Evaluation of Forest Plantations on Rough Fescue Grassland in Riding Mountain National Park, Manitoba

by

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EVALUATION OF FOREST PLANTATIONS ON ROUGH FESCUE GRASSLAND IN RIDING MOUNTAIN NATIONAL PARK, MANITOBA

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of Master of Natural Resources Management.

By

Mr. Christopher D. Higgs

Abstract

Coniferous plantations established from 1918 to the mid 1950's on rough fescue grassland in Riding Mountain National Park (RMNP), Manitoba, were evaluated. In a Canadian national park, forest plantations are considered a disturbance and contrary to present Parks Canada Policy. The plantations were established on rough fescue grassland, a vegetation community that is virtually non-existent outside national parks in western Canada. For these reasons and because it is considered a significant Canadian natural heritage feature, greater research was needed to better manage the Park's rough fescue grassland.

Prior to consideration of any restorative measures for the disturbed rough fescue grassland sites, it was necessary to collect basic information such as the scale, characteristics, and intensity of the disturbances. Information on the plantations was gathered from Forestry Canada and Canadian Parks Service files, National Archives Records, personal interviews, and on site investigation. A series of soil samples was collected from the Ah and Bm horizons from soil profiles in one plantation and in an adjacent fescue prairie. Tests were conducted on the samples to determine the extent of change following afforestation in the levels of four soil properties: pH, moisture content (MC%), organic matter (OM%), and presence of carbonates.

A total of 28 coniferous plantations comprising approximately 98 hectares (ha) of disturbed fescue prairie between two areas in RMNP were observed and evaluated. Eight plantations at Lake Audy and 20 plantations at Clear Lake ranging in size from 0.2 to 24.2 ha were observed. Considerable heterogeneity in the size,

tree density, and remnant fescue prairie vegetation among the plantations was observed. Changes had occurred in the soil pH, MC%, and OM% in Ah horizon and in OM% in Bm horizon under the forest plantation.

A number of recommendations pertaining to restoration of the disturbed sites and to experimental restoration were presented. Depending on the individual plantation's status, it was recommended that either a plantation be eliminated, controlled, or left to evolve naturally. The remaining recommendations were broader in scope and dealt with methods which would improve the protection and management of native grasslands in the Park. The information provided by this study will be utilized to manage the rough fescue grassland within the framework of a park vegetation management plan.

Acknowledgements

Completing this study would have been very difficult without the assistance of many people. I would like to acknowledge my Practicum committee members Professor Thomas Henley, Natural Resources Institute (NRI), for his encouragement; Mr. Ross Dobson representing the Canadian Parks Service (client) whose experience, patience and funding arrangements were appreciated; Dr. Geoffrey Scott (Geography, U of W), for his teaching skills, guidance and especially his thorough review of every page submitted to him; Jim Ball, representing Forestry Canada; and Dr. Fikret Berkes, Oral Exam Chairman, NRI. I would like to acknowledge my funding sources which includes the Canadian Parks Service, World Wildlife Fund, and the Natural Resources Institute.

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CHAPTER 1 Introduction

1.1 Preamble

Preservation of endangered, threatened, vulnerable, and representative flora and fauna is one vital objective of Canada's national parks. The national parks also protect and manage larger, more complex units of our natural environment -- ecosystems. According to Dr. Stan Rowe (1989), preserving ecosystems is more important, "rather than the individual species and organisms that are parts of them".

Rough fescue grassland is an assemblage of inter-related plant species that is identifiable and unique, and is best preserved using an ecosystem approach such as advocated by Dr. Rowe. With the advent of the plough, the introduction of domestic livestock, exotic plant invasion and other alterations to the prairie landscape, only small vestiges of rough fescue grassland remain. At present, rough fescue grassland is unofficially classified as an endangered plant community (Trottier, pers. comm. Aug. 1992) and is virtually non-existent outside of a few national parks in the prairie provinces (Trottier, 1986).

A diminution of Riding Mountain's rough fescue grassland was brought about by the establishment of forest plantations prescribed for the Park's open prairie land. Forest plantations, primarily of white spruce *Picea glauca* were established between 1918 and 1930 on rough fescue grassland when Riding Mountain was a Forest Reserve (Haig, 1958) and later, in the late 1940's and early 50's after its designation as a National Park. The establishment of man-made forests on rough fescue grasslands in Riding Mountain National Park (RMNP) has contributed to the gradual loss of a valuable natural resource in Canada's system of national parks.

1.2 Problem Statement

Forest plantations on Riding Mountain National Park's (RMNP) rough fescue grassland are classified as disturbed sites and are contrary to Parks Canada Policy (Parks Canada, 1979). Disturbed sites are to be rehabilitated using strategies which restore the ecological and wilderness integrity of the park (Canadian Parks Service, 1987a). To develop a restoration strategy, park resource managers require basic information on the disturbances such as: scale, characteristics and intensity.

Following are some of the questions that were addressed in the study in order to meet some of the basic informational deficiencies. How many plantations were established on rough fescue grasslands in RMNP and where were they located? What site preparation, planting method and tending practices were undertaken by the Federal Forestry Branch? What changes might have occurred to various soil properties under the plantations and what are potential alternative rehabilitation strategies for the disturbed sites?

1.3 Research Objectives

The overall objective was to quantify and describe forest plantations established on rough fescue grassland sites in Riding Mountain National Park, in order to provide valuable information for subsequent planning decisions on a relatively unstudied human disturbance.

Specific objectives were

1. to determine the number, location and area of plantations established on rough fescue grassland,

2. to provide an historical background on the plantations,

3. to describe the current status of the plantations,

4. to measure the impacts of afforestation upon the native fescue prairie soil, and

5. to make recommendations on rehabilitation of disturbed rough fescue grassland sites.

1.4 Delimitations

With any historical research, the degree of success achieved is dependent, to a large extent, on the existence and availability of relevant documents. More than 70 years have elapsed since plantation research was initiated in the RMNP, making information difficult to collect. Many of the relevant records and files have been lost and many of the people who assisted with planting the trees and who evaluated the growth of the plantations have since passed away.

Forestry records were located in the National Archives at Ottawa, Ontario, and in Forestry Canada's record depository in Edmonton, Alberta. Inevitably, financial and logistical constraints placed certain limitations on accessing and researching these historical records. These limitations were not so great as to invalidate my research.

CHAPTER 2 Literature Review

Information was gathered on rough fescue grassland, Chernozemic soils, forest research conducted on Riding Mountain National Park's (RMNP) grasslands, and native prairie management and rehabilitation. The rough fescue grassland section (2.1) is broken down into three areas: description, distribution and ecology of the vegetation community. A general description of the Chernozemic Soil Order and particular characteristics of the Black Chernozem Great-Group is summarized in Section 2.2. An historical perspective of forest research in Riding Mountain conducted by the Canadian Forestry Service (CFS) is presented in Section 2.3, with emphasis on afforestation on prairie sites. Also included in this section is a review of the planting prescriptions and monitoring programs of the plantations. The final section (2.4) profiles recent native prairie management initiatives for National Parks in Canada and the United States.

2.1 Rough Fescue Grassland

Riding Mountain National Park (RMNP), an area entirely surrounded by agricultural land, is located in western Manitoba, approximately 250 km northwest of Winnipeg (Figure 1). The rough fescue grassland of Riding Mountain is a complex prairie ecosystem consisting primarily of grasses, forbs and shrubs.

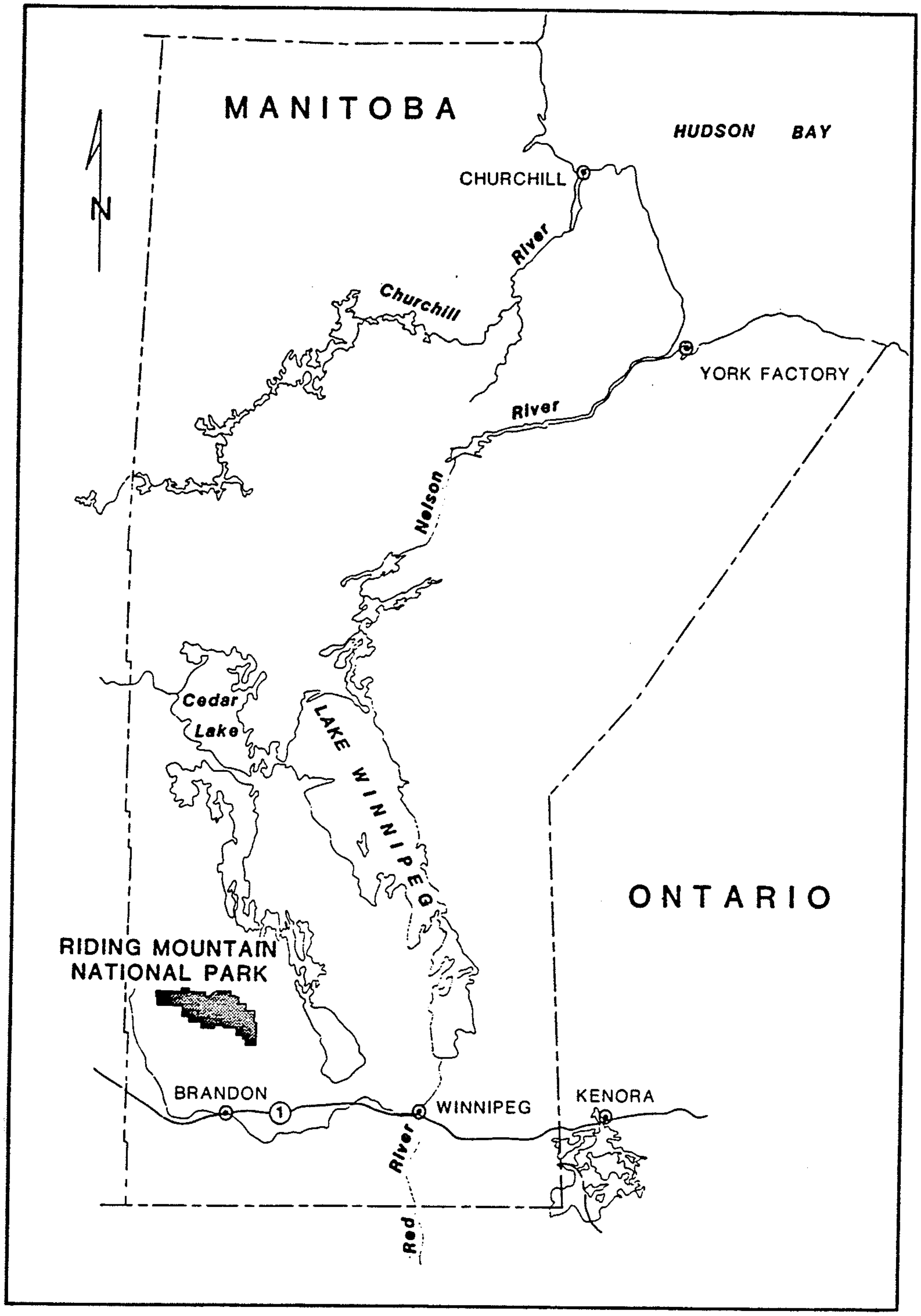


Figure 1. Regional Setting of Riding Mountain National Park (RMNP), Manitoba (Parks Canada, 1984) (1:5,800,000).

2.1.1 Classification and Morphology of Rough Fescue Grasses

The rough fescue species identified in the surveys conducted in Manitoba by Pavlick and Looman (1984) was *Festuca hallii* (Vasey) Piper. Prior to the taxonomic clarification put forth by Pavlick and Looman (1984), *F. hallii* was formerly known as *F. scabrella*. Rough fescues are bunchgrasses and are easily recognized by their densely scabrous and folded leaves, marcescent (dead and persistent) basal leaf sheaths, and deciduous outer leaf blades (Pavlick and Looman, 1984) with aerial stems of *F. hallii* up to 100 cm in height (Cody, 1988). The densely tufted characteristic of the rough fescues makes them resistant to light fire and moderate grazing (Aiken and Darbyshire, 1990).

Festuca hallii bears seed between late May and mid-June depending on environmental conditions (Trottier, 1986). Most fescues are capable of producing creeping rhizomes as an alternative mechanism of reproduction (Pavlick and Looman, 1984; Aiken and Darbyshire, 1990). Rhizomatous growth, in most cases, is a result of temporary physiological stress on the plant or disruption of flowering (Aiken and Darbyshire, 1990).

2.1.2 Grassland Association

In Riding Mountain, the *Festuca hallii* association or Rough Fescue Grassland is a recognizable assemblage of more than 100 different species of grasses, forbs, shrubs, and nonvascular plants (Trottier, 1974). The term "association" refers to a frequently recurring assemblage of plant species typically named after the predominant species of plant(s) (Looman, 1983).

Carbyn and Armbruster (1968), Looman (1969), and Cameron (1975) have shown that rough fescue grassland is not comprised of one representative combination of plants. Fescue grassland is remarkably heterogenous, according to Cameron (1975), and is often recognized or described on the basis of a particular floral composition or faciation. Moss (1952) describes a faciation as a combination of plants that reflects the deviation in habitat conditions from that of the mean community type. In particular, Moss (1952) and Looman (1969) regard faciations as indicators of a temperature-moisture gradient, existing geographically as well as locally or topographically. For example, Cameron (1975) identified 146 species of grasses, sedges, rushes, forbs and shrubs in all faciations of the isolated grasslands of Prince Albert National Park (PANP).

2.1.3 Distribution of Rough Fescue Grasslands in Western Canada and in Two National Parks

The natural vegetation cover of the Canadian Prairie can best be described as a series of vegetation belts situated in an east - west direction extending between southern Manitoba to the east and to south central Alberta to the west (Figure 2). Riding Mountain National Park is located in a mixed forest zone along the southern edge of the Boreal Forest Biome. South of this biome lies Aspen Parkland, a transition between the Boreal Forest and the Great Plains Grassland Biomes (Looman, 1979). Aspen Parkland was described by Looman (1979) as being comprised of open grassland alternating with groves of deciduous trees. Grassland communities within the Aspen Parkland zone are frequently identified as fescue grasslands due to the dominance of *Festuca* spp. (Scott, 1991a). Fescue prairie is the predominant grassland in the Aspen Parkland (Trottier, 1992),

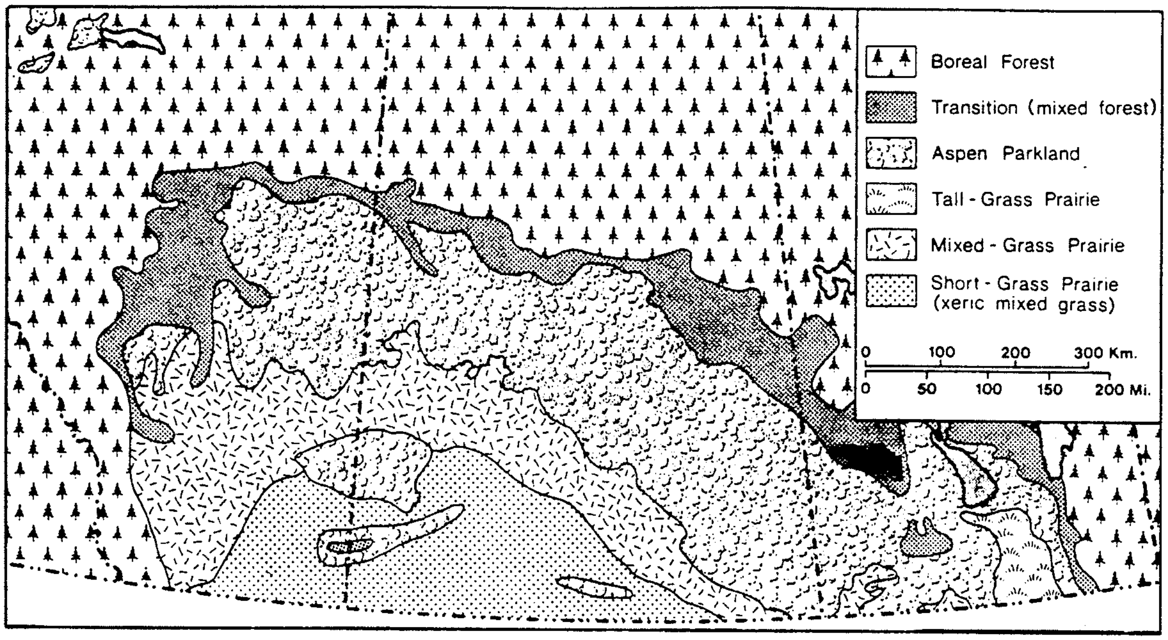


Figure 2. Natural Vegetation Cover on the Canadian Prairies (Scott, 1991a).

represented by F. hallii (Pavlick and Looman, 1984). Festuca hallii is distributed widely throughout western Canada (Figure 3) and overlaps geographically with F. campestris in the Rocky Mountains of southern Alberta and in the eastern Cypress Hills of Saskatchewan (Pavlick and Looman, 1984).

In Prince Albert National Park (PANP), Saskatchewan, the Festuca - Stipa association occupies less than 16 km^2 or 0.4% of total Park area (Environment Canada, 1986). In Waterton Lakes National Park, Alberta, the Festuca - Danthonia association occupies an estimated 33 km^2 or 6.7% of the Park (Canadian Parks Service, 1989).

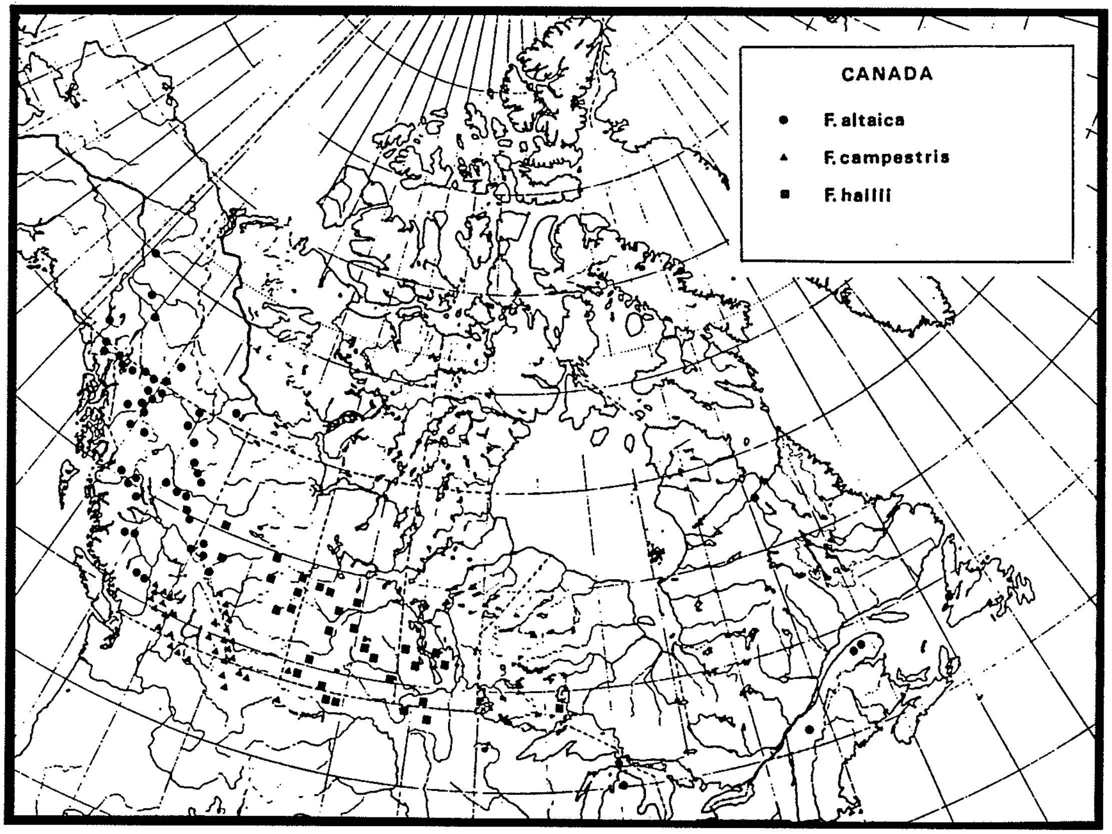


Figure 3. Distribution of Rough Fescue Grassland in Western Canada (Pavlick and Looman, 1984).

2.1.4 Distribution of Rough Fescue Grassland in RMNP

The area of Riding Mountain National Park is 2974 km^2 of which approximately 2.5% or 74.4 km^2 is grassland (Bailey, 1968). Of this, close to one-third or 24.75 km^2 is native grassland of the Plains Rough Fescue association (Trottier, 1986). The most easterly distribution of rough fescue grassland in Canada is located in RMNP (Parks Canada, 1984).

Past disturbance to the Park's native grassland has depleted the *F. hallii* association. Major disturbance to Riding Mountain's rough fescue grassland was brought about by overgrazing by domestic livestock (Trottier, 1974). From the results of a Range Study conducted by Trottier (1974), four different prairie vegetation communities were identified. He identified three types of range brought about by grazing which included disturbed rough fescue, disclimax Junegrass-slender wheatgrass and seral bluegrass-slender wheatgrass. It is more appropriate, therefore, to consider the use of the term rough fescue grassland within the Aspen Parkland as one applicable at the local community level (Scott, 1991a).

Native grassland is heavily concentrated in two areas of the Park, with smaller isolated pockets situated along the Park's southern boundary (Figure 4). In the central portion of the Park, along a north-south axis, a series of large meadows dominate the landscape. The second grassland area of considerable size is in the western portion of the park, nestled in the Birdtail Valley. Smaller pockets are situated to the southeast in the McFadden Valley, to the southwest near Baldy Lake, and at Clear Lake.

2.1.5 Fescue Grassland Ecology and Succession

Grassland ecologists have identified several factors which contribute to the maintenance of native prairie. Two abiotic factors to be examined which affect the distribution of rough fescue grasslands in aspen parkland are climate and fire. Two other factors to be examined include the effects of litter removal/nutrient recycling and the role of large herbivores in maintaining native rough fescue grassland. This subsection will conclude with an examination of plant succession in Aspen Parkland.

