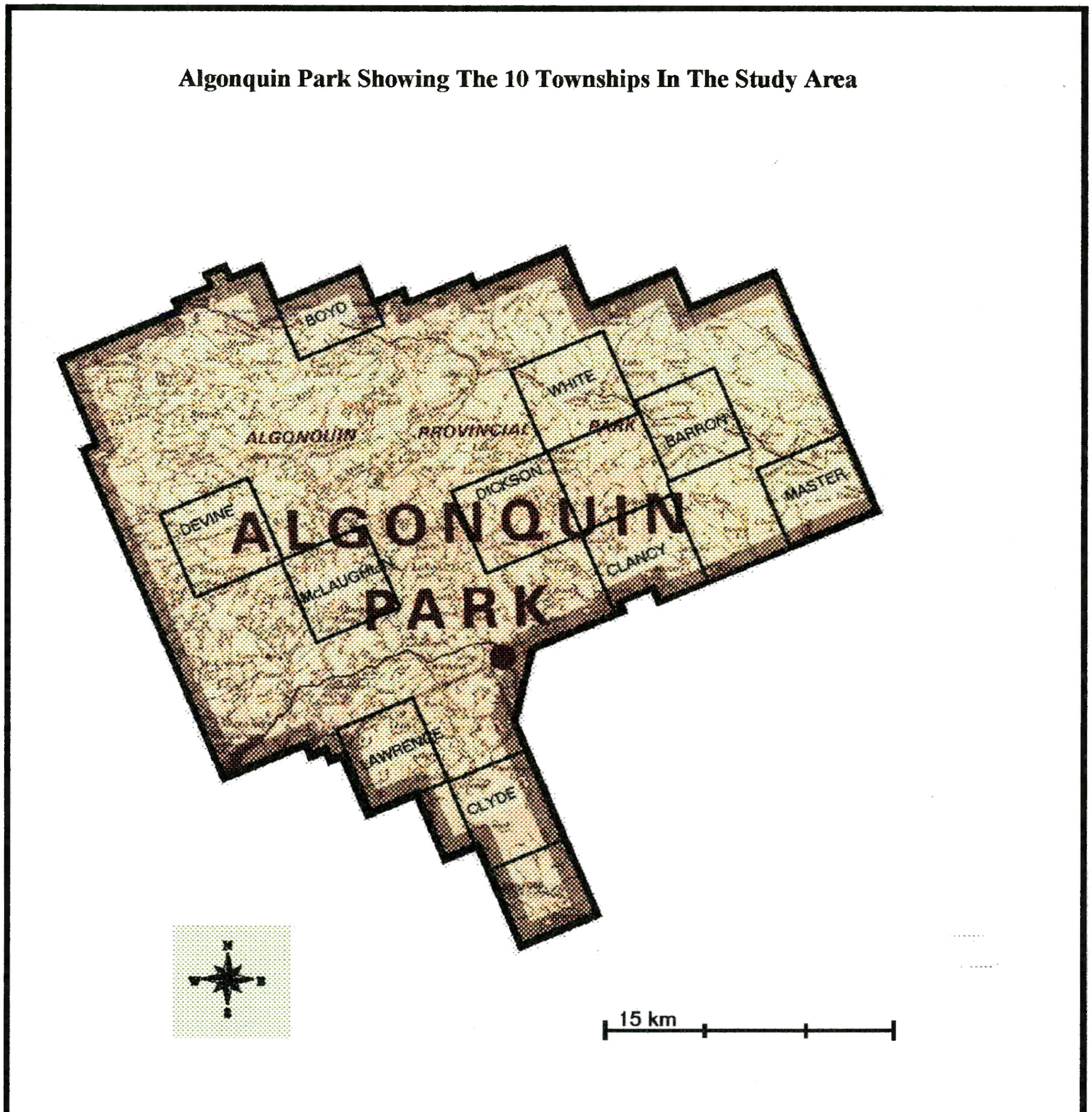

Figure 2.1 A map of Algonquin Park showing the location of the ten sub-divided townships in the study area.

French-Severn

The French-Severn management unit is located directly south west of Algonquin Park (Figure 2.0). The French-Severn shares its eastern border with Algonquin Park and its western border stretches along Georgian Bay. Figure 2.2 shows the ten sub-divided townships that make up the study area.

The French-Severn Management Unit Showing The 10 Townships In the Study Area

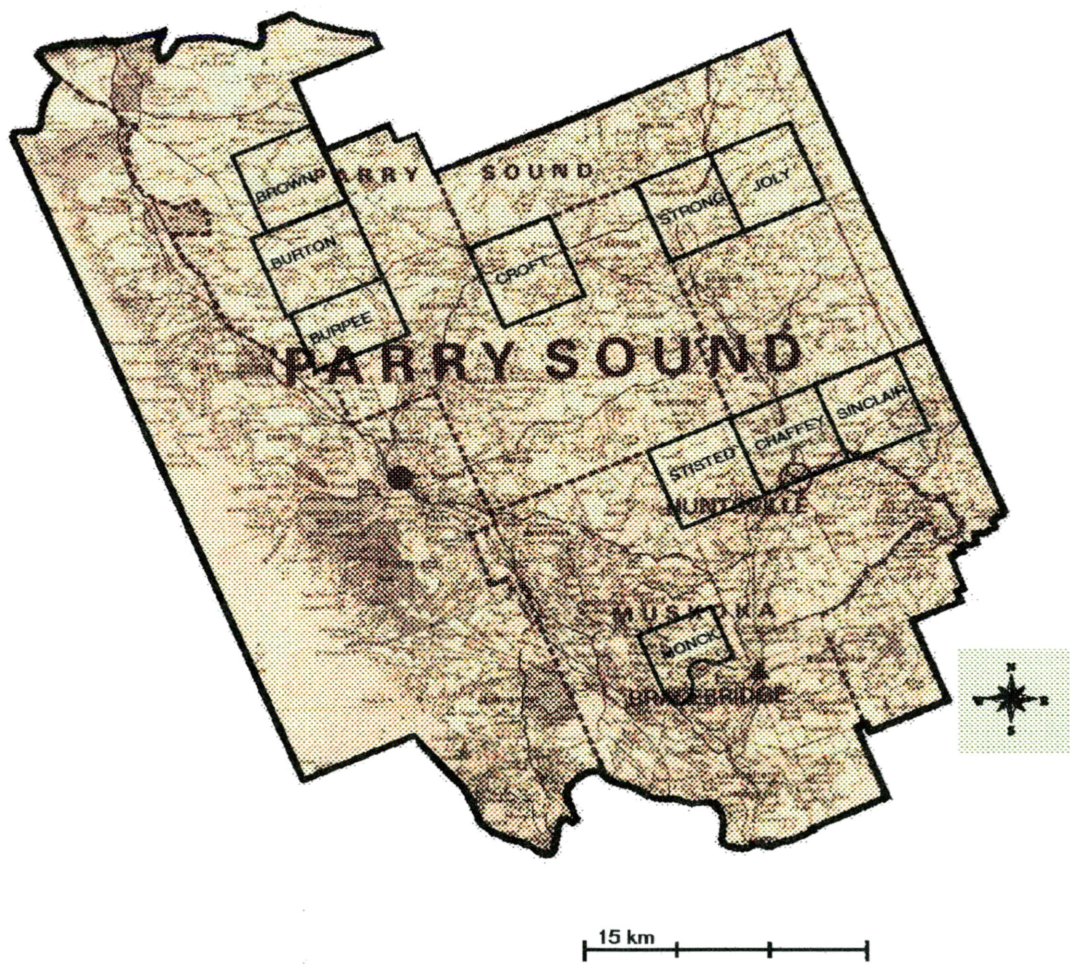

Figure 2.2 A map of the French-Severn management unit showing the ten sub-divided townships in the study area.

Nipissing

The Nipissing management unit is located (Figure 2.0) to the north east of the Algonquin Park and French-Severn management units. Figure 2.3 shows the ten sub-divided townships in Nipissing that are part of the study area.

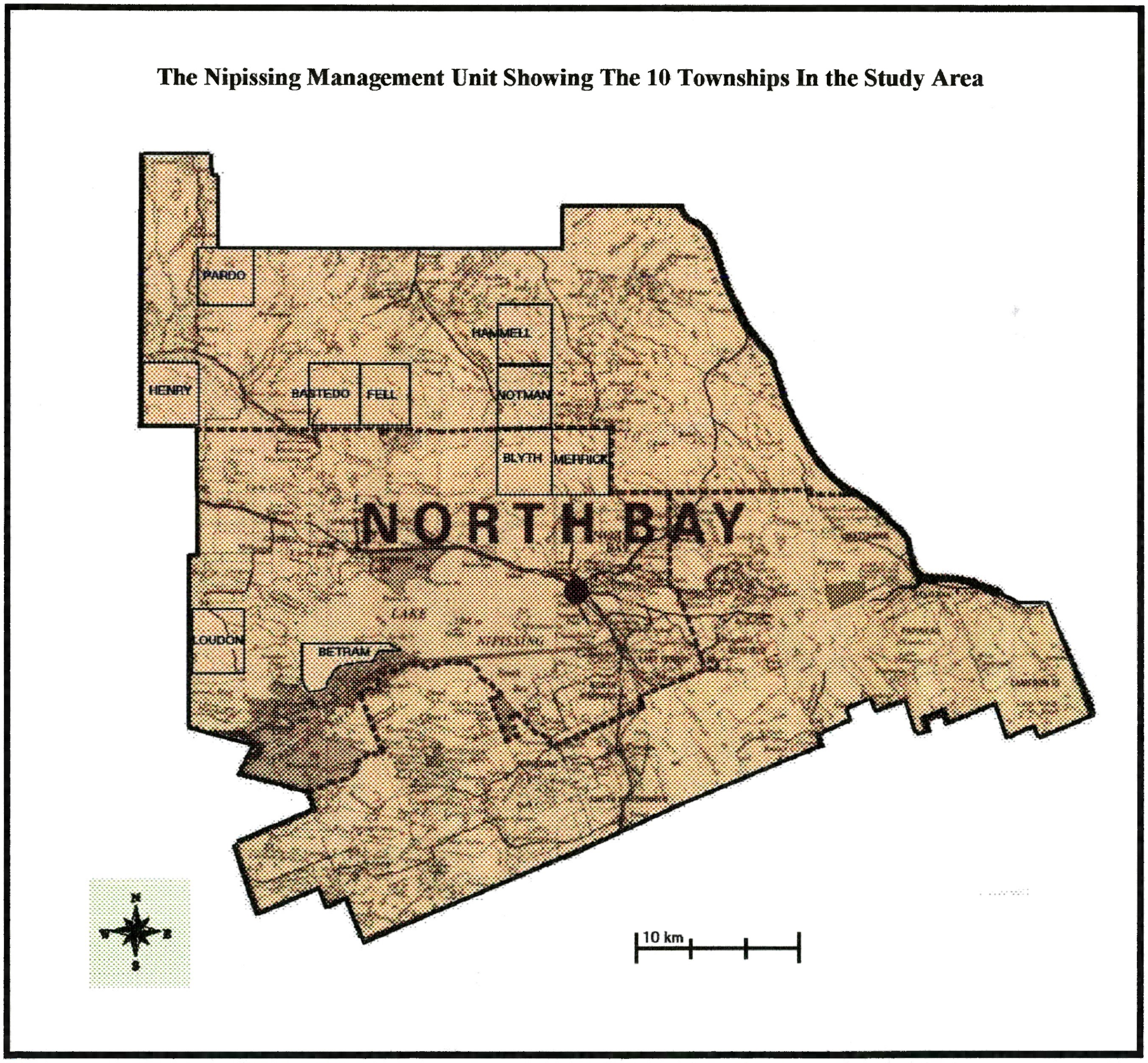

Figure 2.3 A map of the Nipissing management unit showing the ten sub-divided townships in the study area.

Temagami

The Temagami management unit is located directly north of the Nipissing management unit (Figure 2.0). Figure 2.4 shows the non-sub-divided townships that make up the study area. Unlike the three other management units, the Temagami database has been divided into eight groups of 6 to 7 townships per group in an effort to equalize survey line proportions throughout the four management units.

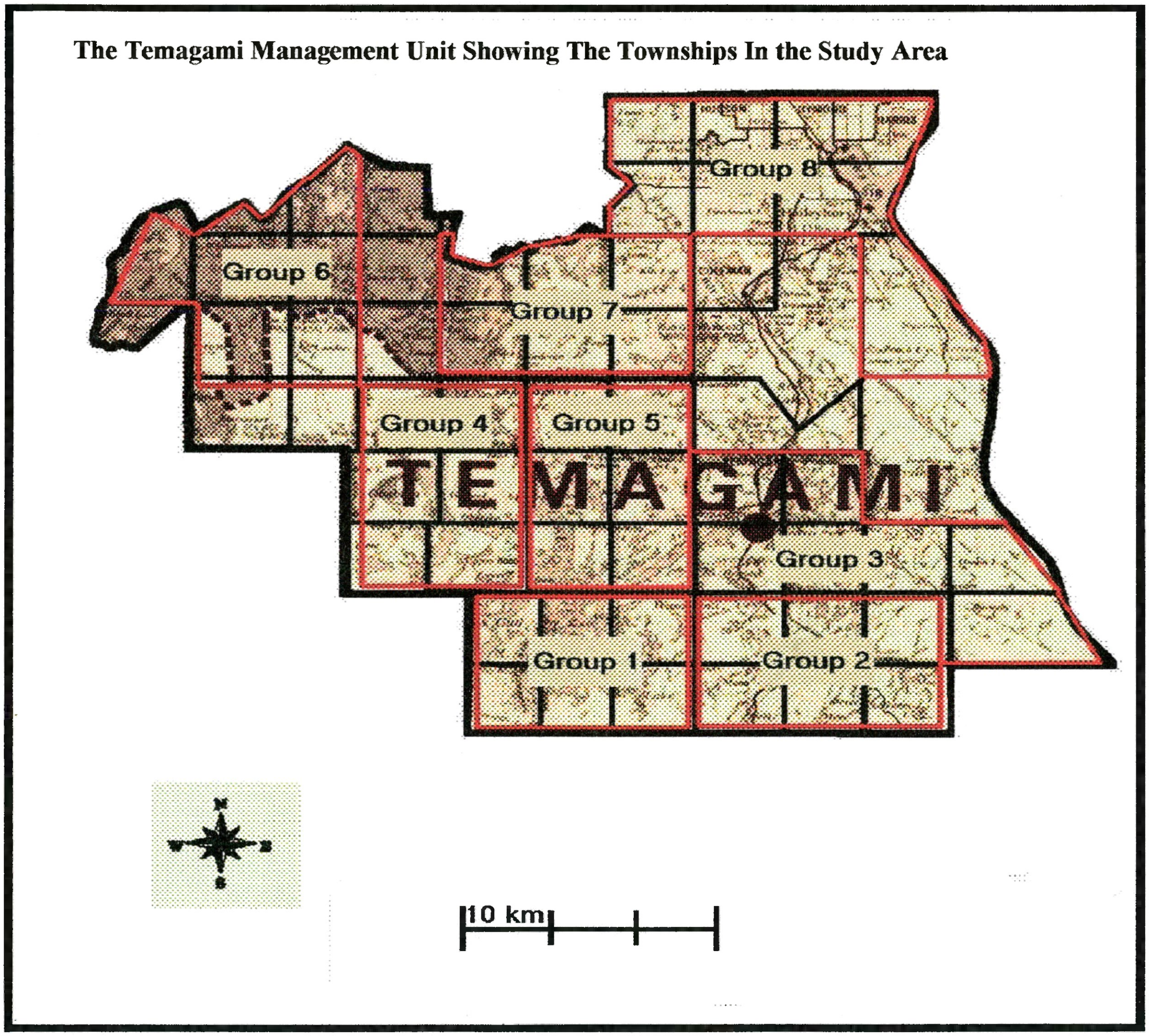

Figure 2.4 A map of Temagami showing the non-sub-divided townships in the study area.

3.0 METHODS

Survey Note Descriptions

Townships in central Ontario are typically divided into two types; non-subdivided and subdivided. Non-subdivided townships (Figure 3.0) are made up of four sides, each side being 480 chains (9.6 km). Sub-divided townships (Figure 3.1) tend to be slightly larger than non-subdivided townships with sizes ranging from 480 chains (9.6 km) to 800 chains (16 km) (Sebert, 1980).

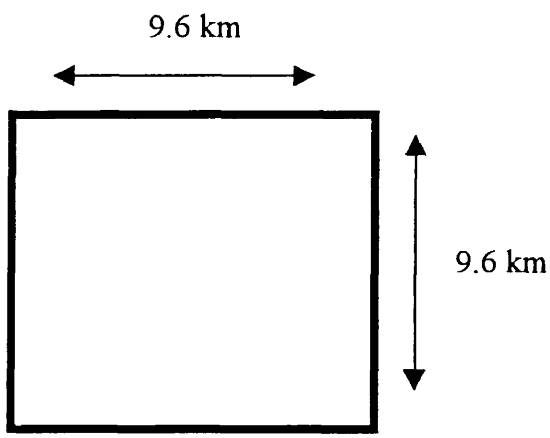

Figure. 3.0 A diagrammatic example of a typical non-subdivided township in central Ontario, Canada.

