DEFINING A FOREST REFERENCE CONDITION FOR KOUCHIBOUGUAC NATIONAL PARK AND ADJACENT LANDSCAPE IN EASTERN NEW BRUNSWICK USING FOUR RECONSTRUCTIVE APPROACHES

by

Donna R. Crossland
BScH Biology, Acadia University, 1986
BEd, St Mary's University, 1990

A Thesis Submitted in Partial Fulfilment of
the Requirements for the Degree of

Master of Science in Forestry

in the Graduate Academic Unit of
Forestry and Environmental Management

Supervisor: Judy Loo, PhD, Adjunct Professor of Forestry and Environmental Management/Ecological Geneticist, Canadian Forest Service, NRCan.

Examining Board: Graham Forbes, PhD, Department of Forestry and Environmental Management, Chair
Antony W. Diamond, PhD, Department of Biology

This thesis is accepted.

Dean of Graduate Studies

THE UNIVERSITY OF NEW BRUNSWICK

December 2006

Your file Votre référence
ISBN: 978-0-494-49667-1
Our file Notre référence
ISBN: 978-0-494-49667-1

DEDICATION

To my parents, Errol and Greta Crossland,

who raised me within an endearing landscape of

forests and lakes

in East Dalhousie, NS,

and to

my husband, Larry,

who adapted quickly and understood.

ABSTRACT

A forest reference condition for Kouchibouguac National Park and the adjacent landscape in eastern New Brunswick was derived by integrating information from historical descriptions, witness tree information, square timber harvest records, and ecosystem archaeology.

Species frequency results indicated that forests were dominated by mid-to late-successional *Picea, Tsuga canadensis, Betula, Acer, Abies balsamea,* and *Pinus strobes*, comprising 70-80 % of 19th century forests. *Fagus grandifolia* and *Thuja occidentalis* existed at 5 and 6 – 14 %. Trees were mostly tall, large diameter, and mature to old growth. Early-successional or shade-intolerant species occurred at 1-3 % of forest composition.

In the current forest, frequencies of *Tsuga canadensis* and *F. grandifolia* have decreased to approximately 1 % and 0.1 % respectively, *A. balsamea* has doubled on many sites, and *Populus* has become the most abundant hardwood species. *Pinus banksiana*, nearly absent *ca*. 1800, has become the most dominant pine species. Six dominant tree species comprise 95 % of contemporary forests, whereas there were nine species *ca*. 1800. Riparian zones have lost approximately 40 % of forest cover, and support little of the former species composition.

ACKNOWLEDGEMENTS

This thesis was funded by Kouchibouguac National Park to meet requirements to establish long-term vegetation management goals. I thank Park Ecologist, Eric Tremblay, and Manager of Resource Conservation, Michel Savoie, for sharing in my belief that this research was an essential requirement for basing sound ecological decisions. Their financial support from a dwindling park budget made it all possible. To my Park Warden colleagues, thanks for their patience and for accommodating schedule changes that allowed more time to be devoted to completion of this research, sometimes at the expense of a wide array of other important tasks.

This research would not have taken place without the support and inspiration of several persons who urged me to pursue my passion for historical forest ecology, though it was well outside my comfort zone as a Park Warden. Dr Elena Ponomarenko gave me the first glimmer of hope that we can describe past forest types with reasonable certainty. I was inspired by nearly every conversation with her, as I assisted with her fieldwork and logistics during several field seasons. Mary-Ellen Badeau found many historical documents through her work as archivist at PANB. She continued to tempt me by providing 19th century survey sketches and forest descriptions of the park until she finally had me convinced that this information must be thoroughly examined to learn the extent of its message.

One of the most rewarding outcomes of this research was the admiration and friendship developed for my supervisor, Dr Judy Loo, Canadian Forest Service. I am indebted to her wise counsel, support, and shared enthusiasm toward this research. She also generously provided additional funding for researching several new ecosystem archaeology trenches. I thank CFS for providing me with office facilities while attending UNB. Conversations and newly formed friendships with staff at CFS enriched my educational experience. I also thank staff at NB DNR for their ready assistance in providing digital information on modern forest types and the ecological land classification that assisted me in measuring the extent of forest change over the past 200 years.

I am grateful for the valuable assistance rendered by to following people: Blayne Peters, Elsipogtog Reserve, assisted me with the time consuming task of entering witness tree into GIS, and helped collect charcoal for ecosystem archaeology research. Ian Demerchant (CFS) provided enormous help with deriving basal area from DNR forest data. His patience was amazing. Erica Reese (volunteer) assisted with tedious ton timber entries. Bill Glenn (PEI Dept. of Ag. and Forestry) and Peter Salonius (CFS) provided some valuable direction on the ton timber calculations. Omer Maillet, farmer, who allowed an ecosystem archaeology trench on his land, and filled in the hole with his tractor, saving some backbreaking work. Audrey Beaudet (Kouchibouguac National Park), helped to incorporate rectangular survey information on GIS, and also aided with occasional difficulties encountered while making map layouts.

Thank you, Larry, for spending many days helping to search through microfilm and fiche at PANB for witness tree material. Your understanding and support during the lengthy period of completing this thesis was a true test of your love and commitment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1. GENERAL INTRODUCTION

"It is very useful to know and understand the past to properly manage ecosystems for the future" (Swetnam *et al.* 1999).

INTRODUCTION

The requirement for a forest reference condition

This study was undertaken to define a 'reference condition' for Acadian forest located in eastern New Brunswick. The forest reference condition refers to the species composition, structure and associated disturbance regime. Forest structure was examined in terms of tree size, spacing, and age class. The disturbance regime included agents of disturbance and their dynamics within a range of natural (or historical) variability. Defining a reference condition for forests prior to European settlement is becoming increasingly accepted as appropriate ecological benchmarks for defining protection and management goals for forest resources in North America (Lorimer and Frelich 1994; Abrams and Ruffner 1995; Zelazny and Veen 1997; Radeloff *et al.* 1999; Stephenson 1999; Swetnam *et al.* 1999; Moore *et al.* 1999; Jackson *et al.* 2000; McLachlan *et al.* 2000; Seymour *et al.* 2002). Comparisons of presettlement and modern forest species composition are valuable for determining the extent of forest change over the past several hundred years, and to evaluate human impacts on the environment.

In the Maritime Provinces of Canada, reconstructing principal features of natural forest is challenging. With the exception of one completed study (Lutz 1997; Betts and Loo 2002), scientific examination of original forests of New Brunswick has been negligible. The Acadian Forest Region extends throughout the Maritime Provinces (Rowe 1972), and was the earliest Canadian forest type to be exploited for timber resources. Accurate knowledge of its historical character has been lost due to human-caused disturbances such as agricultural land clearance, logging, fire, pathogen and insect introductions, as well as natural processes, such as decay. Few original forest remnants remain to provide a link to the time when the caribou (*Rangifer tarandus* L.) roamed eastern NB (Chamberlain 1884), browsing on lichens associated with late-successional forests and large open bogs (Gray 1999). Recent estimates from forest resource inventories suggest that less than 2 % of Acadian forest is currently older than 100 years, and far less exists as *bona fide* old-growth (Mosseler *et al.* 2003).

The nature of original forests and associated disturbance regimes in the Eastern Lowlands of NB (DNRE 1996), has been particularly controversial, and is in need, perhaps more than any other area of NB, of baseline research. Extensive stands of late-successional tolerant softwoods, such as eastern hemlock (*Tsuga canadensis* (L.) Carr.) and red spruce (*Picea rubens* Sarg.) were abundant in colonial forests according to Fowler (1873) and Loucks (1962). Dominance of these tree species implies that relatively long intervals between disturbance (particularly fire) accommodated stable, self-replacing species complexes. The landscape features several physical attributes that would preclude fires of any consequence. These attributes include widespread poor drainage, proximity to humid coastal influences, and high landscape fragmentation by bogs and large river systems that act as natural fire breaks (Crossland 1998). The landscape within the study area has the lowest incidence of lightning-caused fires in the province (Wein and Moore 1977; Patch 1998). Yet the prevalence of shade-intolerant species in current forests poses an apparent contradiction. Stands of jack pine (*Pinus banksiana* Lamb.) and pioneer hardwood species indicate frequently repeating fires. Indeed, fire suppression records indicate frequent fires in the area from the earliest times recorded. The fact that eastern NB is one of the driest and warmest areas in the province (DNRE 1996) could predispose the landscape to more frequent fire. Quantitative data are inadequate to determine which disturbance regime (and resultant species complexes) is more representative of the area under natural conditions. It is essential to define pre-colonial disturbance processes as they are inextricably bound to the forest reference condition composition and structure, and they are the driving forces behind forest change. Defining a reference condition will provide much needed, scientifically objective support for forest management on the Eastern Lowlands.

The current research on the presettlement forest character has been conducted in response to conservation needs at Kouchibouguac National Park (KNP). The Acadian forest is a key terrestrial feature of the park. The role of Parks Canada in protecting and conserving, in perpetuity, a part of the Canadian landscape that is recognized to be of natural significance must include conservation of Acadian forest as an integral component of the character of KNP. Since the park's creation in 1969, many of its forested areas have been recovering from disturbances caused by European colonists and their descendants since approximately 1800. Both National Park Policy (Parks Canada 1994) and the Park Management Plan for KNP (Canadian Parks Service 1993) indicate that maintaining natural vegetation succession is the ultimate goal of vegetation management. This long-term aspiration is vulnerable to subjective interpretations regarding which vegetation types are considered 'natural'. What defines characteristic Acadian forest within this region? Approximately 800 ha of the most fertile arable lands inside the park remain as cleared fields. What should be the natural succession on these lands? Do the remaining forests of today differ substantially from past forests? Should old-growth be dominant or rare, and should it consist of even-aged or multi-aged classes? Answers to these and other questions are not easily obtainable given the lack of unaltered modern forests to serve as a guide.

KNP has been the most frequently burned of all national parks in the Maritime Provinces (Wein 1986). Park managers have questioned whether they should maintain the current fire regime through prescribed burns to prevent the loss of extensive stands of jack pine and other disturbance-dependent species. Alternatively, prescribed fire may serve only to perpetuate anthropogenically-altered forest systems created since 1800. It is apparent that maintaining natural vegetation succession requires a better understanding of natural disturbance regimes and associated ranges of vegetation variability. Retrospective study of original forests may offer valuable insight on ecological processes. It is clear that unwise or uninformed management decisions have the capacity to affect vegetation communities for centuries. The integrity of wildlife communities and other ecosystem components that are dependent on forests will be affected by management actions. The national park lacks a clear vision of which forest communities should be maintained or restored. Long-term vegetation management goals require an ecologically justifiable rationale. Key issues such as the management of fire and other disturbance processes hinge on a scientifically sound definition of forest reference condition.

An integrated research approach using historical ecology

Historical evidence of former vegetation communities offers one of a few avenues that may assist in determining the appropriate reference conditions for the study area. The nature of the historical record on Acadian forest is sparse and fragmentary due to loss of evidence through time and masking of evidence by more recent events, such as repeated human-caused fires. Confidence in conclusions of reconstructive studies drawn from older time periods is reduced, as surviving evidence is increasingly more limited. Using several sources of information may compensate for information gaps, and weaknesses in any one approach. Combining multiple lines of research can reinforce the understanding of ecological relationships and should provide an added degree of confidence in conclusions.

Applied historical ecology is the use of historical evidence (from documentary or field sources) in the management of ecosystems (Swetnam *et al.* 1999). The use of historical-ecological information has recently been accepted in the forestry and ecology communities (Hessburg *et al.* 1999; Millar and Woolfenden 1999; Stephenson 1999; Swetnam *et al.* 1999; Seymour *et al.* 2002; Loo and Ives 2003), and there is a growing acceptance of the value of understanding the past to properly manage ecosystems of the future.

An integrated research approach was selected that employed four historical ecology information sources in order to reconstruct a forest reference condition for KNP and the surrounding landscape (Figure 1.1). Strengths and limitations inherent in each approach were evaluated. Integrating the results from the four different approaches helped compensate for weaknesses in individual information sources. Early documented descriptions (first information source) provided qualitative information on early forests, but were limited to areas most frequently traveled and biased toward personal interests of the writer. Surveyor records of the landscape during early European colonization (second information source) provided valuable quantitative information on species composition through study of witness trees used to mark boundaries of land grants. Information was sparsely distributed on the landscape, but extended over a large area. The third data source, square timber records (accounts of large, high quality logs that were harvested and squared by an axe), provided quantitative values for merchantable white pine during the 19th century, but were limited to riparian zones and provided little information on other species. The fourth information source, 'ecosystem archaeology' (Ponomarenko and Ponomarenko 2000a; 2000b), is a new archaeological research method that is capable of providing detailed information from existing physical evidence in the soil. Information on forest character is both quantitative and qualitative in nature, but from a limited number of locations. This research extended the temporal retrospective of past forests much farther than was achieved through the first three methods that relied on documents generated at the time of European colonization.

Goals and objectives

(I.) To define a forest reference condition for Kouchibouguac National Park and adjacent landscape.

(II.) To describe and quantify, where possible, broad changes in forest composition, structure, and disturbance dynamics that have occurred since European settlement.

Specific objectives include:

- To reconstruct historical forest composition, and to interpret successional status and structure where possible.
- To enhance understanding of historical disturbance processes which drove compositional changes and structural characteristics in the forest reference condition.

Description of study area

Location

The study area is situated on the east coast of New Brunswick, Canada, within the 'Eastern Lowlands' ecoregion (Figure 1.2) (Rowe 1972; DNRE 1996). This region is defined by its low elevation, flat landscape owing to a simple, underlying geology of horizontally-bedded Pennsylvanian sandstones overlain by relatively thin surficial deposits. Limited topographic variation is provided by gently rolling ground moraines, a few eskers and kames, and by short, steep banks of streams and meandering rivers that dissect the landscape surface in a parallel east-west pattern to empty into the Northumberland Strait (Wang and Rees 1983; Beach 1988).

The area selected for study comprises 2,420 km^2, extending from the southern shore of Miramichi Bay, in an approximate 30-40 km wide band to the Richibucto River watershed. Limits were based on natural boundaries of watersheds and broad-scale uniformity of terrain features defined by the ecological land classification (ELC) for NB (DNRE 1996). Three 'ecosections' within the ELC were selected for study, ecosections: 6-6-2, 6-6-3, and 6-6-4. (Figure 1.3) Ecosections are delineated by changes in elevation, watersheds, soil lithology and forest cover patterns and associations. These ecosections are nested within the broader unit of the 'Kouchibouguac Ecodistrict', representing the most coastally influenced part of the Eastern Lowlands Ecoregion, and defined by broad-scale features of elevation and geology, as well as slope and aspect (DNRE 1996).

Kouchibouguac National Park is a 239 km^2 protected area that conserves over 125 km^2 of Acadian forest. Some of the park's most prominent features are barrier island sand dunes and spits spanning approximately 25 km of coastline. Lying behind these dunes are extensive shallow lagoons that enclose estuarine waters of 6 drowned river valleys. Outlets of 3 major rivers, the Kouchibouguac, Kouchibouguacis, and Richibucto transect the coastal sand dunes and form gullies to the sea. Coastal forests receive considerable protection by these offshore dunes which moderate wind, wave action, and salt spray from the open waters of the Northumberland Strait. Further north, in the absence of barrier dunes, white spruce forests are exposed to more harsh conditions, and bogs erode into the ocean. Approximately three-quarters of the park's gentle rolling topography is less than 15 m above sea level. Poor drainage is a prominent feature, resulting in large raised peat bogs over approximately 1/5 of park surface (Beach 1988). A 39.5 km^2 provincially protected area, Black River, borders the western boundary of KNP.

Apart from protected areas, the region comprises mainly provincially-owned crown lands that are currently licensed to pulp and paper companies. The remaining landbase belongs to private landowners: non-industrial woodlot owners, and inhabitants of small towns and villages.

Soils and geology

Most soils in the study area were formed by either marine deposits near the coast, or glacial tills farther inland. Ecosection 6-6-2 (encompassing KNP) features surficial glacial deposits that were repeatedly reworked by marine waters during periods of marine submergence and then re-exposed. Many distinct coastal features, such as raised beach deposits, occur well inland from the current shoreline that was established by 12 600 AD. Three primary parent materials occur: marine modified outwash sand, marine clay, and organic matter (peat bogs) (Wang and Rees 1983). The thinly deposited, marine-influenced outwash sands are typically loose, well drained, and acidic in nature, producing mainly Humo-Ferric Podzols. Sub-layers of marine clay are widespread, commonly overlain by subsequent deposition of sandy clays or sands as the sea level receded (Desloges 1980; Beach 1988). Soils are frequently loamy sand gleysols. Poor drainage is prevalent throughout the study area due to water perched on layers of marine clay deposits and negligible slope. Low permeability of marine clay layers, when occurring in level areas, has resulted in extensive open peat bogs. Some peat bogs and fens have recently been recognized as successional formations from ancient ephemeral lagoons and estuaries (Graillon *et al.* 2000).

Parent materials of ecosections 6-6-3 and 6-6-4, located some 15-20 km farther inland, are characterized by compact, fine, slowly permeable lodgement till (unsorted, generally dense, deposit formed under a glacier) overlain with ablation till (loose, permeable deposit that was either contained within or accumulated on the surface of a glacier) of varying thicknesses. Elevations are only slightly higher than in ecosection 6-6-2, ranging from 40-100 m above sea level, as the flat topography slopes gently upward to the west. Imperfectly and poorly drained soils often have luvisolic B horizons in the compact lodgement till or a weak podzolic B horizon. Humo-Ferric Podzols are most commonly found in thick ablation till and outwash sand (Wang and Rees 1983).

Despite the simplicity of the topography, site conditions are heterogenous and complex. Local soil and drainage patterns are discontinuous, often changing rapidly over distances of only a few meters. The underlying clay and lodgement tills play a large role in the unpredictable drainage patterns. Ortstein horizons (a strongly cemented B horizon formed by Al, Fe, or an organic complex) are commonly found in podzolic soils on the eastern half of the study area, and add to the drainage complexity. The ortstein layer usually occurs within 40 cm of the mineral soil, is at least 3 cm thick, and tends to be very hard, with moderate to slow permeability. Roots do not penetrate it. With increasingly poor drainage, the ortstein horizon may cover nearly the entire lateral extent of the soil unit (Wang and Rees 1983). These soils are actually more frequent than indicated on regional soil maps since most units were too small to map at 1:50 000 scale (Wang and Rees 1983). This results in loss of some detail on the intricate nature of soil drainage patterns in the area, which in turn strongly influence species distributions.

Climate

The study area has one of the lowest precipitation levels in the province (van Groenewoud 1983). Moisture is intercepted by the adjacent highlands to the west and the higher elevations of the Fundy Coastal Ecoregion to the southwest (DNRE 1996). Nonetheless, the area receives 979 mm mean annual precipitation, uniformly distributed throughout the year (Desloges 1980). Marine influences and large bogs can result in high humidity. The mean annual temperature is 4.8° C, with the warmest period of the year occurring in late July (29° C mean daily maximum), and the coldest in mid-January (- 6° C mean daily maximum) (Desloges 1980).

Forest communities

The Acadian Forest Region covers most of the area of the Maritime Provinces of Canada (New Brunswick, Nova Scotia, and Prince Edward Island) (Loucks 1962; Rowe 1972), and comprises approximately 35 tree species forming a high variety of associations and community types. Loucks (1962) categorized forests within the study area as part of the "Red spruce-Hemlock- Pine Zone", which covers the Eastern Lowlands and smaller adjacent areas, as well as most of mainland NS, and parts of PEI. This designation was attributed to the particular prominence (at least historically) of each of the three species: red spruce (*Picea rubens* Sarg), eastern hemlock (*Tsuga canadensis* (L.) Carr.), and white pine (*Pinus strobus* L.). Forests of the Eastern Lowlands are comprised primarily of coniferous and mixed stands (DNRE 1996). Red and black spruce (*P. mariana* (Mill.) BSP.), balsam fir (*Abies balsamea* (L.) Mill.), red maple (*Acer rubrum* L.), eastern hemlock and white pine comprise a distinctive association on the landscape (Loucks 1962). Another prominent species, eastern white cedar (*Thuja occidentalis* L.), may be considered an edaphic climax species on heavy soils with impeded drainage (Dryade 1979). KNP features the largest protected eastern cedar stand east of Ontario (Desloges 1980). Eastern larch (*Larix laricina* (DuRoi) K. Koch) and black spruce predominate on expansive bog lands (Loucks 1962). White spruce is abundant adjacent to the Northumberland Strait where it survives exposure from winds and salt spray (DNRE 1996).

Contemporary forests of the study area exhibit extensive stands of intolerant pioneer species with trembling aspen (*Populous tremuloides* Michx.), red maple, white birch (*Betula papyrifera* Marsh.) (DNRE 1996), grey birch (*B. populifolia* Marsh.), white spruce (*Picea glauca* (Moench) Voss), larch, and speckled alder (*Alnus rugosa* (DuRoi) Spreng.) (Loucks 1962; DNRE 1996). Widespread fires appear to have favoured coniferous species, particularly black spruce and jack pine (*Pinus banksiana* Lamb.) (Rowe 1972), associated with an abundance of sweet-fern (*Comptonia peregrina* (L.) Coult.) (Clayden 2000). Stands of jack pine are common on sandy soils along rivers (DNRE 1996). Loucks (1962) stated that eastern hemlock and red spruce have been depleted, and remain more common along streams in the western portion of the study area. Park vegetation currently comprises 26 tree species, forming 37 forest community types based on tree species composition, understory vegetation and site condition (Desloges 1980; Beach 1988). Black spruce, red spruce, balsam fir, trembling aspen, and white cedar, in various associations, account for approximately 70% of species on forested land (Desloges 1980).

Dominant physiographic factors influencing tree species distribution are soil drainage and soil texture, with climate and relief playing less important roles (Loucks 1962; Desloges 1980). Forest communities are naturally fragmented by large bogs and river systems. Narrow bands of better drained soil feature tolerant hardwood growth, including sugar maple (*Acer saccharum* Marsh.), beech (*Fagus grandifolia* Ehrh.), and small pockets of white ash (*Fraxinus americana* L.) (Clayden 2000). These species, along with yellow birch (*Betula alleghaniensis* Britt.), are minor components, and have probably been greatly reduced in frequency, as the better-drained landscapes where such species grew were favoured for human settlement and agriculture (Desloges 1980).

Synopsis of human history and land use

Knowing the history of human land use is needed to understand the difference between natural forests and forests modified by European settlers. To clarify, forests subjected to activities by the original First Nations inhabitants, the Mi'kmaq, are considered 'natural'. Impacts from both Mi'kmaq and European land uses are presented in greater detail in Appendix 1-1. Human impacts on the original forests in the study area were concluded to be minimal until the mid-late 1800s. Therefore historical documents that contributed to this study, produced mostly between 1800-1860, are believed to convey a reasonable depiction of original forest types.

Until at least 1813, fishing was the most important commerce in the region (Temperley 1980). Earliest timber harvesting was for ship masts, but cutting was highly selective and had little impact on forest composition, as shipmasts used only the largest dimension and highest quality white pine timbers. Forests were searched along watercourses for the scattered timbers that met mast standards. Few historical records were preserved on quantities cut, but mast production was comparatively unimportant in NB after 1807 (falling rapidly from 89 %, 36 %, and 14 % of British-North American exports during years 1803, 1807, and 1811 respectively) (Lee 1987).

European settlement began in earnest in the study area between 1820-1830, and local forests were subjected to increased resource harvesting from that time onwards. Divergent perspectives on forests emerged, one where forest timber was regarded as a valuable resource for harvest and export, and another where the forest was regarded as an imposition to agricultural land clearances. As a consequence of both value systems, forests began to be subjected to rapid change.

The years 1820-1840 witnessed the rise and fall of the square timber industry, which placed huge selective demands on white pine resources (far exceeding demands for shipmasts). Red pine and yellow birch were also sought for square timber in lesser amounts. Large wooden sail ships were required to transport the great quantities of timber to Britain, and so a vibrant shipbuilding industry followed. A total of six shipyards existed in the study area, four on the Richibucto River (the first production began in 1819 (Maxwell 1951)), and two on the Kouchibouguac River (Monro 1855). A total of 194 large ships were built in Kent County (Figure 2.1) during the 19th century (including 42 ships built on the Kouchibouguac alone) (DeGrâce 1984). Heavy demands were placed on high quality white pine, as well as red pine and yellow birch for both shipbuilding and the square timber export market. Shipbuilding tapped additional species: larch, spruce, red oak, eastern white cedar, ash, maple, beech, and elm (Monro 1855; Trueman 1970). Despite the quantities of wood required for shipbuilding, much larger amounts of timber were shipped to Britain. The town of Richibucto became the third largest shipping port in NB as early as 1830 (Monro 1855).

Sawmills were inexorably linked to the shipbuilding industry, but they also served domestic needs of growing populations of settlers. Sawmills were able to use mid-sized timber (mainly pine and red spruce) (Lee 1987). At least 16 sawmills were located within the study area by 1851 (Monro 1855). Red spruce became a valued species in the lumber industry at this time, and much of it, along with pine, was exported in the form of deals and boards (Lee 1987). (Deals were large sawn pieces of lumber, 7.6 cm thick by at least 23 cm wide, and 3 to 7.3 m in length (Wynn 1981).) The sawmill era hastened a collapse in local fisheries from the damming of streams, slab waste and sawdust (Daigle 1948; Lee 1987).

Only the most easily accessible forests along the ocean and watersheds were affected to any degree during the earliest timber exploits. Other than forests subjected to escaped wildfires, the primeval character of inland forests remained intact, as logging and land clearing had not yet reached there. Rivers remained the major mode of inland transportation and the only means to transport huge timbers to shipping ports and mills. Hardwood stands were bypassed for many decades because they floated poorly, therefore incurring difficulties in transporting them to mills (Lee 1987). Kent County had only 3 % (14 365 ha) of land cleared by 1851 (Monro 1855). "*The wealth of vast forests of the best timber [ ] remain untouched*" (Perley 1842).

One of the last tree species of the 19th century to be selectively harvested was eastern hemlock, the bark of which was used for the leather tanning industry. Bark of alder, yellow birch, hemlock and larch were all used for leather tanning (Cooney 1832;

Perley 1847), but hemlock was the most popular in New Brunswick. Stands of hemlock were felled and stripped of bark over approximately 30 years beginning *ca.* 1870 (DeGrâce 1984). Local people recall seeing huge prostrate hemlock trunks in the forests long after the industry was abandoned (B. Hebert, security guard, KNP, NB, Pers. comm.; V. Vautour, maintenance, KNP, NB, Pers. comm.).

Purposeful and accidental fires caused some of the most significant changes to forests. Free land grants stipulated that for every 50 acres considered arable, three should be cleared for cultivation (MacNutt 1963). Trees were regarded as an "*obstacle to cultivation, which must therefore be cut down and burnt*" (Johnston 1850). Nearly all lands in New Brunswick were cleared through the aid of fire (Johnston 1850). The process began with felling and burning the trees, followed by spreading the ashes. Stumps were left to rot for seven to nine years (depending on tree species) before they were hauled out. The first crop was often potatoes, followed by wheat and hay. The land was merely harrowed for the first several years in order to prepare for planting. After the stumps were hauled out, the land was ploughed. A more difficult method, less commonly employed, was to cut the trees, pull the stumps, remove the stones, and plough all in one season. Most settlers did not have the financial resources to pay for so much labour prior to receiving returns for the first year or two of crops (Johnston 1850). Forests were often completely cleared as they were regarded as a fire hazard. Woods around dwellings presented a source of fuel to spreading fires from surrounding woods. Even ornamental trees near buildings could spell destruction (Johnston 1851).

Johnston (1850) criticized the lack of agriculture in the province, stating that the "*ground was cultivated chiefly to raise supplies for the lumberer*". Agriculture was neglected while the seemingly more lucrative timber trade lured the settlers into the lumber camps instead of pursuing the long-term investment of farming. In his task of assessing the province's agricultural potential, he complained that the land on which the timber had been cut resulted in vegetation that was more difficult and costly to clear "*than when it stood in its original state of nature*".

Johnston (1851) stated repeatedly that hardwood land was well suited for farming. It was therefore more likely that lands were cleared in hardwood areas than in softwood forest. Hardwood areas may have been at a premium as some areas were generally described as *"poor and meager"*(Monro 1855). Lands surrounding the towns of Richibucto and Rexton were described as *"poor and not capable of repaying the labors of the agriculturist"* (Monro 1855).

THESIS FORMAT AND INFORMATION SOURCES

The forest reference condition was defined using four sources of historical ecology information. Each of the information sources constituted an independent study, and was written as a separate chapter. As such, four independent, but related chapters, written in article format, addressed aspects of the forest reference condition. Each chapter was organized so results focus on the three components of the forest reference condition (i.e. forest composition, structure, and disturbance processes). A final chapter integrated all information sources to reconstruct pre-European settlement forest composition, structure, and disturbance processes.

The first three sources (listed below) originated mainly from archived documents at the Provincial Archives of New Brunswick (PANB). Witness tree records constituted the majority of the information. Witness tree research has proven to be one of the best sources of quantitative data on pre-European settlement forests, and has been used to reconstruct vegetation in many areas in eastern North America (Bourdo 1956; Lorimer 1977; Abrams and Ruffner 1995; Radeloff *et al.* 1999). Only a single study on historical forests has been completed for New Brunswick in Kings County (Lutz 1997). The current project differed in several ways from this research, by supplementing and verifying witness tree research with other information sources, and by focussing on an entirely different landscape. Historical descriptions and witness tree information (Information sources 1, 2) were supplemented with research on square timber petitions (Source 3). Ecosystem archaeology results (Source 4) (Ponomarenko and Ponomarenko 2000a; 2000b; Ponomarenko 2006) completed the historical reconstruction and provided a means of comparison between historical forest composition derived from witness tree information and ecosystem archaeology information (Figure 1.1).

The study area was expanded to include forests surrounding Kouchibouguac National Park in order to increase sample size of historical data and to include entire watersheds (Figure 1.2). The enlarged area also allowed a more complete understanding of disturbance processes, such as fire, that operate on a large scale. Scientific classification for tree species followed Hinds (2000).

Methods used for the four information sources were as follows:

(1) Historical forest descriptions from early documents (Chapter 2): A summary of historical forest composition, structure, and disturbances was derived from existing documents, the majority written during the 19^{th} century. Frequencies of tree species were derived from the number of times each species was documented within or near the study area.

(2) Witness tree information (Chapter 3) was obtained from surveyor notes and sketches located mainly at the PANB. Most information originated from surveys of private lots, where witness trees were typically used to mark corners and occasionally the edges of lots. Surveys of meridian lines, early roads and timber reserves provided additional witness trees. Witness tree species frequencies were analyzed spatially to determine early forest composition on a range of physiographic sites.

(3) Square timber petitions (Chapter 4): Merchantable timber volume information was derived from the earliest existing square timber petitions made to the crown, for logging white pine, as well as red pine and yellow birch, to a much lesser degree. Square timber, or 'ton timber', values were converted to modern volumetric measurements. Results were presented on total quantities of timber harvested for specific years on the four watersheds of the study area. This information provided an indication of the degree to which large, high quality white pine was selectively removed in the early 1800s.

(4) Ecosystem Archaeology (Chapter 5) is a paleoecological method that was used to examine soil profiles and define former forest composition through identification of macrofossils (charcoal fragments, twigs, buds, bark, and seeds) that are preserved in the soil (Ponomarenko and Ponomarenko 2000a; 2000b). Methods employed in the study included detailed examination of trace fossils, such as imprints, images or moulds that were observed, often contrasting colouration or texture in the soil profile, where former tree root collars, uprooting structures, or other pedoturbations (mixing of soil components by natural processes) occurred. Identification of some tree genera, as well as spatial and structural features of individual trees can be interpreted from the shapes

and distances between root trace fossils. Study of the relative positions occupied by trace fossils in the profile guided collection and chronological interpretation of macrofossils and other artefacts. Macrofossils, charred or otherwise preserved, were extracted from the soil profile and identified to the genus or species level, either in the field or laboratory. Charcoal provided the majority of material for species identification, interpreted from preserved cell structures. Charcoal was also interpreted with regard to disturbance history, mainly through radiocarbon dating.

Chapter 5 focused on comparing ecosystem archaeology results by Ponomarenko (2006) with witness tree results (Chapter 3). Similarities and differences between the number of species detected and their corresponding frequencies were compared. Histograms of witness tree species frequencies, as they occurred on corresponding ecosites were compared with corresponding species frequency histograms derived from ecosystem archaeology. Corroboration between species frequencies from each information source provided additional insight and affirmation of the accuracy, strengths and weaknesses, of these two historical ecology information sources.

Chapter 6 provided a synthesis of the preceding chapters. The resulting integration of several historical ecology information sources converged to produce a well-defined forest reference condition for the Eastern Lowlands. The information is expected to lend objectivity and scientific rigor to forest management decisions in KNP and perhaps aid management of publicly owned forests or private lands in the area. Some recommendations on the management and possible restoration initiatives of forestlands were outlined, based on the forest reference condition.

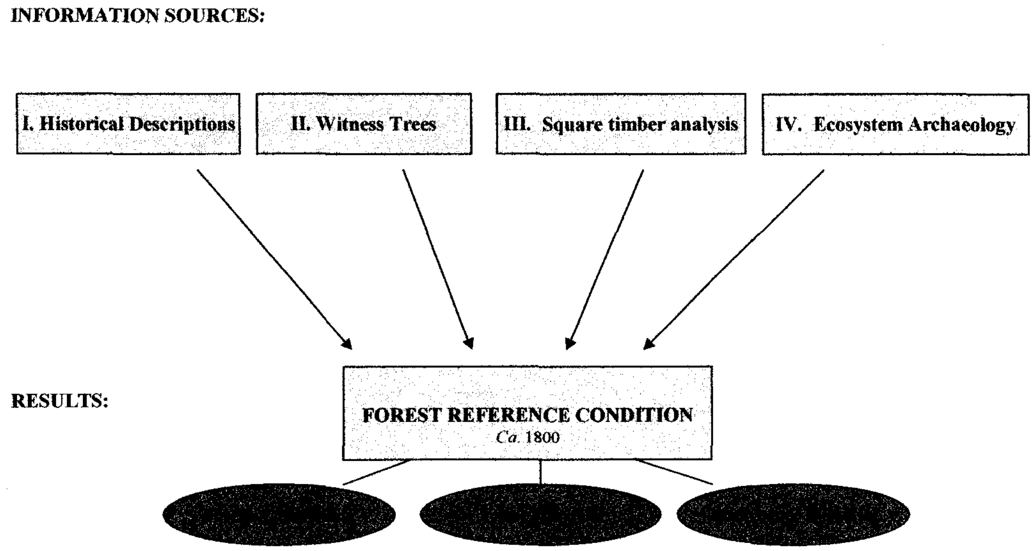


Figure 1.1 Information sources used to define the forest reference condition, based upon species composition, structure, and associated disturbance dynamics.

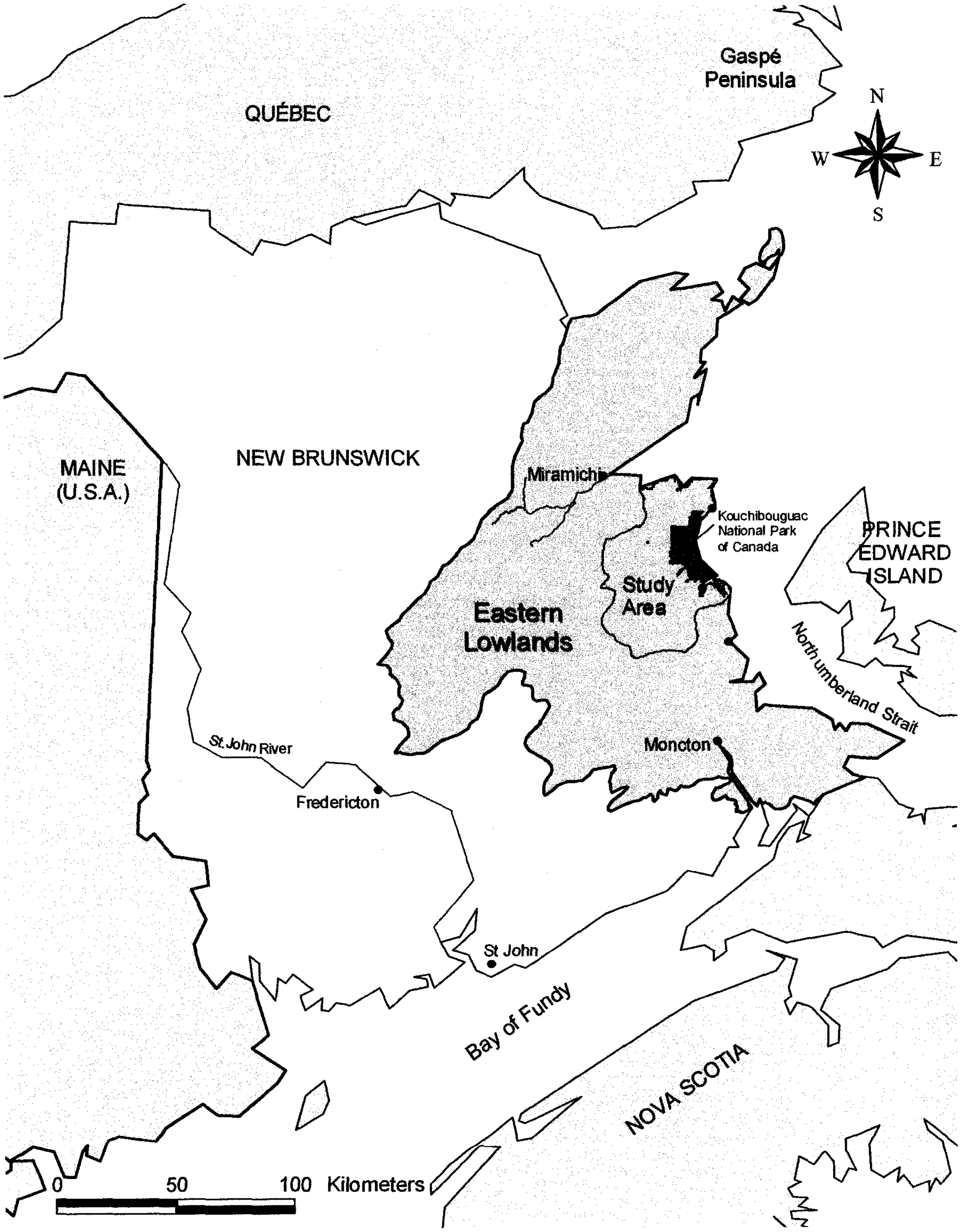


Figure 1.2 Location of the Eastern Lowlands Ecoregion (DNRE 1996) and study area.

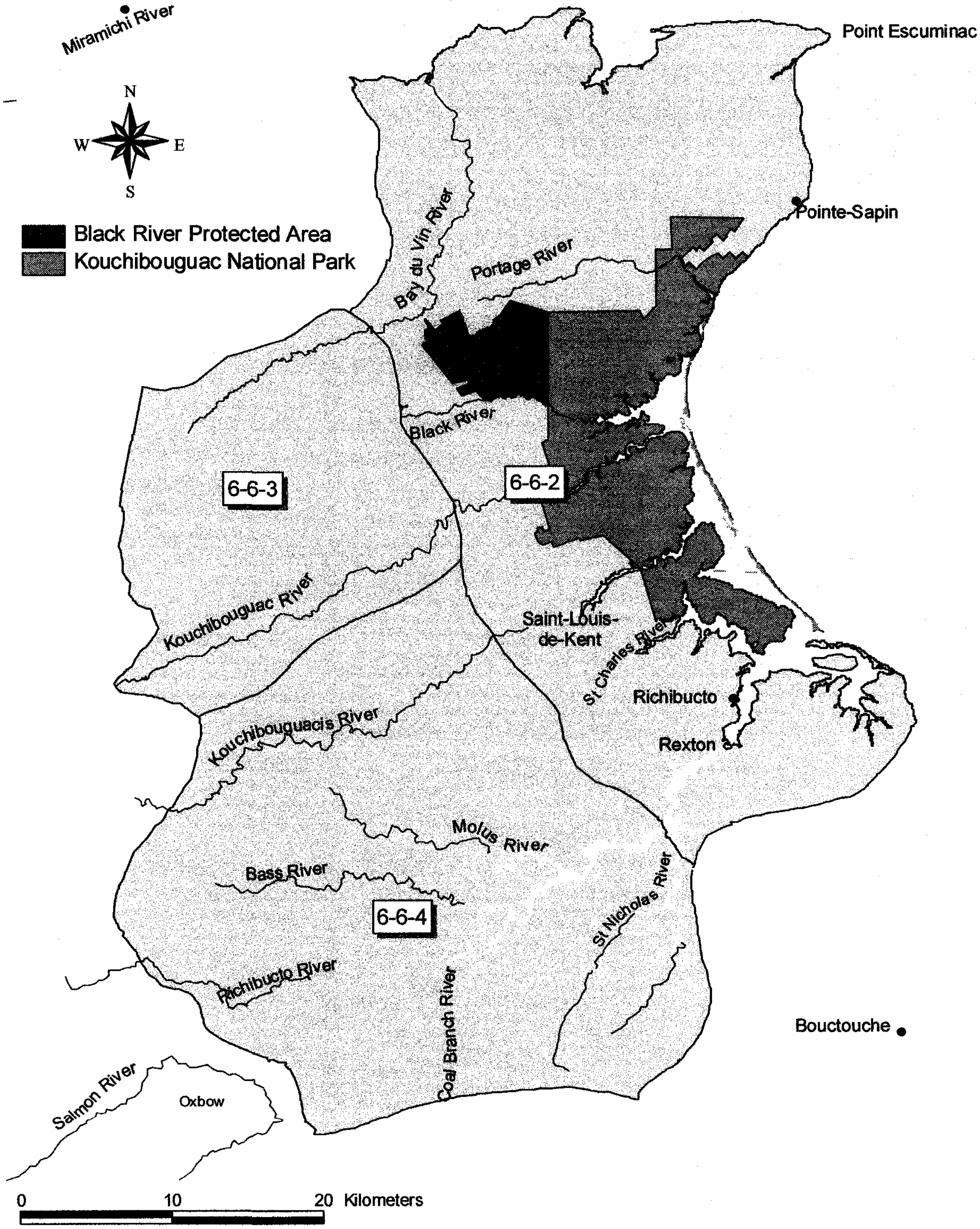


Figure 1.3 Study area features with Ecosections 6-6-2, 6-6-3, and 6-6-4.

REFERENCES

Abrams, M.D. and Ruffner, C.M. 1995. Physiographic analysis of witness-tree distribution (1765-1798) and present forest cover through north central Pennsylvania. Can. J. For. Res. 25: 659-668.

Beach, H., (Ed.) 1988. The Resources of Kouchibouguac National Park: Resource Description and Analysis. Kouchibouguac National Park, Envir. Canada.

Betts, M. and Loo, J. 2002. A comparison of pre-European settlement forest characterization methodologies. The Forestry Chronicle, 78 (3): 422-432.

Bourdo, E.A. (Jr.) 1956. A review of the general land office survey and of its use in quantitative studies of former forests. Ecology 37 (4): 754-768.

Canadian Parks Service. 1993. Kouchibouguac National Park Management Plan. Environment Canada, Canadian Parks Svc. 73 pp.

Chamberlain, M. 1884. Mammals of New Brunswick. Bull. Nat. Hist. Soc. N.B. 3: 37-41 (reprinted- 10:30-33).

Clayden, S.R. 2000. History, physical setting, and regional variation of the flora. *In*: Hinds, H.R. 2000. Flora of New Brunswick (2nd. ed.), Dept. Biol., U.N.B., NB. p 35-73.

Cooney, R. 1832. A compendious history of the northern part of the province of New Brunswick and of the District of Gaspe in Lower Canada. Joseph Howe, Halifax, NS. 158 pp.

Crossland, D. 1998. Recent fire history of Kouchibouguac National Park. Parks Canada-Technical Reports in Ecosystem Science #013, Cat No. R61-2/19-13/1997^{E}, 41pp.

Daigle, L.C. 1948. Histoire de Saint-Louis-de-Kent. L'Imprimérie Acadienne Ltée, Moncton, NB. 245 pp.

DeGrâce, E. 1984. Human history of Kouchibouguac National Park. Unpub. report to Parks Canada. 157 pp.

Desloges, C. 1980. The natural resources of Kouchibouguac National Park. Parks Canada, Atlantic region, Ed.: Le Groupe Dryade, Que. 127pp.

DNRE 1996. An ecological land classification system of New Brunswick. Ecosystem Classification Working Group, New Brunswick Department of Natural Resources and Energy, Fredericton, NB.

Dryade (Le Groupe) 1979. Kouchibouguac National Park forest vegetation. Parks Canada. Unpub. report. 186 pp.

Fowler, J. 1873. Archival letter to G.W. Clintin; Buffalo Museum of Science, Buffalo, NY.

Graillon, P., Provencher, L., and Fortin, M.-J. 2000. Cartographie biophysique d' un grand écosysteme: Parc national Kouchibouguac, Nouveau-Brunswick. Université de Sherbrooke, Département de géographie et télédétection, Bulletin de recherche ISSN 0710-0868, 75 pp.

Gray, D.R. 1999. Updated status report on the woodland caribou in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Grayhound Info. Svcs., Metcalfe, ON. 37 pp.

Hessburg, P.F., Smith, B.G., and Salter, R.B. 1999. Detecting change in forest spatial patterns from reference conditions. Ecol. Applic. 94 (4): 1232-1252.

Hinds, H. R. 2000. Flora of New Brunswick (2nd ed.) Dept. of Biology, UNB. 695 pp.
Jackson, S.M., Pinto, F., Malcolm J.R., and Wilson, E.R. 2000. A comparison of pre-European settlement (1857) and current (1981-1995) forest composition in central Ontario. Can. J. For. Res. 30: 605-612.
Johnston, J.F.W. 1850. Report on the agricultural capabilities of the province of New Brunswick. J. Simpson, Fredericton, NB. 95 pp.
Johnston, J.F.W. 1851. Notes on North America. Vol. I and II., C.C. Little and J. Brown, Boston, 512 pp.
Lee, D. 1987. The forest history of New Brunswick 1780-1930: A systems plan report. Parks Canada Microfiche Report Series 301, 172 pp.
Loo, J. and Ives, N. 2003. The Acadian forest: Historical condition and human impacts. Forestry Chronicle 79(3): 462-474.
Lorimer, C.G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology 58: 139-148.
Lorimer, C.G. and Frelich, L.E. 1994. Natural disturbance regimes in old-growth northern hardwoods. J. For. 92 (1): 33-38.
Loucks, O. L. 1962. A Forest Classification for the Maritime Provinces. Proceedings of the Nova Scotian Institute of Science. Vol. 25, Part 2, p. 85-167.
Lutz, S.G. 1997. Pre-European settlement and present forest composition in Kings County, New Brunswick, Fac. For. Envir. Mgt. U.N.B., Fredericton, NB. 51 pp.
MacNutt, W.S. 1963. New Brunswick, a history: 1748-1867. MacMillan of Canada, Toronto, ON. 496 pp.
Maxwell, L. 1951. 'round New Brunswick roads. Ryerson Press, Toronto. 191 pp.
McLachlan, J.S., Foster, D.R. and Menalled, F. 2000. Anthropogenic ties to late-successional structure and composition in four New England hemlock stands. Ecology 81 (3): 717-733.
Millar, D.I. and Woolfenden, W.B. 1999. The role of climate change in interpreting historical variability. Ecol Applic. 9 (4): 1207-1216.
Monro, A. 1855. New Brunswick; with a brief outline of Nova Scotia and Prince Edward Island. Their history, civil divisions, geography, and productions. Richard Nugent, Halifax, NS. 384 pp.
Moore, M.M., Covington, W.W., and Fule, P.Z. 1999. Ecol. Applic. 9(4): 1266-1277.
Mosseler, A., Lynds, A., and Major, J.E. 2003. Old-growth forests of the Acadian Forest Region. Environ. Rev. 11: S47-S77
Parks Canada 1994. Guiding principles and operational policies. Canadian Heritage Publ.,Cat. No. R62-275/1994E. 125 pp.
Patch, J. 1998. Analysis of lightning fire frequency by ecodistrict. Unpub. report to NBDNRE, Island View, NB.
Perley, M.H. 1842. Reports on Indian settlements, &c. J. of the House of Assembly of the province of New Brunswick, Sixth Session of the twelfth general assembly, (Appendices.), J. Simpson, Queen's Printer, Fredericton, NB.
Perley, M.H. 1847. Report on the forest trees of New Brunswick. *In:* Simmonds's Colonial Magazine, vol. XI: 42, June 1847, p. 129-423.
Ponomarenko, E. 2006. Reconstruction of ecosystem dynamics and natural disturbance history in Kouchibouguac National Park. Report in preparation.
Ponomarenko, E. and Ponomarenko, S. 2000a. Morphometric analysis of charcoal assemblages in soil: an approach to reconstruct fire history, (case study of

Kouchibouguac National Park). Unpub. report to Parks Canada, Kouchibouguac National Park, 40 pp.
Ponomarenko, E. and Ponomarenko, S. 2000b. Reconstruction of pre-agricultural vegetation pattern in Kouchibouguac National Park using the ecosystem archeology method. Preliminary study. Unpub. report to Parks Canada, Kouchibouguac National Park, 26 pp.
Radeloff, V.C., Mladenoff, D.J., Hong, S. He, and Boyse, M.S. 1999. Forest landscape change in northwestern Wisconsin pine barrens from pre-European settlement to the present. Can. J. For. Res. 29: 1649-1659.
Rowe, J. S. 1972. Forest Regions of Canada. Department of Environment, Canadian Forest Service, Publication No. 1300.
Seymour, R.S., Alan, S.W., and deMaynadier, P.G. 2002. Natural disturbance regimes in northeastern North America-evaluating silvicultureal systems using natural scales and frequencies. For. Ecol. and Mgt. 155: 357-367.
Stephenson, N.L. 1999. Reference Conditions for giant sequoia forest restoration: structure, process, and precision. Ecol. Applic. 9 (4): 1253-1265.
Swetnam, T.W., Allen, C.D., and Betancourt, J.L. 1999. Applied historical ecology: using the past to manage for the future. Ecol. Applic. 9 (4): 1189-1206.
Temperley, H. (Ed.) 1980. Gubbins' New Brunswick Journals 1811 and 1813. NB Heritage Publications, Fredericton, NB. 74 pp.
Trueman, S. 1970. An intimate history of New Brunswick. McClelland and Stewart Ltd. Toronto, ON. 154 pp.
van Groenewoud, H. 1983. Summary of climatic date pertaining to the climatic regions of New Brunswick. Info. Report M-X-146, Can. For. Svc. 70 pp.
Wang, C. and Rees, H.W. 1983. Soils of the Rogersville-Richibucto Region of New Brunswick. Ag. Can. 239 pp.
Wein, R.W. 1986. Historic and prehistoric role of fire in the Maritime National Parks. Unpubl. report to Parks Canada. Dept. Biol., U.N.B. 36 pp.
Wein, R.W. and Moore, J.M. 1977. Fire history and rotations in New Brunswick Acadian Forest. Can. J. For. Res. 7: 285-294.
Wynn, G. 1981. Timber colony: A historical geography of early nineteenth century New Brunswick. U. Toronto Press, ON. 224 pp.
Zelazny, V.F. and Veen, H. 1997. The Acadian forest past and present. *In*: Proceedings of an Ecological Landscape Management Workshop, Fredericton, NB, October 1997. Pages 9-13. Canadian Woodlands Forum, Canadian Pulp and Paper Association.

CHAPTER 2. DEFINING A FOREST REFERENCE CONDITION FROM EARLY FOREST DESCRIPTIONS

INTRODUCTION

A wealth of information exists on early New Brunswick forests, but surprisingly few attempts have been made to summarize historical documents that describe the forests as the first European immigrants viewed them. No analysis using historical descriptions has ever been completed for eastern NB forests. Descriptions of pre-colonial forests based upon extracts from historical literature can serve as a useful foundation to which additional sources of historical ecology information may be added or compared (Sobey 2002). Some ecological insights may be gained through extensive reviews of historical literature that are otherwise undetected through more quantitative methods. The value of studying historical forest descriptions has been demonstrated through research on forests of a neighbouring province, Prince Edward Island (Sobey 2002; Sobey and Glen 2004).

The objective of this research was to define the forest reference condition at the time of European settlement through examination of early documents. Descriptions of early forest composition, structure (i.e., tree height and diameter, age class) and disturbance regime were extracted from 26 historical records. Analysis of species frequency (the number of times species were recorded in historical observations of the study area) assisted in defining forest composition from early descriptions.

Documentary evidence exists in a variety of forms, ranging from observations of early explorers, information to assist new settlers on choosing agricultural lands, promotional notes on the utilitarian values of forest resources, and notes from surveyors and other learned travellers. Most forest descriptions reflect the interests of the period in which they were written, and the information was expected to feature bias towards the most valued species. Occasionally these records disclosed unexpected, largely forgotten aspects of early forest character. This research calls attention to the brief period (200 years) during which the forest was rapidly transformed to modern forest types.

METHODS

Records from five archival institutions were searched for relevant information on early NB forests. Archives were: (1) Provincial Archives of New Brunswick (PANB), (2) Harriet Irving Library archives (University of NB), (3) New Brunswick Museum, (4) Centre d'Études Acadiennes (université de Moncton), and (5) Public Archives of Nova Scotia (PANS). The last two archives were searched particularly for information originating from the French period. On line archival websites, particularly Early Canadiana Online (http://www.canadiana.org/eco /index.html), facilitated access to some historical texts otherwise accessible only through inter-library loan using micro reproductions. A series of local newspaper articles were written on various aspects of early forests in order to encourage the local public to contribute historical information that may assist this research.

Representative forest types were determined by gleaning information on composition, structure, and disturbance regime of eastern New Brunswick forests from historical accounts, particularly those of N. Denys (1672), J. Gubbins (1813, *In*: Temperley 1980), R. Cooney (1832), C. Atkinson (1844), J. Alexander (1849), J. Johnston (1851), M. Perley (1842; 1847; 1863), A. Monro (1855; 1862), J. Fowler (1873; 1885), L. Bailey (1876), W. Ganong (n.d.); and J. Hannay (1902). Pertinent background information on each of the principal recorders of early forest descriptions was sought. The degree of confidence in each contributor was determined based on professional background, length of time spent in the study area or in the province, areas visited, and general quality of descriptions. Each document was carefully examined, and all relevant information extracted, frequently using verbatim quotes in order to avoid misinterpretation and personal bias. Square brackets were inserted in some areas to replace deleted sections of irrelevant historical text, and were also placed around text that was added to assist maintaining proper context.

Appendix 2-2 provides scientific names and authorship for all native tree species, according to Hinds (2000), as well as common names found in the historical records. It provides interpretation of former tree species names, an important initial step required in the process of interpreting species composition from historical documents. Historical tree nomenclature often differed from modern species names. Use of former tree names and lack of identification to the species level in some cases required careful interpretation based on application of ecological principles.

Forest descriptions are arranged and classified according to time period, and by species. Information is organized into three sections, according to components of the forest reference condition: (1) compositional descriptions, (2) structural and age class information, and (3) evidence of disturbance dynamics. Greater emphasis was placed on descriptions specific for the study area, but more often only general forest information was available. All information is summarized, where possible, in table form, to facilitate final analyses. Some of the table formatting is similar to Sobey (2002). The reported presence of black birch (*Betula lenta* L.) was checked at the NB herbarium by first, ascertaining that no specimens of *B. lenta* were preserved from NB, and secondly, by examining the features of all yellow birch specimens for possible misidentified black birch specimens.

A separate review of historical forest composition and structure was conducted for the survey of James Alexander in 1844 (Alexander 1849), since it provided more extensive detail on forest condition than other documents. The survey was located within the Eastern Lowlands adjacent to the western boundary of the study area. Analysis of the survey line was undertaken up to, but not including, the area where the survey team encountered the limits of the Great Miramichi fire (near the Gaspereau River) (Figure 2.1). Since the fire was ignited from human causes (Ganong 1902), the regenerating forests noted from that point onward did not constitute part of the original forest condition. Alexander's observations on forest species composition within this adjacent area were compared to results on forest composition obtained for the study area. The number of times each tree species was noted by Alexander was recorded. The frequency of each species was then compared to the frequency with which other historic records noted each species.

Disturbance agents are limited to the earliest ones mentioned, (mainly fire, wind, and insects), in order to focus on those agents that shaped the evolution of original forest character. Disturbances directly associated with European settlement are mainly excluded, with the exception of fire, where there was a close connection with human activities. Examination of fire provided a better understanding of the development of current forest types and successional pathways. (Human-caused disturbances were addressed in Chapter I and Appendix 1-1.)

RESULTS

A total of 26 historical documents, mainly in the form of publications, contained relevant information on the nature and state of original forest types applicable to the study area. Most of the material focused on species composition. Forest structure and disturbance dynamics were noted less frequently. All but three documents (those of Cartier, LeClercq, and Denys) originated from the English period (1707-1900). Nine documents referred specifically to forests located within the study area. The most valuable historical contributions were from Denys (1672), Gubbins (1813, *In*: Temperley 1980), Fowler (1878; 1885), Johnston (1851), Monro (1855), and Perley (1842; 1847). A brief background on qualifications of these and other principal recorders is listed in Appendix 2-1.

One of the most unusual archival discoveries was a book made of 76 wood samples from New Brunswick collected by Alexander Monro (1862). It preserved tangible evidence of forest diversity by featuring samples of all tree and shrub species of NB, plus samples of 'black birch', and other species no longer recognized due to taxonomic changes. Another valuable record was that of James Alexander (1849). His observations provided a vivid picture of the original forest environment. Public response from newspaper articles that invited input on aspects of local historic forests was unsuccessful, producing only one return, a surveyor sketch.

Historical forest composition

Most of the species composition referred to in this section is summarized in Table 2.1. All early accounts agree that New Brunswick was completely forested, with the exception of areas of exceedingly poor drainage, such as bogs. The first explorers and settlers would have seen original growth and some of them provided brief glimpses of its characteristics. The earliest information stems from the well-known explorer, Jacques Cartier, who visited the New Brunswick coast in 1534, and French entrepreneur, Nicolas Denys (1672). Cartier was impressed with the beauty of the country (Biggar 1924). The following excerpt was translated from his journals: *"Nevertheless we went that day ashore in four places to see the goodly and sweet smelling trees that were there. We found them to be cedars, ewe trees, pines, white elms, ashes, willows, with many other sorts of trees to us unknown, but without any fruit."* (Hackluyt; *In:* Hannay 1979). The exact location described is subject to speculation. Hannay (1979) interpreted the land to be within the study area near Point Escuminac. Sobey (2002) believed that Cartier's description belongs to the west coast of PEI. Regardless of which place, both areas are contained within the same ecoregion (Maritime Lowlands) (Loucks 1962) and it therefore describes forests that grew in a climate and landscape similar to the study area. Cartier's descriptions remain a relevant and valuable record because they originate prior to the period when forests were altered by Europeans.

Bearing in mind that Cartier made his brief observations from the coastline, it is fitting that he also described what might be interpreted to be salt marshes and open coastal areas resulting from high winds and salt spray. Forest growth would have been limited in such areas. Cartier in 1534 wrote: *"The grounds where no wood is very fair and all full of peason, white and red gooseberries, strawberries, blackberries and wild corn even like unto rye, which seemeth to have been sown and ploughed. The country is of better temperature than any other that can be seen, and very hot. [ ]; to be short, there wanteth nothing but good harbors*" (Hackluyt; *In*: Hannay 1979).

There is little recorded information for over 100 years following Cartier's observations. The next record on the region's forests was from Nicolas Denys, who arrived in Acadia in 1632 and became one of the first settlers and entrepreneurs along this coastline. Denys wrote of a venture by ship towards the Bay of Chaleur in 1672 (translated to English by Ganong (1908)): *"the coast is well-nigh entirely of sand*" and *"filled with woods like the others, with the exception that the cedars are more common there*". Lands near the Cocagne River (approximately 25 km south of the study area), were recorded as flat and covered with a variety of very fine trees, most likely of old-growth, as Denys wrote that they were *"tant en grosseur qu'en hauteur*", translated, *"as well in their stoutness as in their height*" (Ganong 1908). Forests of Richibucto region were described by Denys as similar to the other areas "*intermixed with firs and pines*" (Ganong 1908). Denys' used the word 'fir' to denote three or more conifer species: red spruce, balsam fir, and most likely eastern hemlock. His descriptions of the three conifer species were unclear, and white spruce and black spruce may also have been included. Judging from his descriptions of 'fir' species, Denys likely saw a mix of pine with spruce, eastern hemlock, and perhaps balsam fir in the Richibucto area (Ganong 1908).

Several accounts depict New Brunswick forests as being more or less continuous cover:

"This province of New Brunswick, [ ] if a bird's eye view were taken of it, it would be seen that the thousandth part of it is not clear, but covered either with wood or water" (Campbell 1793).

"The surface of the earth, in its natural state, is covered with timber" (Atkinson 1844).

"*New Brunswick is a vast ocean of trees through which the compass can alone guide us*" (Alexander 1849).

"*The extensive country of NB [...] may still be considered one vast forest, for the few settlements and its scanty population are as yet confined to the sea coast, and to the lower parts of the noble rivers which everywhere intersect its undulating surface.*" (Alexander 1849).

"The whole surface of the province, in its natural state, is, with very few exceptions, covered with a dense forest of timber trees" (Perley 1863).

A reference to local forests of the study area depicts a similar forested condition:

"*The [Richibucto] River is but thinly settled as far as the head of tide, above which the whole country is in a state of wilderness*" (Perley 1842).

The simplicity of early vegetation descriptions stops with the above historical observations. While it is understood that most of the land was originally forested, attempts to describe the *composition* of early Acadian forest lends to complexity. Atkinson (1844) provided an overall portrayal of the intricate nature of New Brunswick's native forests: "*nature has disposed the growth generally in stripes, ridges, or groves- the deciduous trees, for the most part, by themselves, and changing suddenly, often with scarcely a shade of admixture, to an evergreen growth*". "*The forest cover [ ] demonstrates an alternation of deciduous, coniferous, and mixed forest communities: of climaxes and sub-climaxes: of mesophytic, hydrophytic, and xerophytic zones*".

Forests viewed most frequently by early European visitors were those situated directly on the coast, and as such were likely stunted due to the presence of salt spray, high winds, and occasional flooding. Low sandy coastlines favoured salt marsh, dunes, and coastal heaths rather than forest in many places. As Alexander Taylor (1803) travelled along the coast from Kouchibouguac northward, he wrote "*the lands are generally poor but there are great quantitys of Marsh*". From Buctouche to Richibucto Head (southern part of study area) he stated that "*the lands looked Boggy and Barron* [sic.], *but where the Rivers runs up into the country the land gets much better and makes it Beneficial both for Coast and River Settlers*". Undeniably, forests growing along river systems were in stark contrast to those viewed along the coast, receiving favourable comments by all accounts. Taylor (1803) stated that there was "*very good Timber*" in the area of Kouchibouguac and Kouchibouguacis Rivers. Likewise, he described the woodland of Buctouche, (located within the same ecoregion, only 10-15 km from the southern boundary of the study area), as having "*the largest soundest White Pine Timber of any in the country*" (Taylor 1803). Concurring with Taylor's portrayal of the Kouchibouguacis and Kouchibouguac Rivers: Large quantities of timber were cut from the Kouchibouguac River banks by 1832 "*for the Richibucto market*", but forests still contained "*considerable stock of light birch, spruce, and pine*" (Cooney 1832). The banks of the Kouchibouguac River were "*thickly covered with white and red pine, cedar, birch, and maple*", with "*extensive groves*" of larch "*of large size*" (Perley 1842). The

Kouchibouguacis River was "*well wooded with heavy birch, hemlock and maple*" (Cooney 1832).

Early comments on soil fertility, drainage and other edaphic factors impart an indication of forest composition. Johnston (1851) provided descriptions of the general landscape, soil and drainage patterns as partly interpreted from forest associations. Lands between Black River and Bay-du-Vin River were described as "*poor sandy country, with occasional patches of cold clay and [ ]peat bog*". As Johnston traveled southward to the Richibucto he remarked on "*sandy, often thin, poor, and stony soils*" and level topography. "*Good land*" existed for some distance on either side of the Kouchibouguac, Kouchibouguacis, and Aldouane rivers. "*Hardwood ridges rose now and then above the flat country*", and such areas were considered more valuable for settlements. South of the Richibucto River, the soil was of good quality for several kilometres, and then became similar to lands north of the Kouchibouguac, which he defined as "*flat, poor, pine-clad, sandy soils, except where rivulets and armlets of the sea occurred*".

Early explorers, surveyors, and those with agricultural interests commonly employed the terms: 'good land' and 'poor land'. According to Johnston (1851), good lands "*will grow all the crops suited to the climate*" and the first crop will usually pay for the entire expense of clearing the land. Lands covered in deciduous or hardwood growth were generally considered to be 'good land'. Besides rich deciduous growth, Atkinson (1844) added that cedar swamps made particularly good land for farming. Poor land, where softwoods such as larch and hemlock grow, "*does not yield good first crops*" by simply clearing and burning the trees. Additional expenditure was required in order for the land to be brought into production by hauling the stumps and ploughing (Johnston 1851). Atkinson (1844) provided similar definitions as Johnston, adding that "*land covered in spruce and pine alone*" seldom makes good farmland. Hardwood was defined as "*ash, beech, birches, maple, oak, and all the deciduous trees*" (Atkinson 1844). Softwood was "*cedar, hemlock, spruce, pine* [and] *larch*" (Atkinson 1844).

Johnston's second visit to the Richibucto area provided one of the most specific and valuable forest descriptions: "*West of the south branch of the St Nicholas River, excellent land occurred; and it continued of good quality as far as we were able to* *penetrate. The prevailing tree on this upper part of the river was hemlock, [...], mixed with some white pine, and with birch and beech. None of my companions had ever seen the hemlock so abundant in any other part of the province. From the information we received, these trees prevail over a belt of twenty to twenty-five miles wide, as far west into the wilderness as a remarkable bend of the Salmon River [...], known as the Ox-bow of the Salmon River. Many magnificent stems rose here and there among the woods through which we passed and where clearings were in progress. It struck me as almost amounting to desecration to see those ancient trees cut down while still sound and vigorous, and either condemned to the pile, or left heedlessly rotting on the ground*" (Johnston 1851). According to this, old-growth forest dominated by eastern hemlock extended westward from St Nicholas River in a 32- 40 km wide band. More comments on the abundance of old-growth hemlock pertaining to the same area were placed under specific species descriptions below.

The following is a compilation, listed by species, of all references to historic forest composition that were pertinent in either a general sense to forest character in New Brunswick, or provided insight on specific forest types in the study area.

Coniferous tree species

White pine, red pine, jack pine:

There was a wealth of historical literature on white pine, reflecting its importance as the most valued tree in the Acadian forest. It was the most remarkable due to its great height and size, "*the most majestic of all the American pines*" (Perley 1847). This species was selectively harvested in the study area in unprecedented quantities for shipmasts, square timber, deals and boards during the early to mid-1800s. Many thousands of tons of white pine timber were shipped to the United Kingdom (Hannay 1902). It was the species that drove the economy, and no other wood was used for more purposes.

Overall, white pine is concluded to have been a scattered, patchy component of NB forests (Perley 1847), that often tended to be more abundant, growing in groves, on riparian zones. White pine grew "*scattered through the mixed forests*" (Ganong n.d.), and "*scattered*" on high land (Bailey 1876). Pine growth "*seldom extend*[ed] *back from* [ ] *streams or lakes, in any quantity, further than half or three quarters of a mile*" (Bailey 1876). Pine growing "*distant from streams or lakes*" occurred "*in small groups or bunches or in pairs or solitary, a very considerable distance often intervening between groups or individuals*" (Bailey 1876). In contrast, white pine grew "*in great groves in places, especially on the eastern Carboniferous Plain*", particularly the Miramichi River system (Ganong n.d.) ('Carboniferous Plain' is a former term for the Eastern Lowlands Ecoregion). In 1825, despite extensive harvesting, white pine was still described in the study area, and including all of Northumberland County (Figure 2.1), as growing in "*immense quantities along the numerous streams and rivers with which this part of the country abounds*" (Fisher 1980). Some of the best white pine grew "*most thickly*" near streams and near lakes (Bailey 1876).

The Richibucto and Cocagne Rivers were "*best for white pine*", according to early inhabitant, Andrew Kinnear (1785), who wrote about lumber potential on certain rivers. Forests located on the Richibucto River watershed had a higher abundance of white pine than was present on some other river systems (Kinnear 1785). (The Peticodiac River, for example, had only "*a little white pine*", but a "*great plenty of elm, ash, rock-maple, spruce, and black birch*" (Kinnear 1785).) The existence of four shipbuilding industries and a thriving, albeit brief, square timber export market that relied heavily on white pine on the Richibucto River lend support to those early observations.

White pine grew on a wide variety of soil and on all drainage classes "*except* [those that] *consist wholly of sand, or such as are constantly submerged*" (Perley 1847). Best growth was achieved in "*fertile valleys*", riparian zones composed of "*deep, cool, black sand*", and also in cedar swamps (Perley 1847). White pine also grew on "*low ridges, and surrounding the heaths and bogs*" (Bailey 1876). It grew abundantly in sandy soils, but all soil types along the banks of streams supported the growth of very tall, straight white pine, interspersed with "*every variety of hardwood*" (Monro 1855).

Red pine was specifically noted only on the Kouchibouguac River (Perley 1842). Its absence elsewhere in the historical record seems to indicate that it was not common. Perley (1847) stated that extensive groves of "*sapling red pine*" were found throughout

New Brunswick. ('Sapling red pine' were immature red pine, or pine that contained a lot of sapwood (Perley 1847).) It is likely that many of the young stands of red pine resulted from recent fires caused by European activity. Nearly forty years later, Fowler (1885) listed the species as "*abundant in many places in old forests*". Presumably, Fowler viewed stands of red pine in former disturbance gaps, perhaps from increased incidences of land clearance fires and escaped fires, and that is why his record implied a patchy distribution of red pine growth within old-growth forest. Red pine grew most frequently on dry sandy soil (Perley 1847; Monro 1855). Some red pine was harvested along the St John River for masts during the French regime (Sobey 2002), but it was generally less sought than white pine due to its smaller stature and highly resinous wood (Monro 1855).

Jack pine was a "*low straggling tree springing up abundantly on dry burned barrens*" (Fowler 1878). These dry burnt barrens were specifically noted in Kent and Northumberland counties (Fowler 1885). Bailey (1876) wrote of thick forests of jack pine on the Southwest Miramichi following the Great Miramichi fire in 1825. It was abundant in 'northern Acadia' (Ganong 1908) (probably referring to the Nepisiguit area). General statements for the province, depict it as "*a mere shrub*" growing in poor sandy districts, entirely unfit for agriculture (Monro 1855). There were no earlier references to jack pine in the study area.

Red spruce, black spruce, white spruce:

Red spruce was the species of second most commercial importance, following the great white pine timber era (Ganong n.d.). It was commonly referred to as 'black spruce' in the historical literature, with no taxonomic separation from *Picea mariana* (Monro 1855; Perley 1847; 1863; Fowler 1876). Monro (1862) later identified three spruce species (red, white, and black) in his book of wood samples. Most of the historical statements on black spruce referred to red spruce; the black spruce, of smaller stature than the red spruce, and growing mainly in poorly drained areas, attracted much less utilitarian interest. Monro (1855) stated that "*black spruce*" (i.e. red and black spruce together) was the "*most common evergreen peculiar to the province*". It is fitting that he chose the expression 'peculiar to the province', as red spruce is a key component of the mixed wood forests of the Maritime provinces and New England States, constituting the main extent of its limited species range (Mosseler *et al.* 2003).

Perley (1863) stated that red spruce, (likely including both red and black spruce), was so extensive as to constitute one third of New Brunswick forests "*with which the province is so uninterruptedly covered*". New Brunswick was the best place for red spruce growth, "*nowhere is it found of larger size or finer quality*" (Perley 1863). It was "*second in height only to* [white] *pine*" (Monro 1855).

The "*finest forests*" of red spruce were "*found in valleys where the soil is black, humid, deep, and covered with a thick bed of moss*" (Perley 1847). Besides growing in groves, it formed an important constituent of mixed forests, where it attained maximum growth (Ganong n.d.). Red spruce also grew in poorer soils: stony and dry areas, with a thin bed of moss, but it did not attain the same growth (Perley 1847). Both red and black spruce were referred to as growing in "*large groves, and on a variety of soils; on the top of hills, and in the caribou plains* [i.e. bogs], *it assumes a scrubby character*" (Monro 1855). The 'scrubby' species growing on bogs was invariably black spruce. Fowler (1878) also referred to a "*scrubby form*" that grew in swamps and bogs. The later work by Ganong recognized black spruce as a separate species, stating that black spruce was a tree of smaller stature found throughout NB on boggy lands (Ganong n.d.).

White spruce grew in a much more scattered distribution than red or black spruce (Bailey 1876). It never grew in groves, according to Monro (1855), but grew to a large size, sufficient to be sawn into deals. Perhaps more appropriate to the study area: White spruce "*springs up more readily in abandoned fields and on new-formed coastal lands*" (Ganong n.d.). It was "*much less common in New Brunswick than*" red or black spruce (Perley 1847), though it had "*relatively greater abundance north of the Central Highlands*" and comprised a "*larger proportion of the spruce lumber*" shipped from the Bay of Chaleur (Ganong n.d.). Also, the species was abundant on the rocky Bay of Fundy shore, and was said to "*bid defiance to both the ocean and the storm*", attesting to high tolerance to salt spray, harsh winds and cool temperatures (Perley 1847). White spruce grew on moist fertile soils according to Monro (1855), but a later reference stated that it thrived "*in shallower and poorer soil*" than that preferred by red spruce (Ganong n.d.).

American larch:

Larch was very common throughout NB, growing on a variety of soils, but attaining best growth on ill-drained soils (Monro 1855; Munro 1862). It was found in "*great abundance along margins of lakes, rivers, meadows, swamps, and other alluvial lands*" (Monro 1855), but could also grow on the most rocky and sterile ground (Munro 1862). It attained exceptional size and was in greatest abundance in the study area (particularly the three counties of Kent, Northumberland, and Gloucester) (Perley 1847; Ganong n.d.). "*Very extensive groves of large size* [grew] *on the Kouchibouguac River*" (Perley 1842). These particular groves of larch were in much demand on the Kouchibouguac for the Cunard shipyard. According to Perley (1863), larch was the third species in demand for shipbuilding after white pine and red spruce. It was regarded as among the hardest and most durable wood, and considered of equal quality to English oak (Pierce 1845; Munro 1862).

Eastern hemlock:

More 19th century records were found for eastern hemlock than any other, and they unanimously point to its former dominance on the landscape in the study area. Most compelling is the statement that there was a massive stand of old-growth hemlock stretching for roughly 32 to 40 km east-west across the study area (Johnston 1851). Like most stand types in the Acadian forest, the stand was not entirely pure, but had minor components of white pine, birch, and beech (Johnston 1851). This huge band of hemlock-dominated forest was also noted in correspondence by botanist and Presbyterian minister, James Fowler (1873). While working in the Bass River area, he wrote to a colleague that he had "*lived so long here on the level plain of the Carboniferous region unable to see a single mile in any direction for the huge hemlocks of the forest primeval that a sight of a distant hill or the prospect of a widespread landscape would be received as a precious boon*". Fowler was a leading authority on the diversity and identification of provincial flora, and his lack of enthusiasm for the huge hemlock forests would imply that this forest type was so commonplace that it was dreary and monotonous, rather than exceptional to the region. Several decades earlier, Gubbins, while traveling by boat from Richibucto to Kouchibouguac in 1813, wrote, "*evergreens of the fir kind deepened the gloom. Amongst these the hemlock tree was very conspicuous. It grows to a great height; the timber is useful for common purposes*" (Temperley 1980). Bailey (1876) also noted that hemlock grew in abundance, north of Moncton on Crown lands along the Intercolonial railroad, where the bark harvest was quickly commencing for the tannery industry.

Hemlock grew in nearly pure stands, "*covering extensive districts in some parts of the province*" (Fowler 1878); more specifically, in Kent and Northumberland counties, "*forming large forests*" (Fowler 1885). The species grew in 'belts' (Bailey 1876), as well as a component, commonly mixed with other hardwood and softwood species. It was often mixed with sugar maple, red spruce, yellow birch, and beech (Monro 1855; Perley 1847). Perley (1847) stated, "*In NB, it forms a large proportion of the evergreen forests, and is found abundantly multiplied in every favourable situation*". It grew on "*almost every variety of soil*" (Bailey 1876). Likewise, Johnston (1851) stated that its presence "*was not indicative of any* [particular] *quality of soil*". Monro (1855) wrote that it grew best on moist heavy soil.

The distribution of eastern hemlock throughout the province was "*somewhat singular*" (Johnston 1851), meaning that its occurrence in such abundance was almost unique to this region. It was much less common on the St John River above Grand Falls, and also north of Belledune on the east coast, though suitable soils existed with equally mild climates north of these areas (Johnston 1851). Perley (1847) noted "*a very considerable tract of level land; rather dry and sandy, almost exclusively covered with large trees of the hemlock spruce, and [ ] beech, on the banks of the Tabusintac River, in Northumberland County*".

An official hemlock bark survey conducted by William Fish (1880) on 3000 acres of Crown land bordering the western boundary of the study area revealed that "*the principal growth of wood to be found on the lands now surveyed is hemlock, though scattered through it in all cases are to be found spruce and pine, as also the different hardwoods*". The hardwoods were described as beech, maple and birch. The distribution of hemlock on what was evidently a relatively poorly drained landscape, was as follows: "*hemlock lands lie on the tops and sides of low and irregular shaped* *ridges, surrounded in nearly every instance by extensive heath or barren country*". The irregularity of the landscape evidently caused Fish some difficulty in marking off survey blocks with straight parallel lines that would include the hemlock stands in their entirety yet exclude as much as possible the adjacent heath lands. He presented estimated quantities of hemlock bark per acre, as well as merchantable spruce and pine for each of 13 lots he had surveyed. (While a map was found at PANB that appeared to match the survey area, the numbering of the lots did not correspond with the table and therefore, regretfully, spatial analysis could not be carried out.) Estimates of hemlock bark ranged from 3 to 6 cords per acre (26.9 – 53.7 m^3/ha), with an average of 4 cords per acre (35.8 m^3/ha). Pringle (1884) estimated that 4 hemlock trees were required per cord of bark (Pringle 1884 *In*: Whitney 1994). Therefore, an average of 16 hemlock trees per acre were required for roughly 3.6 m^3 of bark (or 40 hemlock stems per hectare). It is certain that other areas would have yielded a higher hemlock component than the above described mixed hemlock forests that were growing among barren heath lands. Some areas in the US yielded 10 cords of hemlock bark per acre, (89.5 m^3/ha), presumably from pure stands (Walsh 1896 *In*: Whitney 1994).

Some anecdotal evidence of eastern hemlock abundance exists for the study area. Eastern hemlock was well known to the local Mi'kmaq. Gubbins (1813) wrote in his journal, while traveling through the study area, that the Mi'kmaq relied upon this tree for orientation through the landscape when the sun was not available. "*They ascertain their course through the woods in fine weather by the sun and when that is not visible the top branches of the hemlock tree, which always point to the south, is in this part of America their only resource. The Indians have often told me that, where this tree does not abound, they are as liable to lose themselves as we should be without a compass*" (Temperley 1980).

Eastern white cedar:

Only one early historical description directly refers to eastern cedar in the study area. Perley (1842) described it growing on the banks of the Kouchibouguac, along with several other species. Less specifically, cedar "*abounds throughout New Brunswick*" (Perley 1863). "*There are large groves of this species in many parts of the province*"

(Monro 1855). It occurs "*almost always in wet ground*" and "*frequently occupies exclusively, or in great part, swamps from fifty to one hundred acres in extent, some of which are accessible only in winter*" (Perley 1863). While such cedar swamps were where the cedar grew "*thickest*", "*forming for short distances dense forests*", it was "*met with everywhere in low grounds and swales, but especially where the soil is clayey and the drainage imperfect*" (Bailey 1876). Eastern cedar also occurred on "*rocky edges of the innumerable streams and small lakes scattered over New Brunswick*" (Perley 1847). It has an affinity for limestone, which is a common occurrence in the St John area (Ganong n.d.).

As for the composition of eastern cedar stands: "*It abounds exactly in proportion to the degree of humidity, and in the driest marshes it is mingled with the black spruce, hemlock* [ ], *the yellow birch, the black ash, and a few stocks of white pine*" (Perley 1847). In such swamps, the surface was covered with a thick bed of sphagnum (Perley 1847).

Cooney (1832) mentioned that branches "*invariably grow on the south side of the tree, leaving the north side almost totally bare, a peculiarity, which serves the Indians for a compass*".

Given the prevalence of imperfectly drained soils in the study area, eastern white cedar can be deduced to have grown in large quantities there, as it does today.

Balsam fir:

No historical descriptions were found regarding the early abundances and distributions of balsam fir in the study area. General descriptions for the province were ambiguous, though they indicate that it did not comprise a large volume of early forest composition. "*In New Brunswick it does not constitute masses of wood, but is disseminated, in greater or less abundance, among the hemlock and black spruces*" (Perley 1847). It was "*a common tree* [ ], *being found in nearly all localities, but in greatest abundance* [ ] *on the head waters of the St John and Restigouche rivers*" (Bailey 1876). Monro (1855) stated that fir was "*very plentiful throughout the province*", but indicated that it became more plentiful following land clearances: "*it often happens that land formerly covered with hard-wood, when allowed to relapse into* *forest, produces fir in great abundance*". By the early 1900s, balsam fir was believed to be the "*commonest*" conifer in NB (Ganong n.d.). Its resin was well known for its medicinal uses as 'Canada balsam' (Perley 1847; Bailey 1876) and its boughs made a comfortable camp bed (Perley 1847; Alexander 1849). Its wood was "*undervalued*", given "*the great abundance and cheapness of white pine and spruce*" (Perley 1847; 1863).