Fescue Grassland Ecology. The most important climatic variable that influences the distribution of native grasslands is moisture (Hildebrand and Scott,

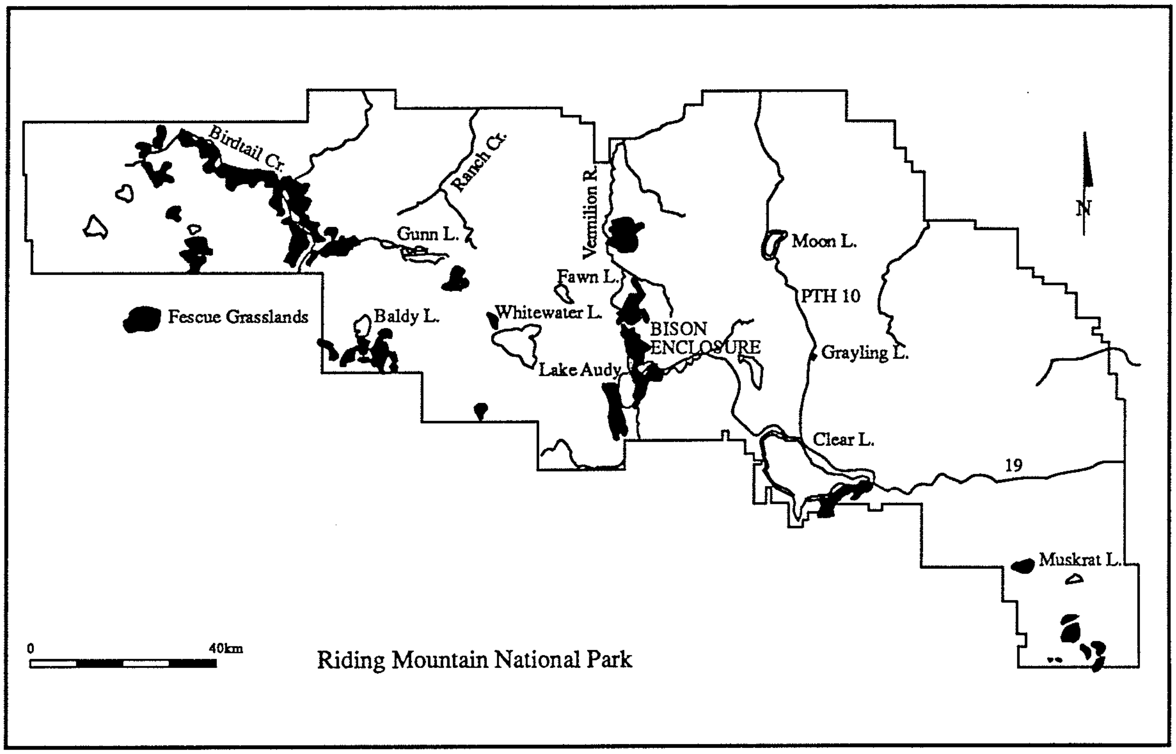


Figure 4. Distribution of Rough Fescue Grassland in RMNP (drafted from Trottier, 1986).

1987). The results of their study showed some correlation between moisture levels and tree cover in the parkland region. A moist climatic period would favour forest vegetation and would move the parkland - forest boundary south, creating a narrower parkland zone (Hildebrand and Scott, 1987). They inferred that climate influences the northern limit of the parkland more than the southern limit.

In Cameron's 1975 study, open fescue grassland consistently had the most vigorous climatic regime when compared with that of aspen and pine forests. During July and August, temperatures of 0° C or lower were recorded and severe killing frosts were restricted to open and slightly depressional rough fescue grassland. In a study by Irving (1992), litter accumulation had a significant effect on plant species composition and production in parkland fescue grasslands in Central Alberta. Given the local climate, he showed that optimal growing conditions for fescue grassland were dependent upon a certain amount of litter accumulation. Litter is beneficial because it protects the growing points of prairie plants from the effects of extreme temperatures and climatic conditions. An excess amount of litter can be detrimental to grasslands as it can suppress the soil temperature in spring (Anderson, 1982) thereby delaying early season plant growth and microbial activity.

Many authors have identified the important role of fire in controlling invasion by woody species (Anderson, 1982). In the parkland region in particular, the spread of aspen into grasslands can be attributed to the absence of frequent fires (Daubenmire, 1968; Archibold and Wilson, 1980). A prescribed burn study in Prince Albert National Park showed that except for saskatoon *Amelanchier alnifolia*, burning effectively top-killed aspen, but stimulated suckering (Trottier, 1985). Neither spring nor fall burning had a significant effect on aspen frequency and on the boundary pattern of woody and grassland vegetation (Trottier, 1985).

One of Trottier's (1985) conclusions was that burning did not alter grassland species composition or the dominance structure and there was no invasion by weedy species. Another conclusion was that the grassland community became established in burned ecotone areas. He also concluded that shrubs did not expand their distribution into burned grasslands. The dominance of rough fescue grass following this type of disturbance can be attributed to its densely tufted and bunchgrass characteristics which makes it more resistant to light fire (Aiken and Darbyshire, 1990).

Under suitable conditions, localized disturbances such as fire probably play a more important role in maintaining fescue grasslands along the northern limit of the aspen parkland belt than along the southern limit. According to Bird (1961), fire may create parkland conditions in the boreal forest by controlling the invasion of spruce into grasslands. Because of the effect of fire on young spruce in particular, the northern boundary of the parkland is not clearly defined (Bird, 1961). Since the 1880's, the aspen parkland cover type has expanded its geographic area into the grasslands following the removal of large ungulates and the reduction of prairie fires (Scott, 1991a).

A distinguishing feature of fescue grassland is the absence of an LFH horizon and the presence of a characteristic dark Ah horizon of high organic content. Fescue grassland produces a litter layer that is readily decomposed and eventually incorporated into the soil by organisms (Spedding, 1971). One of the most important soil macroanimals responsible for the reintroduction of organic matter into the soil is the earthworm (Spedding, 1971; Brady, 1990). In very acid forest soils, which earthworms do not prefer, fewer than one organism/m^2 is common, while in rich grassland soils, more than 500/m^2 have been found (Brady, 1990).

The northern pocket gopher *Thomomys talpoides* is found in grasslands of the parkland region (Bird, 1961) and is an important nutrient recycling agent. The northern pocket gopher prefers a deep, heavy, moist soil where it can excavate metres of tunnel (Banfield, 1977). Transporting large quantities of soil to the surface helps aerate the soil, increases water holding capacity and is an effective means of recycling nutrients.

The reintroduction of surface litter into the adjoining soil horizon affects the temperature regime of the uppermost strata of the soil profile. Golley and Golley (1972) found that litter decomposition in a grassland was 20% less than the annual litter production under normal conditions. They concluded that productivity would decline if this surplus was not removed either by grazing or burning. Litter removal enhances production on disturbed sites because the soil warms up faster in the spring, thus favouring warm season plants (Anderson, 1982). Positive effects also occur at night when the bare soil experiences rapid cooling and depressed respiration, resulting in additional carbohydrate reserve buildup (Peet et al., 1975; Anderson, 1972).

Native ungulates are thought to have once played an important role in maintaining prairie grassland (Looman, 1979). To improve hunting success in the Aspen Parkland, natives burned summer ranges in the fall which forced large herbivores into parkland areas (Hind, 1971). While in the parkland, bison in particular had greater opportunity to rub off the bark of trees and trample younger shoots of woody vegetation (Bird, 1961). Other ungulates such as white-tailed deer *Odocoileus virginianus* and elk *Cervus canadensis* may have played an important role in reducing the vigour of woody plants (Anderson, 1982).

Studies have shown that the grazing patterns of domestic livestock can have an effect on native grasslands. In Riding Mountain, Trottier (1986) found that grasslands lightly grazed by domestic livestock contained a greater number of plant species and a higher cover value than did slightly grazed grasslands. He concluded that light grazing probably opened the grass sward through reduced litter accumulation. According to Dyer et al. (1982) and McNaughton et al. (1982), grazing also stimulates grasses to produce foliage that is more palatable and richer in nitrogen than foliage produced under a nongrazing regime.

As grazing pressure increased on native grasslands in Riding Mountain, rough fescue was eventually replaced by Kentucky bluegrass *Poa pratensis* (Trottier, 1986). As a result of overgrazing, Looman (1969, 1980) and Trottier (1986) similarly showed that a reduction in rough fescue cover was parallelled by a reduction in the number of plant species. Fescues are predominantly perennials and are susceptible to considerable reduction in root growth when 50% or more of the grass foliage is removed (Crider, 1955). Crider (1955) also demonstrated that with a decreasing amount of defoliation, the number of roots produced steadily increased relative to the initial count. Similar results were observed by Sinton (1980) which showed that flowering (seed production) and tillering of *F. hallii* were stimulated by burning. The time of year when grasslands are grazed or mowed can alter the floristic composition. Species that flower earlier or later and species that propagate vegetatively are favoured and can become more abundant (Looman, 1980).

Succession. The typical sequence of succession for upland native grassland sites in the aspen parkland in wet periods is grassland -----> hardwood forest (aspen) -----> mixed-wood forest (white spruce/aspen) (Bird, 1961; Kabzems, 1971; Parks Canada, 1984). Some stages of the sequence do not materialize on occasion, as shown by Rowe (1956) when he described a grassland -----> white spruce successional sequence. This sequence is evident at Lake Audy where white spruce from plantations has invaded adjacent rough fescue grassland.

Rowe (1956) found that the shade of conifers had eliminated the intolerant prairie flora, but surface drought had largely prevented replacement by tolerant forest species. Needles had covered the forest floor, with only a few species present, including *Maianthemum canadense* var. *interius*, *Pyrola secunda*, *Schizachne purpurascens*, or *Corallorhiza trifida* (Rowe, 1956). In the typical sequence of succession, the process is likely to occur over a period of 100 - 200 years (Parks Canada, 1984).

Bird (1961) wrote that the parkland had its successional changes interfered with, but was kept in a relatively stable subclimax condition. He indicated that disturbance seems to play a significant role in maintaining the parkland at this stage. Fire and the effects of large herbivores were viewed as being the major forms of disturbance.

Malin (1984) also described grasslands as a more or less subclimax stage of succession. He identified the actions of pocket gophers as being an important factor in halting the process of succession. The continual small scale disturbance caused by pocket gophers creates microsites for pioneering species of plants and sets back succession to a subclimax stage (Malin, 1984). Where small scale disturbances occur, forb dominated patches almost always exist in grasslands (Biondini, Steuter and Grygiel, 1989) which increases overall plant diversity. The action of animals on plant disturbance should not be viewed as negative or destructive according to Malin (1984), but rather as a positive process of natural renewal.

2.2 Chernozemic Soils

In Riding Mountain National Park, the Chernozemic soil order represents less than 2% or approximately 60 km^2 of the park (Parks Canada, 1984). The Chernozemic soil order is subdivided into four major great groups, the Brown, Dark Brown, Black, and Dark Grey (Canada Soil Survey Committee, 1977). The Chernozems of Riding Mountain are classified as Black (Parks Canada, 1984) and have developed on glacial tills and glaciofluvial deposits such as floodplains (Canada Soil Survey Committee, 1977). Black Chernozems are further divided into at least 4 main subgroups which include Orthic, Rego, Calcareous, and Eluviated (Canada Soil Survey Committee, 1977) and those in the park are typical (Orthic) Black Chernozems belonging to the Orthic Black Subgroup (Parks Canada, 1984). The differences between subgroups are in the patterns of A, B, and C horizons (Canada Soil Survey Committee, 1977).

The following description of Chernozemic soil was extracted from the 1977 publication, Soils of Canada. A typical Chernozem does not contain an LFH horizon because of the rapid decomposition of vegetative matter. Distinct A, B, and C horizons are common in Black Chernozems (Figure 5), with the A horizon characteristically darker than the others. The A horizon is thickest and darkest because of the high organic matter content. An accumulation of lime carbonates usually occurs in the lower part of the solum. Black Chernozems in particular are loamy in texture and weakly to strongly calcareous.

The Black Chernozems of Riding Mountain are a result of centuries of rapid nutrient recycling of herbaceous and graminoid cover types. They are associated

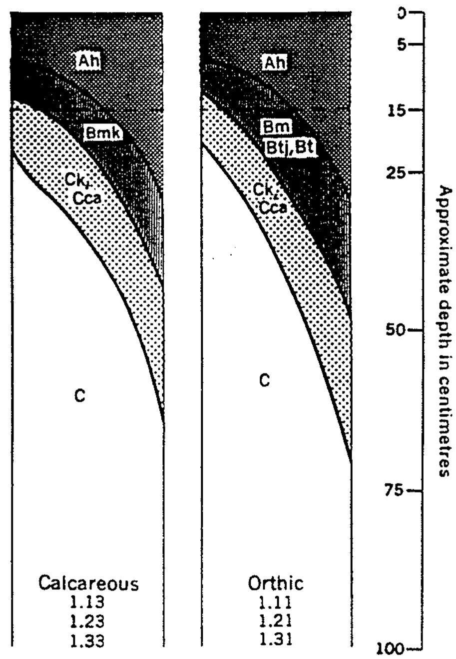


Figure 5. Diagrammatic horizon pattern of Calcareous and Orthic Black Chernozemic profiles (Canada Soil Survey Committee,1977).

with a native vegetation of mesophytic plants characteristic of the Fescue Prairie - Parkland (Aspen-Oak) and True Prairie of western Canada (Canada Soil Survey Committee, 1977). Undisturbed Chernozemic soils are rare and nationally significant and are indicative of areas historically maintained as grasslands (Parks Canada, 1984).

2.3 Forestry Research in RMNP

A number of forestry-related economic and scientific activities were undertaken in Riding Mountain during its status as a forest reserve and later as a national park. In the earlier years, the natural resource base of Riding Mountain was the biggest attraction to local settlers who participated in such endeavours as livestock grazing, haying and logging (Tabulenas, 1983; Trottier, 1986). Timber cutting privileges were seriously abused by settlers and consequently Riding Mountain was withdrawn from settlement and proclaimed a Forest Reserve in 1895 (Tabulenas, 1983). An historical overview of the administration of Riding Mountain and research activities conducted under the Federal Forestry Branch will be presented. The discussion will conclude with an examination of regeneration and of tree growth studies of white spruce planted in forest plantations.

2.3.1 Historical Perspective

From its inception, the Riding Mountain Forest Reserve (subsequently Forest Reserve) was administered by the Forestry Branch of the Federal Department of the Interior (Tabulenas, 1983). In 1930, Riding Mountain's status changed from that of a Forest Reserve to a National Park and subsequently it was managed under the authority and policies of the National Parks Act (1930) (Lothian, 1977). With this jurisdictional change, the Forestry Branch dropped its functions with regard to protection and management of forest resources and concentrated on its research role in the fields of silviculture and forest products (Canada, 1990).

Upon dissolution of the Department of the Interior in 1936, the new Department of Mines and Resources presided over several branches, including the Land, Parks, and Forests Branch (Lothian, 1977). The responsibility of the Forests Branch in a national park setting such as Riding Mountain was still in scientific research and experimentation, but with an increasing shift towards studies of an ecological nature (Tabulenas, 1983).

The Forests Branch acknowledged this shift in the role of the Park during its efforts in 1939 to establish a suitable boundary for the Riding Mountain Forest Experimental Area. The area was described as a white spruce - aspen forest (Pratt, 1978) and was the primary location for forest research in RMNP between 1939 and 1969. Because of the low aesthetic value of scarification, selective cutting and herbiciding, the Forest Experimental Area (FEA) was kept three chains (60 m.) back from the Park's main highway (Tabulenas, 1983). The FEA provided facilities for basic research on silviculture practices with emphasis on white spruce *Picea glauca* and later, on aspen *Populus tremuloides* (Pratt, 1978). By 1969, the need for experimentation of forests was perceived as incompatible in the context of a national park and consequently the FEA was abandoned (Pratt, 1978). The evolving mandate of the FEA over the years is cited only to illustrate the changing values held by Canadians towards their national parks.

2.3.2 Forest Research - Forest Plantations

Since 1904, silvicultural studies examining growth rates, natural reproduction, the effects of thinning and the factors deterring natural reproduction were conducted in the Forest Reserve (Tabulenas, 1983). White spruce was the principal species used for experimental purposes (Haig, 1958; Pratt, 1978) because it was traditionally the most desirable for construction purposes due to its good form and capacity to be transformed into large dimensional lumber. The first part of the discussion will focus on the forest research activities initiated between 1918 and 1930 in the Riding Mountain Forest Reserve. The second part will then focus on the afforestation program conducted in the late 1940's and 50's. Plantings at

Lake Audy and Clear Lake in Riding Mountain presented in this study will be referred to as the Lake Audy and Clear Lake Study Areas (Figure 6).

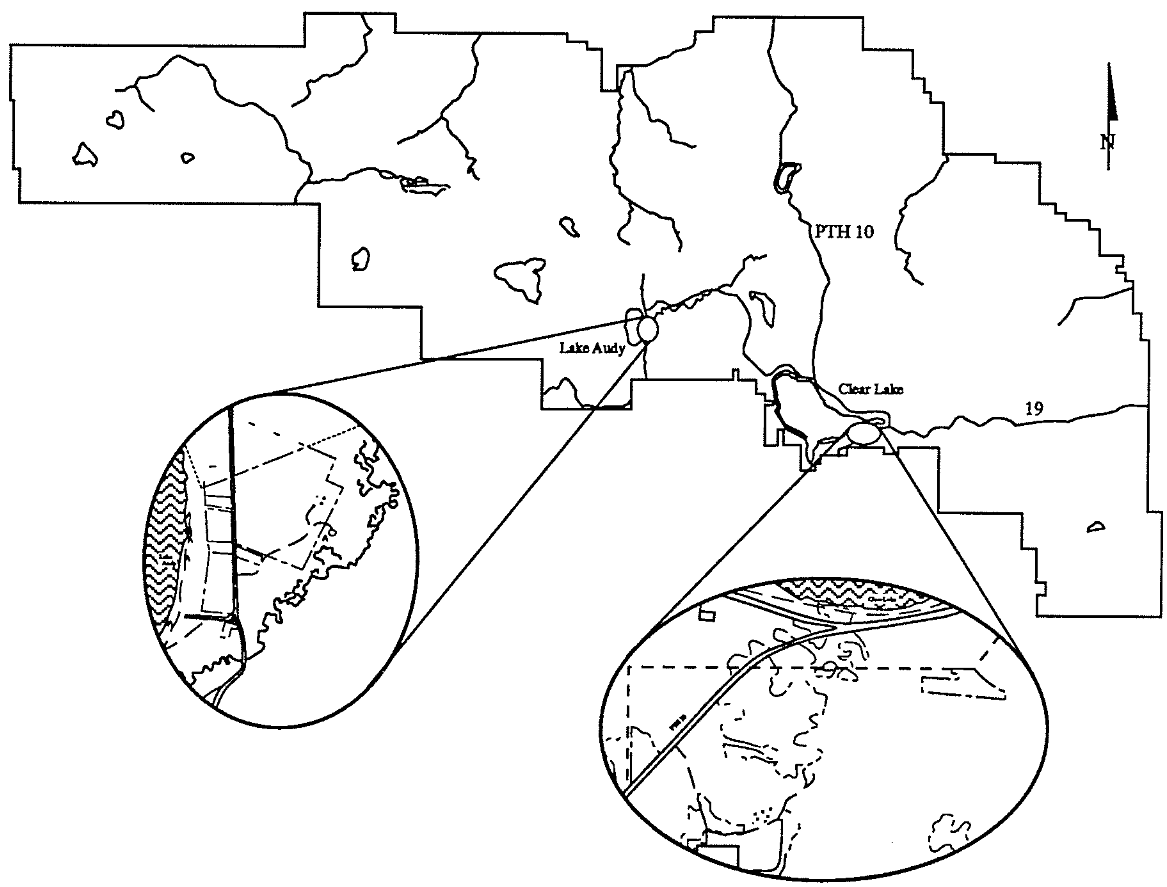


Figure 6. Lake Audy and Clear Lake Study Areas, RMNP.

Between 1918 and 1930, a program of experimental reforestation was initiated inside the Forest Reserve by the Forestry Branch and given the designation Project MS-104, Reforestation by Planting - Riding Mountain (Haig, 1958). The objective of the program was to determine on what sites and under what conditions plantations of white spruce, jack pine, Scots pine and Siberian Larch could be established successfully (Jarvis, Steneker, Waldron and Lees, 1966).

Included in Project MS-104 was the establishment of 44 plantations set out in various areas and site conditions throughout the park (Haig, 1958). In addition to the plantations, a number of seedbeds and a series of aspen and jackpine thinning plots were included in the Project. At Riding Mountain, approximately one-third of the plantations were established on a dry sandy outwash plain occupied by typical prairie vegetation while the remainder were set out on former clear cuts (Jarvis et al., 1966). In order of priority, a list of desired site conditions (Smith, 1918) under which planting was to occur is as follows:

1. open prairie land with heavy soil,
2. open prairie land with light soil,
3. old burn,
4. fresh burn,
5. under mature stand of poplar with light underbrush,
6. under mature stand of poplar with dense underbrush,
7. cutting lanes through mature stand of poplar, and
8. on logged, mixed stand, brush burned areas.

The undulating outwash plain east of Lake Audy was the site where the best conditions for planting were found.

An evaluation survey carried out in 1957 on Project MS-104 revealed that not all of the plantations were successful (Haig, 1958). Of the original forty-four plantations, Haig identified only nine that survived, eight of which were located immediately south of the Bison Enclosure on the Lake Audy Plain. The remaining plantation was located on an old cutover, west of the Park's north gate on PTH #10, near the former site of the Dauphin Warden Station (Haig, 1958).

The transplant stock utilized in the plantations originated from a number of sources. Prior to 1928, the Nursery Station at Indian Head, Saskatchewan, was the principal distribution centre for seed and transplant stock (Department of Interior, 1901 - 1936). The Nursery received and processed (cleaned and provenance tested) seeds collected from throughout the prairie provinces. Seed retained by the nursery was sown in seedbeds and later shipped back as transplant stock to various Dominion Forest Reserves in western Canada.