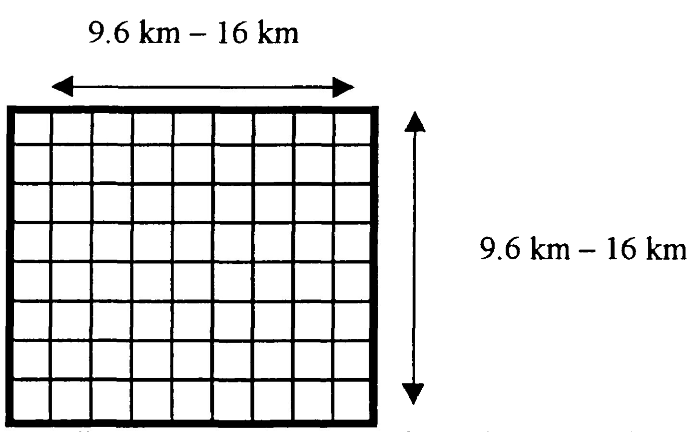

Figure 3.1 A diagrammatic example of a typical subdivided township in central Ontario, Canada. The thin lines represent concession lines within the township.

Survey Note Data

The original Crown Survey records represent, in today's terms, the cruise notes of a particular survey line in a forested area. Surveyors would follow a pre-determined compass bearing through the forest and record all tree species in order of relative abundance. They also recorded the relative ages, health and diameter at breast height of the trees they encountered. Other types of data included: the types of land classes such as lakes, marshes, rock etc. and even some descriptions of soil type, topography and wildlife. Of particular interest to this study is the information regarding forest types. Figure 3.2 represents a typical example of one page of a cruise line from the original Crown Survey notes.

One characteristic of the survey notes that was important to consider was the amount of detail that the surveyor included in the notes. Different surveyors provided different levels of detail in terms of the number of tree species and general topographical data. Thus, I tried to use those survey notes that contained the maximum amount of forest data.

Copies of the Crown Survey records were acquired from the Crown Survey Records Office of the Ontario Ministry of Natural Resources (OMNR) in Peterborough. These pages were then interpreted and transposed into a database as described in Figures 3.2 and 3.3 and Table 3.0. This completed database represents the 1890 (circa) forest condition and will be the basis of comparison to the present forest condition.

Due to the large size of the database, accuracy was important. Townships were picked randomly by using a township list and selecting them using a random number system (although the amount of detail in a set of survey notes was also important). The spreadsheets were checked against the original Crown Survey to ensure data were transcribed correctly. Survey distances were also checked using the distance sums in a survey line. Generally each survey page was 80 chains (1.6 km) long and each survey line was 480 chains long, thus by checking the total after each page and each survey line, numeric accuracy of the data was achieved. These checks were performed to ensure that all of the data been photocopied and that each page had been entered into the spreadsheet.

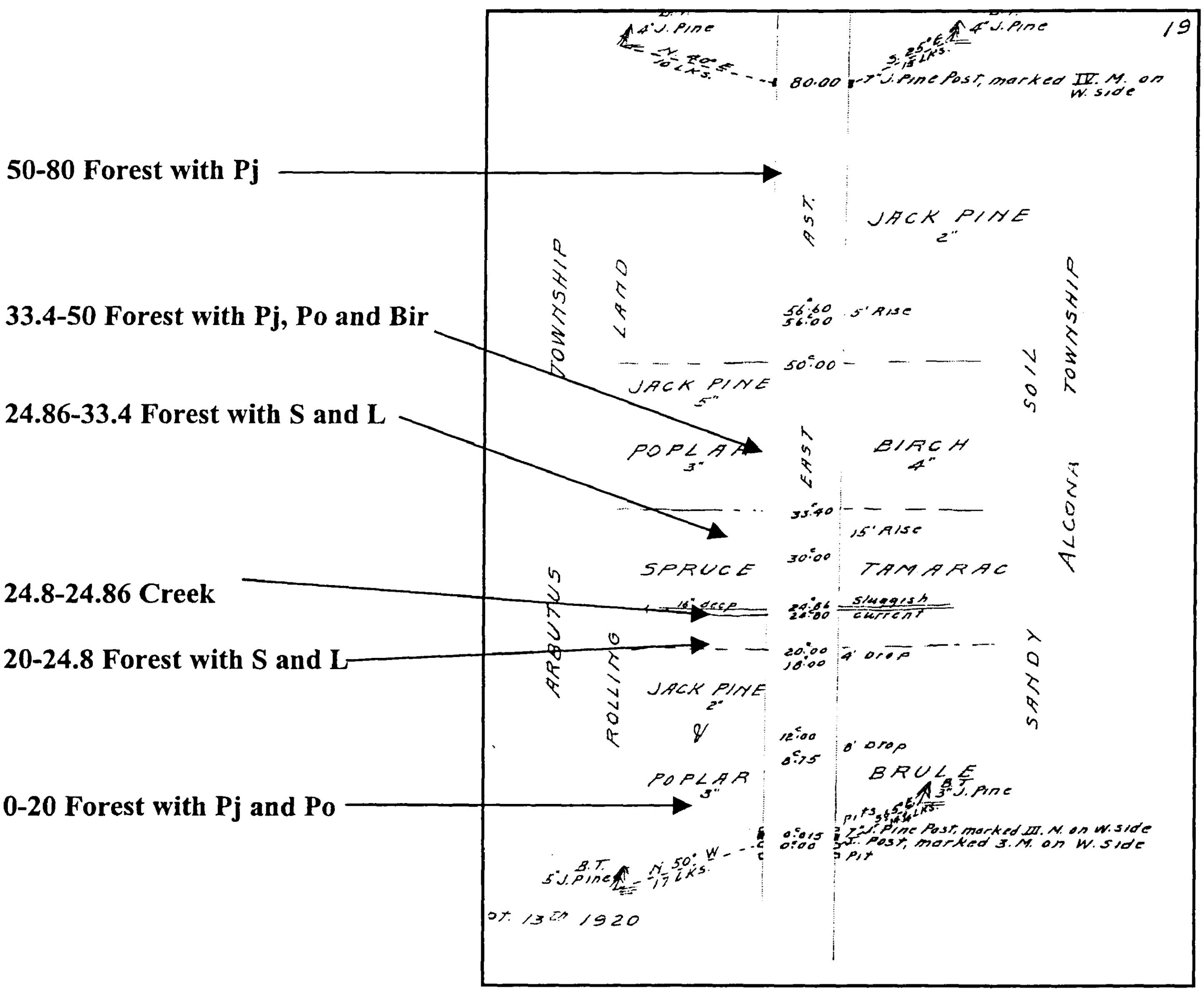

Figure 3.2 A typical example of a Crown Survey note, central Ontario, Canada.

Figure 3.2 shows how the forest information was recorded by the surveyors and the bolded writing shows how these data were interpreted for my database. Each page of survey note runs from 0 to 80 chains (1 chain = 20 m) (80 chains = 1.6 km) with each change in forest or landclass type being designated by a line or species list change. Table 3.0 illustrates how the original surveyors' notes have been summarized. The first three columns give basic information about which township was surveyed, in which year

Table 3.0 A sample of the database spreadsheet from the Crown Survey notes.

Township Name	Year Surveyed	Boundary (N,S,E,W)	Length (Chains)	Land Class	Land Class #	Wg Species	Species Composition	Comments
Brewster	1890	North	36	Forest	20	PJ	PJ B PW	Burn
Brewster	1890	North	14	Lake	70			Smith Lake
Brewster	1890	North	30	Forest	20	PJ	PJ SB PO	
Brewster	1890	North	5.24	Marsh	52			
Brewster	1890	North	43.3	Forest	20	SB	SB L	Windfall
Brewster	1890	North	6.92	Lake	70			
Brewster	1890	North	24.54	Forest	20	SB	SB	
Brewster	1890	North	49	Forest	20	SB	SB BW PO	Burn
Brewster	1890	North	2	Rock	56			
Brewster	1890	North	24	Forest	20	SB	SB L PO	
Brewster	1890	North	0.3	River	71			
Brewster	1890	North	10	Marsh	52			
Brewster	1890	North	58	Forest	20	PJ	PJ	
Brewster	1890	North	17	Forest	20	PJ	PJ PW BW	Burn
Brewster	1890	North	80	Forest	20	SB	SB L PO	
Brewster	1890	North	34.1	Forest	20	SB	SB L	
Brewster	1890	North	22.53	Lake	70			
Brewster	1890	North	3.37	Marsh	52			
Brewster	1890	North	15	Bog	50	SB	SB AB	New burn
Brewster	1890	North	27	Forest	20	PJ	PJ SB PO	
Brewster	1890	North	23	Forest	20	PW	PW PR PO	

and the particular side of the township. The next four columns characterize the forest landscape. The length column reports the distance in chains of that land class. For example, row one is 36 chains in length, is a forest stand, land class number 20 (FRI classification) and is composed of three species: jack pine (*Pinus banksiana*), balsam fir (*Abies balsamea*) and white pine (*Pinus strobus*). Since jack pine was listed first by the surveyor, it has been assumed that it is the working group or dominant species. This assumption has been made for the entire database. The comment column represents any other type of information listed by the surveyor; for example row one was a burned area. Typically the comment column includes information such as disturbances, lake names or any other data that could prove useful to future researchers.

Figure 3.3 shows an example of other important features found in the survey notes. Rivers and lakes were used as a benchmark or reference point by which the accuracy of the survey distances could be measured. Management unit maps were used

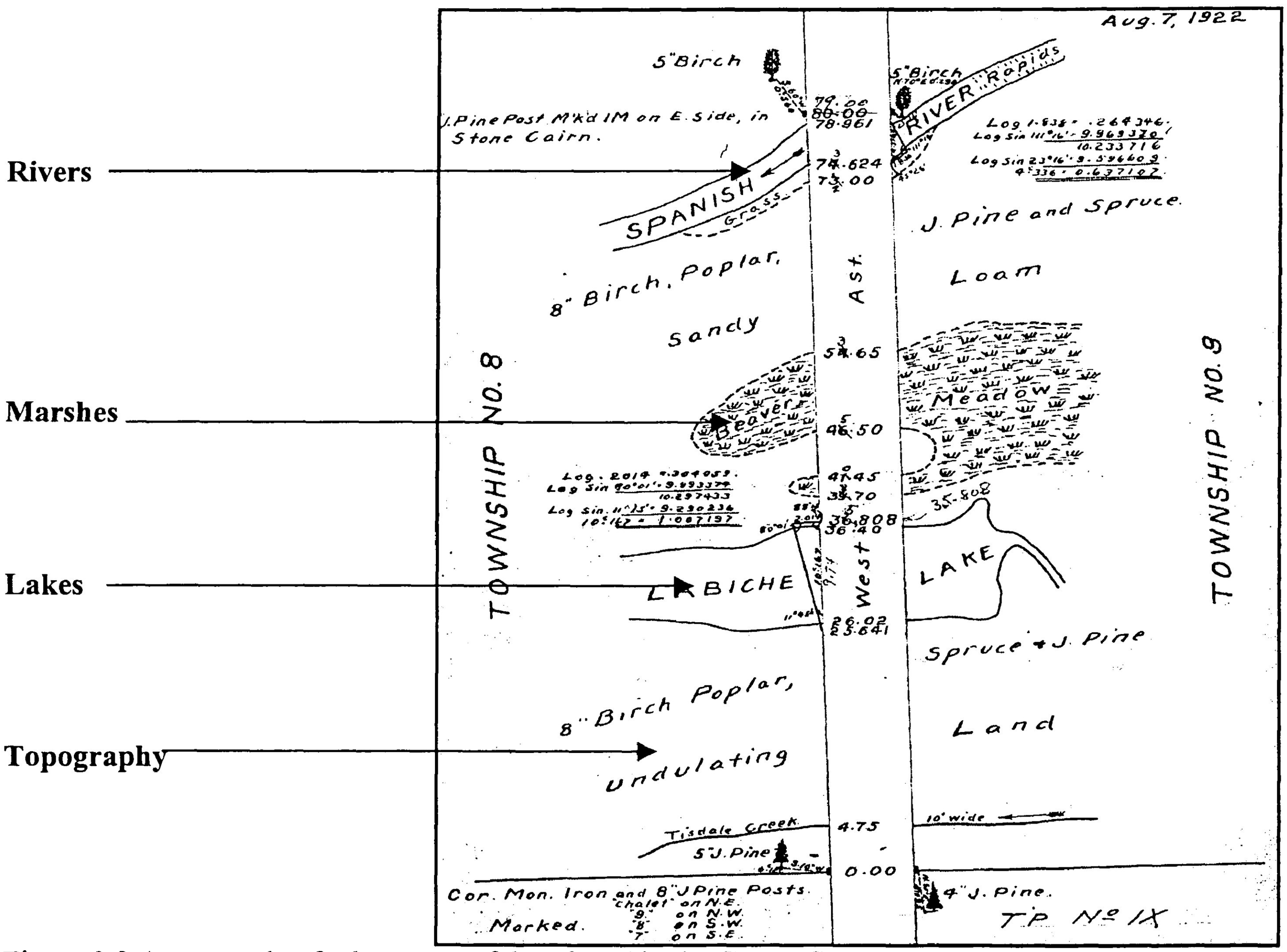

Figure 3.3 An example of other types of data found in the Crown Survey notes.

while the original surveyors' data were converted to spreadsheet form to monitor the accuracy of both the survey notes and the input process. As river and lake positions have not changed much over the last century they could be used as reference points and in most cases the survey notes proved to be most accurate.

An important aspect to consider regarding the Crown Surveys is the difference between the two types of townships (Figure 3.0 and Figure 3.1). Non subdivided townships are made up of four-perimeter survey lines. Sub-divided townships have not only been sampled along the perimeter, but also along concession lines. Depending on the township, sample (concession) lines number from 15 to 20. Thus subdivided townships were more intensely sampled than non-subdivided townships. Temagami (Figure 2.4) is the only management unit with non-subdivided townships and as such the study area makes up 90 percent of all townships. Although there are differences in size and sampling intensity of the two types of townships it is important to understand that these differences were not important as each township regardless of type or size is being compared to itself over two time periods.

Forest Resource Inventory (FRI) Data

If the Crown Survey notes represented the forest condition in (1890 circa), then the FRI data represented the 'current' state of the forest. The 1990 FRI data were supplied by Brian Naylor of the Southcentral Sciences Section of the OMNR. They were in spreadsheet form divided into columns based on township name, working group, species composition, year of origin and the area of each stand. The FRI data that were used in this study were from 1990 as they followed the same township lines as the original Crown Surveys.

The 1996 Forest Resources of Ontario issued by the Provincial government defined FRI as a resource inventory conducted for each management unit on average every twenty years. The FRI divides the area into components such as water, non-forested, non-productive and productive forest. The FRI also gives descriptive information about the timber in each management unit (e.g. stand age, height, species composition and stocking level). These data are usually in the form of interpreted air photographs, forest stand maps or Geographic Information Systems databases.

As with the Crown Survey notes, the FRI data contains inherent errors that need to be discussed. The majority of the FRI data are gathered from interpreting air photographs. This task is assigned to professional interpreters who distinguish the different stands based on the colours, textures and shapes found in the photo. One of the problems with this is that, some interpreters tend to clump certain stands together while others may separate the same stand into several stands. This clumping and separating may also cause certain 'rare' species that make up less than ten percent of a stand to disappear from the database. However, the FRI data represent the best available inventory of the forest that we have and as such will serve as the 1990 data that will be compared to the 'pre-settlement' forest condition.

Database Comparisons

One of the limitations of the survey notes was the identification of certain tree species. Depending on the year of the survey and the individual surveyor, certain species of trees were identified to the genus level but not to the species level, including:

1) Spruce (*Picea spp.*);
2) Pine (*Pinus spp.*);
3) Birch (*Betula spp.*);
4) Maple (*Acer spp.*).

To compensate for this problem, species of these genera were grouped into general categories. The spruce group included black spruce (*Picea mariana*) and white spruce (*P. glauca*), the pine group included white pine (*P.strobus*) and red pine (*P. resinosa*). The surveyors did identify jack pine and as such it was not included in the pine group. The maple group included soft (*Acer rubrum*) and hard maple (*Acer saccharum*).

Due to the silvical differences of white birch (*Betula papyrifera*) and yellow birch (*Betula lutea*), I decided that they could not be placed into a single grouping. White birch is typically found on well-drained sandy or silty loams and is considered a shade intolerant species, (Hosie, 1990). Yellow birch is found on rich moist soils and is an intermediate shade tolerant species, (Hosie, 1990). To compensate for this problem, the birches were separated by their association with other species. Brian Naylor of the Southcentral Sciences Section of the OMNR provided a list (Appendix 1) of birch groupings that had been reviewed by Nipissing, Temagami and Algonquin Park OMNR biologists, ecologists and foresters to arrive at a consensus of white birch and yellow birch groupings. Although this is an assumption based on associations that exist today, I believe that it is a sound assumption for the historical data also. The spruces, pines and maples were not separated due to concerns about making too many assumptions based on today's data.