Broad-leaved tree species

Yellow birch, (black birch), white birch, grey birch:

Interpretation of historical notes on birch was challenging due to early taxonomic designations, and the enigma concerning black birch. The earliest descriptions of birch were from Nicolas Denys (1672) and Patrick Campbell (1793). Denys (1672) identified only two species of birch, black birch (mignogon) and white birch (bouleau). Given that he did not mention yellow birch, which should have been quite common, the species was evidently included as 'black birch'. Campbell stated that black birch was abundant. There was "*as much black birch in Nova Scotia and New Brunswick [ ] as would supply all the dock yards in Europe with ship timber, for 100 years, if not for ever*" (Campbell (1793). Entire vessels were built of it (Denys 1672).

All key recorders during the 19th century, Monro (1855; 1862), Perley (1847; 1863), Munro (1862), Bailey (1876), and Fowler (1878; 1885) identified at least four species of birch: (1) yellow birch, (2) black birch, (3) white and (4) grey birch. (*B. pumula*, and *B. glandulosa*, low shrub birches, were also mentioned by some authors (Bailey 1876; Fowler 1878; 1885; Ganong n.d.). Botanists, Cochran, and Michaux, Sr. and Jr., identified black birch in the Maritimes as *B. lenta* (Perley 1847), while yellow birch was called *B. lutea* (Perley 1847; Fowler 1878) or *B. excelsa* (Monro 1862). Did black birch (*B. lenta*) historically grow in NB? Lack of herbarium specimens does not lend support for its reported presence. Yet some of the historical descriptions are compelling, and they are examined in more detail below. It was treated as a separate species here, in keeping with 19th century records.

Black birch was common (Fowler 1878; 1885), growing in similar distribution and abundances as yellow birch (Monro 1855; Bailey 1876; Ganong n.d.). It grew preferentially in deep, loose, moist soils (Perley 1847, 1863; Monro 1855; Fowler 1878). It was "*especially common on the deep and shady banks of rivers*" (Bailey 1876).

Yellow birch was very common in New Brunswick (Perley 1847). "*Yellow birch is always found on cool and rich soils, with ash, hemlock spruce* [i.e. eastern hemlock], *and black spruce* [i.e. red spruce and perhaps black spruce]" (Perley 1847). The species was "*usually found mingled with ash and fir*" (Monro 1855), while Bailey (1876) noted it mixed with "*spruce and ash*". Both black and yellow birch grew in the same habitat and had roughly the same distributions and soil requirements throughout New Brunswick. They were "*almost always found in deep, loose, and wet soils, where they attained greatest size*" (Perley 1863). Monro (1855), too, stated that it was found in the greatest abundances on deep alluvial soil, and its presence always indicated good land.

There were no clear records of abundances and distributions of white birch at the time of early settlement in the study area, but by 1876, it was common in all areas of New Brunswick (Bailey 1876). Generally, it grew on "*poor dry soils*", but was found on more fertile soils along the coast of Northumberland Strait and near the rivers that empty into the strait (Monro 1855). Fowler (1878) supported the Northumberland Strait observations, and later made a general statement for the province, that it was "*common in rich soil everywhere*" (Fowler 1885). It grew in large groves, "*interspersed with spruce, fir, pine and others of the same class*" (Monro 1855). It grew best on "*the declivity of hills and in the bottom of fertile valleys*" (Perley 1847). Both Perley (1847) and Monro (1855) provided interesting details on the numerous uses of birch bark by the First Nations of NB, including its use to wrap the deceased (Monro 1855) (though spruce bark was also used for this purpose (Adams 1873)). White birch held much less utilitarian value to Europeans, as it decayed quickly when exposed to wet and dry conditions, and it produced less heat than maple as firewood (Perley 1847).

Grey birch was "*less abundant than the other species of the birch tribe*" (Perley 1847). (Early authors commonly referred to grey birch as white birch. See Appendix 2-2.) Denys (1672) did not mention this species, but may have included it with white birch. Alternatively, he may not have seen it frequently, due to its early-successional status, or perhaps he simply regarded it as a shrub rather than a tree. From 19th century descriptions, the early-successional role of grey birch is evident. It was "*generally associated with the aspen or poplar*", and was "*seen by the side of highways growing singly on burnt land, or sandy soils which have been exhausted by cultivation, or which are too poor to produce crops*" (Perley 1847). The species was "*most frequently found in places scantily furnished with trees,* [ ] *where the soil is dry and meager*" (Perley 1847). More applicable to the study area, Bailey (1876) stated that it was especially common near the coast and upon the poorer classes of soils. While it was said to rarely grow in groups (Perley 1847), its abundance almost 30 years later was reported to occur in "*large groves associated with spruce, pine, or other softwood trees* (Bailey 1876). (Later observations likely reflect greater forest disturbance.)

American beech:

"*The beech is one of the most majestic trees of the forest*" (Perley 1847), and was widespread and abundant throughout New Brunswick (Monro 1855; Perley 1863), except on the "*southern coast*" (Bailey 1876). In some parts of NB, beech was "*so abundant as to constitute extensive forests*" (Perley 1863).

Beech grew on a variety of sites, growing best on fertile "*deep, moist soil*" (Perley 1847), or on "*level or gently sloping lands*" suitable for growing grain (Perley 1847; 1863). It often formed large groves on "*ridges of fertile uplands*" (Ganong n.d.), but likewise was commonly found on "*poor soils inferior for agriculture*" (Monro 1855). It was growing throughout a large band of hemlock forest reported on the Richibucto River watershed (Johnston 1851). Lands on the Molus River were described as particularly fertile, and were "*covered with beech, birch and maple of large size*" (Perley 1842). There were likely many other areas with very similar forest cover. The Molus River was mentioned only because it was part of the Elsipogtog (formerly Big Cove) Reserve, which Perley was assessing as part of his responsibility as Indian agent. Of note is the number of times beech was mentioned in the historical record. Nearly every description of hardwood stand listed beech as a key dominant species.

Two and sometimes three species of beech were identified during early colonial times (Perley 1847; 1863; Monro 1855; 1862; Bailey 1876). (See Appendix 2-2.) Samples of white beech (*F. sylvatica*) and red beech (*Fagus feruginea*) are included in the book of wood samples (Monro 1862). Bailey (1876) and Ganong (n.d.) recognized, however, that they were all varieties of the same species, "*the differences depending [ ] simply on the greater or less rapidity of maturation, and the consequent different proportion of the (white) sap wood or (red) heart wood*" (Bailey 1876).

Of ecological importance (a factor rarely noted during this time period), the nuts of beech are "*oily and nutritious and afford a large portion of the nourishment of various wild animals*" (Bailey 1876). Bears, partridges, squirrels, and mice feed on the beechnuts (Perley 1863; Bailey 1876). Early settlers commonly allowed hogs to free range through the forest, and they could "*fatten rapidly on these nuts*" (Perley 1863).

Red oak:

Red oak was recorded as "*rather common*" in Kent and Northumberland counties (Fowler 1885). Cooney (1832) provided the earliest record of red oak, stating that it "*generally grew on high land; but it is very scarce*". It grew best on "*deep alluvial soils, similar to those producing* [sugar] *maple*", with which it was frequently interspersed (Monro 1855). Its presence was used to indicate good soil suitable for farming (Monro 1855). Perley (1847; 1863) did not give any details on the soil preferences or abundances of the species. Its wood was used in shipbuilding and for agricultural implements (Monro 1855), but was of "*inferior value, it being difficult to season*" (Bailey 1876).

White ash and black ash:

White ash was common in Kent County (Figure 2.1) (Fowler 1885), and generally "*abounds in New Brunswick*" (Perley 1847; 1863). Denys (1672) stated that, "*some very fine and straight ones are seen*" on the Gulf coast. It grew best where soils were deep, moist, and fertile (Cooney 1832; Perley 1847; Monro 1855), though it could be found on almost any variety of soil throughout NB (Bailey 1876). Superior habitat was on riverbanks and edges of swamps where it obtained adequate moisture (Perley

1863; Bailey 1876). Though it was sometimes found in swamps, this was "*inferior habitat*" (Monro 1855). White ash did not grow in pure stands, but grew "*scattered*" through the groves of sugar maple, elm, and oak (Monro 1855). Perley (1847) described a similar species association, stating, "*white ash is almost always accompanied by white elm, yellow birch, white maple, and hemlock, and black spruce*". It grew to the north of the study area with elm on the Miramichi River, "*especially towards their sources*" (Cooney 1832).

Black ash grew in fertile, moist soils (Perley 1847; Monro 1855) that were exposed to longer periods of flooding than white ash (Perley 1847). It was "*confined to swamps and the muddy banks of rivers*" (Bailey 1876). It was usually associated with red maple, yellow birch, black spruce, and eastern white cedar (Perley 1847). Monro (1855) provided some excellent notes on black ash, but the taxonomy is inconsistent and difficult to follow as he also described a third species, 'yellow ash', and then later introduced 'swamp ash' (*Fraxinus juglandifolia*) (Monro 1862). Black ash was used by the Mi'kmaq and Maliceet for making baskets as a result of easy separation of its annual rings through pounding (Perley 1847; Monro 1855; Bailey 1876). Again, it is assumed that black ash grew in the study area in appropriate habitat, but pertinent historical descriptions were lacking.

Sugar maple, red maple, mountain maple, striped maple, silver maple:

All references concur that sugar maple was a common upland tree throughout NB and grew to large sizes (Perley 1847; 1863; Campbell 1793; Monro 1855; 1862; Bailey 1876). It was in "*great abundance throughout the province*" (Monro 1855). "*It enters largely into the composition of the forests*" of New Brunswick (Perley 1863). "*They generally cluster in large groves*" (Cooney 1832). It was less common "*directly along the sea board*" (Bailey 1876). There are few direct references to its distribution or abundance in the study area, owing partly to the use of the general term, 'maple', with no identification of species. For example, Perley (1842) recorded "*maple of large size*" mixed with beech and birch on the Molus River. While it might be presumed he was referring to sugar maple, red maple is also possible. Johnston, during his second voyage through the region, wrote that the English of this area did not manufacture much sugar from this tree unlike settlers in other parts of the province (Johnston 1851). Nonetheless, maple sugar production in St Louis during 1861 reached 5 470 lbs (Daigle 1948).

Perley (1863) stated that "*maples are generally found on a free, deep, and loamy soil, rich rather than sterile, and neither wet nor very dry*". Soils most suitable to healthy growth were the "*alluvial meadowlands along the margins of rivers*" and slopes (Monro 1855). "*The natural habitat of the sugar maple is the steep and shady banks of rivers, and elevated situations, where the soil is cold and humid, free, deep, and fertile, and not surcharged with moisture*" (Perley 1847).

Red maple was "*very common in swampy or damp woods*" (Fowler 1878). The species grew "*on the borders of creeks, but chiefly in swamps which are frequently inundated, and always miry, and there only it attains its full dimensions*" (Perley 1847). Monro (1855) and Bailey (1876) similarly stated the preference of red maple for moist or wet areas. From this information, it is likely that red maple flourished in the study area, as optimal edaphic conditions would have been met along the numerous rivers and creeks, and large expanses of poorly drained areas. Atkinson (1844), while reporting on the effects of fire in the province, mentioned that a "*bastard species of maple*", amongst a mix of other species, often succeeds hardwoods after fire. If the words of Atkinson are accurately interpreted, this species was likely red maple, which adapts well to disturbance, and might be regarded by some as a weed species.

Mountain maple was a "*shrubby species*" (Bailey 1876), "*with a single straight slender stem*" (Perley 1847). It was "*abundant in New Brunswick*" (Perley 1847); "*common in damp woods* (Fowler 1878). It preferred "*the declivities of mountains, exposed to the north, and [ ] cool, moist, and shady situations, on the abrupt and rocky banks of torrents and rivers*" (Perley 1847). It "*usually grows in clumps in rocky but somewhat moist situations*" (Bailey 1876). Given its small stature it would not have factored substantially in early forest composition.

Striped maple (or moose maple) was common in Kent County (Fowler 1885), growing in rich woods (Fowler 1878). It did not grow in groves, but was "*generally interspersed through the forest*" (Monro 1855). Perley (1847) offered a more visual portrayal of its ecology: "*In New Brunswick it is found most vigorous in what is called a* *'mixed growth', where the woods are composed of sugar maple, beech, birch, and hemlock. In these forests it constitutes a great part of the undergrowth*". "*In the primitive forests* [ ] *it grows beneath a canopy of impervious shade*" (Perley 1847). The species acquired the name 'moosewood' because bark and branches were a food source for moose (*Alces alces* L.) during winter and early spring (Perley 1847; Bailey 1876). Attesting to its widespread abundance, early settlers also used it as forage for their livestock when fodder was exhausted (Perley 1847). Striped maple was likely a common understory species of forests in the study area, growing under shade of mature hardwood or mixed wood.

Silver maple did not grow in the study area according to Fowler (1878), who stated that the only wild specimens he had seen were on the Kennebecasis River.

American elm:

This "*stately*" tree was "*highly ornamental*" (Monro 1855). Soils of alluvial origin, commonly referred to as 'intervales', were "*generally overspread with a growth of elm, maple, birch and a few thrifty spruces and firs*" (Atkinson 1844). In New Brunswick, it grew best on "*intervale lands, along the banks of rivers or streams, or on the borders of swamps*", where the soil is "*deep and fertile*" (Perley 1847; 1863). No specific mention of elms was uncovered in the study area, but Fowler (1878; 1885) recorded it generally as common. Had it been rare or absent in the study area, (where he also lived), he would most likely have specified its distribution as he had done with other species, such as silver maple or black cherry. There were "*magnificent American elms skirting* [the] *banks*" of the Northwest Branch of the Miramichi (Johnston 1851). Cooney (1832) also mentioned that elms were very plentiful on the Miramichi, especially near the "*sources*" of the river. From this, it is theorized that elm was probably also common along the riverbanks within the study area, particularly on tributaries in more inland situations, similar to the situation described by Cooney (1832). There were also records of elm growing in more upland situations (called red elm by Perley (1863). Though elm was "*comparatively rare*" on uplands (Bailey 1876), it was capable of growing "*on any soil that was not too dry and barren, and in any situation within its natural limits*", regardless of exposure (Perley 1847).

Trembling aspen, largetooth aspen, balsam poplar:

There were few records of aspen species in the historical literature. Taxonomic separation of three species had not even been satisfactorily determined in the early to mid-1800s (Perley 1847). Perley (1847) commented, "*poplar has not yet been much noticed in this province*", partly due to the low value placed on its wood properties. It may also have been due to relatively small amounts of it growing in the province prior to land clearance activities and other disturbances. "*It generally grows in low lands, and where the original wood has been removed by fire*" (Cooney 1832). Atkinson (1844) stated that prior to fire in NB woodlands, "*neither a poplar nor a cherry might have been seen for an immense distanc*e".

Trembling aspen was not plentiful during the early to mid-1800s (Monro 1855; Munro 1862), however, Fowler (1885) stated that it was "*a common forest tree*". Nothing was written on its abundances, distribution, or ecological requirements by any authors.

Largetooth aspen was "*somewhat larger*" than trembling aspen, "*but less common*" (Bailey 1876). Alternatively, it was described as " *rather common*" (Fowler 1885), and "*very abundant throughout the province*" (Monro 1855). This tree grew on a variety of soils and drainage classes (Perley 1847; Monro 1855). On dry less fertile soils, this species grew mixed with spruce and white birch. On moist, more fertile soils, it was found with "*black ash, alder, and a low shrubbery*" (Monro 1855). "*The largest and best specimens [ ], as yet seen, were found on the banks of the River Miramichi*" (Perley 1847). The Acadian French inhabitants of the New Brunswick north coast, "*use the wood for their sabots, or wooden shoes*" and a variety of other domestic purposes (Perley 1847). Perley (1847; 1863) recognized only two species, trembling aspen (i.e. 'American aspen') and balsam poplar. Though he acknowledged that a third species possibly existed, it was believed that largetooth aspen was simply a variety of trembling aspen. Had largetooth aspen been as widespread as it is today, Perley might have been more familiar with its distinctness, as his knowledge of all other species was very thorough.

Balsam poplar was uncommon during the early to mid-1800s (Monro 1855; Bailey 1876; Fowler 1878; 1885), but it was recorded on the Kouchibouguac and Bass Rivers (Fowler 1885). It grew in groves on all soils types (Perley 1847), but Fowler (1878) limits its distribution to "*borders of rivers and swamps*". It was abundant on "*rich alluvial lands*" of the banks of some rivers (Perley 1847). It was found farther north, of large size on the Miramichi and Restigouche Rivers (Cooney 1832; Perley 1847).

Ironwood:

Ironwood was "rather rare", but was recorded at Bass River within the study area (Fowler 1885). In more general descriptions, it was "*scattered sparingly*" (Ganong n.d.) throughout New Brunswick forests, though to a lesser degree than in its southern range (Perley 1847; 1863; Bailey 1876). It was, "*loosely disseminated*", never growing in large groves. It preferred cool, shaded areas with fertile soil, though it was capable of growing in almost every type of soil, "*except in places that are too long inundated, or which are absolutely sterile*" (Perley 1847). Alternatively, Monro (1855) stated "*hornbeam* [ironwood] *requires a rich, deep soil, similar to that producing the white ash, rock maple and oak*". Similarly, Fowler (1878) stated that it grew in "*rich woods*". Perley (1847) regarded it as "*a large shrub*" rather than a tree. The wood is "*exceedingly hard and tough*" (Perley 1863), and despite the species' small dimensions, its wood was in great demand by farmers for axe handles, agricultural tools, and other instruments that required great strength (Perley 1847).

Other minor trees and shrubs:

Monro (1855; 1862), Perley (1847), Bailey (1876), and Fowler (1878; 1885) provided details on other minor trees and shrubs. Fowler (1878) included lists of mosses, liverworts, lichens, and fungi, many of which were collected directly within the study area. However, there were few details on abundances and distributions of such species to aid in characterising the forest primeval. Some species specifically noted to grow in the study area were: witch hazel (*Hamamelis virginiana* L.), though not abundantly (Bailey 1876), ground hemlock (*Taxus canadensis* Marsh.) was "*common in*

Kent" county (Fowler 1885), and sweet fern (*Comptonia peregrina* L.), grew on sandy soils in the Richibucto area; (Aylesford, NS was the only other place it was recorded) (Johnston 1851). *B. pumula* L. was recorded in swamps and bogs of Richibucto (Fowler 1885). Specimens of all these species of shrubs and trees were preserved by Monro (1862), and also in various herbaria.

Species absent from historical descriptions:

There were several tree species that were absent from historical records that may potentially have been in the area, as they have been recorded elsewhere in New Brunswick. According to historical descriptions, black cherry (*Prunus serotina* Ehrh.) did not grow in the study area, but there was a population close by on the Oxbow of Salmon River (Fowler 1878). Butternut (*Juglans cinerea* L.), silver maple, and basswood (*Tilia americana* L.) were not recorded for the study area.

Species composition noted by James Alexander on the Eastern Lowlands

The overland transect made by Alexander in 1844 was the only 19th century record that allowed a glimpse of woodlands near the study area on a similar landscape away from riparian and coastal viewscapes. The transect cut through the forest by the survey team is depicted in Figure 2.1. Species composition was listed in Table 2.2, and summarized in Table 2.3 from most common to least frequently recorded species, and it corroborated the records summarized in previous sections (Table 2.1). Eastern hemlock and spruce were the most abundant species. Maple, birch, and pine were common. Beech was the third most commonly recorded hardwood species. Balsam fir was very frequently recorded, but there was a bias introduced as a result of its utilitarian function. Fir boughs were sought for making comfortable camp beds. It was not recorded growing in stands as were the other species.

Historical Forest Structure and Age Classes

The earliest information on forest structure and stand ages originates from Denys (1672), as translated to English by Ganong (1908). The Mi'kmaq had informed him that on "*the upper parts of these rivers the lands are fine and flat, that the trees are fine,* *large, and in open formation, and that there are no little trees which hinder them in the hunting of the Moose*". (The rivers referred to were apparently those that flow into the Miramichi.) Denys later verified the Mi'kmaq accounts, and indeed, inland forests and those on the upper parts of rivers featured trees that were "*much more beautiful in height and thickness, and stand more open and less confused. One could chase there a moose on horseback. Only the old trees which are fallen in one place and another could offer any hindrance*" (Denys 1672). Ganong (1908) added a footnote that "*this account of the Acadian woods is incorrect*". There are "*only in a few limited areas, especially in occasional pine or hardwood groves, that* [ ] *are open; elsewhere they are dense, obstructed, and practically impassable for horses*". Ganong was adding his observations over 230 years later, long after the forests viewed by Denys had been logged and large areas had burned repeatedly. Nonetheless, Ganong was quite convinced that the nature of early forest structure obstructed travel: "*New Brunswick was originally densely forested, with a forest of such a close tangled character as to be penetrable only with much labour*" (Ganong 1904).

With the exception of forest growth in burned areas (that became more common in mid-1800), there were only two early references to small trees. In swamps, "*there are a great many Firs, but small and very dense*" (Denys 1672 *In*: Ganong 1908). The coast from Miramichi Bay south to Shediac Island "*is thinly covered with small pine, spruce, and fir*" (Cooney 1832). Arguably, the trees may have appeared smaller since the low sandy coastline required ships to sail far at sea and forests were thus viewed from afar.

All other historical records unanimously report that 17th to 19th century NB forests were composed of trees of large structure and old age classes. Specific references for the study area highlight large hemlocks, and also spruce, beech, larch, pine, maple, and birch. Johnston (1851), while viewing the great hemlock forest on the upper reaches of the Richibucto River, referred to the hemlock trees as "*ancient*", and commented on the "m*any magnificent stems*" that were "*still sound and vigorous*" (full quote is located on page 30). Fowler (1873) also spoke of "*huge hemlocks of the forest primeval*" on the Bass River. The term 'primeval' implies old growth. Cooney (1832) recorded "*heavy birch, hemlock and maple*" on the Kouchibouguacis River.

Beech woods were composed of large trees. Denys (1672) spoke of beech woods (*"haistres"*) in his referral to open forests of large tall trees, stating that beech is both large in height and thickness, from which galley oars of 40-50 ft (12-15 m) in length could be made. Beech trees, as well as birch and maple were of *"large size"* on the Molus River (Perley 1842).

Table 2.4 summarizes specific structural comments provided by principal recorders. Qualifiers were added wherever possible to assist in clarifying original comments by authors, as some authors quoted average sizes attained by certain species, while many described maximum growth. Provincial Forest Development Survey data indicate that the great sizes quoted for such species as white pine, red spruce and eastern hemlock are no longer observed in forests of eastern NB today.

Common usage of the term, 'timber' provided another indicator that local forests were generally composed of large size classes. Moses Perley (1863) in his attempts to describe New Brunswick forests in their "*natural state*", stated that the province, "*with very few exceptions*", was "*covered with a dense forest of timber trees*". What was the general application of the term "timber"? "Timber" during the early to mid-1800s was generally used for ton timber or saw logs. None of the early records referred to smaller wood products as timber. Only large sized trees were cut for masts, square timber (see Chapter 4), and the sawmill industry. Size requirements for spruce deals in 1863 (one of the largest exports by that time) were a uniform 3 inches (7.6 cm) thick, and a minimum of 12 feet (3.7 m) in length, and nine inches (23 cm) wide. The most usual dimensions were 9 and 11 inches in width (23 and 28 cm wide), and lengths of 12, 14, 16, 18, 19, and 21 feet (3.7, 4.3, 4.9, 5.5, 5.8, and 6.4 m, respectively) (Perley1863). Early-successional or young forests would not meet the dimensions, nor high quality for "timber trees" of the time.

Alexander (1849) provided a vivid picture of forest structure, beyond mere statements of size. Table 2.5 summarizes his observations of forest structure, with some interesting applications. Some logs were large enough to hollow into washtubs for clothes washing. An unequivocal demonstration of large forest structure was the use of "*forest wells*", or depressions created from large uprootings. Very large trees are required to make such large hummock-hollow terrain features, substantial enough to hold fresh drinking water, and remarkable enough to influence choice of campsites. *"We sometimes made our camp beside a forest well, the hollow formed by the upturned root of a large tree",* [ ] *which the roots flung themselves aloft like the trunks of elephants"* (Alexander 1849).

According to Alexander (1849), there was often little understory to impede walking in Eastern Lowland forests, with the exception of large fallen logs that required them to climb over, and the occasional entanglement with striped maple and *Viburnum lantanoides* Michx. (inferred from his descriptions). This record concurred with Denys' description of inland forests (Denys 1672).

Stand ages:

Exact figures on historical stand ages were rarely recorded. Johnston (1851) referred to the hemlock forest between the St Nicholas and Salmon Rivers as "*ancient*". Old-growth forests, with multiple age classes were common on the Eastern Lowlands according to Alexander (1849): "*primeval forests, which have been growing up since the deluge, decaying and renewed, entangled with prostrate trees and young and middle-aged growth of timber…*" (Table 2.5). Hemlocks, 300 years old were noted in two areas along his travels. Linnaeus stated that larch was capable of a 400-year lifespan (Perley 1847); but an even greater number of annual rings were counted from large larch trees within the province, and so "*they would seem to attain even a greater age in New Brunswick*" (Perley 1847).

Archived records indicated that a survey was conducted to determine forest age in various areas of NB in 1919 (Gorham n.d.), but actual figures were not found despite extensive research effort. What is known from that survey is that there were still many areas "*where trees more than 300 years old could be found*" outside the burned areas of the Great Miramichi fire of 1825 (Gorham n.d.). (The Great Miramichi fire is believed to have missed the study area, but Gorham's descriptions probably came from forests in close proximity to the study area.) "*Hemlocks, maples and birches*" were the principal trees of this age class, with "*giant pines* [ ] *only found in the more inaccessible parts of the province*" (Gorham n.d.).

Johnston (1851) stated that it would take many years to replace "*the old forest trees consumed*" from the Great Miramichi fire, thus implying that most of the burnt forest was old-growth. A Miramichi lumberman affirmed that spruce "*does not make logs fit to cut much under 100 years, and I have counted 265 rings on a* [red] *spruce*" (Ganong 1906b). From shipping records, we know red spruce to be one of the largest and most valuable exports by 1863, and only large-sized spruce were worth shipping. Therefore, they must have attained old age. Pine was not considered to be mature until 150 years old (Grant 1882).

Shade:

At least two authors referred to the deep shade of the local forests, associated with the closed canopy structure of large trees. Gubbins spoke of conifer growth that *"deepened the gloom"*, while visiting the Richibucto-Kouchibouguac area in 1813 (Temperley 1980). *"Sometimes* [ ] *I ascended large trees to look out. The prospect was everywhere the same. To the far horizon wide diffused; A boundless deep immensity of shade"* (Alexander 1849). (James Alexander recorded this statement after viewing the landscape from the top of a white pine, some 30 km south of the study area.) He made six separate references to shade as he wrote of his observations of NB forests. Upon finally sighting the Miramichi River, Alexander expressed that the *"sight was a very cheering one, after toiling so long in the shade"*.

Understory vegetation would have been necessarily limited to very shade-tolerant species. This would account for the frequent comments on 'moosewood' (Perley 1847; Alexander 1849), a species well adapted to survival in heavy shade conditions (Gabriel and Walters 1990). As forage for livestock became exhausted at the end of winter, the buds and shoots of this species provided a welcome food source. Horses and cattle were turned loose in the forest to browse on the species (Perley 1847). There was evidently little else to browse upon in the forest undergrowth. Some historical stand types had particularly open understories, such as beech. No *"verdure"* is found under the shade of beech trees, as the canopy typically grows closed, creating a highly shady environment (Perley 1847).

Forest disturbance dynamics

Defining principal former disturbance agents that operated in the study area helps explain the origins of pre-European settlement forests. Frequent records of large, scattered fallen logs throughout a shaded forest of large trees indicated that gap replacement dynamics predominated over much of the forest *ca.* 1800. Alexander made five separate references to large prostrate trees along the survey from Moncton to Gaspereau River (Table 2.5). Trees appeared to have most often died singly or in small groups. No large exposed areas were encountered with the exception of water bodies, bogs, and the area burned by the Great Miramichi Fire.

Each historical record pertaining to agents that drove change in the forest *ca.* 1800 was categorized and documented in this section. Historical records on soil impacts and successional responses from fire were also included.

Wind, flooding, drought:

There was only one recorded 19th century wind disturbance event that is believed to have affected forests of the study area: the Saxby Gale (Oct. 1869). Its effects were not quantified, except to state that the gale, together with the previous Great Miramichi Fire (1825), "*have done many millions of dollars damage to the pine lands of New Brunswick, and the day is not very far distant when pine trees of any size will be obtained with difficulty in the province*" (Bailey 1876). There were no records on frequency of individual uprootings from high winds, but there were general comments that are probably representative of forests throughout the province: "*Every high wind throws over numberless trees, often of large size, and some of these are sure to fall across the roads…*" (Johnston 1851).

No historical records on flooding in the study area were found, though there are probably some to be uncovered. With several large rivers flowing through low topography, occasional flooding from heavy rains, spring run-off, and ice jams probably played a key disturbance role in riparian forests. Flooding on the low coastal areas during very high tides, coupled with storm surges, would have caused considerable die-off due to salt water in coastal forests. The role of forests as a stabilizer against flooding was noted somewhat early on: Forests perform other "*important duties in protecting the* *surface of the ground and in regulating and maintaining the flow of rivers*"… "*they insure* [sic.] *constant flow*", and "*diminish the danger of destructive floods*" (Sargent 1884).

Dry periods and droughts were recorded periodically in the records. According to historical descriptions, there were significant droughts in 1825, 1840 (Perley 1842), and again during the late 1840s (Johnston 1851). This is by no means a thorough documentation of all 19th century droughts, but indicates that periodic droughts occurred during this period. The link between drought and forest fire was frequently noted (Perley 1842; Atkinson 1844; Johnston 1851), though the majority of drought-associated fire ignitions were human-caused. Therefore, drought-associated impacts on forests prior to European interventions have not yet been ascertained.

Animals:

Some animal species (excluding insects and other arthropods, which are partially covered in the next section) have acted as important disturbance agents, affecting the death and renewal of trees within the Acadian forest. Only those species addressed in the historical record were included, although other species undoubtedly also acted as disturbance agents. Possibly, one of the most powerful disturbance agents in the local forests was the beaver (*Castor canadensis* Kuhl), whose activities resulted in periodic flooding of large areas of forest: "*In every instance that has come under the author's personal observation, [ ], he believes [ ] these meadows have been formed by beaver dams; and they are the only vestiges now remaining in Nova-Scotia of an animal that once existed there in great numbers*" (Weale 1858). A strategically placed beaver dam on the exceedingly flat landscape of the study area floods vast areas. Eventual abandonment of the area by beavers, followed by dam break-up, results in formation of new meadows and eventual reforestation. The early fur trade drastically lowered beaver numbers, which in turn, altered this disturbance dynamic.

With the advent of European settlement, extinctions or severe reductions of some animal species, such as caribou (*Rangifer tarandus* L.) and passenger pigeons (*Ectopistes migratorius* L.), and introductions of others, particularly white-tailed deer (*Odocoileus virginianus* Boddaert), altered disturbance dynamics either directly or indirectly. In the year, 1899, a map, "*Big Game and Fish Map of the province of New Brunswick*" (PANB, RS656/5, no. 60-24, Boundary Plans), indicated that much of the province supported caribou and moose populations. Specifically, the map showed that the study area was "*fair moose ground*", and "*excellent caribou country*" was located on adjacent lands to the west and north of the Miramichi. Since the map was published approximately 100 years following European-caused change in the study area, ungulate population may not have reflected the pre-European condition. Local people insist that caribou were in the study region and some say they can still find caribou trails across bogs. The 19th century shift in ungulate populations, with the introduction of the white-tailed deer and extirpation of the caribou, altered disturbance processes in the Acadian forest through selective browsing of some forest species, and thereby altering growth and regeneration capacity (addressed below in the Discussion). Woodpeckers (Picidae) and flocks of passenger pigeons were observed by Alexander (1849). Such bird species have also been considered for their possible roles as either disturbance, or dispersal agents for some Acadian forest species (Rushmore 1969; Ellsworth and McComb 2003).

Insects and pathogens:

Perley (1847) (pg 418) mentioned several insects that committed "*great ravages [ ] among trees of the fir tribe*" (i.e. conifer species). He described activities of a wood-boring beetle (*Bostrichus piniperda*), as among the most destructive species. Such insects had recently attacked "*black spruce*" (the name Perley used for both red and black spruce) in several districts of NB where the species was most abundant. Cedar, larch, and hemlock were also affected. Since study area forests featured all these species, they were probably affected by such infestations.

Eastern hemlock mortality was particularly evident. "*The woods* [was] *filled with dead stocks*" of hemlock, but fir and spruce remained untouched (Perley 1847). Perley was unsure whether the disturbance agent was insect or disease that selectively attacks hemlock, or if the hemlocks had died of some other cause. This mortality was widespread: "*The dead, moss-grown trees, which stand mouldering for twenty or thirty years frequently deform the forests of New Brunswick, and give them a gloomy and desolate appearance*" (Perley 1847).

Larch in the province was "*practically all destroyed in 1871 by a blight*" (Manny 1945), due to larch sawfly (*Nermatus erichsoni* Hartig) (Richards and Prince 1928). The infestation affected larch stands in the large bog in the northern part of the study area: "*Tamarac was once abundant throughout the greater extent of this locality, but now scarcely a living tree can be seen* [sic.] *in some places acres of dead trees stand as monuments of this once famous wood*" (Stevenson 1900).

Fire:

Documentary evidence of wildfire prior to European settlement was anecdotal and vague. There were references of "*flat, poor, pine-clad, sandy*" areas south of the Richibucto River and similarly poor, stunted areas outside the Kouchibouguac River riparian zone and south of the Richibucto River (Johnston 1851), perhaps indicating a previous wildfire. It is more likely, however, that forests in these areas were strongly influenced by edaphic factors, which produced 'poor, pine-clad' growth, rather than disturbance. Prevalent tracts of nutrient-poor, ancient beach sands, as well as large sterile bogs, provided poor growth conditions. Conclusions on whether such forests were of fire origin might have been assisted by more species-specific documentations, since all three native pines are considered drought-tolerant pioneers on nutritionally poor sites, but each has particular ecological adaptations and responses to fire (McCune 1988; Burns and Honkala 1990).

Two main ignition sources existed prior to European contact: (1) fire use by First Nations, namely the Mi'kmaq; and (2) lightning strikes. Records were somewhat contradictory on Mi'kmaq activities as a cause of wildfire. Titus Smith, who was very familiar with wildfire and its affects in the Acadian forest, spoke of the "*habits of the Indians, who carefully avoided setting the woods on fire*" (Smith 1835). Other records, however, associated wildfire with native burning practices: "*That the forest growth which clothes the surface of the British provinces is not primeval, I am convinced of, by a number of concurrent circumstances; and that it has been devastated at intervals, is [ ] in accordance with the traditions of the Indians, and the relations of the earliest settlers*" (Atkinson 1844). (The exact locations of such observations were unspecified.) Alexander (1849) attributed a burned area on the Eastern Lowlands, estimated at 70-80 years old, to the Mi'kmaq, but he implied that this was not in accordance with Mi'kmaq traditions. Instead it was the "*probable traces of the great fires to which the French settlers are said to have incited the Indians, in order to drive out the English*". Lingering prejudices from war and 19th century ignorance of French and Mi'kmaq cultures make it difficult to interpret such statements. Bruncken (1900) was certain that early settlers caused the vast majority of wildfires rather than First Nations peoples: "*Where Indians are present they get most of the blame*", since settlers were reluctant to assume responsibility for fires they caused through their own negligence. The distribution of fire ignitions by the Mi'kmaq may have been more common along the coast and riparian zones than elsewhere, since those were the locations (particularly near the coast) where they frequented during the fire season (Clermont 1986). Alexander (1849) noted a lack of Mi'kmaq presence as he walked through immense old forests in the New Brunswick interior between Moncton and Salmon River: "*No traces of Indians, or of any human being having ever visited these solitudes*".

No records were found of lightning-caused fires within the study area. This may not indicate the absence of such events, as there was a general scarcity of such reports over the entire province. LeClercq (1691) was the only observer in early times to note a lightning-caused fire, (in northern NB, between the Nepisquit and Miramichi Rivers sometime prior to 1677). Johnston (1851) had a general comment on lightning fires in the province: "*As a fact in natural history, [ ], it is interesting to know that dry trees are sometimes fired by lightning, and, therefore, that such burnings of the woods must have taken place from time to time from the most remote periods. In explaining the peculiar character of the surface-soil in many places, a knowledge of this fact may not be without its use*". Of interest was the observation that, "*the beech is said never to be stuck by lightning*" (Bailey 1876).

One other cause of 'natural' fire ignition was reported: "*Two trees leaning and rubbing against each other with the wind, have been known to catch fire*" (Alexander 1849). Bruncken (1900) rejected this: "*No experienced woodsman or forester will believe in such a tale. It belongs in the same category as the two-headed snake and the hybrid between the rabbit and the lizard*".

Fire ignitions greatly increased after European contact. Ignition sources from this point onwards were nearly entirely allocated to humans: "*Forest fires, practically without exception, are the result of human agency*" (Bruncken 1900). The following excerpt originated from NS, and refers to the resultant effects of fires on forests during early European settlement: "*The great influx of inhabitants in 1783 produced, in the course of a few years, a complete change in the appearance of the forest*" (Smith 1835). There is little cause to believe that effects of settlement and associated fire history in early NB history were vastly different, as NB was still a part of NS at that time, (separating in 1784), and was therefore administered by the same government (Ganong 1906a).

Smith (1835) isolated two basic causes of fire ignitions: fires ignited by (1) "*design*", or (2) "*negligence*". There were some compelling reasons for purposefully setting fires. Land grants clearly stated the terms and conditions in which the forests must be cleared by early settlers. Within five years, grantees must clear forests and "*work three acres*" for every 50 acres of improvable land (i.e. land fit for cultivation), or else "*clear and drain three acres* [ ] *of swampy or sunken ground, or drain three acres of marsh* [if any marshlands were found within the grant]" (PANB F16303 Vol. D, No. 483). Non-compliance resulted in lands reverting to the crown. Settlers, armed with only an axe, found fire to be a necessary tool to clear land and meet the terms of their grants. Countless land clearance fires escaped to surrounding forests without intervention. As Johnston (1851) travelled about NB, he "*...saw fires burning in the woods in many places, which, in this dry season, only required a little wind to spread in one blaze over the whole forest*". During dry periods numerous small land clearance fires, particularly in areas of rapid settlement, sometimes united into large catastrophic fires (Bruncken 1900). This was believed to have been the cause of the Great Miramichi fire (Ganong 1902.)

Fires were purposefully set for other reasons, too. For example, smoke from fires acted as a fly deterrent. Cedar bark was rolled up in long pieces, and then attached across the shoulders while burning slowly at one end to produce smoke around the person while working outside. Small fires were set to provide smoke for cattle (Johnston 1851). Sometimes smoke fires to ward off flies were made by placing small clods of damp moss over fires (Alexander 1849). Johnston purposefully set fires for pure enjoyment: "*we amused ourselves by setting fire to the bark of birch-trees, which [ ] easily kindles [ ]. Winding round the trunk, the flame ascends upwards to the branches, and speedily envelopes the tree, [ ], in one continuous rushing pyramid of fire. This is a very beautiful sight in the day-time; but it is singularly so in the dark woods at night. It destroys the tree, of course; but, in these forests, trees are of no value*" (Johnston 1851). Eventually, there were laws enacted against setting forest fires, but they were "*empty threats*", as they did little to stop wildfire ignitions (Johnston 1851).

Many historical records, too numerous to itemize, closely linked early logging and agricultural activities with increased fire frequency. Such fires were particularly detrimental during dry periods. Perley (1842) mentioned the unprecedented dry season of 1840 whereby many crops of the native peoples he was tasked to manage were destroyed by fires that "*were burning in all parts of the country*". It was again dry in the late 1840s, as noted by Johnston (1851): "*...the fires which have so extensively raged this summer...*"

The limits of the Great Miramichi fire are not believed to have entered the study area, although a generalized map of the Great Miramichi Fire produced by Ganong (1906b), indicated that it may have burned an area west of Richibucto, both north and south of the Richibucto River.

Fire behaviour:

According to historic records, fire was a more frequent disturbance agent in conifer forest than hardwoods. "*The leaves and the woods of the evergreens abound with rosin or gum, which renders them so highly* [flammable] *that on exposure to the action of fire, the flames immediately ascend to the top of the tree, with a roaring crackling noise. The moss, dry leaves, and dead-wood, which covers the surface of the ground, assisted by the wind, communicates the fire to the other trees, and if the breeze be violent, no human being can anticipate where the raging element will terminate its violence. But the fire seldom commits ravages among the hardwood, owing to the want of materials of a highly flammable nature, to increase its fury, consequently, so soon as* *it may have passed through a spruce swamp, and arrived at a ridge covered with a deciduous growth, it is supposed there is sufficient obstacle to stop its further progress. But in the event of a long continued drought, having dried every rotten wind-fall into touch-wood; and if the fire being attended with strong wind, the sparks and the ignited bark would be driven through the hard-wood ridge, and, in a few minutes, the next evergreen tract would be in a fearful blaze"* (Atkinson 1844). Monro (1855) also noted that groves of beech, birch, and maple were "*a class of wood not so favourable to the ravages of fire*". Similarly, Smith (1835) remarked that beech woods do not burn, while adjacent spruce barrens burned frequently.

The behaviour of fire to burn in a patchy distribution was also noted for the Great Miramichi fire. It "*formed irregular patches and net-works scattered over the area, leaving [ ] very extensive tracts, especially in the river valleys, entirely unburnt*" (Ganong (1906b).

Soil damage from fire:

The historic record included several comments on damage incurred to soil from either high intensity fire or from frequent repeated fires (Johnston 1851; Perley 1842; Grant 1882; Bruncken 1900). Fire, in some cases, burned the soil to a depth of 60 cm (Grimmer 1913), and severely retarded succession. The Great Miramichi Fire damaged the soil more intensely in some areas than others. Some districts remained open and barren for many years after the event (Ganong 1906b). The fire "*not only burned all the vegetable matter on the surface, but actually calcined the sand and gravel to such an extent as to leave the land almost incapable of bearing any thing but blueberries*" (Perley 1842).

Johnston (1851) remarked that "*the substance of the soil is gone*" where the Great Miramichi fire (1825) had passed. Because this fire had followed a year of heavy drought, soil damage was more severe: "*desolation was more complete*, [than from other fires witnessed by Johnston] *and a more sullen gloom still rested over the doomed surface"* (Johnston 1851). These observations came some 25 years after the event.

High frequency of fires with short return intervals also caused concern over permanent injury to soil (Smith 1835; Johnston 1851). Burned landscape often served as pasture for cattle for 3-4 years, but it was then necessary to renew vegetation through another fire, followed by successive fires thereafter. Subsequently, the soil "*becomes so exhausted that it produces only a growth of heathy* [ericaceous] *shrubs*". Dense mats of *Kalmia* [*Kalmia angustifolia* L.] frequently predominate until sufficient recovery takes place and "*alder and other large shrubs can be reproduced, as a shelter for another growth of firs*" (Smith 1835). "*When the woods of fir become so thick that the kalmia perishes, the soil generally becomes covered with various kinds of dry moss*" (Smith 1835).

Another record linked soil damage to forest resiliency (i.e., the capacity of forests to regenerate to original forest species complexes destroyed): recovery of "*burned land with the species of the original forest is only accomplished, if accomplished at all, through the restoration of fertility following the slow growth and decay of many generations of less valuable plants*" (Sargent 1884).

Forest successional responses to disturbance during the 19th century:

Historical records indicated some general patterns of forest succession following disturbance. A basic observation was that conifer-dominated forests often replace hardwoods and vice versa, following a disturbance event. "*The kind of growth that often succeeds the hard-woods, is spruce, pine, hemlock,* [ ] *maple, frequently wild cherry, white birch, and sometimes poplar*" (Atkinson 1844). Monro (1855) concurred with this observation: "*When hardwood land has been* [ ] *cleared, and allowed again to grow up* [, it is replaced] *with soft wood (which always follows,...)*". The opposite was also true: Hardwoods "*generally spring up on the removal of soft-wood*" (Monro 1855).

The remainder of historical records on forest succession were derived from Titus Smith (1835). While his observations originated from extensive surveys of NS forests, the successional pathways described by Smith are probably applicable to Acadian forest succession in general. Smith (1835) referred repeatedly to the early-successional roles of red maple and balsam fir:

(1.) "*The red-flowering maple* [*A. rubrum*] *and balsam fir extend their protection to all, as they are to be found on every kind of soil*". "*The roots of the maple are never injured when the stem is killed by fires, or cut down; and, consequently, always throw* *out a number of shoots, which, in the course of one summer, after a fire, form clumps of shrubbery 3 ft or 4 ft in height*".

(2.) "*The thicket, in the course of thirty or forty years, resumes nearly its former appearance, except that the trees are smaller, and that the balsam fir forms a larger proportion of the wood. This tree of rapid growth, by its shelter, covers the more valuable spruce from winds, and prevents it from forming strong lateral branches, which would deteriorate the timber, till, having reached the height of 30 ft. or 40 ft., it is overtopped and suffocated by it*".

(3.) Following disturbance in rich hardwood forests, "*Shoots from the old roots and seedlings spring up, among which a few scattered plants of the balsam fir appear, which, overtopping the hardwood, by their shelter accelerate its growth, and, being short-lived trees, are, in their turn, overtopped and suffocated by the hardwood, when it no longer needs their assistance*".

Following repeated fire, and damage to soil fertility, Smith (1835) presented several early-successional pathways where balsam fir became the first forested stage:

(1.) **Fire** (repeated)→*Acer rubrum*, *Comptonia peregrina*, *Salix* spp. L., *Viburnum nudum* L., and "*brakes*" (fern) → *Alnus* spp. (form shelter for balsam fir)→*Abies balsamea*, mixed with *Betula populifolia* and *Populus* spp.

(2.) In more barren areas following repeated fires:

Fire (repeated)→ *Vaccinium* spp. (specifically blueberries)→ "*by degrees overgrown by [ ] Kalmia* and *Rhodora canadensis*"→ "*overtopped by alder*" after a few years→ "*always soon followed by a growth of firs*" (*Abies balsamea*).

(3.) Hardwood growth on poor soil→**fire** and cattle pasturage→ *Abies balsamea-Picea*.

Since historical records indicated that eastern hemlock was abundant in the study area, it is of interest to include records that explain its demise, as well as its ecological requirements and successional responses. Smith (1835) indicated a certain resiliency of early hemlock forests: "*Most hemlock woods, when killed by fires, are at first overgrown with birch hooppoles, mixed with firs; but, when the birch has reached the height of* [6 to 9 m], *it turns mossy, and continues nearly stationary for perhaps 20 years, during which a young growth of hemlock again springs up, and most of the birches perish*"

(Smith 1835). Sometimes, however, "*old growth hemlock and spruce*" stands are replaced by beech-birch-maple when subjected to fire (Smith 1835).

The resiliency of hemlock had limitations that had perhaps not yet been witnessed by Smith, but was evident roughly half a century later in the eastern US: " *as regards to hemlock, fires kill it out clean, seedlings and seed; and if the 'peelers' and the fires happen to leave any scattering of trees standing, these being more sensitive to changed conditions than pines, are seldom able long to survive as seed bearers*" (Sargent 1884).

Red spruce and white pine were other species that did not thrive under an increased disturbance regime: "*The vast forests of black spruce* [i.e. red spruce] *which once covered the province have been reduced by fire and cutting to less than one third of their original extent*" (Bailey 1876). White pine woods, when burned were sometimes replaced by white birch and poplar, and eventually became forests of yellow birch-oak, or sometimes spruce-larch-pine (Smith 1835). The much later observations of Bruncken (1900) stated that where the original forests of white pine have been replaced by "*the valueless poplars and white birches* [and] *despised jack pine* [ ] *there is a distinct loss of natural wealth.*

DISCUSSION

Historical descriptions, mainly from 19th century publications, provided some useful information on the nature of pre-settlement forests in the study area. Comment on the early forest was sometimes unexpectedly obtained from documents unrelated to forest resources, such as a 19th century report on First Nations of New Brunswick (Perley 1842) and published journals pertaining to military inspections during 1813 in the study area (Temperley 1980). Results provide an incomplete picture, as additional research would undoubtedly reveal more information on original forest types. It is possible that more information exists from surviving Acadian records preserved in archives in France, as was determined to be the case for historical forest research for PEI (Sobey 2002). Such information could make an extremely valuable contribution to ecological knowledge and reference conditions. However, the enormous time and meticulous labor involved in extracting such information was beyond the scope of the current research. Likewise, there are undoubtedly more records from British sources, but time constraints limited research.

The original forest cover cannot, of course, be reconstructed entirely from the localized and brief accounts of Denys, Fowler, Perley, and other early observers. But their observations, combined with results from other research efforts, plus contemporary knowledge of forest ecology, allow us to describe it with a reasonable degree of confidence. What was it like to explore the Acadian forest *ca.* 1800? When the first settlers approached the study area from the sea, they initially met coastal sand dunes and great expanses of salt marsh on flat intertidal zones. Coastal heathlands, located in areas between Kouchibouguac River, Point Sapin, and Bay Ste Anne supported stunted conifer growth, and received little positive comment from early recorders in terms of forest resources. Explorations up rivers in the area presented a very divergent picture from coastal vegetation. There, Denys, Johnston, and other explorers, recorded impressive forests consisting of mainly late-successional species in various associations. Coniferous species were dominant, and mature and old-growth classes were the norm. White pine, commonly reaching heights of 48.8 meters and 1.2 m diameters, impressed the early recorders and caused them to write many comments on the enormous sizes of this tree. Vast stretches of ancient eastern hemlock, growth of tall red spruce, and groves of beech would have placed the viewers in the shadows of an immense forest.

A summary of original forest types of the study area is provided below based on the preceding research results. Extremely important insights into historic forest condition in eastern NB were obtained, despite this research having been based upon non-quantitative, and somewhat anecdotal historical citations.

Synopsis of original forest character in the study area

Forests were predominantly coniferous, but contained a diversity of at least 25 tree species (excluding some minor components that could not be assessed using this research method) (Table 2.1). Ten conifer and 15 broad-leaved tree species contributed to an alternating forest mosaic, consisting of strips of conifer-dominated stands and strips of deciduous-dominated woods. Distribution of hardwood and softwood stands was dictated by a range of edaphic conditions, particularly drainage and soil fertility.

Three conifer species predominated, consisting of late-successional eastern hemlock, with red spruce and white pine, and they commonly achieved mature to old-growth age classes. Eastern hemlock was abundant, forming vast, nearly pure stands over a wide range of site conditions. A great tract of hemlock, of very large dimensions, mixed with white pine, birch, and beech, extended from the St Nicholas River, through the Bass River area (Fowler 1873), to the Salmon River Oxbow (Johnston 1851). Hemlock was also abundant on the Kouchibouguac and Kouchibouguacis Rivers. Red spruce was widely distributed, both in pure stands and intermixed with other trees, and over many types of soils, though specific locations of red spruce-dominated stands were not divulged. Given that red spruce was not differentiated from black spruce in early descriptions, its abundance and distribution can be determined based only on edaphic conditions and current ecological knowledge of the genus. Red spruce, combined with black spruce and perhaps hybrids of both species occupied considerable expanses. Black spruce was abundant over great treed bogs, (as it still is today), and also grew in smaller patches distributed throughout the landscape wherever the complex micro-drainage patterns caused wet soils to prevail. The most common pine species in early 1800 was white pine, which grew either as individual trees, intermixed with other hardwood and conifer species, or in pure stands. It grew to enormous sizes (Table 2.4), meeting specifications for shipmasts and square timber exports, and was harvested in great quantities along the riparian zones. It was common on a wide range of site conditions, but grew stunted on such extremes as wet sphagnum bogs and dry sandy areas. The largest and finest quality trees grew singly or in small groups (Alexander 1849; Bailey 1876).

Hardwood forests were more limited in distribution due to poor soil drainage and low topographic relief. According to historical descriptions, hardwood stands were most commonly found on small ridges and hills, forming ribbons of hardwood-dominated forest interspersed among the conifers. Like the conifers, hardwood stands were also primarily represented by mid- to late-successional, shade-tolerant species, namely beech, sugar and red maple, and yellow birch. All three dominant hardwood genera were described to grow to large sizes on the Molus River (Perley 1842). Beech formed nearly pure stands on low ridges, and was a common late-successional associate with hemlock and other species. Historical records did not indicate whether sugar or red maple was more prevalent. Red maple may have been more common, given the prevalence of poor drainage classes and the fact that many descriptions originated from within riparian zones. Yellow birch was the dominant birch species, as inferred from the absence of large disturbance events, and the prevalence of other late-successional species. The possibility of 'black birch' (*B. lenta*) growing in the area is examined more thoroughly below.

Balsam fir was a common component throughout the forest, but was not present in large volumes (Perley 1847) until disturbances became more frequent following European settlement (Monro 1855). Originally, balsam fir was scattered among most forest types, often as a subdominant or suppressed species (Perley 1847). Eastern cedar grew on the banks of the Kouchibouguac River (Perley 1842), but curiously, nothing was mentioned of the large cedar swamps that persist on the landscape today. It is presumed that cedar was common, growing in either large groves or small groups wherever appropriate edaphic conditions were met. Larch was generally common within the study area (Perley 1847). It grew in extensive groves of large size on the Kouchibouguac River. Red pine was much less common than white pine, but there was at least one stand recorded on the Kouchibouguac River (Perley 1842).

Amongst the minor hardwood components, white ash grew on a variety of suitable sites scattered among other hardwood or mixed stands. Ironwood was likely a minor component of local riparian and upland forests, growing in mesic to dry sites scattered amongst other species. Judging from general descriptions, black ash was probably present but was limited to swamps and perhaps riparian zones. Along riparian zones, American elm, white ash, and balsam poplar were some of the minor species.

Abundances and distributions of early-successional species in the pre-settlement forests of the study area were impossible to deduce from historical records, largely due to their ephemeral status. Relatively short life spans and quick response strategies to disturbance make it impossible to describe former presence of any of these species at any given period. Judging by the relative absence of such species in the earliest records, they were probably relatively uncommon, with limited distribution. There are some notable variations in abundances and distributions of early-successional species between earlier records and those recorded after *ca.* 1880. It is logical to assume that jack pine was present, but not common until subjected to more frequent, catastrophic disturbance (McCune 1988; Bruncken 1900) in the post-European era. Trembling aspen was common, growing both in groves and as scattered trees depending on the disturbance agent. Largetooth aspen may have been less common (Bailey 1876; Fowler 1885). White birch was probably also common, but limited in distribution to disturbed sites. Mi'kmaq were said to have difficulty finding good birch bark to make canoes by the late 1800s (Little 1961). Supporting this, Mi'kmaq canoes made of yellow birch bark have been preserved in the Museum of Civilization in Ottawa (E. Ponomarenko, curator, Museum of Civilization, Ottawa, Ont., Pers. comm.).

In general, forests were composed of a mosaic of uneven-aged, mature to old-growth stand types. Structure of the forest varied with species composition and stand age, but for the most part, trees of very large dimensions were present (Tables 2.4 and 2.5). White pine, hemlock, and red spruce were very tall and large. Beech, yellow birch, red and sugar maples were also large. Large fallen logs more often obstructed travel than a subcanopy or shrub layer. There were exceptions noted, where younger forests, often noted to be post-fire origin, were of denser growth, and presumably of smaller DBH classes. Smaller trees were prevalent along the coast where there may have been more disturbance caused by wind, flooding, and escaped fires from Mi'kmaq encampments.

Black birch enigma:

Frequent records of 'black birch' in NB presented an intriguing taxonomic challenge. Black birch was most commonly identified as *Betula lenta*, known as black or cherry birch in Canada, but *"in New Brunswick it is always called black birch"* (Perley 1847). All 19th century authors recognized black birch as a separate and widespread species in NB. Black birch is *"one of our finest and most valuable forest trees"* (Fowler 1878). Denys, Monro, Perley, and Fowler all lived and traveled extensively throughout New Brunswick over many years. Their familiarity, particularly with eastern New Brunswick lends credence to their knowledge of forest species. Fowler, Bailey and Ganong were well educated in the field of botany. However, black birch is not recorded in NB presently. Could black birch have existed at one time in NB?

Is it possible that black birch remains here today, but it is overlooked? The species is difficult to distinguish from yellow birch, at a distance, as mature growth (Hosie 1990). The bark of very old yellow birch is very dark, almost black, and consists of thickened plates, closely resembling *B. lenta*. Characteristics, such as leaf, flower, and fruit are all very similar (Hosie 1990; Gleason and Chronquist 1991). Historical descriptions were of only minor assistance in describing differences between the two species. Black birch "*has all of the values of yellow birch in yet higher degree*" (Ganong n.d.). "*The bark upon the trunk of trees less than eight inches in diameter, is smooth greyish, and perfectly similar in colour and organization to that of the cherry tree. On old trees the outer bark is rough, and of a dusky gray colour; it detaches itself traversely at intervals, in hard ligneous plates, six or eight inches broad*" (Perley 1847). Several other distinguishing traits between black and yellow birch were presented (Perley 1847), but in most cases a particular trait for one species was simply omitted for the other. Were differences real or perceived?

Perhaps early recorders borrowed from descriptions of forests of more southern regions containing black birch and other additional species. Recorders may have assumed the species was in NB because it grows in mixedwood forests with similar species composition in other areas of eastern North America. If *B. lenta* existed in NB, the next closest populations are near Lake Ontario (with only approximately 50 trees reported in 1967 (Hosie 1990)), and in the US ranging from southern Maine extending westward (Lamson 1990). However, shipping records indicate that NB exported large quantities of both black and yellow birch timber to Britain (Monro 1855), and so the theory that the species was falsely assumed to be in the province seems unlikely. Black birch was highly sought after and was valued in the ton timber trade second only to white and red pine. It was used in shipbuilding (Sargent 1884), "*particularly for the lower timbers and bottom planks*" (Cooney 1832). The bark of black birch was "*much used by tanners*" in NB (Monro 1855). Black birch had a redder wood than other birch species (Denys 1672), and was prized by cabinet and furniture makers for its aesthetic properties in fine woodwork. Some viewed it as "*equal in beauty to mahogany*" (Campbell 1793). Campbell (1793) wrote on the fine qualities of black clouded birch of New Brunswick, as being most probably among the best in the world for use in household finishings and furniture because of its capacity to be finely polished. Monro (1855) remarked upon the variegated appearance of the wood and its various uses in shipbuilding and furniture construction. Wood of yellow birch was considered of inferior quality to black birch, as "*it never assumes as deep a shade, but is strong, and when well polished makes handsome furniture*" (Perley 1847).

Perhaps selective logging pressures for the exceedingly high quality wood of black birch, coupled with frequent fires, brought about its extirpation in NB forests. A characteristic that would not have assisted its persistence is that black birch, unlike many other hardwood species, does not stump sprout after logging. Therefore, it may not have regained its former status in the forest following disturbance events. Still, its reportedly wide distribution throughout the province should have assisted the survival of at least remnant populations.

Evidence for black birch was researched at the UNB herbarium. Some very old yellow birch specimens were preserved, but all were accurately identified, so far as could be determined on specimens containing female catkins. Binocular microscope examination of the characteristically distinguishable pistillate scales of female catkins (Gleason and Chronquist 1991) led to the conclusion that all specimens were of yellow birch. Black birch specimens were not preserved at the E.C. Smith Herbarium (S.P. VanderKloet, botanist, Acadia U., Pers. comm.). Another possible method to verify the former existence of black birch may be procured from wood cell analysis from the sample of black birch in the book of wood specimens (Monro 1862). Wood cell analysis was not carried out at this stage, as it is a destructive technique and would require special permission from archive personnel.

The most plausible answer remains that black birch was actually old-growth yellow birch or a superior variety of yellow birch in New Brunswick. Yet, it is curious that, if this is correct, no mention was made of heart rot or other blemishes that often accompany old-growth trees. Ganong (n.d.) perhaps best answers the debate over the presence of black birch in NB, stating that botanists will be left to resolve the issue, but in the meantime: "*Our lumbermen need not cease to select their Black Birch trees in the forest and bring them to market as superior to the Yellow* [birch]".

Disturbance:

Records of forest disturbance prior to and during the earliest period of European settlement helped achieve a basic understanding of original disturbance agents that operated on the landscape. Historic records, combined with ecological deduction, presented a picture of relatively frequent small-scale disturbances and infrequent large-scale disturbance at intervals that remain undefined.

Small-scale disturbance events predominated in forests of the 19th century, based on the prevalence of widespread, multi-aged, late-successional species complexes. Such forests do not support the presence of large stand-replacement fires in the years leading to European settlement. Remarks on the occurrence of large scattered logs (i.e. coarse woody debris), an indicator of gap dynamics (Runkle 1991), also suggest that large fires were infrequent.

Forest mortality caused by insect disturbances during the 19th century was common and exerted a strong influence on stand dynamics from time to time, sometimes opening small gaps, and other times, causing larger stand-replacement events in the case of the hemlock and larch die-off events. Less clear from historical descriptions is which insect species were the main agents, and the frequency that disturbances occurred, particularly those of large scale.

The role of fire as an agent of forest renewal could not be defined from anecdotal historic records. Nonetheless, one aspect of the local fire ecology is clear: fire frequency prior to European settlement was much lower than the period following European settlement. Evidence for increased fire frequency stems from the prevalence of late-successional species composition of advanced age classes and growth stages, (forest types impossible to attain had fire been of similar frequency prior to European settlement as it was during the 19th century), and very frequent comments on forest fires during the European settlement period. Lightning-caused fires may have been rare in the region, given the lack of historical comment on lightning strikes, and fires from undetermined causes. However, conclusions require more research using a deeper retrospective approach. The role of the Mi'kmaq or other first nations in causing early fire ignitions could not be directly determined from historical documents. Indirect evidence, however, points to the Mi'kmaq as infrequent causes of purposefully ignited fire. The abundance of foods they obtained from the sea, estuaries and riverine systems, as noted by both Gubbins in 1813 (Temperly 1980), and later by Perley (1842) for the Richibucto area, demonstrated a lack of dependency on terrestrial resources and no need to modify local forests. Impacts of Mi'kmaq would most likely have been limited to areas near the coast and along river travel routes. They frequented inland areas mainly during the winter, when wildfires could not occur (Appendix 1-1).

The very nature of the landscape probably influenced the capacity of fires to burn large tracts of local forests. Rivers and bogs have acted as natural fire breaks in the past (Crossland 1998). Even the Great Miramichi fire could not cross the eastern extent of the Miramichi River, leaving Chatham and the northern part of the study area unburned (Ganong 1906b).

Eastern hemlock, spruce, and beech are very fire-sensitive species (Graham 1941; 1943; Rogers 1978; A. D. Revill Associates 1978; Burns and Honkala 1990), and were the most dominant components of local forests. To the other extreme of the fire sensitivity spectrum was the near absence of comments on fire-adapted species, such as jack pine and aspen. Jack pine, though evidently present in the area, was not sufficiently abundant to merit historical mention until after the Miramichi fire, and other fire events in the study area had occurred.

How did a fire dependent species like jack pine remain as a component of local forests if fire events were infrequent? Could jack pine survive in forests where intervals between disturbances were longer than the tree's lifespan? The answer may have been noted very early on by Perley (1847), who probably had not yet realized the tree's adaptation to fire. He commented that that jack pine cones "*do not open to release seeds until the second or third year*". Thus, some of the cones were semi-serotinous and were able to release seeds without the aid of fire. This adaptation may have allowed the species to survive in areas along the coast or rivers where light was adequate and small disturbances occurred frequently enough to maintain at least some trees. Given the species' abundant seed production and delayed seed release (McCune 1988), jack pine was capable of prolific reproduction following the frequent fire events associated with European settlement.

No young forests were described in early records, unless they formed the reportedly scrubby, unremarkable forests near the coast. Coastal forests may have been stunted by salt spray, wind, and poor soils and drainage. Alternatively, they might have recently succeeded fire, flooding, and/or wind disturbance, and therefore have been young, rather than stunted. From historic descriptions, most forests throughout the region probably consisted of multiple age classes, since gap replacement and other localized disturbances were operating on the landscape. The diverse compositional patterns of the early Acadian forest in eastern NB were shaped by small-scale disturbances along with patchy, rapidly alternating edaphic conditions.

The European altered disturbance regime

Early documentary evidence indicated an increased disturbance frequency, most notably from fire, following European settlement (Grant 1882). These events, in turn, began to rapidly alter species composition and forest structure during the 19th century. Early-successional species replaced large structured, late-successional species through land clearance activities, fire, and logging. Balsam fir responded favourably to the changes. "*The thicket, in the course of thirty or forty years, resumes nearly its former appearance, except that the trees are smaller, and that the balsam fir forms a larger proportion of the wood*" (Smith 1835). Smith (1835) interpreted the role of balsam fir in the Acadian forest as a 'nursery tree', assisting re-establishment of later successional species by its shelter. Poplar species, white and grey birch, and red maple also were well adapted to the increased disturbances readily increased on the poor soils as a result of abandoned clearings and fire (Ganong n.d.).

Fire-adapted species, such as jack pine, benefited from frequent human-caused fires. Jack pine is of particular interest in the study area as it is very common today, yet early 19th century references to jack pine in the area were absent, leading to the conclusion that it was uncommon. With increased fire disturbance, jack pine "*sprang up abundantly on dry burnt barrens*" (Fowler 1878), which became dominated by the species (Fowler 1878; 1885). There are two key points to Fowler's record on jack pine in the area: (1) it grew on infertile, sandy soils, and, (2) the areas had burned, most likely within recent human memory in order for the recorders to associate it with former fire events. A general increase in jack pine was noted for the area by (Ganong n.d.) during the early 1900s: Jack pine formed "*thick woods in parts of the interior long ago burnt [ ], and it* [was] *spreading steadily in the province, especially on the great eastern plain* [i.e. Eastern Lowlands], *where it comes in always on land that has been opened and neglected, whether burnt lands or abandoned farms*". Areas closer to the Miramichi watershed that were destroyed by fire were described by Bailey (1876) as having "*become covered so thickly by forests of Banks' pine that it is almost impossible to press one's way through them*".

Other pine species that are considered to be fire adapted (albeit to a lesser extent than jack pine) (McCune 1988), did not flourish under the altered disturbance regime. Selective logging of both species did not assist regeneration, and fire may have been too frequent to allow opportunity for them to grow (Bruncken 1900). Even red pine could not perpetuate itself in some areas under the newly altered disturbance regimes of the 19th century: "*The axe and fire have* [ ] *completely removed* [red pine]" from the Tobique River, which had been known as a "*great nursery of the old red pine*" (Bailey 1876).

With the advent of European settlement, extinctions or severe reductions of some animal species (e.g. caribou, passenger pigeon (*Ectopistes migratorius*), beaver, and fisher (*Martes pennanti* Erxleben), and introductions of others, particularly white-tailed deer (*Odocoileus virginianus* Boddaert), have exerted direct or indirect disturbance forces on early Acadian forest. Ellsworth and McComb (2003) proposed that massive flocks of passenger pigeons might have caused low-intensity crown thinning, which released shade-tolerant vegetation. Heavy nutrient loading in long-term pigeon roost areas altered growth and killed trees. All trees on annual roosting sites, reported to have covered thousands of hectares, were killed off from guano, sometimes exceeding 50 cm deep (Wilson 1814, *In*: Ellsworth and McComb 2003). Such large flocks might have influenced fire intensity and frequency in presettlement forests through widespread limb and stem breakage contributing to accumulation of combustibles (Ellsworth and McComb 2003). White-tailed deer introductions had an impact on forest dynamics during the past century by preferentially browsing branches and seedlings of eastern hemlock, birch, eastern cedar, and Canada yew (*Taxus canadensis*) over other species, such as balsam fir. Regeneration success of hemlock and Canada yew has been reduced in some areas (Russell *et al.* 2001; Telfer 2004). Deer may have also affected beech regeneration as it consumes the fall beech mast (Telfer 2004).

Reductions of predators on herbivore populations can decrease regeneration success of certain tree species. For example, recent observations of eastern hemlock decline in KNP have been partially attributed to heavy browsing by porcupines (*Erethizon dorsatum* L.). The near absence of fisher, the only natural enemy of the porcupine, is probably at least partly responsible for very high populations of porcupine (Earle and Kramm 1982). Fisher populations have dropped to extremely low levels in the area, probably due to over-trapping and loss of habitat.

Other old-growth indicators:

Old-growth associated species were prevalent in the historical record. Signs of caribou were frequently encountered in the woods and bogs of the Eastern Lowlands (Alexander 1849; Monro 1855). Presence of caribou can be regarded as an old-growth indicator since they require suitable lichen-bearing forests and bogs for their principal food source (Adams 1873; Smith 1857; Gray 1999). Lichens are slow-growing, requiring long periods between disturbances to flourish. Arboreal lichens that caribou rely upon, especially during winter (Chapman and Feldmar 1982; Gray 1999), require older age classes of forest to provide suitable structures on which to grow, and required high levels of shade and humidity (Kapusta *et al.* 2004). The number of times that lichens were noted in the scant historical records is an old-growth indicator by itself. Alexander (1849) found it noteworthy to record "*green and black hair-like moss*", 'Absolomon's hair lichen', hanging from branches of trees around bog edges west of the study area. Hemlock was commonly covered with lichen, which indicates that they were probably of great age, since bark of young hemlock trees is very acidic and does not support strong lichen growth (Richardson and Cameron 2004; A. Koffman, botanist, Dept. of Nature Conservation, Gävle, Sweden, Pers. comm). Ganong (n.d.) was inspired to recite: "*Their dead lower branches accumulate lichens which hang in the deep shadow in ways to present a mournful aspect[ ], the hemlocks, bearded with moss like druids of eld stand indistinct in the twilight*". Old-growth forest, as well as good lichen growth are sometimes associated with high humidity levels, a factor that was commented on during Alexander's survey on the Eastern Lowlands: The "*air seems to stagnate there, and the closeness is often times terrible to bear…*" (Alexander 1849).

Alexander's slow walk during May-June, 1844, through eastern NB forests encountered woodpeckers and owls (Strigiformes). (His native guide shot and ate owls by luring them to vocal imitations; an apparent welcome change from a monotonous diet of salt pork and biscuits.) Other bird species recorded along the survey line were ruffed grouse (*Bonasa umbellus* (L.)), kingfishers (*Ceryle alcyon* (L.)), loons (*Gavia immer* (Brunnich)), 'plovers' (i.e. passenger pigeons), ducks, nighthawks (*Chordeiles minor* Forster), and gray jays (*Perisoreus canadensis* (L.)). Missing were bird species indicative of younger forests, with the exception of a 'savannah grouse' (i.e. spruce grouse *Canachites canadensis* L.) that he encountered in a burned area away from the survey line near New Canaan Settlement. During the months of May and June, one might expect to awaken to the songs of warblers and other forest songbirds while camped in modern day forests, but Alexander (1849) noted only the presence of woodpeckers: "*Next morning [ ]the woodpeckers, in black and white coats, were beginning to climb tall stems, I roused all hands at five o'clock...*". "*At various distances and with different degrees of loudness, the woodpeckers with their sharp and strong beaks would interrupt the dead silence around*" (Alexander 1849). As Alexander viewed the "*vast bank of green forest*" beyond Salmon River, he again mentioned the silence of the forest: "*all was lightless and silent*". Lack of songbirds might simply have been an omission stemming from lack of interest, but this is unlikely, as he recorded other forest creatures, such as "*large hairy bees*", the occasional copper coloured beetle on the ground, and "*a small brown butterfly in openings*". Lack of bird song observations may more likely have been testimony to the old-growth forest situation. Passerines that are known to frequent old-growth, with very little fragmentation, such as the bay-breasted (*Dendroica castanea* (Wilson)), Cape May (*D. tigrina* (Gmelin)), and blackburnian (*D. fusca* (Muller)) warblers, and yellow-bellied flycatchers (*Epidonax flaviventris* (Baird and Baird) (B. Forsythe, Blomidon Naturalists Society, NS, Pers. comm.) do not have loud songs and often call from the very tops of trees (Godfrey 1979). Such birds, singing from trees that attained great heights rarely observed today, may not have been very audible to those toiling far down on the forest floor (A.W. Diamond, biology professor, UNB, Pers. comm.).

Some other animals were noted that may be considered indicative of old growth, or at the very least, intact ecosystems. American marten (*Martes americana* Turton) was common (Alexander 1849; Adams 1873). Amphibians and snakes were also common on the Eastern Lowlands. A salamander (Alexander called it a 'lizard', but from his descriptions, it was probably a red backed salamander) was found in a large decayed log with its eggs. Garter snakes were common: "*In swampy ground, checkered snakes glided among rotten branches and leaves*" (Alexander 1849).

A point in time?

Descriptions of 19th century forest types represent a far longer temporal perspective than just one point in time. They are a consequence of at least several hundreds of years of long-term ecological processes. Late-successional species, such as eastern hemlock, predominated over vast areas, had grown up in the shade of a previous forest of early seral species, and had long since fallen and decayed when Europeans arrived. Approximately 100 years is a modest estimate for early-successional forest to have sheltered the hemlock, grown up, then declined, to be eventually replaced by hemlock. Following this must then be added the ages of the hemlocks, themselves, some individuals recorded as 300 years of age. Large trunks covered with slow-growing lichens strongly indicate that the hemlocks were probably of great age. (Hemlock of British Columbian wet temperate rainforests (*T. heterophylla)* do not support cyanolichen growth until at least 120-140 years of age (Radies and Coxson 2004), and lichen growth might be expected to be slower in less humid eastern forests. Eventually, some old-growth hemlock weakened, died, and blew over. Large trunks began to decompose and were covered with moss (a process modestly estimated at perhaps 50-100 years minimum). Young hemlock replaced the gaps. This affords a minimal estimate of 450 to 500 years to achieve the forest type described between the St Nicholas and Salmon Rivers; hardly a 'point in time'. Add the fact that late-successional forests can self-replace indefinitely, and the possibility that such forests were perhaps thousands of years old must be considered. Frequencies of stand-replacing disturbance events, such as fire, are impossible to estimate, based on the scant documentary record.

The criticism that historic descriptions represent only a single snapshot or 'point in time' is most clearly opposed when such descriptions are compared with modern forest types, and human memory. Some large and formerly common tree species have been reduced quite recently (e.g. American elm and beech), yet their absence is rarely reminisced by modern foresters and most citizens. Human nature quickly adapts to a "new norm", and forests as recent as 50 years ago are little-remembered. Only the results of historical ecological study will provide a more holistic perspective of forest potential.

Strengths and limitations of historical forest descriptions

The foremost difficulty with using historical descriptions to evaluate the nature of the original forests is that only a small number of records were directly applicable to the study area. Most documents were very general and intended to portray the forests across the province or Maritimes.

The accuracy and reliability of the historical documents varied. Some authors relied on second-hand information from previous works (with or without acknowledgement), or information from other regions, often farther south. This was noted in Appendix 2-1, when known.

The value of studying historical descriptions is that they can provide a more complete image of early forest types, including vivid details that may not have been recovered through more analytical approaches. For example, several references to dark, gloomy forests, and trees hanging with lichens provided a much clearer ecological picture than would have otherwise been gained had only species composition, diameter, and height measurements been used. Knowing that a forest stand was composed of eastern hemlock is useful, but picturing uprooted trees sufficiently large to create 'forest wells' that could be used for fresh drinking water is a true ecological bonus. Such features are no longer encountered on the landscape, and so might not otherwise have been concluded from research.

Bias:

Objectives for describing early forests were most often to encourage immigration, timber trade, or to guide selection of prospective agricultural lands. Therefore, biases were inherent in most historical descriptions.

Historical descriptions were rarely provided unless trees were of high monetary value, such as white pine, or they supported practical utilitarian objectives, such as shipbuilding, or construction of houses, bridge structures, and various wooden tools. This can lead to an over-representation of some species in the historical record. Less useful species received less attention and may have been more common than indicated. For example, red oak was of little value (Cooney 1832); "*worthless for the purposes of the tanner*" and "*difficult to season*" for firewood (Bailey 1876). It was rarely noted in the records, either due to its rareness, or its inferior properties. Aspen and jack pine were also little mentioned, perhaps mainly due to their inferior sizes and qualities. Other species may have also been under-represented for similar reasons.

Early riparian and coastal forests were described more often than interior forests since observers traveled by water and rarely overland. "*That which I have already said concerns only those [forests] of the coasts*" (Denys 1672, *In*: Ganong 1908). Upland forest descriptions came later, once roads were built and more uplands were surveyed. Bog descriptions were few, even though some bogs supported forests. Little attention was paid to such places, as they presented poor soil and drainage conditions, and as such were of no interest to early settlers or for commerce.

Forest observations were impeded in less accessible landscapes:

The nature of the landscape itself impeded early forest observations in the study area. The sandy shallow nature of the coastline and narrow entrances between treacherous sand bars limited observations. "*The Coast all along from Cockayne* [Cocagne] *to Point Eskiminack,* [Escuminac] *and also from Miramichi to Caraquid* [Caraquet] *is bounded in by a sand bank and by low islands*" (Taylor 1803). Such a shallow coastline required that ships distance themselves safely away from the sandbars, thus impeding close examination of forests. Gubbins, in 1813, while sailing from Buctouche to Richibucto, found it necessary to navigate his boat at about 3.2 km off shore in order to avoid a sand bar running parallel to shore (Temperley 1980). Early observations of the Kouchibouguac and Koucibouguacis Rivers were more limited than those of the Richibucto or Miramichi Rivers. The Kouchibouguac and Koucibouguacis Rivers have narrow, snaking channels through sand bars and very shallow bays that were very treacherous to sailing ships. Both of these rivers are "*Bar harbors that will not receive any but small vessels, but situated with as find land and marsh as any in the Province of New Brunswick*" (Taylor 1803). Nicolas Denys described the Kouchibouguac River entrance as "*a little channel which leads into the river, but it is very crooked; and it is needful to know it well in order to enter. Even then it is only passable for long boats of a dozen to fifteen tons at high tide.*" (Denys 1672, *In*: Ganong 1908).

Problems with early species' nomenclature:

Early taxonomic inaccuracies and varying assignments of common and scientific names presented considerable difficulties in defining early species composition (see Table 2.2). Erroneous names were sometimes of European or more southerly origin. There were often more species listed in historical records than are taxonomically recognized today. Michaux Jr. offered an explanation for some of the previously distinguished species: "*trees of the same genus are more frequently distinguished in America by the complexion of their wood than by the difference of their foliage and flowers*" (Michaux Jr. *In*: Perley 1847). This possibly accounts for some species records, such as 'red beech', 'white beech', and red elm (Perley 1847; 1863; Bailey 1876; Monro 1862).

Variable uses of the same common name were also perplexing at times. Frequent records for 'white maple' were sometimes assigned to red, silver, or sugar maple, depending on the recorder or region. Red maple was often called white maple in northern counties (Fowler 1878) and in NS (Smith 1835). Monro (1862) may have labelled red maple in his book of wood samples as 'white maple', since red maple is otherwise undocumented. White maple may have been considered a fitting name for red maple for two reasons: (1) The underside of red maple leaves is white, unlike that of sugar maple (S.P. VanderKloet, botanist, Acadia U., Pers. comm.); or (2) The wood appeared white, as testified by Bailey (1876), "*the wood of the red maple is whitish, with a tint of rose color*". There remains the possibility that the name, white maple, was sometimes also assigned to sugar maple by woodsmen: "*The wood of sugar maple, which first cut, is white*" (Perley 1863). The result is that former abundances of red and sugar maple could not be determined from historical records. Silver maple was not immediately eliminated from the potential list of historical species until a sole definitive record from Fowler (1878) indicated that it was not in the area. Names of birches also offered some challenges. Both grey and white birch were sometimes called 'white birch' (Perley 1847; Monro 1862; Bailey 1876; Fowler 1878). Records of 'black birch' caused intriguing reflection over the possible historical distribution of *B. lenta* in NB.

Frequent failure to discriminate between species of spruce, pine, maple and birch sharply limited conclusions on forest species composition and early disturbance regimes. Frequent records on 'pine' were theorized to be white pine, but no definitive statements could be made. This severely limited inferences on historical disturbance regimes. (Both jack and red pines require more frequent and intense disturbance than white pine (Burns and Honkala 1990; Bonnicksen 2000).) Likewise, general references to 'birch' were believed to be mainly yellow birch, a species generally considered to be intermediate in shade tolerance and a common gap-phase component of hemlock dominated forests (Burns and Honkala 1990). However, the possibility that such references connote early-successional white birch could not be definitively eliminated.

General usage of the term 'fir' to denote several species of conifer may have led to a reduction in spruce and hemlock records, and inflated levels of balsam fir. Furthermore, hemlock does not grow in Europe, and so many European immigrants did not differentiate it from other short-needled conifers (Forman and Russell 1983).

CONCLUSIONS

Historical documents offer much information on early forests and the causes of forest change, and they have been previously under-utilized. The pre-European Acadian mixedwood forest consisted of a high diversity of species. In the area of Kouchibouguac National Park and adjacent landscape, forests were mainly of mid- to late-successional conifer species, particularly eastern hemlock, red and black spruce, and white pine, forming varying associations with late-successional hardwoods, dominated by beech, maple, and yellow birch. These and numerous other characteristic species, such as eastern cedar, and balsam fir comprised dynamic associations, shaped by disturbances, (not yet fully defined), and interwoven with ranges of preferences for moisture, soil types and other edaphic variables. Trees were often of large diameter and height classes, forming closed canopies, with lichen-covered trunks and branches. Forest understory was relatively open, (particularly farther away from the coast), with a sparse, very shade-tolerant understory, and sometimes large amounts of coarse woody debris, often moss covered.