According to the Annual Reports (1901 - 1936) by the Director of Forestry, Department of Interior (DOI), white spruce cones were collected from the Spruce Woods Reserve in 1904, 1910 - 1912, and 1920 and shipped to Indian Head. White spruce cones were also gathered in 1909, 1912, 1918, and 1921 in the Riding Mountain Forest Reserve and sent to Indian Head. Other locations where cones were collected included the Duck Mountains in 1912, the Dauphin Region in 1916 and unspecified locations in 1913 and 1921.

One of the first shipments of transplant stock from Indian Head to Riding Mountain occurred in 1919 (DOI, 1919). The shipment contained approximately 12,000 white spruce transplants for planting near Dauphin, Erickson, Grandview, and Kelwood, Manitoba. Other species of conifers including jack pine and Scots pine were shipped to Riding Mountain from Indian Head according to the DOI (1921, 1923 - 1925) Annual Reports. Scots pine is an introduced species to North America and has been used mainly for farm and field shelterbelts in combination with other species (Howe, pers. comm. Nov. 1992). According to Howe, it is possible for Scots pine to reproduce naturally under suitable conditions, although this does not occur too often.

In the late 1920's, a nursery was established in the Riding Mountain Forest Reserve at Lake Audy. In the 1927 (DOI) Annual Report, three nurseries were established in Manitoba Forest Reserves. Nurseries were established in the Reserves because they would offer greater convenience for planting operations and would meet individual reserve demands (DOI, 1927). By 1929, approximately 705,000 white spruce and 20,000 Siberian larch were cared for in seedbeds at the government nursery at Lake Audy (Anon., 1929). Between 1928 and 1930, the nursery at Lake Audy provided most of the transplant stock for the plantations in MS-104 (Canada, 1918 - ?).

The original boundary of the Forest Reserve was different from the present day boundary of Riding Mountain National Park. The primary deletion of federal land occurred along the northwest boundary and additions were made along the Park's southern and eastern boundaries. These periodic adjustments to the Park's boundary are noteworthy, as some of the plantations established under Project MS-104 were established outside the present day boundary of the park.

An afforestation program was undertaken in the 1940's and 50's on open prairie sites, south of Clear Lake. In 1939, the Dominion Forest Service established a Forest Nursery approximately 1.6 km east of the townsite of Wasagaming (Lothian, 1979) to meet the needs of the planting program. The nursery was then taken over by the National Parks in 1946, and a forest engineer was hired to supervise its management (Lothian, 1979). In the late 1940's, Domansky (pers. comm. Nov. 1992) indicated that Forest Engineer Goodison had several men collect white spruce cones in the Clear Lake area. Goodison (1949) reported that white spruce seed was collected in Riding Mountain in 1948 and cleaned at the nursery in Indian Head. Twenty six, 4' X 12' (1.2 m X 3.7 m) seedbeds were prepared and sown to white spruce at the nursery station near Clear Lake (Goodison, 1949).

After the first batch of transplant stock was available for planting in 1945 (Tabulenas, 1983), as many as 20,000 to 30,000 seedlings were planted in the following three years with the aid of a Lowther Tree Planter (Heaslip, 1949). Where the Tree Planter had difficulty with certain types of stock and planting conditions, Domansky recalled planting bare root stock by hand along PTH #10 (pers. comm. Nov. 1992) Some of the plantations experienced a failure rate as high as 90% (Domansky, pers. comm. Nov. 1992). A large plantation at Clear lake experienced a high mortality rate and the openings were replanted a short time later (Waldron, pers. comm. Jan. 1990; Domansky, pers. comm. Nov. 1992). A long time Onanole resident, R. Svenson, recalled helping with a planting operation in 1948 (pers. comm. June 1990). In 1949, more than 31,000 white spruce and jack pine seedlings were planted at the golf course, along the Norgate Road, and in old windfall sites in the townsite (Goodison, 1949).

2.3.3 White Spruce Life History

White spruce *Picea glauca* can be found throughout Canada growing on a variety of soils yet rarely forming pure stands (Hosie, 1979). White spruce occurs over a wide range of soil moisture regimes, but optimum growth occurs in soils of intermediate moisture content (Jarvis, 1963). Rowe (1956) referred to white spruce as a tree of wide ecological amplitude. While white spruce can live in a broad spectrum of pH, Spurway (1941) determined that the conifer's optimum range is between 5.0 to 6.0.

White spruce commonly reaches ages of greater than 200 years and is considered to be a long lived tree. Some documented specimens in the Mackenzie delta have been found to be up to 500 years in age (Nienstedt, 1957). On good sites in Riding Mountain, Jameson (1963) found that dominant trees (120 yrs) were 75 cm in diameter and stood 27 m in height. In the Porcupine Provincial Forest, Manitoba, one white spruce measured 42.7 m on the ground (Rowe, 1956).

The flowering process for white spruce, a monoecious softwood, usually occurs from mid-May to early June, with cones ripening in August and September (Jarvis, 1963). In the Riding Mountain Forest Experimental Area, Waldron (1962) observed that white spruce experiences maximum seedfall in mid-September. In Manitoba and Saskatchewan, white spruce typically produces seed between the ages of 45 and 60 years (Rowe, 1955), with good crops every 2 to 6 years (Jarvis, 1963). White spruce is entirely dependent for its survival on seed and is consequently a prolific seed producer (Rowe, 1956). Rowe found that it can produce 15,000 cones/tree with 50 seeds/cone in a good year. Roe (1952) reported that a particular 75 year old specimen in a northern Minnesota study produced 11,900 cones with 271,000 viable seeds in one season. Seed dispersal, according to Crossley (1955), can occur up to 100 m away. Rowe (1955) stated that late falling seeds can scud up to 1.6 km over the snow.

Upon dispersal, germination of the seeds takes place in June and July of the following year (Jarvis, 1963). If seedbeds are dry, seeds can stay dormant until the following year (Rowe, 1958). In seeding experiments in the Mixedwood Section of Saskatchewan, Kabzems (1971) identified general site conditions, hot weather, and especially high temperatures in the exposed surface soil as contributing factors to the poor to complete failure of white spruce seedbeds. Jarvis (1963) found that sites of bare mineral soil and mineral soil mixed with organic material were the best for germination and survival. Depending on the site conditions, white spruce responds to fire in terms of regenerative output. However, due to the higher degree in which a fire burns a dry site in comparison to a moist site, better seedbeds occur on the former (Jarvis, 1963). Spruce regeneration is favoured on sites where severe ground fires have burned away all the humus and destroyed all the competing vegetation (Rowe, 1956; Jarvis, 1963).

Though too much shade will produce a fragile and weak seedling, white spruce seedlings are generally regarded as being more tolerant than the parent trees (Jarvis, 1963). The seedlings' fragility makes them susceptible to the crushing effect of the annual fall of poplar leaves, the greatest cause of mortality (Rowe, 1956). Kabzems (1971) concluded that a good seed supply and favourable seedbed conditions are prerequisites for successful regeneration.

Invasion by white spruce onto prairie vegetation occurs only during wet cycles, where the seedlings have an advantage over the herbaceous plants (Jarvis, 1963). White spruce invades prairie vegetation on dry sands and gravels and is considered to be more tolerant than aspen on such sites (Jarvis, 1963). Frosts in late May or early June can affect the growth of white spruce. The early tender growth on white spruce is very often killed by early frosts, according to Rowe (1956). Considerable damage can be done to the new growth if there are successive years of early frost. Young trees can be stunted, as was the case of plantation #13 (Clear Lake Study Area), and can eventually die (Jarvis, 1963; Waldron, pers. comm. June 1990).

Rowe (1956) indicated that white spruce has a remarkable ability to tolerate extremes of moisture and temperature and suggested the presence of considerable genetic diversity within the species. For white spruce populations within Manitoba, information on their genetic variation is not available (Dojack, 1991). However, the Provincial Forestry Branch has recognized the variation of white spruce by developing seed zones. Criteria were developed to define seed zones which would enable the Forestry Branch to confine its seed collection and distribution to specific areas (Dojack, 1991). Some of the criteria used to define seed zone boundaries were

- restrict seed movement to less than 1.5^{0} of latitude
- restrict seed movement to less than 300 m in elevational change
- confine seed movement to vegetation zones/ecoregions.

Identifying the genotype of the jack pine and white spruce stock planted at Lake Audy and Clear Lake is important because they are probably non-native to Riding Mountain. According to Dojack (1991), the Riding Mountain seed zone for white spruce is different from that of the Duck Mountain and Spruce Woods. Non- native varieties disrupt the Park's natural ecosystem and their presence is contrary to Parks Policy (Parks Canada, 1979).

2.4 Rough Fescue Grassland Management

Continued research, followed by effective intervention management initiatives, is important for preserving rough fescue grassland in Riding Mountain National Park. Effective new initiatives should integrate scientific information gleaned from past grassland studies and grassland management techniques conducted in RMNP and other areas. This discussion will provide an overview of existing information and previously implemented management strategies in national parks in Canada and the United States.

2.4.1 Fescue Grassland Studies in National Parks

In 1961, a range study was conducted of the rough fescue grasslands in Riding Mountain National Park (RMNP) (Blood, 1966). As one of the first published reports on the Park's native grassland, the primary emphasis was to identify the distribution of rough fescue grassland throughout Manitoba and to document its species composition. One observation was that fescue prairie was more extensive in the past and has decreased with the invasion of aspen and white spruce. Blood also observed that rough fescue *Festuca hallii* was the dominant graminoid species and that the species composition was similar to fescue prairie sites in Saskatchewan. No recommendations or management prescriptions were presented.

In 1973, Garry Trottier of the Canadian Wildlife Service conducted a Range Study of RMNP. The primary objective was to determine the extent of the recovery of grass-forb ranges previously altered by cattle grazing and to conduct a reconnaissance survey of all grass-forb ranges for mapping purposes (Trottier, 1974). From the Study's 33 permanent transect sites in the Park, a range of species composition from pristine fescue grasslands to sites completely void of rough fescue plants was observed. Rough fescue was found at 24 of 33 sample sites (Trottier, 1986). Vegetation cover was eliminated in severely grazed sites, but the sites were quickly revegetated by a near monoculture of smooth brome *Bromus* grass (Trottier, 1986). Trottier (1974) indicated that climax rough fescue communities contain a few plant species of relatively rare occurrence and provide invaluable winter range for large native ungulates such as elk. A 1:50,000 scale map of the grassland areas of RMNP was produced. Recommendations presented in the Range Study included studying successional trends, experimenting on grassland conservation techniques, restoring disturbed sites, and the rezoning of certain fescue areas. The response by Parks to these management recommendations will be examined in relation to grassland initiatives.

An unpublished report by Deborah Tosczak (1989) identified and analyzed major issues concerning the management of Chernozemic soils and native grasslands in RMNP. Three of the thirty-three permanent transects set up by Trottier in 1973 were surveyed (Tosczak, 1989). Two of the grassland sites were found to be comprised of a smooth brome monocrop and the third was found to have had more woody species present. She emphasized that further analysis of the study plots was necessary for future management decisions. The relocation of horse facilities from a fescue prairie to a different vegetation community was recommended.

A progress report on the grassland community of Prince Albert National Park (PANP) was completed by Carbyn and Armbruster in 1968. The objective was to classify and determine the extent and nature of the upland grassland communities in the southern portion of the park. Two grassland sites were analysed using 1947 and 1962 aerial photos and the establishment of 11, 33 m randomly chosen vegetation transects. Carbyn and Armbruster reported that 21% and 33% of the grasslands of the two sites in 1947 photos were identifiable in 1962. The authors indicated that most of the grasslands would disappear at that rate, but it was reasonable to assume that grasslands would persist in a few core areas. Rough fescue was dominant at some of the sites, which suggested that the fescue grasslands in that region are not represented by a single or climatic climax. Recommendations were not included in the report.

T.F. Cameron conducted an investigation of isolated pockets of rough fescue grassland and associated communities in 1972 in the southern third of PANP. The fescue grassland was found to be similar in species composition to that in RMNP (Cameron, 1975). Cameron suggested that fire is necessary for the maintenance of rough fescue grassland and that due to the absence of fires, succession has slowed down to core areas. He indicated that some of the grassland pockets had disappeared and successional invasion threatened to eliminate those that remained.

A prescribed burn study was initiated in 1975 on rough fescue grassland in PANP. Prescribed burns were carried out intermittently until 1982 at three study areas of the Park during different seasons (Trottier, 1985). The study had the following objectives:

> to halt the present encroachment of aspen onto the grasslands, and to determine the optimal burn frequency which successfully controls the aspen encroachment and provides a level of biodiversity (Trottier, 1985).

The encroachment of aspen onto the grassland following a fire was not conclusively proven. In certain instances, fire top-killed the aspen and often stimulated aspen suckering, not measurably changing the vegetation pattern. Trottier recommended that the fescue grassland in PANP should not be burned more than once every five years. Prescribed burns promoted the establishment of grassland species in ecotone areas and did not alter the natural species composition of the grasslands. Trottier (1985) recommended that monitoring programs be conducted to identify any changes in the shrub and tree densities in the study areas. In another recommendation, he suggested that grassland management in PANP be conducted in the context of experimental natural resource management over the long term.

Since the initial burns in PANP, no substantive follow-up has occurred and natural succession has been allowed to proceed (Put, pers. comm. Dec. 1992). In a recent visual assessment of several study sites (no date specified), Put indicated that substantial encroachment of *Populus tremuloides* was occurring from the grassland - aspen stand boundaries, as well as from islands of trees within the meadows.

2.4.2 Review of Grassland Conservation Initiatives

One resource management objective in the Park Conservation Plan (PCP) for Riding Mountain is to preserve undisturbed representative Chernozemic Soil/Grassland sites (Canadian Parks Service, 1987a). The Canadian Parks Service (CPS) has designated a large fescue prairie in the Birdtail River Valley in Riding Mountain as Zone I - Special Preservation (CPS, 1987b). Zone I designation, in RMNP's Management Plan, identifies preservation of special features and resources as the primary objective (CPS, 1987b). The designation implies strict control and, if necessary, prohibited access to this zone.

Forest plantations are identified in the PCP for Riding Mountain as an example of a disturbed site and are deemed contrary to Parks Canada Policy (CPS, 1987a). In order to rehabilitate or restore fescue grasslands, Section 3.2.3 of Parks Canada Policy states,

> manipulation of naturally occurring processes may take place only after monitoring has shown that natural processes have been altered by man and manipulation is required to restore the natural balance (Parks Canada, 1979).

Both Toews (pers. comm. Oct. 1992) and Park Warden Vanderschuit (pers. comm. Dec. 1992) indicated that an inventory of disturbed sites is incomplete and no monitoring programs are in place for known disturbed sites. Efforts to rehabilitate two disturbed sites in the Clear Lake area were undertaken in the winter of 1991-92. Tree removal was followed by prescribed burns on the two sites to remove slash and prepare soil.

The entire Birdtail Valley, Birdtail Bench, Bob Hill Prairie and McFadden Valley areas, all of which contain fescue prairie, are designated as Zone II - Wilderness (CPS, 1987b). The primary purpose for Zone II designation is preservation of wilderness with allowance for public access and use consistent with a wilderness setting. Elimination of motorized access in the backcountry and the conversion of the Central and Strathclair roads to trail status (CPS, 1987b) were two initiatives that indirectly helped protect fescue grasslands.

A Vegetation Management Plan for RMNP is currently being developed by the Warden Service (Vanderschuit, pers. comm. Dec. 1992). In the past, the impact of humans has threatened the ecological integrity of several of the Park's plant communities. According to Park Warden Vanderschuit (pers. comm. Dec. 1992), natural processes are viewed as an important mechanism in eliminating the impact imposed on the Park's native flora. He also indicated that a higher priority may be given to active measures to conserve fescue grassland than in the past. The conservation of the Park's rough fescue grassland will be a major objective of the Vegetation Management Plan.

The rough fescue grassland in the southwest corner of Prince Albert National Park (PANP) has been designated as Zone I (CPS, 1987c). No management actions have been followed up in Zone I rough fescue grassland, and Cameron's study is the only documented material to date on the inventory of the Park's grasslands (Put, pers. comm. Jan. 1993). Park Warden Put also indicated that under the current Fire Control Plan the policy is that all fires are to be extinguished until a fire management plan has been developed (pers. comm. Jan. 1993).

In the current Park Management Plan for Waterton Lakes National Park, the Park's rough fescue grassland has been designated as an Environmentally Sensitive Area (ESA) requiring special protection and area specific management guidelines (Environment Canada, 1991). A fire management strategy has been developed for the Park to address the issue of reduced vegetation stability and diversity resulting from past fire suppression (CPS, 1989). According to Park Warden Watt (pers. comm. May 1992), the only significant management activity, as of May 1992, has been a series of small prescribed burns on the grassland/ aspen interface. He indicated that the prescribed burn program is intended to test the Park's burn prescriptions and to provide necessary background information needed to develop a strategy for the maintenance of park grasslands. Some rehabilitation work using native grass species on abandoned gravel pits and along highway rights-of-way has also been undertaken (Watt, pers. comm. May 1992).

Vegetation management strategies were reviewed for two parks in the United States that contain native prairie. Canyonlands National Park in Utah, with a semi-arid or cold desert climate, has scattered pinyon *Pinus edulis* and juniper *Juniperus osteosperma* trees intermixed with a desert shrub community (United States Parks, 1972). The grasslands of the Park have been heavily grazed for over 100 years but, according to Park Superintendent Walter Dabney (pers. comm. June

1992), there are few areas where native grasses have not recovered. He indicated that the Park was searching for methods to reestablish the native grasses but that they were still in the experimental stage.

Mixed Prairie is represented in Badlands National Park in South Dakota (United States Parks, 1972). According to a Park resources staff (pers. comm. June 1992), a prairie restoration plan began in 1992. Badlands contains old agricultural fields that have since been inundated by Canada Thistle *Cirsium* sp. and several brome species. One option for restoring the former prairie areas was to sow the disturbed sites using seed of native grasses.

2.5 Summary

The reviewed literature on rough fescue grasslands of western Canada, including national parks, fell into three categories: 1) classification and distribution, 2) ecological analysis, and 3) management. The classification and distribution of rough fescue grasslands is well-documented by Moss and Campbell, 1947; Blood, 1966; Carbyn and Armbruster, 1968; Coupland and Brayshaw, 1968; Looman, 1969; Cameron, 1975; Looman, 1980; Pavlick and Looman, 1984; and Trottier, 1974, 1985, and 1992. Only three works on ecological analysis and management of rough fescue grassland in Prince Albert and Riding Mountain National Parks have been identified, including Cameron, 1975; Trottier, 1985 and Tosczak, 1989. Apart from Trottier (1992), little published material was located on management and restoration of disturbed rough fescue grasslands. Other than Grasslands National Park which was not consulted, limited information was available on recent native grassland management and conservation initiatives in national parks. For this study, much of the information pertaining to native grassland management programs in National Parks was obtained from written correspondence.

A considerable amount of material has been written on the recovery of soil properties and native vegetation following disturbances, all concerning work done in Alberta. Recovery of rough fescue grasslands and Chernozemic soils in Alberta has been well documented by Dormaar and Smoliak, (1985); Willms, (1988); Dormaar and Willms, (1990a,b); and Dormaar, Smoliak and Willms, (1989, 1990a,b). Most of the references on rough fescue grassland and Chernozemic soils were taken from scientific journals and published and unpublished government reports.

Literature on the surviving plantations established under Project MS-104 (1918 - 30) was thorough and contained in Canada, (1918 - ?); Haig, (1958); Jarvis et al., (1966); Pratt, (1978) and Walker, (1987). Records consulted in Canadian Forestry Service (Record Group 39) and Parks Canada (Record Group 84) contained a limited amount of data for this study (Appendix I). Of the nine Record Volumes consulted, seven were fully researched and two were researched in part. Those Record Volumes that may contain additional information on the plantations in Riding Mountain are identified in Appendix I.

CHAPTER 3 Methods

Investigation of the forest plantations and review of literature on rough fescue grassland of this study began in 1990. Critical to the study was locating and accessing historical records of forestry research conducted in Riding Mountain National Park. To better understand a fescue grassland ecosystem, studies on the grasslands distribution, and biodiversity and its association with Chernozemic soils were consulted. Soil analyses were included to identify the effects of white spruce on grassland soil properties such as pH, organic matter, moisture content and carbonates.

3.1 Data Sources and Selection

Information pertaining to the location, planted stock, and site treatment of the Lake Audy plantations was obtained from original field notes, reports and maps. These records were located at Forestry Canada libraries in Winnipeg and Edmonton. Information on afforestation programs initiated in Riding Mountain was summarized in Annual Reports (1901 - 1936) by the Director of Forestry, Department of Interior.

An invaluable secondary source for the study was the three volume series entitled, A Review of Forest Research Studies Conducted by the Canadian Forestry Service in Manitoba and Saskatchewan to 1970 by H. J. Johnson (1985). The document provided the basis for determining what research projects and activities conducted in Riding Mountain were applicable to my study. The Canadian Forestry Service and Parks Canada Record Groups at the National Archives in Ottawa contained limited information pertaining to Riding Mountain's plantations.

Since no recorded data was available on the Clear Lake plantations, information had to be gathered from field surveys and interviews. Field data on tree age, height and diameter were collected by the author and an assistant on plantations 6, 9, and 12. To calculate an approximate age, increment cores were taken at a height of 1.3 m, using a Swedish Increment Borer, from ten trees in each of the three plantations. The height and diameter of five trees in each plantation were measured using a Haga altimeter and diameter tape respectively. Scientific vegetation sampling was not recommended given the scope of the study. However, general field notes were made on the physiognomy of the vegetation in 12, 1 m^2 plots in plantation 87-30 at Lake Audy, using 35 mm photography and species composition estimations. The plots were either adjacent to or in close proximity to the 10 soil pits dug in the plantation.