The primary objective of this study was to compare pre-settlement forest conditions to the existing conditions in 1990 to ascertain apparent proportional changes in forest composition. Therefore it was important to understand not only how the Crown Survey note databases were produced but also the 1990 OMNR FRI databases. As the 1890 and 1990 databases were being compared, it was important that the groupings of certain species were common to both.

As with the survey note data, the FRI databases contained certain limitations that must be considered. Certain tree species were placed into 'supergroups', and as such it was important to make sure both databases grouped species in the same way. The FRI database grouped eastern white cedar (*Thuja occidentalis*) and tamarack (*Larix larcina*) as 'other conifer' and also grouped beech (*Fagus spp.*), elm (*Ulmus spp.*), basswood (*Tilia americana*) and ironwood (*Ostrya virginiana*) as 'other hardwoods'. Thus for the purposes of comparison the 'other conifer' and 'other hardwood' groups were consistent throughout the databases.

Working Group Comparisons

Data from all management units were compared to determine if there were any apparent differences between working group proportions from the 1890 and the 1990 databases. The databases were queried by working group and were then converted into a percent value for each species. The 1990 FRI data were converted into a percent from an area value, while the 1890 Crown Survey data were converted into a percent from a linear measurement (chains). Percentages were used so that the 1890 and 1990 database could be compared.

The databases were also queried to provide an age class distribution. One other limitation of the surveyor notes is that there were very few data on tree ages. To compensate for this problem I used the comments from the survey notes which specified burned areas. These burned areas were often described as 'five year old burn, ten year old burn, new burn etc.' These areas were the dividing point between the two age classes that could be legitimately determined from the survey notes. Thus, two age classes were used, those being:

1) Greater than 20 years old;
2) Less than 20 years old.

For purposes of comparison, stands less than twenty years old were not included due to the problems of accurately identifying working groups in young stands (Van Wagner, 1978). This age class distinction was also needed in the 1990 FRI data. The FRI database was simply queried by year of origin to eliminate all the stands less than twenty years of age. Thus, the remaining comparisons, which included: Hardwoods vs. Softwoods, Tolerance Groupings and Frequency of Occurrence were based on all stands that are over the age of twenty years.

Hardwoods vs. Softwoods

All management units were compared to determine if there had been apparent changes in the proportions of hardwoods and softwoods over the last century. The database was queried based on the hardwood group which included white birch, yellow birch, maple, oak (*Quercus spp.*), ash, beech, elm, ironwood, basswood, poplar (P*opulus spp.*) and the softwood group which included pine, jack pine, spruce, cedar, larch, hemlock (*Tsuga canadensis*) and balsam fir. These values were converted to percentages for 1890 and 1990 data and were compared between periods.

Shade Tolerance Group Comparisons

Each of the study areas were compared to determine if there were any apparent differences in groupings of shade tolerance proportions over the last century. The USDA (1990) book of Silvics of North America was used to divide the species' into three groups based on shade tolerance.

The shade tolerant group included:

1) Maple;
2) Beech;
3) Balsam fir;
4) Hemlock;
5) Ironwood;

The mid-tolerant group included:

1) Yellow Birch;
2) Oak;
3) Elm;
4) White Pine;
5) Cedar;
6) Basswood;
7) Black Spruce;
8) Ash;

The shade intolerant group included:

1) White Birch;
2) Poplar;
3) Jack pine;
4) Larch;
5) Red Pine;

Frequency of Occurrence

Table 3.0 shows a sample of the data that were taken from the survey notes. The species composition column gives a detailed list of occurrences for all species encountered along the survey line. Occurrence represents the proportion of a particular species throughout the forest landscape. The databases were queried for the occurrence of each species regardless of if it was a working group species or not. The frequencies of each species were then converted into proportions and compared descriptively.

Scales of Comparison

Two scales of comparison were used in this study:

1) Management unit level;
2) Regional level;

Each township was individually queried for all four types of comparisons. These individual township data were then pooled to produce a comparison at the management unit level (Figs 2.1, 2.2, 2.3 and 2.4). Finally, all of the management unit datasets were pooled to give a comparison at the regional level.

Analysis of Temagami

The management unit of Temagami was made up of non-subdivided townships (Figure 2.4). These types of townships have much less data per unit than do sub-divided townships and because of this I decided to group the townships in Temagami so that they were equivalent in survey line length to the other management units. A subdivided township contains on average 6.5 times as much survey line as its non-subdivided counterpart. Therefore I grouped the townships of Temagami into 8 groups with each group containing 6 to 7 townships each. The non-subdivided nature of Temagami's townships was the only difference in the data. The remainder of the comparison of Temagami was treated the same as the other three management units.

One other difference with the Temagami species listings compared to Algonquin Park, French-Severn and Nipissing was that in Temagami the surveyors did distinguish between red and white pine. It is unknown why this occurred; perhaps it was in their survey 'instructions' to do so, as Temagami was known to have large amounts of pine. However, it does allow for a finer comparison of the pine groupings in Temagami.

Comparison Methods

Working Groups

Once the forest composition data were collected and placed into spreadsheet form, they were queried using Microsoft Access based on working groups. Each working group species was queried and totalled. These working group totals were then added to give a total forested area for each township. Table 3.1 shows how the proportions of working groups were calculated. The species column identifies which species have been

Table 3.1 A sample of the proportions used in comparisons.

Wg Species	1890 Length	1890 Percent	1990 Area	1990 Percent
Bf	234	3.89	3467	21.34
Bw	645	10.73	276	1.70
By	21	0.35	354	2.18
He	567	9.43	1456	8.96
M	1345	22.37	7534	46.36
Oc	34	0.57	65	0.40
Oh	197	3.28	35	0.22
P	598	9.95	876	5.39
Pj	798	13.27	275	1.69
Po	1098	18.26	1345	8.28
S	476	7.92	567	3.49
Total	6013	100.00	16250	100.00

totalled. Column two shows the 1890 raw length numbers that were queried using Microsoft Access. For example, there were 234 chains (4.6 km) of survey line that had balsam fir as the working group species in this township. The total row represents the total length of forested survey line within this particular township; in this case there were 6013 chains (120.26 km) of forested survey line. Percentages were then calculated using these data and this process was repeated for each species, each time period and for each township.

Once this process was finished for all ten townships in a management unit, I took the ten 1890 percentages for balsam fir and compared them to the ten 1990 percentages. These percentages were kept in the same order to make sure I was comparing the balsam fir levels of Township X in 1890 to the balsam fir levels of Township X in 1990. It is important to realize that these comparisons were not based on the actual amount of area or timber in the township, but rather the compositional make up of the forest. Table 3.1 demonstrates this point effectively. In 1890 there were 6013 units of forest length, while in 1990 there were 16250 ha of forest. Therefore each time period has a different base number and in some instances the results may show that while there has been an increase in a particular species in terms of area, the actual compositional percentage of that species may have decreased. The results of this study only deal with compositional changes in the forest rather than actual amounts.

Hardwoods and Softwoods

The basic process described in the Working Group comparison method hold true for all other comparisons. The databases were queried for all species', once this information was obtained, each species was given a code; hardwoods 1, softwoods 2. These values were then tallied for each township and compared to determine if any apparent changes had occurred. Once again, the results show compositional proportions of hardwoods and softwoods.

Shade Tolerance Groupings

All species were divided into their tolerance groupings. Once this was established, I queried the databases, assigned each species a value based on its tolerance grouping and totalled each grouping for each township. Each township had three values; percent of shade tolerant, percent of shade intolerant and percent of the intermediate group.

Frequency of Occurrence

The databases were sampled to find how many times each species appeared throughout the sample area. These values were tallied for each species and each township. The data were placed into a table like Table 3.1 and percentages were calculated.

4.0 RESULTS

Algonquin Park

Working Groups

Figure 4.0 shows the percent of each working group proportion in Algonquin Park in 1890 and 1990. Apparent changes occurred in the maple and poplar working groups. The maple working group appears to have increased from 20.3 percent in 1890 to 36.9 percent in 1990. The poplar and white birch working groups seem to have decreased 7.0 percent and 6.7 percent respectively.

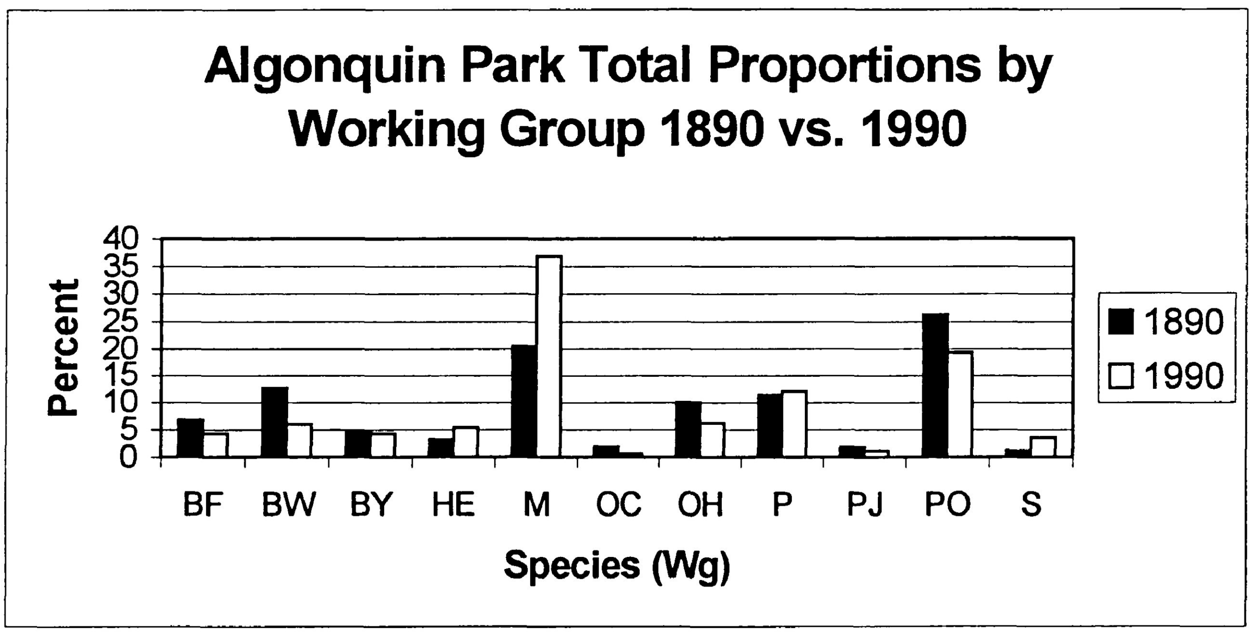

Figure 4.0 The relative abundance of working groups in 1890 and 1990 in Algonquin Park. BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, He = Hemlock, M = Maple, OC = Other Conifer, OH = Other Hardwoods, P = Pine, PJ = Jack Pine, PO = Poplar, S = Spruce.

Hardwoods and Softwoods

Figure 4.1 shows the percent of hardwood and softwood proportions found in Algonquin Park in 1890 and 1990. There were no apparent differences between hardwoods, and softwoods.

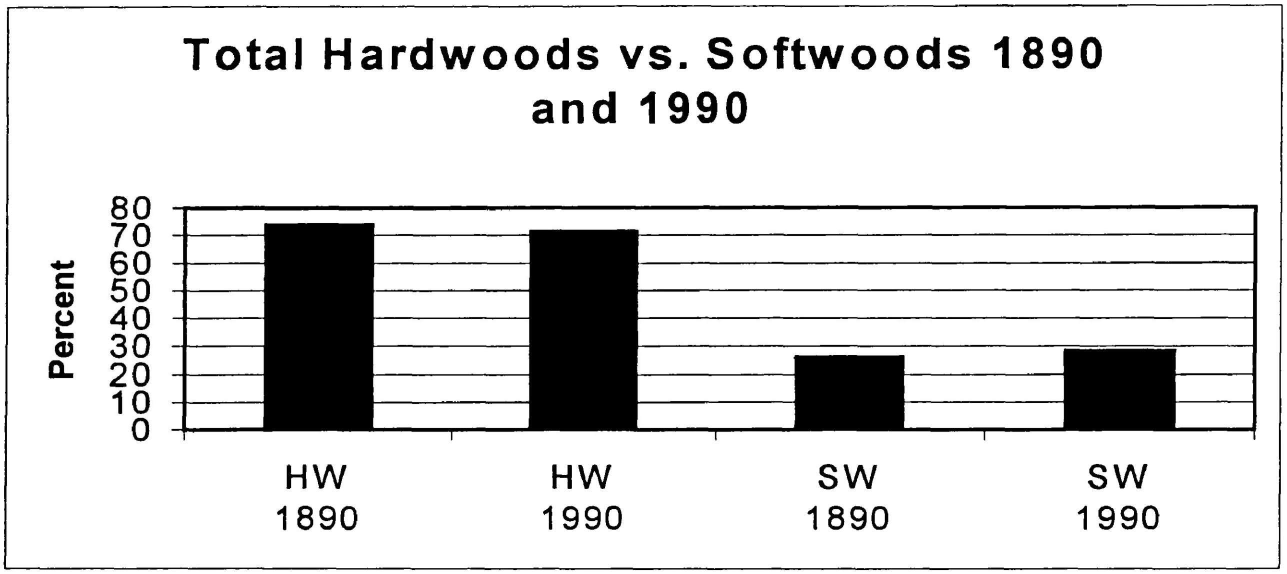

Figure 4.1 The total proportions of hardwoods and softwoods in Algonquin Park in 1890 and 1990. HW = Hardwoods, SW = Softwoods.

Shade Tolerance Groups

Figure 4.2 shows the proportions of the three shade tolerance groupings for Algonquin Park in 1890 and 1990. Large changes seemed to have occurred with the shade tolerant and the shade intolerant species. The tolerant group increased 14.7 percent since 1890 while the shade intolerant decreased 15 percent over the same time.

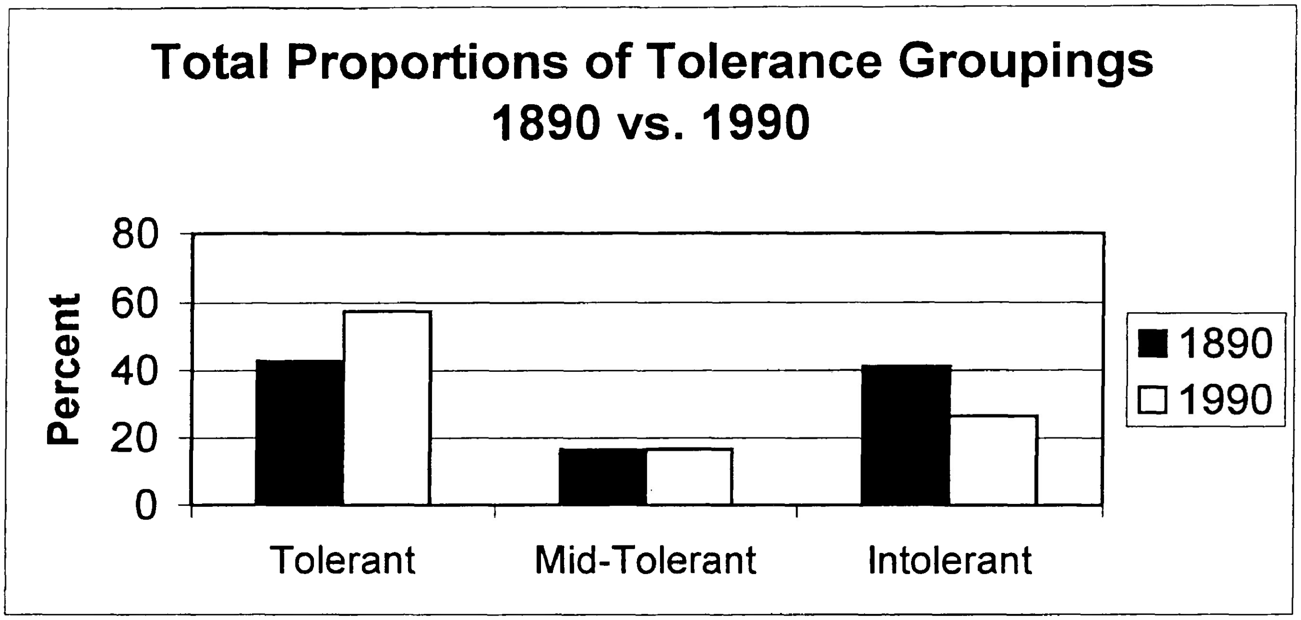

Figure 4.2 The total proportions of tolerance groupings 1890 vs. 1990 in Algonquin Park. See Methods for groupings.

The mid-tolerant grouping appears to have remained stable over the two time periods.

Occurrences

Figure 4.3 shows the frequency of occurrence for all species in the Algonquin Park study area. Large changes appear to have occurred with five species. The occurrence of maple appears to have increased from 11.6 percent in 1890 to 21.0 percent in 1990. The occurrence of spruce and yellow birch also seems to have increased from 4.5 percent to 9.6 percent and 1.0 to 8.4 percent respectively. White birch and 'other hardwoods' appear to have decreased also. White birch decreased from 21.2 percent in 1890 to 9.4 in 1990 and 'other hardwoods' decreased almost 5 percent.