The predominance of early-successional woodlands today (white spruce, fir, poplar, jack pine and white birch), give a very inadequate picture of the nature of the pre-European settlement forest, and its former tree sizes and yields, and the general capacity of the landscape to grow forests. Historical documents clearly point to a landscape where fire disturbance was much less frequent than today.

Historic forest descriptions, despite their qualitative nature, can provide useful evidence of historical forest types, and may in some cases foster more in-depth scientific examination of accepted ecological theories or beliefs. Such documents assist in understanding the complex interacting causes of present forest trends, and can better enable us to predict the resilience of some forest types and development of new forest communities.

Table 2.1 Forest composition during 17th and 19th centuries based on historical descriptions.

SPECIES	RECORDERS														TOTAL	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
CONIFEROUS															[illegible]	[illegible]
Abies balsamea	ɵ	○	○	●	●	○	○		○↓	○	○		○	○	**2**	12
Larix laricina	ɵ	○	○	○		○	○		○	○	○	●	○	○	**1**	13
Picea sp.	ɵ	○		●	●↓			●↓							**3**	5
Picea glauca			○	○		○	○			○	○		○	○	**0**	8
Picea mariana			○	○		○	○		○	○↓			○↓	○↓	**0**	8
Picea rubens			○	○	○↓	○↓	○↓			○↓	○↓		○↓	○↓	**0**	9
Pinus sp.	ɵ	○		●	●				●						**3**	5
Pinus banksiana			○	○	○↓	○	●			○	○		○		**1**	8
Pinus resinosa			○	○		○	○			○	○	●	○		**1**	8
Pinus strobus	ɵ	○	○	●↓	○↓	○	○		●	○	○	●	○	○	**3**	13
Thuja occidentalis		○	○	○	○	○	○		○	○	○	●	○	○	**1**	12
Tsuga canadensis	ɵ	○	○	●	○	○	●	●	●	○	○		○	○	**4**	13
TOTAL CONIFEROUS	**6**	**7**	**10**	**10**	**8**	**10**	**9**	**2**	**7**	**10**	**9**	**4**	**10**	**8**	**8 spp.**	**10 spp.**
BROAD-LEAVED																
Acer sp.	ɵ	○		●	○				○	○		●			**2**	7
Acer rubrum			○	○		○	○			○	○↓		○	○	**0**	8
Acer saccharum		○	○	○	○	○	○		●	○	○		○	○	**1**	11
Acer spicatum			○			○	○						○		**0**	4
Betula sp.	ɵ	○		●	○				●			●			**3**	6
Betula alleghaniensis			○	●↓	○	○	○			○	○		○	○	**1**	9
Betula papyrifera		○	○	○		○	○		●	○	○		○	○	**1**	10
Betula populifolia			○	○		○	○			○	○		○	○↓	**0**	8

Table 2.1 (cont.) Forest composition during 17th and 19th centuries based on historical descriptions.

SPECIES	RECORDERS														TOTAL	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
Fagus grandifolia	ө	○	○	○	○	●	○		●	○	○	●	○	○	3	13
Fraxinus sp.	ө	○			○										0	3
Fraxinus americana			○	○	○	○	●			○	○		○	○	1	9
Fraxinus nigra		○	○	○		○	○			○	○		○	○	0	9
Ostrya virginiana			○	○		○	●			○	○		○	○	1	8
Populus sp.	ө	○							●						1	3
Populus balsamifera			○	○		○	●			○	○		○	○	1	8
Populus grandidenta			○	○		○	○			○	○		○↓		0	7
Populus tremuloides			○	○		○	○			○	○		○	○	0	8
Quercus rubra	ө	○	○	○	○	○	●			○	○		○	○	1	11
Ulmus americana	ө	○	○	○	○	○	○		○	○	○		○	○	0	12
TOTAL BROAD-LEAVED	7	10	15	14	9	15	15	0	7	14	14	3	15	13	9 spp.	15 spp.
TOTAL # species/recorder	13	17	25	24	17	25	25	2	14	24	23	7	25	21		
									TOTAL SPECIES						17 spp.	25 spp.

1. Alexander 1849, 2. Atkinson 1844, 3. Bailey 1876, 4. Cooney 1832, 5. Denys 1672, 6. Fowler 1878, 7. Fowler 1885, 8. Gubbins 1813, 9. Johnston 1851, 10. Monro 1855, 11. Monro 1862, 12. Perley 1842, 13. Perley 1847, 14. Perley 1863

○= grew throughout the province, and probably also inside the study area.

ө= recorded specifically within the Eastern Lowlands Ecoregion, and therefore likely occurred in study area.

●= recorded within the study area.

↓= interpreted to be present according to characteristic descriptions, or from former nomenclature, (e.g. 'black birch' = *B. alleghaniensis* (↓); 'black spruce' = *Picea mariana*, and also *P. rubens* (↓)).

Inside= recorded specifically inside study region.

Regional= record implied a general distribution, including the study region.

Table 2.2 Forest composition from the Bend (Moncton) to Gaspereau River in 1844 (Alexander 1849).

Species / Vegetation Type	**Canopy Position**	**Context**	**Pg.**
fir	unknown	fir twigs for bed	42
pine and maple	dominant	"*covered the whole country on every side*"	77
hemlock, spruce, maple and birch	dominant	at Lutz's Mountain	110
hemlock	witness tree	Moncton	112
hemlock	witness tree		113
birch trees	dominant	large trees used as a backing for campfires	113
fir	unknown	broke off twigs for bed	114
moosewood	understory		121
fir	understory or subdom.	young fir trees	122
spruce (bog)	dominant	"*spruce barrens*"	123
grass-sedge (meadow)			127
white pine	super-canopy	used as a lookout. (Could see Butternut Ridge from there.)	128
fir, spruce, birch (riparian)	dominant	on banks of New Canaan River, (Mile 14)	129
birch, beech, pine, larch, fir, red oak, maple, hemlock	mixed wood	Mile 17 from Moncton	131
spruce	witness tree	growing on bog between fertile tracts	131
grass-sedge (meadow)		fertile meadow.	131
spruce, fir, birch, ash, maple	dominant	surrounding a spring (Mile 21)	133
grass-sedge (fen)		meadow with stream (~80 acres of meadow) (Mile 28)	133
fir, pine, maple, beech, hemlock	dominant	These trees "*rose from ground like pillars of a pagan temple*". Growing on a ridge. No signs of former fire. *~22-24 km from where Coal Br. intersects hwy 126.	133
hemlock, fir, spruce, maple, birch (riparian)	dominant	"*Old forest land*"	152
hemlock, spruce, fir, birch, poplar (riparian)	dominant	"*Many signs of lumbering*"	156

Table 2.2 (cont.) Forest composition from the Bend (Moncton) to Gaspereau River in 1844 (Alexander 1849).

Species / Vegetation Type	**Canopy Position**	**Context**	**Pg.**
hemlock, "*& etc*" (riparian)	dominant	mixed old-growth hemlock stand	157
elm (riparian)	dominant patches	"*In some places there were natural bowers formed with the elm trees*" on Salmon R.	166
hardwood ridges	dominant	*"Good hardwood ridges"*	176
hardwood ridges	dominant	*"Hardwood ridges and intervale land"*	180
unknown		*"We got into indifferent land"[ ], crossed a "barren tract"*	182
spruce, balsam fir	dominant	Made camp among a spruce-fir stand.	182
pine	former dom.	"*pine forests*" burned from Miramichi Fire	186

Table 2.3 Species frequency summary of forest composition from The Bend (Moncton) to Gaspereau River in 1844.

Species	Number of times noted as dominant forest cover
hemlock	8
spruce	8
balsam fir	7
maple	6 *(+ 2 hardwood ridges)
birch	5 *(+ 2 hardwood ridges)
pine	5 (white pine specified at least once)
beech	2 *(+ 2 hardwood ridges)
poplar	1
elm	1
larch	1
ash	1
red oak	1

(Alexander 1849)

* hardwood ridge (pg. 141) described as "*hemlock, maple, etc*".

Table 2.4 Historical descriptions of forest structural characteristics.

SPECIES	HEIGHT	DIAMETER	COMMENTS
Coniferous			
Pinus strobus	24 m (80 ft) (Oromocto-Bay of Fundy)[7] 24-31m (80-100 ft)[2]. Frequently acquires 49 m (160 ft) [1,3] Occasionally 61m (200 ft)[1] Rare instances to over 37 m (120 ft)[8]	0.46 m (18 in)[7] 1.2 m (4 ft)[1] Occasionally 1.5 m (5 ft) at the butt[1,3] at 3 ft from the ground [3]	The most majestic of all the American pines[3] Its summit is seen at an immense distance, aspiring towards Heaven, far above the heads of surrounding trees[3] One of the largest, tallest trees in NB[8]
P. resinosa	21-24 m (70-80 ft)[3]/ 18-31 m (60-100 ft)[2] Sometimes attains 27 m (90 ft)[8]	2 ft and upwards[3] Sometimes 0.9 m (3 ft) or more[8]	Uniform size of trunk for 2/3 of its length[3]
P. banksiana			Scrubby growth[8]. A mere shrub[1]
Larix laricina	24 m (80ft) or more[3,4,7], particularly if close grown[1] 18-31 m (60-100 ft)[2]	0.6 m (2 ft)[1,3,4,7]	Trees of this large size and even larger are most abundant in Kent and Northumberland, and Gloucester Counties[3] Such dimensions were common throughout NB of "greater or less size"[4]
Picea rubens	12-31 m (40-100 ft)[2]/ 21-24 m (70-80 ft)[3,4]	46-61 cm(18-24 in.)[3,4]	Can tower 6-9 m (20-30 ft) above the other forest trees[3]
P. glauca	Rarely exceeding 15 m (50 ft)[3] 15-31 m (50-100 ft)[2]	Rarely exceeding 41 cm (16 in) at 0.9 m (3 ft) from the ground[3]	More tapering trunk than [red spruce] and inferior in stature[3]
P. mariana	15-31 m (50-100 ft)[2]		
Tsuga canadensis	Frequently 18-24 m (60-80 ft)[3,4]/12-31 m (40-100 ft)[2] -12m (40 ft)[2]	0.6-0.9m (2-3ft) [3,4]	Uniform diameter for 2/3 of its length[3,4] Large limbs are usually broken off 1.2-1.5 m (4-5 ft) from trunk[3] Sometimes grows as large as pine[6]
Thuja occidentalis	4.6-6m (15-20ft) [3]; 8 m (25 ft) [2] Up to 12m (40ft) [4]/ Seldom exceeds 12-15 m (40-50 ft)[3]	Rarely more than 0.6 m (2ft) [3] 0.6 m (2 ft) or more at base[4]	Usually not more than 25-38 cm (10-15 in) in diameter at 1.5 m (5 ft) from the ground[4] When close grown, trunk is straight and without branches to height of 4.6-6 m (15-20 ft)[3].
Abies balsamea	11-31 m (35-100 ft)[2] Rarely exceeds 12 m (40 ft)[3,4]	31-41 cm (12-16 in)[3,4]	Tapers from [31 cm] in diameter at ground level to 18-20 cm (7-8 in) at 1.8 m (6 ft) [3].

Table 2.4 (cont.) Historical descriptions of forest structural characteristics.

SPECIES	HEIGHT	DIAMETER	COMMENTS
Broadleaf			
Acer rubrum	14 m (45 ft)[2]		"neither attains the size nor the height of the sugar maple"[3]
A. saccharum	12 m (40 ft)[2]. Not exceeding 15-18 m (50-60ft)[3, 6, 8] Frequently more than 18 m (60ft)[1] Frequently reaches 21-24 m (70-80ft)[3,4] Sometimes rising to 21-24 m (70-80 ft)[8]	46-56 cm (18-22 in)[3, 6] Sometimes exceeding 0.6 m (2 ft)[1] 31-46 cm (12-18 in)[3,4]	More common dimensions[3]
A. spicatum	Ordinary height is 3 m (10 ft)[8]. Seldom exceeding 4.6-6 m (15-20 ft)[1, 3, 8]		Rarely attaining the height of a true tree[8] Frequently shrub-like[3]
A. pensylvanicum	Seldom exceeds 4.6-6m (15-20 ft)[1, 3, 8] 4.6 (15 ft)[2], Ordinary height 3 m (10 ft)[3]	Proportional to height[1]	-can reach more than 6 m (20 ft) in height[3].
Betula alleghaniensis	12 m (40ft)[2]/largest size: 18-21m (60-70 ft)[3,4]	More than 0.6 m (2 ft)[3,4]	Trunk is straight and destitute of branches for 9-12 m (30-40 ft)[3] Noted as having the same dimensions as black birch[2]
*B. lenta**	12m (40 ft)[2] 21m (70 ft), sometimes exceeding[3] 18-21 m (60-70 ft)[4]	0.8m (2.5 ft)[3]/largest attain 0.9 m (3 ft)[3] More than 0.6 m (2 ft)[4]	The handsomest [ ] of the birches[8]
B. papyrifera	11 m (35 ft)[2], 21-24 m (70-80 ft)[8] Largest size approx. 21m (70 ft)[3]	0.6 m (2 ft)[8] 76 cm (30 in)[3]	
B. populifolia	Commonly 6-7.6 m (20-25 ft), sometimes to 14 m (45 ft)[3] (12 m (40 ft)[2]/ Under favourable circumstances, attains 9-12 m (30-40 ft)[8]	Not more than 23 cm (9 in)[3]	Does not attain great heights[1] (Monro[2] may have confused heights with white birch)
Fagus grandifolia	12 m (40 ft)[2]/ Frequently 18m (60ft)[1,3] Attains a height of not less than 21 m (70 ft)[8]		When growing in competitive situations, such as groves[1,3] Boles "clear of branches to a considerable height."[3]/ "No tree forms such a complete roof; but no verdure is found under its shade"[3]
Fraxinus nigra	Not exceeding 12m (40 ft)[3]	0.3 m (1ft)[3]	9 and12 m (30 and 40 ft) for *F. juglandifolia* and *F. sambucifolia*, respectively[2]
F. alba	18 m (60ft)[1]/12 m (40 ft)[2] Sometimes 15-18 m (50-60 ft)[3,4]	About 0.6 m (2 ft)[1] 46 cm (18 in) or more[3,4]	Trunk perfectly straight, often undivided to a height of more than 9 m (30 ft)[3,4]

Table 2.4 (cont.) Historical descriptions of forest structural characteristics.

SPECIES	HEIGHT	DIAMETER	COMMENTS
Ostrya virginiana	6 m (20 ft)[2]. Ordinary stature 4-4.6 m (12-15 ft)[3], Rarely reaches 11 m (35 ft)[3] Sometimes reaching 8-9 m (25-30 ft)[3] Seldom more than 9-12 m (30-40 ft)[1]	15 cm (6 in)[3] Rarely 0.3 m (12 in)[3]	Commonly only reaching half the dimensions indicated[3] Growth is of "smaller dimensions than in a more southern latitude"[3].
Populus grandidentata	15-18 m (50-60ft)[1,3] 18 m (60 ft)[2]	0.6 m (2 ft)[1] 0.5 m (18 in) or more[3]	
P. tremuloides	9 m (30ft)[3]/ 12 m (40 ft)[2] 6-12 m (20-40 ft)[8]	0.1-0.15 m (5-6 in)[3]	Small, but graceful tree[8]
P. balsamifera	8 m (25 ft)[2] to 9 m (30 ft)[6], Largest 24 m (80 ft)[3]	Upwards of 0.6 m (2 ft)[3]	
Quercus rubra	21-24 m (70-80 ft)[1]/18 m (60 ft)[2]	Over 0.9 m (3 ft)[1]	"very commonly rises to [15m] 50 ft without a branch"[1]
Ulmus americana	Occasionally 31 m (100ft)[1] 15 m (50 ft)[2] 24-31 m (80-100ft)[3,4]	1.2 m (4 ft)[1] 0.9-1.2 m (3-4 ft)[3,4] Occasionally girthing 20 ft (6 m) diameter[8]	Regularly shaped trunk to 18-21 m (60-70 ft), where it divides into 2-3 primary limbs[3]. When closed grown, tree often supports two or more small branches 1.2-1.5 m (4-5 ft) long, "proceeding from first ramification, and descending along the trunk"[3].

* Recorded to have been in New Brunswick, but was possibly old-growth yellow birch (*B. alleghaniensis*).

1. Monro 1855, 2. Monro 1862, 3. Perley 1847, 4. Perley 1863, 5. Johnston 1850, 6. Cooney 1832, 7. Atkinson 1844, 8. Bailey 1876.

Table 2.5 Observations of forest structure from The Bend (Moncton) to Gaspereau River in 1844, by J. Alexander (1849).

Stem size	**Spacing**	**Age**	**Condition**	**Context**	**Pg.**
			dark woods (closed canopy)	general description of NB woods	27
		"*old*" hemlock		Witness tree at Mountain Settlement (Moncton)	113
large diam.				"*cut down large birch trees for back-logs for the three fires*"	113
tall				woodpeckers climbing "*tall stems*"	114
(mainly large)	(no openings between stands to allow air circulation)	-"*primeval forests*" - forests exist "*since the deluge*" -old growth	-humid -little air circulation in "*dense forest*" -breezes cannot penetrate to forest floor	"*air seems to stagnate there, and the closeness is often times terrible to bear*". Breezes are only "*heard*" in the treetops, and the closeness of the air is accompanied by several species of pests, such as blackflies.	116
	(variable)	- mixed with young & middle-aged trees	-"*entangled with prostrate trees*" , coarse woody debris, (gap replacement)	Spoke of difficulties hewing the survey line through a mix of forest structures; prostrate trees were entangled with young, middle, and very old age classes.	116
tall trees	open			"*tall trees, not too closely set*"	119
tall stems (large trunks)	(open)		Surrounded by forests of large, tall trees, close grown, devoid of lower branches.	Gave "*praise*" [ ] to the "*mighty forests, which lifted their lofty stems and green tops on every side*"	120
large diameter			- prostrate log, coarse woody debris	Used log for a clothes wash tub by cutting a "*deep*" "*square hole*".	120
(large)			dark forest (close canopy)		121
			- prostrate logs, coarse woody debris - shaded understory.	"*Sometimes [ ] had hard work*" to get over "*logs and entangled twigs of the moosewood*"	121

Table 2.5 (cont.) Observations of forest structure from The Bend (Moncton) to Gaspereau River in 1844, by J. Alexander (1849).

Stem size	**Spacing**	**Age**	**Condition**	**Context**	**Pg.**
large trees	(open)	- old logs - young fir	- prostrate trunks (i.e. coarse woody debris) - *"dead silence around"* - shaded moss forest floor - humidity levels sufficiently high for moss/ to decay logs	Ate lunch where *"large trees lay prostrate, decayed, covered with [ ]moss, and on which young fir trees grew"*..."*old logs*"... (Alexander theorized that the trunks there may have been caused by fire disturbance 70-80 yrs earlier.)	122
large, tall trunks	(no large openings for viewing distances)			*"I ascended large trees to look out"*	128
	(no stand openings)		Deeply shaded tracts of forest, (close canopy).	*"The prospect was everywhere the same. To the far horizon wide diffused a boundless deep immensity of shade"*	128
tall trees				Riparian forests "*covered with tall trees*"	129
-tall trees, 33.5 m (110 ft) -lge. diam.	(open)	old growth	- 'Cathedral-like' forest. - A "*ridge*" of such growth conditions.	*"A ridge of very noble trees of the ancient forest* [ ]. *The trees of 110 ft [ ] rose from the ground like pillars of a pagan temple"*. (*~ 22-24 km from where Coal Branch intersects Rte. 126.)	133
		old growth		"*old forest land*", riparian	152
tall (large)				riparian forest of "*lofty*" hemlocks, spruce, etc.	156
- lge. diam. trunks (sev. spp.) - 4000 board ft/acre		- at least 300 yrs old -"*old forest land*"		- Forest of *"hemlocks, &c., are at least three hundred years old and difficult to remove"* for road building. - "four thousand feet of boards might be got out of an acre of this land".	157

Table 2.5 (cont.) Observations of forest structure from The Bend (Moncton) to Gaspereau River in 1844, by J. Alexander (1849).

Stem size	Spacing	Age	Condition	Context	Pg.
large	open		-Large hummock/hollow depressions here and there from large trees uprooting. (retain surface water.).	"*We sometimes made our camp beside a forest well, the hollow formed by the upturned root of a large tree*",[ ] *which the roots flung themselves aloft like the trunks of elephants*".	157
large trees				around a spring near Salmon River	159
large trees				riparian forest on Salmon River	160
tall spruce	no large stand openings		"*all was lightless and silent*", a vast unbroken forest	Referring to the "*vast bank of green forest*" viewed west of the Salmon River, "*without any apparent savannahs, prairies, or ridges*".	162-163
	open			passed over "*tolerably open country*" for 2 miles (to reach the Upper Gaspereau).	182

* Comments in parentheses were deduced from descriptions provided by Alexander (1849).

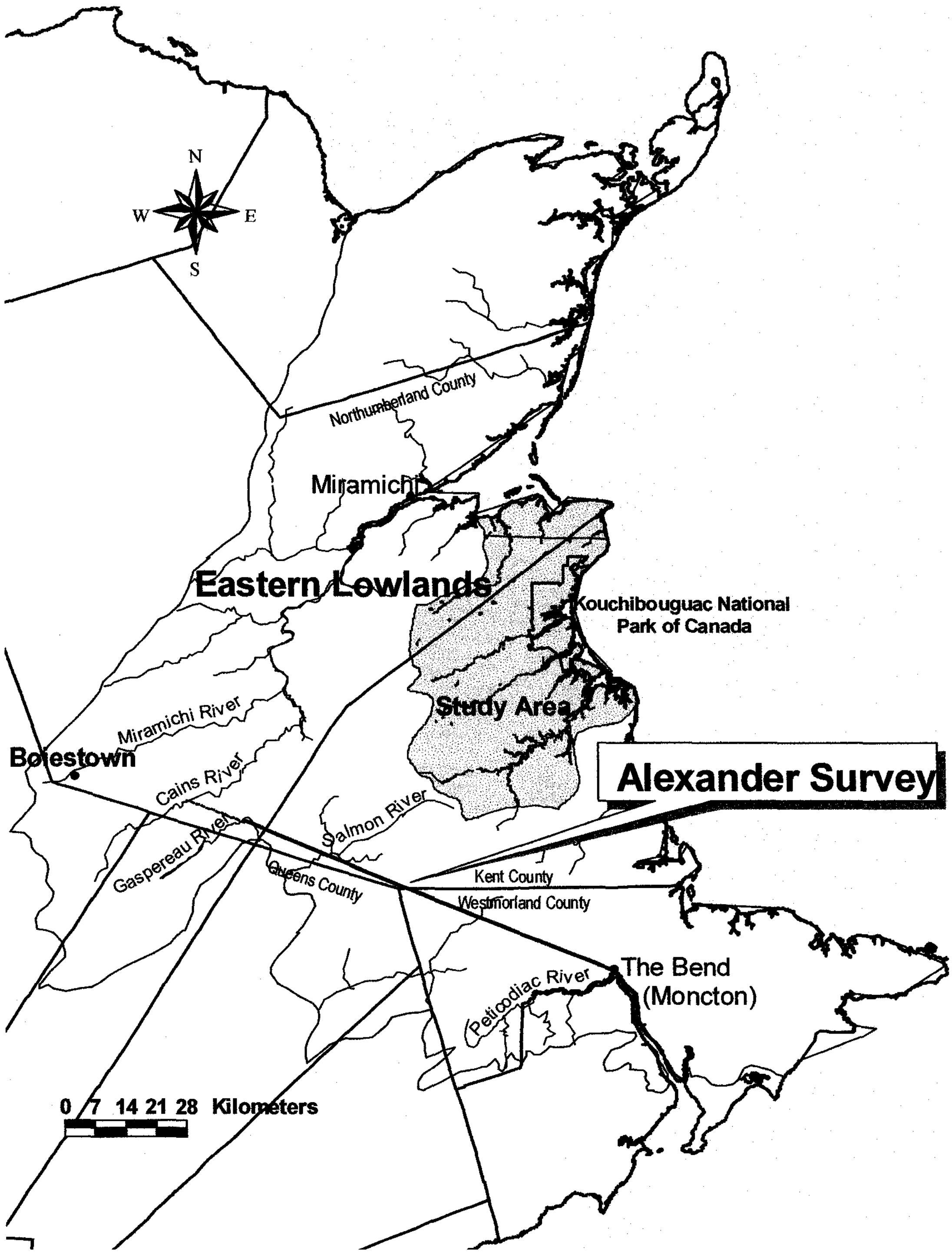


Figure 2.1 James Alexander survey route during 1844 through the Eastern Lowlands ecoregion.

REFERENCES

Adams, A.L. 1873. Field and forest rambles, with notes and observations on the natural history of eastern Canada. Henry S. King & Co., London, England, 333 pp.

A. D. Revill Associates. 1978. Ecological effects of fire and its management in Canada's national parks: a synthesis of the literature. Vols. 1and 2. Lit. Rev. & Annot. Bibliography. Ottawa, ON: Parks Canada, National Parks Branch, Natural Resources Division. 345 pp.

Alexander, J.E. 1849. L'Acadie, or, Seven years' explorations in British North America. H. Colburn. London, England, 370 pp.

Atkinson, C. (Rev.) 1844. Historical and statistical account of New-Brunswick, B.N.A. Anderson and Bryce, Edinburgh, Scotland. 284 pp.

Bailey, L.W. 1876. The woods and minerals of New Brunswick, being a descriptive catalogue of the trees, shrubs, rocks and minerals of the province, available for economic purposes. Daily Telegraph Steam Job Rooms, Saint John, NB. 50 pp.

Beavan, F. 1845. Sketches and tales illustrative of life in the backwoods of New Brunswick, North America. George Routledge, London, 146 pp.

Betts, M. and Loo, J. 2002. A comparison of pre-European settlement forest characterization methodologies. The Forestry Chronicle, 78(3): 422-432.

Biggar, H.P. 1924. The voyages of Jacques Cartier, introduction and translation by Biggar, H.P., Publication No. 11, Public Archives of Canada, ON.

Bonnicksen, T.H. 2000. America's ancient forests. John wiley & sons, Inc. NY. 594 pp.

Bruncken, E. 1900. North American forests and forestry. G.P. Putnam's Sons, NY. 265 pp.

Burns, R. M., and Honkala, B. H., tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol. 2, 877 pp.

Campbell, P. P. 1793. Travels in the interior inhabited parts of North America, in the years 1791 and 1792: in which is given an account of the manners and customs of the Indians, and the present war between them and the federal states, the mode of life and system of farming among the new settlers of both Canadas, New York, New England, New Brunswick, and Nova Scotia. The Champlain Soc. Publication 23, vol. 8, p. xxi-326.

Chapman, J.A. and Feldmar, G.A. (Eds.) 1982. Wild mammals of North America. The John Hopkins Univeristy Press, Balitmore and London, 1147 pp.

Clermont, N. 1986. L'adaptation maritime au pays des micmacs, *In* : Martijn, Charles A. 1986. Les micmacs et la mer. Recherches amérindiennes au Québec, Montréal, Qué. p 11-27.

Cooney, R. 1832. A compendious history of the northern part of the province of New Brunswick and of the District of Gaspe in Lower Canada. Joseph Howe, Halifax, NS. 158 pp.

Crossland, D. 1998. Recent fire history of Kouchibouguac National Park. Parks Canada-Technical Reports in Ecosystem Science #013, Cat No. R61-2/19-13/1997E, 41pp.

Daigle, L.C. 1948. Histoire de Saint-Louis-de-Kent. L'Imprimérie Acadienne Ltée, Moncton, N.-B. 245 pp.
Denys, N. 1672. Description geographique et historique des costes de l' Amerique septentrionale, avec l'histoire naturelle de Pais. Republished English translation by Ganong, W.F. (Ed.). 1908. The description and natural history of the coasts of North America (Acadia). The Champlain Society, Greenwood Press, NY.
Earle, R.D. and Kramm, K.R. 1982. Correlation between fisher and porcupine abundance in Upper Michigan. Am. Midland Nat. 107(2): 244-249.
Ellsworth, J.W. and McComb, B.C. 2003. Potential effects of passenger pigeon flocks on the structure and composition of presettlement forests of eastern North America. Conservation Biology 17(6): 1548-1558.
Fish, W.E. 1880. Orders of survey. Deputy Fish's report in answer to orders of survey issued in relation to hemlock bark lands. In: Journals of the House of Assembly of the province of New Brunswick, Fourth Session of the 24th General Assembly,1882, Supplementary Appendix, Fredericton, NB. 31-32 pp.
Fisher, P. 1980. The first history of New Brunswick. Larson's Printing, Woodstock, NB. 133 pp.
Forman, R.T.T. and Russell, E.W.B. 1983. Commentary: Evaluation of historical data in ecology. Bulletin of the ecological society of America 64 (1) 5-7.
Fowler, J. 1873. Unpublished correspondence to a colleague. Source: Buffalo Museum of Science, Buffalo, NY.
Fowler, J. 1878. List of New Brunswick plants. Report for the Secretary of Agriculture, Appendix B., Fredericton, NB. p. 35-63.
Fowler, J. 1885. A preliminary list of the plants of New Brunswick. Ellis Robertson and Co.-Globe Press, St John, NB. 82 pp.
Gabriel, W. and Walters, R. 1990. *Acer pensylvanicum*; striped maple. *In*: Burns, R.M. and Honkala, B.H. (Tech. Coords.) 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. US Dept. of Ag. , Forest Svc. Washington, DC. vol. 2, 877 pp.
Ganong, W.F. n.d. Flora of New Brunswick, unpublished typescript by W.F. Ganong, NB Museum, Archives, F.186.
Ganong, W.F. 1902. Great forest fires in New Brunswick. Bulletin of the Natural History Society of New Brunswick, 4 (20): 434-435.
Ganong, W.F. 1904. A monograph on the origins of settlements in the province of New Brunswick. Vol X, Sec. 2, James Hope & Son, Ottawa, ON.
Ganong, W.F. 1906 a. Additions and corrections to monographs on the place-nomenclature, cartography, historic sites, boundaries and settlement-origins of the province on New Brunswick. From the transactions of the Royal Society of Canada, second series-1906-1907. Vol. XII.
Ganong, W.F. 1906 b. Notes on the natural history of New Brunswick. 90. On the limits of the great fire of Miramichi of 1825. Bulletin of the Natural History Society of New Brunswick, 5 (24): 410-418.
Ganong, W.F. (Ed.) 1908. The description and natural history of the coasts of North America (Acadia) by Nicolas Denys. The Champlain Society, Toronto, ON.
Gleason, H.A. and Chronquist, A. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. Second edition. New York Botanical Garden, NY. 910 pp.

Godfrey, W.E. 1979. The birds of Canada. National Museum of Natural Sciences, Ottawa, ON. 428 pp.
Gorham, R.P. n.d. A bit of the primitive forest. Unpublished report. Raymond Paddock Gorham collection, PANB, MC 211.3.7.21, 1 pg.
Graham, S.A. 1941. The question of hemlock establishment. J. For. 39(6): 567-569.
Graham, S.A. 1943. Causes of hemlock mortality in northern Michigan. U. Mich. Sch. For., Conser. Bull. No. 10.
Grant, G.M. (Ed.) 1882. Picturesque Canada: the country as it was and is. Vol. I. Belden Bros. Toronto, ON. 491pp.
Gray, D.R. 1999. Updated status report on the woodland caribou (caribou des bois) *Rangifer tarandus dawsoni* and *R. tarandus caribou* in Canada. COSEWIC, Grayhound Info. Svcs. ON. 36 pp.
Grimmer, W.C. 1913. Extract from address to Canadian Forest Convention, Bulletin of the Natural History Society, No 30, vol. 6, part 5: p. 452.
Gubbins, J. 1813. *In*: Temperley, H. (Ed.) 1980. Gubbins' New Brunswick Journals 1811 and 1813. NB Heritage Publications, Fredericton, NB. 74 pp.
Hackluyt, R. 1598-1600. The principal navigations, voyages, traffics, and discovers of the English nation, 3 vol., p. 255. *In*: Hannay, J. 1979. The history of Acadia, from its first discovery to its surrender to England. J.A. McMillan, St John, NB. 440 pp.
Hannay, J. 1902. New Brunswick, its resources and advantages. Crown Land Dept., NB. 208 pp.
Hannay, J. 1979. The history of Acadia, from its first discovery to its surrender to England. J.A. McMillan, St John, NB. 440 pp.
Hosie, R.C. 1990. Native trees of Canada. Fitzhenry and Whiteside Ltd., Ont. 380 pp.
Johnston, J.F.W. 1850. Report on the agricultural capabilities of the province of New Brunswick. J. Simpson, Fredericton, NB. 95pp.
Johnston, J.F.W. 1851. Notes on North America. Vol. I and II., C.C. Little and J. Brown, Boston. 512 pp.
Kapusta, P., Szarek-Lukaszewska, G., and Kiszka, J. 2004. Spatial analysis of lichen species richness in a disturbed ecosystem. The Lichenologist 36(3&4): 249-260.
Kinnear, A. 1785. Letter to Edward Winslow, April 21st 1785. *In*: Winslow Papers, A.D. 1776-1826. Raymond, W.O. (Ed.) 1901. New Brunswick Historical Society, The Sun Printing Co. Ltd. St John, NB. p. 298-299
Lamson, N.L. 1990. *In*: Burns, R.M. and Honkala, B.H. (Tech. Coords.) 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. US Dept. of Ag., Forest Svc. Washington, DC. vol. 2, 877 pp.
LeClercq, C. 1691. New relations of Gaspesia: the customs and religion of the Gaspesian cross-bearer Indians, worshippers of the sun, and other peoples of North America, called also Canada. Republished English translation by Ganong, W.F. 1910. The Champlain Society, Toronto, ON. 452 pp.
Little, G.E. 1961. The birthplace of Andrew Bonar Law and the early history of Kent County. In: Collections of the New Brunswick Historical Society. No 16. Langley Printing Co, Ltd. 70-92 pp.
Loucks, O. L. 1962. A Forest Classification for the Maritime Provinces. Proceedings of the Nova Scotian Institute of Science. Vol. 25, Part 2, p. 85-167.

Manny, L. 1945. The value of larch. *In*: The Chatham Gleaner, edition Oct 11, 1945: Scenes from an earlier day: Miramichi- A hundred years ago. The Commercial and the World, Chatham, NB.

McCune, B. 1988. Ecological diversity in North American pines. Am. J. Bot. 75(3): 353-368.

Monro, A. 1855. New Brunswick; with a brief outline of Nova Scotia and Prince Edward Island. Their history, civil divisions, geography, and productions. Richard Nugent, Halifax, NS. 384 pp.

Monro, A. 1862. Native woods of New Brunswick. Book made of wood containing wood samples. Woodwork by Stephen Truman, Westmorland, NB. 14 pp.

Mosseler, A., Lynds, J.A., and Major, J.E. 2003. Old-growth forests of the Acadian Forest Region. Environ. Rev. 11: S47-S77.

Munro, D.R. 1862. A description of the forest and ornamental trees of New Brunswick. Chubb, Saint John, NB. 17 pp.

Perley, M.H. 1842. Reports on Indian settlements, &c. J. of the House of Assembly of the province of New Brunswick, Sixth Session of the twelfth general assembly, (Appendices.). J. Simpson, Queen's Printer, Fredericton, NB.

Perley, M.H. 1847. Report on the forest trees of New Brunswick. *In:* Simmonds's Colonial Magazine, vol. XI: 42, June 1847, p. 129-423.

Perley, M.H. 1863. Eighty years of progress of British North America, Stebbins, Toronto, ON. 77 pp.

Pierce, unknown. 1845. The value of larch. *In*: The Saint John Courier. Reprinted: Scenes from an earlier day: Miramichi- A hundred years ago. The Commercial and the World. Oct. 11, 1945, Chatham, NB. (Louise Manny collection).

Pringle, C.G. 1884. Report on the principal lumber producing regions of the state [of Pennsylvania]. *In*: Whitney, G.G. 1994. From coastal wilderness to fruited plain. A history of environmental change in temperate North America 1500 to the present. Cambridge U. Press, Great Britain, 451 pp.

Radies, D.N. and Coxson, D.S. 2004. Macrolichen colonization on 120-140 year old *Tsuga heterophylla* in wet temperate rainforests of central-interior British Columbia: a comparison of lichen response to even-aged versus old-growth stand structures. The Lichenologist 36(3 and 4): 235-247.

Richards, C.D. and Prince, G.H. 1928. Forests and forestry in New Brunswick, Special report to the British Empire forestry conference, Minister of Lands and Mines, Fredericton, NB.

Richardson, D.S. and Cameron, R.P. 2004. Cyanolichens: Their response to pollution and possible management strategies for their conservation in northeastern North America. Northeastern Naturalist 11(1): 1-22.

Rogers, R.S. 1978. Forests dominated by hemlock (*Tsuga canadensis*): distribution as related to site and postsettlement history. Canadian J. of Botany. 56: 843-854.

Runkle, J.R. 1991. Gap dynamics of old-growth eastern forests: management implications. Natural Areas Journal 11: 19-25.

Rushmore, F.M. 1969. Sapsucker: Damage varies with tree species and seasons. U.S.D.A. For Svc. Res. Paper NE-136, Upper Darby, PA. 19 pp.

Russell, F.L., Zippin, D.B., and Fowler, N.L. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations and communities: A review. The American Midland Naturalist, 146 (1): 1-26.

Sargent, C.S. 1884. Report on the forests of North America. Dept. of Interior, Census office, Gov. Printing Office, Washington, microfiche CIHM, no. 25264.

Smith, T. 1835. Natural history of Nova Scotia. The magazine of natural history, Dec., vol. VIII:56, p. 641-662.

Smith, T. 1857. A natural resources survey of Nova Scotia 1801-02. Public Archives of Nova Scotia, vol. 380, 179 pp.

Sobey, D. 2002. Early descriptions of the forests of Prince Edward Island: A source book. Part I: The French period- 1534-1758, PEI Dept. Ag. and Forestry, PEI. 180 pp.

Sobey, D.G. and Glen, W.M. 2004. A mapping of the present and past forest-types of Prince Edward Island. The Canadian Field-Naturalist, 118: 504-520.

Stevenson, J. 1900. Deputy land surveyor notes from Crown land survey sketch, PANB Fredericton, NB, microfilm series RS656 34-11.

Taylor, A. 1803. Alexander Taylor's Report, In: Winslow Papers, A.D. 1776-1826. Raymond, W.O. (Ed.) 1901. New Brunswick Historical Society, The Sun Printing Co. Ltd. St John, NB. p. 498-502.

Telfer, E.S. 2004. Continuing environmental change-An example from Nova Scotia. Can. Field-Naturalist 118(1): 39-44.

Temperley, H. (Ed.) 1980. Gubbins' New Brunswick Journals 1811 and 1813. NB Heritage Publications, Fredericton, NB. 74 pp.

Walsh, G.E. 1896. Hemlock for the tanneries. Garden and Forest 9: 222-223, *In*: Whitney, G.G. 1994. From coastal wilderness to fruited plain. A history of environmental change in temperate North America 1500 to the present. Cambridge U. Press, Great Britain, 451 pp.

Weale, L. 1858. Nova-Scotia considered as a field for emigration. Hamilton, Pierce Stevens. Gov. Publications CIHM 44945. 99 pp.

Whitney, G.G. 1994. From coastal wilderness to fruited plain. A history of environmental change in temperate North America 1500 to the present. Cambridge U. Press, Great Britain, 451 pp.

Wilson, A. 1814. American ornithology. *In*: Ellsworth, J.W. and McComb, B.C. 2003. Potential effects of passenger pigeon flocks on the structure and composition of presettlement forests of eastern North America. Conservation Biology 17(6): 1548-1558.

CHAPTER 3. DEFINING FOREST REFERENCE CONDITION FROM WITNESS TREES AND SURVEYOR DESCRIPTIONS.

INTRODUCTION

The 1800s was a period of rapid European settlement along the coastline and rivers in eastern New Brunswick. Government-employed Deputy Land Surveyors were tasked with dividing the landscape into various-sized parcels for new settlers. The bounds of each lot were marked with what was most readily at hand, trees. Such markers, termed 'witness trees' were chosen following careful measure, using chain and compass, then blazed and inscribed with appropriate information, such as year of survey and surveyor initials (Monro 1844). Very few, if any, of these early witness trees remain on the current landscape, but evidence of the types of trees marked by land surveyors remains in their plan drawings stored in archives.

Witness tree information collected from land survey sketches allows a rare opportunity to quantitatively analyze species composition at the earliest period of European settlement (Lorimer 1977; Abrams and Ruffner 1995; Lutz 1997). Forests in each major watershed in the study area began to be modified and subjected to land clearance activities and logging during the early 19^{th} century. Knowledge of the basic character of these early forests has been lost following 200 years of European disturbances. There is currently little basis to determine whether management practices will result in ecological conditions that fall outside the range of historic variability. Decisions in forest management in the Acadian forest region are generally not based on knowledge of early forest conditions, and have been vulnerable to supposition, individual interpretation and industrial forest interests (Betts and Forbes 2005). Witness trees may assist in describing a historic reference condition, useful in sustainable management of ecosystems. Specifically, witness tree research is useful in indicating what forest components and associated processes were dominant prior to widespread European alterations. This information may provide assistance to managers of Kouchibouguac National Park who are interested restoring forest ecosystems to a more representative state considered appropriate for the Eastern Lowlands (Loucks 1962).

Since all historical forest information collected in this study originated from land survey records made by deputy surveyors, some knowledge of their educational background and responsibilities is useful in evaluating their records. All early Deputy Surveyors were Loyalists and former military engineers appointed by the Governor (Thomson 1966). They resided in the area where they were employed and so were familiar with local forest types. Besides surveying, they carried out other important responsibilities, such as inspecting timber licences and levying fines where appropriate, assessing whether adequate 'improvements' were being made on lands granted to settlers, supervising town settlements, exploring and mapping land, timber and mineral resources, and mediating minor disputes. (Thomson 1966; Anon. Provincial Archives of New Brunswick (PANB)).

BACKGROUND

Earliest land survey information sources

Witness tree information was available for the study area beginning in 1805, while under British survey operations. Previous surveys of the landscape, while under French rule, were not found, and have likely not survived, though French survey methods were well advanced and practiced in Canada during that time (Thomson 1966). The Richibucto River seigniory may have been surveyed, (as were other seigniories along the St Lawrence in the 1600 and 1700s) (Thomson 1966), but detailed surveying was not likely carried out since it was never successfully settled. It is not known whether farmlands of the Acadian people in the area were formally surveyed prior to expulsion from the lands that began in 1755. Records from this period may have been destroyed during the expulsion (A. Doiron, Manager of cartographic records, sound and moving images, PANB, Pers. Comm.). As only a small part of the area studied was subdivided prior to 1800, the surviving survey records, dating from 1805, were interpreted to be the earliest documentary information available for study on early forest composition, prior to widespread European-caused changes.

Types of land surveys and surveyor techniques

Witness trees and forest descriptions originated from two main types of surveys. The most common was the metes and bounds survey, used for dividing land into private lots mainly for farms and homesteads, commonly ranging from 50 to 300 acres (20 to 121 ha). The second was the more systematic rectangular survey and line surveys, for marking block lines and timber reserves into large rectangular allotments of 5-10 thousand acres (approximately 2-4 thousand ha), and linear features, such as geographic meridians and parallels, and early highways (Thomson 1966). Techniques differed between the two types of surveys. Metes and bounds surveys focused mainly on the establishment of corner boundaries using witness trees (or occasionally some other form of marker if no tree was nearby), and noted only occasionally the trees that intersected boundary lines, i.e., 'line trees'. Lots were divided irregularly into various sizes and shapes; the corner boundary locations were often influenced by local geographical features, such as rivers and poorly drained areas. Rectangular and line surveys required survey markers placed at precise intervals, using trees, or stakes when trees were not situated appropriately for marking. There were some variations among the rectangular survey methods. In two rectangular surveys, posts were used as markers at intersections and precise midway locations between blocks and ranges. Posts were made of small tree trunks cut nearby, shorn with an axe, and pounded into the ground. The use of posts appeared to be a later technique in eastern New Brunswick, encountered in study area surveys during 1894 and 1900. In other rectangular surveys, two markers were used to mark corners and quarter sections of each block using a combination of witness trees and/or stakes. As no surveyor notebooks were found to accompany the sketches, it was not confirmed whether these surveyors used techniques similar to those of U.S. General Land Office surveyors, where witness tree diameters and distance information were recorded (Bourdo 1956; Siccama 1971; Lorimer 1977). The systematic pattern of rectangular land concessions adopted elsewhere in Canada was not applied to private land holdings, but was used for timber block surveys.

Each Deputy Surveyor commanded a small team of men, consisting of two chain bearers (men employed to carry the chain for the surveyor), and often one or two axemen to clear the survey lines, and blaze trees. A chain was the basic tool used to measure distance, composed of 100 metal chain links equivalent to 66 ft (~ 20 m) (Monro 1844). Basic metes and bounds survey techniques were consistently applied during the study period according to surveyor instructions dating from 1785, 1824, and 1852. Alexander Monro, an early NB surveyor, aptly summarized the protocol:

"*Corner trees, or bounds, are generally blazed on four sides, and the initials of the Surveyor's name, the initials of the owner's name, and the year on which the survey was made should be impressed on them with a marking iron. Trees standing on the line are generally blazed and marked with three notches, made by striking the axe upwards*" (Monro 1844).

Line trees were very infrequently indicated on sketches, with the exception of rectangular and linear types of surveys. Since large trees that obstructed survey lines were not cut down, a bearing was resumed from the opposite side of the tree, and the line continued (Monro 1844; Alexander 1849). Stakes were used in the event that no tree was present at the end place of measurement. It was assumed that the surveyor cut a sapling growing nearby and staked it on the line or corner. The survey team probably did not carry stakes with them as each person was usually already carrying a cumbersome load of equipment and supplies (Monro 1844; Thomson 1966; D. Wedlock, land surveyor, instructor, Geomatics Dept., COGS, NS, Pers. Comm.). Tree species used for all witness trees, stakes, and posts were noted in surveyor notebooks and on accompanying plan drawings.

As many of the witness trees were located on riverbanks, there were some specific instructions for placement of markers in such areas. According to Monro (1844) bounds of properties on streams were to be marked a sufficient distance from the stream edge so that witness trees would not be lost to erosion on banks that were subjected to undercutting. Sometimes three trees were marked at short intervals on lines proceeding from riverbanks.

All survey details were noted by the surveyor in a field book, and later transcribed to a plan drawing. The sketches noted location and type of boundary markers (usually a tree or stake), as well as property boundary lengths and bearings, scale of drawing, year, and sometimes geographic features, such as poorly drained areas, rivers, roads, and forest descriptions.

Metes and bounds surveys provide an irregular distribution of witness trees throughout the landscape. The earliest settlers occupied large parcels of land along major navigable rivers. Boundaries most often ran perpendicular to river courses. Parallel land parcels were of varying widths and total area, depending on the number of settlers to be accommodated and topography encountered. This resulted in witness trees being spaced at large and irregular distances along watercourses. Records of witness trees were usually absent on the back of these lots. The usual practice when surveying early lots along watercourses was to record only two trees per lot, i.e., those on the bounds of rivers and saltwater bodies. Trees marking the corners away from rivers were apparently not required during the earliest land grants, and were rarely recorded by the surveyors, though distances were clearly measured and marked on the plan. Thomson (1966) provided the best explanation for their absence, stating that surveys in New Brunswick were required to be completed quickly to meet demands from large influxes of prospective settlers. Surveyors therefore "*merely traversed the large rivers, monumenting the fronts of tracts to be occupied*" (Thomson 1966). In later years, properties were laid out to the rear of the first lots, the new lines were tied in to the older bounds, and the four corners of these new lots were then reported. Indeed, this appears to explain the customary survey practices during this time, as Moses Perley (1842) noted that the Indian reserves were not surveyed on the sides or backlands, and were vulnerable to squatters: "*few of the side or rear lines have yet been surveyed, their exact situation therefore, is imperfectly known*" Perley (1842).

Modern databases used for analyses

Ecological Land Classification

The Ecological Land Classification (ELC) categorizes the New Brunswick landscape into ecologically meaningful units (DNRE 1996), which were used to stratify the area for analysis, in order to improve the basis for comparisons of historical and modern forest cover. The ELC divides the province into seven broad 'ecoregions', based on climate and major vegetation trends. The study area is situated in the Eastern Lowlands Ecoregion. Nested within each ecoregion are ecodistricts, (defined by broad-scale features of elevation and geology, as well as slope and aspect), and smaller subunits, ecosections. Ecosections are delineated by breaks in elevation, watersheds, soil lithology and forest cover patterns and associations. The finest physiographic units existing in the ELC are ecosites. Boundaries of ecosites are defined by edaphic factors obtained from regional soil survey information (Wang and Rees 1983), and combined with slope and elevation. Ecosites were ultimately used to define forest characteristics on different landscapes.

The study area contained ecosites 1, 2, 3, 3b, 5, and 6b (Table 3.1). In general, ecosites 1, 2, 3 are considered nutrient poor ecosites, where forest growth is slower, due to high soil acidity and slow nutrient cycling. Moisture progressively increases from ecosites 1 to 3. Ecosite 3b represents wet organic soils, namely sphagnum bogs, in the study region. The best growing conditions in the study area are found on ecosite 5, which features mesic soils and a more neutral pH. Ecosite 6b features poor forest productivity even though soils are fertile. These soils have excessive moisture that often leads to low oxygen levels, slowing the cycling of nutrients (DNRE 1996).

A more recent version of the ELC was released during 2004, with minor changes in ecosite boundaries within the study area. The earlier 1996 version was used as analysis was already underway and the new version would not have changed the results.

Forest Development Survey Database

The Forest Development Survey database (FDS) provided forest information *ca.* 2000. The database contains information on major stand parameters used to assess stages of stand development throughout NB. Merchantable forests were assessed on crown lands, and to a more limited extent on private woodlots that were registered with the Southeast New Brunswick Forest Products Marketing Board. Forest managers apply FDS data to a range of management questions, among the most important, to project wood volumes, predict time to stand maturity, and to track forest management interventions. The database is updated on a continuous, approximately 10-year rotation around the province. Developmental stages of stands are classified by DNR (2004 a) as 'Y-O', corresponding to Young (Y), Immature (I), Mature (M), and Overmature (O). Information is collected on younger regenerating forest stands ranging from 15-30 years (DNR 2004 b). The complete methods for data collection are contained in provincial manuals (DNR 2004a; b).

Forest Cover Database

The forest cover database served to classify vegetation communities based on air photos. Forest cover information guided the field sampling for the FDS database. Sections of the study area were flown and photographed during 1999-2002. Forest polygons were defined and interpreted from the updated air photos, and assigned to a 'Forest Unit Name' (FUNA code). Dominant and secondary forest cover layers were interpreted with up to five species for each layer. Percent stand composition and developmental stage were estimated for each species. Each forest layer was assigned classes of density, height, crown closure, and other parameters (DNRE 2001).

METHODS

Reconstruction of 19th century forest composition from witness tree information

Boundaries of the study area were defined according to the ELC. Three ecosections within the Kouchibouguac Ecodistrict comprised the study area: ecosections: 6-6-2, 6-6-3, and 6-6-4. (See Figure 1.3.) To facilitate recognition of pertinent land grants in the study area, a complete list was made of place names, as well as names of rivers and streams. Changes in place nomenclature were common during the 1800s, particularly in the study area (Ganong 1906), so a list of former place names was also compiled (Appendix 3-1).

Pre-settlement forest descriptions were reconstructed from early government land survey records located at the Provincial Archives of New Brunswick (PANB). Other archives in both NB and NS were examined for additional witness tree information but very little was found. Witness tree information originated mainly from 'plan books' containing surveyor sketch maps of land grants to private citizens. All microfilms containing land grants for Kent and Northumberland Counties from years 1700 to 1990 were searched. Microfilm sources were: F17255, F17256, F17257, F17267, F17268, F17269, F17270, F17271, F17272, F17273. Microfiche sources were: RS656/1C (Northumberland County Survey Plans), RS656/1D (Kent County Survey Plans), RS656/7 (NB House of Assembly Plans, containing county lines and road surveys, etc.) and RS686 and RS687B (Grant Survey Plans). Additional witness tree sources originated from road plans (microfiche RS656/4) and timber licence surveys (microfiche RS656/2B and RS656/13). Railway plans were examined (RS656/3, RS656/9), but forest information was from after 1900 and was therefore excluded.

Researching 19th century documents assisted taxonomic interpretation of early tree names encountered on survey sketches. Species identification was not possible in all cases from witness tree records, but some interpretations were made where research demonstrated a reasonable level of certainty (Table 3.2). 'White maple' records were assigned to red maple (*Acer rubrum*), according to Fowler (1878). Silver maple (*A. saccharinum*) did not occur in the region (Fowler 1878). On two plan drawings, both red and white maples were marked on the same sketch, seeming to indicate that white maple denoted a species other than red maple, possibly *A. saccharum*. In order to remain consistent, however, white maple was retained as red maple. 'Black birch' was assigned to yellow birch (*Betula alleghaniensis*). 'Juniper' was interpreted from survey sketches to have been a former name for larch (*Larix laricina*). The possibility that 'juniper' was intended for eastern white cedar (*Thuja occidentalis*) was eliminated as both 'juniper' and 'cedar' often occurred on the same sketches (sketches L1, e72, G6, f36, z1, c 62, c63, 195).

Locations of all witness trees and other types of survey markers were plotted on corresponding property boundaries of digital cadastral maps using ArcView™ GIS 3.2. Because all original property lines have been preserved, cadastral maps served as base maps for spatial portrayal of historical information. The associated witness tree database contained eight fields: (1) type of survey marker, (2) survey name, (i.e. verbatim surveyor terms for tree names), (3) genus, (using modern nomenclature following Hinds (2000)), (4) species, if known, (5) survey label, (a code, generally consisting of two letters to indicate the tree name used by the surveyor, adapted from species codes used in modern forest databases (Table 3.3)), (6) interpreted label, (an interpretation of early surveyor tree names, using a two letter code to indicate current forest species names), (7) year of survey, and (8) sketch number. Year of survey was not always indicated on the survey sketch; however, it was possible to estimate the decade with a high degree of confidence, based on the dates indicated from other sketches contained within the same survey book, the name of the surveyor employed, the style of the sketch, or the neighbouring land grants indicated on the sketch. Estimated years were assigned mid-decadal values so that the majority of estimated dates can be assumed to be within at least five years of the actual date of survey.

Survey markers consisted mainly of witness trees, but stakes, tree stumps, posts, clumps of bushes, stones, and stream edges were occasionally used. Four types of markers were initially included in the database: tree, tree stump, stake, and post. The term 'witness tree' in this study applies only to trees and stumps left *in situ* that had likely contributed to part of the overstory forest. Stakes were examined for their use in indicating understory species composition, as they were assumed to be made mainly from understory saplings, and probably did not comprise part of the overstory forest. Posts were assumed to be larger than stakes, cut from trunks of larger diameter trees, rather than saplings. Posts were rejected from the witness tree database due to species bias. Furthermore, they were unlikely representatives of dominant forest types, having originated from smaller diameter trees.

Geographical location of all witness trees was overlaid on ecosites from the ELC to estimate the original species composition on each physiographic land type. Five ecosites had adequate numbers of witness trees for analysis (ranging from 83 trees on boggy, ecosite 3b to 1246 trees on ecosite 2).

Witness tree species frequency was assumed to be directly proportional to historical forest species composition during the same period. Also, it was assumed that bias in selection of tree species was not significant. This is further addressed in the Discussion.

Analysis of forest compositional change

Both FDS datasets were used to characterize modern forest composition (i.e. data from regenerating stands, age 15-30 years, called 'FDS 15-30', and 'FDS 99': stands over 30 years old, termed 'Y to O') (DNR 2004 a; b). A total of 100 cruise lines in regenerating stands and 404 cruise lines from older forest stands were stratified by ecosite. Data from all prism plots on a single FDS line were averaged by DNR (2004 a; b) to produce one sample of forest cover *ca*. 2000.

Species distributions were spatially stratified by physiographic unit, (i.e. ecosites), by aid of ArcView 3.2™, in order to make comparisons between historical and modern forest species more robust. Stratification reduced potentially confounding effects of sampling variation in witness trees and FDS cruise lines across the landscape. The ecosites were determined for 472 FDS cruise lines based on the center location of each cruise line (Table 3.1). The extent of forest compositional change was measured by comparing historical tree species frequencies (from witness trees) to contemporary tree species frequencies, (using basal area per hectare (BA/ha), which represents the area occupied in cross section of all trees measured at 1.3 m above ground.) BA/ha has been found to be the most suitable measurement for comparison to witness tree data (Lutz 1997). Stand density or volume measures were not chosen for three reasons; (1) number of stems is strongly influenced by stand age and successional stage; for example, a dense understory growth of *Abies balsamea* with a high stand density value may occupy a proportionally small cross-sectional area of the stand; (2) the number of stems may fluctuate radically over time due to self-thinning and disturbance events, while basal area occupied by dominant trees is more stable; and (3) volume measurements were inappropriate as they include only trees greater than 9 cm DBH (the minimum size requirement for merchantable timber). Basal area was derived using the FDS stand tables, where tallies were obtained for each diameter class and corresponding species. BA was expressed as a percentage for each species on each ecosite.

Data from ecosite 6b were not analysed as the ecosite occupied only 0.5 % of the study area. There were no FDS transects located in this ecosite and it included only 15 witness trees (Table 3.1). Ecosites 1 and 5 were also relatively small, but they were included, as witness tree and FDS representation were judged to be adequate (Table 3.1).

Histograms of historical and modern frequencies for each arboreal species by ecosite were produced using ArcView and Excel.

Reconstruction of 19th century forest composition in riparian zones:

Separate analyses of forest composition in riparian zones were conducted to determine whether riparian forest composition was different from nonriparian forest composition in the four major watersheds of the study area. A 300 m wide buffer zone was drawn on each river, extending approximately 150 m inland from each riverbank. The width of 300 m was an arbitrary unit used to ensure that all witness tree points located along rivers were captured in ArcView. Frequencies of witness trees within the buffer zone along rivers were expressed as percentage by species. Historic forest species composition within the buffer zones was compared to the species composition of more inland forests (i.e. those witness trees not contained within the riparian buffer zones). Differences in historic forest composition between rivers were also characterized.

Forest compositional change in riparian zones was analysed by comparing witness trees in riparian zones with current forest types derived from the modern forest cover database. (The FDS database could not be used for this analysis since it did not contain extensive sampling within riparian zones). The forest cover database required some modification. There was no field that best described general vegetation cover for the purposes outlined. For example, the L1FUNA (dominant layer forest unit name) codes were often non-specific, interpreting forest cover as 'non-commercial species', 'regenerating softwood, or 'tolerant hardwood'.) A new field was created and added to the database, using a combination of dominant forest cover layer information and other fields in order to gain a more precise description of forest condition. The following fields were used: dominant layer forest unit name (L1FUNA), and the first two or three species in the dominant forest layer class (L1S1, L1S2, and L1S3) (DNRE 2001; DNR 2004 a). Most forest cover was derived from combining species from L1S1 and L1S2, but there were exceptions. The 'treatment' field was sometimes used to more accurately describe vegetation cover in units that were non-forested, or exhibited very little forest cover. Examples were agricultural fields, clear cuts or 'cuts', or where there were low percentages (indicated as L1PR1 and L2PR2 in the database) for the two most dominant tree species, and their developmental stages (L1DS1, L1DS2 respectively) were classified as 'regen' or 'sapling'. Codes for nonforested land (NFLC) were assigned the symbol 'CL' (cleared land) where the origin of land clearances was human-caused. Once the modified forest classification was completed for forest polygons within riparian zones, the total area occupied by each type of forest cover was derived through spatial analysis using ArcInfo, and then converted to percentages.

Reconstruction of 19th century forest composition from surveyor stand descriptions

General descriptions of forest cover were extracted from all survey sketches (46 in total), to produce 306 records of forest descriptions. Two types of survey records furnished forest descriptions, and allowed separate analytical approaches. Metes and bounds surveys of individual lots, as well as some highway surveys, provided forest descriptions at irregular intervals. The level of detail recorded was highly variable, largely depending on the style of individual surveyors. As it was impossible in most cases to determine the spatial limits of each description, such descriptions were simply tallied and frequencies derived for each tree species or stand type. Descriptions were placed in three broad landscape classes, according to where the surveyors had indicated them to be on the sketches: coastal forests, inland forests, or riparian zones. Disturbances were also recorded. The second type, rectangular surveys, produced much more detailed forest descriptions noted at regular intervals. Survey lines with the surveyor descriptions were redrawn as line segments in ArcView to match the appropriate length and placement corresponding to each original description. Each segment was coded with the surveyor description, interpreted species or stand type, sketch number, and year. Approximately 22 % of the survey lines were unclassified and entered as 'unknown' species composition because of uncertainty as to where the outer limits of surveyor descriptions were intended to apply. Many of the observations were too general to infer specific forest composition (e.g. 'hardwood', 'softwood', or 'good land'). Total lengths were tallied for all line segments (i.e. historical survey transects). Percentages of each major stand type were calculated based on total lengths that each stand type occupied along survey lines.

Some assumptions about information on surveyor descriptions were necessary to complete both analyses. *P. mariana* was assumed to be the species of 'spruce' on 'barrens' and 'plains' (early surveyor terms for bogs). All references to 'good land' or 'fine land' were interpreted as mainly covered in mixedwood ('HWSW'), although some references may have referred to pure hardwoods. Interpreting these references as mixedwood is modest, considering that a large portion of hardwood stands, (consisting of *B. alleghaniensis*, *Acer* spp., and *F. grandifolia*), were probably mixed with conifer species in widely variable proportions. This assumption was supported by the available surveyor descriptions, plus 19^{th} century publications that described good and poor lands (Johnston 1851; Monro 1855). The quality of the land or soil was often assumed according to forest type, particularly the hardwood component. There were 12 references to 'fine hardwood' or 'fine hardwood land' on the metes and bounds surveys. On a 220 acre lot, a surveyor noted "*very good land, timbered with birch, maple, hemlock, and some pine*" (Appendix 3-4). Another lot featured "*good land with a mixed growth of birch, spruce and maple*". Such positive remarks were never associated with conifer land. 'Poor land' was associated with coniferous forests. A third important assumption was that the relative percentages of surveyor descriptions, or lengths of survey line occupied by certain stand types, approximated historical frequency distribution of stand types.

RESULTS

Witness tree analysis

A total of 2537 witness trees were digitally mapped from 1096 archived survey plan drawings, consisting of 2477 trees and 60 stumps. Additionally, the database included 25 survey posts and 319 stakes. The species were recorded for all survey markers. Witness trees were widely distributed throughout the study area, but were more concentrated on riparian zones (Figure 3.1). Witness tree records in more remote locations away from rivers and in areas of poor drainage were assisted by surveys for mill reserves and highways. Witness tree densities were, on average, 1.1 trees/km^2, with the highest and lowest densities found on ecosite 1 (2.6 trees/km^2) and ecosite 3b (0.3 trees/km^2), respectively (Table 3.1).

A minimum of 22 species comprised the witness tree database. There may have been additional species, but surveyor notes were not specific enough to isolate some genera to the species level. Among possible species excluded were jack pine (*Pinus banksiana*) and black ash (*Fraxinus nigra*). 'Poplar' (*Populus* sp.) was analysed as one species, though it likely included three species. Likewise, 'spruce' (*Picea*) was treated as one taxon only, since *Picea rubens* was not differentiated from *P. mariana*, and *P. glauca* was specified only once. Every genus of tree known to grow in the region was utilized, including some uncommon species (e.g., *Ostrya virginiana* and *F. americana*). Some shrubs were also recorded, such as *Alnus*, *Prunus*, and *Acer pensylvanicum*. Interpretation of historical tree names and their abbreviations is featured in Table 3.2. A complete list of witness tree entries broken down by species found in each ecosite is found in Table 3.3, including original surveyor terms, assigned database symbols and scientific names.

Earliest witness tree records were dated at 1805. Approximately 75 % of witness tree information originated from forests from 1805 to 1850 (Figure 3.2 A). It is reasonable to regard the historical tree species frequency to represent forests *ca.* 1800 when the age of trees is factored into the process. Only 23.6 % of witness tree information used in the analysis was post 1850. The later dated witness trees were included in order to gain information on under-represented land types. Ecosites, such as bogs (ecosite 3b) were generally surveyed at later dates and for other purposes than the homesteading rush. Forests on such ecosites were likely to have been less altered than those nearer to expanding settlements and early logging activities.

A selection bias for tree species that were more rot resistant was detected for post markers, and therefore posts were rejected from further analysis. Larch and cedar were the top choices, comprising 88 % of posts (Table 3.4).

19th century forest composition according to witness trees

Analysis using all 2537 witness trees for the study area indicated that species composition *ca.* 1800 was very diverse. Forests were dominated by shade-tolerant, late-successional species. *Picea* and *Tsuga canadensis* were by far the most abundant species throughout 19^{th} century forest, but there was a high diversity of other species, too. Hardwood species collectively comprised approximately 24 % of forest composition, and were dominated by birch-maple-beech (*Betula* spp., *Acer* spp., *F. grandifolia*). Only 35 % of 293 *Betula* witness trees were identified to species, (of these, 52 records were late-successional *B. alleghaniensis*, and 51 early-successional *B. papyrifera*; Table 3.3). Despite lack of quantitative evidence, it was assumed that *B. alleghaniensis* was the most frequent birch species, given that the associated hardwoods were *Acer* spp. and *F. grandifolia*. Sugar maple-beech-yellow birch is recognized as a distinct forest type (Burns and Honkala 1990). *B. alleghaniensis* is also known to form long-lasting associations with *Tsuga canadensis* and *Picea rubens* (Burns and Honkala 1990), which were among the dominant forest components in the area (although the exact proportion of *P. rubens* could not be dissociated from *P. mariana* in this research). *B. papyrifera* is more commonly associated with *Populus* spp., and often forms extensive, nearly pure stands following fire (Burns and Honkala 1990). Early-successional species, such as *Populus spp.* and *Quercus rubra* were rare. However, it is likely that *B. papyrifera* frequency was rapidly increasing throughout the 19th century, given the high frequency of forest fires. Of 22 % of *Acer* identified to species, 90 % were *A. rubrum* (Figure 3.3).

Picea was the most abundant 19th century genus on all site types, although it did not exceed 36 % of forest composition anywhere except on sphagnum bog sites (ecosite 3b) (Figure 3.4). Though surveyors did not recognize taxonomic differences between *P. mariana* and *P. rubens*, *P. rubens* was likely predominant, except in bogs, as it is the most common spruce associated with *T. canadensis* (Mosseler *et al.* 2003). If *P. rubens* was at a selective advantage wherever mesic to drier sites prevailed (i.e. ecosites 1, 2, and 5), then results of GIS analysis indicate that *P. rubens* may have comprised as high as 70 % of the total *Picea* witness trees (Table 3.3).

Tsuga canadensis was very abundant and well-distributed over a broad range of site conditions, from dry, relatively infertile, sites (ecosite 1) to mesic and moderately rich sites (ecosite 5) to very wet sites (ecosite 3b). The species was only 1-5 % less frequent than *Picea* on ecosites 1 and 5. *Abies balsamea* was evenly distributed throughout the landscape, but never exceeded 11 % of the mix. *Pinus* spp. were also equally frequent over a wide range of edaphic conditions, with the exception of extremely wet organic soils. Only 21 % of *Pinus* was identified to species, as either *P. strobus* or *P. resinosa,* with *P. strobus* representing the majority (58 %). Among the hardwoods, *Betula* was by far the most predominant, and gravitated toward dry, poor areas (ecosite 1) and mesic rich sites (ecosite 5). *F. grandifolia* was a relatively important component of 19th century forests, particularly on mesic sites in the study area (ecosites 2 and 5) (Figure 3.4).

Forest change during the past 200 years

Contemporary forests are less diverse than those of 200 years ago. Six dominant tree species comprise 95 % of contemporary forest composition where there were formerly nine species *ca.* 1800 (Table 3.5).

Contemporary forest composition features several marked departures from 19th century forests (Figure 3.4). Most striking is the near complete removal of *T. canadensis* from the landscape. *Fagus grandifolia* and *Fraxinus* have also sharply declined and are now nearly absent. Results show these species to be completely absent on the extreme ends of the moisture gradient, i.e. very dry and very wet sites, ecosites 1 and 3b. Forests, particularly on ecosites 1, 2, and 5, that once featured high percentages of *T. canadensis, Betula*, and *F. grandifolia*, (mainly late-successional, shade-tolerant species), are now dominated by shorter-lived, early seral species, such as *Abies balsamea* and *Populus* spp. *A. balsamea* has at least doubled on all sites with the exception of ecosites 3 and 3b. *Populus* is currently the second most dominant deciduous species following *Acer rubrum.*

While *Pinus* has increased over three ecosites, it is now represented by short-lived, early-successional *P. banksiana*, rather than *P. strobus* (a much longer-lived, mid-successional tree) (Figure 3.5). Similarly, *Betula* predominantly comprises short-lived *B. papyrifera. B. alleghaniensis* is nearly absent in the modern forest composition (Figure 3.5). *Acer* sharply increased on ecosites 1, 2, and 5, but *A. rubrum* is the predominant species, rather than more shade-tolerant *A. saccharum* (Figure 3.5).

Thuja occidentalis was historically found throughout a variety of edaphic conditions, particularly mesic to very wet soils. It was also found on dry sites and mesic rich sites. Today, it is limited mainly to nutrient poor mesic to wet sites, and has been removed from wet organic soils (ecosite 3b) and mesic rich sites.

19th century forest composition on riparian zones and analysis of change

Riparian zones of the four watersheds in the study area (Figure 3.6) contained 833 witness trees. *Picea, Tsuga canadensis,* and *Betula* were dominant in both riparian and nonriparian zones alike (Figure 3.7). Species are listed in descending order of frequency. (*Betula* in riparian zones could not be assigned to species, since surveyors had noted *Betula* witness trees as: 25 'yellow' or 'black birch', 23 white birch, and 62 'birch'.) *Pinus* witness trees occurred 7 % more frequently in riparian zones than in interior forests. Most *Pinus* were assumed to be *P. strobus*, but of the total 16 *P. resinosa* in the dataset, 75 % were located within riparian zones. *U. americana* was more common on rivers. *F. grandifolia* and *L. laricina* were much more common away from riparian zones.

Differences in species composition among the four rivers are depicted in Figure 3.8. Historic riparian forests of the Richibucto River and associated tributaries were composed of a minimum of 15 species. *Tsuga canadensis*, *Picea*, and *Betula* were dominant (61 % of total species frequency). More minor components were *Pinus*, *A. balsamea*, *Acer*, *Thuja occidentalis*, *Fraxinus americana* and *Fagus grandifolia*. The other three rivers each had a total of 11 tree species, though their composition was not identical. Kouchibouguac and Kouchibouguacis Rivers had the most similar riparian forest composition, though Kouchibouguac featured a 6.5 % higher frequency of *Pinus*, while Kouchibouguacis had a 7.2 % higher frequency of *Picea*. In general, riparian forests of the Kouchibouguac River were comprised of *Tsuga canadensis*, *Picea* and *Pinus* (56 % of total species composition) with minor representation by *Betula*, *A. balsamea*, *Acer, Thuja occidentalis* and *Fraxinus americana*. Riparian forests on the Kouchibouguacis were dominated by *Picea*, *Tsuga canadensis*, and *Acer* (59 % of total species composition), with minor components of *Abies balsamea*, *Betula*, *Pinus*, *Thuja occidentalis*, and *U. americana*. Species composition along the Bay du Vin River was unlike that of any of the other three watersheds. *Pinus*, *A. balsamea*, *Betula*, and *Picea* were the most frequent species (comprising 59 % of total species composition). *Tsuga canadensis* was less common than on the other rivers, but still comprised nearly 8 % of the riparian zone. The decrease was probably due to different site conditions as reflected by reduced occurrence of ecosites 1 and 5 on this river, which are preferred ecosites for the species. Other minor species were *Acer*, *Fraxinus americana*, *U. americana*, *Thuja occidentalis*, and *Fagus grandifolia*.

Differences between 19th century and current riparian forests reflect important modifications stemming from two centuries of human impacts. Current forest cover has been reduced by approximately 38 %. Some forest areas were reduced through agriculture, residential clearings, and roads, while forest cover has been temporarily removed in other areas from clear cutting, partial cuts, and fire. Remaining species composition in riparian zones has shifted from late-successional species to species generally well adapted to disturbance: *Picea glauca, P. mariana, Abies balsamea, Populus*, *Acer rubrum*, *B. papyrifera and B. populifolia*. Figure 3.9 portrays 80 % of contemporary vegetation cover within riparian zones. The most notable absences are *T. canadensis* and *B. alleghaniensis*.

Historic forest understory according to survey stake species composition

Survey stakes were composed of a wide diversity of species. A minimum of 13 tree species were used (possibly more, but species were not always indicated), plus shrub species, *Alnus* and *Prunus* (Figure 3.10). Upon reviewing 19th century survey instructions, and through consultation with modern surveyors, it was assumed that stakes were made from saplings in the forest understory, or small trees that were close at hand in areas where there was little forest cover (Monro 1844; V. Stewart, surveyor, Campbelton, NB, Pers. Com.; D. Wedlock, land surveyor, instructor, Geomatics Dept., COGS, NS, Pers. comm.). The most frequent species were shade tolerant, with *Picea* (49 %), *Abies balsamea* (21 %), *Thuja occidentalis* (8 %), and *Tsuga canadensis* (8%). *Picea* and *Thuja occidentalis* were the only species used for stakes on bog sites (ecosite 3b). The highest number of stakes was recorded on ecosites 2 and 3.

Distributions of the six most common species used as survey stakes were summarized in Figure 3.11. Figure 3.12 compares the proportion of stakes to witness trees for each species. Based on these comparisons, there may have been a much higher representation of *Picea* and *Abies balsamea* in the understory (by approximately 19 and 11 % respectively) than in the dominant forest cover. Stake species composition was similarly proportionate to witness tree composition for *Tsuga canadensis*, *Acer*, *Thuja occidentalis*, and *F. grandifolia*.

19th century forest composition according to descriptions on survey plan drawings

A relatively small percentage of survey plan drawings (4 %) contained descriptions of vegetation. Descriptions from metes and bounds surveys (producing 187 records from 42 plan drawings, Appendix 3-4) were summarized as percent frequency of vegetation types in Figure 3.13. Spatial analysis of an additional four plan drawings that featured systematic rectangular survey methods (Figure 3.14), produced 119 records (Appendix 3-5). Relative percentages of lengths of survey lines over each vegetation type were presented in Figure 3.15.

Some important insights on 19th century forests were gained from surveyor descriptions. The forest was not a vast unbroken canopy of trees. It was, rather, a patchy mosaic of deciduous, coniferous, or mixed forest types, often alternating in strips or bands from one to another, and frequently interrupted by open, poorly drained areas and dissected by numerous rivers and streams. Areas of poor soil drainage were recurrent on the low flat topography, and often gave way to wet organic soils, or a rapid alternation between wet and dry conditions. Some wet bogs (up to 6 % of the landscape) supported no forest cover at all. Surveyors termed such areas, 'naked barrens' or 'open plains'. An additional 13 to 20 % of the landscape was covered in wetlands that were forested to some degree, ranging from marshes and swamps to tree-covered bogs (Figures 3.13 and 3.15).

Forest stands of any one species mix were often small. Stand patterns typically alternated between mesic to xeric forest stands and stands of predominantly mesic to hydric species (i.e. species that grow mainly on poorly drained sites). For example, a band of white pine may grow on a mesic to xeric site, then change abruptly to black spruce on a hydric to very hydric organic soil, located parallel to a narrow band of hardwood (birch-maple-beech) on a mesic site. There were some exceptions where one forest type extended over a large area. An extensive, approximately 7 km band of 'fine hardwood land' oriented north-south between Kouchibouguac Village and Bay du Vin River was noted on a highway survey. Spatially contiguous species groupings were noted on some private lots. Along rivers, forest stands often grew in bands or strips parallel to the river. On the Kouchibouguac River, two relatively extensive groves of red pine covered narrow strips, approximately 4.5 km in length, and varying from perhaps 500 m to 2 km in breadth. (This surveyor sketch is presented in Appendix 4-3.) Each red pine stand was situated on opposite banks of the river, and located parallel to the shore. These were the only red pine stands noted in the entire study area. A white pine timber 'grove' spanned approximately 4 km. Hardwood stands extended from 2 to 3.5 km, sometimes alternated with white pine stands. The width or breadth of such stands was impossible to determine from the descriptions on the sketch.

Two black ash (*Fraxinus nigra*) swamps, (one of them mixed with *Thuja occidentialis*), were noted in survey records, (one on each of the two types of survey plan drawings) thereby confirming the presence of an additional species that was not included in the witness tree record. The black ash swamp from the block survey method, covered approximately 0.28 km of survey line.

Forests along the coast were generally stunted, often the result of poor drainage. Metes and bounds surveys described 52 % of coastal areas (12 of 23 records) as: very poor land, 'barrens' or 'plains' (i.e. boggy lands), or marsh. Among these, one description was especially vivid: "*For nearly a mile from the shore, the soil here is a perfect quagmire into which cattle have been known to sink and never seen again* [sic]" (PANB RS687B b). Two records indicated coastal areas with better drainage, but very sterile soil, described as: "*dry sandy*" or "*high gravely*" land. Judging from these conditions, forest types were generally of low quality along the coast, consisting mainly of spruce, often 'spruce barrens', "*scrubby wood*", or bushes. 'Short scrubby pine' was noted near the coast south of Kouchibouguac River. It is possible that this may have been *Pinus banksiana*, though this species was not indicated anywhere in the survey record, including witness trees. Alternatively, it may have been stunted *P. resinosa* or *P. strobus*. There was only one other coastal record for pine, situated in a protected lagoon area, where it was presumably *P. strobus*, which is the current forest cover in that location.

Analyses of surveyor descriptions from both the metes and bounds surveys (Figure 3.13) and rectangular surveys (Figure 3.15) produced some consistent results. There was a wide range of species mixes. Pure hardwood stands covered approximately 12 % of the landscape, but pure stands of *F. grandifolia* or *Acer* were apparently rare, each noted only once. Mixed hardwood-softwood stands were common, comprising approximately 13 % (according to descriptions on metes and bounds plan drawings) to as high as 21 % (according to descriptions from rectangular surveys) when species-specific mixed stands were included. Of the species that were specified in forest stands, *Picea* and *Pinus* were the dominant conifer species. A large portion of *Picea* may have been *P. rubens*, judging by drainage classes, but specific percentages were impossible to calculate with much of the forest having been described as 'softwood' or 'spruce'. The current presumed prevalence of black spruce-red spruce hybridization reduces the clarity of any statement on *Picea*. Both *Pinus strobus* and *Tsuga canadensis* grew either in pure stands or were mixed with a variety of hardwood or softwood species. Descriptions of early seral forests were uncommon. *Abies balsamea* was noted only twice in metes and bounds surveys descriptions.

According to vegetation descriptions encountered along approximately 89 km of survey lines, *Picea* occurred throughout the landscape with a range of other species. *Pinus* covered approximately 6 % of the area surveyed in nearly pure stands. An additional 4.7 % of forest cover supported *Pinus* as a mixed component.

Forest disturbance dynamics

Surveyor plan drawings offered no direct indications of *pre*-European settlement forest disturbances. Only a few indirect anecdotal descriptions point toward possible disturbance agents prior to European settlement. Two plan drawings indicated aboriginal presence on the landscape; one showed line drawings of Mi'kmaq 'wigwams' on the south side of the mouth of the Richibucto River *ca.* 1820, another, an 'Indian portage', located on the north bank of Kouchibouguac River in 1807. Such fleeting glimpses of the former Mi'kmaq presence do not provide evidence of forest disturbance. They serve as a reminder, however, that humans were living on these lands long before 1800, and they had the means to influence the original forest dynamics, particularly through initiation of forest fires. The Mi'kmaq used fire for cooking and as a source of heat (and perhaps for other uses lost in history). Accidental or even purposeful setting of local forest fires may have occurred periodically. As almost nothing is known of their early population sizes and fire practices, human influence on pre-European fire regimes cannot be elucidated from witness tree research alone.

Survey plans provided an indirect source of disturbance information, by enabling the estimation of frequency and distribution of disturbance-dependent species. Low frequencies of disturbance-dependent species in the witness tree record provide little evidence for catastrophic disturbance for an indefinite period prior to 1800. *Pinus* *resinosa* constituted only 0.6 % of all witness trees, and its distribution was too broad to reflect localized disturbances. On the other hand, survey descriptions of two pure red pine stands, and also pure white pine timber stands, all noted on the upper reaches of Kouchibouguac River, may have had pre-European fire origin.

There were no surveyor notations of windfalls or flooding. Evidence of a probable insect infestation was noted only once. Massive larch mortality was noted on a timber survey of a large boggy expanse in the northern section of the study area during 1900. *"Tamarac* [sic.] *was once abundant throughout the greater extent of this locality, but now scarcely a living tree can be seen in some places* [sic] *acres of dead trees stand as monuments of this once famous wood." John Stevenson, D.L.S.* The mortality of larch was attributed to the larch sawfly (*Pristiphora erichsonii* (Hartig)), but the origin of this pest has been debated. Some strains are native and others introduced (Rose and Lindquist 1980). Therefore, it is unknown whether this outbreak was part of the original disturbance regime.