Former Forestry Canada and Park employees involved with the plantings at Clear Lake and long time residents of Onanole and district were interviewed (Appendix II). Aerial photographs were invaluable for locating and analysing the forest plantations, particularly at the Clear Lake Study Area. In 1978, normal colour photography of Riding Mountain was conducted at a scale of 1:12,000. The aerial photographs used during the study were from the set located at the Park's administration office in Wasagaming. Plantations at both study areas were traced from aerial photographs onto acetate, then reproduced as Figures 9 and 10. All photographs presented in the document were taken by the author.

There was considerable variation in size, cover value and physiognomy amongst the plantations. A system that would simplify the description and presentation of the plantations for the study was deemed necessary. Cover value was the parameter that offered the greatest measurability of tree cover per plantation and was best for comparing plantations. Each plantation was assigned to one of three cover value categories as recognized by the Canadian Vegetation Classification System (National Vegetation Working Group, 1990). The three categories were <25% (sparse), 25-60% (open) and >60% (closed).

3.2 Plantation Selection Criteria

General information on the individual prescriptions under Project MS-104 such as the number, tree species and location is presented (Table 1). Most of the research activities conducted under Project MS-104 were located at Lake Audy and north along the Strathclair Road (Appendix III). To be considered for the study, the plantations in MS-104 had to meet two criteria: see columns 6 and 7 in Table 1. The first criterion stipulated that a plantation be located within the present boundary of the park. The second required that a plantation be established on native prairie. Further breakdown of activities on known prairie sites in MS-104 is presented (Table 2). Documentation on the status of three of the nine seedbeds was identified. Though there was no information specific on the remaining six, seedbeds typically had very high failure rates within two to three years of being established.

Criteria were also developed to determine which disturbed fescue prairie sites were most appropriate for restoration and which sites were to be left to evolve naturally. Both of the following criteria were to be met to determine the most feasible plantations for elimination. The first criterion required that a plantation contain a minimum of 40% prairie vegetation. The second required that

Table 1. Forest Research Activities, Department of Interior, Forestry Branch (Canada, 1918 - ?).

No. (1)	Endeavour - Year (2)	Species (3)	Location Sec-Twp-Rg (4)	Description of Location (5)	Vegetation Description (6)	Relative to Park (7)
1.	1-18	Sw	NE 10-19-18	SW of LS1/SE of LS2 of 10-19-18	?	Out
2.	2-18	Sw	SE 15-19-18		Forest	Out
3.	3-18	Sw	SE 13-19-16		Forest	In
4.	*4-18	Sw	NW 28-23-19	Dauphin Administrative Site	Forest	In
5.	5-18	Sw	NW 28-23-19	Dauphin Ranger Station (R.S.)	Forest	In
6.	6-18	Sw	NW 28-23-19	Dauphin Ranger Station (R.S.)	Forest	In
7.	7-18	Sw	SE 31-23-24	1/4 m. south of Grandview R.S.	Prairie	Out
8.	8-20	Sw	SW 6-22-20	Strathclair Road near Mile 9	Prairie	In
9.	9-20	Pj	SE 1-22-21	Strathclair Road near Mile 9	Prairie	In
10.	10-20	Ps	SE 1-22-21	Strathclair Road	Prairie	In
11.	11-20	Sw	SW 6-22-20	Strathclair Road, Mile 9	Prairie	In
12.	12-20	Pj	SW 6-22-20	Strathclair Road	Prairie	In
13.	13-20	Pj	SW 6-22-20	Strathclair Road, Mile 9	Prairie	In
14.	14-20	Sw	NW 31-21-20	Strathclair Road, Mile 9	Forest	In
15.	15-20	Pj	NW 31-21-20	Strathclair Road, Mile 9	Forest	In
16.	16-20	Sw	NE 1-22-21	Strathclair Road, Mile 8	Prairie	In
17.	17-20	Pj	NE 1-22-21	Strathclair Road, Mile 8	Prairie	In
18.	S18-20	Pj,Sw	NE 1-22-21	Strathclair Road, near Kennis Bridge	Prairie	In
19.	S19-20	Pj	NE 1-22-21	Strathclair Road, near Kennis Bridge	Prairie	In
20.	S20-20	Sw	NE 1-22-21	Strathclair Road, near Kennis Bridge	Prairie	In
21.	S21-20	Pj	NE 1-22-21	Strathclair Road, near Kennis Bridge	Prairie	In
22.	S22-20	Sw	NE 1-22-21	Strathclair Road, near Kennis Bridge	Prairie	In
23.	S23-20	Pj	NE 1-22-21	Strathclair Road, near Kennis Bridge	Prairie	In
24.	S24-20	Sw	LS1 6-21-20	Strathclair Road, in Bison Enclosure	?	In
25.	S25-20	Pj	LS2 6-21-20	Immediately South of S24-20	?	In
26.	S26-20	Sw	LS2 6-21-20		?	In
27.	S27-20	Pj	6-21-20	Immediately west of S26-20	?	In
28.	S28-21	Sw		Immediately adjacent to 5-18	?	In
29.	S29-21	Sw		Immediately south of S28-21	?	In

No. (1)	Endeavour -Year (2)	Spp. (3)	Location Sect-Twp-Rg (4)	Description of Location (5)	Vegetation Description (6)	Relative to Park (7)
30.	S30-22	Sw	NW 28-23-19	Near Dauphin R.S., SE of S28-21	?	In
31.	31-22	Pj	NE 3-19-18	LS15, NW of Whirlpool R.S.	Forest	Out
32.	32-22	Pj	NE 3-19-18	LS15, 100 yds. NW of Whirlpool R.S.	Forest	Out
33.	*33-22	Pj,Ps	NE 30-20-20	Near Elphinstone R.S. (Lake Audy)	Prairie	In
34.	34-22	Sw	NE 30-20-20	On south bank of Jackfish Creek	Forest	In
35.	35-22	Sw	NE 30-20-20	Adjacent to 34-22	Forest	In
36.	36-22	Sw	NE 30-20-20	150 yards east of 3422	Forest	In
37.	S37-22	Pj	NW 11-23-23		?	In
38.	S38-22	Sw	NW 11-23-23		?	In
39.	S39-22	Sw	E 1-23-23	East 1/2 Section	?	In
40.	S40-22	Pj	E 1-23-23	East 1/2 Section	?	In
41.	41-22	Sw	NE 3-19-18		?	Out
42.	42-23	Pj	NE 28-23-19		Forest	In
43.	43-23	Pj	NE 28-23-19		?	In
44.	44-24	Pj,Ps	NE 30-20-20	Adjacent to 33-22	Prairie	In
45.	45-24	Pj	NW 28-23-19	East of 5-18	Forest	In
46.	46-24	Sw	NW 28-23-19	Near Dauphin R.S.	?	?
47.	S47-24	Sw	NE 30-20-30	Lake Audy Plains	Prairie	In
48.	S48-24	Sw	NE 30-20-20	Lake Audy Plains	Prairie	In
49.	S49-24	Sw	NE 30-20-20	Lake Audy Plains	Prairie	In
50.	50-25	Sw	33-19-23	Dauphin Administrative Site (D.A.S.)	Forest	Out
51.	51-26	Sw	33-19-23	D.A.S	Forest	Out
52.	S52-26	Sw		Near D.A.S.	?	In
53.	S53-26	Sw		Near D.A.S.	?	In
54.	S54-26	Pl		About 1 mile from D.A.S.	?	?
55.	S55-26	Pj		On Thompson Road near D.A.S.	?	?
56.	S56-26	Sw	E 24-22-21	Strathclair Road, Mile 5	?	In
57.	S57-26	Sw	E 24-22-21	Strathclair Road, near hill	?	In
58.	58-21	Pj		2 miles south and west of Swanson Cabin	?	?

No. (1)	Endeavour - Year (2)	Spp. (3)	Location Sec-Twp-Rg (4)	Description of Location (5)	Vegetation Description (6)	Relative to Park (7)
59.	59-21	Pj		2 miles south and west of Swanson Cabin	?	?
60.	60-21	Pj		2 miles south and west of Swanson Cabin	?	?
61.	61-21	Pj		2 miles south and west of Swanson Cabin	?	?
62.	62-22	Pj		2 miles south and west of Swanson Cabin	?	?
63.	63-26	Po	NW 1-21-20	1/2 m. E. of Jackfish Creek on Lake Audy Road	Forest	In
64.	64-26	Po	NW 1-21-20	1/2 m. E. of Jackfish Creek on Lake Audy Road	Forest	In
65.	65-26	Po	NW 1-21-20	1/2 m. E. of Jackfish Creek on Lake Audy Road	Forest	In
66.	*66-27	Sw	SE 31-20-20	Lake Audy Plains	Prairie	In
67.	*67-27	Sw	SE 31-20-20	Lake Audy Plains	Prairie	In
68.	*68-28	Sw	SE 31-20-20	Lake Audy Plains	Prairie	In
69.	*69-28	Sw	SE 31-20-20	Lake Audy Plains	Prairie	In
70.	70-28	Ls,Sw	SE 31-20-20	Lake Audy Plains	Prairie	In
71.	71-28	Sw	SE 31-20-20	Lake Audy Plains	Prairie	In
72.	72-28	Ls,Sw		Dauphin Woodblock	Forest	?
73.	S73-28	Sw		Dauphin Woodblock	Forest	?
74.	S74-28	Sw		Dauphin Woodblock	Forest	?
75.	S75-28	Pj		Timber Sale #142	Forest	?
76.	76-28	Pj		Timber Sale #142	Forest	?
77.	77-28	Pj		Timber Sale #142	Forest	?
78.	78-28	Pj		Near Kelwood, on Whirlpool Road	?	?
79.	*79-29	Sw	SW 32-20-20	Lake Audy Plains	Prairie	In
80.	*80-29	Sw	NE 30-20-21	Lake Audy Plains	Prairie	In
81.	81-29	Ls,Sw		Lake Audy Plains	Prairie	In
82.	82-29	Sw		Lake Audy Plains	Prairie	In
83.	83-29	Sw		Dauphin Woodblock	Forest	?
84.	84-29	Sw		Dauphin Woodblock	Forest	?
85.	85-29	Sw		Dauphin Woodblock	Forest	?
86.	86-29	Sw		Dauphin Woodblock	Forest	?
87.	*87-30	Sw	SW 32-20-20	Lake Audy Plains	Prairie	In

KEY: Ls - Siberian larch (European) Pj - Jack pine Pl - Lodgepole pine Po - Poplar (Trembling Aspen) Ps - Scots pine
Sw - White spruce S - Seedbed * Lake Audy

a plantation be adjacent to or represent a pocket of fescue prairie. Disturbed sites were to meet the following criteria in order to be considered for restorative measures outlined in Recommendation #4. The first criterion required that a plantation contain a minimum 40% fescue prairie vegetation. The second required that a plantation be in need of immediate restorative action to prevent complete elimination of fescue prairie vegetation. To determine what disturbed sites are to be left to evolve naturally, both the following criteria were to be met. The first required that the forested area of a plantation cover no less than 25%, and the second stipulated that the plantation not be adjacent to remnant fescue prairie.

Sites that previously contained seedbeds were re-examined where possible. Plantations and seedbeds situated inside the Bison Enclosure were not examined. Observations regarding the presence of surviving trees and extent of reinvasion by native prairie into the seedbeds were recorded.

Table 2. Results of Research Prescriptions on Known Prairie Sites Under Project MS-104 as of remeasurements in 1925, 1926, and 1957 (Canada, 1918 - ?; Anon., 1925; Bedell, 1926; and Haig, 1958).

	Failed	Survived	Total
Plantation	14	8	22
Seedbeds	11	0	11
			33

3.3 Soil Sampling and Hypotheses Testing

To measure changes to the soil brought about by afforestation, a comparison was made of soil samples taken from a disturbed and an undisturbed sample area. Plantation 87-30 at Lake Audy was chosen because of its location adjacent to a large and relatively undisturbed fescue prairie (Figure 7). Eight randomly chosen sites in each vegetation community were considered sufficient for comparison purposes. The soil pits in the fescue prairie were approximately 50 m apart and located a minimum of 50 m from stands of trees. Soil profile observations were made on an undulating floodplain east of plantation 87-30 (Figure 8a) where it was assumed that minimal change to the soil's chemical and physical properties would have occurred. The second set of pits was dug in the plantation at sites where tree cover was nearly 100%. The eight pits were dug in undisturbed soil between the rows of white spruce. The sampling period was short and rain free.

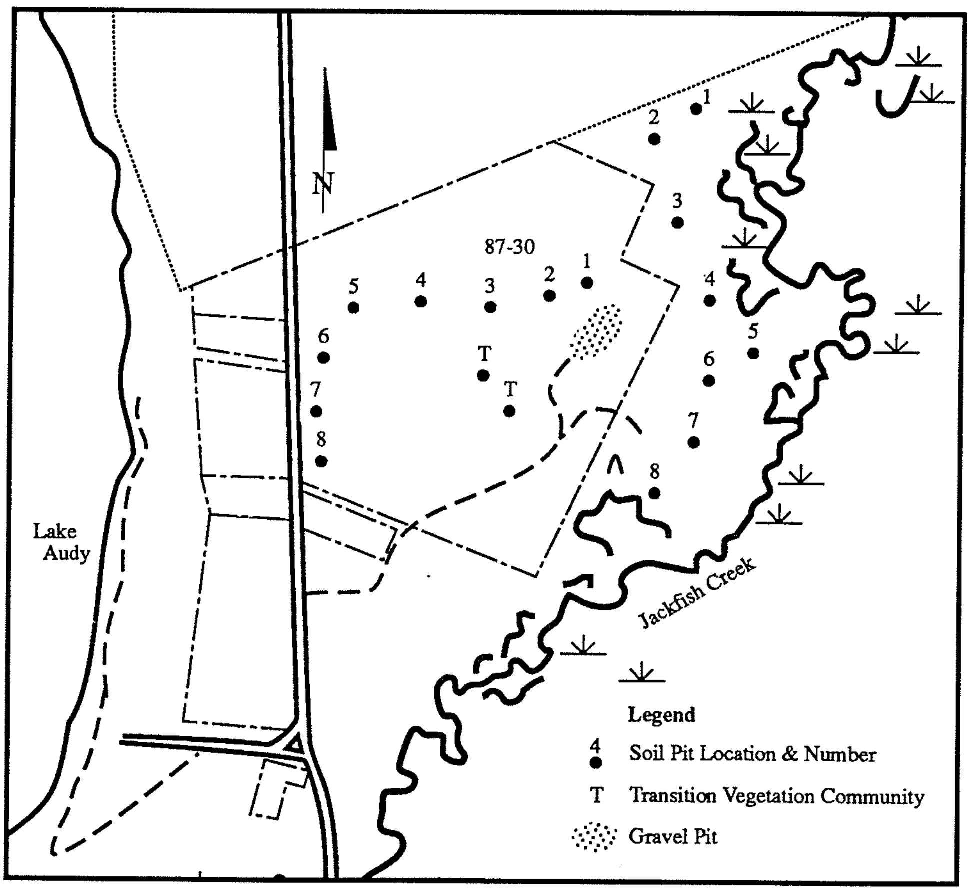


Figure 7. Soil pit location in Plantation 87-30 and adjacent fescue prairie (Scale 1:12,000).

Because plantation 87-30 is not of uniform cover, a third set of data was collected from 2 pits in a less dense stocking of trees. This set of data serves only to provide background on the gradual change which has occurred to the soil under a transition type vegetation community.

All the soil pits were excavated to the C horizon (Figure 8b), a depth ranging between 25 and 60 cm. On one side of each pit, a vertical profile was cut so accurate measurements and samples could be taken of the individual soil horizons. In addition, photographs were taken of each soil profile. The soil digs were refilled and the sod was carefully replaced to restore the disturbed site. No soil digs were performed at the Clear Lake Study Area.

Approximately 500 g of soil was removed from each horizon and sealed in a plastic bag. To avoid moisture loss in the plastic bag during transport to the lab, a smaller quantity of soil was placed in a 250 ml secured tin. All soil samples were brought to the University of Winnipeg Soils Laboratory for analysis. Soil analysis was conducted at the University of Winnipeg under the supervision of Dr. Geoffrey Scott, Geography Department. The presence of carbonates and organic matter, as well as pH level, were tested on soil from the larger sample. Moisture content was measured on the smaller sample.

The following methods employed to test for the four soil properties were extracted from Scott's (1991b) Soils and Vegetation Laboratory Manual. The Calcium Chloride Method was used to determine soil pH. This method involved thoroughly mixing 10 g of soil and approximately 20 ml of (0.01 M Ca Cl_2) solution. The mixture was left for 20 minutes, after which time pH was measured using a pH meter.

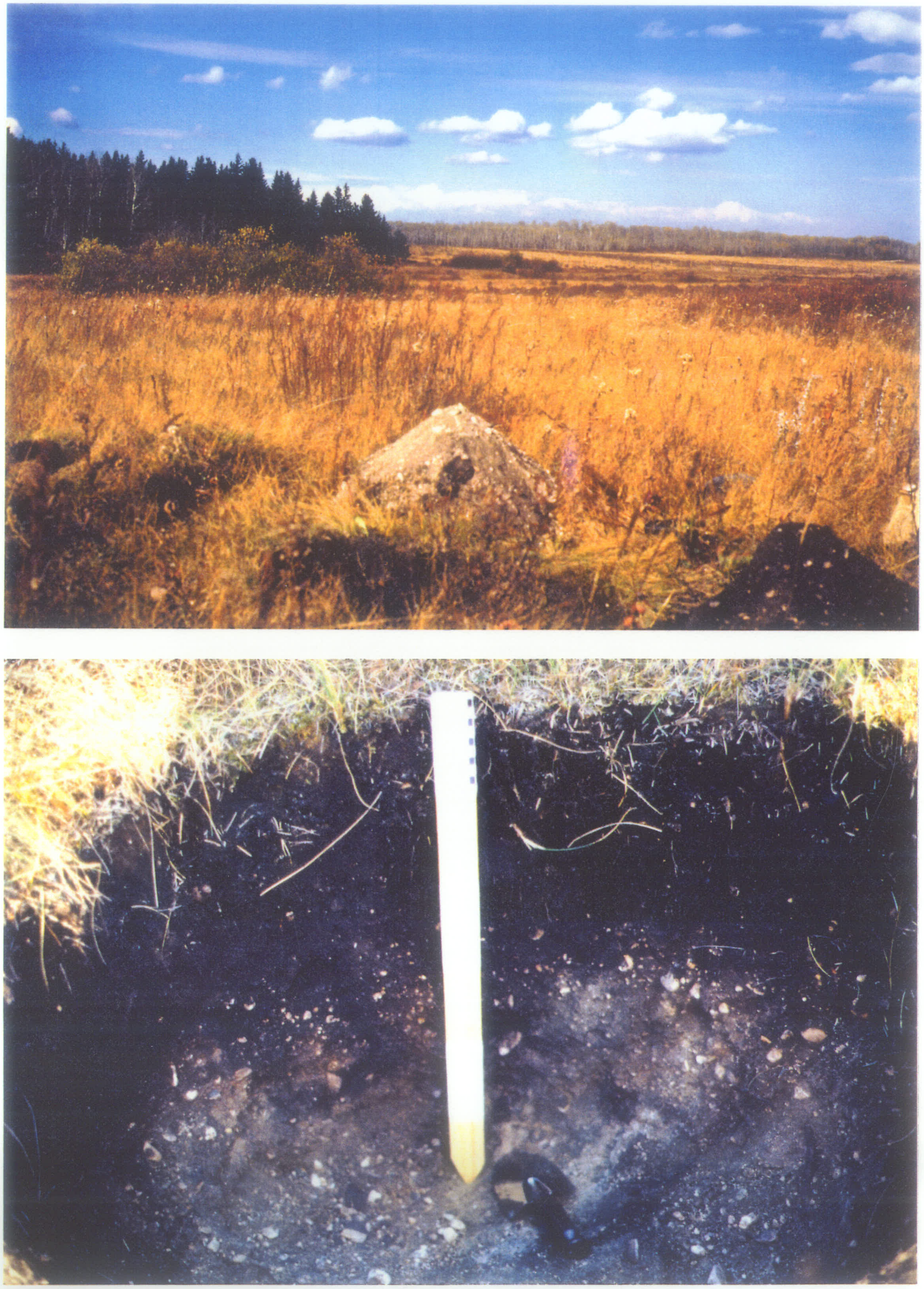


Figure 8. A) Undulating floodplain (Lake Audy) (top) and B) Orthic Black Chernozemic Soil Profile under Rough Fescue Prairie (bottom).

To measure moisture content (MC%), 10-20 g of moist soil was oven-dried for a period of 24 hours at a temperature between 105-110°C. The sample was reweighed and the MC% calculated using the following formula:

$$MC(\%) = \frac{\text{mass of moist sample - mass of oven-dried sample}}{\text{mass of oven-dried sample}}$$

The organic matter (OM%) content was measured using the Loss on Ignition Method (Scott, 1991b). A sample of soil was oven-dried and weighed. The sample was placed in a muffle furnace at a temperature of about 550°C for one hour in order to burn off all organic matter. After cooling in a dessicator, the sample was reweighed and the OM content was calculated using the following formula:

$$OM(\%) = \frac{\text{mass of oven-dried soil before ignition} - \text{mass of incinerated soil after ignition}}{\text{mass of oven-dried soil before ignition}} \times 100$$

The 10% HCl Method is described as a semi-quantitative test for carbonates (Scott, 1991b). Two drops of dilute hydrochloric (HCl) acid were delicately applied to a small sample of soil. After applying the HCl, the level of calcium carbonate content was estimated from the visible and audible effects of released carbonate dioxide gas (Appendix IV).

To establish whether there had been any change to Ah and Bm soil properties as a result of afforestation, results from the soil tests were statistically analysed. Paired sample means were used to test whether the mean soil property of a horizon in fescue prairie equalled mean soil property in a similar horizon of plantation. The null hypothesis (Ho) and the alternative hypothesis (Ha) refer to the population parameter relevant to the particular property. For example, the hypothesis for testing pH was as follows:

H_o: mean soil pH in Ah horizon of fescue prairie equals the mean soil pH in Ah horizon of plantation

vs

H_a: mean soil pH's of Ah horizons are different

A 95% confidence interval was chosen. With every conclusion of a t-test, the significance probability (p-value) was reported. The p-value gauges the strength of evidence against H_o on a numerical scale (Johnson and Battacharyya, 1985). A small p-value indicates a strong justification for rejection of the null hypothesis (Johnson and Battacharyya, 1985).