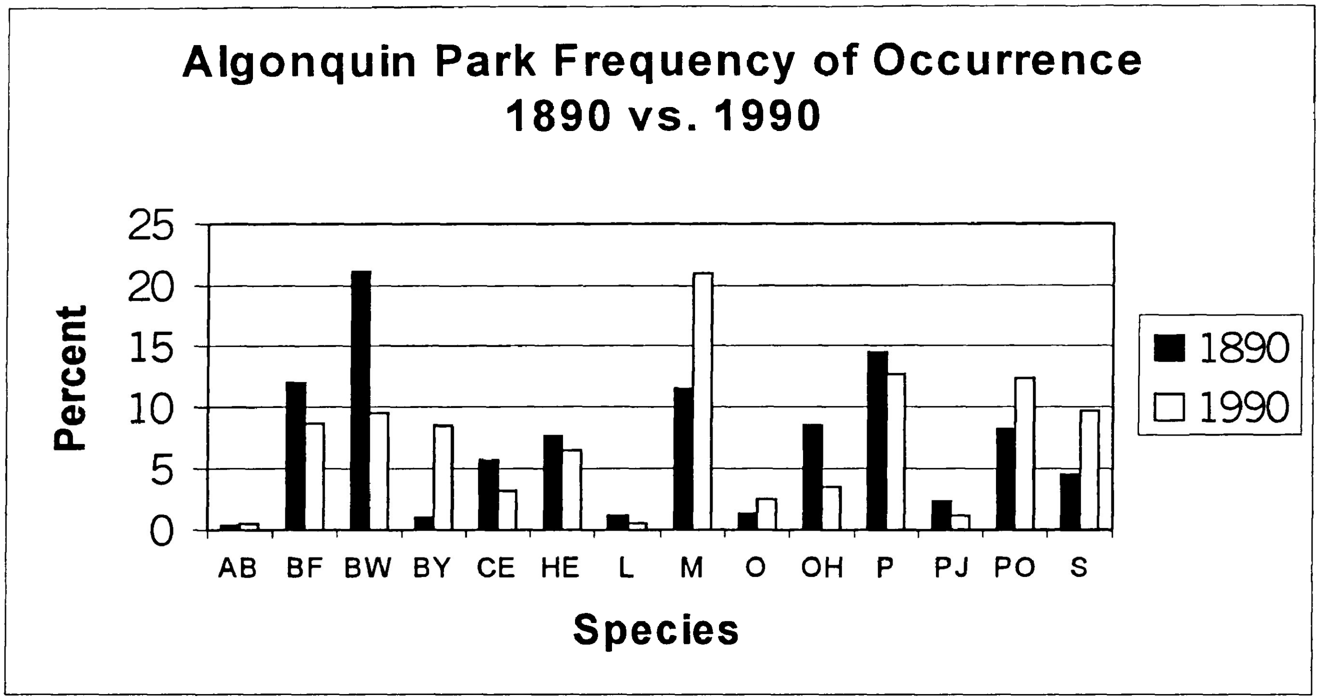

Figure 4.3 The frequency of occurrence for all species in Algonquin Park in 1890 and 1990. AB = Black Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, CE = Cedar, He = Hemlock, L = Larch, M = Maple, O = Oak, OH = Other Hardwoods, P = Pine, PJ = Jack Pine, PO = Poplar, S = Spruce.

French-Severn

Working Groups

Figure 4.4 shows the working group proportions in French-Severn. The largest apparent changes in working groups occurred with maple, hemlock, white birch, poplar and the ‘other conifer’ group. The maple working group seems to have increased from 39.5 percent in 1890 to 56.7 percent in 1990.

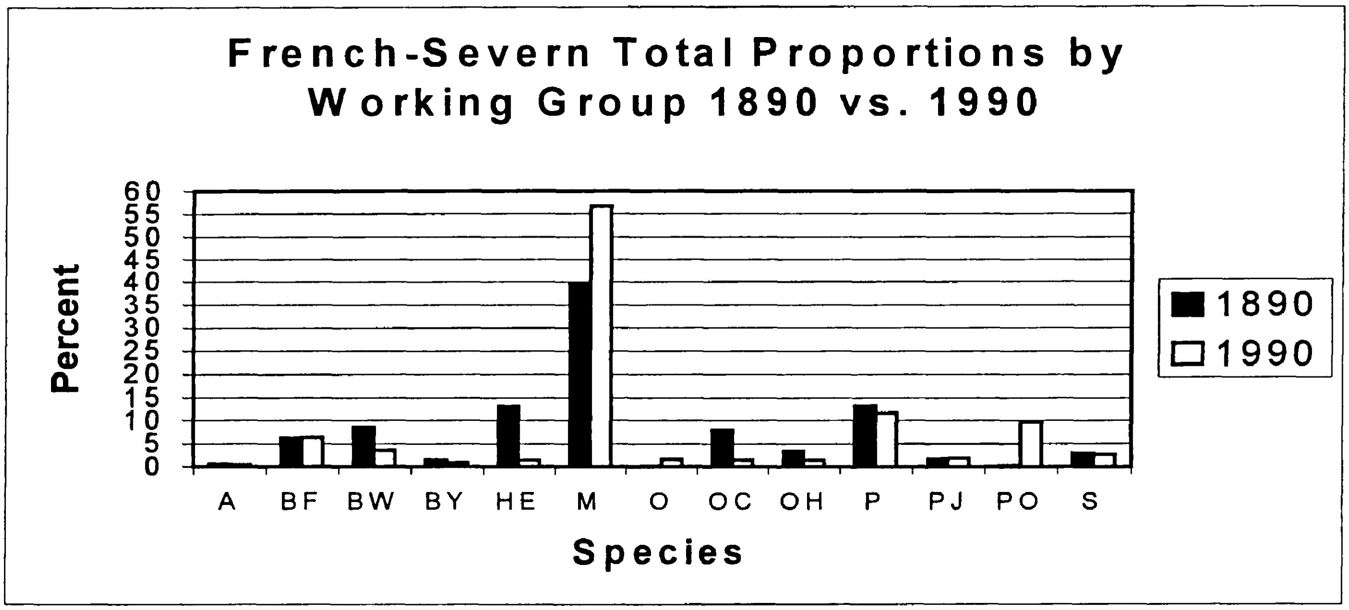

Figure 4.4 The relative abundance of working groups in 1890 and in 1990 in French-Severn. A = Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, He = Hemlock, M = Maple, O = Oak, OC = Other Conifer, OH = Other Hardwoods, P = Pine, PJ = Jack Pine, PO = Poplar, S = Spruce.

The white birch and hemlock working groups appear to have decreased 5.0 and 11.5 percent respectively since 1890, respectively. The poplar working group also appears to have increased from 0.4 to 9.8 percent in 1990. Apparent changes also occurred in the ‘other conifer’ (OC) working group and the oak working group.

Hardwoods and Softwoods

Unlike Algonquin Park, the French-Severn townships showed that some changes may have occurred with the proportions of hardwoods and softwoods (Fig 4.5). The hardwood grouping increased from 55.1 percent in 1890 to 75.7 percent in 1990. Correspondingly the softwood group appears to have decreased from 45.0 percent in 1890 to 24.3 percent in 1990.

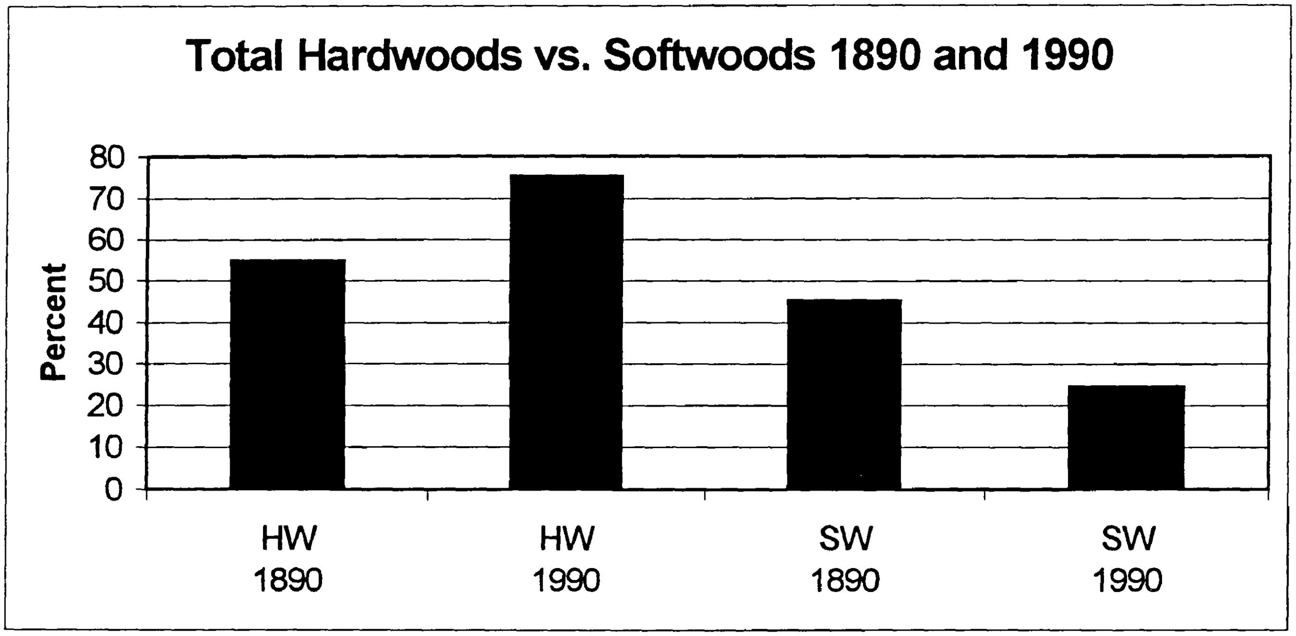

Figure 4.5 The total proportions of hardwoods and softwoods in French-Severn in 1890 and 1990. HW = Hardwoods, SW = Softwoods.

Shade Tolerance Groups

The proportions of shade tolerance groupings for French-Severn are shown in Figure 4.6. Although there were minor fluctuations in the shade tolerances groupings,

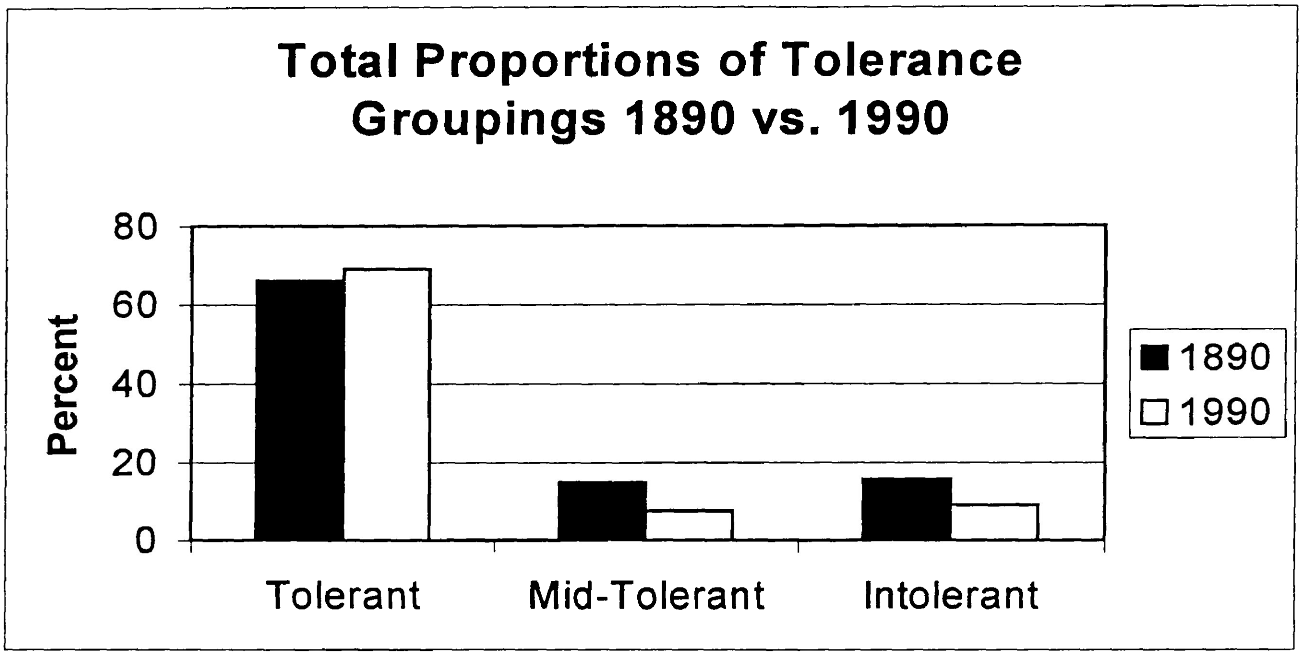

Figure 4.6 The total proportions of tolerance groupings 1890 vs. 1990 in French-Severn.

there were no major differences with any of the three tolerance groupings over the two time periods.

Occurrences

Figure 4.7 shows the frequency of occurrence for all species in the French-Severn study area. Compared with Algonquin Park, French-Severn experienced many more apparent changes in terms of the frequency of occurrence of tree species. The largest apparent change occurred with the frequency of poplar occurrence, which was at the 1.5 percent level in 1890 and increased to 13.8 percent in 1990. Other apparent increases included ash and spruce. The occurrence of hemlock decreased seemingly from 15.6 percent to 4.4 percent. Other apparent decreases included balsam fir, white birch and 'other hardwoods'.

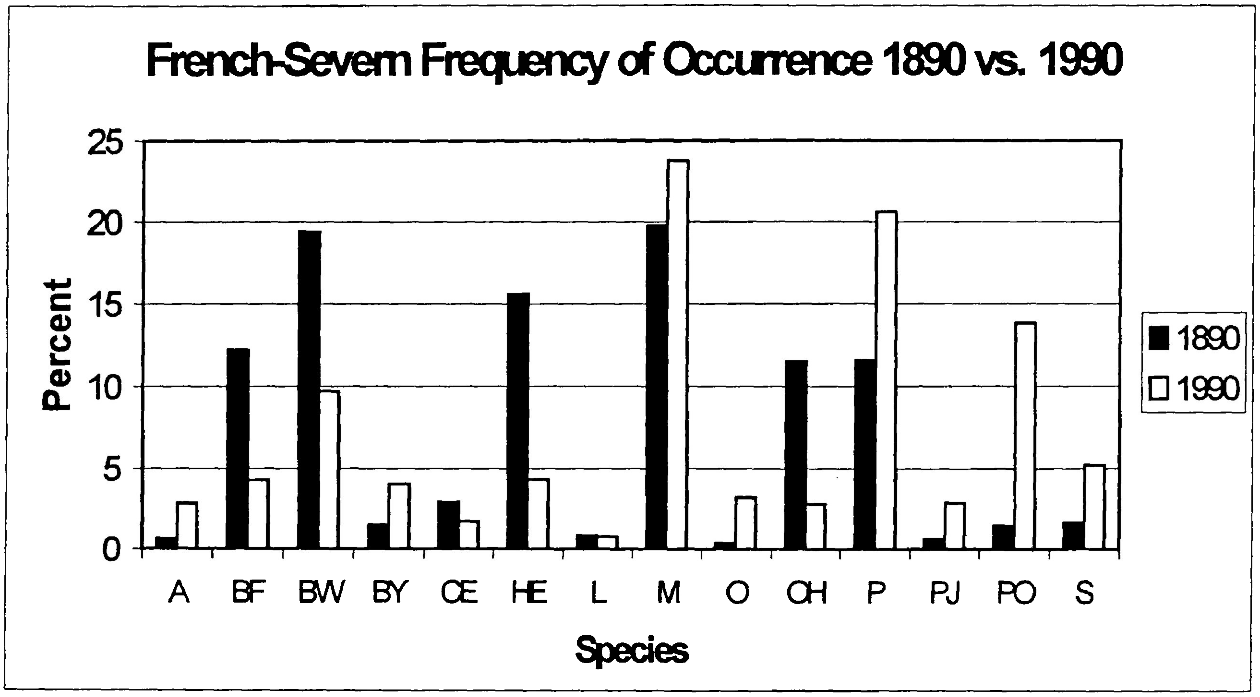

Figure 4.7 The frequency of occurrence for all species in French-Severn in 1890 and 1990.

Nipissing

Working Groups

Figure 4.8 shows the working group proportions in the Nipissing management unit. The largest apparent changes in working groups occurred with maple and the balsam fir. The maple working group increased from 5.8 percent in 1890 to 16.6 percent in 1990.