Surveyor plan drawings revealed a variety of *post*-European perturbations. Fire was the strongest disturbance operating on the post-European settlement landscape. 'Burnt woods' or other descriptions alluding to fire disturbance comprised 13.4 % of all metes and bounds survey descriptions and approximately 7 % of disturbance along deputy surveyor lines (i.e. from block surveys). Nearly all records were linked to very recent events, where ash or dead timber was still evident. Surveyors commonly noted 'burnt woods' and contrasting 'green woods' (unburnt woods). Supporting the link of fire with European causes, burnt areas were often on granted lots or very near areas of human activity, such as mill sites. Seven areas of 'burnt woods' were noted on an 1837 survey of only 20 km of highway (most of which passed in a north-south direction through KNP). It was unclear whether the fires on this sketch were from one large patchy fire or several small fires. There were many private land grants in the area, so they may have been from individual fires. The limits of burned woods were not often indicated, so it was impossible to ascertain the total area burned in the study area. Other indirect signs of disturbance found on survey plans were indications of several sawmills located on small tributaries and a shipyard lot. Selective logging was associated with such operations. The mills also required dams. This would have flooded some riparian areas and contributed to altered forest composition. There were surveys of roads to be built, and shaded areas on granted lands to signify land clearances, all of which indicated forest disturbance.

DISCUSSION

Land survey records provided a valuable source of quantitative evidence for the composition of pre-European settlement forests through analysis of witness tree species information. Additional analysis of surveyor descriptions was complementary to the witness tree results. Archived survey records unlocked some surprising characteristics regarding 19th century forest composition. There was clearly a high predominance of *Tsuga canadensis* in the recent past. This late-successional, highly shade-tolerant species took second place only to *Picea*, which was at a competitive advantage on the poorly drained topography throughout the Eastern Lowlands. A second unexpected result, based on familiarity with modern forests, was the complete absence of *Pinus banksiana* from the survey record. *P. banksiana* was commonly referred to as grey pine in the early records, so it would likely have been distinguished from other pines. Considering the wide range of species and sizes used as witness trees (some which were shrubs), there is no obvious reason for the absence of *P. banksiana* in the survey record, unless it was absent or nearly absent on the landscape during the early 19th century. Dominance of *T. canadensis* and the absence of *P. banksiana* in the records provide strong empirical evidence to dispel a commonly held belief that this area of New Brunswick is mainly suited for fire-adapted species, particularly *Pinus banksiana* and *Picea mariana* (DNRE 1996). The prevalence of early seral and fire-adapted species in modern forests cannot be attributed to a highly fire-prone climate, as it had clearly not been ravaged by fire only 200 years ago. Fires require ignition sources that have been almost entirely attributable to humans in the modern fire record. This implies that modern species assemblages are the result of human-caused disturbance much more so than climate.

Another revelation arising from survey records was the relatively high percentage of *F. grandifolia*, which has now dropped to very low levels. Its reduction was largely due to the introduction of beech bark disease in the early 1900s (Betts and

Forbes 2005). Since it was the only mast-bearing tree, besides *Q. rubra* (which is an uncommon species), its sharp decline may have had a significant ecological impact on animal species such as black bear (*Ursus americana* Pallas), dependent on such autumn food sources (Telfer 2004). Cultural activities have also been affected by loss of this resource. Local Acadian people in the study area still remember going to gather beechnuts, for which they had their own unique expression "*aller à la faîne*". ('Faîne' is a French term for beechnut or beechmast.) This activity is no longer possible.

Precipitous declines of *T. canadensis* and *F. grandifolia* may justify efforts to conserve or restore these species. Information on abrupt reductions of formerly prominent species is particularly valuable for KNP managers, whose mandate is to preserve characteristic indigenous species and portray a representative portion of the Eastern Lowlands landscape to the public. For others who have strong economic interests in forest resources, these results provide strong evidence of the local forest potential as demonstrated by forest characteristics a mere 200 years ago.

Synopsis of historic forest composition

Moderately to very shade-tolerant, late-successional species complexes dominated forests of the study area on the New Brunswick Eastern Lowlands during the 19th century. *Picea* and *Tsuga canadensis* were dominant species, forming stable complexes over all edaphic conditions (except very wet organic soils where *Tsuga canadensis* became minor). These key dominants grew either in pure stands, or mixed with other moderately or highly shade-tolerant trees, namely *B. alleghaniensis, Abies balsamea, Acer rubrum, Pinus strobus, Thuja occidentalis,* and *Fagus grandifolia.* Together, in varying combinations, these species comprised over 90 % of the original forested landscape. Shade-intolerant species, such as *Populus, Pinus resinosa, L. laricina*, *Prunus*, *Q. rubra* (and probably *B. papyrifera*), were only minor components of historic forest composition.

Forest cover was a complex mosaic of highly varied stand types dictated largely according to drainage patterns. Shallow soils over impermeable clay and ortstein horizons and horizontal sandstone bedrock, resulted in low flat topography with an unpredictable patchy distribution of site conditions. Forest stands changed abruptly over sites ranging from very nutrient-poor, dry conditions to vast areas of wet organic soils, and smaller patches of mesic nutrient-rich sites. Approximately 24 % of the landscape consists of wet or very wet organic, infertile sites (ecosites 3 and 3b). Conifers dominated these areas. *Picea mariana* was best adapted to the preponderance of poorly drained sites. *P. mariana* and *L. laricina* formed edaphic climax forests on boggy sites, with minor components of *Abies balsamea, Betula* spp., *T. occidentalis, P. strobus,* and *Acer rubrum.*

Abies balsamea was the most constant species over all ecosites, showing no edaphic preferences. This growth strategy probably assisted it in being well placed to become the second most dominant species 200 years later. *Pinus strobus* was also nearly equally distributed on wet and dry sites, with the exception of very wet organic soils. Although Schaetzl and Brown (1996) suggested that the bimodal distribution of *Tsuga canadensis* on soils that were either drier or wetter than mesic sites may be due to reduced competition from hardwoods, this seems unlikely in this region, as *Betula* and *Acer* had similar site preferences to *T. canadensis.*

Mixed hardwood-softwood stands were found with highly variable species compositions. *Picea, T. canadensis, Betula, Abies balsamea,* and *Pinus strobus* were the species most frequently involved in the mix. Pure hardwood stands, consisting of *Betula, Acer,* and *F. grandifolia,* were the least common, covering approximately 12 % of the landscape. *Betula* was the most frequent deciduous genus, exceeding the 2nd most common hardwood, *Acer*, by approximately 4 % over the study area. *F. grandifolia* was relatively common, comprising 5 % of species composition overall. It was most common on mesic sites (ecosites 2 and 5), where it constituted 6.1 and 8.2 % of the forest composition respectively. *B. alleghaniensis* and *Acer saccharum* were ecologically important original components, though the proportions occupied by these species within the original forests were not precisely determined due to lack of differentiation within the *Betula* and *Acer* genera.

While much of the forest may have been of mature to old-growth condition, consisting of many larger trees than witnessed today, forests along the coast were generally stunted from poor drainage or sterile beach deposits. This impression was gained mainly from surveyor descriptions, rather than the witness tree record, and is supported by this 19th century quote of the local coastline: "*The quality of the land has a certain reference to the coast line- a belt of poorer, generally sandy or stony land, of six to ten miles wide, running along the shore, and behind this a belt of fifteen miles wide, of better, often very good land*" (Johnston 1851).

Some characteristics of the original forest composition could not be discerned from land survey information. Former abundances of *Picea rubens* remain open to debate. *Picea rubens* is the most likely associate in forests with high abundances of *Tsuga canadensis* and *Pinus strobus*, forming the well documented red spruce- eastern hemlock- white pine complex (Mossler, *et al.* 2003). On the other hand, the NB Eastern Lowlands has been identified as a region where *Picea rubens* and *P. mariana* commonly hybridize (Manley 1972), so there may never be a clear answer. Likewise, the ratio of *Betula alleghaniensis* to *B. payrifera* remains unclear. *Betula alleghaniensis* likely comprised the largest proportion of the trees identified as *Betula*, given that the majority of the landscape supported shade-tolerant complexes, but the witness tree record did not prove this beyond doubt. The driest sites (ecosite 1) were probably dominated by *B. alleghaniensis*, as this species was 73 % of the 26 *Betula* trees identified to species. On the other hand, wet mineral soils (ecosite 3) may have supported more *B. papyrifera* than *B. alleghaniensis* (71% of 21 identified *Betula* witness trees were *B. papyrifera*). It is possible that *B. papyrifera* is a sub-climax species on less than optimal sites. It is also possible that *B. papyrifera* was differentiated in surveyor plan drawings more often compared to the more commonplace *B. alleghaniensis*, since its white bark would have appeared in stark contrast to the majority of species in the coniferous forest. Trunks of old-growth *B. alleghaniensis* have darkened bark (Perley 1847), similar to the majority of the other forest trees in the area. Surveyor, James Alexander, remark ed on white birch on the edge of the Great Miramichi burn in a very aesthetic manner: "*The woods were beautiful to look at-that is, they were full of groups of young birch trees, with their silver stems and fresh green leaves…*" (Alexander 1849). He called them "*ladylike trees*". *B. papyrifera* may have appeared more remarkable to Alexander after having spent weeks in forests that he frequently noted as dark and shady.

In summary, forests in the region were a diverse array of species complexes, largely composed of shade-tolerant conifer trees in late-successional associations. Early seral species were mainly found in bogs, coastal and riparian zones.

Historical abundances of Abies balsamea vs. Pinus strobus:

Relative frequency of witness trees is not necessarily equivalent to relative dominance, as defined by either wood volume or canopy dominance. *Abies balsamea* was the 4th most frequent species in the witness tree record, followed by *Acer*, and then *Pinus strobus*. The species attains a smaller stature than the other dominant species, so it may not have been as prominent in forest stands as the witness tree record indicated. It is important to bear in mind that the numbers reflect percent frequency of stems and not volume. *P. strobus* was among the six principal species according to witness tree frequency data, but was 3 % less frequent than *A. balsamea*. Despite its numerical inferiority, immense sizes recorded for the species would have caused it to greatly exceed volumes of *A. balsamea*. Maximum dimensions of white pine are legendary in NB. It can attain at least 30 m in height and 90 cm in diameter, whereas *A. balsamea* might achieve half the height of white pine (15-20 m) and only 30 to 60 cm in diameter (Hosie 1990). In fact, *Abies balsamea* must have been rather unremarkable when growing near old-growth *T. canadensis, B. alleghaniensis, Acer rubrum, A. saccharum,* and *P. strobus*, all of which are capable of exceeding maximum volumes of *Abies balsamea*. If *A. balsamea* rarely achieved prominence in the canopy layer, instead remaining in the subcanopy, then it might have been noted less frequently in surveyor stand descriptions. In fact, it was noted only twice in stand descriptions, while it was very frequently chosen as a witness tree. These discrepancies between witness tree and surveyor descriptions for *A. balsamea* were similarly found by Lorimer (1977) in adjacent Maine, and they were attributed to the smaller stature of the species. He believed that an estimate of 1.3 % white pine, determined from the witness tree record, was reasonable when compared to independent estimates of pine densities in Maine (Lorimer 1977). Similarly, white pine represented 1-6 % of witness tree summaries in north-western and north central Pennsylvania (Abrams and Ruffner 1995). In comparison, the frequency of *Pinus* for the study area of between 3.6 and 8.2 % (depending on site conditions) was high.

Percentages of *P. strobus* may have been much higher originally than witness tree data suggests for two reasons. First, it was the earliest species to be selectively harvested prior to most of the land surveys. Second, the patchy distribution of white pine, particularly within riparian zones where it often grew in groves (Bailey 1876), might result in underestimation using the sparse distribution of witness trees. Thus the frequency of white pine, especially along riparian zones, must have been higher in the original forests than witness tree information indicates.

Riparian forest ecology: past and present:

The character of historic forests along rivers was of particular interest as these forests have been modified for longer than other areas, and therefore less is known of their original character. The reasons for this were twofold: (1) earliest logging activities took place within riparian zones, and (2) the earliest land grants were allocated along navigable rivers, so the first land clearances for settlement and agriculture were within riparian zones. Forests have been annihilated from nearly 40 % of riparian zones (mainly agricultural fields, homesteads, town sites, agriculture, forest harvesting, and roads). Cleared lands remaining along rivers within KNP present a particular park management issue as they represent the largest portion of the most human-altered landscape, but offer the fewest indications of original forest composition to guide possible restoration interventions.

Historically, the narrow strips of fluvial deposits along rivers and streams supported rich and diverse, mid- to late-successional forests. The witness tree record indicated that at least 20 species grew in riparian zones. Frequencies of *Tsuga canadensis* and *Pinus* were approximately 6 and 7 % higher, respectively, than in inland forests. Large *U. americana* added additional diversity to riparian zones. Abundances of *P. strobus* may have been even higher than 7 % within riparian forests prior to selective harvesting activities. Harvesting of white pine for shipmasts and ton timber began very early on, before most lands were surveyed, and thus prior to much of the witness tree record. During the same period, inland forests remained unaltered from logging, as there was neither the financial incentive, nor the means of hauling large timbers to the rivers for conveyance to market.

Contemporary riparian forests have been profoundly altered with respect to both spatial pattern and species composition and structure. Roads form almost 2 % of riparian zones, and along with other cleared lands, have resulted in a highly fragmented forest, particularly near the coast. Forest composition bears almost no resemblance to former forests, currently being comprised largely of *Abies balsamea, Picea glauca*, *Acer rubrum*, and shade-intolerant species: *Populus, B. papyrifera,* and *B. populifolia*. Shade-intolerant, *L. laricina*, which had formerly been limited to boggy sites, has spread to drier sites where it forms mixed stands with *P. glauca*. Forest stands with a component of *T. canadensis* presently form less than 1% of riparian forests. *Pinus banksiana* is now abundant (roughly 4 % of forested land cover within riparian zones, excluding clearcuts, fields, etc), and will probably continue to increase according to forest cover records, which report much of it at stand initiation stages on cleared lands (largely abandoned fields).

Analyzing early riparian forest composition provided opportunity to detect compositional differences that could possibly be attributable to historical Mi'kmaq presence. Significant differences in forest composition between areas of high and low Native American activity have been detected through witness tree analyses in other parts of eastern North America (Ruffner 1999; Black and Abrams 2001; Foster *et al.* 2004). Ruffner (1999) found unusual forest composition near Iroquois villages where there were higher abundances of *Quercus-Carya-Castanea dentata* than in surrounding forests with similar edaphic conditions. He attributed these differences to aboriginal agriculture and fire practices. The Mi'kmaq may have altered forest composition locally through gathering firewood, making small clearances for dwellings, and accidental escaped fires. As a result, there may have been elevated abundances of disturbance-dependant or fire-adapted species on riparian zones.

No conclusive evidence of early Mi'kmaq impacts on the forest was found through riparian zone analysis of witness trees. Of the 16 *Pinus resinosa* in the witness tree record, 75 % fell within riparian zones. However, this species might be expected to occur in such areas, where river and ice scouring might cause more exposed mineral soil and nutrient-poor fluvial deposits (conditions suitable for red pine). Surveyor descriptions along riparian zones indicated some particular signs of disturbance on the Kouchibouguac River. Many Mi'kmaq artefacts have been found along this river (Beach 1988). There were two extensive red pine forests, plus a 'poplar grove' recorded along its banks. *Pinus resinosa* responds positively to fire (Duchesne and Hawkes 2000), however, it was situated on edaphic conditions best suited for its persistence (i.e. very dry and infertile conditions, ecosite 1). Under such edaphic conditions, this stand type can perpetuate itself in the absence of disturbance (Mosseler *et al.* 2003). The poplar grove was situated on granted lands and so its disturbance origin may have been post-European origin. No other compositional differences support the theory of early aboriginal influences on forest composition. *Populus* and *Q. rubra* were present in very low relative abundances, similar to inland forest composition. '*Prunus*' is believed to have referred to one or more shrub species, rather than *P. serotina*, as both the historical and current distribution of the latter were not recorded for the area (Fowler 1878; Hinds 2000).

In summary, the probable impacts of the Mi'kmaq people on local forests were minor. The Mi'kmaq used rivers extensively for travel and food resources, but they may have had little cause to modify local forests. They lived in riparian areas mainly during the winter when the risk of causing forest fires was low. A seasonally nomadic lifestyle and abundance of food from the rivers and sea would not have encouraged agricultural pursuits, particularly considering that riparian areas were mainly winter grounds (Clermont 1986; Leonard 1996).

Forest structure

No direct conclusions on forest structure were drawn from witness tree research. Indirect evidence indicates that trees may have generally been larger than those we see today. Considering that witness trees were generally late-successional species capable of living to great ages, tree sizes were probably larger than those commonly seen in the modern forest. Additional evidence in the witness tree record of large, old-growth structures was the record of 'black birch'. If black birch was actually old-growth yellow birch (the bark of which is characteristically black in advanced age), then perhaps the presence of this tree is an indicator of forest structure characterized by large trees.

Surveyor descriptions of local forests did not provide much information on sizes of trees either. There were common references to 'timber', which implies large trees. Some forests located near the coast were qualified as 'scrubby' or stunted. This implied that forest structure in coastal regions may have been generally smaller than in inland areas. If so, this concurs with historical descriptions of Nicholas Denys (1672) examined in Chapter II.

Forest disturbance dynamics

Pre-European disturbance regime

Knowledge of disturbance agents and how they functioned prior to European settlement provides a key insight on how the original forest developed. The inherent dynamics of change and renewal in the Acadian forest have only begun to be understood. It appears that the 100-year period studied through surveyor records was insufficiently long to capture intrinsic catastrophic agents that may have played a role in the forest dynamic on the Eastern Lowlands.

The *absence* of evidence of large-scale disturbances on surveyor plan drawings is perhaps the most important indication of pre-European settlement forest dynamics. It is unlikely that the sampling of the survey record would have missed a large event had it been present. There were no survey notes recording dead standing timber, fallen timber, fire scars, or dense areas of second growth. Even the strongest indication of natural disturbance agents, i.e. larch mortality attributed to larch sawfly infestation is of questionable natural origin (Rose and Lindquist 1980). Windfalls would have presented major obstructions to survey crews and would almost certainly have been noted, as they were in other landscapes (Lorimer 1977). Similar research on forests of adjacent Maine revealed 50 references to fallen timber, and windfalls were noted on 2.6 % of tallied one-mile segments documented from township surveys (Lorimer 1977). The absence of large-scale disturbance information in survey records does not mean that they did not occur, but disturbance cycles may have been very long and large catastrophic events, infrequent.

The most convincing survey record evidence supporting the theory that disturbances prior to European settlement were infrequent was the high frequency of shade-tolerant, late-successional species, such as *Picea rubens*, *Tsuga canadensis*, *B. alleghaniensis*, and *Fagus grandifolia*. Since these species can self-replace indefinitely, growing under the shade of their own canopies (Burns and Honkala 1990), it is difficult to estimate how long dominant 19th century forest types persisted without large-scale stand-replacement events. The low percentages of shade-intolerant species may have perpetuated themselves by either small-scale disturbances, or by surviving under adverse edaphic conditions, such as on boggy sites and coastal areas.

The landscape may be inherently less prone than other regions to large-scale stand replacement disturbances from wind or fire. It is not situated on any major hurricane tracks, and those hurricanes that reach the area are usually weak (Mosseler *et al.* 2003). Alternating drainage patterns with corresponding patchy forest stand types may have limited fire spread and reduced intensity. Natural fire breaks are formed from rivers, bogs, and swamps. Additionally, fires tend to burn toward the coast instead of spreading inland, since summer breezes prevail from the southwest (Crossland 1998).

If, in fact, forests were largely composed of stable self-replacing complexes, then understory tree composition might logically have been similar to canopy tree composition (Foster *et al.* 1996). Studies of some old-growth forests have detected compositional shifts through comparisons between understory and overstory tree compositions. Figure 3.12 indicates that understory forest composition was likely similar to the original dominant species complexes. Data were not stand specific, so results are inconclusive. However, many of the species that occurred most frequently in the canopy also occurred most frequently as stakes. Similarly, species comprising the least frequent witness trees were generally among the least frequent stake species. An exception was *Abies balsamea*, which was twice as frequent in the understory as the overstory, but its short life span and small stature would have limited its dominance in the canopy. The relatively low percentage in *Pinus* stakes might indicate a pending compositional shift to a decrease of *Pinus* recruitment in the overstory forest in the absence of disturbance. The capacity of *P. strobus* to maintain itself through gap replacement in old growth situations is not fully understood (Quinby 1991; Abrams *et* *al.* 1995). All that is known for certain is that 19th century *P. strobus* tended to be more abundant within riparian zones than more inland localities, commonly growing in groves (Bailey 1876).

Based on the paucity of historical and ecological information about catastrophic events, it may be inferred that gap dynamics from small-scale disturbance events were the key drivers of forest renewal *ca.* 1800, and major stand initiation disturbance events occurred at long intervals. Shade-tolerant understory tree seedlings and saplings grew slowly and persisted in the understory until small gaps in the canopy occurred, providing the opportunity to grow to maturity. Gaps resulted from individual tree deaths or small-scale disturbance events from snow, ice storms, and pathogens. The relatively short time span of 100 years covered in this study of witness trees is insufficient to draw strong conclusions on disturbance cycles. Other research initiatives are required for a better understanding of the role of anthropogenic disturbance (i.e. historical Mi'kmaq culture), insect or pathogen outbreaks, fire frequency and intensity, and other infrequent events.

Post-European disturbance regime

Much more is known about the modern disturbance regime (post-European colonization) than disturbance regimes prior to European colonization. Several human-assisted disturbance agents have exerted strong impacts on forests over the last 200 years. No other force during the 19th and 20th centuries was more destructive to the original forests and inherent dynamics than fire (Johnston 1851; Bruncken 1900; Wein and Moore 1977). Whatever fire cycle existed prior to European settlement, there is little doubt that the frequency increased to unprecedented levels, beginning during the 19th century (Johnston 1851; Ganong 1902). The spike in post-European colonization fires was almost entirely due to human activities (Bruncken 1900). Survey plan drawings confirmed that the distribution and pattern of the fires were closely associated with areas of human population. Records for survey lines situated in more remote areas away from settlement noted fewer fires. The haste of early settlers to clear land was facilitated though fire. Accidental fires often occurred in recently logged sites. Forest harvest activities, particularly for white pine timbers, left enormous amounts of slash, creating abnormally high fuel buildups and increased fire potential. Lumbermen complained that more timber was lost to fire than by harvesting (Lee 1987). Human-caused fire ignitions remain the primary source of fire throughout the region during the 20^{th} century, resulting in a recent fire cycle of approximately 210 years (Crossland 1998).

Other agents were less catastrophic than fire, but their cumulative impacts were significant. Land clearance and logging opened up and fragmented forests. Land clearances were often depicted as shaded areas on the plan drawings, and represented tangible signs of progress in taming the wild landscape. The forest industry, based on early selective logging for white pine and spruce, successively moved from high-grading only the largest, straightest trees toward using ever-decreasing sizes and less valuable species of trees over the past 200 years. Forest cover decreased with the advent of mechanized clear-cutting operations (Thomas 1930). All this has led to increased disturbance frequency and intensity, but not all human-induced disturbance agents were the result of forest exploitation or land clearances. Pathogen and insect introductions have greatly contributed to the demise of two of our most stately hardwood species. Beech bark canker, caused by a scale insect (*Cryptococcus fagisuga* Lind.) and a fungus (*Nectria coccinea* var. *faginata* Lohman, Watson and Ayers), introduced in the early 1900s, has reduced formerly dominant *F. grandifolia* to very low levels. As late as 1928, large *F. grandifolia* trees were still common on the landscape throughout NB and constituted over 2 % of the total standing timber and over 8 % of hardwood cut (Millar 1928). More recently, Dutch elm disease (*Ceratocyctis ulmi* (Buism) C. Moreau) has destroyed most *U. americana* trees in the area.

The current disturbance dynamics reflect a departure from the historic disturbance regime. It has been suggested that the most important factor, regardless of whether disturbance frequencies have increased or decreased over the past 200 years, is that the natural ranges of variability have not been exceeded (Hessburg *et al.* 1999). Otherwise, there is a risk that some native species will not survive and a new suite of forest dominants will be favoured. Forest succession may proceed along new trajectories to create novel conditions. Evidence suggests that the current range of disturbance agents, many operating on short return intervals, do not allow a return to 19th century forest composition, nor structure.

Forest change

An objective of this research was to measure forest change from the pre-European settlement period to current day. Witness tree results (Table 3.5) point to major forest compositional changes. Contemporary forests are less biologically diverse, with six tree species now accounting for 95 % of forest composition where there were formerly nine species. *Tsuga canadensis*, former second most dominant taxon following *Picea,* is now nearly absent from the landscape. Other species, reported in descending order of decline from original forests are: *B. alleghaniensis, Fagus grandifolia, T. occidentalis, Fraxinus,* and *U. americana.* Most of these species are capable of living to great ages and achieving large sizes. Their reduced presence on the landscape likely has far-reaching ecological impacts on a host of other Acadian forest species.

Picea has enhanced dominance on the landscape, particularly on hydric sites, mainly due to increased frequency of *P. mariana* rather than *P. rubens* (Figure 3.5). *Picea mariana* is at a competitive advantage over *P. rubens* on open sites, as it is a pioneer species, (often forming postfire stands), and can grow on a wide variety of soil and drainage types, whereas *P. rubens* is a late-successional species, requiring shade (Major *et al.* 2003). *Picea glauca* has also increased, but marginally compared to *P. mariana*. It followed agricultural land abandonment, and is particularly abundant on drier sites (Figure 3.5) and within riparian zones (Figure 3.9). *Abies balsamea* now rivals *Picea* on the driest and most nutrient rich sites. *Acer rubrum* has proliferated to become the most abundant hardwood species.

Among today's composition, there is a disproportionately high representation of short-lived, generalist species, such as *Abies balsamea,* and early-successional species, such as *Populus*. *Abies balsamea* has increased from being the fourth most frequent species to occupying second place (by percent volume). Had historic levels of *A. balsamea* been ranked by volume rather than frequency, it almost certainly would have been lower than fourth place. *Populus* has made the biggest increase. Exceeded only by *Picea*, *Populus* rose from a marginal eleventh place (frequency) to the fourth most common species (BA). These two species, together with *Acer rubrum* have achieved a new dominance on lands that formerly supported the region's best growth (ecosites 1, 2, and 5).

A casual observation of modern forest cover data may provide a false impression that formerly dominant *Pinus strobus* has responded positively to changes in the landscape. However, the trend remains the same; species composition has shifted to more light demanding, disturbance dependent species. The overall rise of *Pinus* is due to a sharp rise in *P. banksiana,* which is roughly double the percentage BA of *P. strobus* on most sites (Figure 3.5). *Pinus resinosa* remains at very low levels.

Tsuga canadensis has been subjected to the greatest reductions. Besides its sensitivity to the increased frequency of fire, its bark was heavily harvested for the tannery industry for tannic acid (DeGrace 1984). Invasion of white-tailed deer (*Odocoileus virginianus* Boddaert) has been known to affect hemlock regeneration, as it is a favourite browse species (Anderson and Katz 1993). Small isolated remnant stands of hemlock may not return sufficient numbers to persist in future forests.

While land survey records did not provide direct evidence of forest age and structures, former species composition indicates that much of it was old growth. The forest was dominated by species that were capable of living 300-400 years and achieving great sizes. Logging and shipbuilding records lend support to this deduction. There are currently no estimates of percentage of remnant old-growth stands in New Brunswick. In Nova Scotia it is estimated that 0.0008 % of the forest is old growth (Mosseler *et al.* 2003). Old growth was defined as stands in which the dominant trees have an age of greater than 150 years (Mosseler *et al.* 2003).

This research provided strong quantitative evidence of species shifts to novel conditions in the relatively short period of 200 years. Landscape patterns have also dramatically changed, now being highly fragmented including cleared lands, open cut-over areas, and roads. Riparian forests are among the most seriously altered, partly due to their nutrient richness making them most suitable for agriculture and settlement. As a result, present-day forest patches are disproportionately concentrated on poorer soils. The rapid pace and high magnitude of forest change may not allow some species to adapt or recover. Former dominants, such as *T. canadensis* and *P. strobus* have demonstrated remarkable adaptability to climate change, pathogen outbreaks, and other disturbances in the past (Abrams and Orwig 1996; Foster and Zebryk 1993). However, there are limits to forest resiliency, especially when biological diversity has been reduced. The recent compositional shifts will have an enduring impact on the succession of future forests.

Species bias

Bias for species selection of witness trees was not detected. Species bias does not seem likely in light of the broad spectrum of species used, including species of large and small sizes; high and low merchantable value; trees with high resin content; and long and short longevity.

There are no tests for species bias in metes and bounds surveys, unlike witness tree research using rectangular surveys (Black and Abrams 2001). Rectangular surveys, from which most published research on witness tree is based, entailed marking the corner boundaries by placing a post at the corner, that was consequently associated with two, or sometimes four, trees chosen in the vicinity of the post to assist with relocation of the corner. The surveyor, according to instructions that accompanied a particular survey, generally had considerable freedom to mark preferred tree species or diameter classes. Despite this opportunity to choose one species or size class over another, most tests used in rectangular surveys failed to detect significant species bias (Bourdo 1956; Siccama 1971; Delcourt 1976; Lorimer 1977; Black and Abrams 2001). Metes and bounds survey methods did not offer the same freedom to chose tree species, and thus the same potential for surveyor bias. Only one tree was marked at a corner lot; that tree which was at, or nearest the carefully measured corner. If no tree was present, a stake was cut and placed at the corner.

Witness tree species bias was further investigated through surveyor notes and instructions. Early techniques and instruction for metes and bounds surveys render species preferences unlikely, given the required precision. Early eastern New Brunswick surveyor, Alexander Monro, published a textbook on how to conduct woodland surveying, where precision of metes and bounds surveys was heavily stressed. "*Before proceeding to measure any line, the Surveyor should [ ] carefully examine and* *measure his chain. To this point too much attention cannot be paid*" (Monro 1844). Archived instructions to early NB chain bearers supported the precision of measure that Monro insisted was required: *"...Chain Bearers be exact and careful in chaining...to take an oath that they will chain truly... and that they will render [...] a just and true account of the number of chains and links they shall have measured on each course...and that the chain be stretched tight and straight, and at all times to observe that no links be bent, or rings lost; and you are, previous to commencing a survey, to measure your chain, that it may be of the proper standard length...*" (PANB 1852).

A reason for placing great emphasis on exact measurements was to avoid disputes, "*ruinous lawsuits*", and damage to surveyor reputation (Monro 1844). Furthermore, both the Deputy Surveyor and his chain bearers were under strict oath to carry out surveys as precise as possible. The 'Chainman's Oath' from 1785 would have required them to choose no specific tree species, as each chainman swore: *"I will use the greatest exactness possible admeasure all tracts of* land *on which I may be employed without any fraud or partiality what ever...".* Resulting from such stringent requirements, surveyors measured distances to the precise link (1 link = 7.92 inches or 20 cm). Notes of Deputy Land Surveyor, William Layton, are representative of the precise measurement that was evident on survey plans: *"The lines of these lots were run the distance of 73 ch. 33 l^ks^, and the rear line intended to be straight, connecting the two ends;...*

Carlton 1st, October 1826.

Wm. Layton D.L.S."

In conclusion, surveyors most probably marked only the trees that grew at precisely, or closest to, the bounds of lots, given the considerable effort made to take precise measurements.

Surveyor field notes indicated no tree preferences, though the collection of surviving field notes that accompanied the original sketches was surprisingly meagre. It is logical to think that surveyors may have selected trees that endured the longest on a boundary. Short-lived trees or trees in a state of deterioration would not make good choices. There were records, nonetheless, of short-lived species, such as *Populus* spp., and white birch, as well as dead spruce, dead fir, dead pine, burnt juniper, and 'dry spruce' (likely a dead or unhealthy spruce). Likewise, species susceptible to windthrow or sensitive to fire might have been regarded as poor choices for long-term survey markers. Yet spruce and hemlock were the most frequent witness trees used, and both are more susceptible to windthrow than other species, such as pine and maple. They are also very susceptible to fire. All these factors lead to the conclusion that the frequency of witness tree species chosen reflected the frequency of tree species in the local forests.

Precision of survey methods versus actual witness tree locations

Despite the exact measurements, precise locations of witness trees remain only close approximations of their historically noted localities. Erroneous surveys from this early period were fairly common due to difficulties in determining local declination (Thomson 1966), the inaccuracy of early survey tools, and absence of reference locations. Early recorded meridian lines, surveyed slightly off course, remain in evidence on current cadastral maps. Several land disputes in the study area were noted in the records. Another convention that introduced inaccuracies into early surveys was the 10 % area increase to each land grant to allow for future roads and 'waste' (i.e. lands unfit for agriculture or homesteads). Many survey sketches indicated the acreage, followed by the words "*with allowance*", or "*with 10 percent*". It was most likely this practice that lead Monro (1844) to mention that, "*Most of the old grants in these Provinces contain more land than they express. Sometimes, however, they contain less. In either case the recorded description differs from their true dimensions and contents*."

Discrepancies over exact witness tree localities were generally not large enough to affect analyses of witness tree species distributions over ecosite classes. The differences would have rarely changed their assignment to an alternate ecosite.

Strengths and limitations of witness tree analysis and use of modern forestry databases

Witness trees from surveyor plan drawings represent one of the best quantitative sources of presettlement forest information available. An advantage of this research method is that it requires little training. Other historical ecology research methods are more technical (e.g. fossil pollen or radio-carbon dating of charcoal layers). The archived surveyor material required only patience and the time to collect, digitize, and interpret information.

There are limitations to any historical ecology method, however. Success of witness tree research hinges on survey intensity, and the quantity and quality of surviving archival records. Some regions of NB, such as Crown lands, may not have been surveyed sufficiently to allow witness tree research. Other regions may have insufficient surviving archived material to complete such research. As surveyor information was not originally intended to report on forest types, some forest information is unavailable, such as identification of all trees to the species level. Lack of species differentiation limits conclusions. Low density of witness trees across the landscape did not permit detailed mapping of forest types in any specific location. Only more broad generalizations can be gained by pooling witness tree data over sites that feature similar edaphic characteristics, to gain a broad perspective on early forest types. Witness tree information is limited to a relatively brief period in history, the time of early settlement. The advantage of knowing more of this particular time period, however, is that it can provide a benchmark at the time coinciding with the commencement of rapid forest modification. The influences of watersheds in the early settlement patterns lead to some areas being represented more intensively by witness trees than others.

Witness tree research in this study relied heavily on metes and bounds survey plans, which presented greater challenges than using rectangular surveys. Each metes and bounds survey plan may include only one or two witness trees, whereas one rectangular survey may have used hundreds of witness trees. Also, witness trees were not regularly spaced in a grid pattern. The type of surveys available depends upon how the landscape was first divided up. Most of the published witness tree studies were based on rectangular surveys (generally township surveys) (Bourdo 1956; Siccama 1971; Lorimer 1977).

There were some limitations to the modern databases used in this research. Analysis of forest associations using witness tree information would likely be enhanced by having more detailed soil and drainage maps. Current soil and drainage maps do not reflect the complex variation in micro-drainage pattern evident in the study area. A serious limiting factor was lack of detail on physiographic units (i.e. ecosites) used in the ELC. This may be less problematic in other regions of NB where greater topographical variation results in coarser scale drainage pattern, and allows for larger, more readily identifiable physiographic units. It was more challenging over the flat topography of the study area, with fine scale complex drainage patterns. In this region, elevation and slope played smaller roles in deriving ecosite classes.

Another limitation was the origin of the geophysical data used for the study area. The only database available was the work of Wang and Rees (1983), who conducted very little field sampling. Most of the soil polygons, including drainage classes, were defined according to air photo interpretation of forest associations. Hence there is circular reasoning, where soil maps are more or less forestry maps used to interpret physical influences.

An alternative analysis of witness tree associations based entirely on drainage classes was considered, since forest associations were closely linked to soil drainage. Drainage exerts a strong influence on forest patterns (Schaetzl and Brown 1996). The ELC aggregated some of the drainage classes as it used other physical factors in its classification scheme. Ecosite 2, for example, comprised as many as 5 drainage classes.

Bogs are better defined using the ecosite classification, rather than drainage classes that lump sphagnum-dominated areas with other poorly drained areas, such as cedar swales.

The forest cover database used for riparian zone analysis was limited to tree species that air photo interpreters could differentiate. Species, such as *Q. rubra*, and *O. virginiana* were listed as 'OH' since they could not be interpreted from air photos.

CONCLUSIONS

With the exception of the Carolinian forest in southern Ontario, perhaps no other forest region in Canada has lost more of its character than the Acadian forest. Witness tree research on a section of forest on the New Brunswick Eastern Lowlands has provided solid empirical evidence of the original forest composition over a range of site conditions. Forests *ca.* 1800 were dominated mainly by moderately to very shade-tolerant, late-successional species complexes, *Picea, Tsuga canadensis, Betula, Abies balsamea, Acer,* and *Pinus strobus, Thuja occidentalis,* and *Fagus grandifolia*. The most prevalent species complex, over a wide range of edaphic conditions, was concluded to have been *Picea - T. canadensis – B. alleghaniensis*. Species complexes appeared to have been relatively stable according to understory tree species composition, which did not indicate an imminent shift in forest composition (assessed through survey stake species composition).

The pace of forest change has been extremely rapid. Modern forests feature several marked departures from the forest reference condition provided from witness tree information. Former dominants, such as *T. canadensis* and *F. grandifolia* have experienced sharp declines to very low levels, while abundance of *A. balsamea* has doubled on many sites, and *Populus* has risen from only minor occurrences to become the most abundant hardwood species over much of the landscape. Contemporary forests have become notably less biologically diverse after a period of 200 years. Six tree species dominate contemporary forests where there were formerly nine species *ca*. 1800. Riparian zones have lost ~ 40 % of forest cover to human land clearances and development, and clear-cutting. Riparian forests support little of the former species composition, such as key dominants *T. canadensis,* and *P. strobus*.

Dominance of *T. canadensis* and the absence of *P. banksiana* in the survey record provide strong empirical evidence that fire was not a strong disturbance agent *ca*. 1800. Following European settlement, fire became very frequent, often noted on survey sketches. Fire-adapted species, such as *Pinus banksiana, Populus,* and *Picea mariana*, currently flourish in the region in consequence of the human-altered disturbance regime.

This research provides good detail on tree species composition required to define a forest reference condition. Forest management and conservation interventions, based on a forest reference condition from the period prior to heavy European settlement impacts, will be strongly guided by these conclusions. Information on former species compositions and disturbance regimes can be used to restore vegetation to more natural ranges of variability and manage forest health for the future.

Table 3.1 Ecosite descriptions, total area, percent of total area per ecosite, number of witness trees, percentage of witness trees per ecosite, tree density per ecosite, and number of FDS cruise lines per ecosite.

*Ecosite class	Ecosite Description	Area (km^2)	Percent Area	Witness trees (N)	Percent Total Trees	Density (trees/km^2)	FDS cruise lines (N)
1	Coarse-textured deposit	157.19	6.60	405	15.96	2.6	37
2	Coniferous acidic valley slope or coarse-textured deposit	1132.03	47.56	1246	49.11	1.1	288
3	Coniferous wet acidic till plain	625.03	26.26	516	20.34	0.8	88
3b	Bog	277.81	11.67	83	3.27	0.3	9
5	Coniferous or mixedwood moist slope	176.22	7.40	272	10.72	1.5	50
6b	Acadian wet bottomland	11.77	0.49	15	0.59	1.3	0
Total		**2380.05**		**2537**		**1.1**	**472**

*Ecosites from ELC (DNRE 1996), situated within the following hierarchical classification:

Ecoregion: Eastern Lowlands

Ecodistrict: Kouchibouguac

Ecosections: 6-6-2, 6-6-3, 6-6-4

Table 3.2 Witness tree species interpreted from survey names and symbols.

Surveyor Names	Surveyor Symbols	Scientific name	
Broad-lved species			
Maple	Map., Ma.	*Acer*	*saccharum, rubrum*
Red, Swamp, White maple	R.maple, r. ma.,W. Ma., w. ma.	*Acer*	*rubrum*
Sugar, Rock maple	Rk. Maple, W.maple	*Acer*	*saccharum*
Moosewood		*Acer*	*pensylvanicum*
Oak, Red oak		*Quercus*	*rubra*
Elm		*Ulmus*	*americana*
Beech	Bee.	*Fagus*	*grandifolia*
Ash		*Fraxinus*	*americana, nigra*
Cherry		*Prunus*	*pensylvanica, virginiana*
Ironwood, Hornbeam		*Ostrya*	*virginiana*
Birch	Bir., Bi.	*Betula*	*alleghaniensis, papyrifera, populifolia*
White birch	Wh. Bir, W. Bir.,W. birch, W.B.	*Betula*	*papyrifera*
Yellow birch	Y. Bir.,Yel.Bir., Y. Bi., Y.B.	*Betula*	*alleghaniensis*
Black birch	Bla. bir., blk.birch	*Betula*	*alleghaniensis*
Poplar	Pop.	*Populus*	*tremuloides, grandidentata, balsamifera*
Alder	al.	*Alnus*	*incana*
Coniferous species			
Juniper, Larch, Tamarac	Jun., T.	*Larix*	*laricina*
Cedar	Ce, ced., C.	*Thuja*	*occidentalis*
Pine	Pi.	*Pinus*	*strobus*
Red pine	R. Pine, Red Pi.	*Pinus*	*resinosa*
White pine	Wh. pine, w. pine	*Pinus*	*strobus*
Pitch pine		*Pinus*	*resinosa**
Stunted pine		*Pinus*	*banksiana**
Spruce	sp., spr., spru., S.	*Picea*	*rubens, mariana*
Dry spruce		*Picea*	
Black spruce**	B. spruce., bl. sp.	*Picea*	*rubens, mariana*
White spruce	W. Spr.	*Picea*	*glauca*
Fir	F.	*Abies*	*balsamea*
Hemlock	Hem., H.	*Tsuga*	*canadensis*

Scientific names from Hinds 2000.

* These taxonomic assignments could not be verified and remain theoretical.

** Black spruce was assigned to both red and black spruce throughout the 19^{th} century.

Table 3.3 Species composition *ca.* 1800 derived from witness trees over ecosite classes on the New Brunswick Eastern Lowlands (Ecosections 6-6-2, 6-6-3, 6-6-4).

Survey terms	Survey label	Scientific Names	Ecosite 1	Ecosite 2	Ecosite 3	Ecosite 3b	Ecosite 5
alder	al	*Alnus incana*	1	2	3	-	-
ash	_A	*Fraxinus* spp.	8	20	14	1	8
elm	aE	*Ulmus americana*	8	6	1	-	3
fir	bF	*Abies balsamea*	45	138	46	8	24
beech	Be	*Fagus grandifolia*	14	75	16	-	22
birch	_B	*Betula* spp.	43	88	29	7	22
black birch	bB	*Betula alleghaniensis*	4	6	1	-	-
cherry	Ch	*Prunus* spp.	1	1	-	-	-
cedar	eC	*Thuja occidentalis*	12	79	34	5	10
hemlock	eH	*Tsuga canadensis*	88	222	55	2	55
ironwood	Ir	*Ostrya virginiana*	-	-	-	-	1
juniper	Jr	*Larix laricina*	-	9	13	3	4
tamarac, larch	La	*Larix laricina*	1	4	10	6	2
moosewood	mW	*Acer pensylvanicum*	-	1	-	-	-
maple	_M	*Acer* spp.	24	73	28	2	15
oak	_O	*Quercus rubra*		3	2	-	-
pine	_P	*Pinus* spp.	21	72	32	3	13
poplar	Po	*Populus spp.*	5	8	11	-	-
pitch pine	pP	*Pinus resinosa*	1	-	-	-	-
red maple	rM	*Acer rubrum*	2	7	-	-	1
red pine	rP	*Pinus resinosa*	1	7	5	-	2
rock maple	rkM	*Acer saccharum*		2	1	-	-
spruce	_S	*Picea* spp.	90	368	185	46	70
swamp maple	swpM	*Acer rubrum*	1	-	-	-	-
white ash	wA	*Fraxinus americana*	-	-	1	-	-
white birch	wB	*Betula papyrifera*	7	19	15	-	10
white maple	wM	*Acer rubrum*	6	11	4	-	4
white pine	wP	*Pinus strobus*	6	10	5	-	1
white spruce	wS	*Picea glauca*	1	-	-	-	-
yellow birch	yB	*Betula alleghaniensis*	15	15	5	-	6

Numbers refer to witness tree stem frequencies. Scientific nomenclature follows Hinds (2000).

Table 3.4 Tree species used for survey posts.

Genus	**Posts (N)**	**Percent**
Larix	12	48
Thuja	10	40
Picea	2	8
Pinus	1	4
Total	25	100

Table 3.5 Percent tree species composition in historical and contemporary forests and their changes over the last two centuries within the New Brunswick Eastern Lowlands Ecoregion, Ecosections 6-6-2, 6-6-3, 6-6-4.

Values printed in bold face (green) represent dominant taxa that comprise 95 % of forest composition.

Genus	Forests *ca.* 1800	Forests *ca.* 2000	Difference (%)
Picea	**30.00**	**45.48**	51.6
Tsuga	**16.83**	1.18	-93.0
Betula	**11.55**	**3.46**	-70.0
Abies	**10.33**	**16.42**	59.9
Acer	**7.25**	**10.39**	43.3
Pinus	**7.13**	**8.06**	13.0
Thuja	**5.52**	**3.07**	-44.4
Fagus	**5.01**	0.14	-97.2
Larix	**2.09**	2.80	34.0
Fraxinus	2.09	0.06	-97.1
Populus	0.95	**8.55**	800
Ulmus	0.71	-	0.0
Alnus	0.24	0.14	-41.7
Quercus	0.20	0.01	-95.0
Prunus	0.08	0.14	75.0
Ostrya	0.04	0.09	125.0

Forests *ca.* 1800: witness tree frequency (%). Forests *ca.* 2000: species BA (%).

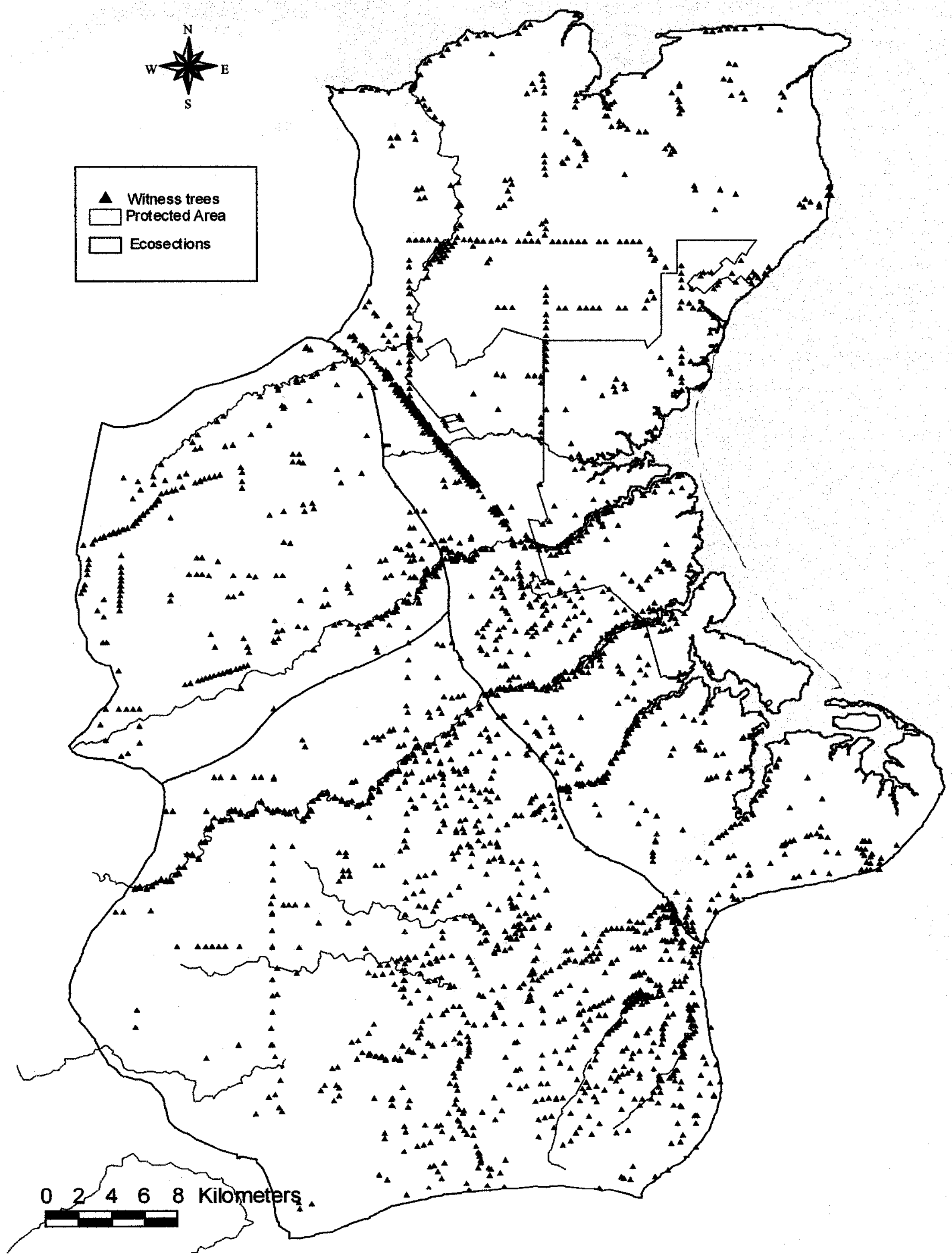
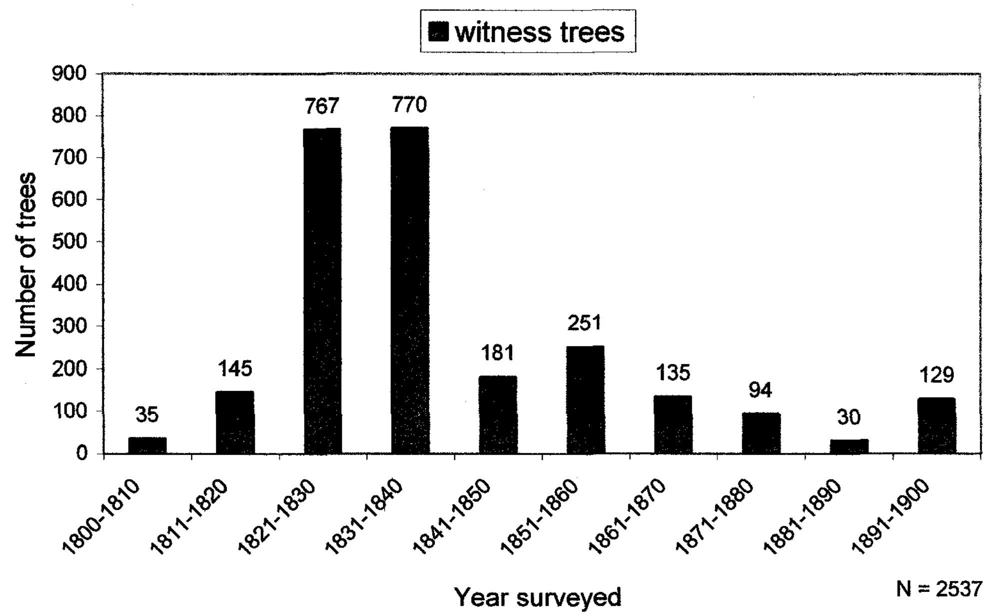


Figure 3.1 Witness tree distribution *ca.* 1800 in New Brunswick Eastern Lowlands Ecoregion (Ecosections 6-6-2, 6-6-3, and 6-6-4).

A.



B.

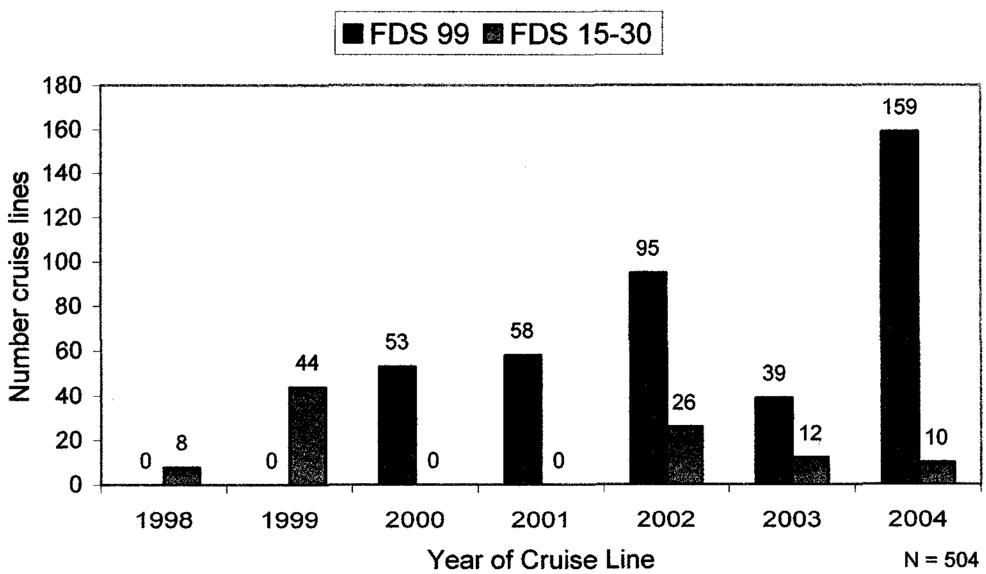


Figure 3.2 Source years of historical and current forest information: (A.) witness trees; (B) FDS (Forest Development Survey) cruise lines.

FDS 99 = Forest stands older than 30 years, FDS 15-30 = stands 15-30 years old.

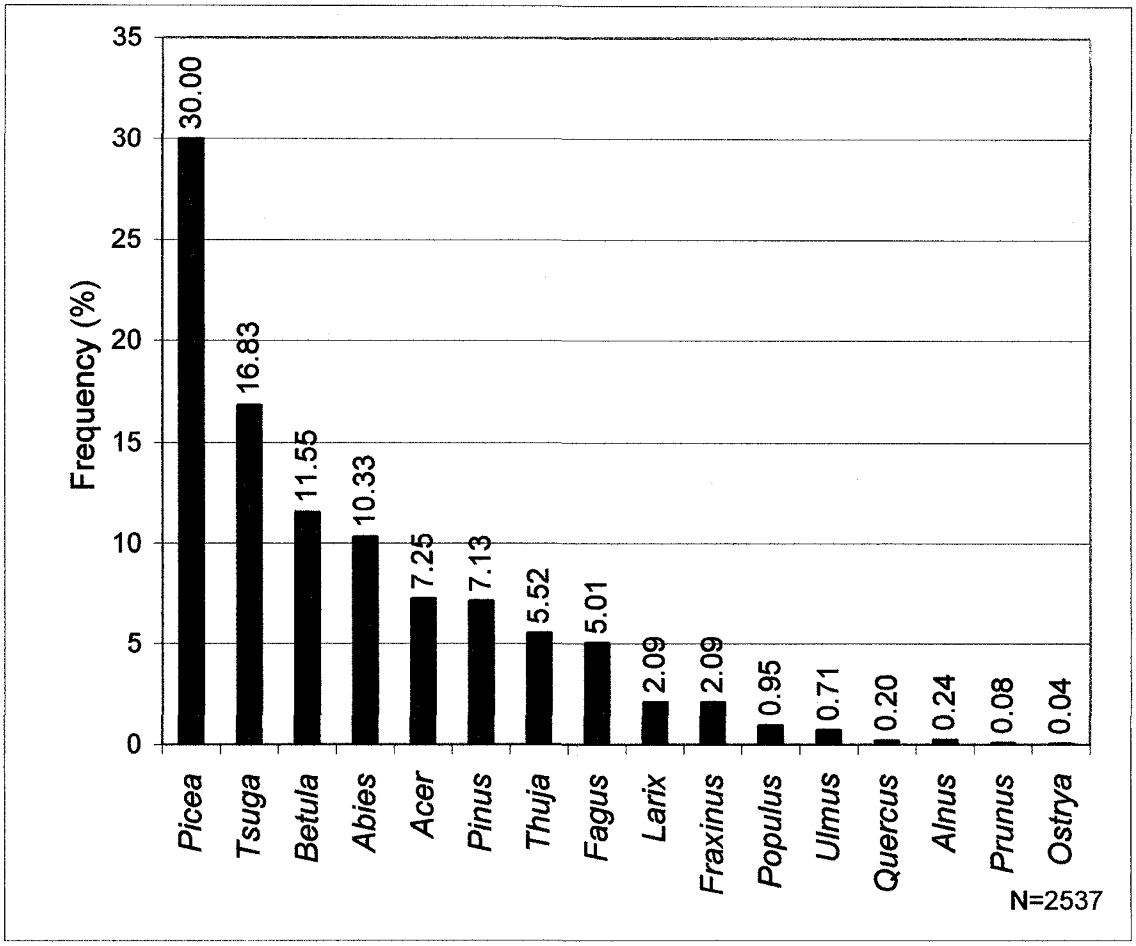


Figure 3.3 Frequency of witness trees by genus.

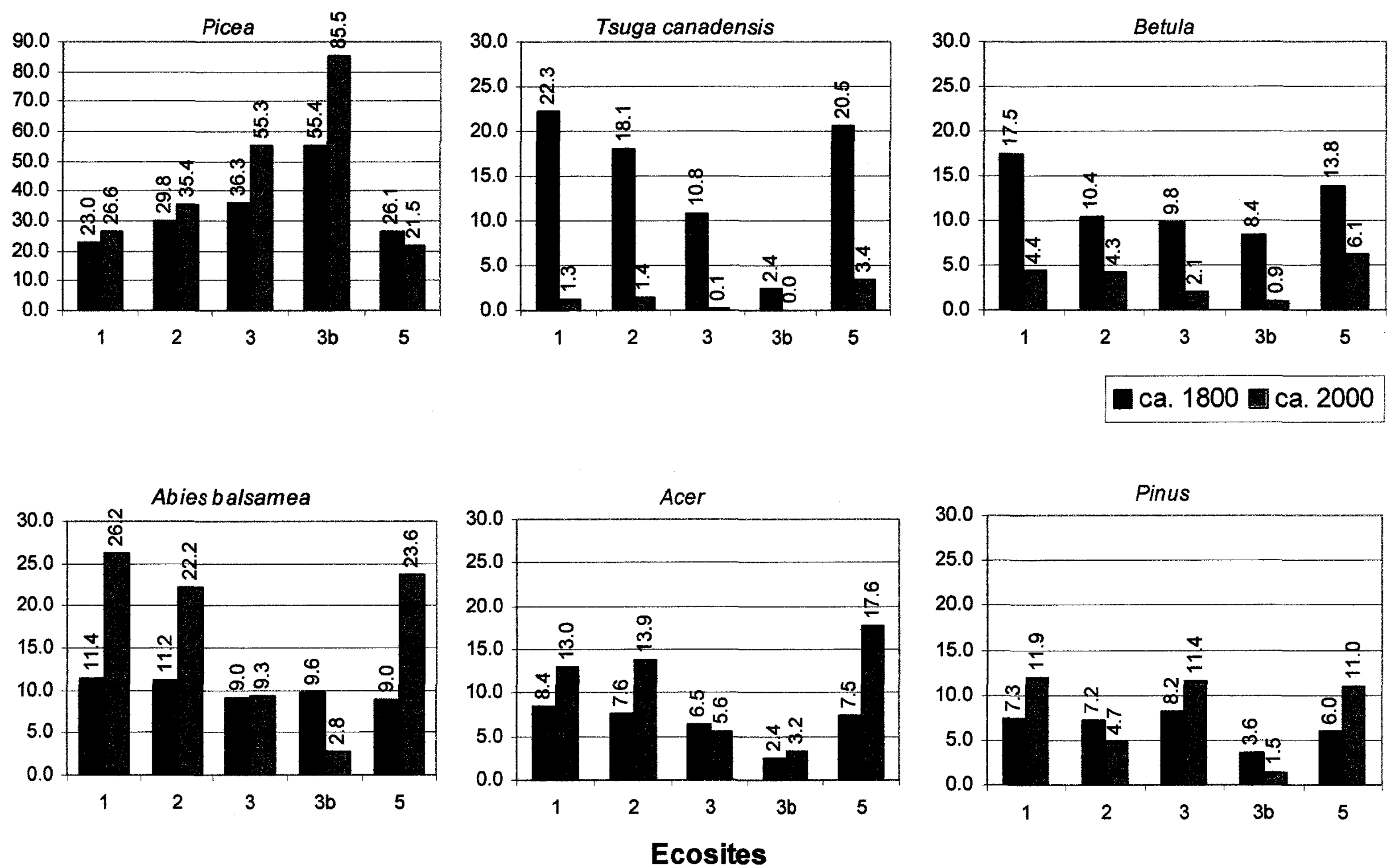


Figure 3.4 A comparison of 19th century and present day tree species frequencies over ecosites 1, 2, 3, 3b, 5 (x-axis) in New Brunswick Eastern Lowlands Ecoregion (Ecosections 6-6-2, 6-6-3, 6-6-4); y-axis = percent. Note: y-axis for *Picea* uses a different scale.

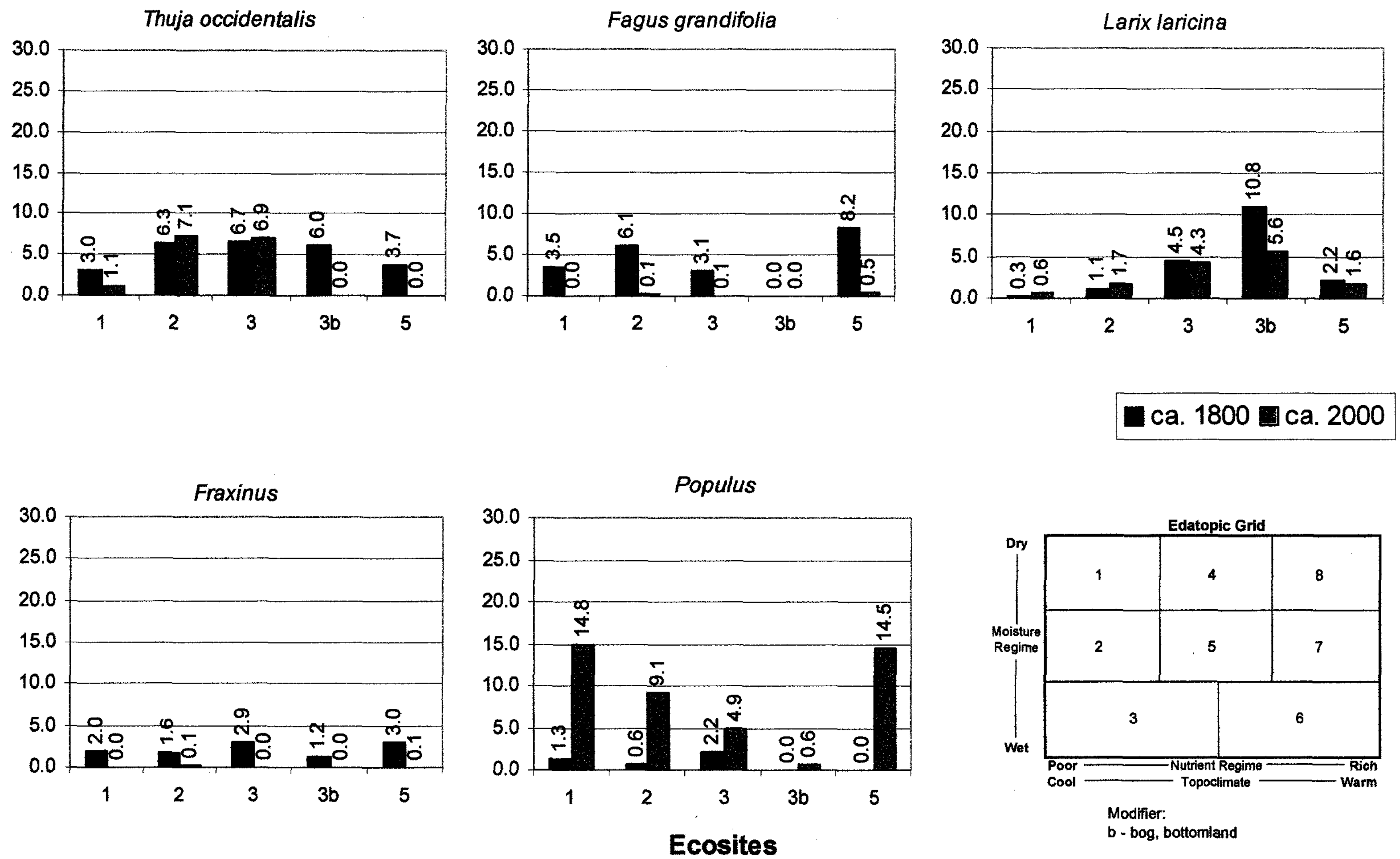


Figure 3.4 (cont.) A comparison of 19th century and present day tree species frequencies over ecosites 1, 2, 3, 3b, and 5 (x-axis) in Eastern New Brunswick Eastern Lowlands Ecoregion (Ecosections 6-6-2, 6-6-3, 6-6-4); y-axis = percent.

Edatopic grid adopted from the New Brunswick Ecological Land Classification (DNRE 1996).

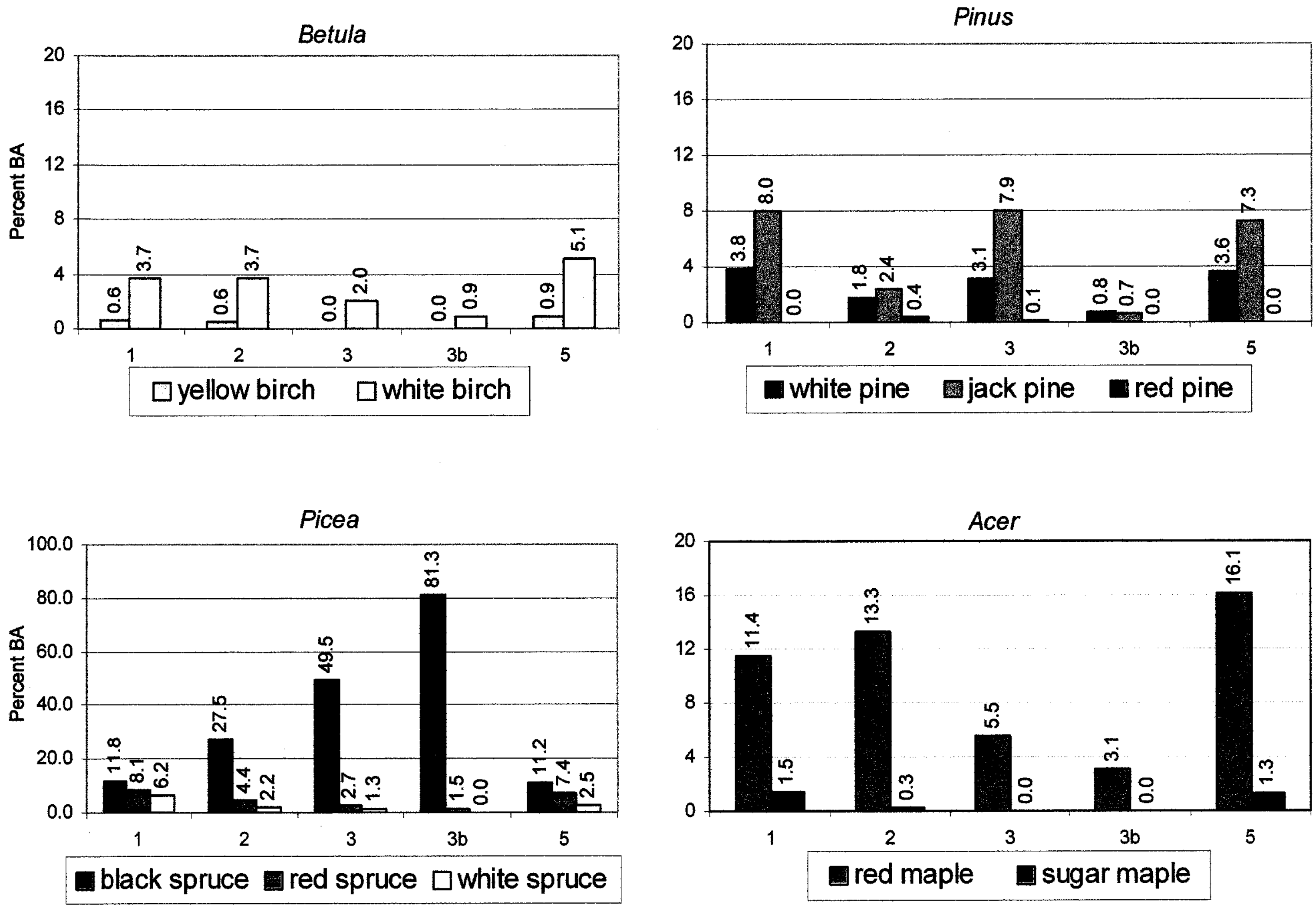


Figure 3.5 Current species breakdown of *Picea, Pinus, Betula*, and *Acer* over Ecosites 1, 2, 3, 3b, and 5 (x-axis) according to FDS data, *ca.* 2000 for New Brunswick Eastern Lowlands Ecoregion (Ecosections 6-6-2, 6-6-3, 6-6-4).

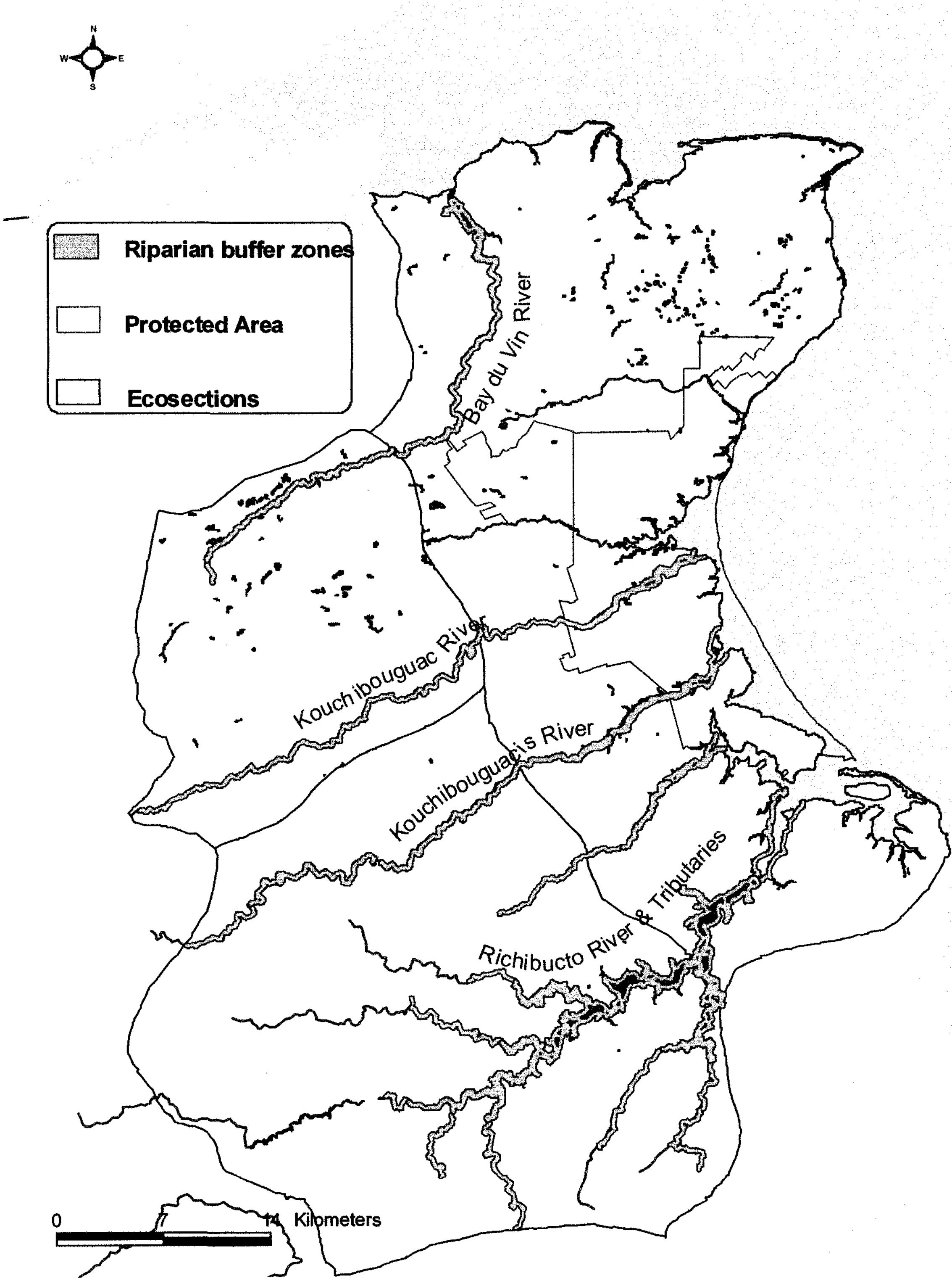


Figure 3.6 Riparian zones analyzed for forest composition.

Width of riparian zones was approximately 150 m from each bank.

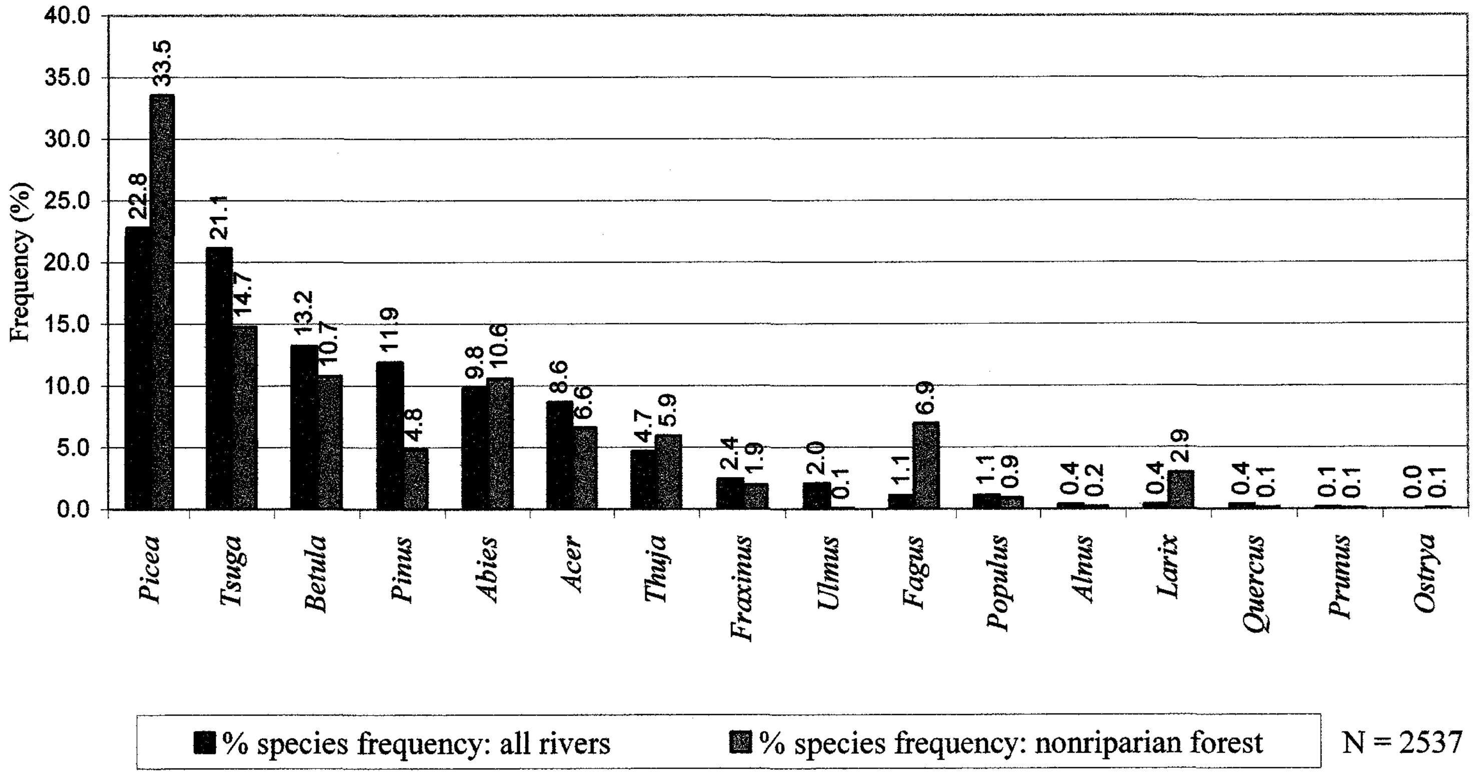


Figure 3.7 Historic composition of riparian forests vs. nonriparian forests *ca.* 1800 in New Brunswick Eastern Lowlands (Ecosections 6-6-2, 6-6-3. and 6-6-4).

Width of riparian zones was approximately 150 m from each bank.

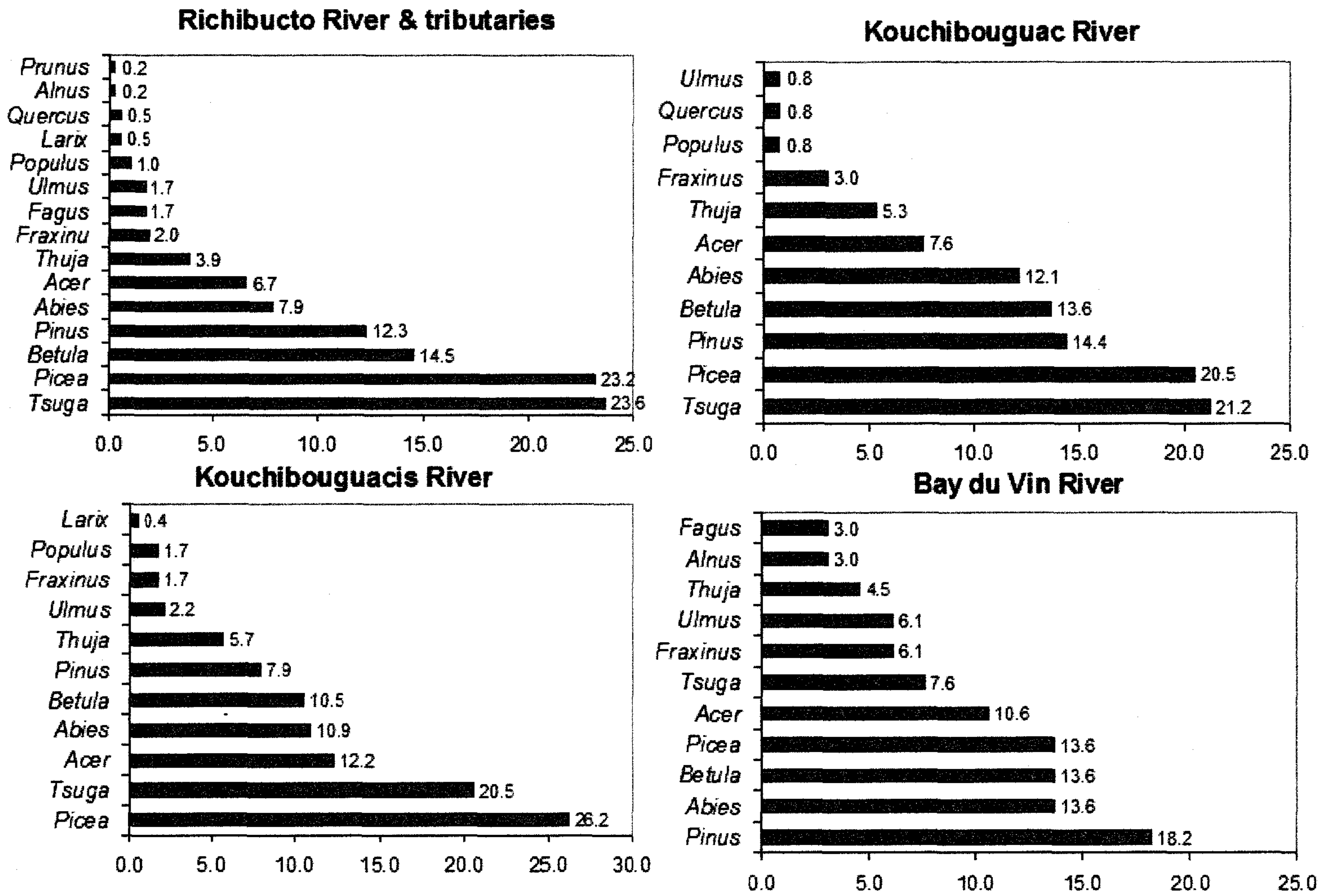


Figure 3.8 Species frequency distribution *ca.* 1800 in riparian zones of four watersheds located in New Brunswick Eastern Lowlands (Ecosections 6-6-2, 6-6-3. and 6-6-4). Width of riparian zones was approximately 150 m from each bank. x- axis = %, N= 833

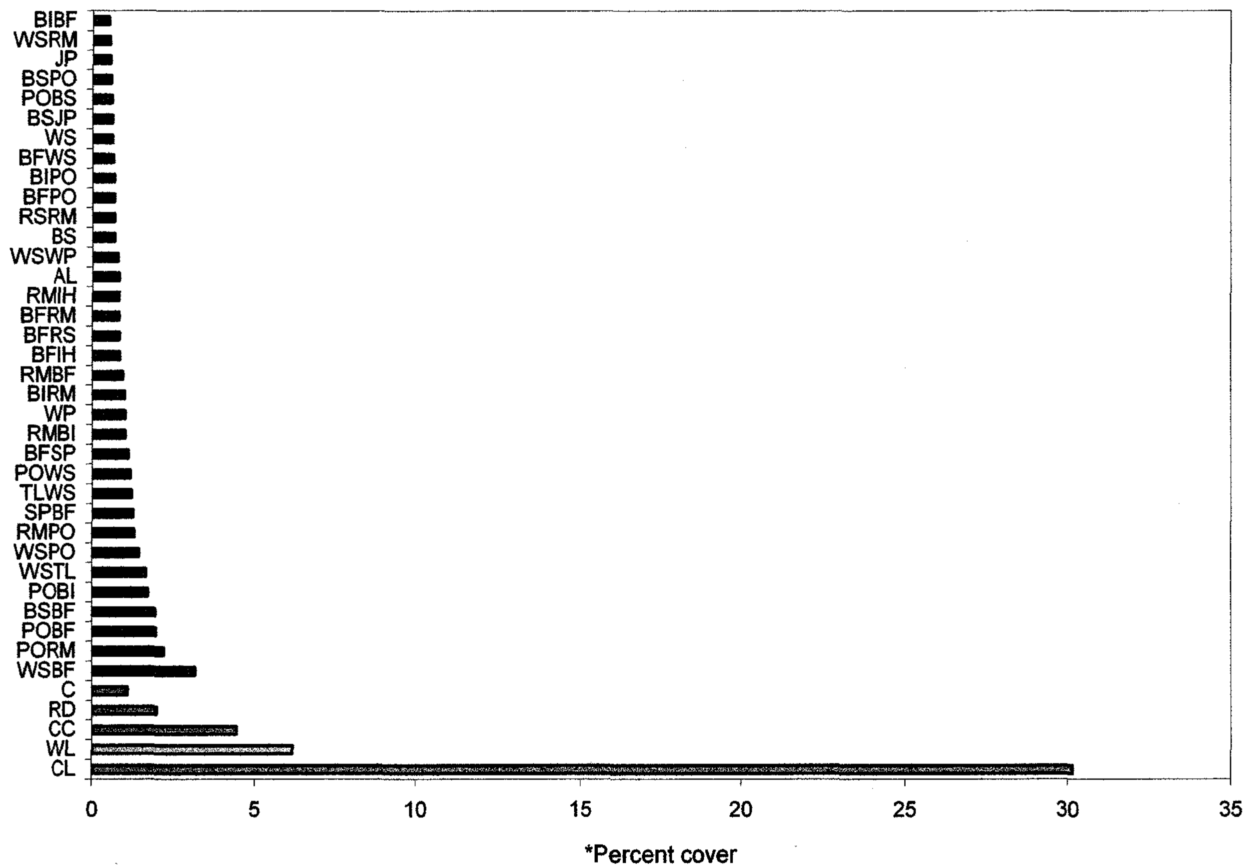


Figure 3.9 Current vegetation or land use cover classes within riparian zones of the Richibucto River and tributaries, Kouchibouguacis, Kouchibouguac, and Bay du Vin Rivers. *Graph shows the majority of cover classes (80%). Width of riparian zones was approximately 150 m from each bank. Forested classes are green. Nonforested classes are brown. Wetland is blue. Symbols from DNRE (2001): AL-alder, BI-white or grey birch only, BF-balsam fir, BS-black spruce, C-cut, CC-clear cut, CL-cleared lands, IH-shade-intolerant hardwoods- white birch, grey birch, poplar, JP, jack pine, PO- poplar, RD- road, RM- red maple, RS- red spruce, SP- red and/or white spruce, TL- larch, WL- wetland, WP- white pine, WS- white spruce.