Sample means were calculated for organic matter, moisture content and pH level. The test of hypothesis employed to compare sample means of similar horizons was the paired Student's t-test. The carbonate observations were ordinal numbers derived from a ranking system. Because no assumptions were made about the form of the population distribution of the carbonate values, a non-parametric test, the Wilcoxon Rank-Sum Test was used to test the hypothesis. It is designed to test a null hypothesis of identical population distributions (Kirk, 1984). Box-plots were used to interpret the carbonate observations.

The statistical calculations were performed mostly by hand and with the aid of Data Desk, an interactive statistical package. Data Desk was employed to illustrate the results of the soil tests and to verify the hypothesis testing. Interpretation of the results were accomplished with the assistance of a statistics graduate student, University of Manitoba.

3.4 Work Schedule

From February to April of 1990, a preliminary review of literature and a workplan for fieldwork were completed. A period of two months throughout the summer and fall of 1990 was required to investigate the plantations, conduct tree measurements and dig soil pits. The soil pits were dug during the first two weeks of September followed by the testing of samples over a two week period in October.

Over a six month period in the winter of 1990 - 91, a further review of literature was conducted and Chapters 1 - 4 were prepared. The study resumed in the summer of 1992 with the completion of Chapter 5 and preparation of the document for the First Draft meeting in July. After the meeting, approximately three and half months were dedicated to addressing the recommended revisions and editing of the document. Approximately one week was spent at the Forestry Canada office in Winnipeg reviewing the field notes and records of Project MS-104 during the course of this study. A total of 16 hours of research was conducted at the National Archives in Ottawa.

3.5 Summary

Most of the historical information on the Lake Audy plantations was contained in the Plantation Record File for Project MS-104. During three separate searches in Canadian Forestry Service and Parks Canada Record Groups in the National Archives, a limited amount of information pertinent to this study was identified. Little information was available on the plantations at Clear Lake; therefore interviews with former Forestry and Parks staff were necessary.

Guidance was provided from committee members on issues pertaining to Park Policy and natural resource conservation in national parks, and in the interpretation of the soil test results. The recommended soil sampling design and intensity was consistent with recent soil studies conducted by Agriculture Canada on Rough Fescue Prairie and Mixed Prairie in Alberta.

CHAPTER 4 Results

A total of twenty eight plantations were inventoried at the Lake Audy and Clear Lake Study Areas. Twenty seven white spruce plantations and one Scots/jack pine plantation were established on approximately 98.0 ha of native prairie. The historical background, including a brief description of stock origin and age, and the planting techniques of the individual plantations will be presented. The results of tests conducted on soil samples from two different vegetation communities will conclude the chapter.

4.1 Inventory and History of Plantations

Lake Audy. Eight plantations, 7 - white spruce and 1 - Scots/jack pine were identified at Lake Audy (Figure 9). The plantations were established south of the Bison Enclosure, on approximately 35.6 ha of native fescue prairie (Table 3). The white spruce stock for four of the plantations as well as the Scots pine stock was shipped from the Nursery Station at Indian Head, Saskatchewan (Appendix V). The nursery at Lake Audy supplied the planting stock for the remaining plantations with the exception of the jack pine stock in plantation 33-22, which was not identified. No information on the origin of the seed trees of the planted stock was located.

Prior to planting, the sites were prepared by burning off the accumulated litter. Furrows were usually ploughed in an east-west direction using a team of horses. In plantations 66-27 and 67-27, furrows were ploughed to a depth of about 25 cm (Walker, 1987). Either a planting spade or grub hoe was used to plant the stock in the furrow.

Seedbeds established on known prairie sites were complete failures within a

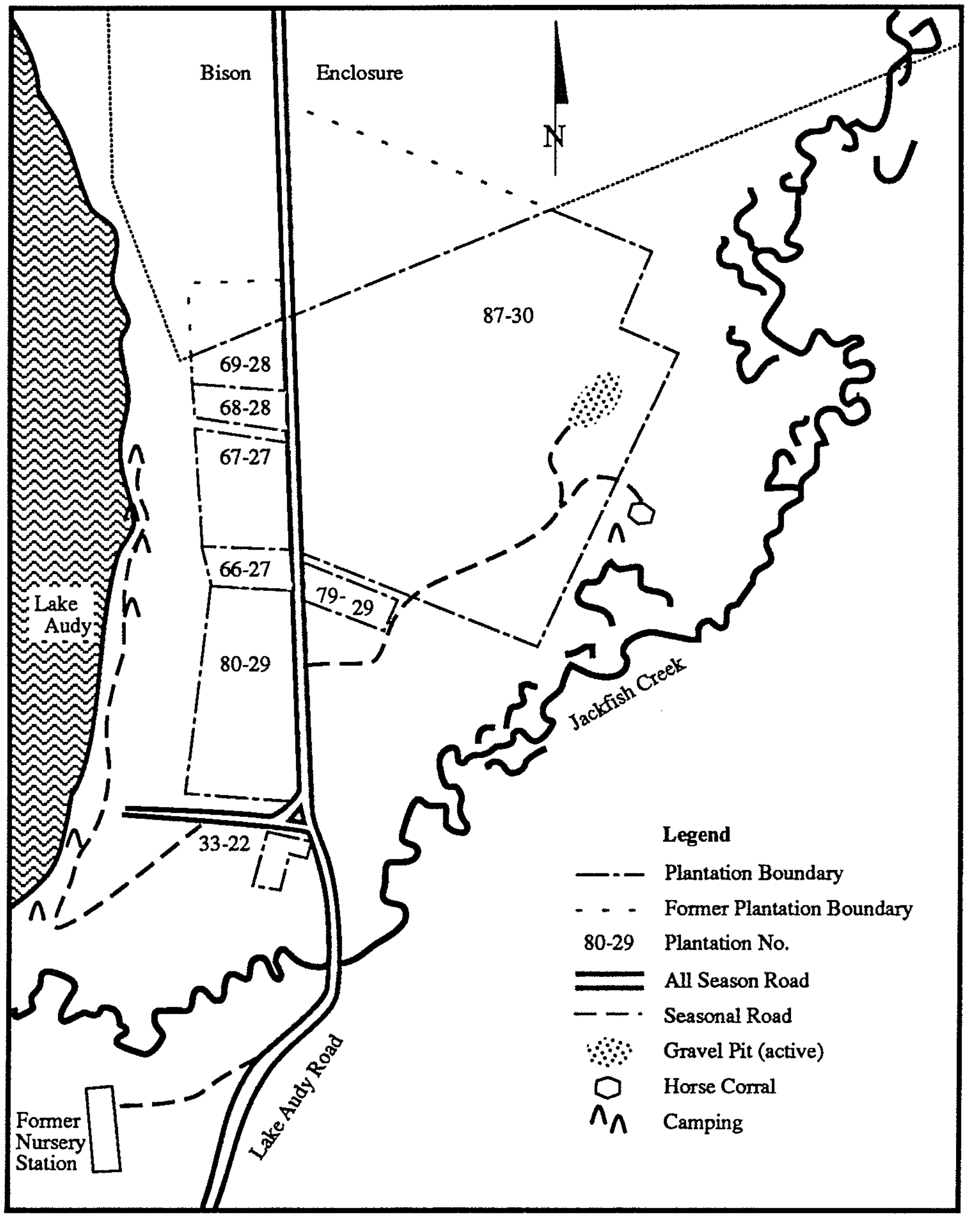


Figure 9. Plantations of Lake Audy Study Area, RMNP. (Scale 1:12,000)

short period of time. The main causes of failure for the seedbeds were either no seed germination or competition from weeds (Appendix VI). Seedbeds S47, S48, and S49 at Lake Audy have been successfully reinvaded by native prairie.

Table 3. Lake Audy Plantations Including Species Planted, Cover Class and Area (Canada, 1918 - ?). Pj-jack pine, Ps-Scots pine, Sw-white spruce.

Plantation no.	Species		Cover class(%)	
		<25	25-60	>60
			Area (ha)	
33-22	Pj, Ps	0.2		
66-27	Sw		0.9	
67-27	Sw			2.2
68-28	Sw	1.0		
69-28	Sw	1.2		
79-29	Sw	0.8		
80-29	Sw	5.1		
87-30	Sw		24.2	
	Subtotal	8.3	25.1	2.2
	Total 35.6 ha			

Clear Lake. Twenty white spruce plantations were identified on native prairie east of the townsite of Wasagaming (Figure 10). The plantations were estimated to have been planted between the late 1940's and mid 50's on approximately 62.3 ha of fescue prairie (Table 4). Written information was not available on the origin of the transplant stock nor on their parent seed trees. In 1948, however, white spruce seed was collected in Riding Mountain and in 1949 white spruce seedbeds were prepared at the nursery on Ta-Wa-Pit Drive, Wasagaming. A former park employee recalled collecting cones from beneath large spruce trees along Ta-Wa-Pit Drive and preparing seedbeds at the nursery around 1948. Between 1945 and 1949, tens of thousands of seedlings from the nursery were reported to have been planted in the Clear Lake area. Given the presence of a

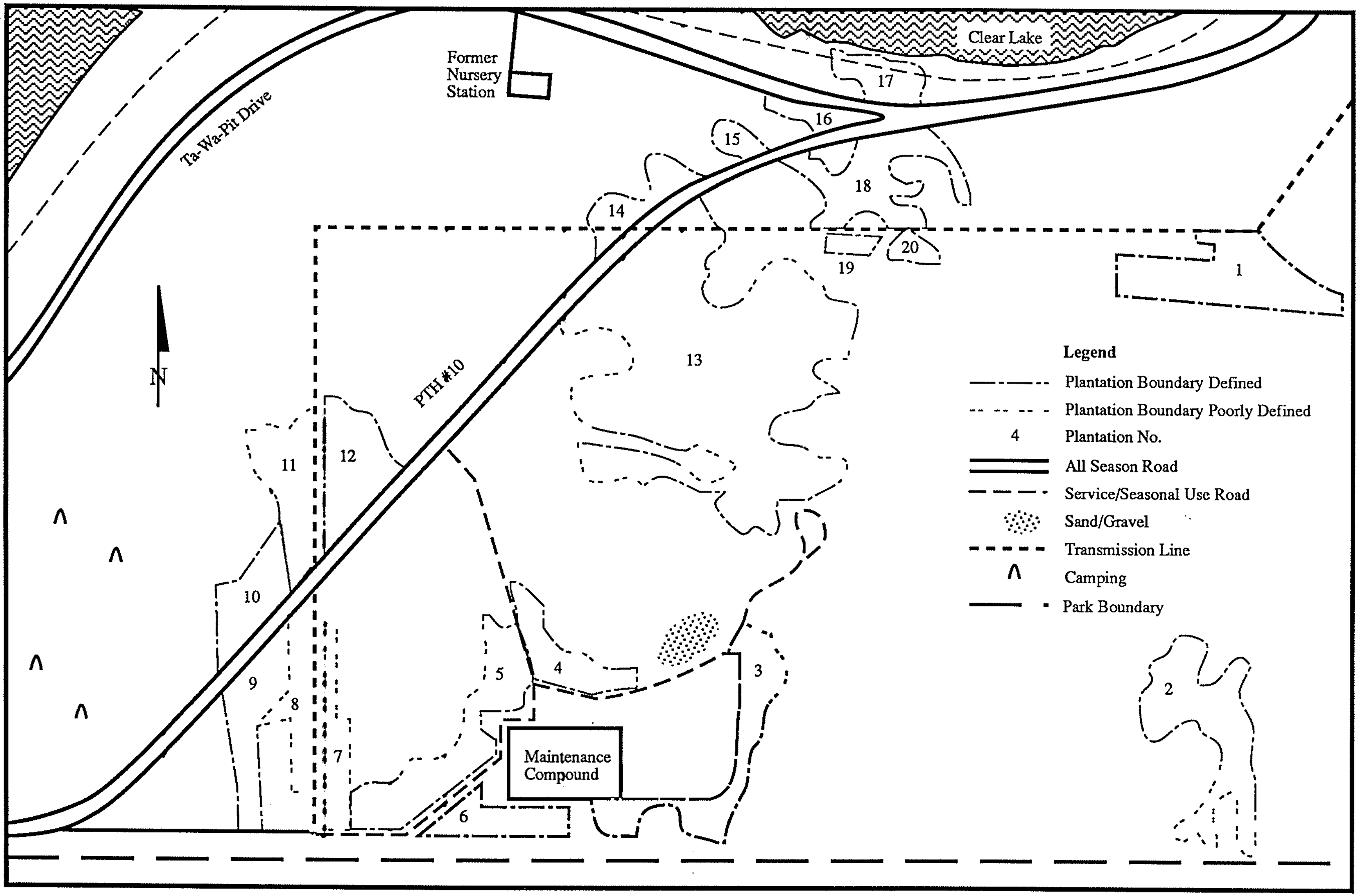


Figure 10. Plantations of Clear Lake Study Area, RMNP. (Scale 1:12,000)

Table 4. Clear Lake Plantations Including Species Planted, Cover Class and Area. Sw-white spruce.

Plantation No.	Species	Cover class (%)		
		<25	25-60	>60
			Area (ha)	
1	Sw			3.1
2	Sw		4.5	
3	Sw		3.2	
4	Sw	1.6		
5	Sw			2.3
6	Sw			3.2
7	Sw		1.8	
8	Sw	1.4		
9	Sw			3.2
10*	Sw			2.3
11	Sw		3.2	
12*	Sw			2.3
13	Sw	20.7		
14	Sw		1.6	
15	Sw			0.7
16	Sw			1.1
17	Sw			1.3
18	Sw			3.8
19	Sw			0.5
20	Sw		0.5	
	Subtotals	23.7	14.8	23.8
	Total 62.3 ha			

* Plantations removed during writing of the document

nursery station in Wasagaming and evidence of seed collected locally, there is reason to believe that the white spruce genotypes in the plantations and in the park are similar.

The method of planting involved the use of a Lowther Tree Planter pulled by a caterpillar. Information was not available on site preparation or on the age of the planting stock. The stock was spaced approximately 1.82 m (6 ft.) between both the rows and the individual seedlings (Figure 11). The direction of the rows was not consistent among the plantations.

On the basis of the oldest core sample taken from trees in plantations 6, 9 and 12, the planting dates were estimated to be 1938, 1945, and 1948 respectively. There was variation among samples within a plantation. The variation in sampling age could be attributed to differential seedling growth or to the common practice of refill planting. The inconsistency of the results has not provided an accurate account of the planting dates. However, if the last plantation

Figure 11. White Spruce Row Planting, Clear lake Study Area.
(former plantation no. 10, photo taken December 1990)

was planted in the mid 1950's or no later than 1955, it can be assumed that all of the plantations at the Clear Lake Study Area are at least 38 years of age.

4.2 Soil Analysis Results

The Student's t-test proved that changes to several of the soil properties occurred (Appendix VII). Soil pH values were, on average, higher in the fescue prairie than in the plantation (Table 5). An acidic litter layer of primarily spruce needles has developed in the forest plantation. The soil moisture

Table 5. Soil pH in Fescue Prairie and Forest Plantation 87-30.

	Fescue Prairie			Plantation			
Soil Pit no.	Ah	Bm	Ck	LFH	Ah	Bm	Ck
1	6.8	7.1	--	6.7	6.4	6.8	--
2	6.9	6.8	--	7.2	5.6	6.0	--
3	7.0	7.2	--	6.2	5.6	6.1	--
4	6.8	7.2	--	6.5	5.5	6.7	--
5	7.1	7.1	--	5.0	6.2	6.6	--
6	6.7	6.8	--	--	5.5	6.9	--
7	6.2	6.9	7.3	--	6.2	7.0	7.1
8	6.2	6.4	--	--	6.5	7.1	--
Mean ($\bar{x}$)	6.7	6.9	--	6.3	5.9	6.7	--

content (MC%) in the Ah horizon for fescue prairie was 15% greater than the MC% in the plantation (Table 6). In comparing MC% between different horizons, the

Table 6. Soil Moisture Content (%) under Fescue Prairie and Forest Plantation.

Soil Pit#	Fescue Prairie Ah	Bm	Ck	Plantation LFH	Ah	Bm	Ck
1	41.65	16.22	--	36.98	17.24	--	9.79
2	34.19	14.47	--	43.89	18.39	14.67	--
3	40.67	14.15	--	53.40	19.94	3.51	--
4	45.85	8.76	--	--	29.95	7.03	--
5	29.27	8.23	--	62.19	35.53	16.77	12.53
6	37.72	17.74	--	--	26.47	12.21	--
7	39.61	18.17	--	--	22.32	8.54	--
8	47.29	20.12	--	--	21.22	10.28	--
(x)	39.53	14.73	--	49.12	23.88	10.43	11.16

MC% was considerably lower in Bm horizons than in Ah horizons. The soil organic matter (OM%) content was predictably higher in the Ah horizon under fescue prairie than in plantation (Table 7). Much of the OM% in the plantation profiles is tied up in the litter, which requires a longer period of time to decompose than accumulated litter in native prairie. The carbonate levels of the two horizons in plantation and prairie did not differ significantly (Table 8).

Not enough samples were taken in the transition vegetation community to confidently identify trends in any of the four soil properties between prairie and plantation (Table 9). The results from this transitional vegetation community

Table 7 Soil Organic Matter (%) under Fescue Prairie and Forest Plantation.

	Fescue Prairie			Plantation		
Soil Pit no.	Ah	Bm	Ck	Ah	Bm	Ck
1	18.90	13.79	--	9.45	--	--
2	16.36	16.11	--	9.06	7.97	--
3	14.96	--	--	12.76	4.37	--
4	--	9.15	--	11.46	--	--
5	12.47	9.60	--	13.53	--	--
6	--	--	--	9.70	4.73	--
7	11.51	7.47	--	2.88	3.99	--
8	12.05	--	--	11.02	2.33	--
Mean ($\bar{x}$)	14.36	11.22	--	9.98	4.68	--

Table 8. Soil Carbonate levels under Fescue Prairie and Forest Plantation.

	Fescue Prairie			Plantation		
Soil Pit no.	Ah	Bm	Ck	Ah	Bm	Ck
1	<0.1	0.5	--	0.4	--	8.0
2	2.5	0.5	--	<0.1	<0.1	--
3	0.3	7.0	--	<0.1	0.2	--
4	0.4	2.0	--	<0.1	7.3	--
5	0.5	5.0	8.0	<0.1	<0.1	4.0
6	<0.1	0.2	--	<0.1	0.4	--
7	0.2	<0.1	4.0	<0.1	2.5	7.0
8	<0.1	<0.1	--	0.5	5.0	--

Table 9. Soil pH, Carbonates, Moisture Content and Organic Matter under Transition Cover Vegetation.

	Transition							
	pH		Carbonates		MC(%)		OM(%)	
Soil Pit	Ah	Bm	Ah	Bm	Ah	Bm	Ah	Bm
1	6.7	6.8	0.3	<0.1	34.89	8.88	10.40	--
2	6.3	6.5	<0.1	<0.1	29.09	11.56	11.60	13.36
$(\bar{x})$	6.5	6.7	--	--	31.99	10.22	11.00	--

do represent, however, a point or points along a continuum between the fescue prairie and plantation 87-30.

4.3 Summary

Basic information on the Lake Audy plantations such as species planted, planting density, and area of all the plantations was complete in the available planting records. Information on the Clear Lake plantations was primarily anecdotal and from a limited number of secondary sources.

Results obtained from tests conducted on soil samples taken from plantation 87-30 and an adjacent fescue prairie revealed that change had occurred to several properties of soil under the plantation. Significant change in Ah horizon soil pH, moisture content and organic matter has taken place under the plantation. A significant reduction in organic matter occurred in Bm horizon under plantation. No significant change occurred in the carbonate content of soil in the Ah and Bm horizons in soil under the plantation.

CHAPTER 5 Discussion

Coniferous forest plantations established in the past at two rough fescue grassland areas in Riding Mountain National Park have been identified and described. Based on the results of tests conducted on soil samples taken from one plantation, it can be seen that the conifers have measurably changed various soil properties at the site. The growing conditions for the native prairie flora have been seriously modified, resulting in a number of vegetational responses to the disturbances. Although the plantations occupy less than 4% of the Park's total fescue grasslands, there is justification for restoring most, if not all of these disturbed fescue prairie sites.

5.1 Present Status of the Plantations

Lake Audy. Walker (1987) described the survival of plantations 66-27 and 67-27 as very patchy; some areas were fully stocked while others had no survivors. All of the plantations at Lake Audy can be similarly described as patchy. As a point of clarification, a plantation refers to planted spruce with its adjacent remnant native prairie.