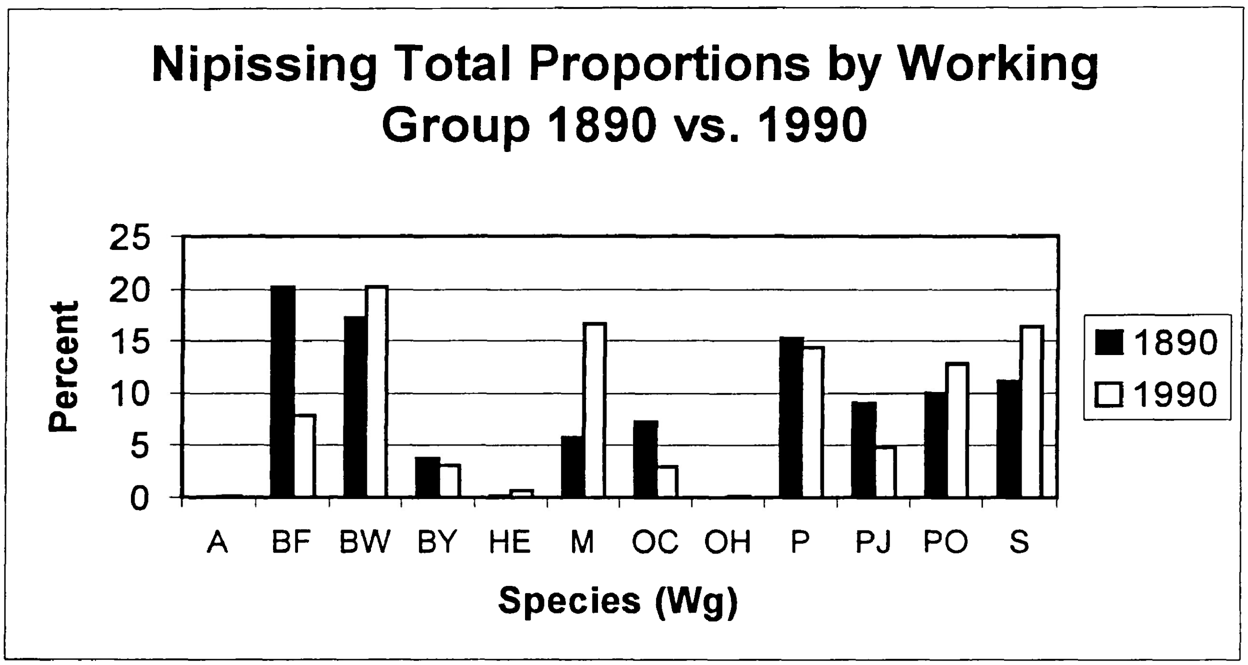

Figure 4.8 The relative abundance of working groups in 1890 and 1990 in Nipissing. A = Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, He = Hemlock, M = Maple, OC = Other Conifer, OH = Other Hardwoods, P = Pine, PJ = Jack Pine, PO = Poplar, S = Spruce.

The balsam fir working group seems to have decreased from 20.2 percent to 7.8 percent since 1890. It also appears that jack pine has decreased 4.2 percent since 1890.

Hardwoods and Softwoods

Figure 4.9 shows the changes in hardwoods and softwoods for all the townships in the Nipissing study area. The hardwood grouping seems to have increased from 36.9 percent in 1890 to 53.0 percent in 1990. Correspondingly the softwood group decreased from 63.1 percent in 1890 to 47.2 percent in 1990.

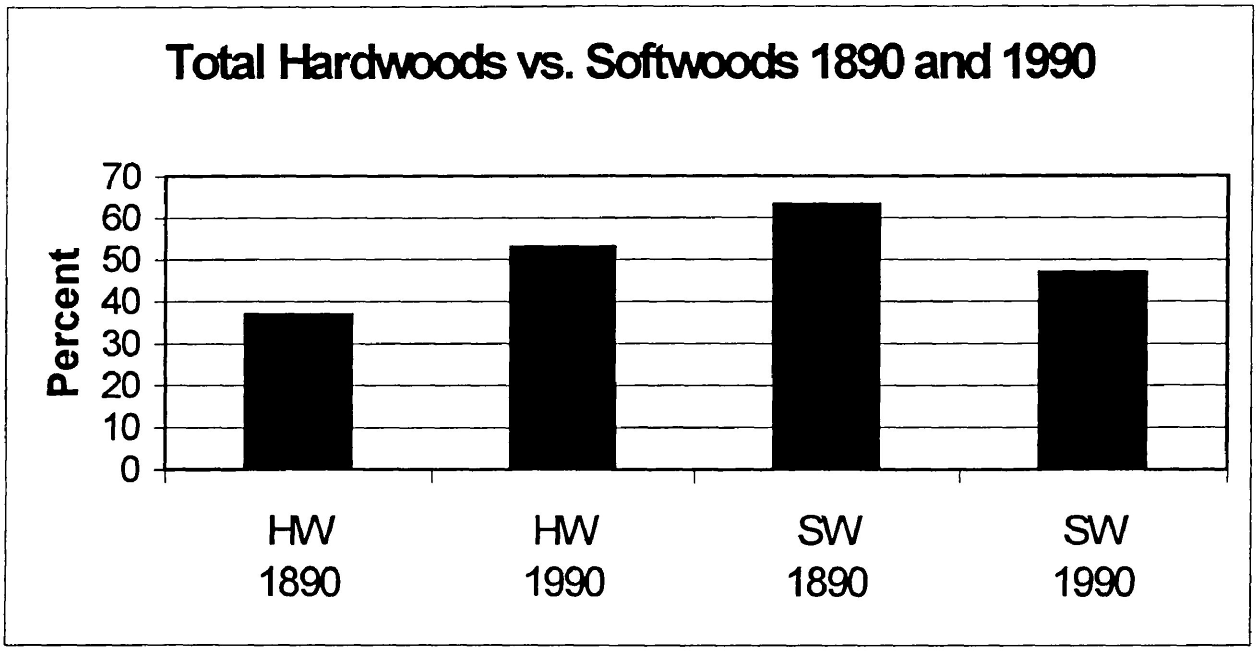

Figure 4.9 The total proportions of hardwoods and softwoods in Nipissing in 1890 and 1990. HW = Hardwoods, SW = Softwoods.

Shade Tolerance Groups

Figure 4.10 shows the proportions of shade tolerance groupings for Nipissing. Unlike Algonquin Park and the French-Severn management units, almost no changes occurred in tolerance groupings in Nipissing. There were no apparent changes in any of the groupings in the Nipissing management unit.

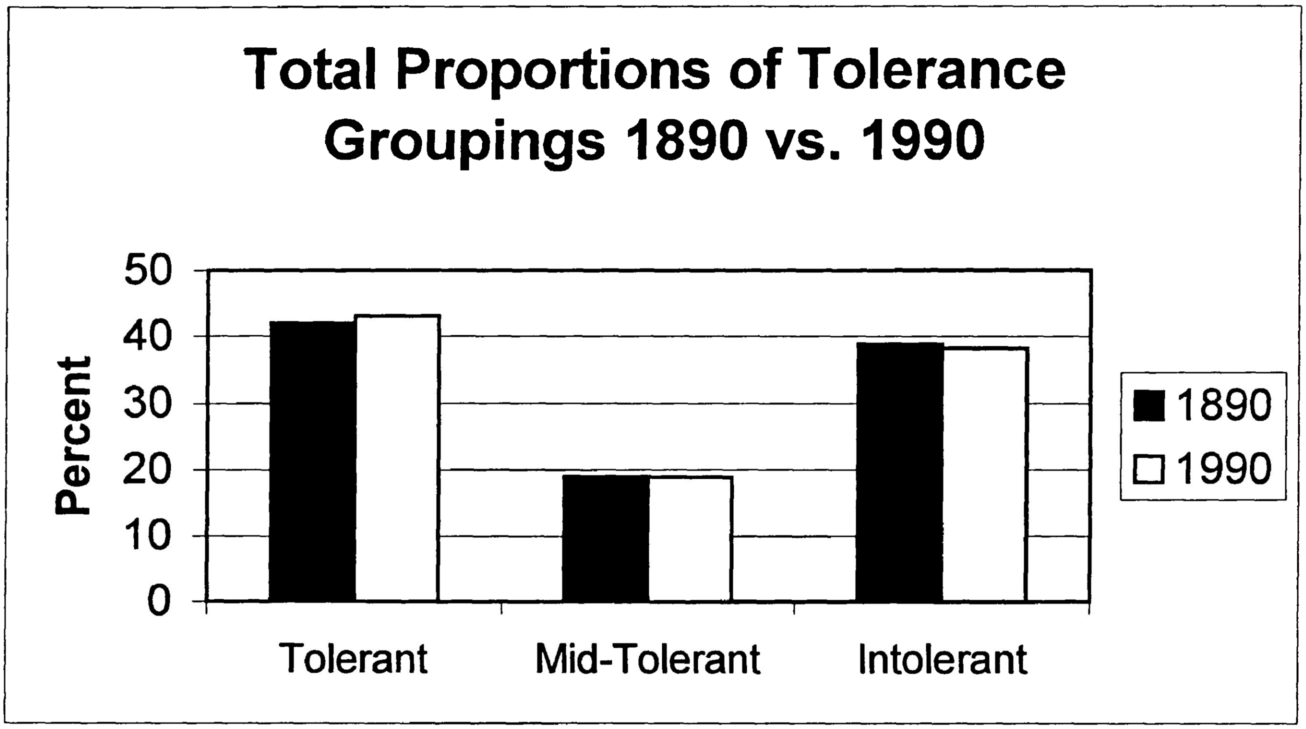

Figure 4.10 The total proportions of tolerance groupings 1890 vs. 1990 in Nipissing.

Occurrences

Figure 4.11 shows the frequency of occurrence for all species in the Nipissing study area. Large changes appear to have occurred with only 3 species. Maple seems to have increased from 4.5 to 16.5 percent, yellow birch also seems to have increased from 2.1 to 7.2 percent over the two periods. Larch shows an apparent decrease from 5.6 to 1.1 percent.

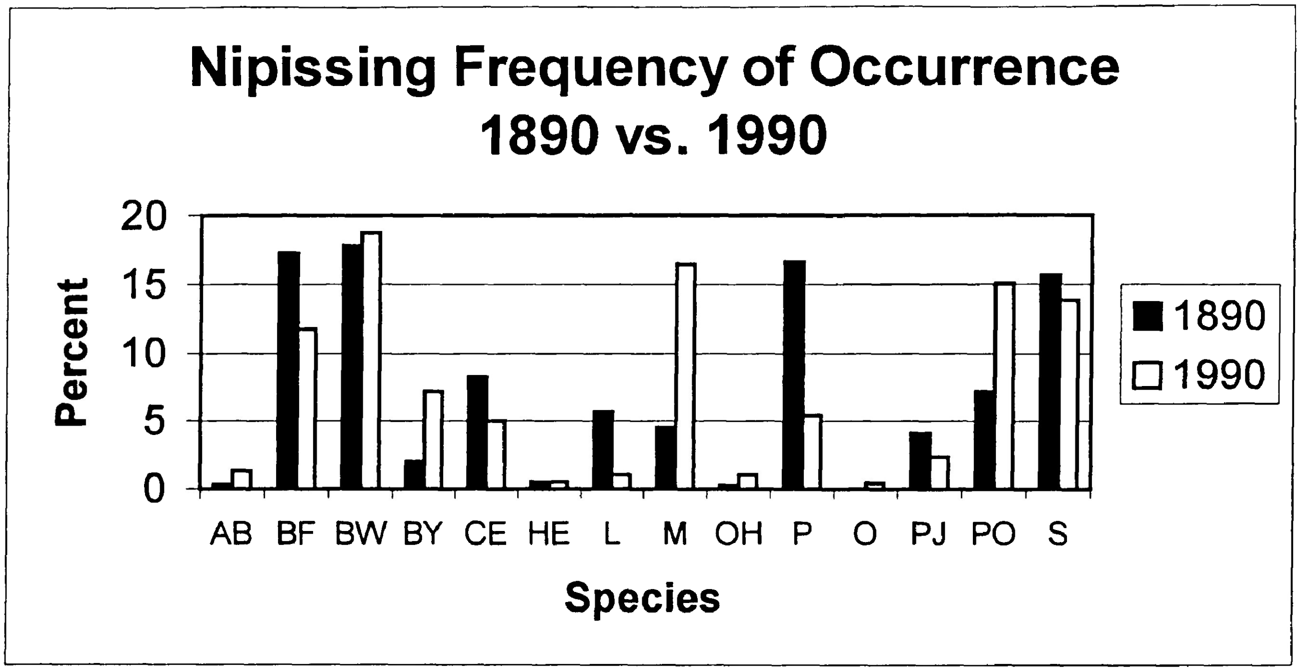

Figure 4.11 The frequency of occurrence for all species in Nipissing in 1890 and 1990. AB = Black Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, CE = Cedar, He = Hemlock, L = Larch, M = Maple, O = Oak, OH = Other Hardwoods, P = Pine, PJ = Jack Pine, PO = Poplar, S = Spruce.

Temagami

Working Groups

Figure 4.12 shows the working group proportions in Temagami. Large changes seem to have occurred with white birch, balsam fir, jack pine, red pine and yellow birch. The white birch working group experienced the largest apparent change with an increase from 8.7 percent in 1890 to 24.2 percent in 1990.

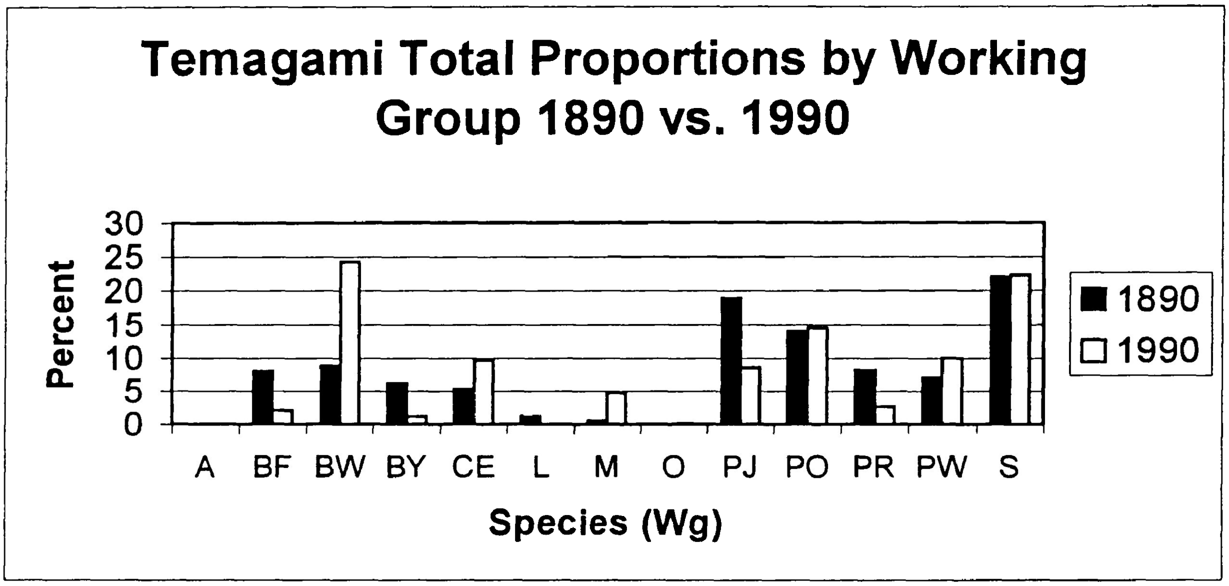

Figure 4.12 The relative abundance of working groups in Temagami in 1890 and 1990. A = Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, CE = Cedar, L = Larch, M = Maple, O = Oak, PJ = Jack Pine, PO = Poplar, PR = Red Pine, PW = White Pine, S = Spruce.

The red pine working group seems to have decreased from 8.2 to 2.6 percent in 1990. Other apparent decreases occurred with balsam fir, jack pine and yellow birch which decreased 6.1 percent 10.3 and 4.9 percent respectively.

Hardwoods and Softwoods

Figure 4.13 shows the changes in hardwoods and softwoods for all the townships in the Temagami study area. The hardwood grouping seems to have increased from 29.8 percent in 1890 to 44.8 percent in 1990. Correspondingly the softwood group decreased from 70.0 percent in 1890 to 55.0 percent in 1990.