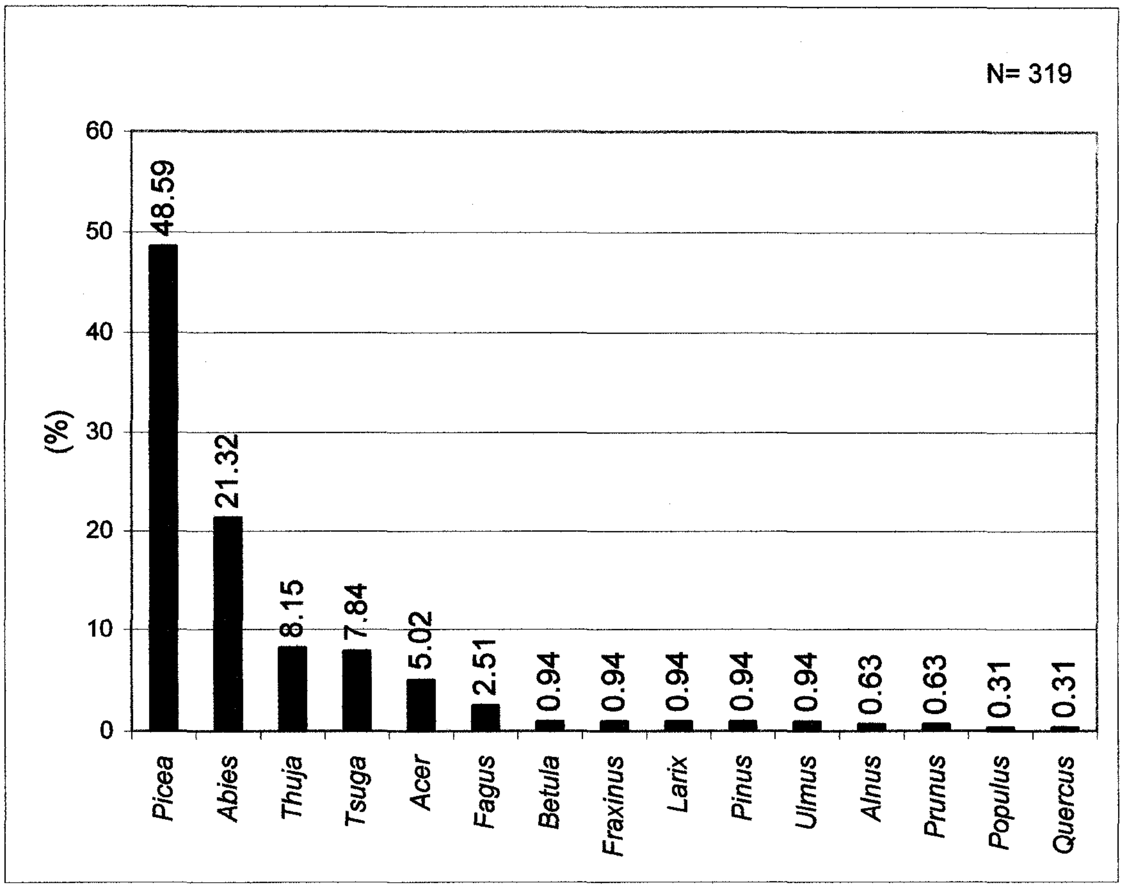


Figure 3.10 Frequency of stake species.

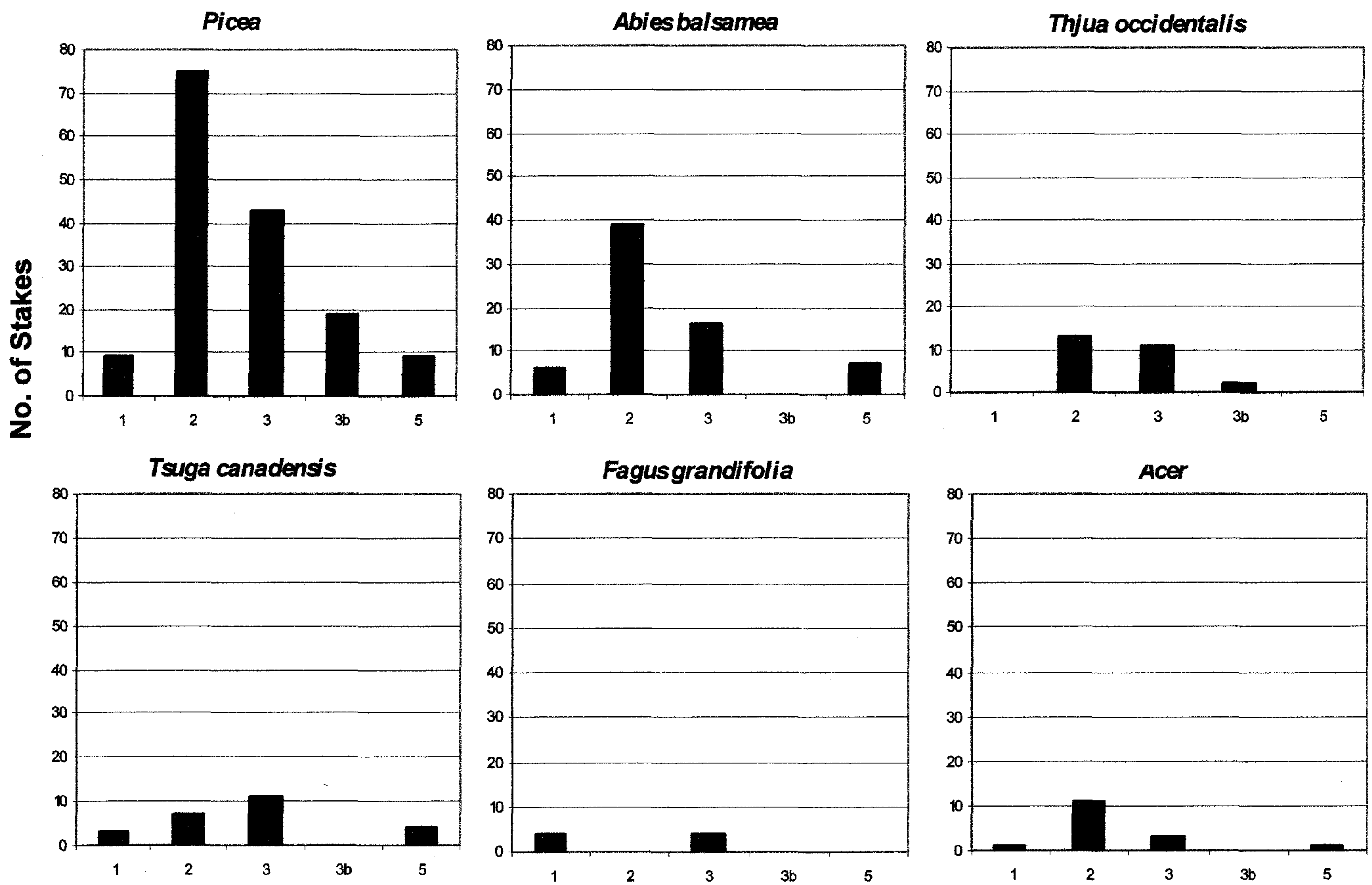
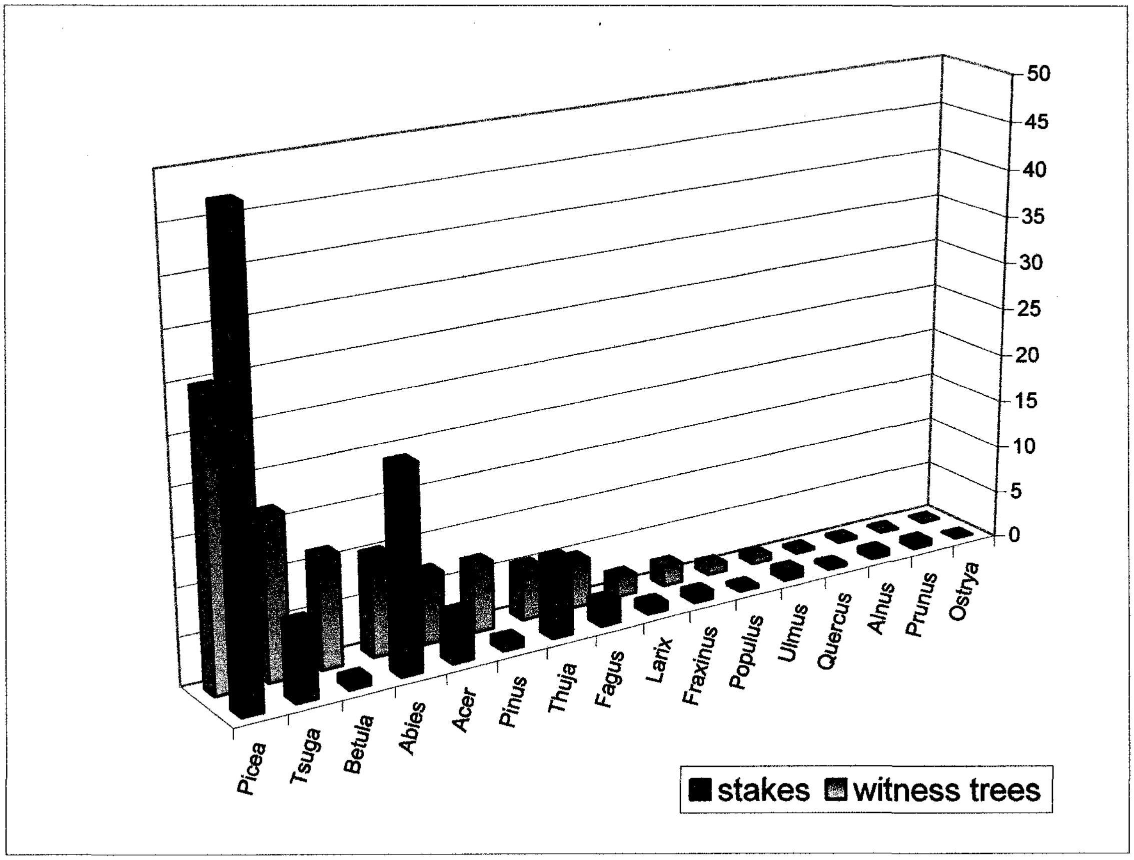


Figure 3.11 Distribution of the six most common species of survey stakes on ecosites within the New Brunswick Eastern Lowlands (Ecosections 6-6-2, 6-6-3, 6-6-4).



(N=2856)

Figure 3.12 Comparison of witness tree species frequency (%) versus stake marker species frequency (%) as a possible indication of overstory tree species composition versus understory tree species composition in forests *ca.* 1800.

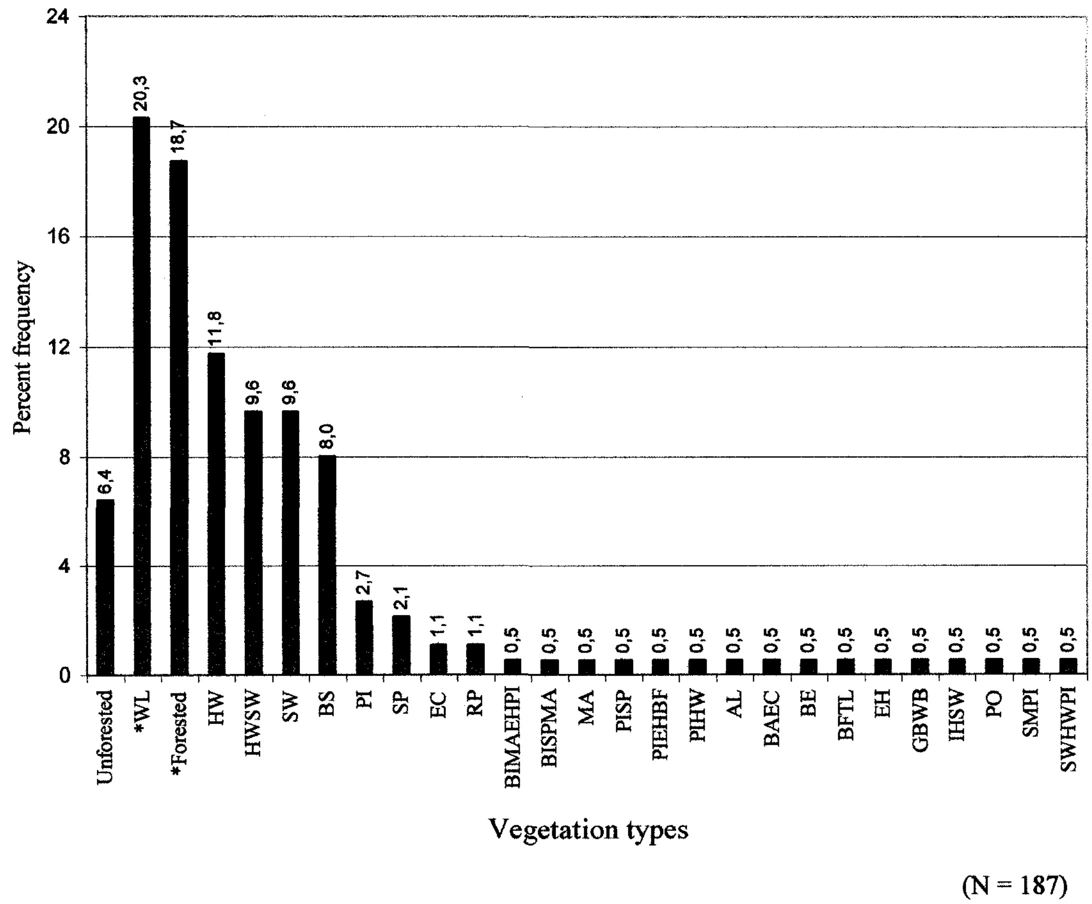


Figure 3.13 Frequency of vegetation types *ca.* 1800, recorded by deputy surveyors on metes and bounds surveys throughout New Brunswick Eastern Lowlands Ecoregion (Ecosections 6-6-2, 6-6-3, and 6-6-4).

Symbols adopted from DNRE (2001): AL-alder, BA-black ash, BE-beech, BF-balsam fir, BI- birch, BS-'black spruce' (also includes red spruce), EC-eastern cedar, EH-eastern hemlock, GB-grey birch, HW-hardwood, IH-intolerant hardwood, MA-maple, PI-pine, PO- poplar, RP-red pine, SM-sugar maple, SP-spruce, SW-softwood, TL-larch, WB-white birch. * WL= wetlands that may or may not be forested, e.g. swamps, marshes, 'plains' or 'barrens' (bogs). Unforested= 'naked barrens', 'open plains'. Forested= unknown forest types comprising <u>60 % burnt forests</u> not described by surveyors. "Green woods" (unburned woods) were also included.

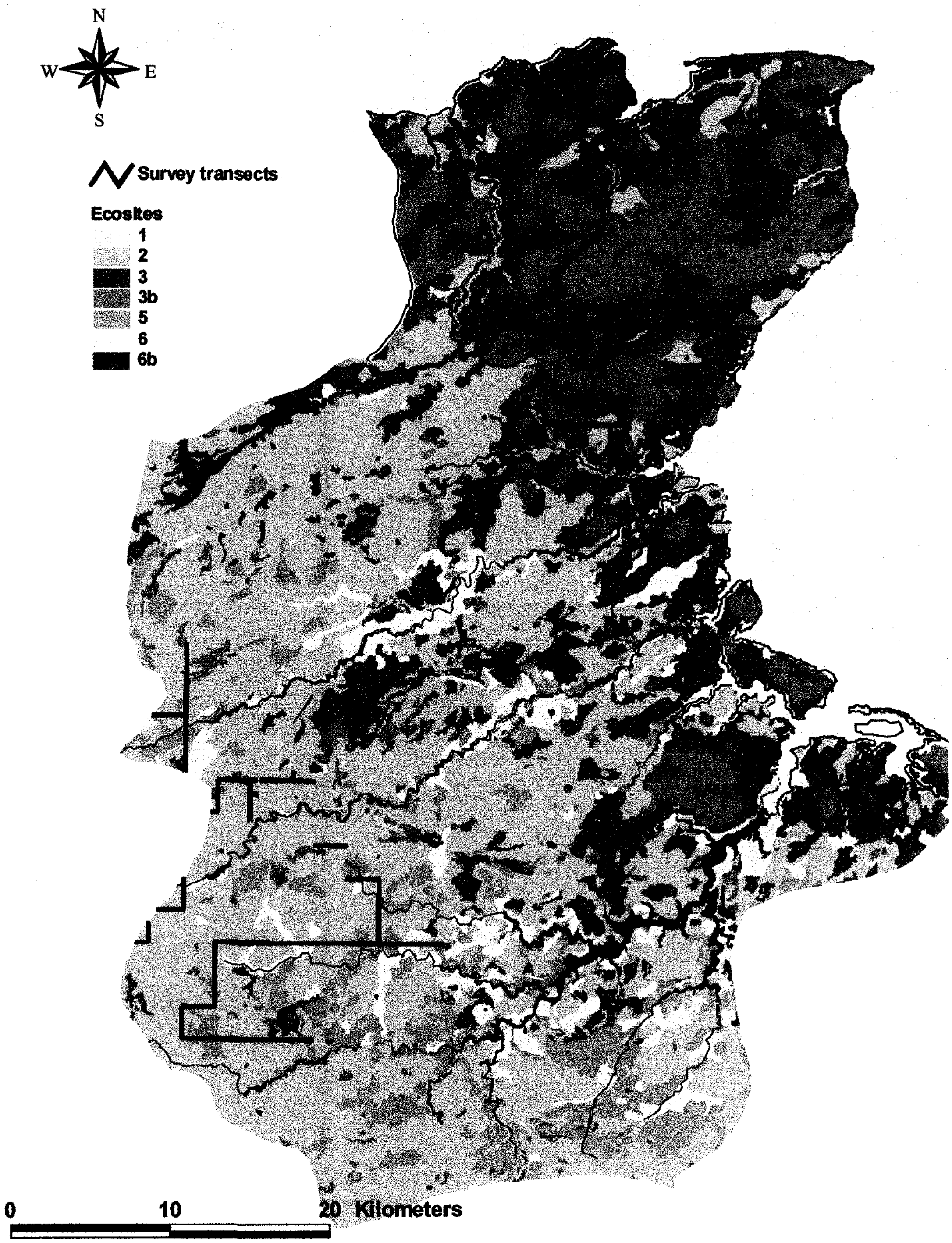
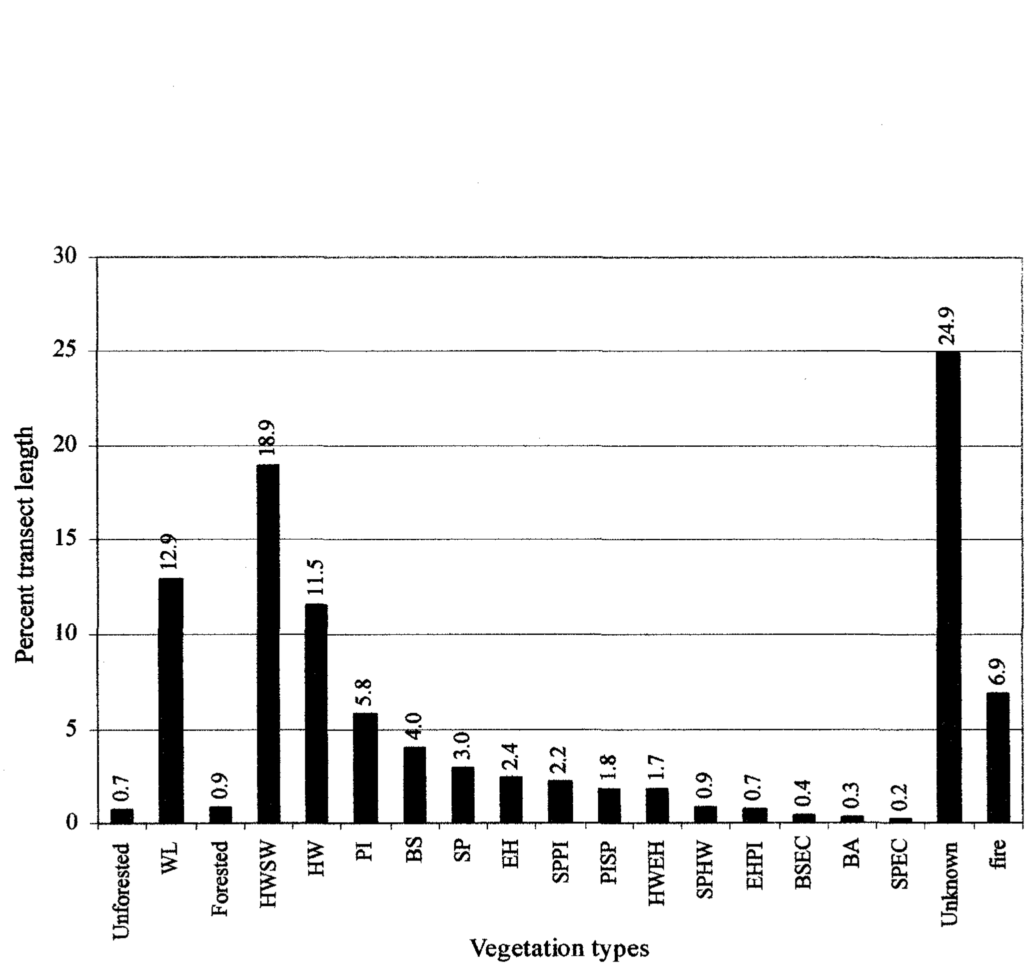


Figure 3.14 Survey transects that contained forest descriptions.



(N = 119)

Figure 3.15 Vegetation types *ca.* 1800 recorded on approximately 89 km of survey line (indicated in Figure 3.14) located throughout New Brunswick Eastern Lowlands Ecoregion (Ecosections 6-6-2, 6-6-3, and 6-6-4).

Symbols follow the New Brunswick GIS Data Dictionary (DNRE 2001). WL = wetlands that may or may not be forested, includes 'barrens' (mainly bogs), swamps, meadows. Unforested = open wetlands. Unknown = areas of survey transects of uncertain forest assignment.

REFERENCES

Abrams, M.D. and Orwig, D.A. 1996. A 300-year history of disturbance and canopy recruitment for co-occuring white pine and hemlock on the Allegheny Plateau, USA. J. Ecology 84: 353-363.

Abrams, M.D., Orwig, D.A., and Demeo, T.E. 1995. Dendroecological analysis of successional dynamics for a presettlement-origin white pine-mixed-oak forest in the southern Appalachians, USA. J. Ecology 83: 123-133.

Abrams, M.D. and Ruffner, C.M. 1995. Physiographic analysis of witness-tree distribution (1765-1798) and present forest cover through north central Pennsylvania. Can. J. For. Res. 25: 659-668.

Alexander, J.E. 1849. L'Acadie, or, Seven years' explorations in British North America. London, H. Colburn. 370 pp.

Anderson, R.C. and Katz, A.J. 1993. Recovery of browse sensitive tree species following release from white-tailed deer *Odocoileus virginianus* Zimmerman browsing pressure. Biol. Conserv. 63: 203-208.

Anon., n.d. Records of the Surveyor General finding aid, RS637, PANB.

Bailey, L.W. 1876. The woods and minerals of New Brunswick, being a descriptive catalogue of the trees, shrubs, rocks and minerals of the province, available for economic purposes. Daily Telegraph Steam Job Rooms, Saint John, NB. 50 pp.

Beach, H., (Ed.) 1988. The Resources of Kouchibouguac National Park: Resource Description and Analysis. Kouchibouguac National Park, Envir. Canada.

Betts, M.G. and Forbes, G.J. (Eds.) 2005. Forest management guidelines to protect native biodiversity in the Greater Fundy Ecosystem. New Brunswick Co-operative Fish and Wildlife Research Unit, UNB, NB. 110 pp.

Black, B.A. and Abrams, M.D. 2001. Influences of Native Americans and surveyor biases on metes and bounds witness-tree distribution, Ecology 82 (9): 2574-2586.

Bourdo, E.A. (Jr.) 1956. A review of the general land office survey and of its use in quantitative studies of former forests. Ecology 37(4): 754-768.

Bruncken, E. 1900. North American forests and forestry. G.P. Putnam's Sons, NY. 265 pp.

Burns, R. M., and Honkala, B. H., tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 pp.

Clermont, N. 1986. L'adaptation maritime au pays des micmacs, *In* : Martijn, Charles A. 1986. Les micmacs et la mer. Recherches amérindiennes au Québec, Montréal, Qué. p 11-27.

Crossland, D. 1998. Recent fire history of Kouchibouguac National Park. Parks Canada-Technical Reports in Ecosystem Science #013, Cat No. R61-2/19-13/1997E, 41 pp.

DeGrace, E. 1984. Human history of Kouchibouguac National Park. Unpub. report to Parks Canada. 157 pp.

Denys, N. 1672. Description geographique et historique des costes de l' Amerique septentrionale, avec l'histoire naturelle de Pais. Republished English translation by Ganong, W.F. (Ed.). 1908. The description and natural history of the coasts of North America (Acadia). The Champlain Society, Greenwood Press, NY.

Delcourt, H.R. 1976. Presettlement vegetation of the North of Red River Land District, Louisiana. Castanea, 41: 122-139.
DNRE. 1996. An ecological land classification system of New Brunswick. Ecosystem Classification Working Group, Department of Natural Resources and Energy, Fredericton, NB.
DNRE 2001. New Brunswick GIS data dictionary. New Brunswick Forest Database, NB library, Department of Natural Resources and Energy, Fredericton, NB. 46 pp.
DNR 2004 a. N.B. forest development survey field manual for Y-O merchantable forest stands. Forest Management Branch, Department of Natural Resources, Fredericton, NB. 102 pp.
DNR. 2004 b. N.B. forest development survey field manual for 15-30 year old plantations, thinnings, and natural regenerating stands. Forest Management Branch, Department of Natural Resources, Fredericton, NB. 100 pp.
Duchesne, L.C. and Hawkes, B.C. 2000. Fire in northern ecosystems. In: Brown, J.K. and Smith, J.K. (Eds.) 2000. Wildland fire in ecosystems: Effects of fire on flora. USDA Forest Service Gen. Tech. Rep. RMRS-GTR-42-vol. 2: 35-51.
Foster, D.R., Orwig, D.A., and McLachlan, J.S. 1996. Ecological and conservation insights from reconstructive studies of temperate old-growth forests. TREE 11 (10): 419-424.
Foster, D.R. and Zebryk, T.M. 1993. Long-term vegetation dynamics and disturbance history of a Tsuga- dominated forest in New England. Ecology 74 (4): 982-998.
Foster, D.R., Black, B., and Abrams, M.D. 2004. A witness tree analysis of the effects of Native American Indians on the pre-European settlement forests in east-central Alabama. Human Ecology 32 (1): 27-47.
Fowler, J. 1878. List of New Brunswick plants. Report for the Secretary of Agriculture, Appendix B., Fredericton, NB. p. 35-63.
Ganong, W.F. 1902. Great forest fires in New Brunswick. Bulletin of the Natural History Society of New Brunswick, 4 (20): 434-435.
Ganong, W.F. 1906. Additions and corrections to monographs on the place-nomenclature, cartography, historic sites, boundaries and settlement-origins of the province on New Brunswick. From the transactions of the Royal Society of Canada, second series-1906-1907. Vol. XII.
Hessburg, P.F., Smith, B.G., and Salter, R.B. 1999. Detecting change in forest spatial patterns from reference conditions. Ecol. Applic. 94 (4): 1232-1252.
Hinds, H. R. 2000. Flora of New Brunswick (2nd ed.) Dept. of Biology, UNB. 695 pp.
Hosie, R.C. 1990. Native trees of Canada. Fitzhenry and Whiteside Ltd., Ont. 380 pp.
Johnston, J.F.W. 1851. Notes on North America. Vol. I and II., C.C. Little and J. Brown, Boston. 512 pp.
Lee, D. 1987. The forest history of New Brunswick 1780-1930: A systems plan report. Parks Canada Microfiche Report Series 301, 172 pp.
Leonard, K. J. 1996. Mi'kmaq culture during the Late Woodland and Early Historic periods. Thesis, U. Toronto, Dept. of Anthropology, 329 pp.
Lorimer, C.G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology 58: 139-148.
Loucks, O. L. 1962. A Forest Classification for the Maritime Provinces. Proceedings of the Nova Scotian Institute of Science. Vol. 25, Part 2.

Lutz, S.G. 1997. Pre-European settlement and present forest composition in Kings County, New Brunswick, Fac. For. Envir. Mgt. U.N.B., Fredericton, NB. 51 pp.

Major, J. E., Mosseler, A., Barsi, D.C., Campbell, M., and Rajora, O. P. 2003. Morphometric, allometric, and developmentally adaptive traits in red spruce and black spruce. I. Species and seed-source variation. Can. J. For. Res. 33: 885-893.

Manley, S.A.M. 1972. The occurrence of hybrid swarms of red and black spruces in central New Brunswick. Can. J. For. Res. 2: 381-391.

Millar, G.L. 1928. Forests and forestry in New Brunswick: Special report to the British empire forestry conference, Australia and New Zealand. Lands and Mines, Fredericton, NB. 69pp.

Monro, A. 1844. A treatise on theoretical and practical land surveying; adapted particularly to the purposes of wood-land surveys. Geldert and Patterson, Eastern Chronicle office, Pictou, NS. 181pp.

Monro, A. 1855. New Brunswick; with a brief outline of Nova Scotia and Prince Edward Island. Their history, civil divisions, geography, and productions. Richard Nugent, Halifax, NS. 384 pp.

Mosseler, A., Lynds, A., and Major, J.E. 2003. Old-growth forests of the Acadian Forest Region. Environ. Rev. 11: S47-S77.

Muzeroll, P. 1837. Exploration of a road from Point Sapin to Kouchibouguac. *In*: Appendix, 1838, J. of the House of Assembly of the province of New Brunswick, 28 Dec. – 9 March, John Simpson, Fredericton, NB.

PANB. RS687B a, KT1/104, microfiche.

PANB. RS687B b, KT2/61, microfiche.

PANB. 1852. RS637/7.b.1.b. Records of the Surveyor General, finding aid, p. 20.

Perley, M.H. 1842. Reports on Indian settlements, &c. J. of the House of Assembly of the province of New Brunswick, Sixth Session of the twelfth general assembly, (Appendices.). J. Simpson, Queen's Printer, Fredericton, ON.

Perley, M.H. 1847. Report on the forest trees of New Brunswick. *In:* Simmonds's Colonial Magazine, vol. XI: 42, June 1847, p. 129-423.

Quinby, P. A. 1991. Self-replacement in old-growth white pine forests of Temagami, Ontario. For. Ecol. and Mgt., 41: 95-109.

Rose, A. H. and Lindquist, O.H. 1980. Insects of eastern larch, cedar and juniper. Can. For. Serv., Forestry Tech. Report 28. 100 pp.

Ruffner, C.M. 1999. A regional and catchment analysis of Native American influences on pre-European forests of the Allegheny Plateau. PhD dissertation, Pennsylvania U.

Schaetzl, R.J. and Brown, D.G. 1996. Forest associations and soil drainage classes in presettlement Baraga County, Michigan. The Great Lakes Geographer 3 (2): 57-74.

Siccama, T.G. 1971. Presettlement and present forest vegetation in Northern Vermont with special reference to Chittenden County. Am. Midland Nat. 85 (1): 153-172.

Telfer, E.S. 2004. Continuing environmental change-An example from Nova Scotia. Can. Field-Naturalist 118 (1): 39-44.

Thomas, L.O. 1930. The Province of New Brunswick: Its natural resources and development. Dept. of the Interior, Ottawa, ON. 167 pp.

Thomson, D.W. 1966. Men and Meridians. The history of surveying and mapping in Canada, Vol. I.- III., Queen's Printer, Ottawa, ON.

Wang, C. and Rees, H.W. 1983. Soils of the Rogersville-Richibucto Region of New Brunswick. Ag. Can. 239 pp.

Wein, R.W. and Moore, J.M. 1977. Fire history and rotations in New Brunswick Acadian Forest. Can. J. For. Res. 7: 285-294.

CHAPTER 4. QUANTIFICATION OF HISTORICAL WHITE PINE IN EASTERN NEW BRUNSWICK FORESTS FROM SQUARE TIMBER ANALYSIS.

INTRODUCTION

Characteristics of early nineteenth century eastern New Brunswick forests are not represented in paintings, photographs, or other portrayals, and so attempts to grasp an accurate impression of the pre-European harvest condition is difficult. Even more challenging is to quantitatively evaluate aspects of the original forest character, given that these forests have been removed from the landscape. Selective harvesting of large white pine (*Pinus strobus* L.) on watersheds of eastern New Brunswick began *ca.* 1800, prior to extensive settlement. White pine was a commodity in demand for everything from masts to construction timber, and was a fundamental necessity in the shipping industry, likened to the requirement for oil and steel in modern industries (MacKay 1978). White pine was reputed to be a majestic tree of incredible height and massive diameter, prominent throughout pre-European forests of NB. Such legends may have exaggerated the actual quantities on the landscape. A low representation of white pine in modern forests may cast doubt on the belief that white pine was once a strong component. With little tangible evidence available on early forest structure and composition, historical sources of information were explored.

Examinations of nineteenth century records, such as lumber shipping documents and wood sales demonstrate that harvest information can be used to provide minimum value estimates for some species on the pre-European landscape (Simard and Bouchard 1996; Wilson 2005). Considerable archival information exists on early timber harvesting in New Brunswick, though to date, there has been little or no attempt to extrapolate quantities of harvested material to pre-harvest forest character. One of the earliest and largest collections of timber harvest information is the applications and license records for square timber. Square timbers are large pieces of timber, mainly white pine, hewn approximately square by aid of an axe to a minimum dimension of 30.5 cm per side (stipulated as '12 inches square' on early timber licenses). Timbers were squared so that they could fit more snugly into the hold of ships for the long transatlantic voyage to Great Britain, where they were sawn into lumber (Wynn 1981).

Historical information on square timber was tentatively explored for its value as the earliest quantitative measure of the mature white pine component in riparian forests within the Richibucto-Kouchibouguacis-Kouchibouguac-Bay du Vin watersheds of eastern NB. According to the literature, square timber records have never before been used to reconstruct volumes of standing timber, though there has been considerable focus on the industry from a historical context (Lower 1938; 1973; MacKay 1978; Wynn 1981). Wynn (1981) researched NB square timber records extensively and made some general comparisons between harvested white pine quantities (in ton units) within districts (encompassing several rivers or watersheds per district), but did not extrapolate harvested amounts to standing timber volumes.

Reconstructing volumes of large white pine that existed prior to European settlement allows specific restoration targets to be developed, based on quantifiable evidence. Insights gained from analysis of harvested volumes of square timber is of particular interest for Kouchibouguac National Park, (located within the study area), where silvicultural prescriptions or other interventions, such as prescribed fire, have been contemplated for restoration of various Acadian forest components, including white and jack pine (*P. banksiana*). Desired restoration goals require quantitative evidence to set ecologically appropriate targets. Nineteenth century volumes of white pine reconstructed from square timber analysis may also be compared and integrated with results from other historical sources of information on white pine, such as witness tree research.

The square timber industry has been nearly forgotten in the evolution of New Brunswick's forest industry, though it constituted the single most important source of provincial revenue, surpassing the fur trade by 1810 (MacKay 1978). Boom years occupied a brief period between 1820-1840 in the study area. Revenue from square timber was the mainstay of early trading between Britain and North America. Monies earned from this staple economy sponsored the costs of building the first roads, bridges, public buildings and other necessary infrastructure at the beginning of settlement (Johnston 1850; Wynn 1981).

The square timber industry was the second of four major phases of the New Brunswick forest industry (Dominion Bureau of Statistics 1934). The first was the extraction of ship masts and spars, which began in the 1790s on the St John and St Croix Rivers (Lee 1987), and was highly selective for the best quality, and largest mature white pine. These wood products were the only ones of sufficient value to warrant the high costs of transatlantic transport. By 1805, most of the easily accessible trees, meeting ship mast requirements, had been depleted from New Brunswick forests and the focus was shifting to sources on the St Lawrence (Wynn 1981). Few details remain from this early industry other than some export statistics, and some notes on the extraordinary sizes of the cut timbers. Another hindrance to the study of mast timber is that records were not specific for which rivers supplied the masts. The square timber industry began during the turn of the 19^{th} century and constituted almost entirely white pine timber, though smaller volumes of red pine (*P. resinosa* Ait.) and yellow birch (*Betula alleghaniensis* Britton) were also harvested. Square timbers could be made of pine trees considerably smaller than those required for ship masts, yet by today's standards, they were of exceptional size and quality. As demands for square timber were more general, far greater quantities were extracted for this industry than for ship masts (Wynn 1981). The remaining two forest industry phases are briefly presented in order to complete the historical context of where the square timber era fits into the general sequence of timber exploitation. They are the saw mill industry, which began to flourish in the study area *ca.* 1830 (PANB RS 663 E.7.b; DeGrâce 1984), and the pulp and paper industry, which began in the 1880s and became the major industry by 1930 (Gibson 1953; Parenteau 1994). These phases offered less insight into presettlement forest character, largely due to their late occurrences.

White pine was the most valuable softwood tree in eastern Canada during the 1800s. Indeed, it was considered the "*most important building wood in the history of the world*" (Maxwell 1915; *In*: Whitney 1994). It was the tallest of all trees in eastern Canada, with large trunks that were straight and knot free to considerable heights. Its wood was high quality and of great strength, yet lightweight and easily worked. A valued feature for early transportation requirements was its high buoyancy in water. All of these qualities helped make the white pine the most sought after tree in New

Brunswick forests. In addition to the attractive qualities of the species, there were key events that helped plunge New Brunswick into the age of white pine timber export; the war of Independence between Britain and the US (1776-1783), followed by the Napoleonic War of 1793-1814. Napoleon attempted to disrupt the British economy by impeding access to its chief supply of timber from Baltic forests in 1806 (MacKay 1978; Wynn 1981). By 1808, Britain had been cut off from these countries, and found itself in a precarious position. England had very little forest of its own and the timber blockade was hampering the growing demands of the Royal Navy. As a result, timber prices sharply increased and Britain looked toward its colonies in North America to fill the market void. New Brunswick abruptly rose from supplying only 1 % of Britain's timber needs to meeting approximately 75 % of the demand (Trueman 1970; Lee 1987).

Dimensions and quality of square timber

Square timber is synonymous with the more popular historical term 'ton timber', the term and measurement consistently used in New Brunswick for all timber applications, licenses, and correspondence during the 19th century. The terms 'ton timber' and 'square timber' were used interchangeably in this research. The word 'ton' was used as a volumetric rather than weight measurement, and was originally spelled 'tun'. The unit tun had originally signified the space occupied on British ships by a large cask or 'tun' of wine (Zupko 1968; Klein 1974; Honer 1998). The British were more concerned by the space occupied by such bulky cargo than by its weight.

One ton of square timber was equal to 40 cubic feet (1.13 m^3) (Govt. NB 1831; Lee 1987; Parenteau 1994; Johnson 1986). (Some historic documents refer to one ton equivalent to 50 cubic feet, but this is applied to rough timber 'in-the-round' (i.e. unhewn) (Johnson 1986).) One white pine tree, felled and hewn square, often yielded two, and sometimes three tons of timber (MacKay 1978). A simplistic visualization of a one ton timber stick is a 40 foot (12 m) piece of timber measuring one foot square (30.5 cm^2).

There were minimum size restrictions for ton timber. White pine square timber could not be shorter than 4.9 m (16 ft) (Govt. NB 1831). A minor discrepancy existed in the historical record regarding minimum diameter. According to written regulations accompanying all timber cutting licenses from 1824, persons were to cut pine trees "*large enough to square 12 inches*". Therefore, timbermen in search of white pine stands during the ton timber era were obliged to select pine of at least 43 cm (17 in) top diameter under the bark in order to produce timbers squaring a minimum of 30.5 cm per side. (See Figure 4.1.) It is doubtful that timbers were ever cut smaller than this stipulation, as most of the literature spoke of average timber sizes exceeding the minimum requirements (Lower 1938). However, all provincial statutes regulating the exportation of timber during years 1797, 1810, 1816, and 1831 specified smaller minimum size requirements of, "*not be less than 10 inches* [25 cm] *square, nor shorter than 16 feet* [4.9 m]" (Govt. NB 1797; 1810; 1816; 1831). Exceptions were made for red pine timber, which was allowed to be less than 10 inches (25 cm) square. Timber of larger diameter could be of shorter length: "*White pine timber over 16 inches* [40.6 cm] *square, and hardwood over 12 inches* [30.5 cm] *square, may be 12 feet* [3.7 m]" in length (Govt. NB 1816; 1831). Regardless of dimensions of timber harvested, one ton of square timber removed remained equivalent to 1.13 m^3 (40 ft^3).

The British market set stringent standards for merchantable square timber. New Brunswick was obliged to export only top quality large pine. Lumber export statutes stipulated that all timber be "*free from knotty tops, plugs, rots, rotten or concase knots, decayed sap and worm holes*" (Govt. NB 1816; 1831). Therefore, the stem below live crown was the only portion of the tree suitable for export, as the portion of the trunk that supported branches would have contained too many knots. There were also stipulations on maximum permissible taper, wane (or 'bevel'), and sweep. Taper could not exceed 2.5 cm (1 in.) for every 5.5 m (18 ft) in length. Wane varied from a maximum of 7.6 cm (3 in.) allowable on every corner on largest square timbers (51 cm (20 in.) square and upwards), to only 2.5 cm (1 in.) wane allowable for timbers squaring less than 41 cm (16 in). No timber could have a sweep unless two sides were straight (Govt. NB 1816; 1831).

Timber petition and extraction processes

The removal of square timber operated under the petition and licensing system, beginning in 1817. The process allowed the Province some much-needed control over timber operations (PANB RS 663). It may have taken some time to enforce this new system, as both archival records and historical literature indicate that unregulated cutting continued on Crown lands until approximately 1820 (Lower 1938; PANB RS 663). The process began with the submission of a petition requesting permission to cut timber. The applicant provided rough specifications on which lands he wished to cut the timber, the quantity (in tons), and in later years, the species (nearly always white pine). Petitions were submitted to the local deputy surveyor who then, on his discretion, would send them to Fredericton to be reviewed by the Committee of Council. The lumberman paid a nominal fee ('tonnage money') of 1 shilling per ton of white pine, (1 shilling and 4 pence per ton of red pine) within three months from submitting the petition. Following payment of fees, the license for harvesting white pine was usually granted, providing the proposed area was available for cutting. Each license indicated the amount of timber to be cut and the area where the cutting would take place (PANB RS663, timber regs.). Fees were imposed mainly to cover costs of administration, surveys, and enforcement (Lee 1987).

Cutting of square timber began at the onset of winter and continued, weather permitting, until early spring, or until the licensed timber quota was attained. Licenses expired on the first day of May. Each tree was carefully felled, so as to cause the least damage to the bole, and the trunk below the live crown bucked into lengths. To prepare for the squaring process, the bark was removed, and the sticks were marked longitudinally with two chalk lines and notched at regular intervals to the line. Timbers were then hewn square with a specialized axe with a broad blade, appropriately termed a broad axe (Figure 4.2). Following hewing of two sides, the log was turned over, using chains and cant-hooks, to square the remaining two sides. Timber ends were pointed-shaped in order to deflect impacts and subsequent damage when floating down river. The ends were squared off prior to shipping to Britain (MacKay 1978; Lee 1987). One of the most difficult aspects of the operation was transporting the heavy squared sticks to the river. The end of each square timber was placed on a type of rudimentary sled to reduce drag and hauled singly by teams of oxen or horses along primitive winter logging roads to the nearest stream with water deep enough to drive the timber in the spring (Grant 1882). Sufficient snow was required to reduce friction in hauling the wood, though too much snow impeded operations (Parenteau 1994). Timbers were carefully piled on the river ice or at a brow that was strategically located on the riverbank until spring.

Each of the timbers was marked with the owner's registered symbol. In this way, they could be identified should they mix with timbers of other loggers on the way down stream, and the registered symbol also facilitated inspections by deputy surveyors who were required to inspect the total timber quantities cut by each license holder (Aldred 1985). Many of these timber marks were observed in the provincial timber records.

During optimal high waters of the spring freshet, timbers were floated downstream to market. The timber drive was the most hazardous part of the forest operation. The spring freshet endured only a brief period (particularly in smaller tributaries), and so there was often a race to get the timber out before water levels dropped too low to float timbers over obstacles along the drive. Field notes from deputy surveyors working in the study area indicated that lumbermen were frequently forced to wait until the following year to convey their winter harvest to market. At port the timbers were given a final smoothing with a broad axe to rid them of any surface damages incurred en route. Shipping ports that received timbers from the rivers studied were the Miramichi port for Bay du Vin timbers, and the Richibucto port for timbers from all rivers further to the south. Timbers were placed in holding ponds for grading. Both the Richibucto and Miramichi harbors must have presented spectacular scenes each spring while hosting thousands of massive timbers from every local tributary for hundreds of kilometers. The final stage required that timbers be loaded into the holds of sailing ships for transport to Britain (MacKay 1978; Wynn 1981).

Other ton timber species

Red pine and large yellow birch were also harvested for square timber, but in much smaller amounts than white pine. Records of harvested volumes were not assumed to indicate proportionate volumes within pre-harvest forests, and so analyses were limited. Red pine typically did not grow to the large sizes of white pine and was less plentiful on the landscape. Enormous squared timbers of yellow birch were more problematic to convey to market as they became waterlogged and would sink in the rivers unless they were buoyed up. Usually they were lashed with adjacent white pine timbers to keep them afloat.

Larch was exploited as ton timber only on the Kouchibouguac, and spruce was harvested to an extremely limited extent during the late 1830s.

Objectives

1. To ascertain whether square timber records can be used to reconstruct historic volumes of white pine in the Acadian mixedwood forest.
2. To use square timber volumes to reconstruct minimum estimates of standing volumes of large white pine within riparian forests of the study area *ca.* 1800.
3. To examine information on forest structure and disturbance regime inferred from white pine square timber records.
4. To examine what other minor species harvested for square timber may indicate about pre-European forest character.

METHODS

Primary sources, mainly consisting of timber petitions, licenses, and application books from 1820 (the earliest date available) to 1839, were consulted at Provincial Archives of NB (PANB). Other primary sources consulted for square timber information were: reports on timber petitions, forfeited or rejected timber petitions, dockets of timber petitions, indexes to timber applicants, and tonnage received from pine timber. Most information was filed under PANB series RS663. Material applicable to the study area was either photocopied or hand-copied. As timber licenses and applications were recorded in no particular order and ranged over the entire Province, the task of extracting information applicable to the study area from thousands of entries written in 19th century handscript was tedious, and required a period of several weeks to complete. Records were entered on an Excel^{TM} spreadsheet. Information included in the database were: date of petition or issuance of timber license, application or license number, quantity of timber to be cut, species, location (river), and name of applicant. Records on 'excess timbers', (wood that was cut beyond the quantities stipulated on a timber license), provided some additional information on timber quantities extracted from certain rivers. This original information on ton timber was stored in the Kouchibouguac National Park database.

Only timber quantities that were most certain to have been extracted were entered into the database. Applications and licenses were excluded when accompanied by comments such as: the application has been "*dropped*", "*not issued*", "*given up*", or "*not paid*". Some entries from later years were excluded in cases where they could not be substantiated by a license or application number, or timber bond. Most records from earlier years were included even though none of them contained license numbers because the style of record keeping during that early period apparently did not rely on license numbers. The records were assumed to be valid, as substantial ton timber harvesting took place during these years, (according to Journal of the House of Assembly records), and given the great void in the British market and the source of revenue generated for the Province. Records from timber auction books and deputy surveyor ledger books were useful in cross-referencing and substantiating timber information, and in some cases providing missing information, such as license numbers.

It was appropriate to quantitatively analyze timber extraction by watersheds. Rivers were integral to all early logging operations. For well over a century, they offered the sole means of conveying harvested timbers from forests to shipping ports. Ton timber operations occurred widely in the forests of the study area because the landscape is well endowed with extensive river networks that reach far into the interior. Four watersheds were included in the square timber analysis. From north to south they were: (1) Bay du Vin, (2) Kouchibouguac, (3) Kouchibouguacis, and (4) Richibucto (Figure 4.3). Tributaries flowing into these watersheds were included. Specifically, ton timber entries for McInnes Brook, Tweedy Brook, and McKay's Brook were included in Kouchibouguac River data. Trout Brook was included in Kouchibouguacis data (where it was specified as belonging to this particular river). Richibucto River consisted of five major tributaries: St. Charles (also recorded as 'Northwest', 'Aldouane', and 'Ardoine'), Molus, St Nicholas, Coal Branch, and Bass. Tributaries of the Richibucto watershed were sufficiently large to warrant some individual examination (Table 4.1). Some smaller watersheds were excluded, either because of insufficient data, or to avoid errors stemming from confusion over names of rivers. For example, Black and Portage Rivers, which flow into the Kouchibouguac lagoon, share place names with more than one river, rendering it impossible to identify which records belong to the study area.

As a means of verifying recorded timber volumes, export records of ton timber from the port of Richibucto were compared to the total ton timber quantities licensed for harvest during the year 1823-24 on the three watersheds that exported from Richibucto (the Kouchibouguac, Kouchibouguacis, and Richibucto). Timbers cut on some rivers were excluded from analysis because of uncertainty of which rivers the timber was from, due to duplication of names.

Conversion of square timber quantities to modern measurements and adjustments for waste

All square or 'ton' timber values were converted to cubic meters (1 ton =1.13 m^3). (Note that all volumetric measures refer to solid timber.) Figures were then adjusted upward to include wood volumes left as waste by the ton timber industry, but which otherwise would have been captured using modern forest mensuration methods for merchantable volume.

A combination of basic geometric calculations and modern measurements of white pine were used to derive the percentage of merchantable tree volume unaccounted for in the ton timber records (volume lost from the squaring process and the unused top portion of the trunk that fell below minimum size requirements, including the entire portion contained within the live crown that would not have met knot-free quality standards). To derive the percentage of waste generated from manufacturing a square piece of timber from a cylindrical log, the ratio of the cross sectional area of a round tree bole, in relation to its area when squared was obtained. Simple geometric calculations for the area of a square versus the area of a circle resulted in a difference of approximately 36.3 % wood lost from squaring (Figure 4.1 and steps 1-4 below). Minimum square timber size requirements were used to demonstrate the calculations in Figure 4.1, though any size of square timber could have been used, as the area of the cross-sectional square is proportionate to the size of the round bole. A timber 12 inches square requires a tree bole of at least 17 inches (~ 43 cm) inside the bark.

An average estimate of wood volume contained within the unused top portion of a white pine tree was difficult to ascertain, as this volume is dependent on several criteria, such as growth condition, taper, and portion of trunk within live crown. Stem analysis measurements for white pine were not readily available, neither were diameter measurements at live crown available from white pine within the study area. Furthermore, it is possible that a portion of the trunk wood immediately below the live crown was often left as waste, since it may have contained too many knots, or because it fell below minimum diameters suitable for ton timber. For simplicity, only the portion of the trunk contained in live crown was considered in these calculations, thereby representing minimum estimate of waste derived from unused top portion of trees.

The average percentage volume of white pine stem consisting of live crown was determined to be approximately 29 %, derived using formulae for calculating stem wood volume (Husch *et al.* 2003), and unpublished data on modern measurements of large white pine trees obtained by Ontario Ministry Natural Resources (OMNR) (Appendix 4-2). Data from OMNR were used since diameter at the point of live crown was measured, and this dimension was required in volume equations used to derive percentage volume of trunk within live crown. Only trees equivalent to or greater than 48 cm DBH, including bark, were used to calculate percentage volume of bole within live crown (Appendix 4-2). Formulae used to calculate white pine bole volumes were Smalian's formula for paraboloid frustrum (the stem portion below live crown) and cone formula for portion within live crown (Husch *et al.* 2003). Total merchantable volume for white pine derived from calculations compared favorably to white pine merchantable volume tables (stump and top included) (Honer *et al.* 1983).

Since the live crown was determined to be approximately 29 %, the harvested bole comprised a resultant 71 % of total merchantable tree volume. An adjustment of the percentage volume of bole waste lost from squaring to the volume of the bole within the whole tree (step 5) was approximately 25.8 % (Figure 4.4). The final estimate of total waste (step 6) was derived by adding the percentage volume (adjusted) waste from squaring process and percentage volume of the unused top portion of bole left behind in the forest. Hence, approximately 55 % of the harvested tree was wasted through harvesting only the clear bole and squaring it prior to arrival at the shipping port (Figure 4.4).

WASTE FROM SQUARING PROCESS

1.) Area of square timber = (base X height)
= (30.5cm X 30.5 cm)= **930.25 cm²**

2.) Area of circular bole= (πr^2)
= $3.14*(21.5 \text{ cm})^2$ = **1458.22 cm²**

3.) Percentage sq. timber: $\frac{\text{area sq. timber}}{\text{area timber bole}}$ X 100 = 63.8 %

4.) Percentage waste of ton timber stick: 100 % - 63.8 % = **36.3 %**
5.) Percentage waste of whole tree: 36.3 % X 0.71 = **25.8** %

TOTAL WASTE

6.) % waste whole tree from squaring process + % unused top portion of trunk = total % waste

25.8 % + 29 % = 55 **%**.

The estimated values of timber waste presented here are conservative and offer only approximations. Several omissions were made in the calculations for waste, due to lack of absolute figures. Taper on the bole would have caused more than the 36.3 % of wood volume to be removed during the squaring process. No allowance was provided for bark waste from squaring of the bole, which would have been included in modern forest mensuration techniques used to estimate tree volume on the landscape. An average volume of bark may constitute 11 % of tree bole volume according to Pinchot and Graves (1896). A conservative estimate of at least 2.5 cm bark thickness is considered a reasonable assumption (Pinchot and Graves 1896). Therefore, if an additional 5 cm is added to the harvested bole diameter (2.5 cm on both sides, Figure 4.1), a tree of minimum diameter requirements (i.e. a bole suitable to square a 30.5 cm^2), would have a volume lost to squaring of 48.6 % with bark, rather than 36.3 % without bark. This would result in a total volume of waste of 63.5 % rather than 55 %. Since bark volume was not a proportionate measure, it was excluded from these rough calculations on timber squaring. For example, if bark thickness remained 2.5 cm thick on boles of increasing diameter, the bark would constitute proportionately less of the total volume.

Derivation of white pine volume per hectare

Estimates on the average volume of white pine harvested per hectare necessitated an estimate of total area harvested on each river. More specifically, the approximate length of each river that supported ton timber harvesting, and the approximate width of early timber berths were used to calculate area harvested. (A timber berth is an allotted area on a license granted from the Government to cut timber (Lower 1973).) It was assumed that ton timbers were harvested as far up rivers as possible, while maintaining sufficient water depths to float timbers to market during the spring freshet.

The minimum water depth required to float white pine ton timber was approximately 18 cm, as determined by floating a white pine square timber of minimum size requirements (30.5 cm^2). The pine timber used to derive this figure was seasoned by approximately one year, and was therefore more buoyant than pine timbers cut during the previous winter would have been, and thus provided an absolute minimum water depth required to float such timber. Use of a one-year-old squared pine log was appropriate, given that ton timbers were often floated during the spring drive from the previous harvest year. Attempts were subsequently made to ascertain the coordinates on the headwaters of each river where the threshold water depth of 18 cm occurred during the spring freshet of 2003. The coordinates could only be used as a rough guide, however, due to alterations in riverbeds during the last century and for other reasons presented in the Discussion. Final determination of the approximate length of rivers and tributaries were made using the ArcView™ measuring tool. River length was measured from the river mouth to each headwater, but excluded small meanders, since they would falsely augment the total number of hectares subjected to harvesting in each riparian zone.

Approximate distances that timber berths extended landward from each tributary were estimated to be a minimum of one km, and a maximum of two km, based on the historical literature (Wynn 1981), a surveyor plan drawing of timber berths within the study area, a timber petition, and landscape factors (e.g. the landscape within the study area is generally situated not farther than two kilometers from a tributary, and so haul distances should have been shorter). A single surveyor plan drawing (dated *ca.* 1820) illustrated two timber berths on the South Branch of the Saint Nicholas River (Appendix 4-4). The timber berths were measured to extend the equivalent of approximately 2050 m away from the riverbank. The second piece of historical evidence, a timber petition, specified a distance for cutting away from the river: The application of James Davidson in 1820 requested permission "*to cut and carry away from ungranted lands [ ] four hundred tons of pine timber to commence half a mile below Ragged Island on the north side of Kouchibouguack River and to extend up as far as beaver Island (which is about two and a half miles) and* <u>*one and a half miles back*</u> [2.4 km]" (PANB RS663 A). Although it exceeded two km, all other timber documents were written in a manner suggesting that cutting would have been most intensive in areas closest to the rivers. The average maximum would almost certainly have been less than 2.4 km, given that the areas of easiest exploitation were in closest proximity to the riverbanks. No other sketches of timber berths or applications that specified a timber berth width were found for the study area.

Other ton timber species

The total red pine and yellow birch volumes removed from each watershed were also derived from the record books. Total harvested volumes in tons were converted to cubic meters, but no attempt was made to adjust for waste, as this would have required additional research on growth form of each species (e.g. stem taper and percent live crown).

RESULTS

Examination of twenty years of ton timber records (1820-1839) provided a total of 1916 timber applications and licenses (Table 4.1). Every river and tributary within the study area contained large white pine suitable for square timber. An estimated total of 871,433 m^3 of ton timber, comprising only large, perfect, white pine with top diameters exceeding 48 cm DBH, was felled within four watersheds within the study area over a 20-year period.

A clear pattern of white pine timber exploitation emerged. During the first three years, total amounts of timber harvested were relatively small (Figure 4.5). Cutting increased abruptly during license years 1823-24. The abrupt boom until about 1830 was followed by a general, rapid decline in harvests. By 1839, total volume of white pine square timber was only 5 % of total quantities fifteen years earlier.

Total white pine timber volumes derived from ton timber licenses and applications compare favorably with export statistics. In 1824, Richibucto port declared 24,269 tons of timber (Fisher 1980). The total quantity of timber licensed to be harvested on watersheds for that year (cutting would have taken place from licenses allocated in 1823) was at least 22 620 tons (Appendix 4.1). This corresponds reasonably well, considering that not all of the harvested timber was accounted for through the petition process. For example, timbers cut on private land ('granted lands') required no license. Timbers harvested along seashores and lagoons were not included in the figures.

Results of total white pine volume per hectare on each watershed are presented in Table 4.1. If timbers were removed on average along all watersheds to approximately one km back from rivers (i.e., a one km wide timber berth), then volumes of white pine ton timber ranged from 13.6 m^3/ha to 31.0 m^3/ha on the Richibucto and Kouchibouguac watersheds, respectively. The more modest estimate, using a two km wide timber berth, logically resulted in exactly half these values. Though pine timber volumes on the Richibucto watershed were much lower than those of the Kouchibouguac and Kouchibouguacis, there were some tributaries of the Richibucto that had relatively high white pine volumes, such as the Bass and Molus rivers (Table 4.1).

Yellow birch was relatively unimportant in the timber trade. Results indicated that it was distributed throughout early New Brunswick forests, and harvested everywhere except Bay du Vin (Figure 4.6). Red pine was harvested most abundantly on the Kouchibouguac River, but comprised very minimal amounts compared to white pine volumes for the same watershed.

DISCUSSION

Evaluation of pre-harvest standing volumes of white pine in forests of eastern North America has never been attempted using the evidence from square timber records. Former research of ton timber records in eastern Canada focused mainly on the historical perspective, recounting patterns of timber exploitation, timber drives, and dynamics of the timber trade (Lower 1973; Wynn 1981). No attempt has been made to convert white pine ton timber quantities to modern volumes, or to extrapolate harvested timber to standing volumes, though some regional comparisons of harvested ton timber in New Brunswick were made by Wynn (1981). When the archival timber ledgers were first examined, it was not certain to what extent the information could be applied to pre-harvest characteristics. Based on the results of this study, ton timber records for New Brunswick can be used to derive reasonably accurate minimum volumes of large, healthy white pine within nineteenth century riparian forests.

There is little doubt that white pine was available in substantial quantities in many parts of the Province to have afforded large exports of ship masts, spars, ton timber, and the manufacture of numerous other white pine products. But just how much pine was historically present in the pre-European settlement forests on individual river systems? Though there is little evidence in the present species assemblage to support what may once have been, results obtained from square timber analysis confirm that the history books have not exaggerated former dominance of great white pines.

Adjustment of timber volumes to allow for wasted timber volume

The ton timber industry was repeatedly described in historical literature as reckless and wasteful (Johnston 1850; Grant 1882; Fisher 1980). During the early 1820s, P.

Fisher criticized the opportunistic American lumbermen for "*cutting few but prime trees*", and manufacturing "*only the best part of what they felled, leaving the tops to rot; by this mode more than a third of the timber was lost. This with their practice of leaving what was not of the best quality after the trees were felled, has destroyed hundreds of thousands of tons of good timber*" (Fisher 1980). Tree tops, branches, wood slabs and bark left behind in the woods constituted more than half of the tree, as demonstrated in the present research.

Quantification of white pine harvested through ton timber exploitation is substantially underestimated without adjusting the figures upward to capture 55 % of the volumes unrecorded in the timber records, i.e. volume of top stem (approximately 29 %) and wood volume discarded during the squaring process (approximately 25.8 %) (Table 4.1; Figure 4.4). This adjustment remains very modest when some additional aspects of square timber operations are taken into account.

The highest percentage of waste originated through leaving the top bole behind in the woods. As quality requirements demanded wood free of knots and other blemishes, wood could not be harvested from the live crown. Of course, the amount of live crown would have been variable, depending largely on growth conditions and ages of white pine. Most white pine was probably growing in old growth conditions, with late-successional species, and more shaded conditions, causing them to form smaller crowns. However, Mackay (1978) referenced a 19th century mast pine with approximately 55 % live crown on a tree that was 43 m tall and 1.8 m in diameter. The average length of trunk containing live crown for close grown white pine within Kouchibouguac National Park was 45 %. Hence, it was probably not uncommon for approximately half the length of a white pine stem to have been left as waste by the square timber industry. There may have been an additional bole portion unaccounted for in some trees in the section located immediately below live crown where timber was too knotty to be suitable for squaring, or where the diameter dropped below the merchantable 48 cm limit. All factors considered a minimum estimate of 29 % trunk volume discarded from the upper portion of harvested white pine was probably very conservative.

Most boles likely lost more than 36 % volume from the squaring process, as the expertise of the broad axe men, amount of taper, and damage incurred during river transport would have contributed to total volume discarded after the final squaring process. A more exact figure is impossible to calculate. Bark thickness would constitute an additional loss of wood volume. Bark would have been included in modern timber cruising measurements for standing timber volumes. Bark thickness can range from 9-12 % of total tree volume on trees over 100 years old. Very old trees may have bark nearly 10 cm thick on the stump (Pinchot and Graves 1896).

It is possible that some timbers may not have been cut precisely square, as a wane was permissible, thereby reducing the waste. It is not clear how much timbermen took advantage of this allowance. It is probable that ton timber with wanes was not shipped much prior to 1860, when British merchants began to worry over timber supplies, and began to import 'waney pine' in order to reduce waste and protect their supply (MacKay 1978).

An additional 20 % of square timber quantities may have been lost during the final re-hewing process at port (Wynn 1981). This was necessary to remove surface damages incurred during the conveyance from the forest to port. In consequence, surveyors generally allowed 15 % over the licensed quota prior to receiving a final hewing (Wynn 1981). This percentage was not added to the 55 % waste volume, as damages would have been highly dependent on the nature of rivers. The slow moving rivers in the study area featured no waterfalls and few rapids, and therefore probably resulted in far less damage to timber than those that flowed through rough and rocky terrain. For example, a waterfalls in northwestern New Brunswick (Grand Falls) was particularly damaging to timbers, and many were "*ground to pieces*", incurring large annual losses (Alexander 1849).

Structure of the white pine component in the pre-colonial forest

Analysis of ton timber harvests indicated that a large component of pre-colonial forests comprised mature white pine of large structure (i.e. tall with large diameters). Even the minimal size requirements of a 48 cm top diameter are considered to be a relatively large size by modern standards. A large proportion of the timber surpassed the minimum size requirements. During early years of the timber trade, square timbers measuring over 51 cm (20 in.) per side (requiring a 72 cm top diameter without bark) were commonly cut in NB (Parenteau 1994). Some square timbers measured "*8 to 9 tons of 40 solid feet each*" (MacKay 1978), which converts to 9 to 10 m^3 per stick. Only as timber supplies began to be exhausted, were pines of smaller dimensions felled (Wynn 1981).

Unfortunately, no timber records were found that indicated average sizes of ton timbers being floated into Richibucto or Miramichi ports. In Ontario, average volumes for square timber passing through the Chaudière slides (Ottawa River) in 1842 were 1.95 m^3 for white pine (well over 1 ton per stick); red pine averaged 1.1 m^3. Lower (1938) extrapolated these figures to estimate that the average timber originated from 60-90 cm diameter trees.

It is reasonable to include mast timber in speculation about forest structure. Mast cutting was still taking place during the ton timber phase, though mast and spar numbers were gradually decreasing (Table 4.2). Such primeval pines attained enormous sizes (MacKay 1978; Wynn 1981). The largest ship masts exported during the 1790s exceeded 30.5 m in length and 76 cm top diameter. To meet such size requirements, white pine trees would have likely been 45 m or more in height and over 180 cm in diameter at the base (Wynn 1981).

Very large trees were harvested even when logs were to be sawn into lumber instead of hewn into square timbers. According to timber regulations, three logs of 5.5 m (18 ft) lengths were assumed to make approximately 305 m (1000 board feet) of lumber.

While pre-colonial forests contained tall, straight, large diameter white pine trees, it is not assumed that the species occurred in uniform sizes, or that it was evenly distributed. Finding mast timber, for example, required searching through the forest for the occasional pine tree suiting the standards. This suggests that white pine was probably present in multiple age classes.

The decline of white pine ton timber harvesting, evident in Figure 4.5, also marked a general decline in availability of very large diameter timbers in local forests. Trees were no longer of a size suitable for ship masts or square timber. The sawmill phase that replaced the ton timber era began to take advantage of smaller pine and spruce timbers, and the pulp and paper industry that began in the late 1800s continues to use smaller trees.

Total white pine volume per hectare

Absolute measures of original white pine volumes were impossible to calculate, but the resultant volumes based on historical ton timber logging offered a reliable indication of minimum quantities of large white pine. If volumes of large white pine per hectare determined for one-kilometer wide timber berths are assumed, rather than for two-kilometer wide timber berths, then volumes of large white pine for rivers, such as the Richibucto and Kouchibouguac were relatively high (13.6 m^3/ha to 31.0 m^3/ha, respectively) (Figure 4.7). Surveyors in Maine recorded "*considerable pine timber*" in some valley areas of 500 board feet per acre (Lorimer 1977). Using a rule of thumb of 1 board-foot per acre = 0.0133 m^3/ha (Husch *et al.* 2003), this is equivalent to approximately 6.7 m^3/ha. Hence the values obtained in this study region indicate more than "considerable pine timber" volumes. Timber cruise estimates for white pine between years 1826 and 1846 for Maine averaged 290 board-ft per acre (Lorimer 1977), or 3.87 m^3/ha. A good average for the north shore of Lake Huron, Ontario was 13.3-26.6 m^3/ha (Lower 1938). Thus, values obtained from this research indicate higher white pine quantities within the study area than for other areas, especially considering that minimum diameter limits were high, and stringent quality demands during this period resulted in lower estimates than compared with the use of modern merchantable volume standards.

The accuracy of white pine volume estimates per hectare is limited by the nature of white pine presence on the pre-European landscape, since the species was not evenly distributed. This was particularly evident from study of early surveyor sketches. White pine grew in nearly pure stands in some areas and was dispersed throughout other forest types in other areas. MacKay (1978) likened searching for white pine in New Brunswick to prospectors searching for gold and finding a 'vein' or grove of pine. Volumes of white pine timber in pure stands would have achieved much higher values. In Quetico Reserve, Ontario, pure stands of white pine contained 53.2 m^3/ha, and a fair average for pineries in Michigan or Wisconsin was 80 m^3/ha (Lower 1938).

Estimated maximum and minimum widths of timber berths

The estimated maximum and minimum distances of two and one km respectively that timber berths extended back from the rivers contributed to the most realistic estimates possible of maximum and minimum white pine timber volumes per hectare. Precise information was lacking on widths of timber berths, and it was probably highly variable according to watershed distribution patterns and available white pine volumes. Harvesting operations nearest the rivers were most attractive, as shorter haul distances to the water's edge incurred the least labor for man and beast, and therefore the lowest costs.

Timber licenses and ledgers did not indicate limits of timber berths any more precisely than timber petitions. On licenses, local landmarks were often used to define the starting point of the timber berth. The river was indicated, and which side was to be harvested. Licenses were written in a manner that granted considerable freedom to the timberman to harvest the most easily accessible trees. Licenses stated that the operator was to cut along the river "*a sufficient distance*" to fulfill the specified quantity of timber. Fourteen licenses applicable to the study area were found for the year 1824. A typical example was that of George McInnes, who was authorized: "*to cut* [ ] *eight hundred tons of white pine timber from ungranted and unapplied for Crown Lands, situate* [sic] *as follows on the north side of Kouchibouguack River, to commence about a half mile above Beaver Island, and extend up stream <u>a sufficient distance</u>*" (PANB RS663 F1). Four timber licenses provided the additional detail of extending not only along a particular stream a sufficient distance, but also to the rear of the timber berth a sufficient distance. From this, one can assume that the operator had considerable liberties to cut in the choicest areas closest to watercourses, and there would have been little incentive to cut inland for great distances.

There were apparently some attempts to prevent operators from extending their licenses along rivers (Wynn 1981), but such limitations may have been put in place to avoid monopoly control of river access, rather than to encourage more thorough logging farther away from river banks (Lee 1987). After 1820, the river frontages were generally less than four km, and in the 1830s, berths were generally laid out to a standard one mile (1.6 km) of frontage per 100 tons or less of timber. Section 15 of the ton timber regulations (1824) stipulated, however, that lumberers were not "*permitted to range through the ground allotted to them, and select the best timber, but shall cut to the extent of their license all pine trees that are sound and large enough to square twelve inches*" (PANB RS 663 F1). Whether any of these standards were followed within the study area seems doubtful according to the licenses and surviving deputy surveyor notes. None of the deputy surveyors recorded violations of this regulation.

Timber hauling was probably the most critical factor contributing to the distance that timber berths extended away from tributaries, as it was one of the most expensive aspects of the square timber operation (Parenteau 1994; Whitney 1994). Timbers logged farther away from the river required more time and labor to haul to the river, thereby increasing the cost. Sticks of ton timber, at minimum over 12.2 m long and over 30.5 cm weighed a formidable amount. A team of at least four to six oxen was required to haul the largest ton timber to its destination (Wynn 1981). Shipmasts in New Brunswick were usually hauled from within roughly 910 to 1830 m of major tributaries, and required perhaps a dozen oxen to haul each timber (Wynn 1981). As most square timber was smaller than mast timber, hauling would have been slightly easier. Ton timbers were less valuable than mast timbers and so longer hauling distances were less profitable. Draft animals were not plentiful in the earliest days of timber harvesting, and hiring such services cut into profits. Winter hauling conditions were also a factor, as too much snow or a period with no snow inhibited hauling. Ultimately, maintaining timber operations as close to rivers as possible was more profitable and incurred less financial risk.

A final argument for restricting hauling lengths to two km is based on the topography of the study area. Closely situated river systems in many areas would have negated requirements for hauling distances over two km. Beyond such a distance, there is, in many cases, alternative transportation on other nearby streams.

A minimum average distance of one km is probably a more reasonable assumption for the width of timber berths. This is based on inferences from timber licenses and the close distribution of tributaries (both arguments submitted above). A one km distance was probably a generous estimate, as it is suspected that the heaviest harvests may have been much closer to the watercourse. The best drainage conditions suitable for optimal white pine growth are commonly situated in narrow strips within riparian zones, sometimes extending only 200-300 m away from rivers, beyond which poorer drainage classes are commonly encountered. This was evident using the NB Ecological Land Classification (ELC), where ecosites 1, 2, and 5, representing dry to mesic conditions, were common along rivers and are better suited for white pine growth (DNRE 1996). Therefore, cutting which concentrated in areas of best white pine growth, possibly focused on areas only 200-300 m away from the rivers. Descriptions of Bailey (1876) support this theory, as he stated that white pine in NB grew "*most thickly near the shores of streams, or on hill sides fronting on [ ] streams, but seldom extending back [ ] in any quantity further than half or three quarters of a mile*" (0.8-1.2 km). A story told by a timberman caught in the Great Miramichi fire of 1825 spoke of prime white pine growth next to the water's edge: "*the trees stood on the banks of the river, as if growing there on purpose to be handy for rafting*" (Beavan 1845).

Additional support for the assumption of a one km wide timber berth stems from the short period of time under study. Years 1820-1839 fell within a period of frenzied cutting, when loggers were still migrating from watershed to watershed after the most accessible white pine had been depleted. This represented the first large selective cut of white pine along the rivers (in combination with ship mast harvesting). Harvesting took place farther away from rivers only as the most easily accessible white pine groves were exhausted, but such ventures remained limited by profits versus expenditures. There was a critical point at "*which profits ceased and work must stop*" (Grant 1882). Years later, Bailey (1876) spoke of the largest white pine trees becoming scarce in the Province, such that it was necessary for the lumberman to expend more effort to reach the largest high quality trees: "*The lumberman often cut roads half a mile or more* [0.8 km] *in length to reach a choice tree*".

In summary, the boom-bust nature of the industry favoured operators seeking the most accessible, large pine stands, then migrating to another river to seek out the best pine. There was little time to stray far afield in search of white pine, which would incur greater hauling distances. The costs and added risks of getting the pine out of the woods would reduce profits while choice pine remained more easily accessible from other locations. Hence, one km wide timber berths are probably a more sound assumption than two km wide berths.

Estimation of river length harvested for ton timber

Estimates of river lengths are believed to be the maximum possible lengths that sustained ton timber harvesting, and these estimates subsequently contributed to the most modest calculations of timber volume per hectare. Attempts to estimate the length to which each river and tributary was exposed to square timber harvesting involved taking into account spring water depths, stream obstructions, white pine buoyancy, and historical accounts.

Difficulties encountered during spring log drives increased proportionately as operations moved upstream. Sufficient quantities of water during the spring freshet were crucial to floating the product to the main rivers. Water depths drop more quickly on small streams, thereby increasing the risk of the winter harvest being left behind in the woods should the brief spring freshet be missed for floating timbers to market.

Climatic conditions sometimes resulted in inadequate spring freshets to float the timbers (MacKay 1978). A gradual thaw was not as favorable in producing the required high water levels as a rapid one. The river drive was "*the 'finale' of the winter's work, the financial success of which is dependent altogether on the continuance and extent of the thaws. Sometimes when the latter are gradual, more than half of the timber is left in the forest until the following year, and of course the market is influenced accordingly*" (Adams 1873). Similarly, Springer (1856) grieved the loss of a particularly large pine due to this problem: "*The butt log was so large that the stream did not float it in the spring and when the drive was taken down we were obliged to leave it behind, much to our regret and loss. [ ] that log would have been worth fifty dollars.*"

Smaller tributaries were often grown over with alders and large over-hanging trees, as well as rocks, sandbars, and other obstructions, and entailed large expenditures of labor and financial resources before they could be logged (Wynn 1981). Notes by Deputy Surveyor Davidson, concerning a timber dispute on McInnes Brook (a tributary of the Kouchibouguac River) in 1829, mentioned that timber had been driven from "*about three miles below the forks and it might perhaps at a great expense be cleared* *out to drive timber even up to the forks but all the branches above that are small brooks. None of them could be made sufficient to drive timber out of*". Given such difficulties, the ton timber industry migrated closer to headwaters and smaller tributaries only after the largest and finest quality pines growing in the easiest accessible areas had been exhausted. By the1840s, harvesting was occurring considerable distances up the main rivers. On the Kouchibouguac, for example, "*square timber and logs have been driven down* [the Kouchibouguac] *river 40 miles* [64 km] *from its mouth*" (Perley 1842). This appears to have been somewhat exaggerated; as such a distance would include the very headwaters of the Kouchibouguac where there is very little flow. Dams have played a major role in altering water levels, but they did not appear to be extensively used for ton timber driving in the study area. There were no dams recorded on the upper reaches of the Kouchibouguac during the period studied, but there were dams erected on smaller tributaries of the Richibucto river for saw mill operations that had begun to spring up.

The minimum water depth required to float the smallest white pine ton timber, as determined through field examination, was approximately 18 cm. However, it was impossible to ascertain the coordinates on the headwaters of each river where the threshold water depth of 18 cm occurred during spring run off period, given that dams, bridges, and land clearances have altered riverbeds and subsequent water levels in the intervening years. Changes in climate and reduction of forest cover were also believed to have altered snow depth and spring melt rates. Thus, the initiative was abandoned as it was apparent that current water levels may be vastly different than during the ton timber era. An example of the significant river changes that have taken place since early 1800 is that the former shipyard site on the Kouchibouguac River, which was able to receive and dispatch large sail ships, is now treacherous to access even with small motorized craft. Obviously the river was very different some 200 years ago.

In summary, the estimated lengths of rivers included the headwaters of all rivers and major tributaries within the bounds of study area, but excluded small brooks and streams that were not in the timber records. They are probably very generous estimates considering the risks, difficulties, and costs of logging farther up streams.

Total ton timber volumes: A modest estimate of the original white pine component

Quantification of white pine timber volumes through analysis of ton timber records established that large, high quality white pine were once prevalent in substantial amounts, particularly on the Richibucto and Kouchibouguac rivers. The resultant timber volumes provide the most accurate estimates derived thus far for 19th century white pine of diameters exceeding 48 cm at a minimum of 4.9 m up from the stump. Such analyses resulted in modest estimates of white pine composition in early forests for the following reasons:

1. MacKay (1978) estimated that possibly only 10 % of the white pine in a given stand was harvested, given the industry's high quality demands. Trees bearing defects and rot were excluded from these figures.
2. White pine timbers under approximately 48 cm DBH were excluded, as they did not meet size requirements. This size component was harvested during the later sawmill era, and may have constituted a far greater white pine timber amount than the volumes removed for ton timber.
3. Timber volumes did not capture white pine harvested for shipmasts and spars.
4. Square timbers harvested from granted lands did not contribute to final totals since the timber petition system only applied to Crown lands. No records were kept on private ton timber harvests or timbers harvested for domestic use.
5. Illegal, unauthorized cutting of white pine could not be quantified, though primary source documents indicate that such activities were prevalent.
6. The percentage waste from rehewing the timbers, prior to placing them into the holds of vessels to ship to Britain, was not included.
7. Figures do not include white pine volumes removed before or after the 20-year period of study.