The survival rate among the plantations was not measured; however, differences were determined quantitatively. The plantations were assigned to one of the following cover categories: <25%, 25 - 60% and >60% (Figure 12). Based on aerial photo interpretation, plantation 67-27 was assigned to >60%, 66-27 and 87-30 to 25 - 60% and the remaining plantations to <25%. Heights and diameters of trees in plantation 66-27 and 67-27 were measured in 1985 by the Canadian Forestry Service. Mean height and diameter at breast height (DBH) for trees in

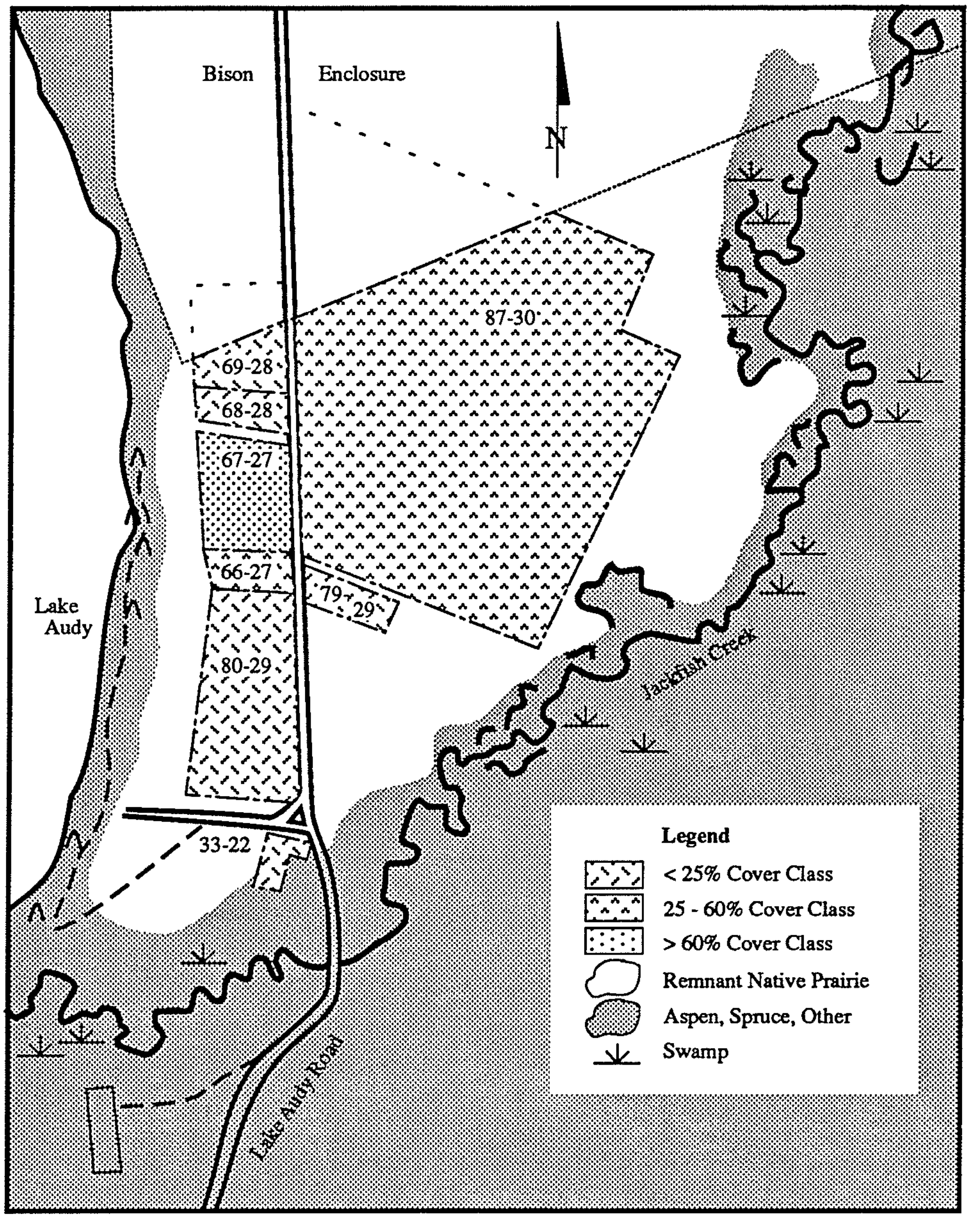


Figure 12. Plantation cover values, remnant fescue prairie and surrounding cover type at Lake Audy (Scale 1:12000).

plantation 66-27 were 13.1 m and 19.3 cm respectively (Walker, 1987). The mean height and diameter for trees in plantation 67-27 were 15.5 m and 20.8 cm

(Walker, 1987). Severe white pine weevil damage had occurred in both plantations by 1945 (Walker, 1987).

The planted spruce are bearing cones and it is probable that between 3 - 10 seed crops have been produced. The uneven-age stand of natural regeneration has developed primarily at the spruce - prairie ecotone (Figure 13). Favourable site conditions at the ecotone have resulted in densely stocked stands of young white spruce. Natural regeneration was present beyond the boundary of the plantations and most noticeable along the north and west exposures. The extent of encroachment was not measured, but seedlings were observed up to 15 m into the native prairie. Woody shrubs such as raspberry, rose, shrubby cinquefoil and snowberry are present in many of the smaller patches of remnant native prairie.

Clear Lake. Different rates of survival were experienced among the Clear Lake plantations. As in Lake Audy, the plantations were assigned to one of three cover value categories (Figure 14). Heights and diameters were recorded for ten randomly sampled trees in plantations 6, 9 and 12. The mean heights were 12.7, 12.8, and 11.8 m and mean DBH's of 19.4, 19.8, and 18.5 cm respectively. The habit of white spruce to retain dead lower branches made investigation of the three sampled plantations difficult. Aspen encroachment was occurring in plantations 3, 8, and 13. Plantations 10 and 12 were cut down by Parks Staff during the preparation of this document. The highest mortality at Clear Lake appeared to have occurred in plantation 13. Tree cover in the centre of the plantation is sparse, but towards the periphery survival tends to gradually increase. Interestingly, the centrally located trees appeared to have been stunted and were considerably

Figure 13. Uneven-aged natural regeneration along margin of Plantation 87-30.

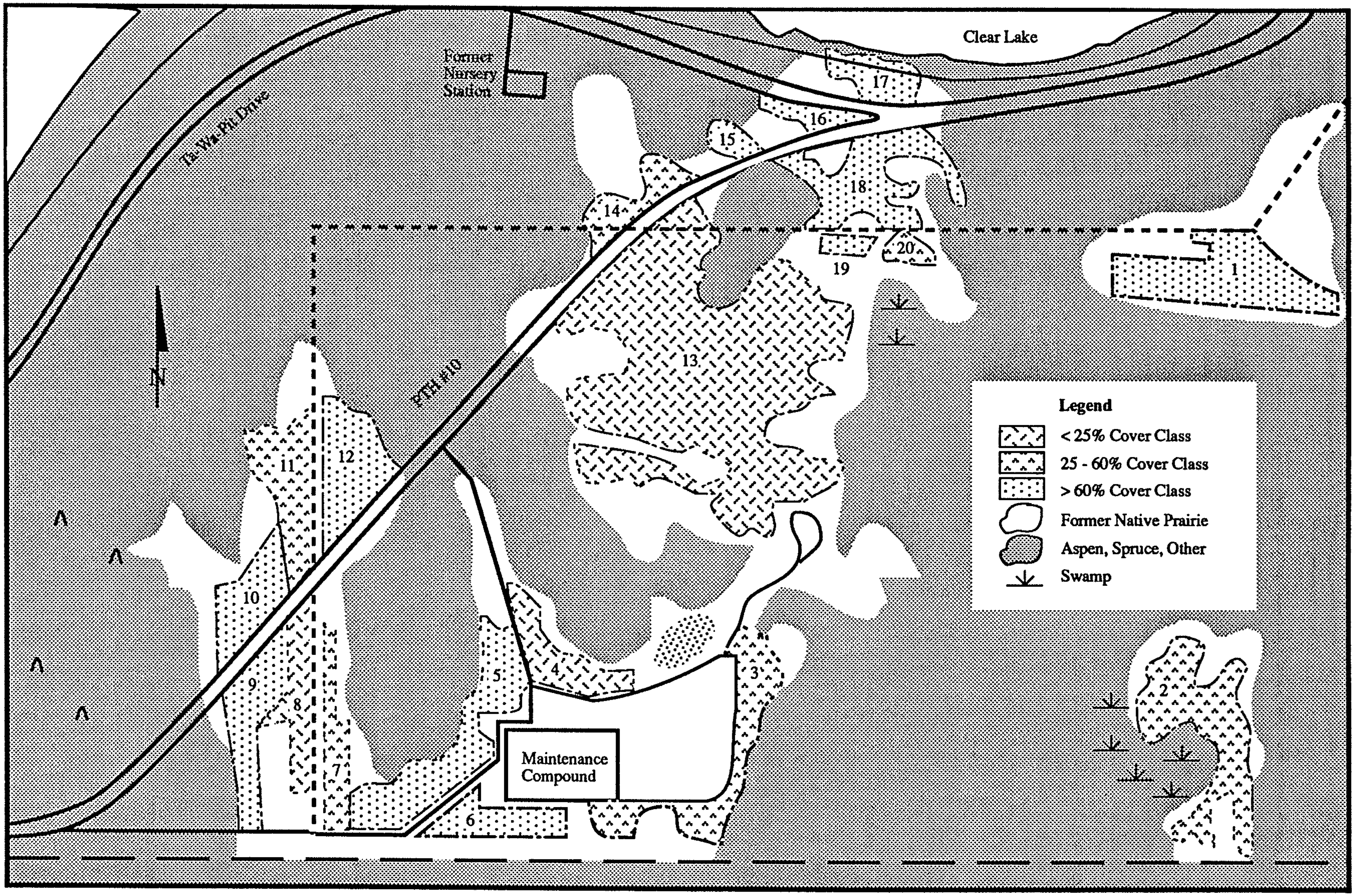


Figure 14. Plantation cover values, former distribution of native fescue prairie and surrounding vegetative cover type at Clear Lake (Scale 1:12,000).

shorter than those on the periphery. One factor or a combination of factors may have contributed to the trees' stunted appearance and low survival rate.

Plantation 13, the largest at Clear Lake, occupies a low lying area which makes the site highly susceptible to late spring frosts. Waldron (pers. comm. Jan. 1990) indicated that when young spruce are exposed to repeated frost damage, the tree will become stunted (Figure 15) and eventually die. Another factor to consider is the effect of the white pine weevil *Pissodes strobi*. In November 1992, a browning of needles and a curling effect of the terminal section of branches of shorter spruce was observed. The white pine weevil prefers open-growing, plantation, and nursery stock coniferous species where it attacks and always kills

Figure 15. Sparse and stunted 35+ year old white spruce in plantation 13, Clear Lake Study Area. (Photo taken October, 1991)

the leader or main shoots of the tree (Drouin and Langor, 1991). Frost and insect damage to young spruce appear to be contributing factors in the maintenance of this particular fescue prairie.

5.2 Effects of a Coniferous Plantation on Prairie Soil and Vegetation

In Part A, an interpretation of the results of the tests conducted for four soil properties and a description of the changes where applicable will be presented. To better understand the changes which have occurred to some of the soil properties, examples will be provided of changes to the same soil properties in similar prairie Chernozems elsewhere.

A. Effects on the Soil

The soil profiles under conifers in plantation 87-30 contained typical Orthic Black Chernozemic Ah, Bm and Ck soil horizons. There was, however, an LFH horizon present ranging from 2.5 to 8.5 cm thick. Typically, prairie Chernozems do not have an LFH horizon because of the rapid reintroduction of ground litter to the Ah horizon. The C horizon was reached at an average depth of 39 cm below the mineral soil surface for both vegetation communities.

pH. The pH values illustrated in Figure 16 strongly support the hypothesis that the Ah horizon has undergone acidification following afforestation. A mean pH value of 6.7 (very slightly acid) was recorded for prairie (pr) Ah horizon compared to a mean pH value of 5.9 (medium acid) for plantation (pl) Ah horizon. The sample mean of 5.9 in the Ah horizon (pl) represents more than eight times as many H^+

ions present as in an equivalent Ah horizon under fescue prairie. pH is a soil chemical analysis that gives an indication as to what extent cations in the soil are actually divided up between acids (non-nutrients) and bases (primarily plant nutrients such as Ca and Mg) (Scott, 1991b). The pH values recorded for Bm horizon indicated that a significant change had not occurred to Bm horizon (pl).

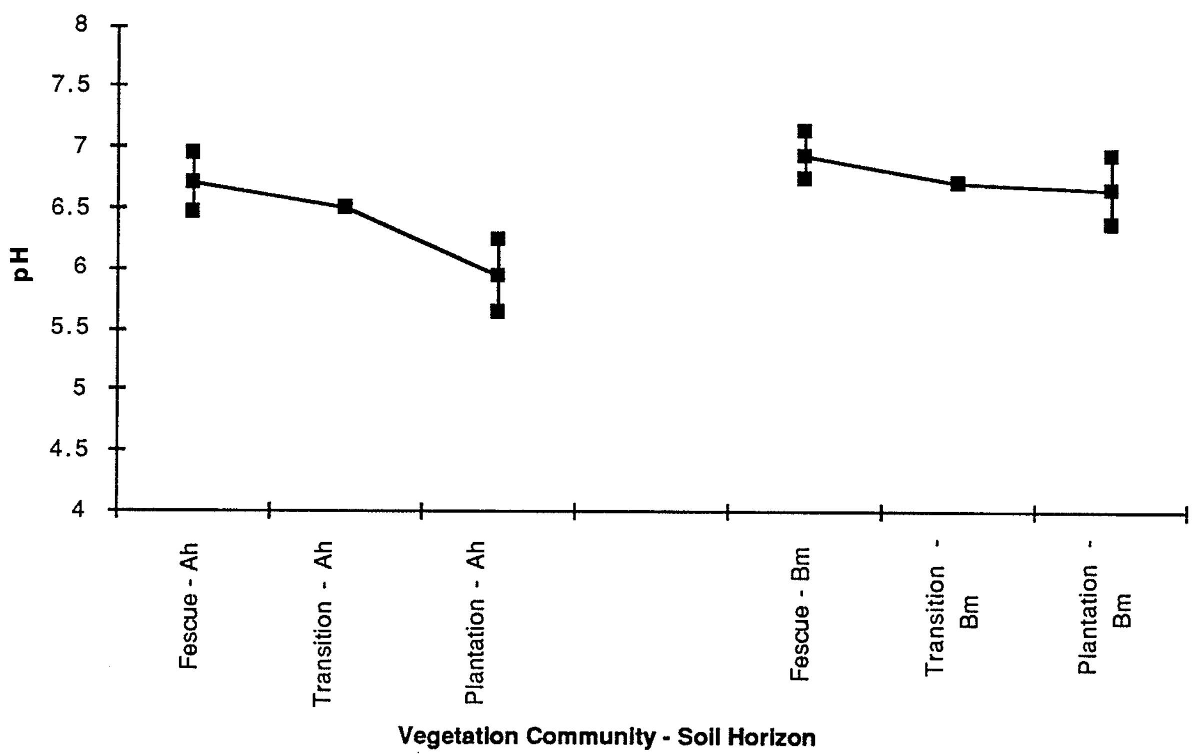


Figure 16. Plotted sample means and standard deviations of soil pH under fescue prairie and plantation communities.

Moisture content. The moisture content (MC%) values illustrated in Figure 17 strongly support the hypothesis that the Ah horizon under plantation is drier than Ah horizon under prairie. The mean MC% of soil in Ah horizon (pl) was approximately 40% less than the mean MC of Ah (pr). Less soil moisture in Ah horizon (pl) than in Ah horizon (pr) could be attributed to a number of factors.

These factors include 1) reduced organic matter content, 2) vegetation use of available water, 3) variation in precipitation / microclimate, and 4) role of litter (Scott, 1991b).

Soil moisture is a critical factor in the maintenance of fescue grassland. In an experiment where the response of fescue plants to controlled conditions was measured, plant height was most responsive to soil water deficits and least responsive to temperature fluctuations (Willms, 1988). Plant growth and height were adversely affected when water content reached 60% of field capacity (Willms, 1988).

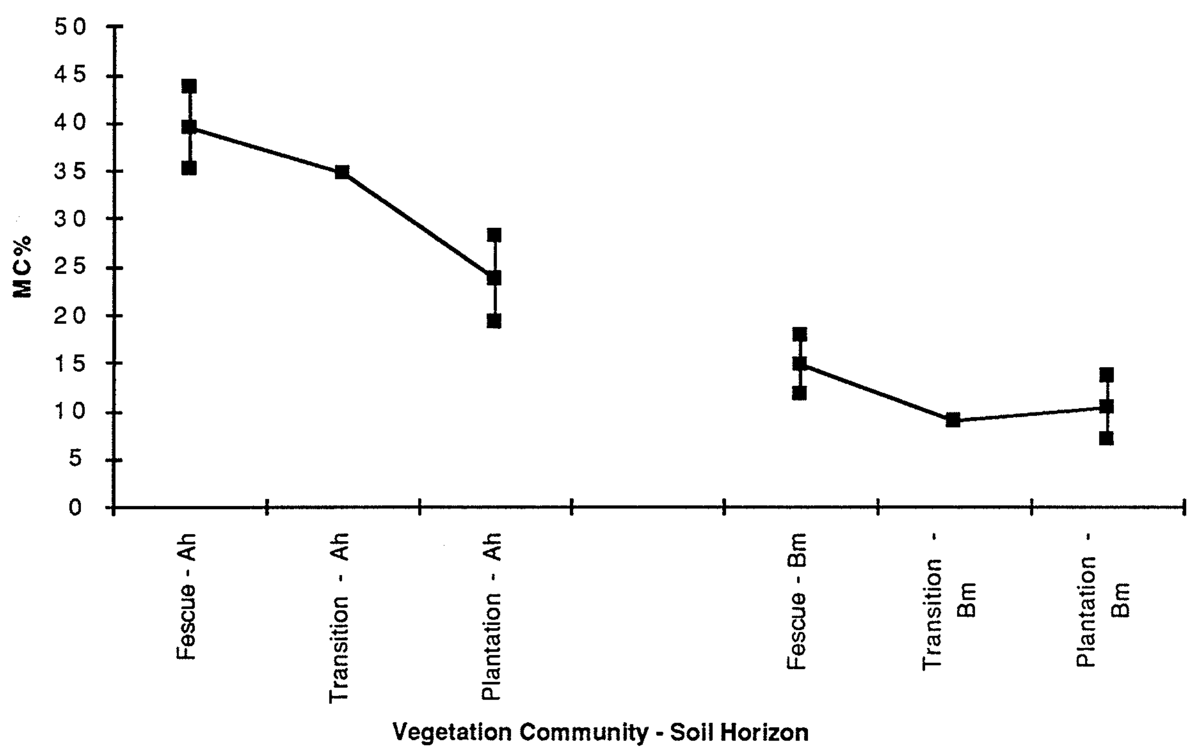


Figure 17. Plotted sample means and standard deviations of soil moisture content of soil under fescue prairie and plantation communities.

In meeting soil moisture needs, fescue grassland is dependent upon a combination of factors including accumulated litter and the soil's physical properties. In a study on Fescue Prairie near Stavely, Alberta, Dormaar and Willms (1990a) indicated that a change in vegetation from fescue to shorter and shallow-rooted plants resulted in less snow catch which contributed to reduced soil water. Accumulated litter slows down runoff and enhances surface conditions for water infiltration to Ah horizon.

In a study by Dormaar, Smoliak and Willms (1989) in Alberta of Black Chernozemic soil under short duration grazing and ungrazed conditions, moisture was always significantly higher in the ungrazed soils. Rough fescue rapidly expanded into the ungrazed control plots (Dormaar et al, 1989). Increased defoliation and soil compaction in a different study, resulted in reduced water infiltration and contributed to the continual deterioration of range condition (Dormaar and Willms, 1990). Cameron (1975) showed that higher organic matter content (or humus) in upper horizon of Chernozemic soil improved the soil's moisture storage capacity.

Cameron (1975) indicated that ground water supplies may not influence the moisture levels of Chernozemic soils under fescue grasslands of Prince Albert National Park. Because of coarse soils in lower horizons and the limited water storage capacity of the parent material, fescue grassland is cut off from groundwater supplies (Cameron, 1975).

Organic matter. The values illustrated in Figure 18 strongly support the hypothesis that afforestation was the cause of a reduction in organic matter (OM%) in both Ah and Bm horizons. Organic matter was reduced in Ah and Bm horizons

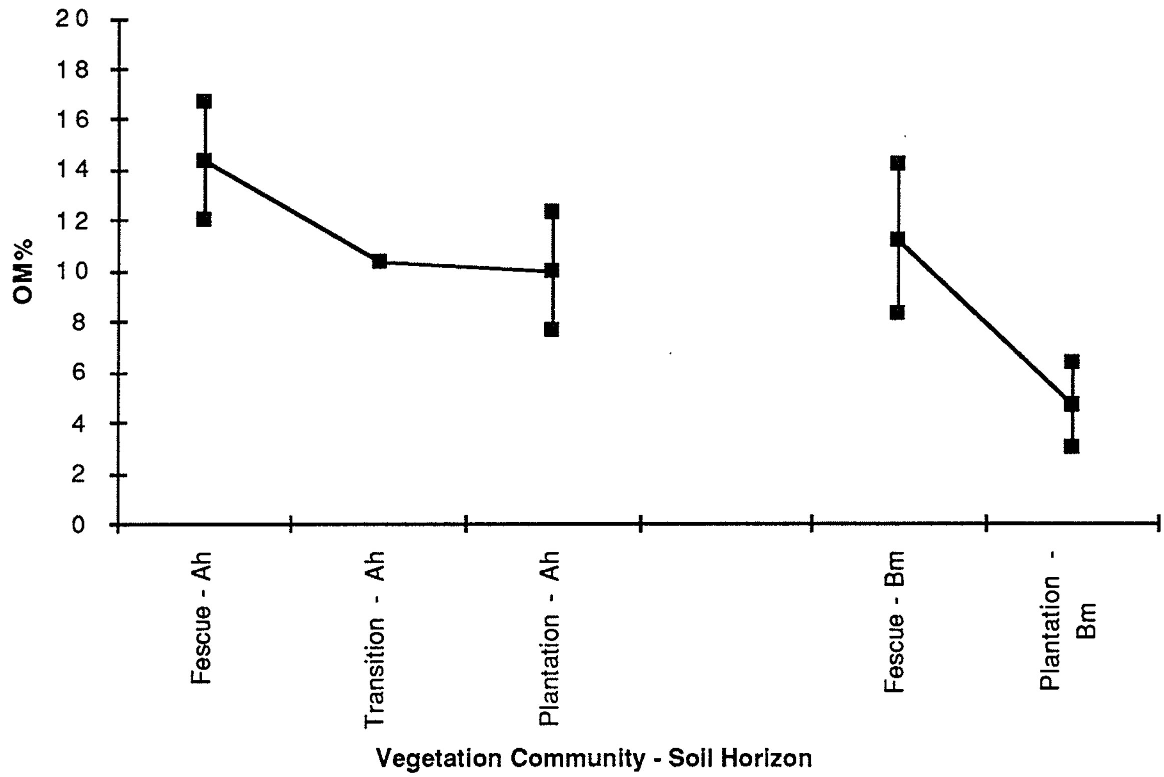


Figure 18. Plotted sample means and standard deviations of soil organic matter content under fescue prairie and plantation communities.

under the plantations by 30% and 58% respectively. A change in colour value of the Ah horizon was observed from black (10 YR 2/1) in fescue prairie to very dark grey (10 YR 3/1) in plantation. A number of factors may have caused the change in colour value. However, Scott (1991b) indicated that a correlation between organic matter and value for Chernozems on the Canadian Prairies is striking. A portion of the available organic matter in the plantation is tied up in a forest litter layer of undecomposed needles. As in the Boreal Forest, the accumulated litter under plantations will not decompose as quickly as that in fescue grassland.