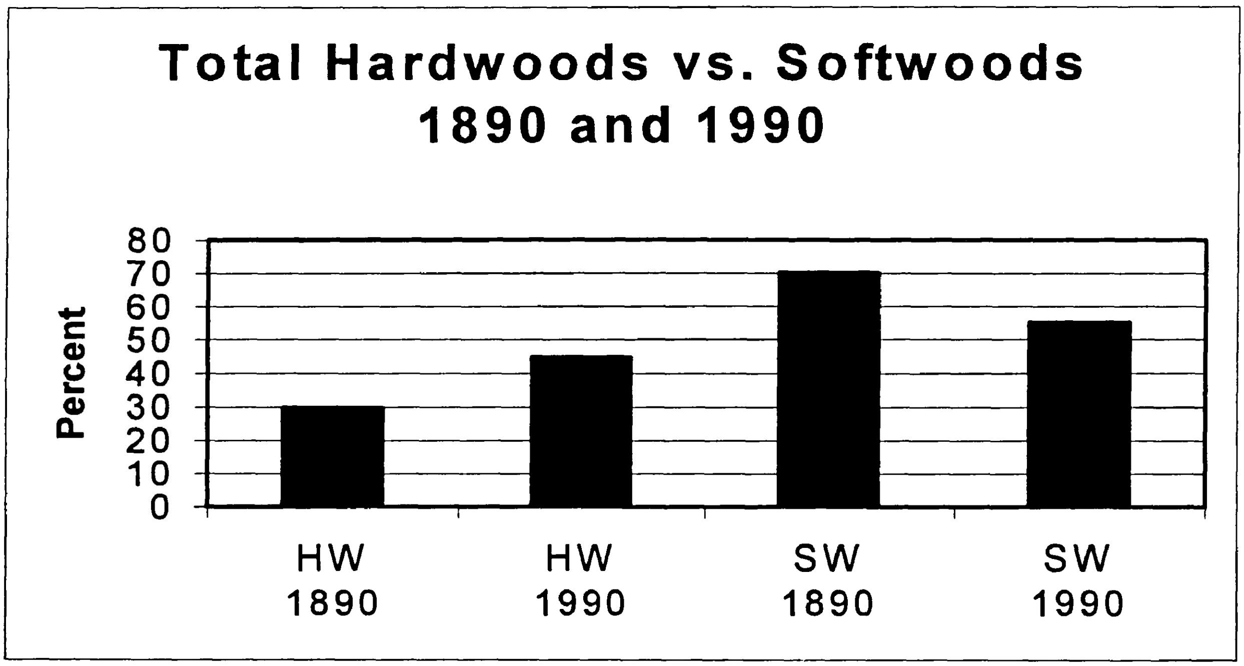

Figure 4.13 The total proportions of hardwoods and softwoods in Temagami in 1890 and 1990. HW = Hardwoods, SW = Softwoods.

Shade Tolerance Groups

Figure 4.14 shows the proportions of shade tolerance groupings for the Temagami management unit. The shift in tolerance groupings in Temagami appears to have occurred from the mid-tolerant group towards the tolerant and intolerant groups.

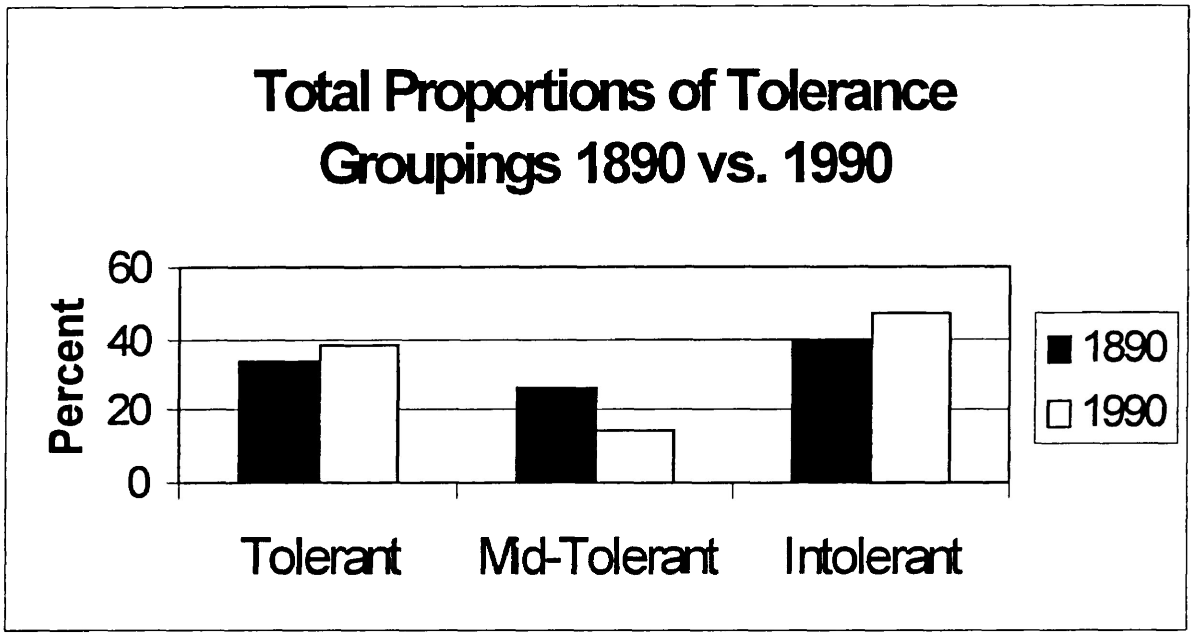

Figure 4.14 The total proportions of tolerance groupings 1890 vs. 1990 in Temagami.

The shade tolerant and shade intolerant have both seemingly increased in proportion since 1890. However, a large decrease seems to have occurred with the mid-tolerant group which has decreased 12.4 percent since 1890.

Occurrences

Figure 4.15 shows the frequency of occurrence for all species in the Temagami study area. Maple, red pine, balsam fir and spruce seem to have experienced large

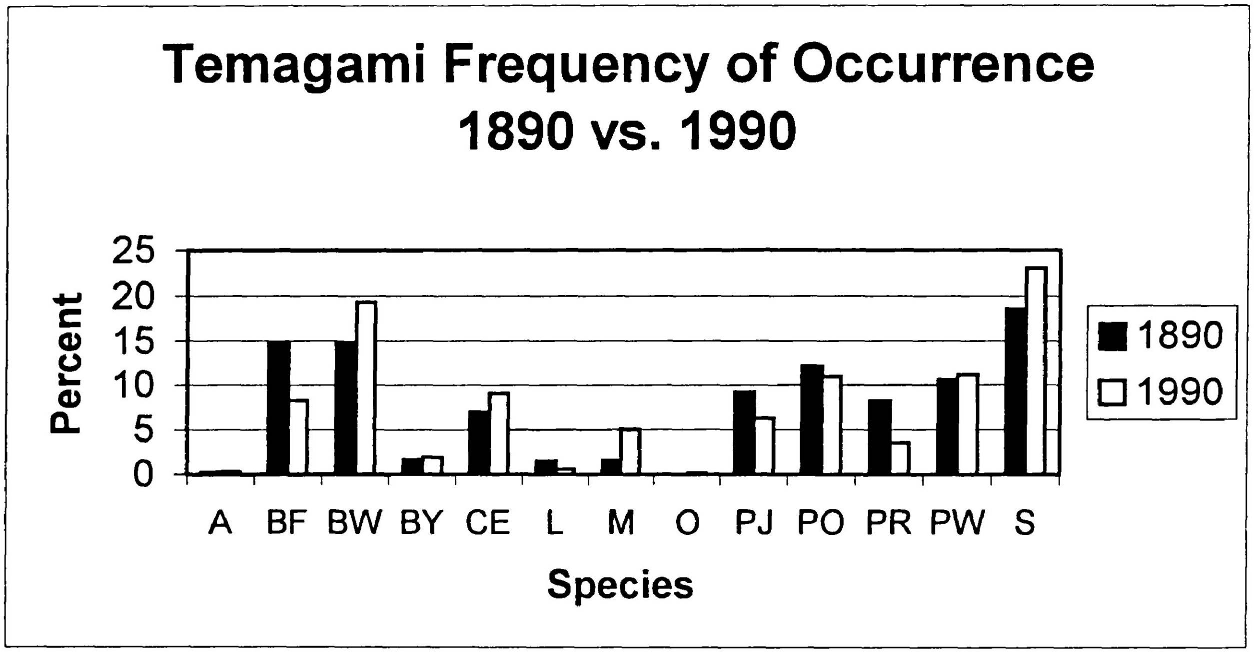

Figure 4.15 The frequency of occurrence for all species in Temagami in 1890 and 1990. A = Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, CE = Cedar, L = Larch, M = Maple, O = Oak, PJ = Jack Pine, PO = Poplar, PR = Red Pine, PW = White Pine, S = Spruce.

changes. Maple occurrence appears to have increased from 1.5 percent in 1890 to 5.1 percent in 1990. Spruce also apparently increased from 18.5 to 23.1 percent. Large decreases appear to have occurred in both red pine and balsam fir which decreased 4.6 and 6.4 percent respectively.

Regional Comparison

Working Groups

Figure 4.16 shows the working group proportions in all four management units and will be referred to as the regional comparison. Regionally large changes seem to have occurred with balsam fir, hemlock, maple and 'other conifers'. The balsam fir working group appears to have decreased from 9.5 percent in 1890 to 6.1 percent in 1990.

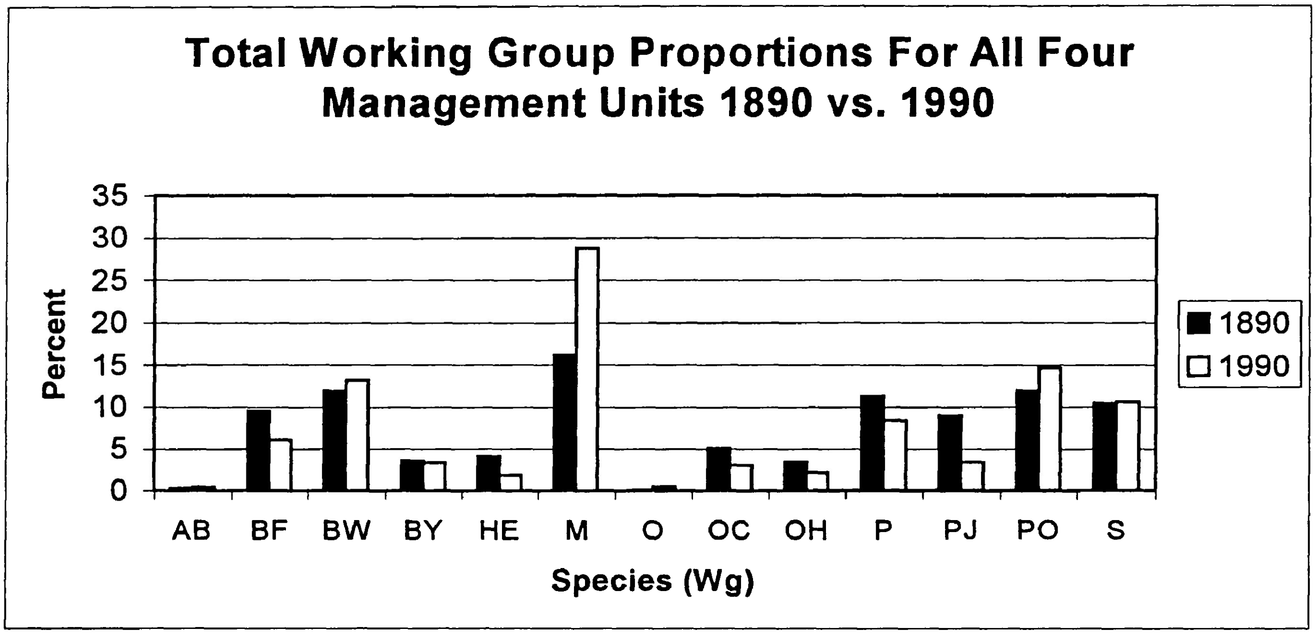

Figure 4.16 The relative abundance of working groups in 1890 and 1990 for all four management units. AB= Black Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, He = Hemlock, M = Maple, O = Oak, OC = Other Conifer, OH = Other Hardwoods, P = Pine, PJ = Jack Pine, PO = Poplar S = Spruce.

On average, it appears that hemlock decreased throughout the region over the last century. The hemlock working group appears to have decreased from 4.2 to 1.9 percent. The largest apparent change occurred with the maple working group which increased from 16.2 percent to 28.7 in 1990. A large change seems to have occurred with the 'other conifer' working group which decreased from 5.0 percent in 1890 to 2.9.

Hardwoods and Softwoods

Figure 4.17 shows the changes in hardwoods and softwoods in the regional analysis. The hardwood grouping seems to have increased from 49.5 percent in 1890 to 61.6 percent in 1990. Correspondingly the softwood group decreased from 50.4 percent in 1890 to 38.4 percent in 1990.

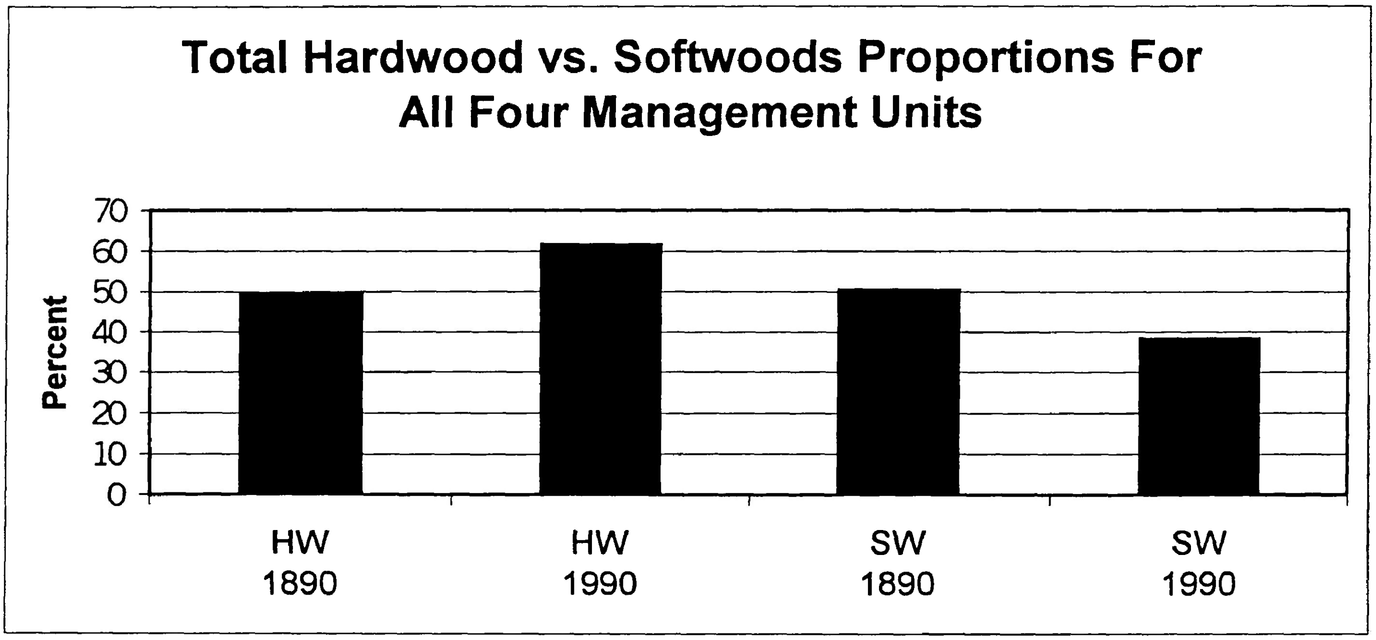

Figure 4.17 The total proportions of hardwoods and softwoods in all four management units in 1890 and 1990. HW = Hardwoods, SW = Softwoods.

Shade Tolerance Groups

Figure 4.18 shows the proportions of shade tolerance groupings for all four management units. The largest apparent change occurred in the regional tolerance analysis. This change occurred with the shade tolerant grouping which increased from 45.8 percent in 1890 to 52.4 percent in 1990.

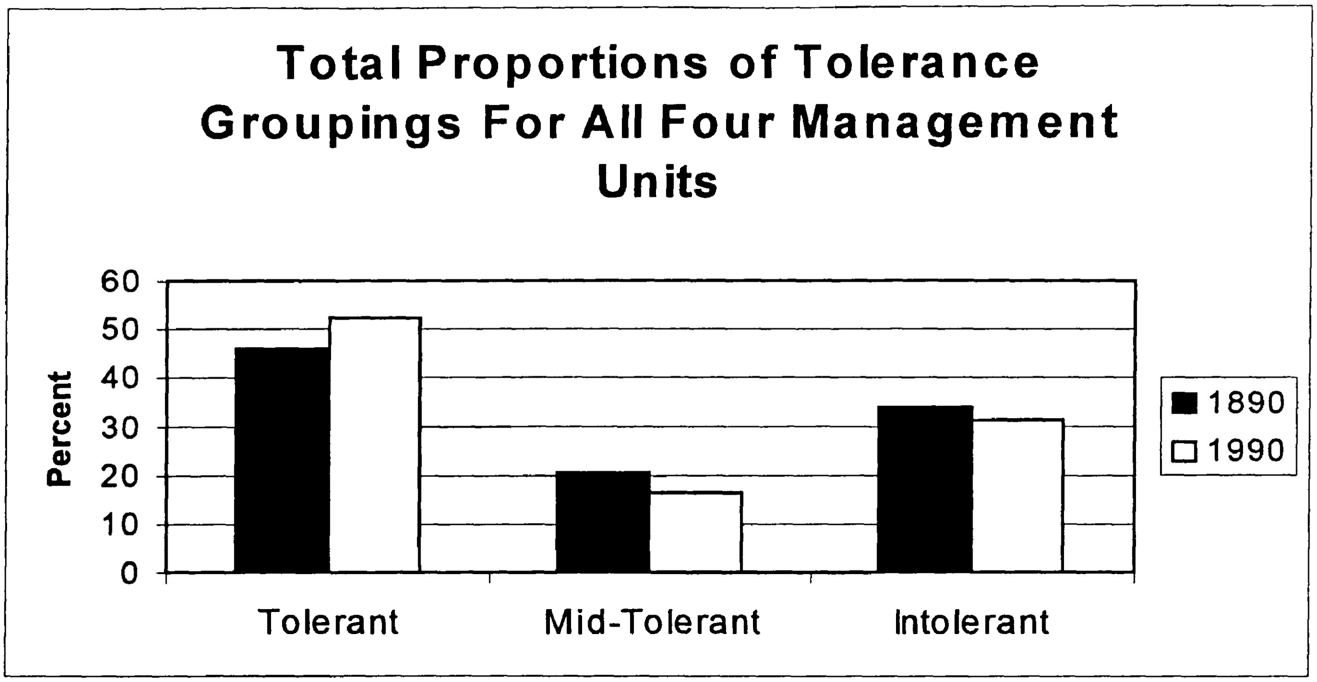

Figure 4.18 The total proportions of tolerance groupings 1890 vs. 1990 for all four management units.