In spite of these underestimates, timber volumes calculated in this research constitute a far greater white pine component than current white pine volumes in the study area (which were determined to be 2-4 % of BA forest composition according to recent Forest Development Surveys, NB DNR).

The contribution of illegal cutting to the underestimate of total white pine timber volumes is an interesting issue. Unauthorized cutting was a constant problem, especially during the earliest years when few inspections were made of timber operations. Cutting was either conducted without a license, or individual timber operations over-cut the amount in the license. Deputy surveyors had large territories to cover under difficult travel conditions to monitor harvest operations. Deputy surveyor notes for the study area recorded some of the difficulties in assessing timber quotas when timber was buried under deep snow, or was mixed with timbers from granted lands (PANB RS 663 E.7.a; b). They often had to assess total harvest by examining the stumps left behind, or the number of men logging a timber berth. There were many ways to harvest beyond the quota and escape detection. It is likely that only those who blatantly over-cut their quota were successfully prosecuted.

There were several challenges encountered in working with historical documents that may have contributed in more minor ways to under estimates of total square timber harvests. One such difficulty stemmed from place name changes within the study area, which featured more official name changes than any other region in the Province (Ganong 1906). (See Appendix 3-1.) Since analysis was dependent on searching through timber ledgers for names of certain rivers where timber harvests took place, it was crucial to recognize the former names of such rivers. Within the study area, Aldouane River was used interchangeably with St Charles, and during earlier years, it was recorded as Northwest River, Ardouane, and Ardoine. All of the currently named rivers had Mi'kmaq names prior to European settlement, some of which were used extensively in timber records. For example, St Nicholas River was Helknowkon. Kouchibouguac River had several early names, Pichibouguack, Pissabeguake, and Passibiguac. Although attempts were made to conduct research using both early and modern names, it is possible that some timber records were over-looked.

Another challenge in working with historical data originated from variations in record keeping styles over two decades. The format of the timber ledgers changed continually depending on the style of the recorder, and also with imposed changes during the evolution of the timber industry. The process of standardizing the database may have resulted in under estimating total timber volumes. For example, there was changing use of ditto marks, which made them difficult to interpret. Ditto marks were sometimes used in their true sense (i.e. to indicate that timber amounts were the same as the preceding amount). More frequently, however, the symbol was placed in the ledger simply to maintain a straight line across the page. In such cases, they were meaningless, and care was taken not to interpret them otherwise. There is the chance, however, that some timber quantities may be under-represented because ditto marks were authentic, thereby causing an underestimation of registered harvest. (This use of ditto marks was particularly troublesome when saw log records began to be entered with the square timber records; this led to an early decision to abandon attempts to incorporate saw log volumes with ton timber volumes.)

Disturbance regime deduced from ton timber records

Former quantities of red pine, yellow birch, and white pine harvested for square timber allowed some broad deductions of the pre-European disturbance regime. The presence of relatively high abundances of red pine on the Kouchibouguac River, and relatively little or no red pine on other watersheds may indicate that the Kouchibouguac River experienced more frequent and recent fire than the other riparian zones. Red pine is considered to be an early-successional species, intolerant of shade (Burns and Honkala 1990). Maintenance of pure stands require intense stand replacement fire events at roughly 300 year intervals or shorter (Bonnicksen 2000). Hence, a high abundance of red pine indicates a former forest fire, perhaps 100-300 years prior to harvest (to allow red pine opportunity to achieve the size required for ton timber). Red pine can grow without fire disturbance under the right edaphic conditions, but not in large, even-aged stands. Dry gravelly deposits are conditions where it has a competitive advantage over many other forest species. Low levels or absence of red pine on other watersheds in the study area may reflect relatively long fire return intervals.

Ton timber records appear to be fairly accurate in reflecting the historical distribution of pine forests. Large quantities of red pine on the Kouchibouguac River were supported in research of 1096 survey plan drawings from the 19th century. The only red pine stands surveyed in the entire study area were found on the Kouchibouguac (Appendix 4-3). These are most likely the very stands that contributed to the ton timber tally. Two red pine stands were approximately 4.5 km in length, running along both sides of the river. According to the New Brunswick Ecological Land Classification

(DNRE 1996), these historic red pine stands were growing on poor, dry sites (mainly ecosite 1).

Large yellow birch of adequate sizes to harvest for ton timber reflected a forest free of fire disturbance for long periods. It was found in mature to old growth form throughout the study area, with exception of Bay du Vin watershed, where more wet edaphic conditions may have not been suitable for its growth. Given the difficulties in harvesting this species due to lack of buoyancy, it was probably proportionately much higher than ton timber records indicated. Exports of yellow birch exceeded pine in 1869 in NB (Lee 1987). The tree was more heavily harvested during the sawmill phase. Thin bark of yellow birch renders it very susceptible to fire, and unlike other hardwoods, it does not regenerate vegetatively after disturbance, but must rely on seed. This is a distinct competitive disadvantage in areas with frequent fire. (A more recent reduction occurred due to birch dieback during 1937-1950, that resulted in an 80 % reduction of mature yellow birch (Gibson 1953).)

Deduction of pre-European disturbance regimes, based on former quantities of white pine ton timber, delivers a less clear message than does red pine and yellow birch. White pine is much more versatile in its disturbance requirements, thriving in a variety of stand types and successional stages. It is documented as a fire-maintained species, but it can also persist as a long-lived tree in mature, late-successional, gap-replacement driven forests (Abrams 2001). It is generally regarded as an early to mid-successional species, of intermediate shade tolerance (Burns and Honkala 1990). Conclusions of studies of white pine near the limit of its northern range were that it is self-maintaining, but it benefits from disturbances. Recruitment may be episodic, and linked to wind and/or fire events. White pine can be susceptible to wind throw because of its exceeding heights and where roots grow in shallow soils (Foster and Boose 1992). White pine has generally been found in large quantities in riparian zones. This has been linked to more frequent fire disturbances by First Nations peoples, and maize cultivation elsewhere in North America (Bonnicksen 2000; Abrams 2001).

Given the historical abundances and distribution of white pine, sometimes in pure or nearly pure stands, within the study area, it seems probable that fire and/or wind events may have assisted its prevalence. However, these events were sufficiently infrequent to allow white pine to achieve great sizes.

The relatively small, patchy distribution of both white pine and red pine stands indicate that disturbances may have been quite small. Rivers and bogs that fragment the landscape may have limited fire spread.

Ton timber decline

As early as 1825, there was already comment on ton timber decline and the wastefulness of the industry, published by P. Fisher (NB historian 1782-1848): "*The forests are stripped and nothing left in prospect, but the gloomy apprehension when the timber is gone, of sinking into insignificance and poverty*" (Fisher 1980).

Like the ship mast phase, the square timber industry was of remarkably short duration and generated minimal dividends to the provincial economy by the 1850s (MacKay 1978; Wynn 1981; Parenteau 1994). Given the brief time frame, there is little wonder that this timber harvest phase is all but forgotten in NB history. Highly selective cutting of the largest pine timber rapidly depleted the resource. Easily accessible pine timbers of the dimensions and quality required for square timber were exhausted in the study area within approximately twenty years. As the ton timber industry depleted accessible stands of pine timber on these watersheds, the industry was forced to migrate to other watersheds, such as the rivers further north along the eastern coast and up the St Lawrence. The height of the square timber trade in Canada actually occurred between years 1840-1870, finishing in the lands draining to Great Lakes of Ontario *ca.* 1880 (MacKay 1978).

Coupled with the exhaustion of timber supplies, decline of the timber industry was hastened by reductions in preferential tariffs in 1842 (Wynn 1981; Parenteau 1994). Britain had originally imposed tariffs on loads of timber to encourage a constant source of raw timber from the colonies during the Napoleonic wars. As the wars ended, Britain was once again in a position to trade with other countries for timber supplies (Wynn 1981; Parenteau 1994). The reduction in colonial preference reduced the demand for New Brunswick timber in British markets. Tariffs were completely abandoned after 1860 (Parenteau 1994).

With the largest and best quality white pine supplies all but gone by the mid-1840s, the ton timber industry was replaced by the production of deals and other wood products from New Brunswick saw mills (Parenteau 1994). The lumbermen turned attention to red spruce and pines that did not meet the size and quality requirements for squaring (Whitney 1994). Red spruce, followed by eastern hemlock (*Tsuga canadensis* L.) were among the species that took on higher importance in the post-white pine era. The square timber economy evolved into a sawn lumber economy, followed by the advent of the pulp and paper industry.

White pine harvests have never returned to the quantities, large sizes, and high quality known during the ton timber era. The following saw timber era, wildfires, and land clearances greatly added to the decline of white pine. The riparian zones, where white pine was most prevalent, now represent the most human modified regions on the landscape. Early statistics plot the decline of white pine. By 1870 New Brunswick was producing only about 20 000 loads of white pine per year for trade with Britain, which constituted less than 2 % of the square timber utilized by Britain at that time (Parenteau 1994). During this same year, white pine constituted only approximately 33 % of the annual cut, while spruce constituted over 60 % (Gibson 1953). Depletion of the most accessible white pine towards the end of the 19th century left timbermen with few options but to exploit the remaining species. By 1940, pine formed 5 % of the total annual cut, while spruce (excluding pulpwood) formed less than 33 % (Gibson 1953).

The wasteful cutting and rapid decline of high quality white pine timber raised many concerns during the 19th century, but to little avail. "*It is abundantly clear that if more wood is annually destroyed than the amount benignant Nature adds to our national store, we are killing the goose that lays the golden eggs, or acting like spendthrift who draws upon a capital that he cannot replace. We must consider what are the chief causes of waste, and how one can best guard against the destruction or reduction of our splendid capital*" (Grant 1882). Complaints such as that of Major General Sir Howard Douglas Bart in 1829 were delivered to the Crown Lands Office: "*during the* [ ] *inspection I paid attention to the manner in which the Crown Timber is destroyed by individuals obtaining licence to cut square pine timber and* [ ] *in every instance vast quantities of lumber unfit to make merchantable square timber is in every* *respect fit for mill logs which by the present system is left to rot in the woods*" (PANB RS 663E.1.a). In consequence, Bart suggested that licenses for logs should be required when taking licenses for square timber. This suggestion appears to have been heeded, as ton timber records more frequently included applications for saw log harvesting during the 1830s.

Criticisms of the ton timber industry during the 19th century were not unlike those leveled against modern industrial forest companies. Much of the local ton timber was cut by non-residents or foreigners (mainly European naval contractors and Americans), who did not have local interests in mind, nor did they remain in the area once the best of the forest resources was removed (Mackay 1978; Wynn 1981). Fisher, in 1825, expressed this criticism of the ton timber industry within Northumberland County, (which encompassed the entire study area at that time): "*The persons principally engaged in shipping the timber have been strangers who have taken no interest in the welfare of the country; but have merely occupied a spot to make what they could in the shortest possible time*" (Fisher 1980). Indeed, most of the surnames recorded as applicants for timber licenses in the timber ledgers are unheard of in the region today, such as Farrish, Platt, Bowser, and Sanders. These and other timbermen were intent on exploiting the timber for quick profits, and then moving on (Gibson 1953).

Farming was often neglected in favour of timber pursuits. The two industries were antagonistic, as early settlers often abandoned farms for part of the year to chase dreams of fast profits from the forest (Johnston 1850; 1851). Both Fisher (1980) and Johnston (1850) criticized the neglect of agricultural interests caused by the sudden, accelerated efforts to cut pine timber. Many of the lands granted during that period were allocated to persons who were simply interested in exploiting the ton timber, and who then abandoned the land once the forest value was exhausted. These cut over lands were more difficult to clear for farming (Johnston 1851).

Ecological impacts from the square timber era were produced on several fronts. One of the greatest impacts was to river ecology. As early as 1786, the Province had appointed 'Surveyors of Roads' to also be 'Surveyors of Rivers', and to ensure that all rivers be cleared of obstructions to navigation of boats and also rafts of lumber (J. House of Assembly 1786). Any method used to carry out these orders was acceptable as long as trees and bushes were removed, and rivers were straightened where possible. This was sometimes accomplished by blasting with gun powder and later, with dynamite (Lee 1987). All interests of the government were focused on revenues, not forest protection. Another ecological impact was the sharp reduction of the best local white pine seed sources following selective removal of the best quality trees. Perhaps most wasteful of all were the forest fires associated with the ton timber harvesting activities (Grant 1882). Some claimed that more timber was lost to fire than to the axe (Lee 1987). There were enormous heaps of combustible materials left behind after the winter timber harvest, consisting of tree tops, branches, twigs, and needles, as well as slabs of bark. Many tree tops remained propped above the ground by their stilt-like branches, and dried out quickly instead of rotting as they would have if laid on the ground (Pinchot and Graves 1896). Often, this tremendous fuel buildup burned the following spring or summer (Bruncken 1900).

On a positive note, the ton timber industry was the leading source of employment in the Province in the early 1800s. Cutting operations provided local farmers and fishermen the benefits of otherwise scarce winter employment, while working in close proximity to their homes. For some timber operators, fortunes were made (MacKay 1978). Wooden shipbuilding was one of the spin offs of the timber-based economy. Many timber cargoes were exported in New Brunswick built ships, some of which were built at Richibucto shipyards.

The prospects of owning a natural stand of timber consisting of over 21.7 m^3/ha of large, straight, high quality, mature white pine over 48 cm DBH would present a valuable economic boost to the average woodlot owner today. Natural white pine stands of such quality and large structure can be rarely viewed anywhere within current eastern NB forests.

CONCLUSIONS

The square timber trade between New Brunswick and Britain is a little-remembered, unstable, boom-and-bust industry that selectively removed many of the large white pine trees from the original forests. During a period of approximately 20 years, beginning *ca.* 1820, most of the top quality white pine timber was removed from riparian zones of all watersheds. Substantial volumes of yellow birch and red pine were harvested, but in minor amounts compared to quantities of white pine. Square timber harvest records indicate that large, straight yellow birch grew throughout the study area, while red pine was very localized in distribution.

Quantification of the original white pine component through analysis of ton timber records represented a unique research approach. It provided a plausible estimate of minimum volumes of the largest, healthy white pines that grew in the forests *ca.* 1800. Large diameter white pine (greater than 48 cm diameter at the top end) comprised a substantial component of original forest types, achieving a value of 31 m^3/ha in the Kouchibouguac watershed.

The study of ton timber records allowed some deductions on local disturbance regimes before European settlement. Fire was probably infrequent in the watersheds examined, with exception of Kouchibouguac, where there were extensive groves of fire-dependant red pine. Such infrequent disturbance would support advanced age classes that, in turn, produced large timbers suitable for ton timber harvesting.

Table 4.1 Total white pine volumes harvested for square timber on four watersheds within New Brunswick Eastern Lowlands between 1820-1839 according to ton timber records. Calculations convert ton timber to cubic meters, include adjustment of waste, and maximum - minimum timber volumes (based on assumptions of 1 km and 2 km wide timber berths).

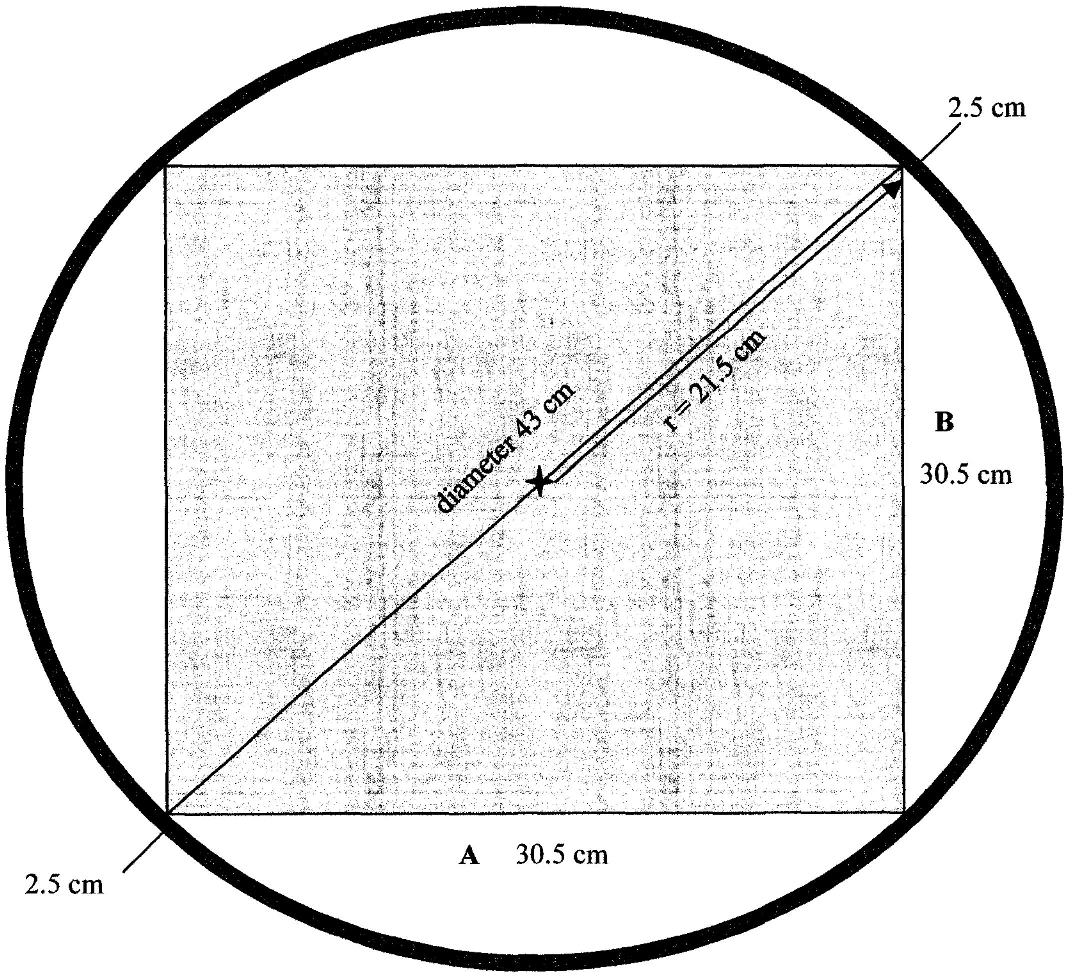
	Bay du Vin	Kouchibouguac	Kouchibouguacis	Richibucto Watershed	Total	*Richibucto	*Bass	*Coal Branch	*Molus	*St Nicholas	*St Charles
Total white pine timber (tons)	43710	108891	70197	124580	347378	42185	17230	5800	15095	34920	9350
Total white pine timber (m^3)	49392.3	123046.8	79322.6	140775.4	392537.1	47669.1	19469.9	6554.0	17057.4	39459.6	10565.5
Total timber (55 % adjustment) (m^3)	109650.9	273164.0	176096.2	312521.4	871432.5	105825.3	43223.2	14549.9	37867.3	87600.3	23455.4
River length (km)	38	44	52	115	249	45	10	11	10	24	15
Area timber berth 2 km wide (ha)	15200	17600	20800	46000	99600	18000	4000	4400	4000	9600	6800
Area timber berth 1 km wide (ha)	7600	8800	10400	23000	49800	9000	2000	2200	2000	4800	3000
Total no. applications and licenses	315	552	309	740	1916	275	109	52	84	171	49
Calculated harvest per hectare											
m^3/ha (2 km wide berth)	**7.21**	**15.52**	**8.47**	**6.79**	**8.75**	5.88	10.81	3.31	9.47	9.13	3.45
m^3/ha (1 km wide berth)	**14.43**	**31.04**	**16.93**	**13.59**	**17.50**	11.76	21.61	6.61	18.93	18.25	7.82

* Individual tributaries that drain the Richibucto watershed provide additional detail on white pine distribution and volumes.

Table 4.2 White pine timber harvested for shipmasts and spars from Port of Richibucto during the study period.

Year	Shipmasts and spars exported from Richibucto Port
1825	545
:	-
1835	869
1836	455
1837	316
1838	285
1839	235
1840	243
Total	**2948**

Sources: J. of the Legislative Council of NB (1847); Fisher (1980).



Minimum top diameter (without bark) = diameter of bole inside bark

= sq. rt $(A^2 + B^2)$

= **43 cm**

Minimum top diameter (with bark)= sq. rt $(A^2 + B^2)$ + (2.5 cm *2)

= 43 cm + 5 cm

= **48 cm**

Figure 4.1 Derivation of minimum top diameter required for white pine square timber of minimum accepted dimensions (30.5 cm^2) for British market.

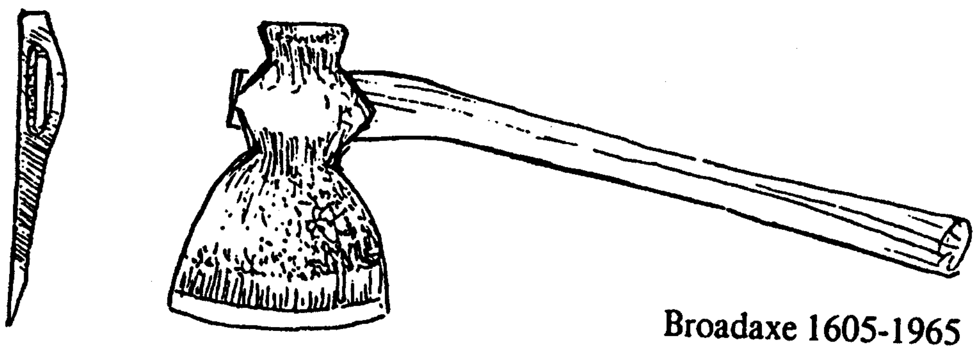


Figure 4.2 Sketch of a broad axe made and used specifically for squaring ton timber. Cross section of the axe bit demonstrates that one side was flattened for hewing the timbers as flat as possible. Sketch by Wyllie 1985, *In*: Johnson (1986).

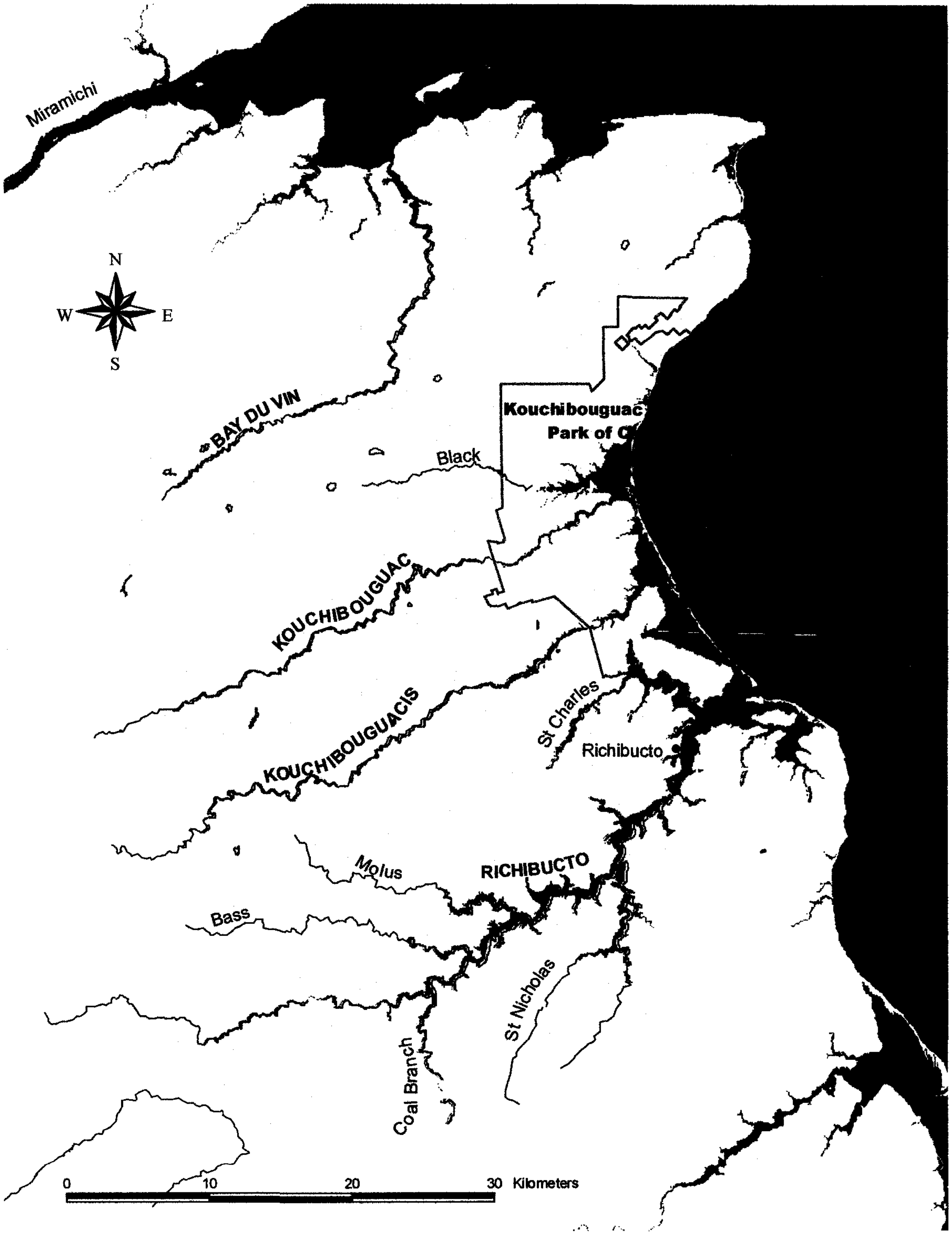


Figure 4.3 Watersheds within the study area that were included in the square timber analysis.

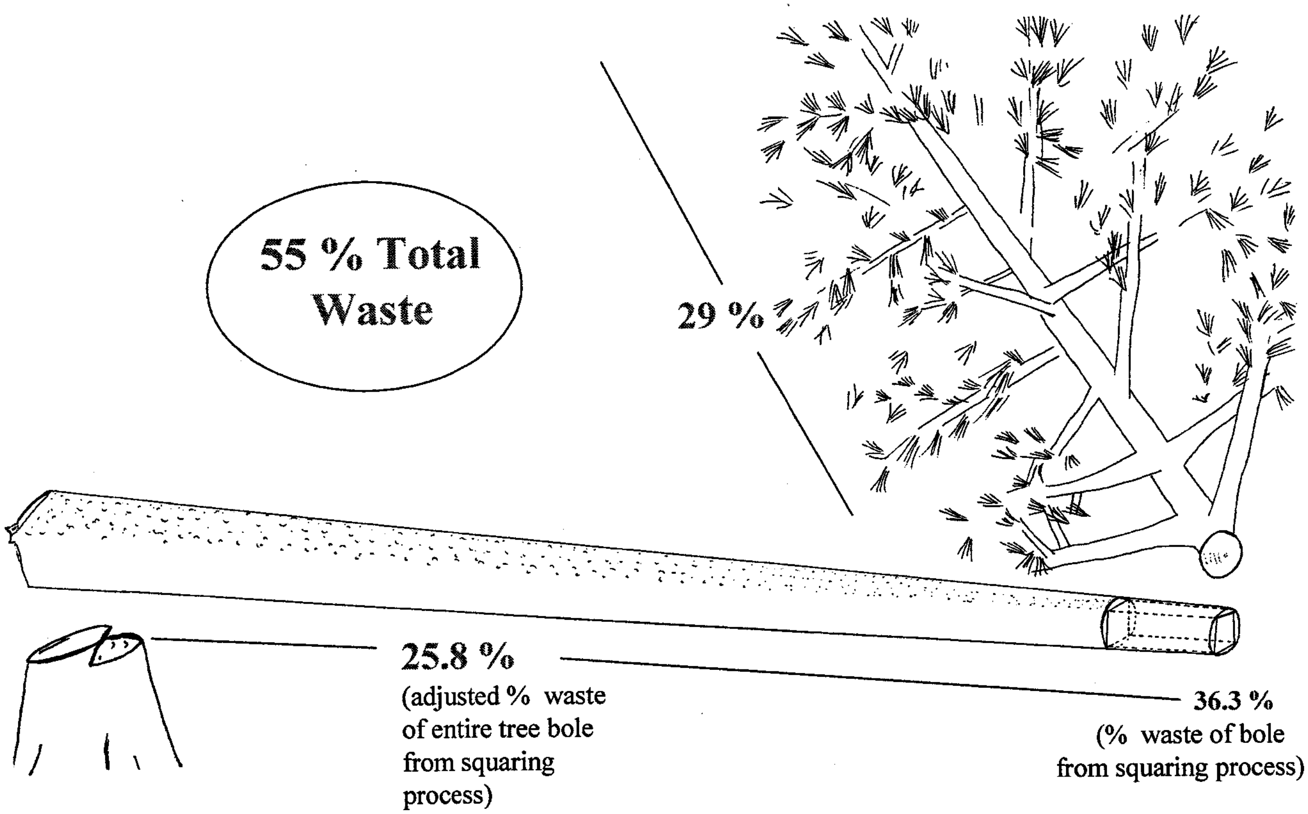


Figure 4.4 Diagram of a white pine log depicting a minimum of 55 % waste following the squaring process and excluding the upper portion of the tree.

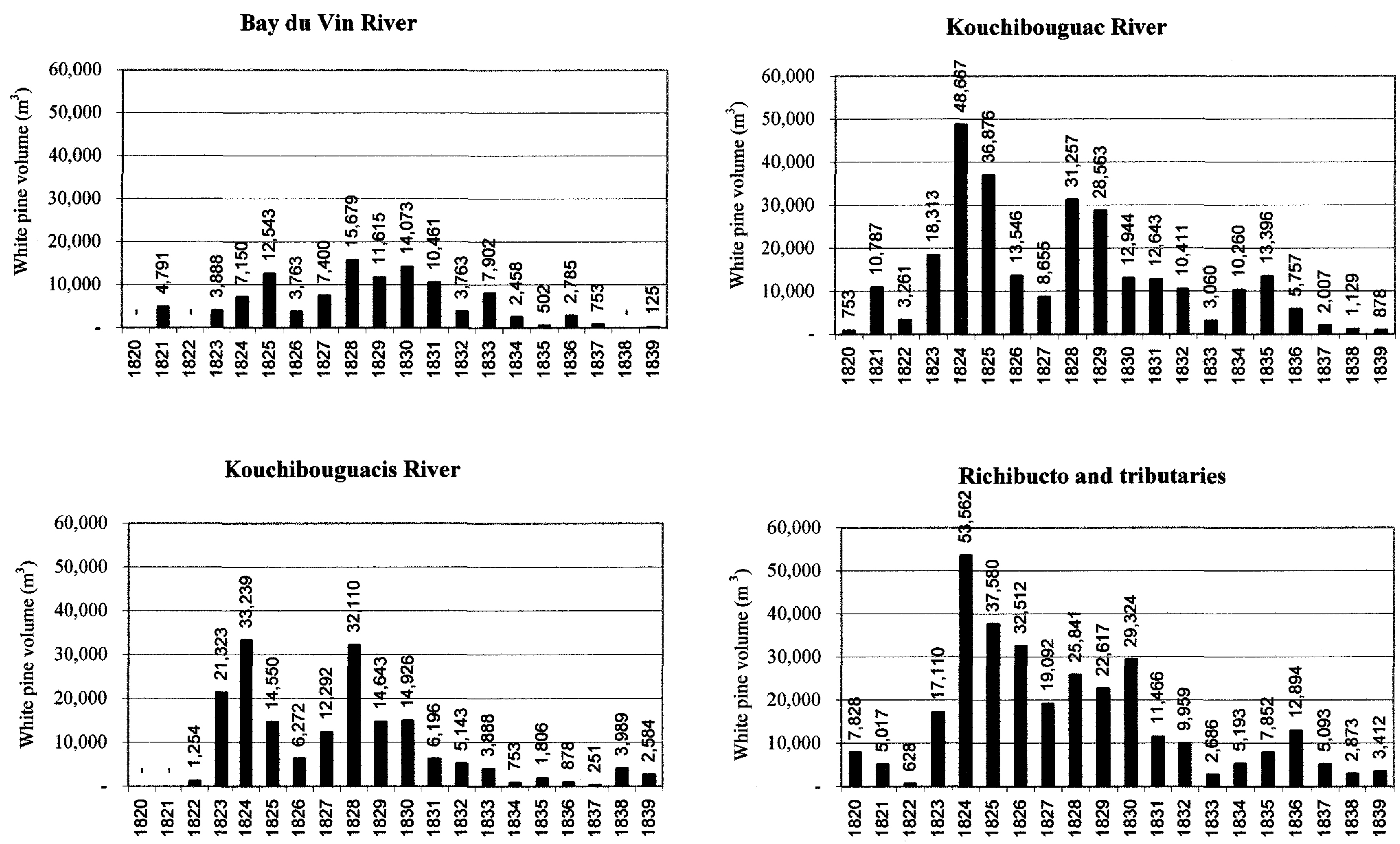


Figure 4.5 Total white pine square timber volumes harvested on four eastern New Brunswick watersheds during 1820-1839 according to archived timber ledgers. Volumes were adjusted upward to include merchantable timber volumes (55 %) excluded through the squaring process. (Year indicates the year license was issued, though each year spans over early winter to May of the following year.)

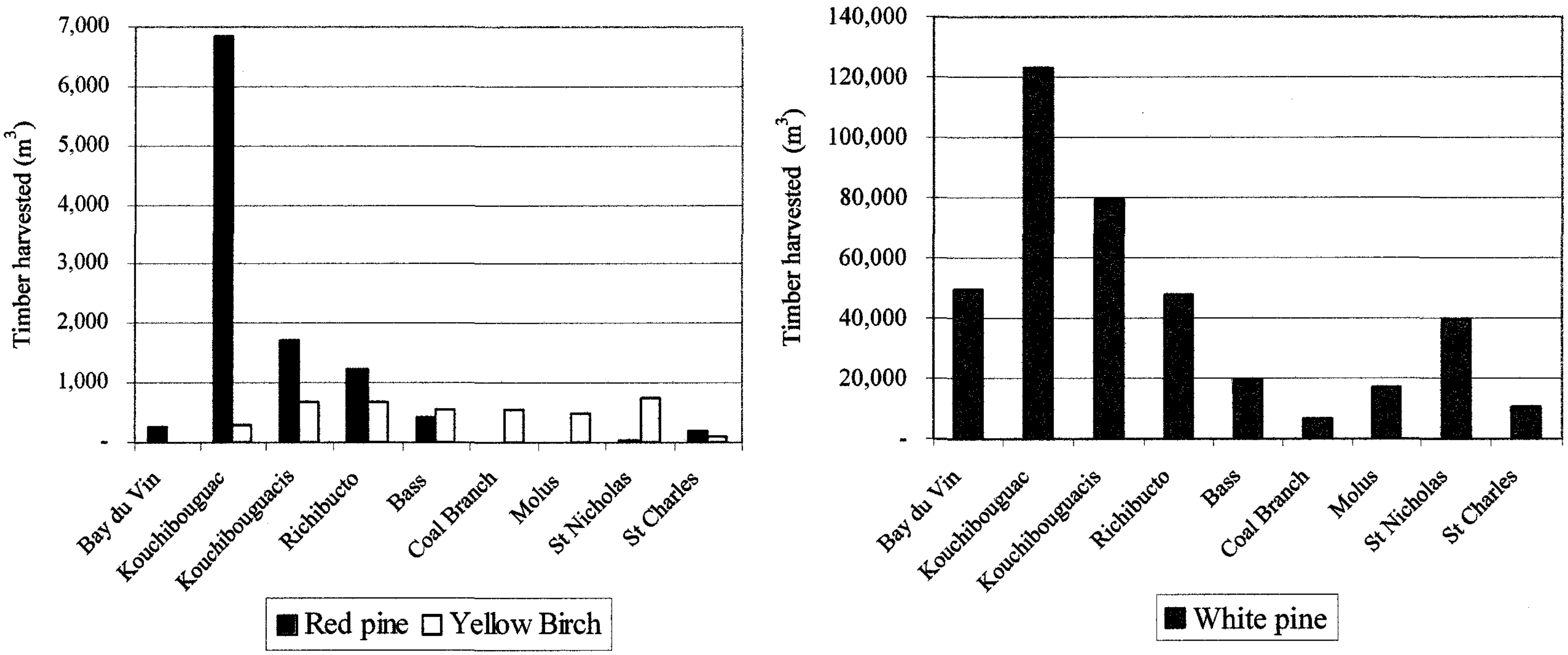


Figure 4.6 Historical distribution and volumes of red pine, yellow birch, and white pine harvested as square timber between years 1820-1839 on individual rivers located on the New Brunswick Eastern Lowlands.

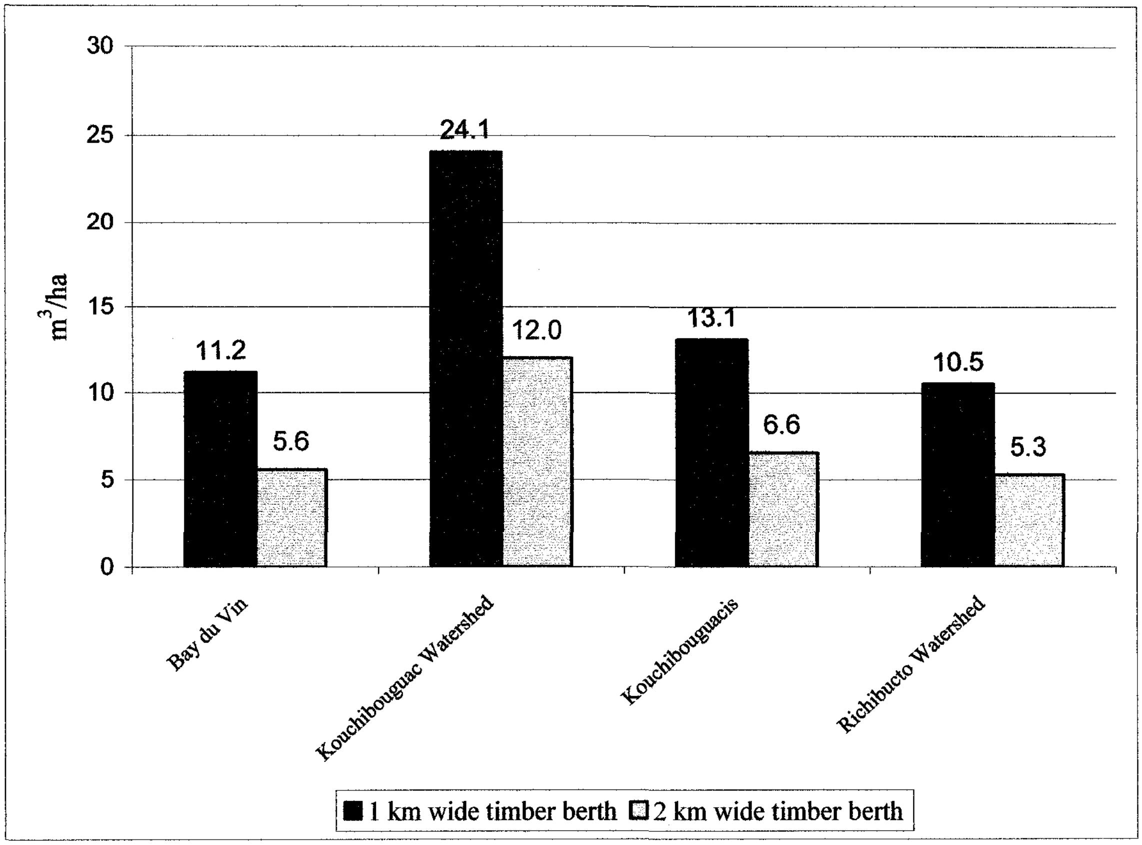


Figure 4.7 Maximum and minimum white pine timber volumes *ca.* 1820 on major watersheds in Eastern New Brunswick, according to assumptions of a 1 or 2 km wide timber berth allowance.

REFERENCES

Abrams, M.D. 2001. Eastern white pine versatility in the presettlement forest. Bioscience, 51(11): 967-979.

Adams, A.L. 1873. Field and forest rambles with notes and observations on the natural history of eastern Canada. Henry S. King & Co., London, England, 333 pp.

Aldred, D. 1985. Registered timber marks of eastern Canada from 1870-1984. Multiscience Publications Ltd. Can. For. Svc., Can. Govt. Publ. Centre, ISBN 0-919868-24-X, 833 pp.

Alexander, J.E. 1849. L'Acadie, or, Seven years' explorations in British North America. London, H. Colburn. 370 pp.

Bailey, L.W. 1876. The woods and minerals of New Brunswick, being a descriptive catalogue of the trees, shrubs, rocks and minerals of the Province, available for economic purposes. Daily Telegraph Steam Job Rooms, Saint John, NB. 50 pp.

Beavan, F. 1845. Sketches and tales illustrative of life in the backwoods of New Brunswick, North America. George Routledge, London, 146 pp.

Bonnicksen, T.H. 2000. America's ancient forests. John Wiley & Sons, Inc. NY. 594 pp.

Bruncken, E. 1900. North American forests and forestry. G.P. Putnam's Sons, NY. 265 pp.

Burns, R. M., and Honkala, B. H., tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 pp.

DeGrâce, E. 1984. Human history of Kouchibouguac National Park. Unpublished report to Parks Canada. 157 pp.

DNRE. 1996. An ecological land classification system of New Brunswick. Ecosystem Classification Working Group, Department of Natural Resources and Energy, Fredericton, NB.

Dominion Bureau of Statistics, 1934. The Maritime Provinces in their relation to the national economy of Canada. A statistical study of their social and economic conditions since confederation. Minister of Trade and Commerce, NB. 131 pp.

Fisher, P. 1980. The first history of New Brunswick. Larson's Printing, Woodstock, NB. 133 pp.

Foster, D.R., Boose, E.R. 1992. Patterns of forest damage resulting from catastrophic wind in central New England, USA. J. of Ecology 80: 79-98.

Ganong, W.F. 1906. Additions and corrections to monographs on the place-nomenclature, cartography, historic sites, boundaries and settlement-origins of the Province on New Brunswick. From the transactions of the Royal Society of Canada, second series-1906-1907. Vol. XII.

Gibson, J.M. 1953. The history of forest management in New Brunswick. An H.R. MacMillan Lectureship Address delivered at the university of BC, University of British Columbia, 14 pp.

Government of New Brunswick, 1797. NB Statutes. C. IV. An Act for regulating the same. J. of Legislative Assembly, p. 93-95.

Government of New Brunswick, 1810. NB Statutes, C. 28, An Act to explain and amend the Laws now in force for regulating the exportation of Fish and Lumber, J. of Legislative Assembly, p. 130-133.
Government of New Brunswick, 1816. NB Statutes, C. 13, An Act in addition to, and to explain an Act, entitled "An Act to explain and amend the laws now in force for regulating the exportation of fish and lumber", J. of Legislative Assembly, p. 273-275.
Government of New Brunswick, 1831. NB Statutes, C. 45. An Act to repeal the Acts now in force regulating the exportation of lumber, and to make other provisions in lieu thereof. J. of Legislative Assembly, p. 553-557.
Grant, G.M. (Ed.) 1882. Picturesque Canada: the country as it was and is. Vol. I. Belden Bros., Toronto, ON. 491 pp.
Honer, T.G., Ker, M.F. and Alemidag, I.S. 1983. Metric timber tables for the commercial tree species of central and eastern Canada. Maritime Forest Research Centre, Can. For. Svc., Fredericton, NB. Information Report M-X-140.
Honer, T.G. 1998. Without fear or favour: culling & scaling timber in Canada 1762-1992. T.G. Honer & Assoc., Victoria, BC. 213 pp.
Husch, B., Beers, T.W., Kershaw, J.A. (Jr.) 2003. Forest mensuration (4^{th} Ed.). J. Wiley, NY. 443 pp.
Johnson, R.S. 1986. Forests of Nova Scotia: a history. NS Dept. Lands and Forests: Four East Publications, Halifax, NS. 407 pp.
Johnston, J.F.W. 1850. Report on the agricultural capabilities of the province of New Brunswick. J. Simpson, Fredericton, NB. 95 pp.
Johnston, J.F.W. 1851. Notes on North America. Vol. I and II, C.C. Little and J. Brown, Boston. 512 pp.
Journal of the House of Assembly, 1786. CAP. XXXIII, NB. p. 49
Journal of the Legislative Council of NB. 1847. Reports on railways, &c., (Appendix), J. Simpson, Fredericton. p. cxl.
Klein, A. 1974. The world of measurements. Simon and Schuster, NY. 736 pp.
Lee, D. 1987. The forest history of New Brunswick 1780-1930: A systems plan report. Unpublished report to Parks Canada, Microfiche report series 301, 172 pp.
Lorimer, C.G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology 58: 139-148.
Lower, A.R. 1938. The North American assault on the Canadian forest: A history of the lumber trade between Canada and the United States. Greenwood Press, NY. 377 pp.
Lower, A.R. 1973. Great Britain's woodyard: British America and the timber trade, 1763-1867. McGill-Queen's Univeristy Press, ON. 271 pp.
MacKay, D. 1978. The lumberjacks. McGraw-Hill Ryerson Ltd. Toronto, ON. 319 pp.
Maxwell, H. 1915. The story of white pine. American Forestry 21: 34-46. *In*: Whitney, G.G. 1994. From coastal wilderness to fruited plain. A history of environmental change in temperate North America 1500 to the present. Cambridge U. Press, Great Britain, 451 pp.
Parenteau, B. 1994. The New Brunswick forest heritage: A history of the forest industries, 1780-1930. Unpublished report submitted to Envir. Canada, Can. Parks Svc. 401 pp.

Perley, M.H. 1842. Reports on Indian settlements, &c. J. of the House of Assembly of the province of New Brunswick, Sixth Session of the twelfth general assembly, (Appendices.). J. Simpson, Queen's Printer, Fredericton, NB.

Pinchot, G. and Graves, H.S. 1896. The white pine: A study with tables of volume and yield. The Century Co., NY. 102 pp.

PANB (Provincial Archives of New Brunswick). 1824. Timber Licenses, Regulations to be observed be all persons applying for, or obtaining licenses to cut pine timber, RS 663 F1.f

Simard, H. and Bouchard, A. 1996. The precolonial 19th century forest of the Upper St. Lawrence Region of Quebec: a record of its exploitation and transformation through notary deeds of wood sales. Can. J. For. Res. 26: 1670-1676.

Springer, J.S. 1856. Forest life and forest trees: comprising winter camp-life among the loggers, and wild-wood adventure. Harper & Bros. NY. 259 pp.

Trueman, S. 1970. An intimate history of New Brunswick. McLelland and Stewart Ltd., Toronto, ON. 154 pp.

Whitney, G.G. 1994. From coastal wilderness to fruited plain. A history of environmental change in temperate North America 1500 to the present. Cambridge U. Press, Great Britain, 451pp.

Wilson, J. 2005. Nineteenth century lumber surveys for Bangor, Maine: Implications for pre-European settlement forest characteristics in northern and eastern Maine. J. Forestry, p. 218-223.

Wynn, G. 1981. Timber colony: A historical geography of early nineteenth century New Brunswick. U. Toronto Press, ON. 224 pp.

Zupko, R.E. 1968. A dictionary of English weights and measures; from Anglo-Saxon times to the nineteenth century. U. Wisconsin Press, Madison, 224 pp.

CHAPTER 5. COMPARISONS BETWEEN WITNESS TREE AND ECOSYSTEM ARCHAEOLOGY METHODOLOGIES TO CHARACTERIZE HISTORICAL FORESTS *CA.* 1800 IN EASTERN NEW BRUNSWICK AND KOUCHIBOUGUAC NATIONAL PARK.

INTRODUCTION

One of the challenges of historical ecology research is that much of the evidence required for strongly supported conclusions has been destroyed through time. Landscapes that have been cleared for agriculture, or that have been repeatedly cut or burned over a two or three-century period provide little tangible proof of original forest conditions.

There are currently two schools of thought regarding the species composition of the characteristic forest types within the study area under natural disturbance regimes. According to the New Brunswick Ecological Land Classification (ELC) (DNRE 1996), forest types in the eastern New Brunswick Kouchibouguac ecodistrict (that encompasses the study area and comprises lands within watersheds of the Richibucto, Kouchibouguac, Kouchibouguacis, and Bay du Vin) have an innate tendency to support high components of coniferous boreal species, rather than more characteristically temperate assemblages of the Acadian mixedwood forest. Supporting this line of thinking, *Picea mariana*, *Pinus banksiana* and *Populus* spp. are among the most prominent tree species in the region. These species are known to respond positively to frequent fire (Burns and Honkala 1990; Bergeron 2000). The region experiences some of the warmest and driest weather in the Province, and therefore forests are believed to be predisposed to a high frequency of fire (DNRE 1996). Among the explanations for a reduction of *Pinus strobus*, and the presence of *Thuja occidentalis* and late-successional *Tsuga canadensis* is that the naturally occurring, short-interval fire regime has been suppressed, for example by private landowners and through forest fragmentation by roads and land clearances (DNRE 1996).

An alternative school of thought postulates that late-successional, self-replacing forest complexes of species, such as *Picea rubens* and *Tsuga canadensis*, are the naturally predominant forest types in the region (Loucks 1962). However, there is currently little tangible evidence that such forest types existed. A quite different disturbance paradigm is deduced if forest types were predominantly comprised of late-successional, fire-sensitive species; one that is characterized by long intervals between fires. Although fires have been very frequent in the area since 1900, according to research in Kouchibouguac National Park (KNP), most were attributed to anthropogenic ignitions, rather than to lack of rainfall or dry lightning ignitions (Crossland 1998).

Such alternate theories on characteristic dominant forest types and fire disturbance are of particular concern to KNP, where knowledge of natural disturbance regimes is required to meet Parks Canada's policy of using 'natural regulation' to manage park vegetation over the long term (Parks Canada 1994). There is little or no original vegetation remaining that pre-dates European occupation. The absence of baseline, scientific evidence of natural forest characteristics or disturbance regimes means there is no scientifically sound guidance for long-term vegetation management goals. An overall synopsis of historic forest character will ultimately provide a reference condition that will guide park or forest managers, and help determine long-term management goals. To address this lack of information, several historical ecology research approaches have been used to achieve a better understanding of former, as well as potential forest condition.

The principal objective of the present study was to determine whether two historical ecology research methods, ecosystem archaeology and witness trees, provided similar estimates for defining a forest reference condition. Three essential components of a forest reference condition were examined: species composition, structure (tree sizes, ages, density, and spacing), and associated disturbance regime (e.g., agents, size, frequency, and intensity of disturbance events). Both methods characterize local forest types at the same temporal scale, i.e. the period of early European settlement, before significant human-induced changes occurred.

METHODS

Witness tree research method

Large numbers of European settlers arrived in the study area during the early 1800s. Deputy Surveyors carefully measured and divided the landscape into various-sized parcels, and marked trees on the bounds of each lot. These 'witness trees' were blazed with an axe (Monro 1844), and the location and species (or genus) of each witness tree were recorded on surveyor plan drawings. A large number of these sketches are preserved at the Provincial Archives of New Brunswick (PANB). Locations of all witness trees and other types of survey markers were plotted on corresponding property boundaries of digital cadastral maps using ArcView™ GIS 3.2. Because all original property lines have been preserved, cadastral maps served as base maps for spatial portrayal of historical information. A total of 1096 survey plan drawings were found for the study area, resulting in 2537 witness trees used in subsequent analyses. Detailed methods are presented in Chapter 3.

Ecosystem archaeology research method

Ecosystem archaeology is explained more thoroughly by Ponomarenko in Appendix 5-1. In short, former forest cover can be elucidated through careful study of the soil profile. The soil preserves information on former forest communities in the form of charcoal fragments and other macrofossil evidence. Macrofossils, when identified to the species level, provide reliable evidence of the presence of certain taxa in former forests (Pielou 1991; Mayle and Cwynar 1995). Charcoal fragments were identified by Dr E. Ponomarenko to genus or species, (depending on tree species), from burned twigs and branches that were incorporated within the plough horizon at the time of land clearance. Other types of macrofossils preserved in the soil, e.g. buds, bark, or seeds, were less common, but were readily identified by Ponomarenko when available.

A difficulty that researchers often encounter when using pollen or macrofossils to reconstruct vegetation is that previous uprootings cause soil strata or deposition layers to become inverted, thereby mixing the chronosequence. Ecosystem archaeology minimizes this problem by carefully identifying trace fossils, particularly those of uprootings, and then taking note of where macrofossils occur in relation to trace fossils.

Trace fossils are three-dimensional imprints, images or moulds left by tree roots or uprooting structures. They often appear in vivid contrast to surrounding soils due to oxidation-reduction reactions or from infilling of surface materials. Tree species identification, as well as structural and spatial features of forests, can be interpreted from the shapes and sizes of root trace fossils, and the distances between them. Trace fossils of uprootings, tree roots and root collars aid in identification of soil inversions below the plough horizon, and through measurements of diameters and spacings, they can also provide information on pre-colonial tree size and spacing. Figure 5.1 provides examples of trace fossils identified in trenches in KNP.

Species identified from study of charcoal assemblages in trenches and/or test pits can be extrapolated to represent general forest species composition that once grew within the field or cleared area in which each trench is located. Although ecosystem archaeology research methods can be employed in any area to determine former forest composition, including forested sites and bogs, there is an advantage to studying abandoned fields. In fields, the plough horizon acts as a time marker for when European land clearance began. In other locations, it is more difficult to ascertain approximate ages of strata, and in some cases, it is only possible by radiocarbon dating. This relatively new historical ecology research approach has been applied in several Atlantic Canada national parks (Ponomarenko and Ponomarenko 2000a, b; Ponomarenko and Ponomarenko 2003; Ponomarenko 2004; Ponomarenko 2006a, b).

KNP was the first to employ ecosystem archaeology research techniques for reconstruction of pre-agricultural forest composition (Ponomarenko and Ponomarenko 2000 b). This method proved advantageous in areas where pre-existing forests were completely removed from the landscape, and little evidence was available to indicate the types of forests existing prior to European land clearance. Furthermore, the richest forest sites were most often selected for farming, so nearly all of these forests, particularly within riparian zones, were heavily modified or removed during the early 19th century.

Field work and data analysis

Field research was conducted by Dr. Ponomarenko during four field seasons (1999-2002). A total of 34 soil trenches (averaging 5 m long X 2 m deep X 1 m wide) were utilized. Three to five test pits (50 cm^2) were associated with each trench, located at approximately evenly spaced intervals across each cleared area, or 'field unit', and charcoal fragments were extracted. During 2003, additional test pits were placed in under-sampled ecosites by the author, to determine additional research sites. Ponomarenko subsequently chose the final four trench sites, according to preliminary test pit research and ecosite classification. Research results from the additional trenches allowed ecosystem archaeology data to be more comparable to witness tree data, which was stratified by ecosite classes. Additional information was included from two sites where charcoal fragments were extracted from test pits alone.

Charcoal was extracted from trenches by sampling the entire perimeter of trench walls at each study site by either prying the pieces from the walls or by sifting soils from the plough horizon through a sieve with 2 mm openings. Preference was given to large fragments, but often smaller pieces, or the entire available charcoal assemblage, were collected where charcoal was sparse. A minimum of 30 to 50 identifiable fragments per trench site was collected. Relative positions of macrofossils within the trench walls were discerned according to trace fossils, plough horizon, or depth within the soil column if located below the plough horizon, so as to ensure species assemblages identified were allocated to the same generation of tree species.

Charcoal fragments comprising twigs and branches were sorted according to size from the remaining collection of charcoal collected from each site (which often included bark and semi-coke or 'reburned charcoal' fragments). Approximately 25 to 50 of the largest fragments were then identified to genus or species according to wood cell morphologies (Butterfield and Meylan 1980; Panshin and de Zeeuw 1980; Barefoot and Hankins 1982). Binocular and SEM microscopy assisted identification. Appendix 5-2 provides results of charcoal fragment identification.

Species assemblages determined from trenches were interpreted to represent an entire cleared field, or 'field unit', rather than being limited to the trench site alone. This was a logical assumption because arboreal material was dragged from all areas of a field, including the very edges, to burn in slash fires. The charcoal fragments were then re-distributed throughout the field during many years of ploughing.

Comparing ecosystem archaeology results with witness tree results

Comparisons between ecosystem archaeology results with witness trees were carried out using several approaches to elucidate possible strengths and weaknesses of each information source and to strengthen conclusions on the forest reference condition.

The first means of comparison utilized the frequency of all species, including shrubs, identified by each method. This comparison showed the maximum number of species that each method was able to capture. Ecosystem archaeology species frequencies were calculated as the number of sites in which each species occurred divided by the total number of species occurrences (244) that were identified in the 36 trenches (Figures 5.2 and 5.3a). Species assemblages determined from ecosystem archaeology trench sites were treated as representative of an entire cleared field in which each trench was located. Witness tree data were summarized as frequency of each species that was used as a survey marker (either tree or shrub) across the study area, divided by the total number of witness trees (2537) (Figure 5.3b).

A second, more compatible comparison of the two methods was carried out using frequencies of tree species only, and excluding witness trees from bogs, since there were no corresponding sites sampled using ecosystem archaeology (Figure 5.4). Comparison was limited to the genus level because early surveyors did not consistently identify some taxa to species.

In a third assessment, tree species from each method were spatially stratified over ecosite classes from the ELC (DNRE 1996) using ArcView 3.2™ to provide historical species frequency distributions over major physiographic land types (Figure 5.5). A different approach was taken with ecosystem archaeology data, which were examined based on percentage of charcoal fragments identified per species per ecosite. This approach increased the sample size (N = approximately 1320) (Table 5.1) because it was based on the number of identifiable charcoal fragments, rather than presence/absence of each tree species in all trench sites (N=216) (Appendix 5-2). Witness tree information was analysed as species frequency of witness trees that were located in each ecosite.

Inferences on disturbance processes (e.g. fire, wind, insect infestations, small gaps, and flooding) were drawn from the data, and were compared between the two approaches where possible. The main method of comparison of disturbance regimes was simply deduced from the silvical characteristics of dominant species assemblages defined by each approach. Ecosystem archaeology provided information on the fire regime through radiocarbon dating of charcoal and identification of trace fossils.

RESULTS AND DISCUSSION

Integration of two historical ecology research approaches, ecosystem archaeology and witness trees, corroborated and reinforced the independently drawn conclusions from each research method. The process also highlighted areas where information was less trustworthy. All information presented on species assemblages characterizes the local Acadian forest *ca.* 1800, just prior to heavy modification by harvesting, wildfire, and European land clearances.

Each research method detected a high diversity of species in 19^{th} century forests (Figure 5.3), including tree species that are generally not common on the landscape, for example, *Ulmus americana* and *Ostrya virginiana*. Witness tree analyses revealed 22 species, (including 3 shrub or understory species), but analyses were carried out at the genus level, comprising 14 tree genera. Ecosystem archaeology captured all tree genera that were represented in the witness tree record, and the method allowed some genera to be consistently identified to the species level, but not others. *Pinus strobus* was separated from *P. resinosa* (Figure 5.3), and *Quercus rubra* was distinguished from a *Quercus* species belonging to the white oak group (believed to be *Q. macrocarpa*). *Pinus resinosa* was found on only one site (Palmer Creek, Ecosite 3) (Appendix 5-2), where it comprised 10 % of identifiable charcoal. The remaining *Pinus* fragments originated from *P. strobus*. *Pinus banksiana* was absent. Witness tree results also confirmed minor amounts of *Pinus resinosa* (a total of 16 trees, translating to a minimum frequency of 0.6 % *P. resinosa* on the landscape). *Pinus banksiana* was absent. Species of *Picea, Betula,* and *Acer* were not distinguished by ecosystem archaeology methods, nor were they consistently discerned in the witness tree record, so analyses were confined to the genus level. The pre-colonial frequency of all tree genera

(14 in total) was analyzed (Figure 5.4). *Quercus macrocarpa,* (most likely identity, as there are no other native species possibilities from the white oak group) detected at Beer's field, represents a new species record for the region.

Both methods revealed some detail on prevalence of shrub or understory species. *Alnus* and *Prunus* (interpreted to consist of shrub species only) were detected by both methods. Ecosystem archaeology identified three additional shrub genera that were not detected in the witness tree record: *Taxus canadensis, Corylus cornuta,* and *Salix spp* (Figure 5.3). *Taxus canadensis* was particularly common, at 4.8 % of identifiable charcoal fragments. An understory tree species discerned in the witness tree record, but not through ecosystem archaeology was *Acer pensylvanicum.*

General forest composition *ca.* 1800

Species compositions derived from each method were relatively similar, both indicating that historic forests in the area were mixed and comprised mainly of mid- to late-successional species, including *Picea, Tsuga canadensis, Betula* (assumed to be mainly *B. alleghaniensis*, explained below), *Acer, Abies balsamea,* and *Pinus strobus.* These tree species generally comprised approximately 70-80 % of 19th century forests in the region (according to data used in Figure 5.4). *Fagus grandifolia* was found across much of the region with a frequency of approximately 5-7 %. *Thuja occidentalis* frequency was very high (14 %), according to ecosystem archaeology results, and approximately 6 % according to witness tree results. It is clear from both methods that this species was much more frequent in the past than in the modern local forests, where recent forest development surveys (DNR 2004) for the study area place it at 3 %. Early-successional or shade-intolerant species, such as *Pinus resinosa, L. laricina, Populus spp.,* and *Q. rubra* occurred at low percentages of 1-3 % of forest composition according to both methods (Figure 5.3). *Abies balsamea* may appear to have been more dominant than *Pinus* or *Acer* in Figures 5.3 and 5.4, but both datasets reflect species frequency, rather than basal area or wood volume. *A. balsamea* may have a high stem frequency, but it does not attain the large sizes of *Pinus* or *Acer* (Burns and Honkala 1990), and so it was unlikely to have been more 'dominant' than *Pinus* or *Acer*, had measurements that are more commonly used today been available for comparison.

Three forest understory species also assist in indicating the presence of late-successional forest cover. *Taxus canadensis* was very common, having been detected on 11 of the 36 sites, with a frequency of 4.8 %, based on charcoal fragments. *Tsuga canadensis* characteristically grows in cool damp woods and climax coniferous forests (Zink 1998). *Corylus cornuta* is also sometimes found in late-successional forests, but prefers dry open woods (Zink 1998). *Acer pensylvanicum*, or 'moosewood' is a common understory tree that prefers cool, moist soils in the shade of mature forest (Hosie 1990). Remaining shrub taxa did not assist in delineating forest types, and more likely indicate wet areas, such as *Alnus*, or forest edges or former disturbance, such as *Prunus*.

Betula was one of the genera that neither ecosystem archaeology nor witness tree methods could directly identify to species, but *B. alleghaniensis* was deduced to have been much more common than *B. papyrifera ca.* 1800. Ton timber records provided quantitative evidence that large, healthy, old growth *B. alleghaniensis*, sold under the name of black birch, was very common in the local forests. *Betula*, growing in complexes with late seral species, such as *Tsuga canadensis*, and *F. grandifolia*, is most often *B. alleghaniensis,* as it is more shade tolerant than other birch species (Burns and Honkala 1990). *B. alleghaniensis* is known to be 'stable' on moist sites, conditions that are commonly encountered over the flat landscape. Some additional indirect evidence that *B. papyrifera* was the least common of the two birches originated from the Canadian Museum of Civilization in Ottawa. The museum has archived 19th century Mi'kmaq birch bark canoes, two of which are made from the bark of yellow birch rather than white birch. Had there been plenty of *B. papyrifera* on the landscape, the Mi'kmaq would presumably have preferred its bark to that of *B. alleghaniensis,* as the bark of the former species more readily separates from the trunk in large uniform sheets (Hosie 1990) required for canoe construction.

Tree species across ecosites

Pre-European forest types and species associations were more precisely defined through analysis according to distinct edaphic conditions, i.e. ecosite classes (Figure 5.5), and by utilizing percent charcoal composition. Species composition derived from frequency of charcoal fragments provided an indication of which species were dominant on each site, rather than using only the number of sites in which each species occurred (i.e. presence or absence of each species per trench). Late-successional species predominated over all site types. There was no ecosite where early-successional, or pioneer species exhibited dominance.

Witness tree frequencies consistently indicated that *Picea, Tsuga canadensis,* and *Betula* were key dominants across all site conditions. *Picea* was more common on moist to wet, nutrient-poor sites (ecosites 2 and 3), and was at least 10 % more common on wet, nutrient poor sites than in drier areas. *Tsuga canadensis* and *F. grandifolia* were more strongly associated with mesic forests, with slightly higher preference for richer sites (ecosites 2 and 5). Frequencies of some taxa were fairly constant across all sites conditions: *Abies balsamea* at 9-11 %, *Pinus* at 6-8 %, and *Acer* at 6-8 %.

According to ecosystem archaeology methods, dominant forest species were highly variable, and fluctuated in relative order of dominance according to ecosite. Dry sites (ecosite 1) supported birch-beech forests with *Picea, Thuja occidentalis,* and *Pinus* (in descending order). Such sites were probably reminiscent of the "*hardwood ridges,*" observed by Johnston (1851) on his travels through the district, which emerged here and there "*above the flat country.*" Forests of mesic sites (ecosites 2 and 5) were dominated by *Pinus,* with various combinations of *Thuja occidentalis, Betula, Tsuga canadensis*, and *Picea.* The high frequency of *Pinus* on moist sites was unexpected, as it was hypothesized to reach highest levels on drier ground (ecosite 1). Wet sites featured the least diverse forests, with *Thuja occidentalis, Picea, Acer*, and *Betula* in decreasing order of dominance. *Fraxinus*, (probably *F. nigra*) was highest (5 %) on wet sites. *Tsuga canadensis* was dominant on moist, nutrient poor to rich sites (similar to witness tree results). In addition to *Fagus grandifolia* being the second most dominant species on the driest sites, it was the 4th most frequent on moist, nutrient rich sites (ecosite 5).

Considerable differences were evident between dominant species associations derived from the two research methods. While both approaches indicated that *Thuja occidentalis* was more abundant on the wettest sites (ecosite 3), it occupied 1st place according to ecosystem archaeology data, but dropped to 6th place according to witness tree data. *Thuja occidentalis* was at least 3 times more abundant on all sites by ecosystem archaeology than percentages indicated by witness trees. In either case, *T. occidentalis* was much more abundant some 200 years ago than we might assume from examining current forest types. Furthermore, ecosystem archaeology research in Prince Edward Island National Park found proportionally very little cedar charcoal (in only 2 sites) (Ponomarenko 2006 a), though it is located within the same ecoregion as KNP according to forest classification by Loucks (1962). Thus it seems that the proportion of cedar in the Kouchibouguac area was, in fact, comparatively high.

Larix laricina was slightly less common according to ecosystem archaeology results than witness tree results. This was probably because larch was restricted to boggy sites, and rarely occurred on lands suitable for agriculture where ecosystem archaeology study sites were located. Its shade intolerance did not allow it to compete in most forested situations under eutrophic conditions.

Analysis of percent charcoal fragments, by ecosite, probably portrays a more realistic picture of the order of dominance of some species than do frequency data. On all site types, *Abies balsamea* occupied only 7th or 8th place in order of dominance (Figure 5.5). This reflects that *A. balsamea* was probably a small understory tree in most forest types, thereby contributing relatively small volumes of combustible material to charcoal assemblages. Using frequency data alone, *A. balsamea* occupied 4th or 6th place (according to witness tree frequencies and ecosystem archaeology frequencies, respectively (Figure 5.4). In contrast, *Pinus strobus* was most dominant on mesic sites (ecosites 2 and 5). Its dominance may reflect a more realistic estimate of its presence since it has the capacity to achieve the greatest volume, above all other species, and therefore may have been more proportionately represented in charcoal percentages.

Why study charcoal?

Clearing the forests that were present at the time of European settlement was always assisted in the initial stages by fire. Settlers had few tools beyond the axe with which to clear forests, and so fire was necessary to remove huge piles of slash and debris. The resultant charcoal produced from this activity endured and became incorporated in the soil through ploughing. Thus studying charcoal assemblages is appropriate for determining pre-European forest complexes.

Charcoal assemblages from the land clearance period reflect the species that were present on the landscape at that time. Tree species can be identified from wood cell morphology preserved in charcoal of branches and twigs. Some trunk wood can also be identified to species, but trunk wood contributes very little to the charcoal record because it does not generally burn during forest fires (Wein 1978). Instead, it remains standing with scorched bark, then later topples to the ground to decompose. Furthermore, early settlers had many uses for trunk wood, especially for building materials and firewood (Bouchette 1831).

Land clearance methods aided by fire were described by some early recorders (Bouchette 1831; Johnston 1851). Forests were generally burned in May to consume "*all the branches and small wood*" (Bouchette 1831). Large logs were often hauled away for various uses. Grain was often directly sown in the blackened, charred soil around the tree trunks without additional preparation. Some farmers, who were fortunate enough to have oxen, furrowed the ground around the tree trunks, but this required the tree roots to be cut with an axe. Potatoes were planted, often by simply using a hoe to make small hollows. In four to five years, spruce, beech, birch, and maple stumps were decayed sufficiently to haul out. Pine and hemlock stumps often took much longer to decay (Bouchette 1831).

Examination of charcoal also offers information on the pre-European fire regime. C^{14} dating of charcoal assemblages provides details on fire frequency, and approximate dates of fire. Charcoal that has burned more than once from successive fires (termed semi-coke) commonly occurred in the study area (Ponomarenko and Ponomarenko 2000 a; Ponomarenko 2006 b), rendering separation of historical fire events problematic. Analysis of these thermally altered, or semi-coke fragments, provided evidence for several fire events through study of shapes and other features, such as de-gassing pores and mineral coating (Ponomarenko 2006 b).

Discrepancies in percent tree species between methods

Despite many similar research findings, there were large inconsistencies between dominant forest species derived from the two techniques. Several explanations are proposed for why species compositions from the two research methods were not entirely congruent. Disturbance processes, physiographic variations across the landscape, and a diverse array of possible Acadian forest species capable of occupying similar sites, lead to inherently diverse and stochastic forest compositions, where no two forest stands are ever exactly alike. Thus, we cannot expect exact agreement.

Several explanations proposed below might explain why frequencies of *Thuja occidentalis* and other species, such as *Betula*, appear to be relatively high, while other species, such as *Fagus grandifolia* and *Tsuga canadensis* may be under-represented in ecosystem archaeology analyses. Most of the explanations focused on ecosystem archaeology methods and originated from Ponomarenko (2006b).

1. Differential preservation of wood. The wood of some species is more rot resistant and thus is better preserved in soil. *Thuja occidentalis* is the most rot-resistant of all species in the region, and this characteristic may have augmented the number of fragments for this species since some partially burned fragments were included in the total fragments analysed. Investigation of only fully burned fragments might place *T. occidentalis* on more equal terms of comparison with other species.

2. Differential preservation of charcoal. The wood of some species burns to produce charcoal in smaller and more fragile shapes (e.g. *Picea, Abies, and Tsuga*), while other species produce charcoal in larger chunks (e.g. *Betula, Acer*, *Pinus*, and *Thuja*) (unpublished field observations by E. Ponomarenko). Species in the former situation may be underrepresented in species assemblages because charcoal less than 2 mm was not collected. Species that produce large charcoal fragments are more resistant to grinding experienced through years of repeated ploughing and frost action. Therefore, they may be represented in higher than their original proportions.

3. Differential ashing. Some tree species produce more ash than charcoal (E. Ponomarenko, curator, Museum of Civilization, Ottawa, Ont, Pers. comm.). This is applicable for *F. grandifolia*, for example, which inevitably causes it to be underrepresented. More research is required to determine by what correction factor such species should be adjusted to reflect their original proportions on the landscape. An 'ashing coefficient' (charcoal: ash ratio) for each tree species, under similar conditions of combustion, would enhance resolution of species proportions.

4. Species assemblages were represented from more than one ecosite per trench. In the process of clearing forests to make fields, branches of woody species were dragged from all areas of the field, including the very edges, to burn in slash piles. Many fields situated within the study region typically border on wet areas, including bogs. It is possible that tree species more characteristic of such wet areas were incorporated into the field clearing process, thereby augmenting charcoal records of *Thuja occidentalis.*

5. Edaphic features modified by European 'improvements' indirectly caused increases in representation of species characteristic of wet areas. The wet, boggy landscape of the Kouchibouguac ecodistrict was drained in many areas by early settlers, thereby transforming formerly wet forested areas to cleared lands with dry or moderate drainage. Land grants to new European immigrants clearly stated that land must be 'improved', or grants would be forfeited to the Crown. In the case of wetland, settlers were to "*clear and drain three acres of swampy or sunken ground, or drain three acres of marsh*" (archived land grant to former resident, Jacob Kollock (PANB 1808)). The ecological land classification (DNRE 1996) accurately interprets such areas as mesic or dry, even though pre-colonial species composition from charcoal may indicate that the site had been wet. One field in particular (Halfmoon Road trench) featured *T. occidentalis* as the dominant species (Appendix 5-2), but the area had, in fact, been drained from an adjacent bog by a shallow trench system.

6. Site selection bias for agricultural fields. Since Kouchibouguac National Park had specifically requested that ecosystem archaeology research focus on agricultural lands, a resultant bias towards species associated with richer soils may have resulted. Settlers were advised to select lands believed to be best suited for agriculture and homesteading according to certain tree species associations, such as *Thuja occidentalis* and most hardwood species (Atkinson 1844; Johnston 1851). This site selection bias may assist in explaining the high proportion of *T. occidentalis* charcoal in ecosystem archaeology results. This species requires soils high in calcium (Burns and Honkala 1990), and therefore soils are generally more fertile for agriculture. This possible bias should have been somewhat compensated by having placed trenches in a range of ecosite classes, some of which would feature species associations more typical of poorer soil classes.

7. Low number of study sites. More trenches on all ecosites would have reduced the risk of under-representing some tree species on a particular ecosite, and compensated for any atypical situations.

8. Tree species that grew in localized situations may be under-represented. Forests dominated with *Tsuga canadensis*, for example, may have grown in concentrated areas, or patches across the landscape. Trench sites may have missed such areas, whereas species that were dispersed across the landscape were found in nearly all trench sites.

Causes for other discrepancies may have originated from the witness trees data:

1. Site selection bias of witness trees. Surveyors did not typically survey lots in very wet areas. Large boggy expanses, for example, were not suitable for settlement and therefore did not require surveys. Likewise, this type of physiography did not produce preferred forest types desired for early mill reserves, thus surveys in such areas were fewer. The resultant witness tree record may under-represent frequencies of species from such wet areas, such as *Thuja occidentalis*.

2. Witness tree stem species frequencies were compared to species frequencies from charcoal fragments that are more apt to reflect a *volumetric* measurement. Analysis by stem frequency may produce a bias towards species that grow with the largest number of stems per hectare, such as *Abies balsamea*. This species may have a higher stem frequency without actually contributing high tree volume. For comparisons of species composition on ecosites, the percentage of identifiable charcoal fragments from ecosystem archaeology portrays a more volumetric proportion of the former species present. *A. balsamea*, a tree of small stature, was represented in much lower frequencies in ecosystem archaeology data.

3. Species selection may be biased. Although no surveyor bias was detected towards certain tree species, there were few means of verification beyond those based on documentary evidence (e.g. surveyor notes, instructions, training manual (Monro 1844), and oaths). The wide range of species, including small trees and shrubs, implied that surveyors chose whichever species occurred at the end of their careful measurements. In any case, bias was improbable for such species as *Thuja occidentalis* and *Pinus*, as these species were of generally higher frequencies in ecosystem archaeology results.

Disturbance processes

Knowledge of disturbance processes that produced the pre-colonial forest is essential for understanding how to maintain natural forest conditions today. Natural disturbance processes are believed to be beneficial for maintaining biodiversity and overall health of ecosystems (Pickett and White 1985; Bonnicksen 2000; Parks Canada Agency 2005). Parks Canada approves the management of disturbance regimes, particularly in landscapes where fire has been suppressed (Parks Canada 1994; Parks Canada Agency 2005). One of the inhibiting factors to developing burn prescriptions in national parks in eastern Canada is the dearth of scientifically-based information about natural ecosystem function prior to the over-riding influences of European settlement.

The predominance of late seral forest communities during the 19th century, determined through witness tree and ecosystem archaeology methods, provides evidence useful in elucidating disturbance regimes. Forests comprised of late-successional species that are capable of forming stable, self-replacing complexes, must have had relatively long intervals between high intensity or stand-replacing disturbances, such as fire and hurricanes. *Tsuga canadensis*, *Picea rubens, and Thuja occidentalis* were among the dominant species. They are long-lived species that are capable of self-perpetuation in the shade of their own canopy (Burns and Honkala 1990). They are all highly sensitive to fire due to thin bark, and *Tsuga canadensis* and *P. rubens* have shallow root systems that are vulnerable to fire (Rogers 1978; A. D. Revill Associates 1978; Burns and Honkala 1990). Fire is rare in *Tsuga* dominated forests (Frelich and Lorimer 1991), and has been known to stop at the edges of *P. rubens* forests (Saunders 1979) (likely due to lack of fuels on the forest floor and higher humidity levels). Forest stands dominated by all three species, especially *Thuja occidentalis*, do not burn easily due to high humidity (Little 1946). *Betula alleghaniensis* is another species that does not benefit from frequent disturbance. Similarly, low levels of pioneer species, such as *Populus,* indicate that relatively long interval disturbance regimes were operating prior to European occupation. *Pinus banksiana* was not detected through either research method, indicating that it must have been in minimal abundances *ca*. 1800. Had fires been frequent, it would have surely been encountered, as it is very widespread today.

Witness tree research did not greatly assist in clarifying early disturbance processes apart from the deductions made from species complexes. Only one survey record noted evidence of insect disturbance: larch mortality from larch sawfly occurring during the late 19th century. Surveyor notes provided no evidence of windthrow or flooding, but they confirmed that land clearance fires were common on or near granted lands, and fires were common on boggy expanses (often noted as 'plains' or 'caribou plains'). On several sketches where the limits of forest fires were defined, they were relatively small. This coincides with landscape features which may impede spread of large fires, such as widespread poorly drained terrain, proximity to humid coastal influences, and high landscape fragmentation by bogs and large river systems that act as natural fire breaks.

Ecosystem archaeology detected tree uprooting events, fires, and also insect epidemics and flooding events. Charcoal assemblages provided details on species burned, fire frequencies, and approximate dates of fire (C^{14} dating). Some of the basic conclusions determined by Ponomarenko (2006b) were that:

1. An average fire return interval was ~2900 years for the period from 250 to 9000 years ago. Research on 20th century fire history indicated that the fire cycle was ~210 years (Crossland 1998). This is a much higher fire frequency than was experienced during all other millennia evaluated (250- 9000 year period), and it does not coincide with climatic episodes. Ponomarenko (2006b) determined that fires occurred frequently and at regular intervals, without lengthy breaks during the 20th century, which reflects anthropogenic causes.

2. Prior to European influences, fire intervals alternated between short periods of high fire frequency and very long periods without fire. Periods of low humidity (possibly from drought conditions) coincided with high fire frequencies, but not all dry periods experienced fires.

3. Increase in fire frequency was especially dramatic for the time shortly preceding and coinciding with the land clearance: features of fires (such as increased charcoal layer deposits and synchronous up-rooting events) closely preceding, or coinciding with land clearances were recorded in approximately 20 % of sites.

4. The number of ecosystem archaeology study sites affected simultaneously by pre-agricultural fires varied from one to four for the time period from 250 to 9000 years ago. This indicates that fire events were generally small and did not burn the entire landscape in any single event.

5. The occurrence of semi-coke (charcoal that has burned more than once from successive fires) in many sites indicated that there were at least two periods with frequent fires during the last 9000 years. Semi-coke generally indicates a consequential composition of fire tolerant species, as is observed from modern forests within the study area. The presence of semi-coke renders separation of historical fire events problematic. However, 'morphometric' analysis of semi-coke sampled from the study area was used to delineate several fire events through study of shapes and characteristics of re-burned,

thermally altered charcoal (Ponomarenko and Ponomarenko 2000a; Ponomarenko 2006b).

6. More frequent fires were detected near the coast than in upland sites.

7. Massive uprootings and smaller, individual gap uprooting events were detected through examination of trace fossils and areas of pedoturbation. Massive uprootings were mainly associated with areas that had burned, and trees eventually uprooted. However, some trenches displayed uprootings that were not associated with fire, and appeared to be single-tree events, likely associated with self-thinning or dying off of old-growth trees.

The prevalence of pre-European fire caused by the Mi'kmaq has been debated without support of any direct research to date. The Mi'kmaq were a nomadic, nonhorticultural society, and thus had little cause for purposefully setting woods on fire. Escaped fires from Mi'kmaq activities would have burned mainly near the coast, near summer encampments where they lived off estuarine resources. This coincides with ecosystem archaeology results. Mi'kmaq presence in more inland sites occurred mainly in winter when fires would not spread. Changes in lifestyle brought about by European influences, including increased fur harvesting, loss of fishing resources, and adoption of European customs, may have directly caused them to alter fire ignition patterns and frequencies at the onset of European settlement.

Forest structure was altered through harvesting, land clearance, and escaped clearance fires to produce younger age classes that were more susceptible to intense and frequent wildfire. Fine fuels, extending to the ground made stand-replacement fires more possible. Large piles of logging slash were extremely flammable (Bruncken 1900). Such forests were more able to support more intense fires.