An acidic environment is less favourable for micro-organisms such as bacteria and fungi, which are largely responsible for decay and decomposition of organic matter (Spedding, 1971). Brady (1990) found that the biomass of soil animals under a grassland meadow was 174.4 g/m^2 or 12.5 times greater than that under a spruce forest. Rowe (1956) attributed the combined affect of shade and drought conditions to the buildup of "needle cover" under white spruce. Dead and decaying perennating organs of an herbaceous strata, such as in a fescue prairie, contributes to the soil's organic matter content as well. Soil organic matter was significantly reduced with the elimination of an herbaceous strata under the canopy of spruce. Dormaar and Willms (1990a) noted that a change in vegetation from deep-rooted to shallow-rooted vegetation led to a reduction of organic matter and a loss of soil structure.

On Rough Fescue Prairie in Alberta, Dormaar and Willms (1990b) observed that soil compaction by domestic livestock affected the soil's organic matter. They noted that over a 20 year period, OM% content was higher under light grazing than under very heavy grazing. In abandoned cropland in southern Alberta, recovery of organic matter in Black Chernozemic soils through natural succession and under moderate grazing may take at least 150 years (Dormaar et al, 1990a).

Carbonates. Carbonate values for Ah and Bm recorded in Table 8 do not support the hypothesis that afforestation has changed the levels of carbonates. The distribution of carbonate values between fescue prairie and plantation in both horizons (Appendix VIII) was not significantly different. The presence of carbonates indicates the relative absence of H^+ ions and that the soil will therefore be close to neutral or alkaline in reaction (Scott, 1991b). Testing for carbonates in the soil horizons in a profile may help researchers find out if weathering in the Ah horizon, eluvial and illuvial processes are taking place (Scott, 1991b). In Black Chernozems, carbonate enrichment typically occurs in lower horizons (CSSC, 1977; Scott, 1991b). Similar results of carbonate testing showed higher carbonate levels in the Bm horizon under both prairie and plantation than under Ah horizon.

Soil testing has provided valuable insight into the degree of change to the soil's pH, MC%, OM% and carbonates brought about by afforestation. The measurable results are but a fraction of the number of chemical and physical modifications that have occurred to the soil. The changes that have occurred to soil properties under plantation 87-30 at Lake Audy will not necessarily have similarly occurred in other plantations in both study areas. Under the prevailing conditions of the time, the results do show an association between white spruce and its effect on various soil properties. To what degree the changes will occur from plantation to plantation is perhaps impossible to predict. Under similar conditions and over a relatively short period of time, it can be assumed that afforestation using white spruce affects the pH levels, moisture content, and organic matter content in the upper soil horizon of an Orthic Black Chernozem.

Soil development. Recent modifications by humans and climatic change have influenced the distribution of aspen and fescue grasslands in the Aspen Parkland. Several authors have shown that a change in climax vegetation has corresponded to historical fluctuations in wet and dry climatic periods. The dominant vegetation produces a distinct soil profile which reflects the character of the vegetation, ie fescue grasslands - Chernozemic soil. By understanding this association, it is possible to trace the recent floral history of a particular region.

Rowe (1956) indicated that, under suitable conditions, grasslands can reinvade forested areas and vice-versa in the Parkland area over time. In small areas along the prairie-parkland transition zone which presently supported typical native prairie flora, the presence of decayed wood was evidence of prior tree growth on the site.

Moss and Campbell (1947), Jungerius (1969), Cameron (1975) and Dormaar et al (1990a) suggest a sense of reversibility to soil processes. In Aspen Parkland, soil degradation sequences from Black Chenozems have been to Dark Grey Chernozems (Cameron, 1975) and to Grey Luvisols on well drained sites (Canadian Soil Survey Committee, 1977). The aggradation of Luvisolic profiles is possible according to Cameron (1975) and can occur when environmental conditions, including fire, favours fescue grassland. He noted that where fescue prairie had been occupied by groves of aspen for a period of 85 years, soil degradation was evident. Depending on soil texture, precipitation and character of invading forest, Cameron estimated approximately 200 years would be required to degrade a Chernozemic profile.

Soil transformation is a very slow and gradual process, where measurable change to soil properties is dependent on the character of the dominant vegetation. Upon a change in vegetation a correlation between soil organic matter content and soil aggregate size has been noted by authors. In a study by Dormaar and Smoliak (1985) of abandoned farmland in Alberta, a change from grazed to native range vegetation brought about a change in organic matter and soil aggregate size. Dormaar and Smoliak suggested that an increased root mass resulted in increased exudates, which eventually became the dominant cementing agent of soil on abandoned farmland. A reverse situation can occur as identified by Scott (1991b) where a decrease in soil aggregate size in Ap horizons of Dark Brown Chernozem under long term cultivation correlated with a decline in organic matter. Under turf-forming fescue grassland, Cameron (1975) estimated that a Chernozemic Ah horizon can develop in 50 - 100 years.

B. Effects on the Vegetation

This discussion will examine how afforestation can modify the prairie environment. A modification of the local environment has not only resulted in a change to a number of soil properties, but has had a significant effect on the grass-herb-shrub vegetation strata (Figure 19). In a number of ways, air temperature is an important climatic factor in maintaining fescue grassland. Compared to the vigorous temperature regimes associated with fescue prairie, plantations greatly reduce the frequency of killing frosts during the growing season and depress early growing season soil temperatures. Cameron (1975) identified a definite correlation between vegetation cover and air temperature close to the ground. A comparison of temperatures among five different vegetation communities showed that open fescue grassland had the highest monthly mean maxima and the lowest monthly mean minima. Pine and aspen forests had the highest monthly mean minima and the lowest monthly mean maxima. Late spring or early summer frosts inhibit growth of trees that encroach into fescue grassland.

The period of growth for rough fescue is from mid-April to early May, and on occasion, regrowth in the fall (Trottier, 1986). Compared to a forest floor, fescue grassland receive greater insolation which warms up the soil earlier in spring and

Figure 19. Typical Fescue Prairie (top) and vegetational response to effects of white spruce, Plantation 87-30 (bottom) (Photos taken August 1990).

stimulates plant growth. Since soil temperatures are depressed in spring under trees, this modification would result in a degradation of the favourable growing conditions for rough fescue.

The modifying effect of shade over a prolonged period of time has resulted in three vegetational responses in the Lake Audy plantations. Where closed stands exist among the plantations, a feather moss stratum has developed (Figure 20). In an examination of a closed white spruce stand in RMNP, Rowe (1956) noted the presence of a "moss mat" of *Hylocomium splendins* and *Calliergonella schreberi*. He indicated that moss is more dependent on shade than on moisture and that under white spruce vegetation, it probably represented the final stage in development on a dry site.

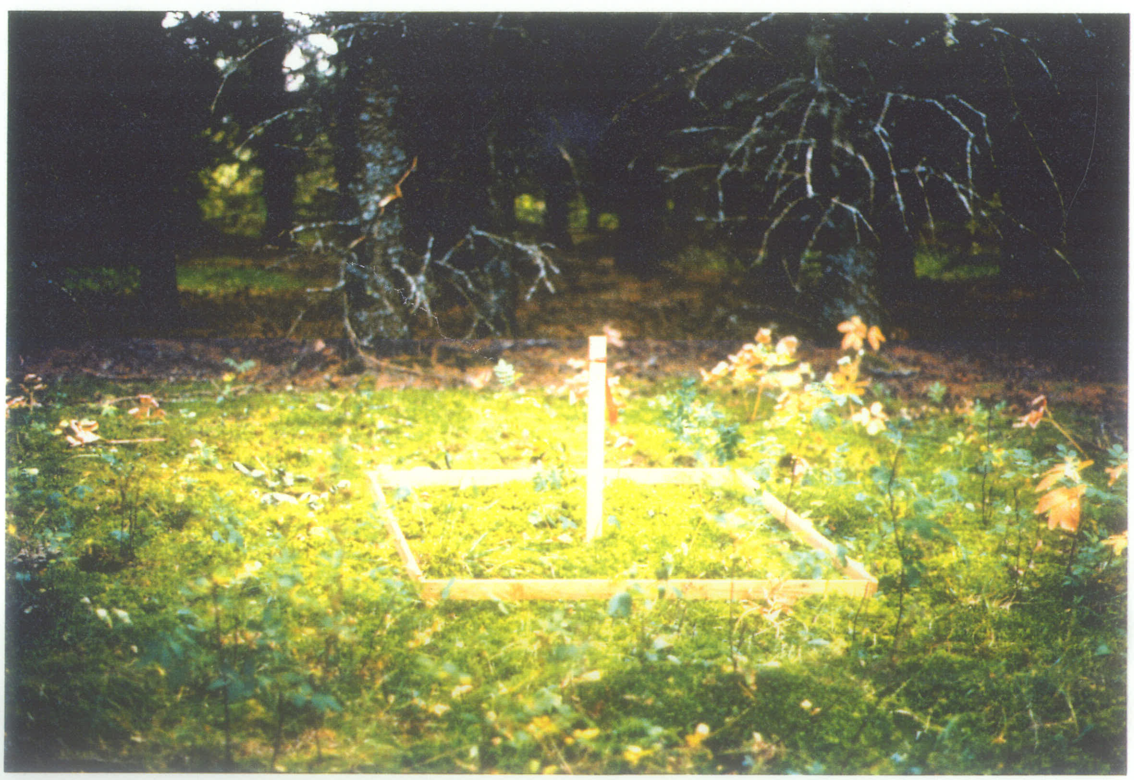


Figure 20. Feather moss stratum in Plantation 87-30 (Photo taken August 1990).

Another vegetational response to shade has been the establishment of a vigorous crop of young spruce both inside and outside the plantations, primarily along the northern and western margins. From nearby seed trees, young spruce have invaded the remaining open patches of prairie in a way similar to that observed by Rowe (1956). The shade of adult spruce provides favourable growing conditions in which young shade tolerant spruce grow, thereby facilitating further spruce encroachment (Cameron, 1975). A third response has been the elimination of shade intolerant plants among the closed stands of spruce. Cameron (1975) noted the same effect with shrubs and aspen as they invaded prairie sites in PANP. From plantation to plantation in both study areas, the extent of these vegetational responses is not homogenous.

The encroachment of aspen into plantations at both study areas was observed. Aspen encroachment is pervasive in plantations 69-28, 3, and 8. In others, however, it is occurring only to a limited degree. In many of the open patches of prairie, tall and short woody shrubs dominate the area at the expense of graminoid species. In plantations of high tree cover value, the native prairie vegetation has been all but eliminated. With the exception of the small meadows south of plantation no. 8 and in the vicinity of nos. 19 and 20, the former native prairie in Clear Lake Study Area (Figure 14) has succeeded mostly to either willow *Salix* spp., aspen or white spruce. White spruce will eventually replace the native prairie as the dominant vegetation cover.

5.3 Protection of Disturbed Fescue Grasslands in RMNP

The establishment of spruce and pine plantations on rough fescue grassland in Riding Mountain have contributed to the reduction of an endangered vegetation community in the park. The plantations are interfering with the natural processes of the native prairie and pose a threat to a valuable park resource. To address this issue, an overview of the causes of prairie loss and justification for restoring the disturbed sites will be presented. An assessment of present conditions of the disturbed sites and an immediate first step restoration technique for selected sites will follow. The section will conclude with an overview of the beneficial role of interpretation for a restoration program and an examination of a number of interpretive themes regarding the forest plantations.

5.3.1 Need for Fescue Prairie Restoration

The fescue grasslands at the two study areas have been subjected to intense use by Parks and park visitors during the last several decades. In addition to the effect of the plantations, other factors have contributed to the continual degradation of the Parks' native grasslands. Some of the most notable are the existence of service roads, parking lots, a maintenance compound and continued horse use on native fescue prairie. Due to its susceptibility to invasion by woody shrubs, willow and aspen in the absence of fire, rough fescue grasslands have been reduced in area throughout the park.

Four reasons for restoring the disturbed prairie sites to some extent at Lake Audy and Clear Lake have been identified. The establishment of forest plantations on rough fescue grassland in RMNP provides a clear example of a man - induced change on a natural environment. Such a change is contrary to current Parks Canada Policy (Parks Canada, 1979). Secondly, rough fescue grassland of western Canada is unofficially designated as endangered (Trottier, 1992) and considered a significant natural heritage feature. Fescue grassland is virtually non-existent outside of Prince Albert and Waterton Lakes National Parks, and what remains represents less than 5% of its former range. In Riding Mountain National Park, rough fescue grassland represents less than 1% of the total park area. Preserving Plains Rough Fescue *Festuca hallii* grassland in RMNP has added significance because the park contains the most easterly distribution of the grassland in Canada and is the only parks land in Manitoba that offers full protection for this association. Duck Mountain Provincial Forest/Park contains some of the northernmost fescue grassland in the province (LaRoi and Babb, 1974). The significance and status of the fescue grasslands have not been actively documented by the Provincial Parks Branch (Hernandez, pers. comm. April 1993).

The third reason for protecting this grassland association in Riding Mountain is that it contains perhaps the greatest plant species richness of any vegetation community in the Park. Of the 669 species of vascular plant species in Riding Mountain (Cody, 1988), approximately 127 or 19% can be found in the grassland (Trottier, 1974). Of added significance, some species of plants common to fescue prairie are considered rare in the Park (Trottier, 1974; Cody, 1988). Limited distribution and site specific adaptations place the rarer species of plants at a high risk of being extirpated from the park. In addition, the rough fescue grasslands provide invaluable habitat throughout the year for the Park's elk and other native wildlife.

Lastly, the rough fescue grassland at both study areas provide excellent viewing opportunities for park visitors from an all-weather road and within walking distance of a campground. However, an estimated 30% of the fescue prairie at Lake Audy is all that remains which is accessible by foot to the public for interpretive hikes and general viewing. Serious disturbance has reduced the fescue prairie to less than 25% of its former range in the Clear Lake Study Area. With the existing infrastructure, maximum accessibility and viewing opportunities of the remaining grassland are afforded to the vast majority of park visitors and user groups. Restoring the disturbed fescue prairie sites at Lake Audy and Clear Lake, therefore, satisfies several park objectives.

5.3.2 Short Term Restoration Strategy for Less Disturbed Sites

The study and application of native prairie restoration in arid climates of western Canada and in adjacent parts of the United States is in its infancy. The theoretical understanding of the ecological processes of native prairie appears to be not well understood. Lauenroth and Laycock, (1989) indicated that assessment of range condition and trend remains a source of controversy, despite years of practical experience and discussion. Given the different native prairie associations and their regional distribution, research in restoration to date has been suited to a local prairie type. There is limited hard data on revegetation by *F. hallii* following on disturbed sites, consequently little experience is available on how to appropriately restore Riding Mountain's disturbed fescue grasslands.

Data on the changes to various soil properties and the vegetational responses to afforestation has been provided. Evidence of rough fescue's ability to reinvade disturbed sites has been demonstrated in other studies. Predictions have been made on the time required to reverse altered soil properties and to revegetate disturbed sites following particular disturbances. Despite the lack of hard data, there is an expanding knowledge base upon which a restoration plan might be developed for the disturbed sites in Riding Mountain.

An initial step for resource managers to take in a restoration plan could be to assess the condition and trend of the disturbed sites. A second step will be to determine whether the disturbed sites can be reversed to a desired fescue prairie community. If so, what type of strategy can be applied and when to force such a change? For the more seriously disturbed sites, monitoring of grassland successional trends and experimenting with restoration techniques might be considered over the long term. For some of the plantations or portions thereof, there is a restorative strategy over the short term that ought to be seriously considered.

A restorative action would involve the removal of isolated stands (ie. 10 trees or less) and individual trees from sites completely surrounded by native prairie. Removing small stands and/or individual trees will result in three site modifications which will force change and enhance growing conditions for rough fescue prairie. One modification will be a change to the microclimate of the site, whereby the shade and eventually surface drought conditions will be greatly reduced. This process will not ameliorate surface drought conditions immediately nor directly. The emerging vegetation will create its own microclimate over time as the process of reinvasion occurs via rhizomes, stolons and seed dispersal from adjacent native prairie plants. With minimal ground disturbance during tree removal, the reinvading species would typically be pioneer prairie grasses and forbs.

A vegetational change will trigger changes to soil forming processes and eventually to soil properties over the long term. Changes to some soil properties of a Chernozem have been estimated to require over 100 years. The third site modification would be to the local climate. Spruce trees, especially, moderate the local climate of a native prairie by inhibiting air flow and reducing ground insolation. The vigorous climatic regime typical of an open fescue grassland is not conducive to encroachment by woody plants, and therefore acts to maintain native prairie. An increase in insolation, in particular in the spring and early summer during the most active growing season for rough fescue, gives the plant a competitive edge over warm season plants. To further increase the surface insolation in spring, periodic prescribed burns would open up the *F. hallii* sward.

One theory of invasion for rough fescue that is noteworthy given examples of reinvasion occurring at other locations was proposed by Cameron (1975). He proposed that when a preferred site of fescue prairie is exposed to drought conditions, the site serves as a focus from which expansion occurs. A study in the Rumsey Ecological Reserve in Alberta indicated that rough fescue prairie has the ability to encroach onto disturbed pipeline routes. On the Reserve, Gerling (pers. comm. Feb. 1993) noted that ditch-line stripping less than one metre wide revegetated naturally within five years. In Riding Mountain, prairie flora has successfully reinvaded old seedbeds located at Lake Audy and Kinnis Meadows. Another example of successful reinvasion has been in old unplanted furrows at a number of the Lake Audy plantations.

5.3.3 Interpretive and Economic Opportunities of Restoration

A coordinated prairie restoration and interpretive effort would enhance the Park's Interpretive Program. An interpretive program to inform visitors on the need for human intervention in native grassland conservation in a national park would be beneficial. Another benefit would be to educate the public and Park's staff on the merits of managing the Park's sensitive areas wisely so they can be enjoyed by future generations. Finally, preserving the biodiversity of a native prairie for no other purpose than for preservation alone, is an imporatnt Park message and would be an excellent theme for an interpretation prgram. The meadow south of plantation 87-30 at Lake Audy or plantation 13 at Clear Lake are ideal locations for an interpretive program and guided hikes. At either location, park visitors could experience the phenology and species diversity of rough fescue grassland.

Interpretive themes presented here on the natural history of rough fescue grassland have been developed from other sources cited throughout the document. As testimony to man's success at exploiting and degrading rough fescue grasslands, less than 5% of this vegetation community remains and must therefore be protected. Trottier (1974) noted that the existence of grasslands in RMNP adds to the diversity of landscapes. The open areas provide excellent panoramic vistas and landscapes for park visitors. He also noted that species variation resulting from past disturbances of the ranges presented in an interpretive program could provide visitors with an understanding of vegetation dynamics. Grassland succession is worth documenting according to Cameron (1975), due to the implications for other national parks and as a contribution to general ecological knowledge.

Two historical themes involving forestry and forestry-related research in Riding Mountain must be recognized in some form. In acknowledging this important legacy, some of the plantations could be retained for interpretive purposes and research. In recognition of its highly valued timber supply, Riding Mountain was set aside as a Forest Reserve in 1895. In addition, the Reserve's forest supplied numerous sawmills which created employment opportunities for many of the surrounding communities. As a Forest Reserve, Riding Mountain was an important regional location for growth studies on white spruce. Many scientific reports and articles written on Riding Mountain's forest plantations have no doubt contributed to the wealth of knowledge for the Canadian forest industry and to the benefit of many Canadians. The plantations which represent the best example of this particular historical period are situated at Lake Audy.

The number of potential economic benefits to the Park and surrounding communities could help offset the cost of restoration. A supply of firewood and rough construction material for the Park are two practical uses for the trees. The smaller trees could be utilized for landscaping purposes or donated as Christmas trees to a local charity or non-profit organization. The author is not an advocate of consumptive use of a park resource. But in meeting park management goals for protecting natural ecosystem integrity, utilization of the trees is suggested in the context of wise resource management.

5.4 Evolution of Park Values and Policy

Since the earliest inhabitants occupied the area known today as Riding Mountain National Park, the significance and importance of these highlands have undergone many transformations. The values held, and subsequent management practices employed, at any point in Riding Mountain's history were as justifiable then, as the dominant values influencing today's management policies. This concluding section will reflect on the evolving management policies affecting Riding Mountain National Park since the area was withdrawn from settlement in 1895 by the federal government. Concurrent to the policy discussion, an overview of the change in values held by Canadians towards natural areas will be presented.

Early settlers to Riding Mountain were dependent upon the area's natural resources for their livelihood and gradually pursued the resources further into the Riding Mountain Forest Reserve. Timber cutting operations in Riding Mountain began as early as the 1870's, with grazing and haying activities commencing in 1909 (Tabulenas, 1983). By 1910, increasing public use of Canada's national parks as well as their increasing value to the nation brought about a need for a separate administration branch of the Department of Interior (Lothian, 1977). In order to designate new national parks out of portions of forest reserves, the Dominion Forest Reserves and Parks Act (1911) was established (Lothian, 1977).