Although some fluctuations occurred with the other two tolerance groups, no major changes appeared to have occurred since 1890.

Occurrences

Figure 4.19 shows the frequency of occurrence for all species in the regional analysis. It appears that apparent changes occurred in balsam fir, white birch, yellow birch, hemlock, larch, maple, poplar, spruce and the 'other hardwood' group.

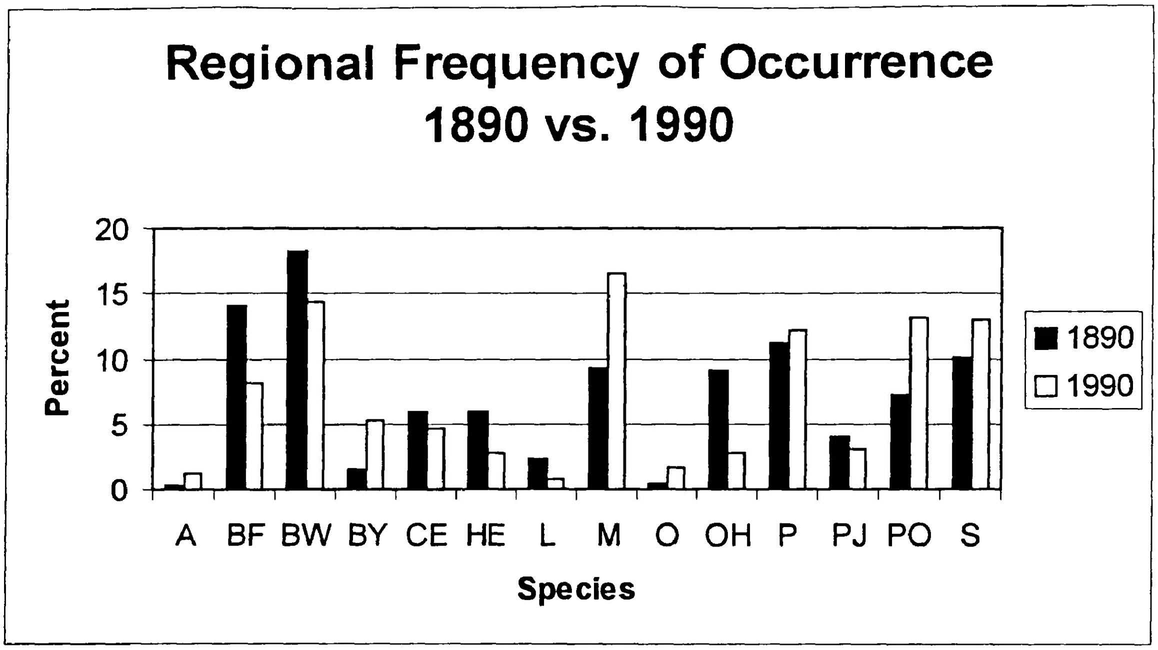

Figure 4.19 The frequency of occurrence for all species in all four management units in 1890 and 1990. A = Ash, BF = Balsam Fir, BW = White Birch, BY = Yellow Birch, CE = Cedar, He = Hemlock, L = Larch, M = Maple, O = Oak, OH = Other Hardwoods, P = Pine, PJ = Jack Pine, PO = Poplar, S = Spruce.

Apparent increases occurred with yellow birch, maple, poplar and spruce occurrences 3.8, 7.2, 5.8, 2.8 percent respectively. Large decreases seemed to have occurred with balsam fir, white birch, hemlock, larch, and 'other hardwood' occurrences 5.7, 3.9, 3.1, 1.6, 6.2 respectively.

5.0 DISCUSSION

Hardwoods and Softwoods

Table 5.0 shows all of the comparisons for the four management units including the regional level. The values refer to apparent proportional changes in working groups, hardwoods and softwoods, tolerance groupings or frequency of occurrence groupings. The working group comparison shows the changes found in stands that are dominated by a particular species, while the frequency of occurrence comparison shows the changes found in the amount of a particular species throughout the forest. Negative values represent an apparent decrease in that species or grouping, while a positive value indicates an apparent increase in that species or grouping.

The regional hardwood versus softwood comparison (Figure 4.17) and (Table 5.0) show that apparent changes in hardwood proportion occurred since 1890. The hardwood grouping appears to have increased 12.0 percent with an equivalent decrease in softwoods. Table 5.0 shows that regionally there has been an apparent corresponding increase in the maple working group (12.4 percent). Figure 4.16 shows that in 1890 and in 1990 the maple working group made up the largest proportion of the forest cover and consequently a large proportion of the hardwood grouping. Thus, it appears that a large increase in maple working groups seems to have caused an apparent increase in the hardwood grouping at the regional level.

Only the French-Severn and Temagami management units had apparent large increases in hardwoods as a whole. The French-Severn (Table 5.0) experienced the largest change with hardwoods increasing 20.6 percent. It appears that this was due to

Table 5.0 The final results for all comparisons in all of the Management Units.
(-) = decrease, (+) = increase

Comparison	Species	Regional	Algonquin Park	French-Severn	Nipissing	Temagami
Working Group	A	0.22	N/A	-0.13	0.09	0.01
Working Group	BF	-3.47	-2.55	0.12	-12.40	-6.01
Working Group	BW	1.20	-6.71	-4.96	2.92	15.51
Working Group	BY	-0.18	-0.07	-0.77	-0.68	-4.96
Working Group	CE	N/A	N/A	N/A	N/A	-4.39
Working Group	HE	-2.33	2.21	-11.55	0.50	N/A
Working Group	L	N/A	N/A	N/A	N/A	-1.10
Working Group	M	12.48	16.70	17.11	10.81	4.16
Working Group	O	0.48	N/A	1.41	N/A	0.13
Working Group	OC	-2.06	-1.23	-6.56	-4.31	N/A
Working Group	OH	-1.24	-3.73	-2.05	0.14	N/A
Working Group	P	-2.98	0.71	-1.69	-0.93	N/A
Working Group	PJ	-5.59	-0.75	0.11	-4.20	-10.34
Working Group	PO	2.72	-7.05	9.38	2.85	0.61
Working Group	PR	N/A	N/A	N/A	N/A	-5.54
Working Group	PW	N/A	N/A	N/A	N/A	2.96
Working Group	S	0.11	2.48	-0.42	5.21	0.19
Hardwood vs.	HW	12.01	-2.27	20.63	16.10	15.00
Softwood	SW	-12.01	2.27	-20.63	-16.10	-15.00
Tolerance	Tolerant	6.55	14.71	2.84	1.09	2.73
Tolerance	Mid-Tolerant	-3.81	0.26	-7.27	-0.26	-12.37
Tolerance	Intolerant	-2.74	-14.96	-6.68	-0.65	4.68
Occurrence	A	0.89	0.24	2.22	1.01	0.07
Occurrence	BF	-5.77	-3.36	-7.93	-5.43	-6.38
Occurrence	BW	-3.95	-11.79	-9.73	0.96	4.64
Occurrence	BY	3.83	7.34	2.55	5.09	0.29
Occurrence	CE	-1.18	-2.43	-1.18	-3.25	2.14
Occurrence	HE	-3.14	-1.31	-11.24	0.003	N/A
Occurrence	L	-1.59	-0.69	-0.10	-4.62	-0.92
Occurrence	M	7.23	9.42	3.97	11.95	3.56
Occurrence	O	1.25	1.20	2.82	N/A	0.17
Occurrence	OC	N/A	N/A	N/A	N/A	N/A
Occurrence	OH	-6.24	-4.97	-8.65	0.81	N/A
Occurrence	P	0.91	-1.75	9.11	-11.33	N/A
Occurrence	PJ	-0.91	-1.28	2.28	-1.77	-2.84
Occurrence	PO	5.83	4.09	12.35	7.96	-1.08
Occurrence	PR	N/A	N/A	N/A	N/A	-4.65
Occurrence	PW	N/A	N/A	N/A	N/A	0.51
Occurrence	S	2.84	5.14	3.52	-1.81	4.47

an apparent increase in the proportions of the maple and poplar working groups (Table 5.0) and decreases in certain softwoods such as hemlock and the 'other conifer' group which was made up of cedar and larch.

The Nipissing and Algonquin Park management units did not seem to experience any changes in overall hardwood and softwood proportions. However, in Nipissing, maple apparently increased 10.8 percent while balsam fir decreased 12.4 percent yet it is unclear as to why these changes may have occurred. In Algonquin Park, it is also unclear why there were no apparent changes in hardwoods or softwoods considering the maple working group seemed to increase and only the 'other conifer' group seemed to decreased. However, this lack of change may reflect the increase in maple balanced by an apparent decrease in both poplar and white birch.

The Temagami management unit experienced an apparent minor increase in hardwood proportions (Table 5.0). Unlike the French-Severn, maple working group levels did not increase much at all in Temagami. This is likely because Temagami is at the northern most point of the region and as such is almost at the geographic limit of the maple working group (OMNR, 1996). Thus, maple levels in Temagami have typically been low. Figure 4.15 shows that maple made up less than one percent of the working group proportions in 1890 in Temagami and seem to have remained unchanged since.

White birch working group levels seemed to have increased in Temagami since 1890. Table 5.0 shows that hardwoods seem to have increased 15.0 percent while white birch working groups increased 15.51. It appears from the data that the increase in hardwoods was due to an increase of white birch. This suggests that there have been many disturbances in the Temagami management unit since 1890. White birch tends to thrive on disturbed sites such as burns or cut-over areas, (Hosie, 1990). Thus a large increase in white birch would point to large scale disturbances such as the Joan Peninsula burn of the 1970's in Temagami. Benson et al. (1989) described the estimated areas of each working group in the Old Temagami Management Unit for 1959 and 1980. Benson et al. (1989) estimated that white birch was by far the largest single working group in the area. Benson's estimates support the results in Figure 4.12 that shows white birch at 24.2 percent.

Jack Pine and red pine seemed to have decreased in Temagami since 1890 (Table 5.0). Temagami has become well known for its pine communities and has had historically high levels of jack, red and white pine (Figure 4.12). As a result much of the pine in Temagami has been harvested since 1890. Benson et al. (1989) described the harvest of red pine since 1900; red pine harvesting peaked around 1906 and has steadily declined with a slight increase in the late 1980's. As red pine became depleted, logging operations turned their attentions more to jack pine. So as the century progressed more and more jack pine was harvested, a result that is reflected in the results of Figure 4.12 and Table 5.0. The apparent decline in jack and red pine working groups total to just over 15 percent, which is equivalent to the decrease of softwoods in this management unit.

Overall it appears that white birch has replaced many of the pine communities in Temagami. Jack pine, white birch, red pine and white pine are all fire-adapted species, yet in Temagami white birch was the dominant working group species. This might be because of the nature of white birch seed dispersal and the effects of harvesting pine communities. White birch produces seeds that are dispersed easily in the wind, therefore they can repopulate over very large areas. However, pines, typically have large heavy cones whose seeds cannot be spread very far by aeolian vectors and as such are somewhat limited in their dispersal area. When pine is removed from a stand most of the seed source is also removed and consequently a much slower regeneration rate occurs. However, white birch can regenerate from seed sources that are much farther away and in Temagami it appears that this occurred.

The final apparent large change that occurred in the Temagami working groups was with yellow birch. Macfie (1987) reported that most of the yellow birch in the French-Severn area was harvested during World War Two for use in the outer skin of the Mosquito intruder bomber and was also used for hardwood flooring. Although Macfie (1987) did not specify harvesting in Temagami, it is possible that the yellow birch was used throughout the region for the war effort and subsequent civilian uses.

Working Groups

The regional working group comparison (Figure 4.16) and (Table 5.0) show that the largest apparent change occurred with the maple working group. The data from the comparison of the Algonquin Park working groups show that maple seems to have almost doubled in proportion since 1890. As with Algonquin Park, the largest apparent increase in the French-Severn and Nipissing management units occurred with the maple working group (Table 5.0). In all three instances the maple working group apparently increased, showing a distinct trend of increasing maple dominated stands.

This regional increase in maple may be due to the nature of the maple species and the forest management techniques employed. Maples are shade tolerant climax species and as such can survive at most light levels. Burns and Honkala (1990) describe that maples can grow in a wide variety of soil types and moisture regimes. One other important characteristic of the maple to consider is its relatively long life span, which can easily reach 200 years. This long life span means that this problem of maple dominance will go on far into the next century.

The reasons for the increase in maple working group are difficult to directly identify. However, it is likely that the removal of other commercially important species provided the ideal conditions for maple to flourish. When an area is disturbed either by harvesting or a natural occurrence, the canopy is opened up and shade tolerant species such as maple have little competition for light or other resources and quickly dominate the area. Maples are prolific seed-producers and seedlings can remain in the understorey for years waiting for a space to open in the canopy. Forest practices such as the selection management of maple tend to perpetuate maple working groups (Burns and Honkala 1990). Fire suppression efforts over the last century have also produced a less disturbed environment in which shade tolerant hardwoods such as maple can thrive and it appears from the results that this has happened. Forest succession may also play an important role in explaining why there appears to be more maple in this region today.

The pre-settlement forest found in the four management units of this study were relatively undisturbed by Europeans. Thus, a forest ecosystem that had reacted mainly to natural disturbances had evolved. Once European settlement occurred and the forest was harvested the proportions of the forest changed. In the four management units of this study, large amounts of pine, hemlock, jack pine, yellow birch and other merchantable timber were removed with little thought of regeneration.

This apparent region wide increase in maple is important to consider. Bourdo (1956) discussed the shortcomings of survey note data but concluded that they represented an unusually thorough survey. Thus, the regional increase of maple (and other species) can be explained four ways:

1) The surveyors misrepresented the amount of maple;
2) The 1890 working groups were not actual working groups,
3) The 1990 FRI data overestimated the amount of maple;
4) There actually are more maple working groups today than 100 years ago.

The idea that the surveyors misrepresented the amount of maple or any species is important to consider. Bourdo (1956) discussed that some amount of fraud did occur in the early days of surveying in the United States. However, this fraud usually was of linear measurements within the survey. Lambert (1967) pointed out that after 1849 surveyors in Canada were rigorously trained and swore an oath that the information contained within the survey notes was true in nature. Interestingly, today, OMNR air photo interpreters do not have to swear to a similar oath. As with any kind of survey or data gathering a certain amount of error will occur. However, the pre-settlement surveys of Ontario were of good quality and are considered to be a sound method of reconstructing the forest.

One of the main purposes of the original Crown Surveys was to identify good farming land and merchantable timber. The surveyors were to list timber in order of relative abundance. The idea of misidentifying a species is possible but considering these people were professional it is unlikely. Maple was and still is a very important species in Ontario. For the surveyors to incorrectly identify a maple is also very unlikely as they are easily identified. Therefore the premise that the surveyors misrepresented the amount of maple in a given stand seems unlikely.

One of the problems with comparing an 1890 database to a 1990 database is that they may not be totally compatible. The definition of a working group is of particular importance in this project. Typically a working group is defined as an aggregate of stands, having the same predominant species (OMNR, 1996). This current definition of working group is based on air photo interpretation of large areas, while the surveyor did not have the advantage of such technology. However where the survey notes may have limitations as far as scale, they have the advantage of being written on site with likely 100 percent 'ground truthing', which is not the case with FRI data. Therefore both 1890 and 1990 have their strengths and weaknesses. In the final analysis it appears that although surveyors did not perhaps identify working groups exactly the same as today, the similarities outweigh the differences for the purposes of this project.

The third possibility as to the differences in maple working groups (which applies to all the working group comparison) is that the 1990 FRI data has overestimated the amount of maple in the forest. The 1990 data is produced by the provincial government and reflects the best available representation of the current forest condition. Although there are minor inconsistencies in the database, the likelihood of the FRI data over-estimating working groups is minimal. After consideration of the three previous possibilities, it seems valid to conclude that there is an apparent higher proportion of maple working groups today than there was in 1890.

An apparent regional decrease in the 'other conifer' working group seems to have occurred. This group is an amalgamation of cedar and larch as deemed by the OMNR. The 'other conifer' working group has dropped to almost 50 percent of its pre-settlement level (Figure 4.16). Larch was heavily harvested in the first half of this century for uses in World War Two. Howse (1983) pointed out that larch was almost eradicated in the late 1800's and early 1900's by the larch sawfly (*Pristiphora erichsonii*).