Other research supports the conclusion that there were substantially longer intervals between fires prior to agricultural land clearances. Lorimer (1977), who studied similar mixedwood forests in adjacent Maine, proposed that the pre-European settlement fire interval was approximately 1900 years. This is much longer than that proposed by Wein and Moore (1977) through analysis of fire statistics from 1920-1975. Using the fire information they provided for the present study region (the red spruce-hemlock-pine zone), a fire cycle of approximately 480 years can be derived. Most of the fires occurred during the 1930s and were associated with agricultural land clearance activities. It is, therefore, difficult to transpose their findings to the pre-European condition. Of greater importance, is that the study area landscape receives among the lowest incidence of lightning-caused fire in the Province (Wein and Moore 1977; Patch 1998).

Ecosystem archaeology research detected one insect epidemic in *Picea* between 500-600 years ago in the study area and in PEI (Ponomarenko 2006 b). Ecosystem archaeology has demonstrated the capacity to reveal other types of insect epidemics in other national parks in the Maritimes (Ponomarenko and Ponomarenko 2003; Ponomarenko and Telka 2004). More research is required to make strong conclusions on the types and lengths of insect-caused disturbance cycles in the study area, but this research tends to indicate that insect epidemics may have been infrequent. Furthermore, some aspects of ecosystem archaeology research have not yet been peer-reviewed, thereby reducing confidence in conclusions by some readers.

In summary, both witness tree and ecosystem archaeology methods confirmed that fire disturbance intervals prior to European occupation were very long, as deduced from late seral species compositions. Ecosystem archaeology provided much more powerful evidence that the fire cycle was long, possibly averaging 2900 years prior to the 19th century. The recently increased fire frequency appears to be entirely due to anthropogenic influences. Neither method fully answered questions surrounding the influence or frequency of other types of disturbance regimes beyond the inference that such types of disturbances occurred, but were not frequent or widespread.

Strengths and limitations of each method

Each research approach utilized completely different information sources, and in turn, each brings a unique set of strengths and analytical limitations. Witness tree research was based purely upon documentary information, since very few, if any, of the original witness trees have survived on the landscape in the form of 'real evidence' sources. Ecosystem archaeology employed real evidence sources in the form of macro and trace fossils retrieved from the soil column.

Strengths demonstrated by ecosystem archaeology were:

1. It can provide precise detail on forest species composition in areas where trenches are located. This is especially useful where human impacts have removed all vestiges of former forests.

2. It has a high capacity to detect a wide range of woody species, including understory species.

3. It has the capacity to detect uncommon species and even new species records. On three occasions during research in national parks in the Maritime Provinces, ecosystem archaeology has detected species that had never been recorded. (Species were *Juglans cinerea* L, *Castanea dentata* (Marsh.) Borkh, and white oak group (tentatively *Q. macrocarpa*), found correspondingly in the following national parks: Prince Edward Island, Fundy, and Kouchibouguac.)

4. It provided very confident species identification, since microscopic examination of wood cell structure, preserved in charcoal fragments, and identification of other macrofossils (e.g. seeds or buds), provided verifiable evidence for each species.

5. The temporal perspective from some study sites can be extended to several generations of forest (depending on soil types and disturbance history), and if radiocarbon dating is involved, to several millennia. Therefore, it is able to capture infrequent events and very gradual forest changes.

6. The capacity of ecosystem archaeology to identify various forms of pedoturbation that sometimes leads to inversion of the chronosequence, allows for precise collection of macrofossils that belong to the same sequence. This can result in a considerable reduction in costs for radiocarbon dating.

7. Use of trace fossils allows versatility of research environments. Traditional paleoecology research techniques (such as fossil pollen studies) are more limited and less exact when strata had been disturbed or inverted. Fossil evidence from more than one age may be combined, thereby mixing species assemblages or events, or, producing misleading radiocarbon dates. To avoid mixing of the chronosequence, such research has been traditionally carried out in bogs and lake sediments.

Limitations of ecosystem archaeology research were:

1. Not all of the methods used in ecosystem archaeology (such as use of trace fossils) have been peer-reviewed in scientific journals. Therefore, confidence in conclusions may be reduced until the scientific community scrutinizes the research.

2. Research techniques require a high level of skill and knowledge of soils, paleo-ecology techniques, and the capacity to identify species from fragments of material. The identification and use of trace fossils requires considerable practice to apply with confidence.

3. Differential ashing of each tree species causes under- or over-representation of some species. Additional research to develop correction coefficients for some species may correct this impediment. This difficulty is not unlike problems encountered with fossil pollen studies, where some tree species, e.g. *Pinus*, produce copious amounts of pollen, while other tree species, such as those that rely on insect pollination produce only small amounts that are not widely dispersed. Some species, such as *Populus* and *L. laricina* are under-represented in fossil pollen studies because their pollens decay readily (Pielou 1991).

4. Differential preservation of charcoal can cause species that tend to produce more fragile charcoal fragments to be less proportionately represented than species that produce larger charcoal fragments. Over time, such species may be decreasingly represented in the plough horizon, with mechanical weathering, and in active fields that are repeatedly ploughed.

5. The relatively low number of trenches that were employed can lead to over- or under-representation of tree species that have patchy distributions.

6. Species percentages may be corrected to represent truer proportions by adjusting the sampling of charcoal size distributions. In this research, only the upper quartile of the charcoal size range was analysed. Species that consistently combust to produce very small charcoal fragments may be under-sampled within the size range. Ecosystem archaeology methods are relatively new, and such adjustments will probably be carried out in future research.

Strengths demonstrated by witness tree research were:

1. A wide range of species, including less common ones, can be detected.
2. Skill level required is relatively low, while a large amount of forest compositional information can be retrieved for research effort.
3. Research costs relatively little compared to other methods.
4. A wide range of ecological relationships may be elucidated through spatial analyses, including physiographic and moisture gradient relationships research, and impacts of pre-colonial disturbances, such as First Nation settlements (Black and Abrams 2001).

Limitations of witness tree research were:

1. The witness tree record is entirely dependent on surviving archival survey documents. Sufficient historical information was preserved in this study, whereas surviving information may be lacking in other regions.
2. Metes and bounds surveys, prevalent in eastern NB, offer less information per survey sketch than rectangular surveys that are prevalent in areas settled by townships. Hence, the method of survey greatly influences the amount of effort required to compile a sufficient number of witness trees, with metes and bounds surveys being the most challenging.
3. The locational bias present in metes and bounds surveys resulted in larger samples of witness trees being located on well-drained land classes, mainly within riparian zones, rather than in poorly-drained areas unsuitable for settlement, such as bogs.
4. Forest composition derived from witness tree research can only be applied to a landscape context. Witness trees are spaced too far apart to provide species composition at the stand level.
5. The witness tree record was limited to the taxonomical knowledge of the 19th century, and there is no opportunity to examine wood samples to verify proper taxonomic assignments. For example, *Picea rubens* was not recognized during this period as a separate species from *P. mariana*.
6. Surveyors did not always identify witness trees to the species level and so analysis must be carried out on tree genera. This limits conclusions, since some species within the same genus feature widely different silvics, and predominate at different seral stages. For example, the three species of *Pinus* were not identified consistently to species.

7. Surveyors may have misidentified some species. Also, an unusual or uncommon species may have gone unrecorded, and been identified as another species with similar characteristics.

8. Witness trees are limited to the brief temporal period of survey.

On a final note, other research approaches on early forest complexes have been less useful than the two methods investigated in this paper, in answering questions on forest characteristics just prior to European settlement. Available palynological research for the study area (Warner, *et al.* 1991; Robichaud 2000) provides valuable information on the development of local forests over thousands of years, but does not provide precise details on forests *ca.* 1800. Furthermore, all research was completed on the Point Escuminac bog (within the northern sector of the study area). This bog covers a vast, wet open terrain, and limits conclusions about forests on other land types.

CONCLUSIONS

Eastern New Brunswick forests located within and adjacent to KNP were composed predominantly of late seral complexes *ca.* 1800. These broad conclusions were reinforced through critical comparisons of two separate historic ecology research approaches. *Picea, Tsuga canadensis, Betula, Acer, Abies balsamea,* and *Pinus strobus* comprised 70-80 % of 19th century forests in the region according to analyses of both witness tree and ecosystem archaeology data. *Fagus grandifolia* grew across much of the region with relatively high frequencies (5-7 %). *Pinus banksiana*, a currently dominant tree species in the region, was not detected in 19th century forests through either approach. Hence, the species was probably present at only low levels, most likely in very localized areas. Likewise, other early-successional taxa, such as *Populus* spp., were nearly absent. Both research approaches detected a wide variety of species, including less common taxa such as *Ostrya virginiana,* and *Ulmus americana.* Levels of *Thuja occidentalis* were high, but ecosystem archaeology results indicated that its frequency may have been as high as 13 %. Since ecosystem archaeology study locations were in old fields, the former levels of cedar in rich upland situations may have been much higher than in similar modern situations.

Ecosystem archaeology revealed some detail that was unattainable through witness tree research. For example, *Pinus strobus* was determined to be the dominant pine species in 19th century forests. Witness tree analysis was limited to the level of *Pinus*. Ecosystem archaeology provided additional proof that much of the forest may have been in mature or old-growth stages *ca.* 1800. For example, *Taxus canadensis* was a widespread understory shrub (4.5 % frequency of all species detected).

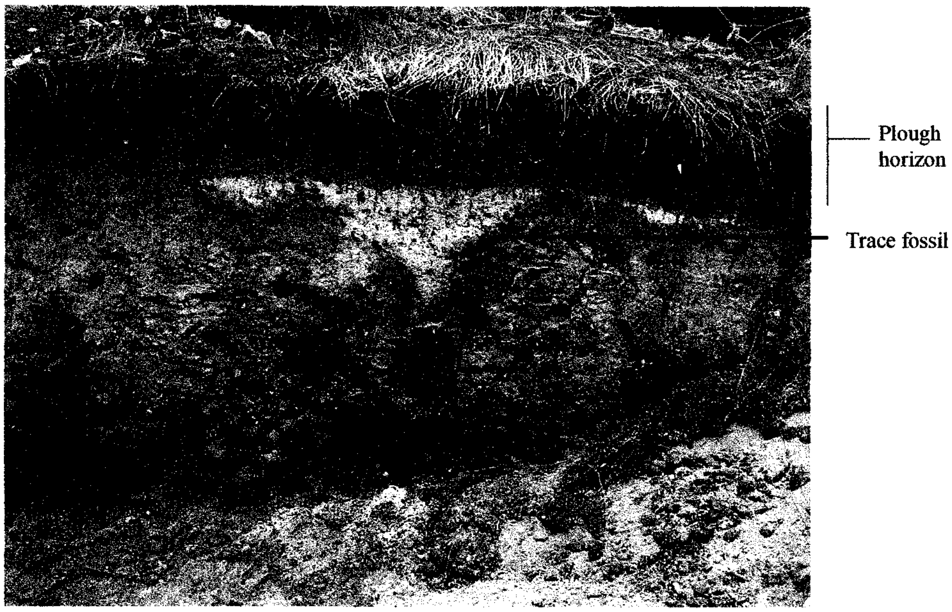
An inconsistency exists between the order of dominance for *Thuja occidentalis* and *Tsuga canadensis* determined through the two approaches. Ecosystem archaeology gave noticeably higher estimates of abundances for *Thuja occidentalis* and lower abundances for *Tsuga canadensis* than indicated from witness trees.

Combining and comparing results of witness tree and ecosystem archaeology methods compensated for analytical limitations encountered in either method individually. Witness tree data provided conclusions on tree species frequencies across the landscape, but trees were too far apart to allow conclusions about forest stand compositions. Ecosystem archaeology data provided information on tree species composition at the stand level, thereby confirming that the scattered trees identified through witness tree analysis were indeed growing together in stand situations. Together, the two research approaches deliver the most valuable proxy determined thus far of 19th century tree populations.

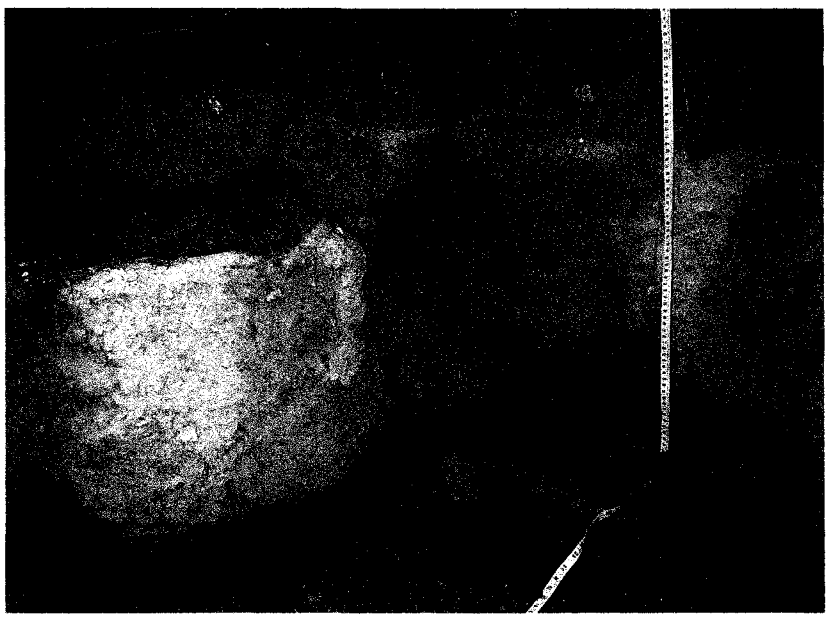
Ecosystem archaeology results indicated that the pre-European fire regime was very long, perhaps operating on a 2900 cycle. Given this result, plus evidence from both approaches that indicate late seral species dominated forests and fire dependent species were at minimal levels *ca.* 1800, it is recommended that managers at KNP do not attempt to maintain current abundances of *P. banksiana* and other early seral species.

Table 5.1 Number of witness trees, trench sites and approximate number of macrofossil fragments per ecosite class.

	Witness Trees	Ecosystem Archaeology	
	(N)	No. field sites	Approx. No. Fragments
Ecosite 1	405	9	310
Ecosite 2	1246	10	360
Ecosite 3	516	7	230
Ecosite 5	272	10	420
Total	**2439**	**36**	**1320**



a.



b.

Figure 5.1 Photos of Ecosystem Archaeology trenches that display trace fossils. Note the discernable plough horizon in each photo. Photo b shows measurement of a tree tap root trace fossil.

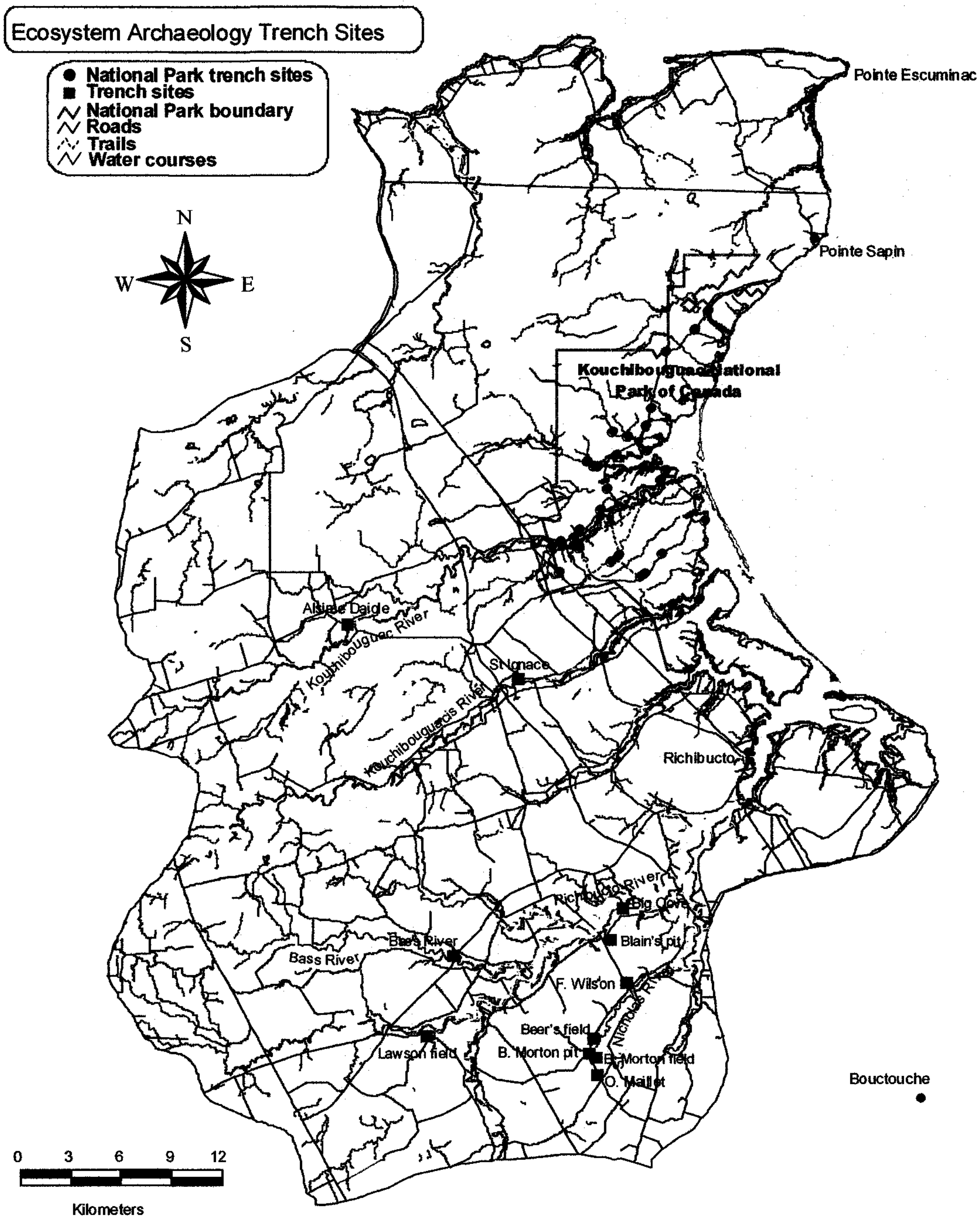
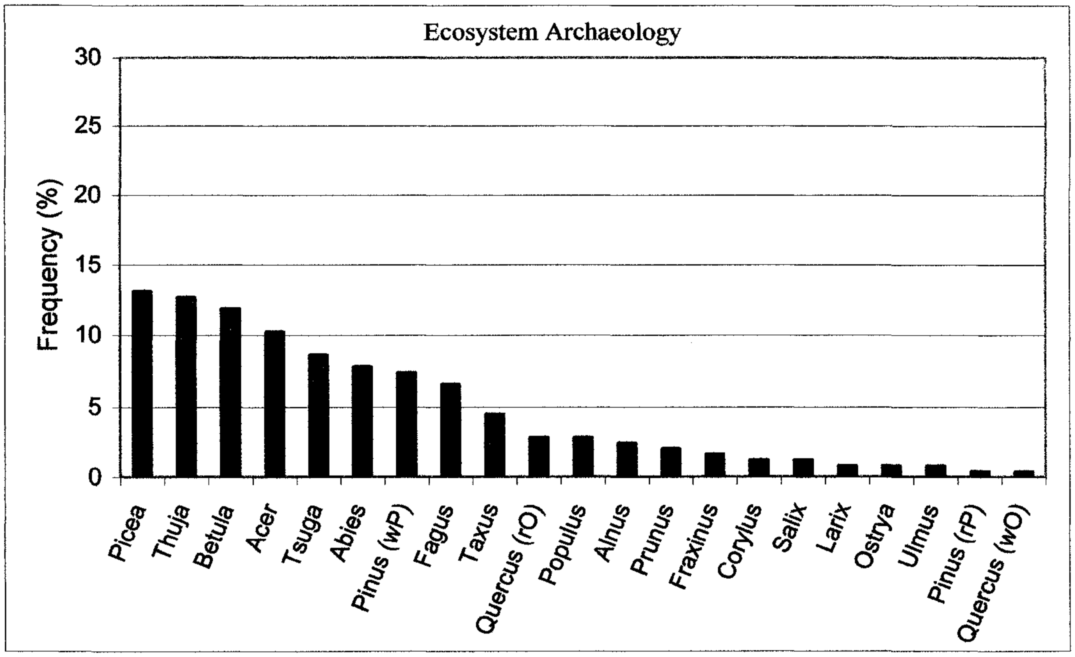
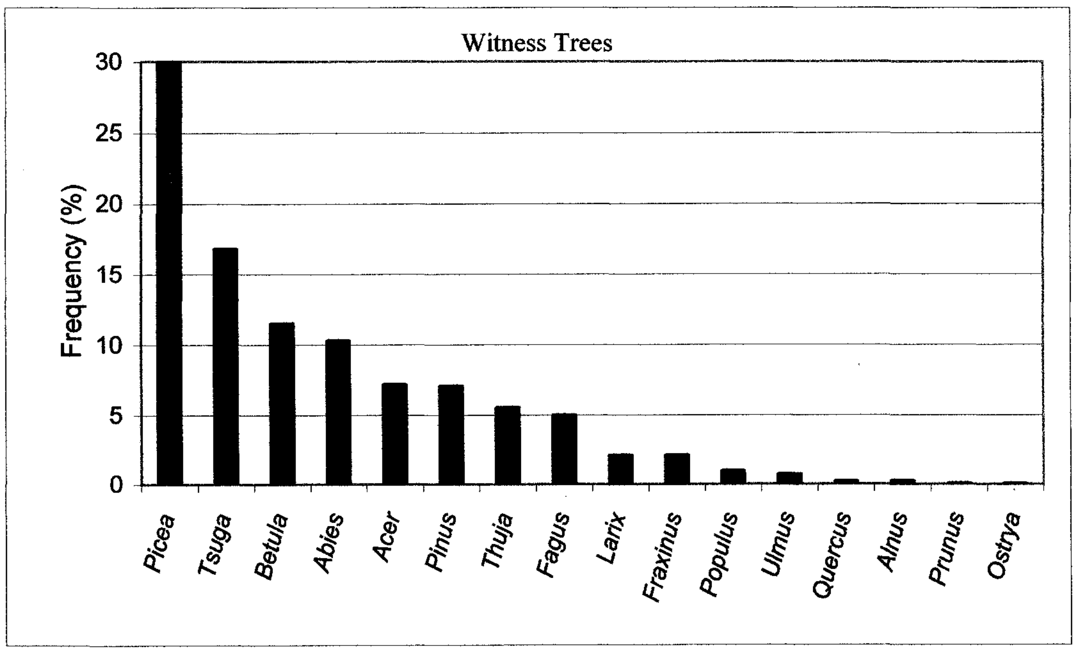


Figure 5.2 Location of Ecosystem Archaeology trench sites located on the New Brunswick Eastern Lowlands, including Kouchibouguac National Park.

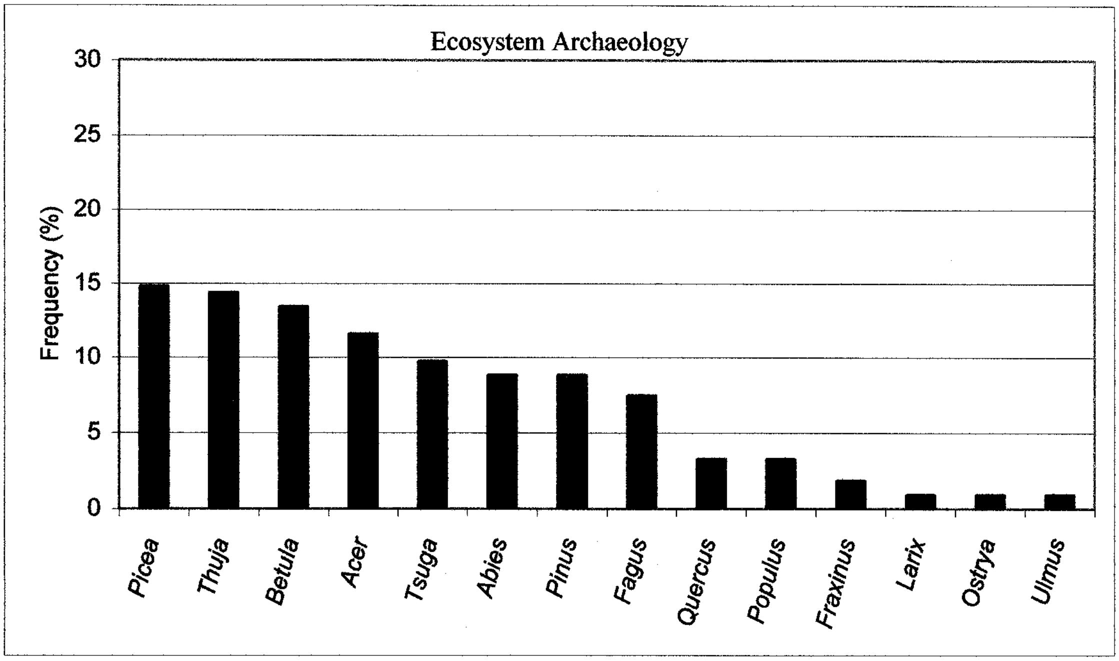


a.

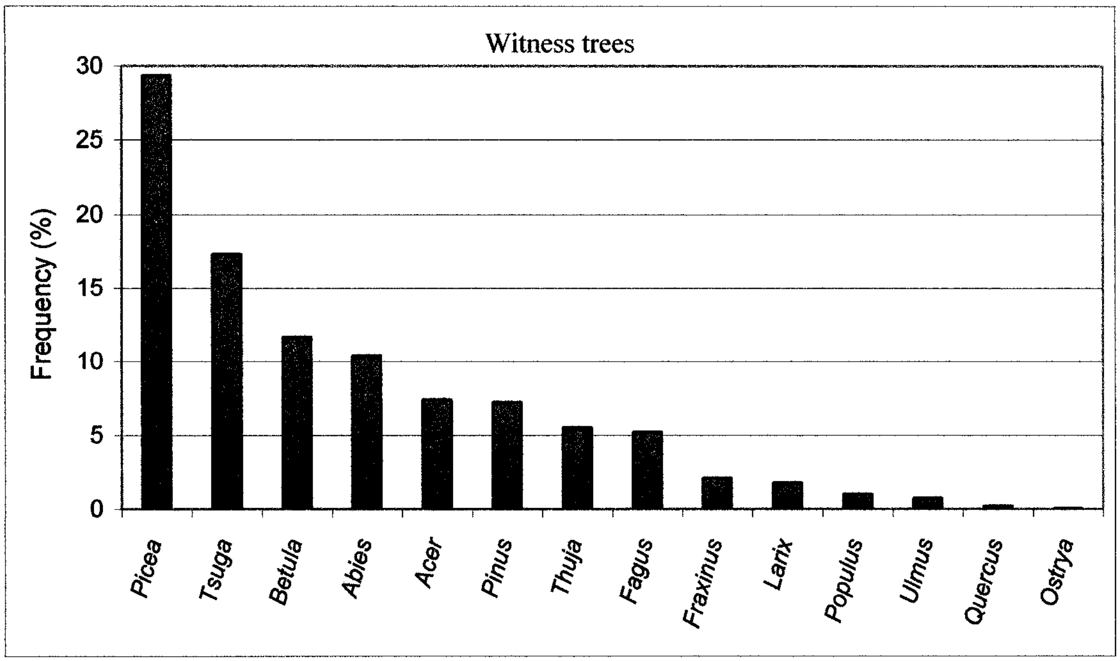


b.

Figure 5.3 Frequency of all genera *ca.* 1800 detected within the New Brunswick Eastern Lowlands Ecoregion according to: (a) Ecosystem Archaeology research, using macrofossil evidence of species occurrences (N=244); (b) witness tree research (N=2537).



a.



b.

Figure 5.4 Frequency of tree species (only) *ca.* 1800 within the New Brunswick Eastern Lowlands Ecoregion according to: (a) Ecosystem Archaeology research, using macrofossil evidence of species occurrences (N=216); (b) witness tree research, excluding trees on boggy sites (N=2430).

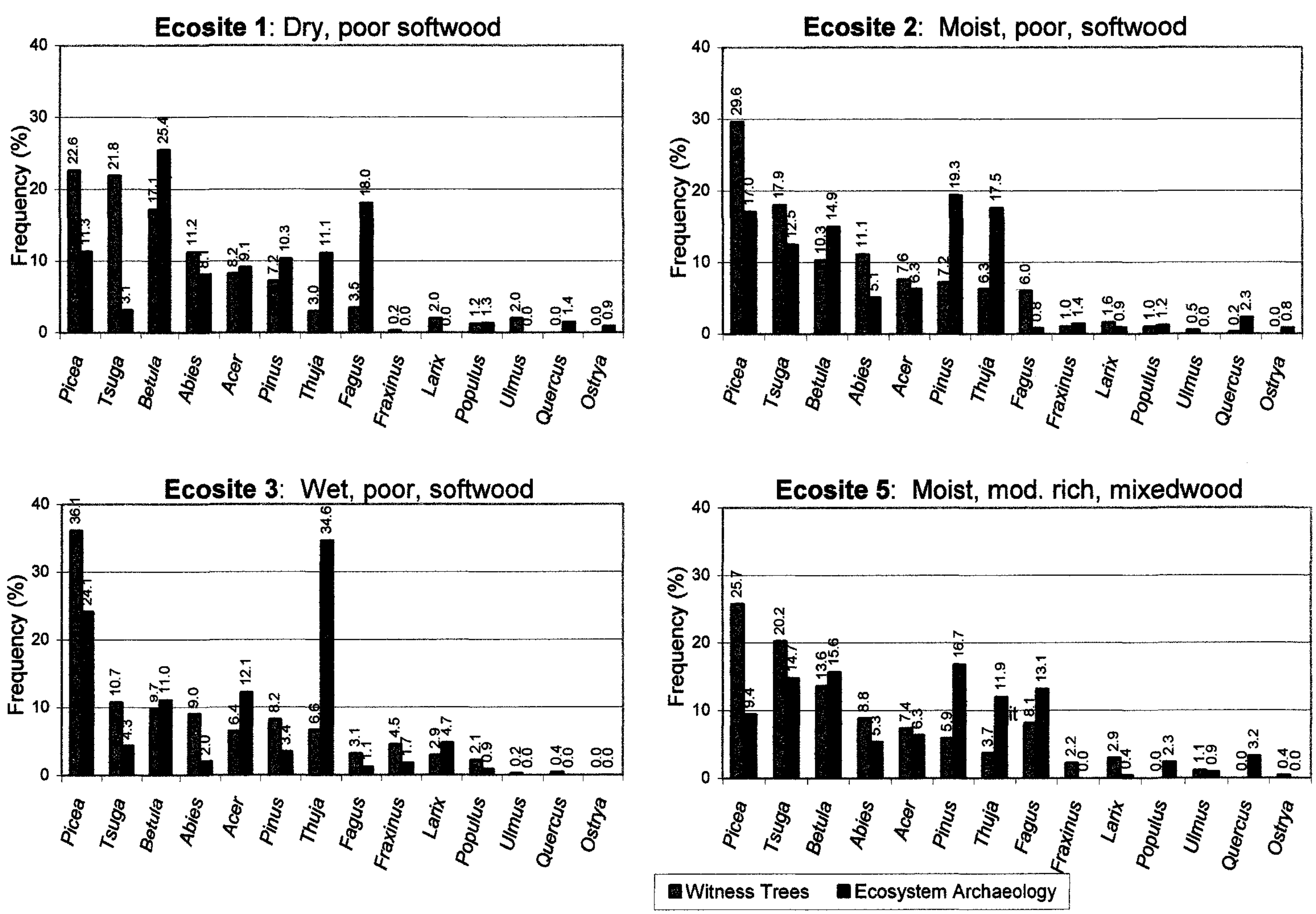


Figure 5.5 Comparison between witness tree and ecosystem archaeology data, each portraying percent tree species composition *ca.* 1800 over ecosite classes. Witness trees (frequency of stems), Ecosystem archaeology (frequency of charcoal fragments). Ecosites adopted from Ecological Land Classification (DNRE 1996). (Sample sizes as in Table 5.1.)

REFERENCES

A. D. Revill Associates. 1978. Ecological effects of fire and its management in Canada's national parks: a synthesis of the literature. Vols. 1and 2. Lit. Rev. & Annot. Bibliography. Ottawa, ON: Parks Canada, National Parks Branch, Natural Resources Division, 345 pp.

Alexander, J.E. 1849. L'Acadie, or, Seven years' explorations in British North America. London, H. Colburn, 370 pp.

Atkinson, C. (Rev.) 1844. Historical and statistical account of New-Brunswick, B.N.A. Anderson and Bryce, Edenburgh, Scotland. 284 pp.

Barefoot, A.C. and Hankins, F.W. 1982. Identification of Modern and Tertiary Woods. Clarendon Press, Oxford, UK. 189 pp.

Bergeron, Y. 2000. Species and stand dynamics in the mixed woods of Quebec's southern boreal forest. Ecology, 81 (6): 1500-1516.

Black, B.A. and Abrams, M.D. 2001. Influences of Native Americans and surveyor biases on metes and bounds witness-tree distribution, Ecology 82(9): 2574-2586.

Bonnicksen, T.H. 2000. America's ancient forests. John Wiley & Sons, Inc. NY. 594 pp.

Bouchette, J. 1831. Topographical and statistical description of the provinces of Lower and Upper Canada, New Brunswick, Nova Scotia, the Islands of Newfoundland, Prince Edward, and Cape Breton. London, Colburn and Bentley, 289 pp.

Bruncken, E. 1900. North American forests and forestry. G.P. Putnam's Sons, NY. 265 pp.

Burns, R. M., and Honkala, B. H., tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 pp.

Butterfield B.G. and Meylan, B.A. 1980. Three-dimensional structure of wood. An ultrastructural approach. London, UK; NY. 103 pp.

Crossland, D. 1998. Recent fire history of Kouchibouguac National Park. Parks Canada-Technical Reports in Ecosystem Science #013, Cat No. R61-2/19-13/1997E, 41pp.

DNR 2004. N.B. forest development survey field manual for Y-O merchantable forest stands. Forest Management Branch, Department of Natural Resources, Fredericton, NB. 102 pp.

DNRE. 1996. An ecological land classification system of New Brunswick. Ecosystem Classification Working Group, New Brunswick Department of Natural Resources and Energy, Fredericton, NB.

Fish, W.E. 1880. Orders of survey. Deputy Fish's report in answer to orders of survey issued in relation to hemlock bark lands. In: Journals of the House of Assembly of the province of New Brunswick, Fourth Session of the 24th General Assembly,1882, Supplementary Appendix, Fredericton, NB. 31-32 pp.

Fowler, J. 1873. Unpublished correspondence to a colleague. Source: Buffalo Museum of Science, Buffalo NY.

Fowler, J. 1878. List of New Brunswick plants. Report for the Secretary of Agriculture, Appendix B., Fredericton, NB. p. 35-63.

Frelich, L.E. and Lorimer, C.G. 1991. Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes region. Ecol. Monographs 61, 145-164.

Hosie, R.C. 1990. Native trees of Canada. Fitzhenry and Whiteside Ltd., Ont. 380 pp.

Johnston, J.F.W. 1851. Notes on North America. Vol. I and II., C.C. Little and J. Brown, Boston, 512 pp.

Kinnear, A. 1785. Letter to Edward Winslow, April 21st 1785. In: Winslow Papers, A.D. 1776-1826. Raymond, W.O. (Ed.) 1901. New Brunswick Historical Society, The Sun Printing Co. Ltd. St John, NB. p. 298-299.

Little, S. 1946. The effects of forest fires on the stand history of New Jersey's Pine Region. Forest Management Paper No. 2. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 43 pp.

Lorimer, C.G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology 58: 139-148.

Loucks, O.L. 1962. A Forest Classification for the Maritime Provinces. Proceedings of the Nova Scotian Institute of Science. vol. 25, part 2, p. 85-167.

Mayle, F.E. and Cwynar, L.C. 1995. Impact of the younger Dryas cooling event upon lowland vegetation of Maritime Canada. Ecol. Monographs, 65 (2): 129-154.

Monro, A. 1844. A treatise on theoretical and practical land surveying; adapted particularly to the purposes of wood-land surveys. Geldert& Patterson, Eastern Chronicle office, Pictou, NS. 181pp.

Monro, A. 1855. New Brunswick; with a brief outline of Nova Scotia and Prince Edward Island. Their history, civil divisions, geography, and productions. Richard Nugent, Halifax, NS. 384 pp.

PANB (Provincial Archives of New Brunswick) 1808. F16303, Land grants, Vol. D,. No. 468.

Panshin, A.J., and de Zeeuw, C. 1980. Textbook of wood technology: structure, identification, properties, and uses of commercial woods of the United States and Canada. McGraw-Hill, NY.

Parks Canada. 1994. Guiding principles and operational policies. Canadian Heritage Publ.,Cat. No. R62-275/1994E. 125 pp.

Parks Canada Agency. 2005. National fire management strategy-Parks Canada Agency. Ottawa, ON. 9 pp.

Patch, J. 1998. Analysis of lightning fire frequency by ecodistrict. Unpub. report to NBDNRE, Island View, NB.

Pickett, S.T.A. and White, P.S. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, Inc. Toronto, ON. 472 pp.

Pielou, E.C. 1991. After the Ice Age. The University of Chicago Press, Chicago, 366 pp.

Ponomarenko, E. 2004. Reconstruction of pre-agricultural forest vegetation pattern in Prince Edward Island National Park: Dalvay section. Report on file with Parks Canada

Ponomarenko, E. 2006 a. Reconstruction of pre-agricultural forest vegetation pattern in Prince Edward Island National Park: Data synthesis. Unpub. report to Parks Canada, PEI, 67 pp.

Ponomarenko, E. 2006 b. Reconstruction of ecosystem dynamics and natural disturbance history in Kouchibouguac National Park. Report in preparation.

Ponomarenko, E. and Ponomarenko, S. 2000a. Morphometric analysis of charcoal assemblages in soil: an approach to reconstruct fire history (case study of Kouchibouguac National Park). Unpub. report to Parks Canada, Kouchibouguac National Park, 40 pp.

Ponomarenko, E. and Ponomarenko, S. 2000b. Reconstruction of pre-agricultural vegetation pattern in Kouchibouguac National Park using the ecosystem archaeology method. Preliminary study. Unpub. report to Parks Canada, Kouchibouguac National Park, 26 pp.

Ponomarenko, E., and Ponomarenko, S. 2003. Reconstruction of ecosystem dynamics and natural disturbance history in Fundy National Park. Report on file with Parks Canada.

Ponomarenko, E. and Telka, A. 2004. Paleoentomological investigation of forest insect influences on older growth eastern hemlock in Kejimkujik National Park and National Historic Site. Unpub. report to Parks Canada, Kejimkujik National Park, 28 pp.

Robichaud, A. 2000. Étude paléoécologique de la végétation ligneuse de la tourbiere de Pointe-Escuminac, Nouveau-Brunswick. PhD Thesis, Geography Dept., Université Laval, Qué. 218pp.

Rogers, R.S. 1978. Forests dominated by hemlock (*Tsuga canadensis*): distribution as related to site and postsettlement history. Canadian J. of Botany. 56: 843-854.

Saunders, P.R. 1979. The vegetational impact of human disturbance on the spurce-fir forests of the southern Appalachian Mountains. Dissertation. Durham, NC: Duke University, 188 pp.

Warner, B.G., Tolonen, K., and Tolonen, M. 1991. A postglacial history of vegetation and bog formation at Point Escuminac, New Brunswick. Can. J. Earth Sci. 28: 1572-1582.

Wein, R.W. 1978. Historic and prehistoric role of fire in the Maritime national Parks. Unpub. report to Parks Canada, 45 pp.

Wein, R.W. and Moore, J.M. 1977. Fire history and rotations in New Brunswick Acadian Forest. Can. J. For. Res. 7: 285-294.

Zink, M. 1998. Flora of Nova Scotia. Vols. 1 and 2, NS Museum and Nimbus Publ., Halifax, NS. 1297 pp.

CHAPTER 6. SYNTHESIS

Defining a forest reference condition is a critical step to formulating scientifically objective, long-term goals for a 'natural' forest management approach. In the context of the current study, the forest reference condition provides a framework for setting appropriate vegetation management objectives for species composition, structure (tree sizes, ages, density, and spacing), and associated disturbance regimes (e.g., agents, size, frequency, and intensity of disturbance events).

Forests of the Eastern Lowlands ecoregion of New Brunswick, specifically growing within the watersheds of Bay du Vin, Kouchibouguac, Kouchibouguacis, and the Richibucto have been significantly transformed during approximately 200 years of European occupation. Parks Canada's guiding principles and policies require that ecosystems be managed to maintain or restore characteristic biodiversity within ranges of natural variability (Parks Canada 1994). An essential prerequisite to meeting policy requirements is the ability to distinguish between European-modified forests and those that are natural. Resource managers at Kouchibouguac National Park (KNP) sought direction on whether extensive stands of jack pine (*Pinus banksiana*) and other disturbance dependent species that currently dominate some areas should be maintained, or whether long-term goals should allow such forest types to be succeeded by mid- to late-successional species. Loucks (1962) surmised that, "*prior to the repeated burnings, red spruce, hemlock, and white pine were probably more abundant*". This species complex requires much longer disturbance-free intervals than forests dominated by jack pine and aspen (*Populus* spp.). Resource managers at KNP chose to use historical reconstruction of forests to generate a reference condition as a context for evaluating present forest conditions.

Four retrospective approaches were used to define a forest reference condition for the study area: 1) historical descriptions from early documents; 2) witness tree information that provided quantitative evidence on species frequencies; 3) square timber harvest records that provided quantitative evidence for the volume of large white pine within riparian zones, and to a limited extent, the volumes and distributions of large, healthy yellow birch (*Betula alleghaniensis*) and red pine (*Pinus resinosa*); and 4) ecosystem archaeology that relied primarily on macrofossil evidence, mainly identifiable charcoal fragments preserved in the soil, to reconstruct pre-agricultural forest characteristics and disturbance regime (Ponomarenko 2006). The integration of four research approaches provided a more comprehensive retrospective understanding of pre-European settlement forests than any one method alone.

The forest reference condition defined according to four historical ecology information sources

Forest composition

Forests of the region were a diverse, patchy mosaic of species complexes, consisting largely of shade-tolerant coniferous trees in late-successional associations. Species that comprised approximately 70-80 % of 19th century forests were spruce (*Picea* spp.), eastern hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), yellow birch, cedar (*Thuja occidentalis*), maple (*Acer* spp.), and balsam fir (*Abies balsamea*). These species were key dominants across a wide range of site conditions. The region supported 26 tree species, including at least one species that is no longer present, a member of the white oak group, most probably bur oak (*Quercus macrocarpa*). Shrubs were excluded from the total count, such as willow (*Salix* spp.) and cherry (*Prunus* spp.). Hardwood species collectively comprised only approximately 24 % of general forest composition, and were dominated by birch-maple-beech (*Betula* spp., *Acer* spp., *Fagus grandifolia*). Large old-growth eastern hemlock predominated over extensive areas (Gubbins 1813 *In*: Temperly 1980; Johnston 1851; Fowler 1873). A great tract of ancient hemlock, mixed with minor components of white pine, birch (deduced to have been yellow birch) and beech extended over a 32-40 km east-west band within the Richibucto watershed (Johnston 1851). Beech was a relatively important hardwood component, generally constituting approximately 5-7 % of forest composition, though it is uncommon today.

Forests were dissected by numerous rivers, streams and areas having poor drainage. Wet organic soils without forest cover constituted up to 6 % of the landscape. The drainage patterns resulted in strips of alternating coniferous and deciduous forest or mixed forest types covering the area, with coniferous forest dominating. Some general conclusions about species dominance over certain site conditions (ecosite classes) were possible despite complex micro-drainage patterns and some variations between research results from witness tree (frequency of stems) and ecosystem archaeology (frequency of charcoal fragments). Hemlock thrived on all site types except very wet organic soils. On ridges and other areas having better drainage, historical descriptions and ecosystem archaeology results indicated that hardwood-dominated forests of birch and beech developed, with lower frequencies of spruce, maple, white pine, hemlock, balsam fir, and cedar. Witness tree research, however, maintained that spruce and hemlock were the most frequent species on dry sites, with birch and beech occupying 3rd and 8^{th} place, respectively. Where birch was identified growing with beech, it was concluded to have been yellow birch, although only square timber records provided direct evidence that yellow birch was the most common birch species of early forests. In addition, it is known that yellow birch forms a 'stable' complex with late seral species, such as hemlock and beech, and is more shade tolerant than other birch species (Burns and Honkala 1990; Woods 2000).

Mesic sites supported forests dominated by spruce, white pine, and hemlock, with varying frequencies of cedar, yellow birch, balsam fir, maple, and beech. White pine was relatively frequent on dry sites (approximately 7-10 % according to frequencies of both witness tree stems and charcoal fragments), and it was possibly more frequent in mesic conditions, ranging from 17-19 % according to frequency of charcoal fragments. Frequencies of cedar on both mesic and dry sites were relatively high, though it is mainly encountered in swamps today. Cedar frequencies on mesic sites according to ecosystem archaeology research were 12 – 18 %, though witness trees indicated frequencies of 4 - 6 %. On dry sites under less optimal conditions, it may have achieved 3 % frequency (witness tree results) or perhaps much higher according to ecosystem archaeology research. Wet, poorly drained areas supported the least diverse forests, dominated by black spruce (*P. mariana*), cedar, red maple (*Acer rubrum*), birch, hemlock, and balsam fir. Black spruce and larch (*Larix laricina*) formed the edaphic climax on boggy sites, with components of balsam fir, cedar, birch, pine, and red maple. Cedar swamps were common, and there were occasional black ash (*Fraxinus nigra*) swamps, according to surveyor descriptions. Black ash stem frequency ranged from 3-5 % on wet sites with black spruce and cedar.

Early-successional or shade-intolerant species were mainly found in bogs, coastal and riparian zones. Red pine, larch, poplar, and red oak (*Quercus rubra*) occurred in low frequencies, representing 1-3 % of forest composition. The near absence of jack pine in the historical record was in striking contrast to its current abundances in modern forests in the area. So limited was its former distribution, that it was confirmed from only one historical description of the study area.

Riparian forests were diverse and featured some notable differences from inland forests. Elm trees (*Ulmus americana*) added to the species richness, though the species occurred at low frequencies, at approximately 2 % of riparian forests. Frequencies of hemlock and white pine were approximately 6 and 7 % higher, respectively, within riparian zones, than in inland forests, while beech was approximately 6 % less frequent within riparian zones than elsewhere.

Forest structure

Forests at the beginning of the 19th century were comprised of a mosaic of uneven-aged, mature to old growth, late-successional stand types. Forest structure varied with species composition and stand age, but trees were often very tall with large diameters. Local historical references, particularly regarding eastern hemlock and white pine, provided descriptions of enormous tree sizes and advanced age classes. In the Richibucto watershed, forests were dominated by "*huge hemlocks of the forest primeval*" (Fowler 1873), comprised of "*many magnificent stems*" of "*ancient*" growth (Johnston 1851). Hemlock was recorded to reach 18-24 m (Perley 1847; 1863), and to sometimes grow "*as large as pine*" (Cooney 1832). Hemlock of such large growth inspired nearly as many 19th century comments as did white pine, though it was far less valuable economically.

White pine towered above the forest canopy, frequently acquiring 49 m in height (Perley 1847; Monro 1855). Large, tall, straight, blemish-free white pine trees were sufficiently abundant in the study area to support harvesting more than 3000 masts and spars between 1825-1840 (J. of the Legislative Council of NB 1847; Fisher 1980). An estimated total of 608,433 m^3 of white pine was harvested as square timber within four watersheds of the study area during 1820-1839. The structure of white pine suitable to meet square timber industry requirements allowed only top quality trees, with minimum dimensions of at least 48 cm top diameter (below live crown) and at least 4.9 m long clear bole. Square timbers measuring over 51 cm per side (requiring a 72 cm top diameter without bark) were commonly cut in NB (Parenteau 1994).

Beech, yellow birch, red and sugar maples (*Acer saccharum*) also grew to large sizes in the area (Perley 1842). Yellow birch grew scattered throughout the forest, as tall (18-21 m (Perley 1847)), straight, healthy, large diameter trees, suitable to meet the stringent standards of the square timber market (minimum 30.5 cm^2 and 3.7 m long, and blemish-free) (Govt. NB 1816; 1831). Trees were described as smaller, occasionally referred to as 'scrubby', along the coast and in boggy areas. Smaller trees were most likely associated with poor drainage, sterile soils, or more frequent disturbance. Trees became larger and more widely spaced farther inland.

Many indirect indicators support conclusions that forests were comprised of large, mature to old-growth trees. Constant shade and high humidity from a nearly continuous distribution of tall, large diameter trees caused some lament from early recorders who toiled on the forest floor, far below the canopy. Large fallen logs obstructed travel more often than a subcanopy or shrub layer (Alexander 1849). Large tree structures resulted in some applications unheard of today. Large, water-filled depressions caused by uprooting of giant trees, termed 'forest wells' were selected as campsites by a survey team. Deep square holes were cut in fallen logs to wash clothes (Alexander 1849).

Caribou (*Rangifer tarandus* L.) were common (Alexander 1849; Monro 1855), and old-growth forest structure supported suitable growth conditions for slow-growing arboreal lichens, an important part of the caribou diet (Smith 1857; Adams 1873; Chapman and Feldmar 1982; Gray 1999).

Composition of understory shrub taxa also indicated the shade that would be provided by mature to old growth structure. Canada yew (*Taxus canadensis*), a characteristic shrub of cool damp woods and climax coniferous forests (Zink 1998), was widely distributed, and in relatively high percentages in the charcoal record. Moose maple (*Acer pensylvanicum*) was a common understory tree in 19th century forests, and prefers cool, moist soils in the shade of mature forest (Hosie 1990).

Disturbance regime

Periodic, small-scale disturbance events, or gap dynamics, predominated in forests prior to European settlement. High frequencies of late-successional species, of large dimensions, indicate that large-scale disturbances must have occurred infrequently and at very long intervals. Large scattered logs, (i.e. coarse woody debris), recorded by Alexander (1849), were another indicator of gap dynamics (Runkle 1991; Kneeshaw and Burton 1998). Single-tree uprootings were recorded in the soil profile, as well as larger synchronous uprooting events. Forests may have featured similar understory and canopy tree compositions (according to comparisons between stake and witness tree species compositions), a sign of relatively stable, self-replacing species complexes (Foster *et al.* 1996). Late-seral forests, comprised of red spruce, hemlock, sugar maple, and beech can self-replace indefinitely, growing under the shade of their own canopies (Burns and Honkala 1990), and so it is possible that dominant 19th century forest types persisted hundreds or even thousands of years without large-scale stand-replacement events.

Insects or pathogens were detected at the time of early European settlement, sometimes causing tree mortality that resulted in small gaps, and occasionally causing larger stand-replacement events in the case of the hemlock and larch die-off events. Mortality of spruce from insect infestations was detected in the literature and from ecosystem archaeology research (Ponomarenko 2006). Forests along the coast were probably subjected more frequently to disturbances from agents such as wind, salt spray, and flooding. Fire frequency was higher near the coast (Ponomarenko 2006).

Fire *absence* was essential to the dominant species composition and structure present on the landscape. Eastern hemlock, spruce and beech are very fire sensitive (Graham 1941; 1943; Rogers 1978; A. D. Revill Associates 1978; Burns and Honkala 1990), and forests comprised of these species did not support large stand-replacement fires in the years leading to European settlement. The average fire return interval was approximately 2900 years from 250 to 9000 years ago (Ponomarenko 2006). Furthermore, fires did not burn over large areas at a time. The very nature of the landscape, itself, probably impeded the capacity of fires to burn large tracts. Rivers and bogs have acted as natural fire breaks (Crossland 1998), and winds generally push fires northeast towards the ocean. Rapidly alternating edaphic conditions result in patchy distributions of fuels associated with changing stand types.

Low frequencies of shade-intolerant species may have perpetuated themselves by either small-scale disturbances, or by surviving under adverse edaphic conditions, such as on boggy sites, sterile soils, and coastal areas.

Forest change

Contemporary forests have become less diverse than those 200 years ago and are dominated by short-lived, early-successional tree species instead of long-lived, late seral species. Six dominant tree species comprise 95 % of contemporary forests, whereas there were formerly nine species *ca.* 1800. Late-successional, former dominants, such as eastern hemlock and beech, have dropped to remnant levels (approximately 1 % and 0.1 % basal area, respectively). White pine has been replaced by jack pine, which has become a dominant species. Balsam fir has increased from fourth place (stem frequency) to second place (percent volume). Poplar species rose from very low levels to become a dominant hardwood species over much of the landscape (fourth most common species according to basal area). Cedar, once commonly encountered on the landscape, has now dropped to approximately 3 % (basal area) in regional forests (DNR 2004). The most valuable or richest forest types, such as those located within riparian zones, have been most extensively cleared. Forest cover has decreased by approximately 40 % in riparian zones.

Fire from anthropogenic causes was very common everywhere in the post-European settlement forest, and it was the dominant force behind forest change. The fire cycle was shortened to approximately 210 years for lands situated in Kouchibouguac National Park, with all fires stemming from anthropogenic ignitions (Crossland 1998). Recovery is slow, as intense or very frequent fires, (in some places recurring every two years), have reduced soil fertility. Extremely rapid destruction of red spruce-hemlock forest types has occurred in response to increased fire frequency, along with intensive harvesting, and land clearance activities. Fire-adapted species, such as jack pine and aspen, rose from extremely low levels to become dominant species. Accidental pathogen and insect introductions have greatly contributed to the demise of two of our most stately hardwood species, beech and elm. Large stems have been eliminated.

Strengths and weaknesses of methods

Each of the four research approaches was associated with unique advantages as well as some limitations. The shortfalls or information gaps from one approach were compensated by using information divulged from the other three information sources.

Historical descriptions confirmed general vegetation patterns, tree species associations, and less common forest stands, such as black ash swamps. Such descriptions also revealed details of forest structure, not otherwise 'visualized' through other information sources. References to dark, gloomy forests, and trees hanging with lichens provided a much clearer ecological picture than would have otherwise been gained had only species composition, diameter, and height measurements been examined. Knowing that a forest stand was composed of eastern hemlock is useful, but learning that there were uprooted tree structures sufficiently large to create water-filled depressions for drinking and campsites is ecologically important, as these structural features are no longer present. The drawback of using historical descriptions is that only a small number of them apply directly to the study area, and the search was time consuming. Descriptions were subjective, and most documents described forests in very general terms. Accuracy and reliability of information varied.

Witness tree research provided valuable quantitative evidence on species composition, but cannot fully substitute for an early forest inventory. Trees were often not identified to the species level. There was no direct evidence of forest structure. The application of this technique relies on surviving survey records, which may be insufficient for some areas. Witness tree investigations of early New Brunswick forests can be more labour intensive than in other parts of North America because lands were surveyed mainly using metes and bounds techniques that tend to record only one or two witness trees per sketch. Therefore, many survey sketches are required to produce a sufficient witness tree database for analysis.

Square timber analysis was limited to examination of the most perfect, large white pine trees that were harvested over a period of roughly 50 years. This was the only method that enabled volume estimates and relative distributions of large, disease-free white pine. Yellow birch and red pine square timber harvest records also provided information on their volumes and distributions. Structural characteristics were measurable to a limited extent according to stringent size and quality requirements of the timber market, thereby indicating that these trees were disease-free and present in mature to old-growth condition. Information revealed little of other forest components, but improved understanding of the rapid, early removal of former dominant high-quality species.

Ecosystem archaeology provided the most detailed evidence on early forest characteristics and disturbance regimes. An advantage to deriving species composition through identification of charcoal and other macrofossils is that results can be subjected to additional examinations for species identification. Preserved seeds, buds, and other macrofossils provide very reliable evidence on species presence. Opportunities to verify historical ecology research results through other approaches are rare. Forest composition derived from ecosystem archaeology methods were generally from the same generation of trees that the witness tree record portrayed, and so the temporal scale was ideal for comparison. Results from the two methods were in general agreement and were corroborated by information from other research approaches on large forest structures and disturbance regimes. Ecosystem archaeology was the only information source capable of providing direct evidence of the pre-colonial fire cycle and quantifying increases of fire frequency following European settlement. Radiocarbon dating extended the depth of retrospective to forest complexes prior to the Holocene. Limitations of ecosystem archaeology were mainly encountered through incomplete understanding of species-specific charcoal formation and charcoal preservation. Trenches provided highly detailed information for very small geographic areas. Witness tree research provides the opposite situation, where scant detail is provided over a large area. Ecosystem archaeology research was limited to a small number of trenches due to the intensive labour and time involved to collect and interpret information. A high degree of expertise is required to carry out this research.

None of the historical ecology approaches completely resolved key questions concerning the pre-European disturbance regime, although ecosystem archaeology demonstrated the greatest capacity to reveal answers with some additional research and radiocarbon dating. Some characteristics of the original forest composition were not discerned from any information sources. Former abundances of red spruce remain unclear since it was not discerned from black spruce. Former abundances of sugar maple were not separated from red maple. Which insect species were the main agents of disturbance and what were their approximate frequencies? Did fire generally follow insect mortality events, or were dead trees predisposed to rapid decay in a climate with humid coastal influences, and aquatic features that impeded the spread of wildfires? Were low intensity surface fires important in some stand types? How frequent were moderate and catastrophic windstorm events? What was the ecological role of the Mi'kmaq in forest disturbance? Did selective removal of the tallest white pine reduce the frequency of dry lightning ignitions, thereby altering the fire regime?

Closing messages derived from the forest reference condition

Defining a forest reference condition for the Acadian forest demonstrated that many fundamental aspects of this forest type no longer exist, or have been drastically modified during the 200-year period since European colonization. Conclusions that late-successional species, particularly eastern hemlock, predominated, dispel the view that the region is prone to frequent fire and therefore, fire-dependent forest complexes. This important conclusion reinforces the views of Swetnam *et al.* (1999): "*It is very useful to know and understand the past to properly manage ecosystems for the future*". Baseline knowledge of the past has brought new insights to forest ecology and is expected to guide management of forest communities into the future. Defining a forest reference condition for Kouchibouguac National Park and adjacent landscapes provides important insights on potential forest types that could re-establish in the region under a more natural, less intense disturbance regime. The Eastern Lowlands ecoregion is capable of producing and perpetuating forests of high quality, long-lived species, such as white pine, hemlock, red spruce, and yellow birch.

Hemlock achieved unusual dominance in forests of the study area, and Loucks (1962) regarded the hemlock - red spruce complex as representing, more than any other, "*a distinctive forest in the Maritime Provinces*". Forests were none other than spectacular from an ecological viewpoint, featuring giant trunks of hemlock and other late seral species, draped with lichens in dark shadows.

While the forest reference condition focused on 19th century forests, it represents a far longer temporal perspective than just one point in time. This forest reference condition is the consequence of at least several hundred years of ecological processes that likely consisted of frequent, small-scale disturbance events, with larger-scale stand replacement events spaced at long intervals, possibly 2000-3000 years apart. Information on pre-colonial forest composition and associated disturbance dynamics is a useful reference for understanding the developmental history of modern-day forests.

Recommendations to Parks Canada and other land owners within the study area

Conclusions on the forest reference condition are useful for formulating ecologically appropriate forest management goals at Kouchibouguac National Park and elsewhere on the adjacent landscape. Resource managers at the national park should focus on restoring characteristic late-successional species that defined forests a relatively short time ago. Formerly dominant components, such as eastern hemlock, white pine, red spruce, yellow birch, and beech could benefit from some interventions to assist their return to levels more consistent with pre-colonial patterns. Early seral species, such as trembling aspen and jack pine should be allowed to diminish in quantity on the landscape. This strategy will not jeopardize their perpetuation, since frequent disturbances on lands outside protected areas will ensure continued high representation. These long-term goals can be achieved to a large extent through passive management or a 'leave-alone' approach, and through minimizing anthropogenic disturbance, particularly wildfire. Only long periods of time between disturbance events will allow species composition and structure of the forests to be more representative of the Acadian forest. Tall, large diameter trees and coarse woody debris require forests of advanced, multiple ages. Spaces between trees will increase as stands progress through self-thinning and maturation processes (Kneeshaw and Burton 1998; Waring and Running 1998).

Defining a forest reference condition from approximately 200 years ago does not imply that forest managers should attempt to recreate such forests. The forest reference condition is intended to be used as a guide to identify tree species that may be best suited to the region, if disturbance and climate remain within suitable ranges that allow their survival and perpetuation. In an era of unprecedented climate change, increased disturbances, and increased rates of introductions of exotic forest pests and diseases, it is probable that some formerly dominant species may no longer thrive in the area. Additional research is required to predict which tree species may most successfully be restored over the long term. Current range distributions of some former dominant species extend father south than New Brunswick, such as those of hemlock and beech (Burns and Honkala 1990), and so restoration of such species may remain appropriate. Species associated with boreal forests, such as jack pine, white and black spruce, will likely be less suited to a new, warmer climate.

Human impacts have caused dramatic and irreversible changes to forest ecosystems. In turn, it will require some human-assisted interventions to restore a more representative species composition. Riparian zones, for example, where early land clearances replaced some of the most diverse forest types could be a focus for restoration. It will take many generations of trees to restore a more natural species and structural complex to abandoned fields. Tip up mounds from large tree uprootings will eventually restore a more natural hummock-hollow terrain where the surface currently remains flat from ploughing. It is unclear whether exotic invertebrates, such as earthworms, will endure and impede the return to a more natural ecosystem function (Ponomarenko 2006).

Restoring former drainage patterns would assist in restoring the forest mosaic. Many fields in KNP feature narrow hand-dug drainage ditches along their perimeter that assisted drainage of formerly wet landscapes. Restoring natural drainage patterns by filling in these ditches may result in better habitat for eastern cedar. Similarly, old roadbeds that transect the landscape have altered drainage patterns (and therefore altered stand patterns), and should be dismantled.

An ecologically important research result, particularly for managers at KNP, was quantification of the diminution of formerly dominant species in the Acadian forest of the Eastern Lowlands. Having measured the sharp declines of hemlock, white pine, yellow birch, beech and other species provides a platform to prioritize restorative interventions on lands owned by the park. Precipitous declines of eastern hemlock and beech caused by human disturbances are of ecological concern, and efforts to restore these species are justifiable. Eastern hemlock, in particular, may have dropped below a critical threshold for which active interventions are required to assist in maintaining even a minimal presence on the landscape. Hemlock dominated much of the study area, and it contributed to this unique and distinctive forest region. Beech played an ecologically important role as a large, mast-bearing tree, important in the fall diet of some birds, including the extinct passenger pigeon (*Ectopistes migratorius*) (Ellsworth and McComb 2003), and many mammals, including black bear (*Ursus americanus* Pallas). Gathering of beechnuts was also a tradition in the Acadian culture. For these and other reasons, consideration should be given to restoring beech to more historically representative levels. Such efforts rely, however, on the feasibility of growing stock of canker-resistant beech. Human assistance may not be required to re-establish white pine dominance on the landscape, as it is currently regenerating in abundance on abandoned fields and other disturbed sites.

For the foreseeable future, the *absence* of fire will be important to achieving more ecologically appropriate forest types for KNP, particularly stand replacement events. This is the opposite situation from many other national parks that feature shorter fire return intervals, and where years of successful fire suppression have interfered with the perpetuation of natural forest types and tree species that benefit from fire. Since fires occurred very rarely, perhaps every 2900 years in KNP, the frequent arson and accidental fires in the Eastern Lowlands should continue to be suppressed whenever possible. Additional research would be beneficial to identify differences between fire regimes of coastal forests versus inland forests. Reconstructing the entire chronology of events for any one site, particularly a remnant stand of late-successional species, such as hemlock, would enhance understanding of frequency and types of disturbance events required for restoration and maintenance of such stands. Strategic placement of some ecosystem archaeology research trenches in remnant late-successional stands would greatly assist in uncovering developmental histories.

The forest reference condition draws attention to the loss of two valuable hardwood species, beech and elm, from accidental foreign pest and disease introductions. It is recommended that initiatives be adopted where possible to reduce vectors of exotic forest pests and pathogens. For example, the current practice of allowing visitors to import firewood to park campgrounds should be terminated since the wood could be contaminated by foreign pests or diseases. Monitoring forest health is essential to early detection of foreign introductions that threaten ecological integrity.

This research demonstrated that it truly is useful, perhaps crucial, to know the past to manage forests of the future. To all landowners, and to those who have economic or ecological interests in forest resources, these results provide strong evidence of the local forest potential. Through careful stewardship, a more valuable and biologically diverse Acadian forest that more closely resembles the forest reference condition can be achieved. Cutting regimes should mimic natural disturbances where possible. Selection cuts favour the high quality, shade-tolerant species that once dominated the area. Larger cuts favour low quality, shade-intolerant species (Pickett and White 1985). Imagine what it would be like if future generations could one day experience camping beside a 'forest well'. Such an achievement might indicate the ultimate survival of this unique terrestrial ecosystem.

REFERENCES

Adams, A.L. 1873. Field and forest rambles, with notes and observations on the natural history of eastern Canada. Henry S. King & Co., London, England. 333 pp.

A. D. Revill Associates. 1978. Ecological effects of fire and its management in Canada's national parks: a synthesis of the literature. Vols. 1&2. Lit. Rev. & Annot. Bibliography. Ottawa, ON: Parks Canada, National Parks Branch, Natural Resources Division, 345 pp.

Alexander, J.E. 1849. L'Acadie, or, Seven years' explorations in British North America. H. Colburn, London,. 370 pp.

Burns, R. M., and Honkala, B. H., tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 pp.

Chapman, J.A. and Feldmar, G.A. (Eds.) 1982. Wild mammals of North America. The John Hopkins Univeristy Press, Balitmore and London, 1147 pp.

Cooney, R. 1832. A compendious history of the northern part of the province of New Brunswick and of the District of Gaspe in Lower Canada. Halifax, NS. 158 pp.

Crossland, D. 1998. Recent fire history of Kouchibouguac National Park. Parks Canada-Technical Reports in Ecosystem Science #013, Cat No. R61-2/19-13/1997E, 41pp.

DNR 2004. N.B. forest development survey field manual for Y-O merchantable forest stands. Forest Management Branch, Department of Natural Resources, Fredericton, NB. 102 pp.

Ellsworth, J.W. and McComb, B.C. 2003. Potential effects of passenger pigeon flocks on the structure and composition of presettlement forests of eastern North America. Conservation Biology, 17 (6): 1548-1558.

Fisher, P. 1980. The first history of New Brunswick. Larson's Printing, Woodstock, NB. 133 pp.

Foster, D.R., Orwig, D.A. and McLachlan, J.S. 1996. Ecological and conservation insights from reconstructive studies of temperate old-growth forests. TREE, 11 (10): 419-424.

Fowler, J. 1873. Archival letter to G.W. Clintin; Buffalo Museum of Science, Buffalo, NY.

Government of New Brunswick, 1816. NB Statutes, C. 13, An Act in addition to, and to explain an Act, entitled "An Act to explain and amend the laws now in force for regulating the exportation of fish and lumber", J. of Legislative Assembly, p. 273-275.

Government of New Brunswick, 1831. NB Statutes, C. 45. An Act to repeal the Acts now in force regulating the exportation of lumber, and to make other provisions in lieu thereof. J. of Legislative Assembly, p. 553-557.

Graham, S.A. 1941. The question of hemlock establishment. J. For. 39 (6): 567-569.

Graham, S.A. 1943. Causes of hemlock mortality in northern Michigan. U. Mich. Sch. For. Conser. Bull. No. 10.

Gray, D.R. 1999. Updated status report on the woodland caribou (caribou des bois) *Rangifer tarandus dawsoni* and *R. tarandus caribou* in Canada. COSEWIC, Grayhound Info. Svcs., ON. 36 pp.

Gubbins, J. 1813. *In*: Temperley, H. (Ed.) 1980. Gubbins' New Brunswick Journals 1811 and 1813. NB Heritage Publications, Fredericton, NB. 74 pp.

Hosie, R.C. 1990. Native trees of Canada. Fitzhenry and Whiteside Ltd., Ont. 380 pp.

Johnston, J.F.W. 1851. Notes on North America. Vol. I and II., C.C. Little and J. Brown, Boston. 512 pp.

Journal of the Legislative Council of NB. 1847. Reports on railways, &c., (Appendix), J. Simpson, Fredericton, NB. p. cxl.

Kneeshaw, D.D. and Burton, P.J. 1998. Assessment of functional old-growth status: A case study in the sub-boreal spruce zone of British Columbia, Canada. Natural Areas Journal, 18: 293-308.

Loucks, O.L. 1962. A Forest Classification for the Maritime Provinces. Proceedings of the Nova Scotian Institute of Science. vol. 25, part 2, p. 85-167.

Monro, A. 1855. New Brunswick; with a brief outline of Nova Scotia and Prince Edward Island. Their history, civil divisions, geography, and productions. Richard Nugent, Halifax, NS. 384 pp.

Parenteau, B. 1994. The New Brunswick forest heritage: A history of the forest industries, 1780-1930. Unpublished report submitted to Envir. Canada, Can. Parks Svc. 401 pp.

Parks Canada 1994. Guiding principles and operational policies. Canadian Heritage Publ.,Cat. No. R62-275/1994E. 125 pp.

Perley, M.H. 1842. Reports on Indian settlements, &c. J. of the House of Assembly of the province of New Brunswick, Sixth Session of the twelfth general assembly, (Appendices.). J. Simpson, Queen's Printer, Fredericton, NB.

Perley, M.H. 1847. Report on the forest trees of New Brunswick. *In:* Simmonds's Colonial Magazine, vol. XI: 42, June 1847, p. 129-423.

Perley, M.H. 1863. Eighty years of progress of British North America, Stebbins, Toronto, ON. 77 pp.

Pickett, S.T.A. and White, P.S. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, Inc. Toronto, ON. 472 pp.

Ponomarenko, E. 2006. Reconstruction of ecosystem dynamics and natural disturbance history in Kouchibouguac National Park. Report in preparation.

Rogers, R.S. 1978. Forests dominated by hemlock (*Tsuga canadensis*): distribution as related to site and postsettlement history. Can. J. of Botany 56: 843-854.

Runkle, J.R. 1991. Gap dynamics of old-growth eastern forests: management implications. Natural Areas Journal 11: 19-25.

Smith, T. 1857. A natural resources survey of Nova Scotia 1801-02. Public Archives of Nova Scotia, vol. 380, 179 pp.

Swetnam, T.W., Allen, C.D., and Betancourt, J.L. 1999. Applied historical ecology: using the past to manage for the future. Ecol. Applic. 9(4): 1189-1206.

Waring, R.H. and Running, S.W. 1998. Forest ecosystems: analysis at multiple scales. Academic Press, NY. 370 p.

Woods, K. 2000. Long-term change and spatial pattern in a late-successional hemlock-northern hardwood forest. J. of Ecology. 88: 267-282.

Zink, M. 1998. Flora of Nova Scotia. Vols. 1 and 2, NS Museum and Nimbus Publ., Halifax, NS. 1297 pp.

APPENDICES

APPENDIX 1-1 HUMAN LAND USE HISTORY

The Mi'kmaq

The original inhabitants in the area of study, leading up to European contact, were the Mi'kmaq people (Ganong 1904; Leonard 1996). There were at least four known seasonally occupied villages located within the study area; one near the mouth of Bay du Vin River, another near Baie Ste. Anne, and two near the mouth of the Richibucto River (Denys 1672). Indian Island, on the Richibucto River, supported a very large population of 2000-3500 people (Desloges 1980). Given their nomadic lifestyle, and according to archaeological evidence, (e.g., shell middens and arrowheads), the Mi'kmaq frequented the other rivers and lagoons in the area (Desloges 1980).

It is difficult to deduce the impacts of the Mi'kmaq on the landscape given that pre-contact population sizes are not known and some aspects of their culture were obliterated very early on in our history. Several waves of epidemics killed many of the area's original inhabitants. Father Chrestien LeClercq (1691), noted that "*in three or four visitations*", "*maladies*" had "*caused the deaths of a very great number*" of Mi'kmaq. Populations continued to decline from the French period onward well into the 1840s. Johnston (1851) stated that the Mi'kmaq were more numerous in New Brunswick during the French period, but he did not quantify the decline. Only 188 people were enumerated in the Richibucto area in 1841 (assumed to be the total for the entire study region), with a total of only 935 Mi'kmaq in all of NB (Perley 1842).

Despite the inability to ascertain how many Mi'kmaq lived on the pre-contact landscape, their impacts on forest composition, structure, and disturbance dynamics are believed to be negligible, particularly when compared to other First Nation groups. Mi'kmaq had little cause to clear forests given that they were non-horticultural (Clermont 1986). They "*do not plough the ground, nor do they harvest Indian corn, or peas, or pumpkins, as do the Iroquois, the Hurons, the Algonquins, and several other nations of Canada*" (LeClercq 1691). The Mi'kmaq survived principally on marine and riverine resources (Perley 1847; Clermont 1986). Historically bountiful fisheries attracted them to reside in the productive coastal environment during the summer months (Temperley 1980; Clermont 1986). Gubbins in 1813, while visiting Richibucto, noted seeing the local Mi'kmaq and their "*little fishing fleet of canoes, sailing to the beach, heavily laden with salmon, cod, lobsters, oysters, etc*" (Temperley 1980). Great quantities of clams, oysters, lobsters, mackerel, and cod provided plenty of easily attainable food (Little 1961). Additional foods were seals and American eel (Clermont 1986). During winter months, they moved farther inland to the shelter of the forest where they fished through the ice and hunted moose and other mammals (Little 1961). LeClercq (1691) wrote that hunting and fishing were "*profuse, and that one can find, without much difficulty, everything necessary for life*". They moved camp whenever resources diminished (LeClercq 1691).

In addition to the forests providing shelter to these First Nations people, they used forest products in many ways. Bark of white birch was used for canoes, wigwams, to wrap the deceased prior to burial, and for small domestic utensils (Monro 1855; Little 1961). White spruce roots were used to sew bark together, and its pitch was used to plug the holes against leakage (Perley 1847; Monro 1855). Maple sap was tapped from sugar maple trees (Denys 1672). Black ash was used to make baskets (Monro 1855). Cedar was manufactured into gunwales and ribs of the canoe, while cross bars were made of sugar maple. Red or sugar maple was employed for canoe paddles (Perley 1847). It is likely that at least 15 woody species were used for medicinal purposes (Monro 1862), in addition to medicinal herbaceous plants that were harvested from the forest understory. The forest provided habitat for key mammal species they harvested for food and pelts. Easily accessible dead wood and branches would have been used for campfires. The Mi'kmaq historic use of fire requires more research, but it was unlikely to have included purposeful setting of forest fires (Patterson and Sassaman *In*: Nicholas 1988; Crossland 1998). Mi'kmaq did not appear to routinely burn the forests like other native cultures to the south, who practiced horticulture. This does not rule out accidental fire. In conclusion, it would appear that the Mi'kmaq impact on the local forests in the study area was relatively non-intrusive.

The French Period (1623-1763)

The French period as defined by Ganong (1904) was 1623-1763. In the study area, however, it is believed that French began to settle later, *ca*. 1680. According to an early map of Acadia (1703), two large seigneuries were granted in the area to Georges

Duplessis (1696) and Mathieu de Line (1697) (Fontaine 1703). Though large on paper, their impacts on forests were minor, as the seigneurial system did little to promote settlement (Daigle 1982). The few French inhabitants who came settled close to one another in limited areas near the mouths of the rivers at the coast. French seigneuries were extinguished in 1759 (Ganong 1908).

The first French settlers are believed to have lived on the Aldouane River, near where it joins at the mouth of the Richibucto River (Maxwell 1951). There were approximately 150 French people living near the mouth of the Richibucto River in 1688 when the English pillaged a fishing outpost, "Compagnie de l'Acadie". Eighty of these people were fishers and were likely only seasonal residents (Rumilly 1981). In 1756, another small village, or perhaps the same one as previously mentioned, was recorded at the mouth of the Aldouane River (Cooney 1832; Little 1961). It was apparently smaller than the main French settlement recorded on the Richibucto River at that time, which had "*upwards of 40 houses*" (Little 1961). Acadians were deported from 1755-1763, and unknown numbers of Acadian settlers were likely forced out of the present study area (Daigle 1948; Daigle 1982). Only 11 Acadian families and 68 individuals were living at Richibucto by 1760, and by 1787, populations declined to only 6 Acadian families in all of Kent County (Daigle 1948). The Kouchibouguacis River had Acadian settlers some time prior to 1800 (Ganong 1904). In Northumberland County, French settlers were located on Bay du Vin (formerly known as Baie des Ouines) watershed in 1786 (Ganong 1904).

Impacts of French settlement on forest resources were likely negligible, given small population numbers and lifestyle. Chief occupations of earliest French settlers were fishing and the fur trade (Johnston 1851). Acadians have been traditionally described as marsh farmers, after their preference to build dykes and cultivate salt marshes. They rarely cleared uplands for agricultural purposes (Daigle 1982). Extensive salt marshes that expand over the large tidal flats in the study area were farmed, and Acadians were attracted to the Kouchibouguacis River area for its extensive salt marshes (Daigle 1948). Yet a small area of woodland here and there must have been cleared. Lieutenant Colonel Gubbins wrote in his travel journals that Loyalists were often granted lands in NB that included the "*improved farms*" of the former tenants, the

Acadians, and that these cultivated lands, the Acadians had labored to create "*from the morass* [marshes] *or forest*" (Temperley 1980). Yet in the Richibucto area, the French settlers could not have greatly affected the landscape. Gubbins, while visiting Richibucto to inspect the militia, stated that the French settlers were "*bad farmers*", and criticized them for being content with only the "*absolute necessaries of life whilst the comforts are easily within their reach*" (Temperley 1980). It is unlikely from such comments that Acadians had cleared any substantial tracts of forest, which would have been regarded by the English as 'improvements' at that time. It is possible that Acadians cleared forests only when faced with insufficient resources from the marshes. This was found to have been the case in PEI, where 18th century Acadians were obliged to clear some uplands because of inadequate quantities of available marshland (Sobey 2002). And so it is likely that only occasional, small clearings of forest were made for cultivation or homesteads during the French period.

Shipmasts may have been selectively harvested to a minor extent, though no proof of this was found for the study area. There would have been some selective cutting for firewood and other domestic applications, but forest composition and structure would have been little changed in the study area during this period.

English colonization (1707-1900)

Colonization by the English was delayed in the study area, most likely due to treacherous access to the landscape by ship. The rivers are smaller and less navigable than neighbouring rivers, the entrances only accessible through narrow channels between shallow shifting sandbars; a formidable navigational impediment that wrecked numerous large sailing ships (MacDonald 1989). Alternatively, late British colonization was theorized to be partly due to the aggressive reputation of the Richibucto Mi'kmaq (Little 1961). English settlement began in 1787 with the arrival of Loyalist, Solomon Powell, followed by other family members (Kinnear 1785; Ganong 1904). They resided on the Richibucto River, where they fished and operated a trading post, and later, a shipbuilding business (Ganong 1904; Little 1961). The first land grants were issued in the area in 1793 to 33 persons, claiming 15 000 acres in the area of Aldouane and Richibucto Cape (Little 1961). Other watersheds began to receive settlers in early 1800, though the Richibucto River remained the area of greatest focus. A settlement boom occurred between 1812 and 1850 (Ganong 1904) and reached approximately 6900 persons living in the study area by 1851 (according to statistics for Richibucto, Weldford, and Carleton Parishes) (Monro 1855). A total of approximately 22 346 acres were cleared in these parishes. Immigrants, (many of Scotch and Irish decent), extended settlement up the Richibucto River, and supported approximately 44 % of the population. The remaining inhabitants lived on other rivers and along the seaboard (Monro 1855). Kouchibouguac River experienced a similar rapid settlement after 1803. Acadians also immigrated to the area (Beach 1988).

The Mi'kmaq most likely became involved with timber harvesting for the first time in their history at the beginning of 1800. Col. Gubbins in 1811 wrote that the Mi'kmaq would "*cut lumber for the merchants*" when poor weather inhibited them from fishing at sea (Temperley 1980). It is not clear whether this wood was for European export or for domestic purposes.

Despite the rapid influx of settlers, forests remained largely uncleared away from the mouths of rivers, and towards the interior. By 1841, the Richibucto River was "*thinly settled*" on both sides as far as the head of the tide (approximately 40 km), "*above which the whole countryside* [was] *in a state of wilderness*" (Perley 1842). Lands were yet in a wilderness state as seen along the newly built road from Kouchibouguac to Chatham, and lands above the mills on the Kouchibouguac River remained almost entirely ungranted (Perley 1842). Land was "*not inhabited except on the streams, where there are some thriving settlements; along the seaboard also, in the direction of Point Escuminac lighthouse, the land is generally settled*" (Monro 1855). Likewise, Johnston (1851) commented that on this flat country, there were only a few, thinly scattered clearings.

Human land uses during the 1800s greatly changed the original forest character. Escaped wildfire was one of the strongest agents of forest change, mainly caused by land clearances and associated land-clearance fires, and impacts of early forestry operations. The first forest industries, removed the largest and highest quality trees for shipbuilding and the export trade (DeGrâce 1984). Shipmasts were required for British sailing fleets, and large quantities of the tallest, highest quality white pine were removed from the watersheds in early 1800. (See Chapter 3.) Still larger quantities of white pine were removed for the ton timber industry, along with lesser quantities of yellow birch and red pine (Chapter 3). Shipbuilding used a wide diversity of timber, adding larch, spruce, and oak to the list of highly sought species. By 1851, Richibucto-Rexton area had four shipyards and two steam sawmills, in addition to numerous water-powered mills (Monro 1855). Kouchibouguac River supported three shipyards and other smaller boat-building operations (DeGrâce 1984). Lumber sawmills were situated on nearly all tributaries at one time or another during 1800, and were able to use smaller timbers than those first sought for masts and square timber. Pine and red spruce were among the most sought after for lumber.

The cessation of wooden shipbuilding and ton timber industries saw continued demand of forests for other wood products, such as cedar shingles, laths, boxes, and spools for thread. The last forest species to be selectively removed in large quantities from the landscape was eastern hemlock, during the late 1800s. The wood was not valuable, resulting in large trunks being left behind to rot in the woods, but hemlock bark was stripped and taken to Richibucto in large barges, from where it was shipped to various North American tanning industries (DeGrâce 1984).

Fishing and farming provided the other major sources of livelihood for local inhabitants. A canning industry began in 1843 for manufacturing tins of lobster that were shipped to many parts of the globe (Maxwell 1951). The cannery on Kouchibouguac River also preserved blueberries and huckleberries.

REFERENCES

Beach, H., (Ed.) 1988. The Resources of Kouchibouguac National Park: Resource Description and Analysis. Kouchibouguac National Park, Envir. Canada.

Clermont, N. 1986. L'adaptation maritime au pays des micmacs, *In* : Martijn, Charles A. 1986. Les micmacs et la mer. Recherches amérindiennes au Québec, Montréal, Qué. p. 11-27.

Cooney, R. 1832. A compendious history of the northern part of the province of New Brunswick and of the District of Gaspe in Lower Canada. Joseph Howe, Halifax, NS. 158 pp.

Crossland, D. 1998. Recent fire history of Kouchibouguac National Park. Parks Canada-Technical Reports in Ecosystem Science #013, Cat No. R61-2/19-13/1997E, 41 pp.

Daigle, L.C. 1948. Histoire de Saint-Louis-de-Kent. L'Imprimérie Acadienne Ltée, Moncton, NB. 245 pp.

Daigle, J. (Ed.) 1982. The Acadians of the Maritimes: Thematic studies. Minister of Envir. Centre d'études acadiennes, Moncton, NB. 637 pp.

DeGrâce, E. 1984. Human history of Kouchibouguac National Park. Unpub. report to Parks Canada. 157 pp.

Denys, N. 1672. Description geographique et historique des costes de l' Amerique septentrionale, avec l'histoire naturelle de Pais. Republished English translation by Ganong, W.F. (Ed.). 1908. The description and natural history of the coasts of North America (Acadia). The Champlain Society, Greenwood Press, NY.

Desloges, C. 1980. The natural resources of Kouchibouguac National Park. Parks Canada, Atlantic region, Ed.: Le Groupe Dryade, Que. 127 pp.

Fontaine, L. E. 1703. (cartographer) Carte de l'Acadie et d'une partie de la Nouvelle France. PANS 3.5.1.1703

Ganong, W.F. 1904. A monograph on the origins of settlements in the province of New Brunswick. Vol X, Sec. 2, James Hope & Son, Ottawa, ON.

Ganong, W.F. (Ed.) 1908. The description and natural history of the coasts of North America (Acadia) by Nicolas Denys. The Champlain Society, Toronto, ON.

Johnston, J.F.W. 1851. Notes on North America. Vol. I and II., C.C. Little and J. Brown, Boston, 512 pp.

Kinnear, A. 1785. Letter to Edward Winslow, April 21st 1785. In: Winslow Papers, A.D. 1776-1826. Raymond, W.O. (Ed.) 1901. New Brunswick Historical Society, The Sun Printing Co. Ltd. St John, NB. p. 298-299.

LeClercq, C. 1691. New relations of Gaspesia: the customs and religion of the Gaspesian cross-bearer Indians, worshippers of the sun, and other peoples of North America, called also Canada. Republished English translation by Ganong, W.F. 1910. The Champlain Society, Toronto, ON. 452 pp.

Leonard, K. J. 1996. Mi'kmaq culture during the Late Woodland and Early Historic periods. PhD Thesis, Dept. of Anthropology, U. Toronto, 329 pp.

Little, G.E. 1961. The birthplace of Andrew Bonar Law and the early history of Kent County. In: Collections of the New Brunswick Historical Society. No 16. Langley Printing Co, Ltd. 70-92 pp.

MacDonald, M. 1989. Richibucto: River of fire. Centennial Print and Litho, Fredericton, NB. 120 pp.

Maxwell, L. 1951. 'round New Brunswick roads. Ryerson Press, Toronto, ON. 191 pp.

Monro, A. 1855. New Brunswick; with a brief outline of Nova Scotia and Prince Edward Island. Their history, civil divisions, geography, and productions. Richard Nugent, Halifax, NS. 384 pp.

Monro, A. 1862. Native woods of New Brunswick. Book made of wood containing wood samples. Woodwork by Stephen Truman, Westmorland, NB. 14 pp.

Patterson, W.A. and Sassaman, K.E. 1988. Indian fires in the prehistory of New England. *In*: Nicholas, G.P. (Ed.) 1988. Holocene human ecology in northeastern North America. Plenum Press, NY. 319 pp.

Perley, M.H. 1842. Reports on Indian settlements, &c. J. of the House of Assembly of the province of New Brunswick, Sixth Session of the twelfth general assembly, (Appendices.), J. Simpson, Queen's Printer, Fredericton, NB.

Perley, M.H. 1847. Report on the forest trees of New Brunswick. *In:* Simmonds's Colonial Magazine, vol. XI: 42, June 1847, p. 129-423.

Rumilly, R. 1981. L'Acadie Française (1497-1713). L' Imprimerie Gagné Ltée., Louiseville, 253 pp.

Sobey, D. 2002. Early descriptions of the forests of Prince Edward Island: A source book. Part I: The French period- 1534-1758, PEI Dept. Ag. and Forestry, PEI. 180 pp.

Temperley, H. (Ed.) 1980. Gubbins' New Brunswick Journals 1811 and 1813. NB Heritage Publications, Fredericton, NB. 74 pp.

APPENDIX 2-1 BACKGROUND INFORMATION ON PRINCIPAL RECORDERS.

Recorder	Length of time spent in or near study area	Area(s) visited	Type of forest record	Quality of information
Alexander, James (1849) surveyor	Approx. 2 months	Moncton to Boisetown, Miramichi, western NB.	Diary form. General forest composition, structure, and disturbance.	Provided vivid portrayal of forest composition and structure as he walked through unexplored interior forests. Original work.
Atkinson, Christopher (1844) Reverend, author	A day or more.	Richibucto, Miramichi, Shediac, Moncton.	Intended for immigrants. General narrative on forests, fire ecology, forest succession, etc.	Species composition information is completely lacking, but very useful observations on forest ecology.
Bailey, Loring (1876) geologist, botanist, educator	Perhaps none.	Lived in western NB for approx. 64 yrs.	Species list with general information on abundance and use.	Forest observations are mainly based on Fredericton-St John area. Relies heavily on pre-existing work, e.g. Perley (1847). Frequent reference to James Fowler.
Cartier, Jacques (1534) French explorer	Possibly a few hours-day.	Possibly Point Escuminac (Hannay 1979)	Translated notes from an early explorer. General observations of N. Am. viewed from the coast.	Earliest record of forest species viewed on coast. Species nomenclature unclear. Brief.
Campbell, Patrick (1793) forester, farmer, traveler	Perhaps none.	Miramichi, Sussex Corner, Fredericton	Agricultural advice for immigrants. Species list with utilitarian uses.	One of few 18th century travelers through NB.
Cooney, Robert (1832) historian, clergyman, journalist	Possibly weeks to months. At least 12 yrs in Miramichi.	Richibucto, Rexton, Ford's Mills. St Nicholas River, Kouchibouguac, Kouchibouguacis	Very general description of NB resources. Forests were not the main focus of the document, but a species	Brief generalizations of forests on major rivers described in one or two sentences. Observations are very early, and viewed first-hand.

Recorder	Length of time spent in or near study area	Area(s) visited	Type of forest record	Quality of information
Cooney, Robert (1832) (continued)		Rivers. Miramichi.	list is included.	
Denys, Nicolas (1672) entrepreneur: fish, fur, and lumber trade, Governor of Gulf coast.	More than 25 yrs in Gulf of St Lawrence region, visiting most rivers in study area.	Richibucto, Kouchibouguac, Miramichi. The entire eastern shore of NB.	Promotional towards settlement and economic potential. General forest comment, with early utilitarian application.	Valuable early observations prior to British settlement. General forest comment on Richibucto River. General references to "firs and pines" cannot be specifically interpreted with confidence.
Fowler, James (1873; 78, 85) minister, botanist, educator, curator. A leading botanical authority on NB flora.	Resided 15 yrs (1861-1876) in study area (Bass River). Extensively explored Kent Co.	Bass River, Richibucto, Kouchibouguac, Miramichi, also counties of York, St John, & Restigouche	(1873) Letter form: Comment on hemlocks at Bass R. (1878; 85) Botanical lists, largely based on specimens personally collected.	The first true botanical reference. Careful observations, many based from the study region. Original work.
Ganong, William (ca.1900) historian, naturalist, botanist	Unknown.	Fredericton, Saint John	Species list with some information on abundance, distribution, and uses.	Work relies heavily on previous historical accounts. Knowledge of tree species' characteristics is strong.
Gubbins, Joseph (1813) Lt. Col., Inspecting field officer of militia in NB.	Approx. 5 days.	Richibucto River, Kouchibouguac, Point Sapin, Pt. Escuminac, Baie Ste Anne	Diary form. General forest comment, as viewed along the coast, rivers, and by horseback.	A very early, direct observation of forests in the study area, but extremely brief.
Hannay, James (1902) lawyer, historian, newspaper editor	Unknown. (Likely visited the area.)	Fredericton, Saint John	Researched archival records.	

Recorder	Length of time spent in or near study area	Area(s) visited	Type of forest record	Quality of information
Johnston, James (1850; 51) professor, agriculturalist	Two to several days.	Traveled on roads through study area on two occasions.	Diary form.	Forests described as they relate to soil quality and agricultural potential. Knowledge of local forest species is good.
LeClercq, Chrestien (1691) Missionary	Perhaps none.	Miramichi area	General comments Mi'kmaq uses of forest.	Pre-European settlement observations.
Monro, Alexander (1855; 62) surveyor, author, JP	Most of his lifetime in eastern NB. Traveled extensively in study area.	Miramichi, Baie Verte, Port Elgin	(1855) Comprehensive summary of provincial resources, with a section on botany, listing tree species and utilitarian application. Promotional information, statistics. (1862) Handcrafted sample book of all woody species in NB.	(1855) Factual information. Original work. Sound knowledge of Eastern Lowland forests. (1862) Taxonomy is difficult to decipher in places, but generally identifies more species than recognized today. Provides opportunity to study early taxonomic identification.
Munro, David (1862) (possibly an engineer)	unknown	unknown	Tree species list with brief statements on utilitarian application.	Fowler (1885) denounced the work. Much information may have been borrowed from other sources. Lacking detail.
Perley, Moses (1842; 47; 63) lawyer, Indian agent, fishery commissioner, naturalist	months, off an on, during numerous visits on Government work for Mi'kmaq, fisheries, etc.	Richibucto, Molus, Kouchibouguac, Miramichi, Bouctouche (probably most rivers in study area)	(1842) A report on state of 1st Nations people in NB. (1847) Tree species described, with distributions and abundances. Promotes	(1842) Provided brief forest descriptions on rivers in study area. (1847; 63) Reflects thorough knowledge of local forests from years of travel throughout NB.

Recorder	**Length of time spent in or near study area**	**Area(s) visited**	**Type of forest record**	**Quality of information**
Perley, Moses (1842; 47; 63) (continued)			development of forest resources. (1863) A summary of Perley (1847).	

Information was obtained from the Dictionary of Canadian Biography.

APPENDIX 2-2 SCIENTIFIC NOMENCLATURE AND COMMON NAMES OF NEW BRUNSWICK TREE SPECIES NOTED IN HISTORICAL DOCUMENTS.

SCIENTIFIC NAME (Hinds 2000)	MODERN ENGLISH NAMES (Hinds 2000)	HISTORICAL NAMES				
		Common names				Scientific Names
Coniferous:						
Abies balsamea (L.) Mill.	balsam fir	fir 1, 8b, 11	American silver fir 12	balsam 1	sappine 5	*Pinus balsamineae* 1, 11 *Abies balsamifera* 12
Larix laricina (DuRoi) K.Koch	larch, tamarack, hackmatack	cypress 13, 14	juniper 5, 7, 8b, 10, 11, 13, 14	Epinette rouge 2	black larch 3	*Pinus microcarpa* 1 *Pinus pendula* 2, 11 *Pinus larix* 2 *Larix americana* 2, 7, 8b, 12
Picea glauca (Moench) Voss	white spruce, cat spruce	single spruce 3, 8b, 12				*Pinus alba* 1, 3, 11 *Abies alba* 7, 12
Picea mariana (Mill.) B.S.P.	black spruce	épinette à la biére 12	double spruce 7, 12			*Pinus nigra* 1, 11 *Abies nigra* 7, 12
Picea rubens Sarg.	red spruce	black spruce 3, 7, 10, 12, 13	double spruce 7, 12	épinette à la biére 12	Norway pine 10	*Pinus nigra* 1 *Pinus rubra* 11 *Abies nigra* 12
Pinus banksiana Lamb.	jack pine, scrub pine	grey pine 3, 10, 12 cypress 8b	banksian pine 8a Banks' pine 3	princess pine 8a,b	yellow pine 5 chipré 12	*Pinus rupestris* 12
Pinus resinosa Ait.	red pine	pitch pine 10, 11	Norway pine 8b, 10,12			*Pinus rigida* 11 (possible)

SCIENTIFIC NAME (Hinds 2000)	MODERN ENGLISH NAMES (Hinds 2000)	HISTORICAL NAMES				
		Common names				Scientific Names
Coniferous:						
Pinus strobus L.	white pine	var.: 'pumpkin' 3, 8b/ sapling'3/ 'bull sapling'3	yellow pine 8b	Weymouth pine 8b, 9a		
Thuja occidentalis L.	eastern white cedar, arbor-vitae	cypress 10a, 12,13 (more commonly used on the Gulf shore)13	juniper 13	yellow cedar 5	American arbour vitae 3, 7	*Cupressus thyoides* 12 (white cedar) / *Thuya occidentalis* 1, 12 (Arbor Vitae)
Tsuga canadensis (L.) Carr.	eastern hemlock	hemlock spruce 3, 12				*Pinus Canadensis* 1, 9b, 11 *Abies canadensis* 3, 7, 12
Broad-leaved:						
Acer pensylvanicum L.	striped maple, moosewood	black moosewood 11	striped dogwood 3			*Acer stratium* 11 *Acer striatum* 1, 12
A. rubrum L.	red maple, soft or swamp maple	red flowering maple 12, 13	(soft sugar maple possible 11)	white maple 7, 10		(*Acer dasycarpum* 11 possible)
A. saccharum Marsh.	sugar maple, hard or rock maple var.: bird's eye, curly	black sugar maple 11	(white sugar maple 11)	(white maple possibly employed by some)		*Acer nigrum* 11 *Acer saccharinum* 1, 3, 7, 11, 12

SCIENTIFIC NAME (Hinds 2000)	MODERN ENGLISH NAMES (Hinds 2000)	HISTORICAL NAMES				
		Common names				Scientific Names
Broad-leaved:						
A. spicatum Lam.	mountain maple,	low maple 12	(white moosewood possible 11)			(*Acer barbatum* possible 11) *Acer montanum* 12
A. saccharinum L.	silver maple, white maple	soft sugar maple 11	(white sugar maple possible 11)			*Acer dasycarpum* 1, 3, 7, 11
Betula alleghaniensis Britton	yellow birch	*black birch 3, 4, 5, 6, 7, 8a,b, 10, 11,12 cherry birch 3,4, 7 sweet birch 3, 7	gray birch 7 (syn. yellow birch)	Mignogon 6 Nimnogun-k 8a (Mi'kmaq for black birch)		*Betula excelsa* 1, 3, 11 *B. lutea* 7, 12 (yellow birch) / *B. lenta* 1, 3, 7, 11, 12 (black birch)
B. papyrifera Marsh	white, paper, or canoe birch					*Betula papyracea* 1, 3, 7, 10, 11, 12
B. populifolia Marshall	grey birch	white birch 1, 3, 11, 12	American white birch 3	small white birch 7		*Betula alba* var. *populifolia* 3, 7
Fagus grandifolia Ehrh.	American beech	white beech 3, 10, 11, 12, 13	red beech 3, 10, 11, 12, 13	common beech 10		*Fagus sylvatica* 11 or *F. sylvestris* 12 (white beech) / *F. ferruginea* 1, 3, 7, 10, 11, 12, 13 (red beech)
Fraxinus americana L.	white ash					*Fraxinus acuminata* 11

SCIENTIFIC NAME (Hinds 2000)	MODERN ENGLISH NAMES (Hinds 2000)	HISTORICAL NAMES				
		Common names				Scientific Names
F. nigra Marsh.	black ash	swamp ash 5, 11	water ash (in US) 7, 12	yellow ash possible 10		*Fraxinus sambucifolia* 11, 12 (black ash) / *Fraxinus juglandifolia* 11, 12 (swamp ash)
Ostrya virginiana (Miller) K. Koch	ironwood, American hop hornbeam, lever wood	hornbeam 3, 11, 12	bois dur 12			*Carpinus americana* 1, 3,11, 12/ *Carpinus ostrya* 12 / *Carpinus virginica* 3, 7
Populus balsamifera L.	balsam poplar	balm of Gilead 5, 11, 12, 13	tacamahac 7			*Populus augulata* 11
P. grandidentata Michx.	largetoothed aspen	tree poplar 11	white poplar 5			*Populus grandentata* 11
P. tremuloides Michx.	trembling aspen	white poplar 7, 10	American aspen 3, 12, 13	trembling poplar 5	birch-leaved poplar 11	*Populus candicans* 11
Quercus rubra L.	northern red oak					
Ulmus americana L.	American or white elm	slippery elm 12	red elm possible 3, 10, 11, 12, 13,	river elm possible 10, 11, 12, 13		*Ulmus nemoralis* (river elm) 11

1. Alexander 1849, 2. Atkinson 1844, 3. Bailey 1876, 4. Campbell 1793, 5. Cooney 1832, 6. Denys 1672, 7. Fowler 1878, 8a Ganong 1908, 8b Ganong n.d., 9a Johnston 1851, 9b Johnston 1851, 10. Monro 1855, 11. Monro 1862, 12. Perley 1847, 13. Perley 1863, 14. Pierce 1845

Note: Authors are specified only where names deviate from modern nomenclature. Species were listed only if they grew in the study area, or were recorded for the area in historical literature. *See Discussion for explanations on black birch.

APPENDIX 3-1 PLACE NOMENCLATURE CHANGES

Former names	Current Names	Notes
Northumberland County	Kent County and Northumberland Counties	Kent Co. was separated from Northumberland in 1826.
Liverpool	Richibucto	Renamed in 1832.
Palmerston	St Louis	Renamed in 1866.
Kingston	Rexton	Renamed in 1901.
Point Edward	Loggiecroft	Changed sometime after 1805.
Murphy's Creek	Fontaine River	Survey sketch L11, yr. 1837.
Meadow Brook	Rankin Brook	
Little River	Kollock Creek	
Jann's Creek	Palmer Creek ??	
Island Creek	McKay's Brook	
North West River, Ardouane River, Aldoine	St Charles River or Aldouane River	
Helnowkon	St Nicholas River	
Pichibouguack, Pesamaquack, Pissabeguake, Kagobougouette Kishaboguac	Kouchibouguac River	Numerous derivations and spellings.
Pissebeguacees, Piziebougacksis, Kichibouguacis	Kouchibougacis or St Louis River	Numerous derivations and spellings.
Lith-e-book-took	Richibucto River	
Weldford	Harcourt	

Sources: Survey sketches, PANB; Ganong 1906.

APPENDIX 3-2 WITNESS TREE SPECIES INTERPRETED FROM SURVEY NAMES AND SYMBOLS.

Surveyor Names	Surveyor Symbols	Scientific name	
Broad-lved species			
Maple	Map., Ma.	*Acer*	*saccharum, rubrum*
Red, Swamp, White maple	R.maple, r. ma.,W. Ma., w. ma.	*Acer*	*rubrum*
Sugar, Rock maple	Rk. Maple, W.maple	*Acer*	*saccharum*
Moosewood		*Acer*	*pensylvanicum*
Oak, Red oak		*Quercus*	*rubra*
Elm		*Ulmus*	*americana*
Beech	Bee.	*Fagus*	*grandifolia*
Ash		*Fraxinus*	*americana, nigra*
Cherry		*Prunus*	*pensylvanica, virginiana*
Ironwood, Hornbeam		*Ostrya*	*virginiana*
Birch	Bir., Bi.	*Betula*	*alleghaniensis, papyrifera, populifolia*
White birch	Wh. Bir, W. Bir.,W. birch, W.B.	*Betula*	*papyrifera*
Yellow birch	Y. Bir.,Yel.Bir., Y. Bi., Y.B.	*Betula*	*alleghaniensis*
Black birch	Bla. bir., blk.birch	*Betula*	*alleghaniensis*
Poplar	Pop.	*Populus*	*tremuloides, grandidentata, balsamifera*
Alder	al.	*Alnus*	*incana*
Coniferous species			
Juniper, Larch, Tamarac	Jun., T.	*Larix*	*laricina*

Surveyor Names	Surveyor Symbols	Scientific name	
Coniferous species (*continued*)			
Cedar	Ce, ced., C.	*Thuja*	*occidentalis*
Pine	Pi.	*Pinus*	*strobus*
Red pine	R. Pine, Red Pi.	*Pinus*	*resinosa*
White pine	Wh. pine, w. pine	*Pinus*	*strobus*
Pitch pine		*Pinus*	*resinosa**
Stunted pine		*Pinus*	*banksiana**
Spruce	sp., spr., spru., S.	*Picea*	*rubens, mariana*
Dry spruce		*Picea*	
Black spruce**	B. spruce., bl. sp.	*Picea*	*rubens, mariana*
White spruce	W. Spr.	*Picea*	*glauca*
Fir	F.	*Abies*	*balsamea*
Hemlock	Hem., H.	*Tsuga*	*canadensis*

Scientific names from Hinds 2000.

* These taxonomic assignments could not be verified and remain theoretical.

** Black spruce was assigned to both red and black spruce throughout the 19th century.

APPENDIX 3-3. SPECIES COMPOSITION CA. 2000 ACCORDING TO TOTAL *BASAL AREA/HA BY ECOSITE ON THE NEW BRUNSWICK EASTERN LOWLANDS, (ECOSECTIONS 6-6-2, 6-6-3, 6-6-4).

FDS Species Symbols**	Ecosite 1	Ecosite 2	Ecosite 3	Ecosite 3b	Ecosite 5
BF	6.11	4.92	2.24	0.68	5.16
RM	2.71	3.09	1.42	0.78	3.59
TA	3.31	1.93	1.19	0.14	3.13
BS	2.81	6.41	12.81	20.44	2.49
RS	1.93	1.02	0.70	0.37	1.65
JP	1.89	0.56	2.06	0.17	1.62
WB	0.88	0.85	0.52	0.22	1.15
WP	0.91	0.41	0.81	0.19	0.80
EH	0.30	0.32	0.03	0.00	0.75
WS	1.47	0.50	0.35	0.00	0.57
TL	0.13	0.38	1.08	1.36	0.36
SM	0.35	0.07	0.00	0.00	0.29
OH	0.26	0.38	0.59	0.71	0.21
YB	0.15	0.13	0.00	0.00	0.20
BE	0.01	0.03	0.02	0.00	0.11
LA	0.17	0.15	0.04	0.00	0.06
NC	0.00	0.15	0.15	0.00	0.04
DS	0.05	0.14	0.12	0.00	0.03
DF	0.02	0.02	0.01	0.00	0.03
I	0.00	0.01	0.00	0.07	0.03
AS	0.01	0.03	0.01	0.00	0.02
RP	0.00	0.10	0.02	0.00	0.00
O	0.00	0.01	0.00	0.00	0.00
EC	0.26	1.63	1.75	0.00	0.00

*Total basal area per hectare (m^2ha^{-1}) was derived from Forest Development Survey (FDS) database. **Symbols from DNRE (2001): AS-ash, BE-beech, BI- birch (white or grey birch), BF-balsam fir, BS- black spruce, DF-dead fir, DS-dead spruce, EC-eastern white cedar, EH-eastern hemlock, I-ironwood, IH- intolerant hardwoods, JP-jack pine, LA-Largetooth aspen, NC- noncommercial species, O-oak, OH-other hardwoods, PO- poplar, RM- red maple, RP-red pine, RS- red spruce, SM-sugar maple, SP- white or red spruce, TA-trembling aspen, TL- larch, WB-white birch, WP- white pine, WS- white spruce, YB-yellow birch.

APPENDIX 3-4. FOREST DESCRIPTIONS CITED FROM METES AND BOUNDS PLAN DRAWINGS, WITH INTERPRETATIONS OF STAND TYPES AND TREE SPECIES, AND WHEN POSSIBLE SOIL QUALITY, FOREST STRUCTURE, AND DISTURBANCE AGENTS.

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil qualitiy/ Veg. Unit class	Structure	Disturbance
1807	1	Lewis Dennis	Kouch R.- So. Side	R	chiefly hardwood	HW			
1807	1	Lewis Dennis	Kouch R.- So. Side	R	mixed timber	HWSW		timber	
1807	1	Lewis Dennis	Kouch R.- So. Side	R	mixed timber with pine	SWHW _P		timber	
1807	1	Lewis Dennis	Kouch R.- So. Side	R	hardwood	HW			
1807	1	Lewis Dennis	Kouch R.- So. Side	R	some good land,	HW	good		
1807	1	Lewis Dennis	Kouch R.- So. Side	R	then mixed with soft?_ timber,	HWSW		timber	
1807	1	Lewis Dennis	Kouch R.- So. Side	R	some sugaries, some pine	sM, _P			
1807	1	Lewis Dennis	Kouch R.- So. Side	R	small pines	_P		small	
1807	1	Lewis Dennis	Kouch R.- So. Side	R	hardwood in spots then-	HW			
1807	1	Lewis Dennis	Kouch R.- So. Side	R	mixed timber	HWSW		timber	
1807	1	Lewis Dennis	Kouch R.- N. side	R	mixed timber	SWHW		timber	
1807	1	Lewis Dennis	Kouch R.- N. side	R	mixed with hardwood	HWSW			
1807	1	Lewis Dennis	Kouch R.- N. side	R	poor land	SW	poor		
1807	1	Lewis Dennis	Kouch R.- N. side	R	some hardwood	HW			
1807	1	Lewis Dennis	Kouch R.- N. side	R	small pine, hemlock, and fir, about 1/4 of a mile	_P, eH, bF		small	
1807	1	Lewis Dennis	Kouch R.- N. side	R	a plane here...		Bog		
1807	1	Lewis Dennis	Kouch R.- N. side	R	some cedars along the banks, and -	eC			
1807	1	Lewis Dennis	Kouch R.- N. side	R	some spots hardwood, but chiefly poor on this side of the river	SWHW	poor		
1807	1	Lewis Dennis	Kouch R.- N. side	R	largest pine in this quarter, but not very good- some hardwood	_P, HW		largest	

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil qualitiy/ Veg. Unit class	Structure	Disturbance
1807	1	Lewis Dennis	Kouch R.- N. side	L	upland mixed timber (25 acres)	HWSW			
1807	1	Lewis Dennis	Kouch R.- N. side	L	swamp		WL		
1807	1	Lewis Dennis	Kouch R.- N. side	L	barrens		Barren		
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	burnt woods	unknown			F
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	burnt woods	unknown			F
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	green woods	unknown			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	burnt woods	unknown			F
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	green woods	unknown			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	green mixed woods	HWSW			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	burnt woods	unknown			F
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	burnt woods	unknown			F
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	plains		Bog		
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	burnt woods	unknown			F
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	green woods	unknown			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	burnt woods	unknown			F
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	green woods	unknown			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	green softwood land	SW			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	swampy land		WL		
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	mixed hardwood land	HW			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	good land	HWSW	good		
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	hardwood land	HW			
1837	L11	Peter Muzzeral	Kouch R.- Hwy 117	L	plain		Bog		
1838	142	William Layton	Richi townsite	L	poor land clothed with wood	SW	poor		
1838	142	William Layton	Richi townsite	L	the plain		Bog		
1838	142	William Layton	Richi townsite	L	barren land		Barren		
1838	142	William Layton	Richi townsite	L	burnt woods	unknown			F

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil quality/ Veg. Unit class	Structure	Disturbance
1838	142	William Layton	Richi townsite	L	The Great Plain		Bog		
1838	L7	Peter Muzzeral	Portage R.	R	Spruce Barren	bS	Barren		
1831	4	Alfred Layton	Kouch R.	R	Very poor land	SW	v.poor		
1831	4	Alfred Layton	Kouch R.	R	Open Plain	unforested	Bog		
1831	4	Alfred Layton	Kouch R.	R	Poor Land	SW	poor		
1830	154	Alfred Layton	Kollock Creek-So. Side	C	soil here is a perfect quagmire (cows known to sink, never to return)		WL		
1838	151	Peter Muzzeral	Kouch R.	R	Spruce Barren	bS	Barren		
1838	151	Peter Muzzeral	Kouch R.	R	Open Plain	unforested	Bog		
1807	165	Lewis Dennis	Portage R.	R	Barrens		Barren		
1807	165	Lewis Dennis	Portage R.	R	Barrens		Barren		
1807	165	Lewis Dennis	Portage R.	R	Barrens		Barren		
1807	165	Lewis Dennis	Portage R.	R	Marsh		WL		
1807	165	Lewis Dennis	Portage R.	R	Marsh		WL		
1807	165	Lewis Dennis	Portage R.	R	Considerable sunken marsh		WL		
1807	165	Lewis Dennis	Portage R. area	C	A narrow strip of scrubby wood	unknown		scrubby	
1807	165	Lewis Dennis	Portage R. area	C	barren		Barren		
1830	157	Alfred Layton	Kouch'is R.	R	Open Plain	unforested	Bog		
1830	157	Alfred Layton	Kouch'is R.	L	Swampy land		WL		
1830	157	Alfred Layton	Kouch'is R.	L	Fine hardwoods	HW		fine	
1830	157	Alfred Layton	Kouch'is R.	L	Barren land unfit for cultivation	unknown	barren		
1834	3	William Layton	Kouch R.-entrance	C	Very open wood	unknown		V. open	
1834	3	William Layton	Kouch R.-entrance	C	Dry sandy land	unknown	Dry sand		
1834	3	William Layton	Kouch R.-entrance	R	Very poor land	SW	v.poor		
1826	138	William Layton	Kouch R.	R	poplar grove	Po			
1807	150	Lewis Dennis	Kouch R.- Kellys Beach	C	Chiefly w. birch bushes in front about 5 chs wide	gB, wB		bushes	

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil qualitiy/ Veg. Unit class	Structure	Disturbance
1807	150	Lewis Dennis	Kouch R.- Kellys Beach	C	little timber to be seen but short scrubby pine	P		short, scrubby	
1837	z10	William Layton	Kouch R.	R	Plain		Bog		
1834	159	William Layton	Kouch R.	R	Open Plain	unforested	Bog		
1830	z8	Peter Muzzeral	Kouch R. - N. side	R	Open Plain	unforested	Bog		
1830	z8	Peter Muzzeral	Kouch R. - N. side	R	Spruce Barren	bS	barren		
1827	z5	William Layton	Kouch R.- N. side	R	Strip of good land	HWSW	good		
1827	z5	William Layton	Kouch R.- N. side	R	Spruce swamp	bS	WL		
1827	z5	William Layton	Kouch R.- N. side	R	Naked barren	unforested	barren		
1827	z5	William Layton	Kouch R.- So. side	L	Cedar swamp	eC	WL		
1825	185	Alfred Layton	Mocauque (Eel River)	L	green spruce woods	S			
1825	185	Alfred Layton	Mocauque (Eel River)	L	stinted growth	unknown		stunted	
1825	185	Alfred Layton	Mocauque (Eel River)	L	green woods	unknown			
1825	185	Alfred Layton	Mocauque (Eel River)	L	Plains		Bog		
1825	185	Alfred Layton	Mocauque (Eel River)	L	green woods	unknown			
1825	185	Alfred Layton	Mocauque (Eel River)	L	Spruce swamp	bS	WL		
1825	185	Alfred Layton	Point Sapin	C	Hard woods	HW			
1825	185	Alfred Layton	Point Sapin	C	High gravelly land	unknown	high, gravelly		
1832	153	William Layton	Kouch R.	R	Open Plain	unforested	Bog		
1832	153	William Layton	Kouch R.	R	Very poor land	SW	V. poor		
1832	153	William Layton	Kouch R.	R	good land	HWSW	good		
1832	153	William Layton	Kouch R.	R	Plain		Bog		
1820	2	William Layton	Polly's Creek	C	Very poor land	SW	V. poor		
1820	2	William Layton	Polly's Creek	C	Plain		Bog		

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil quality/ Veg. Unit class	Structure	Disturbance
1820	2	William Layton	Polly's Creek	C	softwood growth	SW			
1820	2	William Layton	Polly's Creek	C	pine woods	_P			
1820	2	William Layton	Polly's Creek	R	softwood land	SW			
1820	2	William Layton	Polly's Creek	R	Spruce Barren	bS	Barren		
1820	2	William Layton	Polly's Creek	R	Pine and Spruce Growth	_P, _S			
1820	2	William Layton	Polly's Creek	R	pine woods	_P			
183?	8a	?	Point Sapin	C	sunken wet		WL		
1825	6	Alfred Layton	Kouch R.-N. side	R	Fine Hardwood Land	HW	fine	fine	
1825	6	Alfred Layton	Kouch R.-N. side	R	Extensive Grove of Red Pine Timber	rP		timber	
1825	6	Alfred Layton	Kouch R.-N. side	L	White Pine Timber	wP		timber	
1825	6	Alfred Layton	Kouch R.-N. side	R	Fine Hardwood Land	HW	fine	fine	
1825	6	Alfred Layton	Kouch R. - So. Side	R	Extensive Grove of Red Pine	rP			
1825	6	Alfred Layton	Kouch R. - So. Side	L	White Pine Timber Grove	wP		timber	
1825	6	Alfred Layton	Kouch R. - So. Side	R	Fine Hardwood Land	HW	fine	fine	
1831	K25	Alfred Layton	Richi R.	R	Dry Beech Land	Be	Dry		
1831	K25	Alfred Layton	Richi R.	R	Maple Growth	_M			
1831	K25	Alfred Layton	Richi R.	R	Very poor land	SW	v. poor		
1831	K25	Alfred Layton	Richi R.	R	Ash and Cedar Swamp	bA, eC	WL		
1831	K25	Alfred Layton	Richi R.-St Nicholas R.	R	Very poor land	SW	V. poor		
1831	K25	Alfred Layton	Richi R.-St Nicholas R.	R	burnt woods	unknown			F
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Fine Hard Wood Land *which with few exceptions continues to the Bay du Vent R.	HW	fine	fine	
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Fine Hard Wood Land	HW	fine	fine	
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Burnt Spruce Swamp	bS	WL		F
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Burnt Spruce	_S			F
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Burnt Spruce Barren	bS	barren		F

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil qualitiy/ Veg. Unit class	Structure	Disturbance
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	All very poor land *being nothing but spruce barren	bS	barren/ v. poor		
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Poor Land	SW	poor		
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Barren Land		barren		
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	Barren		barren		
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	*Fine hardwoods in front (a witness t.=Be) but-	HW	fine	fine	
1830	L1	Alfred Layton	Hwy 11-North Kouch R.	L	*Spruce swamp in rear	bS	WL		
1856	227	Peter Muzzeral	Aldouane R.-So side	L	Hard and Soft wood land	HWSW			
1844	302	J.G.G. Layton	Richi R.-So. Side	L	*good land with a mixed growth of Birch Spruce and Maple over 124 acres	_B, _S, _M	good		
1831	K3	Alfred Layton	Betw/Kouch R.-Kouch'is R.(post rd.)	L	Fine Land	HWSW	fine		
1831	K3	Alfred Layton	Betw/Kouch R.-Kouch'is R.(post rd.)	L	burnt woods	unknown			F
1831	K3	Alfred Layton	Betw/Kouch R.-Kouch'is R.(post rd.)	L	Spruce barren	bS	Barren		
1831	K3	Alfred Layton	Betw/Kouch R.-Kouch'is R.(post rd.)	L	Fine Hardwood Land	HW	fine	fine	
1831	K3	Alfred Layton	Betw/Kouch R.-Kouch'is R.(post rd.)	L	Spruce Barren	bS	barren		
1831	K3	Alfred Layton	Betw/Kouch R.-Kouch'is R.(post rd.)	L	Good land	HWSW	good		
18??	K56	B.R. Jousm?	Bay du Vin R.	R	*on a 220 ac lot: very good land, timbered with Birch, Maple, Hemlock, and some pine	_B, _M, eH, _P	V. good	timber	
1834	225	Alfred Layton	Eel River	L	burnt woods	unknown			F
1834	225	Alfred Layton	Eel River	L	burnt woods	unknown			F
1834	225	Alfred Layton	Eel River	R	Meadow of an inferior description		WL		
1834	225	Alfred Layton	Eel River	L	burnt woods	unknown			F
1825	K24	unknown	St Nicholas R.	R	Hardwood Land	HW			
1825	K24	unknown	St Nicholas R.	R	Hardwood	HW			
1825	K24	unknown	St Nicholas R.	R	Swampy		WL		
1825	K19	unknown	St Nicholas R.	R	good land	HWSW	good		

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil qualitiy/ Veg. Unit class	Structure	Disturbance
1825	K20	unknown	St Nicholas R.	R	Barren		barren		
1825	K21	unknown	St Nicholas R.-East Br	R	good land	HWSW	good		
1825	K22	unknown	St Nicholas R.-East Br	R	good land	HWSW	good		
1825	K23	unknown	St Nicholas R.-East Br	R	poor land	SW	poor		
1825	z25		North	C	Open Plains		Bog		
1837	z26	William Layton	Point Sapin	L	Open Plain		Bog		
1837	z26	William Layton	Point Sapin	C	Spruce Barren	bS	Barren		
1837	z26	William Layton	Point Sapin	C	Plain		Bog		
1826	z6	William Layton	Eel River	L	Naked barren		Barren		
1826	z6	William Layton	Eel River	R	All burned	unknown			F
1826	z6	William Layton	Eel River	R	Naked barren		Barren		
1826	z6	William Layton	Eel River	L	Fir or Tamarack	bF, La	Barren		
1826	z6	William Layton	Eel River	R	All burned, root and branch, no marks left	unknown			F
1826	z6	William Layton	Eel River	R	Alder land (directly on brook bank)	al			
1826	z6	William Layton	Point Sapin	C	Naked Barren (adjacent to ocean beech)	unforested	Barren		
1826	z6	William Layton	Point Sapin	C	Sunken Barren Land (adjacent to beech)		Barren		
1826	z6	William Layton	Point Sapin	C	Very Poor land	SW	V. poor		
1826	z6	William Layton	Point Sapin	C	Very Poor	SW	V. poor		
1899	301	unknown	Kouch'is R.-So side	R	burnt woods	unknown			F
1899	301	unknown	Kouch'is R.-So side	R	burnt woods	unknown			F
1899	301	unknown	Kouch'is R.-N. side	R	burnt woods	unknown			F
1899	301	unknown	Kouch'is R.-N. side	R	mossy plain	unforested	Bog		
1899	301	unknown	Kouch'is R.-N. side	L	second growth	unknown			?
1899	301	unknown	Kouch'is R.-N. side	R	green woods	unknown			
1899	301	unknown	Kouch'is R.-N. side	R	burnt woods	unknown			F
1831	z2	Alfred Layton	Kouch R.- N. side	L	Burnt Spruce Woods	S			F

Year	Sketch No.	Surveyor	Place	Land Class	Descriptions from Surveyor Plans	Species Interpretation	Soil quality/ Veg. Unit class	Structure	Disturbance
1831	z2	Alfred Layton	Kouch R.- N. side	R	good land	HWSW	good		
1831	z2	Alfred Layton	Kouch R.- N. side	R	Fine Hardwood	HW		fine	
1831	z2	Alfred Layton	Kouch R.- So. Side	R	Fine Hard Land	HW	fine	fine	
1831	z2	Alfred Layton	Kouch R.- So. Side	R	Low Barren Land		Barren		
1831	K26	Alfred Layton	Richi R.-Molus R.	R	Fine Hardwood	HW		fine	
1831	K26	Alfred Layton	Richi R.-Molus R.	R	Fine Hardwood	HW		fine	
1831	K26	Alfred Layton	Richi R.-Molus R.	R	Spruce Barren	bS	Barren		
1831	K26	Alfred Layton	Molus R.	R	Burnt Woods	unknown			F
1838	z16	unknown	Kouch'is R.-N. side	R	burnt woods	unknown			F
1894	L9	John Stevenson	Black River	L	open plain	unforested	Bog		
1894	L9	John Stevenson	Black River	R	second growth of mixed wood	IHSW			?
1894	L9	John Stevenson	Black River	L	Hemlock land	eH			
1894	L9	John Stevenson	Black River	L	Clear open plain	unforested	Bog		

Land class codes: R= Riparian, L= Land, C= Coastal

Species codes: HW= hardwood spp., SW= softwood spp., HWSW and SWHW= mixed timber, IHSW= intolerant hardwood-softwood, al= *Alnus* spp., _B= *Betula* spp., bS= *Picea mariana*, bA= *Fraxinus nigra*, Be= *Fagus grandifolia*, bF= *Abies balsamea*, eC= *Thuja occidentalis*, eH= *Tsuga canadensis*, gB= *Betula populifolia*, La= *Larix laricina*, _M= *Acer* spp., sM= *Acer saccharum*, _P= *Pinus* spp., Po= *Populus* spp., rP= *Pinus resinosa*, _S= *Picea* spp., wB= *Betula papyrifera*, wP= *Pinus strobus*
WL= wetland

Disturbance: F= Fire, '?'= unknown disturbance agent

APPENDIX 3-5 FOREST DESCRIPTIONS CITED FROM RECTANGULAR SURVEY PLAN DRAWINGS, WITH INTERPRETATIONS OF STAND TYPES AND TREE SPECIES, AND WHEN POSSIBLE DISTURBANCE AGENTS.

Year	Sketch No.	Surveyor	Place	Descriptions from Surveyor Plans	Species Inter-pretation	Disturbance
1835	L3	William Layton	Kouchis R.	Unknown	Unknown	
1835	L3	William Layton	Kouchis R.	Unknown	Unknown	
1835	L3	William Layton	Kouchis R.	Barren Land	bog	
1835	L3	William Layton	Kouchis R.	Pine and Spruce Land	_P, _S	
1835	L3	William Layton	Kouchis R.	Unknown	Unknown	
1835	L3	William Layton	Kouchis R.	Spruce and Pine Land	_S, _P	
1835	L3	William Layton	Kouchis R.	Unknown	Unknown	
1835	L3	William Layton	Kouchis R.	Lower Meadow	WL	
1835	L3	William Layton	Kouchis R.	Mixed Land	HWSW	
1835	L3	William Layton	Kouchis R.	Spruce Land	_S	
1835	L3	William Layton	Kouch R.	Good Land	HWSW	
1835	L3	William Layton	Kouch R.	Hardwood Land	HW	
1835	L3	William Layton	Kouch R.	Swamp	WL	
1835	L3	William Layton	Kouch R.	Mixed Land	HWSW	
1835	L3	William Layton	Kouch R.	Unknown	Unknown	
1835	L3	William Layton	Kouch R.	Pine and Spruce Land	_P, _S	
1835	L3	William Layton	Kouch R.	Barren Land	bog	
1835	L3	William Layton	Kouch R.	Hemlock Land	eH	
1835	L3	William Layton	Kouchis R.	Unknown	Unknown	
1835	L3	William Layton	Kouchis R.	Swamp	WL	
1835	L3	William Layton	Kouchis R.	Good Hemlock Land	eH	
1835	L3	William Layton	Kouchis R.	Unknown	Unknown	
1835	L3	William Layton	Kouchis R.	Barren	bog	
1835	L3	William Layton	Kouchis R.	Mixed Land	HWSW	
1835	L3	William Layton	Kouchis R.	Spruce Barren	bS	
1835	L3	William Layton	Kouchis R.	Hardwood Land	HW	
1835	L3	William Layton	Kouchis R.	Unknown	Unknown	
1835	L3	William Layton	Kouchis R.	Mixed Land	HWSW	
1835	L3	William Layton	Kouchis R.	Spruce and Pine Land	_S, _P	
1835	L3	William Layton	Kouchis R.	Mixed Hemlock and Pine Land	eH, _P	
1835	L3	William Layton	Kouchis R.	Barren	bog	
1835	L3	William Layton	Kouchis R.	Pine and Spruce Land	_P, _S	
1835	L3	William Layton	Kouchis R.	Hardwood and Hemlock Land	HW, eH	
1835	L3	William Layton	Kouchis R.	Mixed Land	HWSW	

Year	Sketch No.	Surveyor	Place	Descriptions from Surveyor Plans	Species Inter-pretation	Disturbance
1835	L3	William Layton	Kouchis R.	Swamp	WL	
1835	L3	William Layton	Kouchis R.	Mixed Land	HWSW	
1835	L3	William Layton	Kouchis R.	Hardwood and Hemlock Land	HW, eH	
1838	L7	unknown	Ptge R.	Unknown	Unknown	
1838	L7	unknown	Ptge R.	Unknown	Unknown	
1838	L7	unknown	Ptge R.	Green Swamp	WL	
1838	L7	unknown	Ptge R.	Burnt Wood	Unknown	F
1838	L7	unknown	Ptge R.	Barren	bog	
1838	L7	unknown	Ptge R.	Plain	bog	
1838	L7	unknown	Ptge R.	Green Swamp	WL	
1838	L7	unknown	Ptge R.	Burnt Land	Unknown	F
1838	L7	unknown	Ptge R.	Mixed Land	HWSW	
1838	L7	unknown	Ptge R.	Swamp	WL	
1838	L7	unknown	Ptge R.	Good Hemlock Land	eH	
1838	L7	unknown	Ptge R.	Swamp	WL	
1838	L7	unknown	Ptge R.	Mixed	HWSW	
1838	L7	unknown	Ptge R.	Spruce and Cedar Swamp	bS, eC	
1838	L7	unknown	Ptge R.	Low Land	bog	
1838	L7	unknown	Ptge R.	Good Land	HWSW	
1838	L7	unknown	Ptge R.	Mixed Land	HWSW	
1838	L7	unknown	Ptge R.	Lime Stone Land	Unknown	
1838	L7	unknown	Ptge R.	Burnt Land	Unknown	F
1838	L7	unknown	Ptge R.	Green Wood	Unknown	
1838	L7	unknown	Ptge R.	Burnt Land	Unknown	F
1838	L7	unknown	Ptge R.	Spruce Swamp	bS	
1838	L7	unknown	Ptge R.	Hemlock Land	eH	
1838	L2	William Layton	Richi R.	??	Unknown	
1838	L2	William Layton	Richi R.	Mixed Land	HWSW	
1838	L2	William Layton	Richi R.	??	Unknown	
1838	L2	William Layton	Richi R.	Mixed Land	HWSW	
1838	L2	William Layton	Richi R.	??	Unknown	
1838	L2	William Layton	Richi R.	Mixed Land	HWSW	
1838	L2	William Layton	Richi R.	Spruce and Hardwood	_S, HW	
1838	L2	William Layton	Richi R.	Hemlock	eH	
1838	L2	William Layton	Kouchis R.	??	Unknown	
1838	L2	William Layton	Kouchis R.	Hardwood Land	HW	
1838	L2	William Layton	Kouchis R.	Mixed Land	SWHW	
1838	L2	William Layton	Kouchis R.	??	Unknown	
1838	L2	William Layton	Kouchis R.	Mixed Land	SWHW	

Year	Sketch No.	Surveyor	Place	Descriptions from Surveyor Plans	Species Inter-pretation	Disturbance
1838	L2	William Layton	Kouchis R.	??	Unknown	
1838	L2	William Layton	Richi R.	Spruce Barren	bS	
1838	L2	William Layton	Richi R.	Hardwood Land	HW	
1838	L2	William Layton	Richi R.	Unknown	Unknown	
1838	L2	William Layton	Richi R.	Mixed Land	SWHW	
1838	L2	William Layton	Richi R.	Hemlock Land	eH	
1838	L2	William Layton	Richi R.	Spruce Land	_S	
1838	L2	William Layton	Richi R.	Mixed Land	SWHW	
1838	L2	William Layton	Richi R.	Unknown	Unknown	
1838	L2	William Layton	Richi R.	Unknown	Unknown	
1838	L2	William Layton	Richi R.	Pine Land	_P	
1838	L2	William Layton	Richi R.	Hardwood Land	HW	
1838	L2	William Layton	Kouchis R.	Unknown	Unknown	
1838	L2	William Layton	Kouchis R.	Pine Land	_P	
1838	L2	William Layton	Kouchis R.	Mixed Land	SWHW	
1838	L2	William Layton	Kouchis R.	Spruce Barren	bS	
1838	L2	William Layton	Kouchis R.	Unknown	Unknown	
1838	L2	William Layton	Richi R.	Mixed Land	SWHW	
1838	L2	William Layton	Richi R.	Hemlock Land	eH	
1838	L2	William Layton	Richi R.	Pine Land	_P	
1838	L2	William Layton	Richi R.	Pine Land	_P	
1838	L2	William Layton	Richi R.	??	Unknown	
1838	L2	William Layton	Richi R.	Pine Land	_P	
1838	L2	William Layton	Richi R.	Hardwood Land	HW	
1838	L2	William Layton	Richi R.	Ash Swamp	bA	
1838	L2	William Layton	Richi R.	Spruce Barren	bS	
1838	L2	William Layton	Richi R.	Spruce Barren	bS	
1838	L2	William Layton	Richi R.	Mixed Land	SWHW	
1838	L2	William Layton	Richi R.	??	Unknown	
1838	L2	William Layton	Richi R.	Unknown	Unknown	
1838	L2	William Layton	Richi R.	??	Unknown	
1838	L2	William Layton	Richi R.	Mixed Land	SWHW	
1838	L2	William Layton	Richi R.	Large Meadow	WL	
1838	L2	William Layton	Richi R.	??	Unknown	
1838	L2	William Layton	Kouchis R.	Mixed Land	SWHW	
1838	L2	William Layton	Kouchis R.	??	Unknown	
1838	L2	William Layton	Richi R.	Mixed Land	SWHW	
1838	L2	William Layton	Richi R.	Spruce Barren	bS	
1838	L2	William Layton	Richi R.	Unknown	Unknown	

Year	Sketch No.	Surveyor	Place	Descriptions from Surveyor Plans	Species Inter-pretation	Disturbance
1836	L5	William Layton	Black R.	Burnt Barren Land	Unknown	F
1836	L5	William Layton	Black R.	Unknown	Unknown	
1836	L5	William Layton	Black R.	Plain	bog	
1836	L5	William Layton	Black R.	Good Mixed Land	SWHW	
1836	L5	William Layton	Black R.	Barren	unforested	
1836	L5	William Layton	Black R.	Pine Land	_P	
1835	L3	William Layton	Kouchis R.	Spruce and Cedar Land	bS, eC	

Species codes: HW= hardwood spp., SW= softwood spp., HWSW and SWHW= mixed timber, IHSW= intolerant hardwood-softwood, al= *Alnus* spp., _B= *Betula* spp., bS= *Picea mariana*, bA= *Fraxinus nigra*, Be= *Fagus grandifolia*, bF= *Abies balsamea,* eC= *Thuja occidentalis*, eH= *Tsuga canadensis*, gB= *Betula populifolia*, La= *Larix laricina,* _M= *Acer* spp., sM= *Acer saccharum*, _P= *Pinus* spp., Po= *Populus* spp., rP= *Pinus resinosa,* _S= *Picea* spp., wB= *Betula papyrifera,* wP= *Pinus strobus*, WL= wetland

APPENDIX 4-1 TOTAL WHITE PINE SQUARE TIMBER VOLUMES (YRS 1820-1839) HARVESTED ON RIVERS LOCATED WITHIN THE EASTERN NEW BRUNSWICK LOWLANDS.

RIVER	1820	1821	1822	1823	1824	1825	1826	1827	1828	1829	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839	Total
Bay du Vin	**0**	**1910**	**0**	**1550**	**2850**	**5000**	**1500**	**2950**	**6250**	**4630**	**5610**	**4170**	**1500**	**3150**	**980**	**200**	**1110**	**300**	**0**	**50**	**43710**
Bay du Vin	*0*	*2158*	*0*	*1752*	*3221*	*5650*	*1695*	*3334*	*7063*	*5232*	*6339*	*4712*	*1695*	*3560*	*1107*	*226*	*1254*	*339*	*0*	*57*	*49392*
Kouchibouguac	**300**	**4300**	**1300**	**7300**	**19400**	**14700**	**5400**	**3450**	**12460**	**11386**	**5160**	**5040**	**4150**	**1220**	**4090**	**5340**	**2295**	**800**	**450**	**350**	**108891**
Kouchibouguac	*339*	*4859*	*1469*	*8249*	*21922*	*16611*	*6102*	*3899*	*14080*	*12866*	*5831*	*5695*	*4690*	*1379*	*4622*	*6034*	*2593*	*904*	*509*	*396*	*123047*
Kouchibouguacis	**0**	**0**	**500**	**8500**	**13250**	**5800**	**2500**	**4900**	**12800**	**5837**	**5950**	**2470**	**2050**	**1550**	**300**	**720**	**350**	**100**	**1590**	**1030**	**70197**
Kouchibouguacis	*0*	*0*	*565*	*9605*	*14973*	*6554*	*2825*	*5537*	*14464*	*6596*	*6724*	*2791*	*2317*	*1752*	*339*	*814*	*396*	*113*	*1797*	*1164*	*79323*
Richibucto	**1920**	**0**	**250**	**2520**	**8550**	**5600**	**3410**	**1160**	**3040**	**3705**	**1780**	**990**	**2300**	**400**	**210**	**800**	**2910**	**1110**	**720**	**810**	**42185**
Richibucto	*2170*	*0*	*283*	*2848*	*9662*	*6328*	*3853*	*1311*	*3435*	*4187*	*2011*	*1119*	*2599*	*452*	*237*	*904*	*3288*	*1254*	*814*	*915*	*47669*
Bass	**0**	**0**	**0**	**1300**	**1650**	**1700**	**1500**	**2100**	**2550**	**820**	**760**	**2320**	**100**	**0**	**760**	**770**	**700**	**0**	**200**	**0**	**17230**
Bass	*0*	*0*	*0*	*1469*	*1865*	*1921*	*1695*	*2373*	*2882*	*927*	*859*	*2622*	*113*	*0*	*859*	*870*	*791*	*0*	*226*	*0*	*19470*
Coal Branch	**600**	**0**	**0**	**500**	**0**	**0**	**300**	**500**	**260**	**100**	**2040**	**0**	**700**	**50**	**400**	**0**	**200**	**50**	**0**	**100**	**5800**
Coal Branch	*678*	*0*	*0*	*565*	*0*	*0*	*339*	*565*	*294*	*113*	*2305*	*0*	*791*	*57*	*452*	*0*	*226*	*57*	*0*	*113*	*6554*
Molus	**0**	**0**	**0**	**500**	**6700**	**1350**	**200**	**300**	**1750**	**740**	**800**	**910**	**0**	**0**	**240**	**450**	**900**	**230**	**25**	**0**	**15095**
Molus	*0*	*0*	*0*	*565*	*7571*	*1526*	*226*	*339*	*1978*	*836*	*904*	*1028*	*0*	*0*	*271*	*509*	*1017*	*260*	*28*	*0*	*17057*
St Nicholas	**600**	**2000**	**0**	**900**	**2550**	**5450**	**5550**	**2700**	**2300**	**3100**	**5410**	**250**	**670**	**520**	**360**	**1110**	**430**	**570**	**0**	**450**	**34920**
St Nicholas	*678*	*2260*	*0*	*1017*	*2882*	*6159*	*6272*	*3051*	*2599*	*3503*	*6113*	*283*	*757*	*588*	*407*	*1254*	*486*	*644*	*0*	*509*	*39460*
Aldouane/ St Charles	**0**	**0**	**0**	**1100**	**1900**	**880**	**2000**	**850**	**400**	**550**	**900**	**100**	**200**	**100**	**100**	**0**	**0**	**70**	**200**	**0**	**9350**
Aldouane/ St Charles	*0*	*0*	*0*	*1243*	*2147*	*994*	*2260*	*961*	*452*	*622*	*1017*	*113*	*226*	*113*	*113*	*0*	*0*	*79*	*226*	*0*	*10566*
Total annual tons	**3420**	**8210**	**2050**	**24170**	**56850**	**40480**	**22360**	**18910**	**41810**	**30868**	**28410**	**16250**	**11670**	**6990**	**7440**	**9390**	**8895**	**3230**	**3185**	**2790**	**347378**
Total annual m³	*3865*	*9277*	*2317*	*27312*	*64241*	*45742*	*25267*	*21368*	*47245*	*34881*	*32103*	*18363*	*13187*	*7899*	*8407*	*10611*	*10051*	*3650*	*3599*	*3153*	*392537*

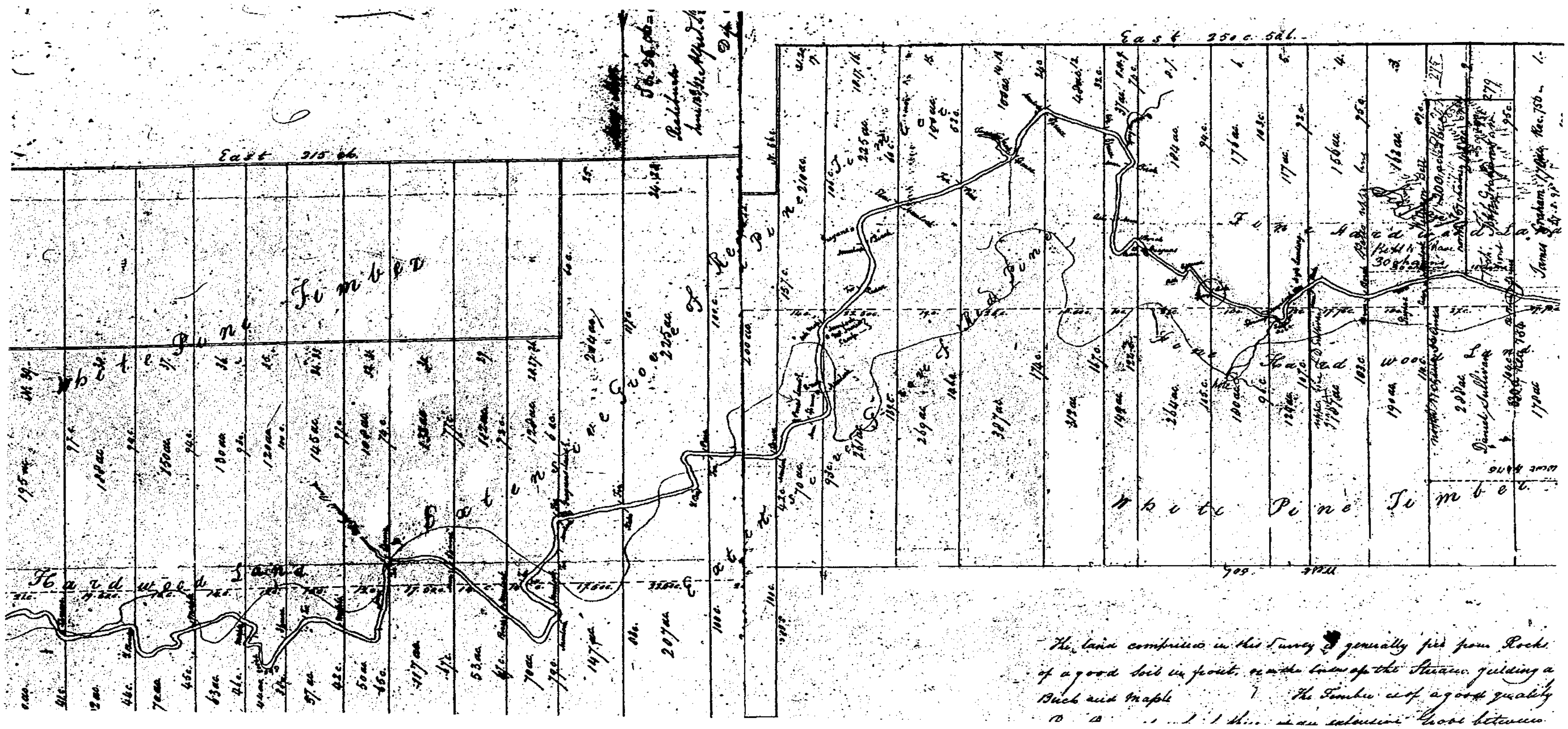
Bold type depicts original quantities derived from archived ton timber records. Italic type represents quantities converted to cubic meters.

APPENDIX 4-2. PERCENTAGE VOLUME LIVE CROWN OF EASTERN WHITE PINE (*Pinus strobus*) ON TREES LARGER THAN 48 CM DBH OUTSIDE BARK.

DBH outside bark	radius at DBH	Tree height	Height to live crown	Diameter outside bark at live crown	% length trunk in live crown	bole length within live crown	radius at crown	Area at live crown (cm^2) Ab= pi r^2	Area at live crown (m^2) Ab= pi r^2	Area at DBH (m^2)	Vol. of bole below crown (Parab. Frust)	Vol of bole within crown (Cone)	Total stem volume	**% vol. stem within live crown**
78	39.00	33.1	11.0	61	66.77	22.1	30.3	2882.8	0.288	0.48	4.2255	2.1024	6.328	**33.22**
72.4	36.20	24.2	6.1	50	74.79	18.1	25.2	1994	0.199	0.41	1.8587	1.1910	3.050	**39.05**
62.9	31.45	35.5	25.2	37	29.01	10.3	18.3	1045.8	0.105	0.31	5.2237	0.3555	5.579	**6.37**
62.7	31.35	29	6.8	54	76.55	22.2	27.1	2306	0.231	0.31	1.8381	1.6894	3.527	**47.89**
61	30.50	30.8	4.4	58	85.71	26.4	28.9	2622.6	0.262	0.29	1.2150	2.2848	3.500	**65.28**
54.3	27.15	30.8	18.9	34	38.64	11.9	16.8	886.23	0.089	0.23	3.0110	0.3480	3.359	**10.36**
53.3	26.65	25.5	11.1	41	56.47	14.4	20.5	1313.2	0.131	0.22	1.9498	0.6240	2.574	**24.24**
52.8	26.40	36	22.3	31	38.06	13.7	15.4	739.85	0.074	0.22	3.2779	0.3345	3.612	**9.26**
50.8	25.40	32.2	4.4	45	86.34	27.8	22.7	1618	0.162	0.2	0.7960	1.4844	2.280	**65.09**
50.7	25.35	28.4	17.6	32	38.03	10.8	15.8	778.92	0.078	0.2	2.4454	0.2776	2.723	**10.19**
49.8	24.90	22.4	9.9	39	55.80	12.5	19.6	1206.3	0.121	0.19	1.5376	0.4976	2.035	**24.45**
47.8	23.90	28.7	15.0	33	47.74	13.7	16.7	870.48	0.087	0.18	2.0029	0.3935	2.396	**16.42**
													Average	**29.32**
													St. Dev.	21.10

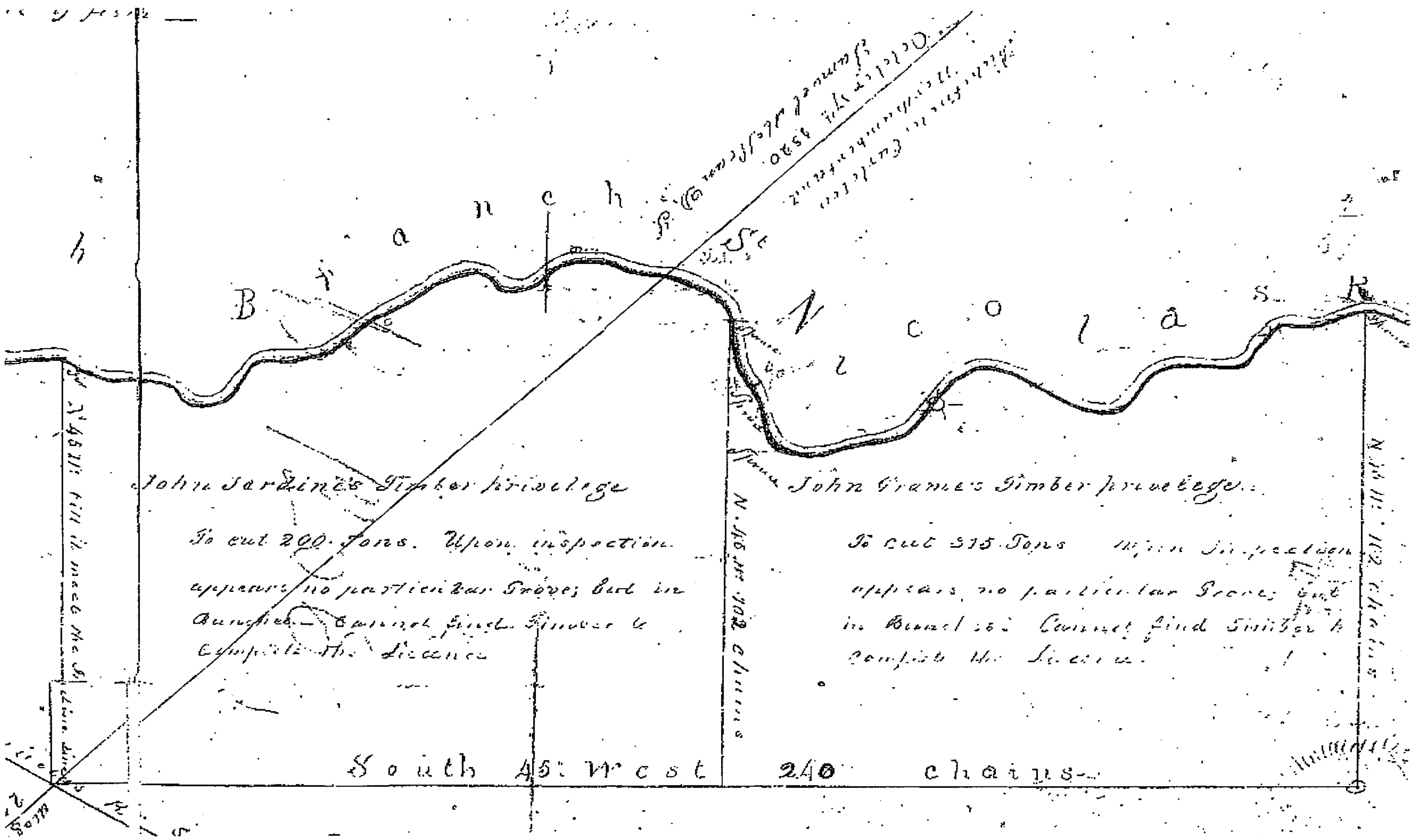
Data from OMNR.
Paraboloid frustrum and cone formulae from Husch *et al.* (2003).

APPENDIX 4-3. SURVEY SKETCH OF KOUCHIBOUGUAC RIVER *CA.* 1825 DEPICTING '*EXTENSIVE GROVES OF RED PINE TIMBER*' AND OTHER FOREST TYPES.



(PANB RS687B, KT2/61, microfiche)

APPENDIX 4-4. PLAN DRAWING *CA.* 1820 ILLUSTRATING TWO TIMBER BERTHS ON THE SO. BRANCH OF ST. NICHOLAS RIVER THAT EXTEND APPROX. 2050 M (102 CHAINS) AWAY FROM THE RIVERBANK.



(PANB RS687.B, KT 1-30)

APPENDIX 5-1 ECOSYSTEM ARCHAEOLOGY METHODS

- An excerpt from Ponomarenko (2006 *in progress*), internal report to Kouchibouguac National Park.

Introduction

Botanical identification of macroscopic (> 2 mm) charcoal from former plough horizons in abandoned farmlands was used to reconstruct pre-agricultural species composition within the Kouchibouguac National Park. Land clearance for agricultural purposes always involves burning. It can be burning of logging slash piles in the sites cleared to establish a permanent field or *in situ* burning of litter and shrubs in swiddens. Even if localized initially, products of combustion become spread throughout the field by the lateral mass movement during ploughing. The species composition of cleared tree stands can therefore be reconstructed by analyzing a sufficient sample of charcoal fragments from the plough horizons. The reconstruction can be done by identifying charcoal to either species or (in most cases) genus level. Such analysis can be complemented by the trace fossil analysis: traces of root systems of the last pre-agricultural tree generation preserved *in situ* give some idea of tree species at the time of the land clearance, as well as of the density and spatial distribution of the pre-agricultural tree generation on abandoned fields.

Botanical identification of soil charcoal.

Botanical identification of charcoal is based on comparison of its structure with wood descriptions, wood microphotographs, and reference collections (e.g., Miles 1978; Butterfield and Meylan 1980; Panshin and de Zeeuw 1980; Barefoot and Hankins 1982). Many deciduous species can be identified using a binocular microscope. Identification of coniferous species requires a higher magnification with the utilization of incident-light petrographic microscopes and, in some cases, scanning electron microscopy.

Charcoal fragments in formerly ploughed layers are fairly small, ranging from 2 to 20 mm. The soil charcoal usually originates from branches and twigs, which impedes a distinction between some species *(e.g.,* white oak and chestnut*)*. Fairly young twigs (1-10 years) of some species have so called juvenile wood that is not identifiable.

However, a large proportion of the twigs that appeared in our charcoal assemblages is older than 10 years and could be as old as 80 years: such twigs represent a good opportunity for wood identification.

Wood of some genera, such as *Acer and Betula* cannot be identified to the species level based on the charcoal investigation, whereas wood of many other genera can be. Given the small size of charcoal fragments in former plough layers and a great number of samples needed for a site representation, identification of charcoal down to the species level would be impractical in our study. In most cases, we identified charcoal down to the genus level only. However, some genera are represented in the study area by only one species. Examples are balsam fir (*Abies balsamea*), beech, (*Fagus grandifolia*), hemlock (*Tsuga canadensis*), and cedar (*Thuja occidentalis*). Further identification has been made for pine and oak species. Pine wood morphology allows pine species to be discerned into several groups. These are represented by Strobus, Sylvestris, and Taeda groups in New Brunswick. Only one species of pine from each group is recorded in the area: they are *P. strobus, P. resinosa,* and *P. banksiana* respectively. Red oak wood has a morphology that allows distinguishing it from the wood of the white oak group (e.g. white and bur oaks).

Sources of charcoal in plough horizons

Logging slash charcoal

In several trenches, under the plough layer we recorded logging slash fireplaces (burn pits), where logging slash was piled and burned. The structures contained several (3 to 6) layers of charred wood and ash, alternated with sand layers. The charcoal originated from branches and twigs, often represented by fragments with a well preserved rounded surface of the twigs. In lower layers, charcoal had features of re-burning under a high temperature, but with a lack of oxygen. Such structure reflects several stages of clearing a forest plot, possibly separated from another by one or several nights. The species composition of the charcoal assemblages from the logging slash fireplaces was compared to that of a combined charcoal sample collected from the plough horizon in several (3-5) test pits within the same sites. The species composition appeared the same in both assemblages, which confirms that the majority of charcoal comes from the logging slash fireplaces. To confirm that the age of the charcoal used to reconstruct the species composition correlates with the time of the land clearance, charcoal assemblages from nine sites were radiocarbon dated. The ages ranged from 138 to 250 years, which correlates with the historical data on the time of the land clearance; differences are likely related to the difference in the absolute age of burned trees in different sites at the time of the land clearance.

Charcoal fragments that we find in the plough layers likely originate from several logging slash fireplaces within the field. During ploughing, the fragments are dragged for some distances from the places of their original bedding in various directions. A single ploughing action moves a particle only for 0.5-2.0 meters (Van Oost *et al.* 2000), but a multiple repetition of such action leads to a significant re-distribution of charcoal particles. The distance and extent of such movement can be estimated by applying research of ceramic fragments in archaeological sites. Long-term field experiments and surficial archaeological surveys show that the dispersal may reach ~100 meters after 200 years of ploughing (Yorston *et al.* 1990).

We assumed that if several fireplaces were set within a field during the land clearance, it would provide a sufficient mixing of combustion products throughout the field.

Natural wildfire and escaped land clearance fires

A proportion of fields were situated in areas deforested by fires, either natural wildfires or escaped land clearance fires. Prior to this study, no technique was available to reconstruct effects of escaped fires on charcoal assemblages in subsequently cultivated sites. Our data showed that plough horizons in some sites contained a high amount of charcoal, with an average size of fragments much higher than an upper quartile of fragment sizes in the other sites. In the same sites, the species represented in charcoal assemblages were always strongly dominated by confers, often with a significant proportion of ground cover species (such as *Taxus*). These sites have either no charcoal of deciduous tree species or some charcoal of the deciduous species that shed branches frequently (e.g., aspen and ash). Finally, in the largest cultivated massifs within Kouchibouguac NP, such plough horizons were associated with margins/peripheries of the massifs. The above-described set of features was interpreted as the result of bringing into ploughing the sites deforested by fires shortly prior to their cultivation. In such sites, the species composition of the charcoal assemblages does not reflect the species composition of a cleared tree stand as accurately as in the sites cleared by logging: mostly the easily ignited species will be represented in the charcoal assemblages.

Sampling techniques

Charcoal was collected using two methods:

1) In each site, charcoal was collected from a trench wall so that the whole perimeter of the trench was represented in the charcoal assemblage. During such sampling, preference was given to larger fragments, but in most cases they were so sparse that all charcoal available was sampled. In the collected assemblages, 20 to 50 fragments were identified per site, depending on the diversity of species represented in the assemblages and a number of identifiable fragments.
2) To collect uniform data for each field, charcoal was sampled from test pits in catenas running across the fields. The test pits were of a uniform size, 50x50 cm^2. The soil mass from the plough layer within the 50x50cm^2 squares was sifted through a sieve with 2 mm openings, and all charcoal fragments larger than 2 mm were collected for a further identification. Amount of charcoal fragments and their size varied substantially within the catenas: in some test pits, we were able to collect only several charcoal fragments less than 4 mm in diameter, whereas in others charcoal was abundant and of a diameter up to 1 cm. As we realize now, those test pits that were rich in charcoal, were located in close proximity to logging slash fireplaces. We were not able to process all the charcoal sampled within the catenas, as the amount of material by far exceeded the available budget. At this stage, we limited identifications to 3-5 test pits within each field.

Data analysis and presentation

The number of fragments identified for each field had to be statistically representative. At the same time, charcoal identification is a time consuming procedure. Therefore, it was impractical to do more than 30 identifications per sampling unit due to time and budget constraints. We identified a minimum of 30 fragments for sites with a monotonous species composition (1-3 species), and a maximum of 50 fragments for sites with high species diversity (6-10 genera).

The results are presented in two forms. For each tree species/genus, its percentage of the whole charcoal assemblage in the site was calculated. Besides the identifiable charcoal, most assemblages contained bark and semi-coke that are not identifiable; therefore the sum of percentages for all tree species in a site is less than 100%. To estimate the proportions/ratios between various tree species in each site, their percentages were calculated taking into account tree species only (total percentage of tree species was assumed 100%; ground cover species, such as *Taxus*, and non-identifiable components were excluded). It must be noted that in some sites a number of species recorded in charcoal assemblages was so high (7-10 genera) that identification of even 50 fragments may be insufficient for the appropriate characterization of the percentage of each species in the richest tree-stands.

In each assemblage, length and width of charcoal fragments were measured for a further analysis of size distributions/selective preservation of the identified species. Commonly, larger fragments (an upper quartile of the length distribution) originated from such species as birch and maple, pine, and unburned or slightly burned fragments of cedar. Therefore, we can conclude at this stage that the above-mentioned species have a better preservation than the other components of charcoal assemblages, and can be therefore overrepresented in comparison to other species logged and burned along with them.

References

Barefoot, A.C. and Hankins, F.W. 1982. Identification of Modern and Tertiary Woods. Clarendon Press, Oxford, UK. 189 pp.

Butterfield B.G. and Meylan, B.A. 1980. Three-dimensional structure of wood. An ultrastructural approach. London, UK; New York, USA. 103 p.

Miles, A. 1978. Photomicrographs of world woods. London, UK. 234 pp.

Panshin, A.J., and de Zeeuw, C. 1980. Textbook of wood technology: structure, identification, properties, and uses of commercial woods of the United States and Canada. New York, McGraw-Hill.

Van Oost, K., Govers, K.G, Van Muysen, W., and Quine, T.A. 2000. Modeling translocation and dispersion of soil constituents by tillage on sloping land. Soil Society of America Journal, 64: 1733-1739.

Yorston, R.M., Gaffrney, V.L., and Reynolds, P.G. 1990. Simulation of artifact movement due to cultivation. Journal of Arch. Science, 17: 67-83.

APPENDIX 5-2 ECOSYSTEM ARCHAEOLOGY FIELD SITES WITH PERCENT CHARCOAL FRAGMENTS AND ECOSITE DESIGNATIONS.

Site	*Picea*	*Thuja*	*Betula*	*Acer*	*Tsuga*	*Abies*	*Pinus* (wP)	*Fagus*	*Taxus*	*Quercus* (rO)	*Populus*	*Alnus*	*Prunus*	*Fraxinus*	*Corylus*	*Salix*	*Larix*	*Ostrya*	*Ulmus*	*Pinus* (rP)	*Quercus* (wO)	*Total (%)	Ecosite
Cap St. Louis	4	12	4				16		24			4										64	1
Pointe-Auguste	12	8	28	16			8															72	2
Callander's	5	50	25	10																		90	2
Patterson	3	6			7	7	26	3		7												59	5
McKays	15	3			19		11	19		8									3			78	5
Kouch. Village		18	5	5				18	9		5		5									65	5
Tweedy (6)	5	10	20	5		5	5	10		5	10		5									80	5
Rankin (8)	4	4	13	4	9	9	4		13				4									64	2
Loggiecroft	6	6	18	6	3	3	18	6			6							6				78	1
Cote-a-Fabien	4		20	8		4	4	13		8		8	4		4							77	1
Hwy134	14	57	5		5																	81	3
Bikeway	10	23	20	3		10		3	10													79	1
Petit Large		9	32	13	5			32			4											95	1
Service Road	15	15	5	5		5		45							10							100	1
Pine Trail	22		9	5	5	9		23														72	1
Beaver Trail	5	19			24	5			14					5								72	2
Black River-2	10	10	3		14		24		24													85	2
BMP	26	5	5	5	13	13					5				5							77	2
Cemetery	24		4	4	4					8		4										48	2
½ Moon Road	9	32	14		5						5					5	9					78	3
Comeau -2	4	9			10		38	5	14													80	2
Claire Fontaine	5	10	21	3		3	11			3								5				61	2
Source Spring	30	50		5		5																90	3
Porter's Pond	25	40		5	15		10		5													100	3
Palmer Creek	20	10	5	10										20						10		75	3
Polly's Creek			30	25	10		15		5													85	1
Germain Brook	10		30			20		10														70	1
Eric's Pond	6	9					39				3					6	9					72	2
Portage River	38	5	20	20								5		5		5						98	3
St. Ignace	7		7	7		7	29	14	14													85	5
Wilson's field	13	9	11	11	2		27	7				2										82	5
Maillet Field	9	9	19	32	2	7		7														85	3
Mortan's field	7	10	7		48	3			3					3								81	5
Beers' field	14	9	6	3	9	3	9					6							3		6	68	5
Warmen's field	4	4	36	9	20	7																80	5
Blaine's pit		13	31	6	6	6	12	25					6									105	5
% fragments total	385	474	453	225	234	131	306	240	135	39	38	29	24	33	19	16	18	11	6	10	6	**2831**	
Fragments (%)	13.6	16.7	16.0	7.9	8.3	4.6	10.8	8.5	4.8	1.4	1.3	1.0	0.8	1.2	0.7	0.5	0.6	0.4	0.2	0.4	0.2		
No. occurrences	32	31	29	25	21	19	18	16	11	7	7	6	5	4	3	3	2	2	2	1	1	**244**	
Frequency (%)	13.1	12.7	11.9	10.2	8.6	7.8	7.4	6.6	4.5	2.9	2.9	2.5	2.0	1.6	1.2	1.2	0.8	0.8	0.8	0.4	0.4		

* Total percentage of identifiable charcoal fragments, excluding bark and semi-coke.

VITA

Candidate's full name: Donna Rosanne Crossland

Universities attended: Acadia University 1982-1986
Bachelor of Science with Honours in Biology

St Mary's University 1989-1990
Bachelor of Education

Publications: Crossland, D. 1998. Recent fire history of Kouchibouguac National Park. Parks Canada-Technical Reports in Ecosystem Science #013, Cat No. R61-2/19-13/1997^{E}.

Crossland, D.R. and VanderKloet, S.P. 1996. Berry Consumption by the American robin *Turdus migratorius* and the subsequent effect on seed germination, plant vigour, and dispersal of the lowbush blueberry *Vaccinium angustifolium*. Canadian Field-Naturalist 110(2): 303-309.

Conference Presentations:

Crossland, D. 2006. Historical forest types of eastern New Brunswick *ca.* 1800; how archival records can provide baseline information for historical ecological research. Presented to the Tantramar Heritage Trust, Live Baits' Theatre, Sackville, NB.

Crossland, D. 2005. Historical forest research results and management implications in Kouchibouguac National Park, Presented to Atlantic Cooperative Wildlife Ecology Research Network (ACWERN), Kouchibouguac National Park, NB.

Crossland, D. 2005. Historical forest research results and management implications in Kouchibouguac National Park, Presented at a Parks Canada red oak-white pine workshop, Kouchibouguac National Park, NB.

Crossland, D. 1996. Fire history of Kouchibouguac National Park. Presented at a Parks Canada fire research conference, parc de la Mauricie, Quebec.