A change seems to have occurred in the proportions of the hemlock working group (Table 5.0) at the regional level. Hemlock levels seem to have dropped to almost a quarter of their pre-settlement proportions. This drop in hemlock may be due largely to heavy harvesting of this species in the early part of this century for railway ties and its bark which was used in the tanning process (Macfie, 1987, Kershaw and Gordon, 1991). Kershaw and Gordon (1991) also point out that there is still a slow decline in hemlock proportions due to its removal along shorelines for cottage development and the absence of regeneration success in areas heavily browsed by ungulates.

Although there seemed to be a decrease in the hemlock working group, only the French-Severn management unit experienced an apparent decrease of over 11.5 percent (Table 5.0). Algonquin Park, which has had historically relatively large amounts of hemlock, did not show any major changes since 1890. Kershaw and Gordon (1991) described historical accounts of hemlock in central Ontario. According to Kershaw and Gordon (1991), the period of 1870 to the 1950's was an intense harvesting period of hemlock in this region. Hemlock made up over 40 percent of the total harvest in the Georgian Bay management unit and similar trends were common in the Algonquin Park area. They explained that some of the hemlock in the park was and still is inaccessible to harvesting which might explain why hemlock levels have remained relatively stable in the park. It is also possible that very specific selection cutting occurred in the park that left high levels of hemlock in the residual stands. In either case, the lack of any change in hemlock working groups in Algonquin Park is somewhat of a mystery.

The final regionally large apparent change occurred in the balsam fir working group (Table 5.0). Balsam fir is a species that is of little commercial value and as such is not heavily harvested. However, it has seemingly decreased regionally, particularly in the Nipissing and Temagami management units. This decrease may be due to the outbreak of the spruce budworm (*Choristoneura fumiferana*). It is unclear as to why Algonquin Park and French-Severn levels of balsam fir have remained apparently unchanged (yet the frequency of occurrence in balsam fir seemed to decrease in French-Severn). However it is possible that these management units did not experience the spruce budworm outbreak as severely as Nipissing and Temagami.

Shade Tolerance Groups

The regional shade tolerance comparison (Figure 4.18) and (Table 5.0) show that an apparent increase in shade tolerant species occurred since 1890. The shade tolerant group (which contains the maple and balsam fir working groups) increased 6.5 percent. Although only Algonquin Park showed an apparent increase in shade tolerant species at the management unit level it seems that this increase in maple has had a cumulative effect on the regional comparison. Shade tolerant species appear to have replaced mid-tolerant and intolerant species. In terms of working group proportions it appears that not only has an apparent increase in maple caused tolerant species levels to rise but that in Algonquin Park tolerant species seem to have directly replaced intolerant species, while in Temagami mid-tolerant species have decreased which corresponds to an apparent decrease in yellow birch. In contrast maple and white birch, shade tolerant and shade intolerant species respectively, seem to have increased in Temagami. It seems that these relative changes have caused the apparent large decrease in the mid-tolerant grouping in Temagami.

Occurrences

Both the survey notes and the 1990 FRI data contained not only working group data, but also all the species in each stand in order of relative abundance. Thus, I decided to use these other data in a frequency of occurrence comparison. I wanted to have a more in-depth study of forest diversity than just working groups. The frequency of occurrence comparison allowed a finer scale examination than working groups did. Working group comparisons only allowed a look at changes at the stand level while the frequency of occurrence reflected changes that occurred within stands. I have made the assumption that there was a relationship between the occurrence of a species and a working group and that they shared a similar importance in the composition of a forest. This relationship is based on the idea that a working group is made up of many occurrences of a particular species. Therefore a comparison of occurrences within the entire database will give a better idea of the diversity of the forest.

It is important to consider the relationship between the frequency of occurrence of a species and its working group proportions. In the case of the maple working groups, not only have apparent increases occurred in three of the four management units and at the regional level, but also apparent increases in the frequency of occurrence of maple as a species throughout the forest. This finding is perhaps the most important of this study, as it shows that maple seems to have increased in other working groups. For example, if a typical stand of balsam fir in 1890 was composed of 70 percent balsam fir, 20 percent poplar and 10 percent maple, then today (considering the frequency of occurrence results) it would be made of a higher occurrence of maple, e.g., 50 percent balsam fir, 30 percent maple and 10 percent poplar. This concept is very important to consider, as these changes not only affect working group proportions, but they also affect the proportions of frequency of occurrence in the forest landscape. Therefore, this apparent increase in maple as a working group and as an occurrence has changed the pre-settlement diversity of the forests of central Ontario.

The apparent large increases in maple working groups and hardwoods have many implications in terms of wildlife habitat. Certain species such as red-shouldered hawks that prefer hardwood forests may experience increases in their populations, which may be beneficial to species with dwindling populations. However, populations of other softwood-dependent species including the red-breasted nuthatch will probably decline because of the apparent increase in hardwoods in the region. An apparent increase in hardwoods also means that there are fewer conifers in the forest and this will have detrimental effects for species such as deer and moose that rely on softwoods such as hemlock and spruce for food and winter shelter. An increase in hardwoods also means a more open understorey which may effect the balance of predator-prey relationships within the forest. All in all there are many consequences that an increase in hardwoods specifically maple will have on wildlife populations and due to the long life span of the maple species, the problem will be long lasting.

Other apparent large increases in frequency of occurrence were found with poplar and spruce. Poplar, is a shade intolerant species that tends to move in quickly after a disturbance and form pure stands (Hosie, 1990). Poplar increased as an occurrence while white birch appears to have decreased. But as working groups neither poplar nor white birch seemed to increase. These species are both shade intolerant and usually become established after a disturbance. However, poplar is a more aggressive competitor especially on cutbacks. Thus at the regional level it appears that poplar is replacing white birch in terms of frequency of occurrence.

Throughout the comparisons the spruce group (which includes white and black spruce) has experienced little change, with the exception of the frequency of occurrence. Table 5.0 shows that regionally spruce has apparently increased in occurrence in three of the four management units. This increase may be due to the decrease in balsam fir because of the spruce budworm outbreak. Therefore, spruce, more specifically black spruce may have increased at the expense of balsam fir.

Regional occurrences of balsam fir and hemlock have seemingly decreased since 1890 (Table 5.0). These findings correspond to a regional decrease in balsam fir and hemlock working groups. In 1990 there was less balsam fir and hemlock in any form (working group or occurrence) than there was in 1890. This indicates that the outbreak of spruce budworm not only attacked balsam fir working groups but also balsam fir in other working groups. One interesting difference with balsam fir and hemlock occurrences was found in Algonquin Park. Neither of these two species experienced any changes since 1890, which corresponds with no change in their working group proportions either. It is difficult to ascertain why this has happened in Algonquin Park except that perhaps balsam fir and hemlock were not harvested as heavily in Algonquin Park as they were in other management units.

The frequency of occurrence comparison shows that apparent increases were found with yellow birch at the regional level and within three of the four management units. However, the working group comparison of yellow birch shows that no large changes occurred except in Temagami. These results indicate that as a working group yellow birch proportions appear to be unchanged, while they decreased in Temagami yet as an occurrence throughout the forest they have increased with the exception of Temagami. This means that like maple, yellow birch is found more often in other working groups than it was in 1890 and unlike maple, yellow birch working groups have remained relatively stable. Yet, in Temagami the opposite situation has occurred with working groups of yellow birch on the decline and no changes in frequency of occurrence.

6.0 CONCLUSIONS

This study has shown the usefulness of the Crown Survey notes in reconstructing certain elements of the pre-settlement forest in central Ontario. This original condition of diversity is extremely important to understand and this study has shown that the proportional makeup of the forest seems to have changed since 1890. The resulting comparisons have shown several important trends regarding the proportional makeup of working groups, hardwoods, softwoods, tolerance groupings and frequency of occurrence. It appears that the most evident trend identified by this study was the apparent increase in the maple working group. On the surface it may seem that higher levels of valuable hardwoods such as maple would be a desirable end. Perhaps the most significant problem with this increase in maple is that it severely limits the regeneration of other species and as such limits not only economic opportunities but reduces the forest diversity of the region.

Due to the large amounts of maple-dominated stands it will be very expensive and time consuming to reproduce the proportions of species found in the pre-settlement forest. This problem is exacerbated by the long life of maple. Thus I believe that this problem will not remedy itself and could last for many decades to come. In essence, it appears that the forest resource has changed from a once diverse forest into a relatively homogenized hardwood stand that appears to have a different proportional diversity than pre-settlement days.

The second important trend that has emerged from this study is the apparent increase in hardwoods as a group. This is due in large part to the increase in maple and to a lesser extent, white birch and poplar. This increase in hardwoods also represents a decrease in forest diversity and future management plans need to contend with this phenomenon.

Perhaps the most interesting results in this study are shown in Figure 4.19, which reveals that many species in the region have apparently changed in terms of occurrence proportions. This finding suggests that the frequency of occurrence proportions have been altered and that management plans should strive to maintain these "original' forest conditions.

This study should be considered as the preliminary attempt at reconstructing the forests of central Ontario. The findings of the study show that it is possible to obtain data from the Crown Survey notes and that to fully appreciate and understand pre-settlement diversity conditions further studies should occur. It would be beneficial to industry and the OMNR to obtain survey notes for all harvested areas in northern Ontario so that better decisions can be made in terms of conserving the diversity of the forest of Ontario.

Recommendations

Future Studies

This study was the first to examine the pre-settlement forest condition of Algonquin Park, French-Severn, Nipissing and Temagami. Future studies could easily expand the pre-settlement forest database by using all of the townships in each management unit. The time constraints of this study only allowed me to use 10 sub-divided townships in Algonquin Park, French-Severn and Nipissing while using most of the non-sub-divided townships in Temagami. However, by using all of the townships in each management unit it would be possible to strengthen the results and give a more complete picture of pre-settlement diversity conditions. I believe that this type of baseline study is very important to forest management and that a complete inventory of all forested areas is needed to ensure better management techniques in the future.

One of the problems with my comparison of the 1890 to the 1990 forest was that there was a 100-year period in between, of which there was very little mention. Incorporating data from other decades would enhance this study. This would allow a better examination at how things had changed over a shorter period. By using the century period, there was a chance of misinterpreting what had happened in the forest. For example, it was difficult to ascertain what had happened with some of the short-lived species such as poplar. If data from other decades such as the 1940's the 1960's and 1980's could be used a much clearer picture of the dynamics of change in the forest would appear. The resources for such a study do exist in the form of survey notes taken at later dates and other government data such as the publication Forest Resources of Ontario 1996 which claims to have data dating back to 1922.

Although survey notes are considered by most researchers to be the best data available for reconstructing the forest, they do have one major flaw. With the exception of Temagami, pines were not differentiated into species, and in most cases spruce, birch and maple were not fully identified. This problem can be remedied by using associative methods, which I did use for the birches. However, I was concerned about making too many assumptions based on today's associations. But, I believe that identifying species based on associations was one of the few methods available. A standardized associative method needs to be produced so that future studies of this type can avoid the problem of unidentified species. This will allow a finer scale analysis of the forest landscape and may benefit diversity conservation efforts.

Due to the very large region and due to time and economic constraints, ground truthing in the study area was not a possibility for this study. However, I believe that it would be prudent to go into some of these management units, to look for some of the stumps, and to check the accuracy of the identification of tree species by the surveyors. This type of sampling would involve a commitment of both money and time and may best be accomplished in a long-term government or university study.

Management Implications

The primary goal of this study was to compare specific measures of diversity from 1890 to what exists today. This study focused on coarse scale comparisons such as working groups and occurrences. The results have shown that apparent changes have occurred in the proportions of the forest. These comparisons should be reviewed and incorporated into future management plans.

Management plans for all management units should consider the type of data available from the survey notes and follow methods similar to those of this study to produce a reconstruction of the forest. This will give important information as to the proportions of the forest. This information could then be used as the 'pre-settlement' state of the forest and could guide future practices towards this state. It would be naïve to think that forest management could or should return any forest to its 1890 condition, but the important consideration should be the proportions and the relative rankings of working groups or hardwoods, etc.

The most expedient course of action for any given management plan would be to try and maintain the rankings of working groups. This sounds like a fairly simple task, however it is more likely a very lofty goal. This study has shown that in many cases the rankings of working groups have apparently increased or decreased. Each management unit needs to set specific goals and a time period in which to reach that goal. For example maple as a working group and occurrence appears to have increased in the Algonquin Park management unit. Specific goals for this area could be to reduce the amount of maple by 10 percent in the next 20 years via stand conversion to softwood species such as hemlock, to increase the amount of hardwood harvesting in areas with pure maple stands and to allow natural succession to replace the maple in these areas.

I believe that the first step in any management scenario should be to reduce the amount of hardwoods especially maple. However this will be difficult to do as the seed source for maple in these areas is probably immense and the maples in the understorey will replace any new opening in the canopy. Therefore, thinning of young maple will be required to reduce its levels in the understorey. Replanting of desirable softwoods after the thinning could be the next step and with a comprehensive hands on management approach the amounts of maple could be reduced to near pre-settlement levels.

If the major goal of modern forestry is to consider and conserve biodiversity then we must continue to monitor the relative abundances of the different communities to ensure healthy forests ecosystems (Ontario, 1994). By expanding these baseline historical surveys to include as much of the province as possible a clearer picture of pre-settlement conditions will provide a goal for forest management to strive towards. The new century could be a time for Canadian forest management planners to lead the way to a sustainable ecological and economic future so that we may leave a diverse and healthy forest landscape for future generations.

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8.0 Appendix 1 The Potential Associative Groupings of Yellow Birch

When found in the following associations Species 1 is a Yellow Birch.

Forest Cover							Working Group	
Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Type of Birch	
Bir	He	Bf	Map	Ce			By	
Bir	He	Bf	Pin				By	
Bir	He	Be	Bf				By	
Bir	He	Be	Map				By	
Bir	He	Be	Map	Pin	Bf		By	
Bir	He	Ce					By	
Bir	He	Ce	Bf				By	
Bir	He	Ce	Map				By	
Bir	He	Ce	Map	Pin			By	
Bir	He	Ce	Pin				By	
Bir	He	Ce	Pin	Sp			By	
Bir	He	Ce	Sp				By	
Bir	He	Ce	Swamp				By	
Bir	He	Map					By	
Bir	He	Map	Bf				By	
Bir	He	Map	Bf	L	Ce	Be	By	
Bir	He	Map	Be				By	
Bir	He	Map	Ce				By	
Bir	He	Map	Ce	Bf			By	
Bir	He	Map	Ce	Bf	Ab		By	
Bir	He	Map	Ce	Pin			By	
Bir	He	Map	Sp				By	
Bir	He	Map	Sp	Pin			By	
Bir	He	Pin					By	
Bir	He	Pin	Bf				By	
Bir	He	Pin	Sp	Ce	Bf		By	
Bir	He	Sp					By	
Bir	He	Sp	Ce	Pin			By	
Bir	He	Sp	Pin				By	
Bir	He	L					By	
Bir	Map	Be					By	
Bir	Map	Be	Bf				By	
Bir	Map	Be	Bf	Pin			By	
Bir	Map	Be	He				By	
Bir	Map	Be	He	Ce			By	
Bir	Map	Be	He	Ir	Bf		By	
Bir	Map	Be	He	Pin	Bf	Sp	By	
Bir	Map	Be	Pin				By	
Bir	Map	Be	Pin	He	Ir		By	
Bir	Map	Be	Pin	He	L	Ce	By	
Bir	Map	Ce					By	

Forest Cover							Working	Group
Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Type of	Birch
Bir	Map	Ce	Pin	Sp			By	
Bir	Map	He					By	
Bir	Map	He	Bf				By	
Bir	Map	He	Bf	Be			By	
Bir	Map	He	Bf	Be	Pin		By	
Bir	Map	He	Be	Pin			By	
Bir	Map	He	Ce				By	
Bir	Map	He	Ce	Ab			By	
Bir	Map	He	Ce	Bf			By	
Bir	Map	He	Ce	Pin			By	
Bir	Map	He	Sp	Bf			By	
Bir	Map	He	Pin				By	
Bir	Map	He	Pin	Bf			By	
Bir	Map	He	Sp				By	
Bir	Ab						By	
Bir	Bf	Ab					By	
Bir	Bf	Ce					By	
Bir	Bf	Ce	Pin				By	
Bir	Bf	Ce	Sp	Pin			By	
Bir	Bf	He					By	
Bir	Bf	He	Ce	Pin			By	
Bir	Bf	He	Ir				By	
Bir	Bf	He	Map				By	
Bir	Bf	He	Pin				By	
Bir	Bf	He	Sp				By	
Bir	Bf	Map					By	
Bir	Bf	Map	Be				By	
Bir	Bf	Map	Ce				By	
Bir	Bf	Map	Ce	He			By	
Bir	Bf	Map	He				By	
Bir	Bf	Map	Pin				By	
Bir	Bf	Map	Sp				By	
Bir	Ce	Bf					By	
Bir	Ce	Bf	Pin				By	
Bir	Ce	Bf	L	Pin			By	
Bir	Ce	He	Bf	Pin			By	
Bir	Ce	He	Pin				By	
Bir	Ce	He	Sp				By	