In 1930, Parliament approved the National Parks Act which provided legislative protection for national park lands and, at the same time, permitted public use for activities that would leave the area unimpaired for future generations (Parks Canada, 1979). In the same year, Riding Mountain's status as a forest reserve changed to that of a national park. Despite the Depression of the 1930's which brought about high unemployment, development of Riding Mountain for wider public use was deemed necessary (Tabulenas, 1983). A series of make-work projects, involving local unemployed, were initiated in RMNP such as the construction of a Park roadway and administrative buildings (Tabulenas, 1983). After WWII, the economic conditions of Canada improved resulting in increased numbers of park visitors. It soon became obvious that overdevelopment of many of the parks was a distinct possibility (McKim, 1968).

The reappraisal, development and application of park policies from the early 1950's culminated in the National Parks Policy of 1964 (McKim, 1968). Among some of the contentious aspects of the new policy at the time was the restriction of residence and business development, and perhaps most importantly, the discontinuation of the issuance of renewable-type leases (McKim, 1968). Haying and grazing were phased out in 1970 and, upon expiration of the remaining timber permits, logging was discontinued in 1972 (Tabulenas, 1983).

Since 1964, Parks Canada's policies have evolved in response to values held by Canadians to natural and historically significant areas and to the economic realities of the 1980's and 90's. The primary objective for the protection of national park resources appears in the 1979 Parks Canada Policy:

> To protect for all time representative natural areas of canadian significance in a system of national parks, and to encourage public understanding, appreciation and enjoyment of this heritage so as to leave it unimpaired for future generations (Parks Canada, 1979).

Canadians appreciate both the natural and human history of our country and desire to protect special areas for educational, scientific and spiritual purposes.

The responsibility of administering and managing special areas such as Riding Mountain National Park is also changing. In accomplishing this task, greater emphasis is placed on cooperative management efforts whereby federal, provincial and municipal governments as well as private landowners, environmental organizations and universities help manage protected areas. A good example of such a cooperative effort is in the management of the Riding Mountain Biosphere Reserve (RMBR) (Krawchuk, 1990). The RMBR consists of a core area (RMNP) as well as a zone of cooperation made up of the surrounding rural municipalities (Krawchuk, 1990). Some of the resources and resource problems in RMNP affect neighbouring lands and cannot be managed by Parks independently. Recent financial constraints facing all levels of government is another reason for a movement towards shared responsibilities in managing resources in protected land.

Policies governing the management of Riding Mountain National Park's resources have evolved considerably during the past 100 years. During this period, a change in values towards the use of protected areas was recognized as a major factor in the evolution of park policy. The way society views the protection of national park resources, today, is outlined in the most recent Parks Canada Policy which states that:

> National parks are special areas which are protected by federal legislation from all forms of extractive resource use such as mining, forestry, agriculture, oil and gas, and hydro electric development and sport hunting (Parks Canada, 1979).

In the past, extractive utilization of Riding Mountain's resources was necessary and considered appropriate for the time. However, management with an emphasis on protection of the Park's resources is the basis of Park's current policy.

CHAPTER 6 Summary, Conclusions and Recommendations

6.1 Summary

The overall objective was to quantify and describe forest plantations established over 38 years ago on rough fescue grassland sites in Riding Mountain in order to better understand this relatively unstudied human disturbance. Rough fescue grassland represents less than 1% in area of the total Park, and, consequently, greater emphasis in protecting this unofficially endangered vegetation community is required.

Twenty eight plantations were established between 1918 and 1930, and in the late 1940's and early 50's. Between two separate rough fescue grassland areas in Riding Mountain National Park (RMNP), approximately 98.0 ha of the grassland was disturbed. The information provided by this study will be utilized to manage the fescue grasslands within the framework of a Park Vegetation Management Plan. Recommendations were made to rehabilitate most of the disturbed fescue prairie sites.

Planting records and interviews were the primary sources of information on the plantations' history. Aerial and ground photographs and ground surveys were the principal secondary sources to help identify growth, development and vegetational responses of the plantations. A series of soil tests was conducted on samples taken from soil profiles in prairie, transition, and plantation vegetation communities. Several conclusions can be drawn from this investigation.

6.2 Conclusions

Forest plantations established on rough fescue grasslands in RMNP have depleted an already endangered vegetation community and incremental losses of this valuable resource will continue to occur due to encroachment unless some restorative efforts are undertaken.

Planting Prescriptions

1. A total of 28 plantations established on rough fescue grasslands in RMNP have been identified and comprise an area of 97.9 ha. Eight plantations initiated under Project MS-104 that survived were located at Lake Audy. Twenty plantations were located south of Clear lake. Twenty seven white spruce plantations and one Scots/jack pine plantation were identified.

2. Limited historical information was found on the plantations. The Lake Audy plantations were established between 1922 and 1930 with bare root stock. Stock for four of the plantations originated from the former nursery at Lake Audy and seed trees of the stock used at Lake Audy were not identified. Stock was planted using either a shovel or grub hoe in furrows made by a team of horses and a plough. Sites were prepared through the use of prescribed burns to remove accumulated litter and to eliminate woody shrubs.

3. The Clear Lake plantations were estimated to have been planted in the late 1940's to mid 50's time period using stock of unknown origin. The stock was planted either by machine or by hand.

Current Status

4. There was considerable variation in size, mortality rate and degree of degradation among the plantations, both within and among study areas. Cover value best reflected a plantation's status and each was assigned to one of the following cover value categories: sparse < 25%, open 25 - 60%, and closed >60%. The number of plantations in each category is 8, 8, and 12 comprising 32, 39.9, and 26 ha respectively.

5. In two plantations at Lake Audy, mean tree height and diameter were 13.1 m and 19.5 cm, and 15.5 m and 20.8 cm respectively. Given the heterogeneity in tree height and diameter both within and among the Clear Lake plantations, measurements taken on three plantations were considered to be of limited value.

6. The trees at Lake Audy were bearing cones, whereas there was no evidence of cone production observed at Clear Lake. White spruce natural regeneration in uneven-aged stands has invaded open patches of remnant prairie inside the plantations and in prairie exterior to the plantations at Lake Audy but not at Clear Lake. Encroachment by trembling aspen was observed in a few of the plantations in both areas.

7. The regenerative capacity exhibited by the plantations at Lake Audy indicates that these plantation forests will persist for at least another 100 - 150 years. The invasion of white spruce into adjacent native prairie indicates that incremental losses of native fescue prairie will continue to occur in the Lake Audy Study Area.

Soil Analyses

8. Following afforestation as predicted, soil pH was lower in plantation (pl) Ah horizons than in prairie (pr) Ah horizons. The soil moisture content of the forested Ah horizon (pl) was less than MC% of Ah horizon (pr). A reduction in organic matter occurred in both the Ah and Bm horizon in plantation, and a change in Ah color from black in fescue prairie to very dark grey in the plantation was observed. Levels of carbonates ($CaCO_3$) for Ah and Bm horizons were the same under both vegetation communities.

6.3 Recommendations

In the context of fescue grassland management in Riding Mountain National Park, preservation of disjunct pockets of native prairie, as represented by those at Lake Audy and Clear Lake, is fundamental. Preserving isolated pockets of fescue grassland maintains biodiversity and reduces the risk of individual plant species loss in the park. The following recommendations will lead to greater plant diversity and maintain the greatest species-rich vegetation community in the Park.

1. Elimination of trees in a number of plantations over the long term is recommended to help restore some of the disturbed rough fescue prairie sites. The plantations recommended to be eliminated include 79-29 and 80-29 at Lake Audy and 2, 4, 8 and 13 at Clear Lake. These plantations contain considerable amounts of remnant prairie vegetation and the vegetation would be an important source of propagules for reinvasion of the disturbed sites. Plantation 33-22 should also be eliminated, because Scots pine, a species non native to Canada is present.

2. The spread of natural regeneration in a number of plantations should be controlled to help maintain pockets of remnant native prairie. Less intrusive measures such as prescribed burning or mowing prairie areas might be effective techniques for containing natural regeneration. Because of the real threat of incremental loss of native prairie to natural regeneration, the recommended control measures might be considered for plantations 66-27 at Lake Audy and plantations 7 and 9 at Clear Lake. Though the Clear Lake plantations are not yet producing cones, seed production and natural regeneration might be expected to occur within the next 15 - 20 years.

3. Plantations not included for treatment in Recommendations #1 and #2 should be left to evolve naturally. The plantations recommended to be left fall under the 25 - 60% and >60% cover categories, and those where native prairie vegetation has been significantly reduced. Without remnant prairie vegetation to reinvade the disturbed sites, any restorative measures would probably be highly costly and meet with very little success.

4. As an initial step in a restoration effort, a cutting operation to remove isolated stands and individual trees from sites completely surrounded by native prairie should be conducted. Following this operation, the conditions for reinvasion by native prairie plants into the newly opened sites are anticipated to improve. A change to the micro- and macroclimate and soil conditions brought from such action will probably be beneficial for reinvasion. The best results might be expected in plantations 79-29, 80-29, and 87-30 at lake Audy and 2, 4, and 13 at Clear Lake.

5. Seeding should be attempted on a few sites on an experimental basis as one alternative to revegetating the newly opened sites as proposed in Recommendation #4. Seed could be collected from nearby native prairie plants and spread over the sites by hand. The effectiveness of this method of revegetation might be compared to that observed for natural reinvasion from adjacent sources of propagules.

6. The volunteer association in the Park should consider assisting Parks in the restoration of one or two disturbed sites as a long-term project. The restorative action presented in Recommendation #5 might be undertaken by the volunteer association in cooperation with Parks. In addition to restored native prairie benefitting the Park, the local volunteer association would benefit through participating in a restoration effort and thereby share the responsibility of managing the native grassland. A local effort would heighten the awareness of the grassland's near endangered status and would have greater incentive to protect the grassland.

7. Experimental mowing should be undertaken on a series of similar sites to find out its effectiveness in controlling natural regeneration. A number of different mowing techniques to test the height, time of year, and frequency of treatment that would be most effective in controlling the natural regeneration might be considered. Monitoring the test site(s) over a number of years would be necessary to measure the relative effect of such actions.

8. To better understand grassland successional trends and vegetational responses following restorative measures, the activities performed in Recommendations #4 and #5 should be monitored. Reinvasion of newly opened disturbed sites as outlined might be monitored annually over several years to detect trends and/or shifts in species composition of the successional vegetation. In the event of unfavourable results following restoration in Recommendation #4 and under experimentation in #5, the status of the particular site will probably be no worse than if no restorative efforts had been conducted.

9. Active rehabilitation of the disturbed native prairie sites should be undertaken within the next 5 - 10 years. If immediate restorative measures are not undertaken, white spruce, aspen, and woody shrub encroachment will eventually preclude any future option to sustain a viable amount of fescue prairie.

10. A resurvey of the 33 permanent transects established by Trottier (1974) on grassland areas in RMNP should be undertaken. A second inventory of plant species and composition at these grassland sites will be beneficial to the Park. Park resource managers can use this information to identify any successional trends, and, under a scenario of continued fire suppression, predict what the species composition will be in the undisturbed rough fescue grasslands. For the grassland areas designated as disturbed (Trottier, 1974), an analysis on the extent of recovery could be undertaken.

Other aspects of fescue grassland management not directly relevant to the objectives of this study which either directly or indirectly impact upon the Park's grasslands need to be addressed. The following recommendations deal with some of these concerns.

11. Given the similarities of fescue grasslands between Riding Mountain and Prince Albert National Parks, future research in grassland management or restoration should be a collaborative effort and applicable to both parks. A cooperative effort by both Parks and by Universities in providing financial, logistical, and scientific/ technical support might be considered for future grassland studies that one park alone might not be able to provide.

12. Present uses which threaten remnant prairie at both study areas should be reevaluated. Extraction of gravel and the use of service roads in plantation 87-30 should be curtailed. The site of the outfitters camp southeast of plantation 87-30 should be abandoned and reestablished in a more appropriate location, such as the site of the former Lake Audy Nursery. Open native prairie at Clear Lake is easily accessible and continues to be seriously threatened or destroyed. Efforts to remove stored construction material and a horse corral and to restrict vehicle use on fescue prairie in the vicinity of the maintenance compound at Clear Lake should be considered. Horse trails which dissect the native prairie should be abandoned and reestablished in adjacent forest areas or at a plantation's periphery where impact will be less significant.

13. Prescribed burns as a management tool for maintaining fescue grasslands should be designed and implemented in the park. Historically, fire is a contributing factor to the maintenance of native rough fescue grassland. A periodic burn is beneficial to fescue grassland because fire removes accumulated litter, recycles nutrients and eliminates encroaching woody vegetation.

14. Plantations not recommended for elimination should be utilized in the Park's Interpretive Program and for educational and scientific purposes . The plantations would be a reminder to Park visitors of the role the forests and forest research have played in shaping Riding Mountain National Park as it is known today. Interpretive themes pertaining to the successional pattern of a disturbed site and to the reduction in plant species resulting from afforestation might be considered. Another theme that could be considered is in regard to the Island Biogeography Theory presented by MacArthur and Wilson (1967). The plantations as islands, as well as the individual pockets (ie. Lake Audy Plain) of native prairie as islands could be viewed as models where studying this theory might be feasible. The Lake Audy Study Area might be a suitable candidate for an interpretive/ educational program and for any scientific studies due to the closeness of a campground and its island like setting.

15. Protection of rough fescue grassland should be expanded to include the Riding Mountain Biosphere Reserve (RMBR). This applies to the zone of cooperation where private landowners and other land agencies could participate in protecting rough fescue grassland. Protecting native grassland over a larger area

would help prevent the continued reduction of this highly biologically diverse vegetation community. Furthermore, the cost and responsibility of protecting and managing rough fescue grassland will be shared by more people and encourage greater stewardship of the regions natural resources.

Glossary of Terms

afforest - To convert into a forest, to establish forest cover on (as land not previously forested).

ecotone - A transition area between two adjacent ecological communities (as forest and grassland) usually exhibiting competition between organisms common to both.

exotic - A species introduced to an area outside its natural range.

genotype - Genetic constitution of an organism.

reforest - To renew forest cover on (denuded) land by natural seeding or artificial planting.

rehabilitation - To put on a proper basis or into a previous good state: restore (as something damaged or decayed) to a state of efficiency and good management.

restoration - 1. a bringing back to or putting back into a former position or condition, 2. a putting back into an unimpaired or much improved condition.

solum - The layer of soil which lies above the parent material in which the natural processes of soil formation takes place.

BIBLIOGRAPHY

Aiken, S.G. and S.J. Darbyshire. (1990). Fescue Grasses of Canada. Biosystematics Research Centre, Research Branch, Agriculture Canada.

Anderson, Roger, C. (1972). The use of fire as a management tool on the Curtis Prairie. Proc. Tall Timbers Fire Ecol. Conf. No. 12: 23-35.

________. (1982). An Evolutionary Model Summarizing the Roles of Fire, Climate, and Grazing Animals in the Origin and Maintenance of Grasslands: An End Paper. Pages 297-308. In Estes, James R., Tyrl, Ronald J., and Jeve N. Brunken. Grasses and Grasslands, Systematics and Ecology.

Anonymous. (1925). Plantation Plots Growth Record (2-18 - 14-20, 16-20, 34-22 - 36-22). Riding Mountain Forest Reserve. Department of Interior, Forestry Branch. in Canada, (1918 - ?).

________. (1929). "Reforestation Now Serious Industry Near Clear Lake." Newspaper clipping, Oct. 12, 1929. RG 39, Vol.101, File 32674. National Archives, Ottawa.

Archibold, O.W. and M.R. Wilson. (1980). The natural vegetation of Saskatchewan prior to agricultural settlement. Can. J. Bot. 58: 2032-2042.

Bailey, R.H. (1968). Notes on the vegetation of Riding Mountain National Park, Manitoba. National Parks Forest Survey No. 2. Department of Forestry and Rural Development Forest Management Institute, Ottawa.

Banfield, A.W.F. (1977). The Mammals of Canada. University of Toronto Press.

Bedell, G. (1926). Memorandum re. "List of Unsuccessful Plantations on the Riding Mountain Forest Reserve". December 24, 1926. Department of Interior, Forestry Branch. In Canada, (1918 - ?).

Biondini, Mario, Steuter, Allen A., and Carolyn E. Grygiel. (1989). Seasonal fire effects on the diversity patterns, spatial distribution and community structure of forbs in the Northern Mixed Prairie, USA. Vegetatio 85: 21-31.

Bird, Ralph D. (1961). Ecology of the Aspen Parkland of Western Canada. Canada Department of Agriculture, Winnipeg.

Blood, D.A. (1966). The *Festuca scabrella* Association in Riding Mountain National Park, Manitoba. Canadian Field Naturalist 80: 24-32.

Brady, Nyle C. (1990). The Nature and Properties of Soils. (10th edition). Macmillan Publishing Co., New York.

Cameron, T.F. (1975). Fescue Grasslands and Associated Communities of Prince Albert National Park, Saskatchewan. Unpubl. Report, Environment Canada, Parks.

Canada. (1990). Organization of the Government of Canada - 1990. Minister of Supply and Services, Ottawa.

________. (1918 - ?). Reforestation by Planting, Riding Mountain National Park, Field Data Binder (Project MS-104). Department of Northern Affairs and National Resources, Forestry Branch, Ottawa.

Canada Soil Survey Committee. (1977). Soils of Canada, Vol. 1, Soil Report, CSSC. Canada Dept. of Agriculture, Research Branch.

Canadian Parks Service. (1987a). Riding Mountain National Park, Park Conservation Plan. Resource Conservation, RMNP, Wasagaming, MB.

________. (1987b). Riding Mountain National Park Management Plan Review. Environment Canada, Parks.

________. (1987c). Prince Albert National Park Management Plan Review. Environment Canada, Parks.

________. (1989). Background Information: management plan review. Waterton Lakes National Park, Alberta.

Carbyn, L.N. and H.J Armbruster. (1968). Study of Grassland Community, PANP. Canadian Wildlife Service, Progress Report No. 82-5-2-135, Edmonton, Alberta.

Cody, William J. (1988). Plants of Riding Mountain National Park, Manitoba. Biosystematics Research Centre, Agriculture Canada.

Coupland, R.T. and T.C. Brayshaw. (1953). The fescue grassland in Saskatchewan. Ecology 34: 386-405.

Crider, F.J. (1955). Root-growth stoppage resulting from defoliation of grass. U.S. Dept. of Agriculture Tech. Bull. 1102.

Crossley, D.I. (1955). The production and dispersal of Lodgepole pine seed. Canada Department N.A. and N.R., Forestry Branch, Forest Resource Division, Technical Note 25.

Daubenmire, R. (1968). Ecology of fire in grasslands. Adv. in Ecol. Res., 5: 209-266, in Hildebrand and Scott, 1987.

Department of Interior, (1901-1936). Annual Reports 1901 - 1936, Director of Forestry, Department of Interior (DOI). Ottawa.

Dojack, John. (1991). Manitoba's Tree Improvement Strategy. Manitoba Natural Resources, Winnipeg.

Dormaar, Jan F. and Sylvester Smoliak. (1985). Recovery of Vegetative Cover and Soil Organic Matter during Revegetation of abandoned Farmland in a Semiarid Climate. J. Range Manage. 38(6): 487-491.

Dormaar, J.F. and Walter D. Willms. (1990a). Sustainable production from the Rough Fescue Prairie. J. Soil and Water Conservation. 45(1): 137-140.

________. (1990b). Effects of grazing and cultivation on some chemical properties of soils in the mixed prairie. J. Range Manage. 43(5): 456-460.

Dormaar, J.F., Smoliak, S. and W. D. Willms. (1989). Vegetation and soil responses to short duration grazing on fescue grasslands. J. Range Manage. 42(3): 252-256.

________, (1990a). Soil chemical properties during succession from abandoned cropland to native range. J. Range Manage. 43(3): 260-265.

________. (1990b). Effects of grazing and cultivation on some chemical properties of soils in the mixed prairie. J. Range Manage. 43(5): 456-460.

Drouin, J.A and D.W. Langor. (1991). White pine weevil. Forestry Canada, Northwest Region, North. For, Centre, Edmonton, AB. Forests Leaflet 8.

Dyer, M.I. J.K. Detling, D.C. Coleman, and D.W. Hilbert. (1982). The Role of Herbivores in Grasslands, pages 255-295, In Estes et al, (1982) Grasses and Grasslands, Systematics and Ecology.

Environment Canada - Parks. (1986). Prince Albert National Park Resource Description and Analysis. Natural Resources Conservation Section, Env. Canada, Parks, Prairie and Northern Region, Winnipeg. 2 Volumes.

________ (1991). Waterton Lakes National Park Management Plan (Draft). Environment Canada, Parks Service, Western Region.

Golley, P. M. and F.B. Golley, eds. (1972). Papers from a symposium on tropical ecology with an emphasis on organic productivity. Institute of Ecology. Univ. Georgia, Athens.

Goodison, John. (1949). Annual Nursery Report, RMNP. in Canada, (1918 - ?).

Haig, R.A. (1958). Reforestation by Planting, Riding Mountain National Park, Manitoba (Project MS-104). Department of Northern Affairs and National Resources, Forestry Branch, Forest Research Division.

Heaslip, Otto E. (1949). Memorandum to Smart, Jan. 31, 1949. Wasagaming, Manitoba. In Canada, (1918 - ?).

Hildebrand, David V. and Geoffrey A.J. Scott. (1987). Relationships between Moisture Deficiency and Amount of Tree Cover on the Pre-Agricultural Canadian Prairies. Prairie Forum 12: 203-216.

Hind, H.Y. (1971). Narrative of the Canadian Red River exploring expedition of 1857 and of the Assiniboine and Saskatchewan exploring expedition of 1858. Second publication. Charles E. Tuttle Co. Inc., Rutland, Vermont. (2 volumes).

Hosie, R.C. (1979). Native Trees of Canada. 8th Edition. Canada - Supply and Services.

Irving, Barry. (1992). The Effect of Litter on Herbage Growth, Soil Water, and Soil Temperature in Parkland Fescue Grasslands of Central Alberta. The First Alberta Rough Fescue Grasslands Workshop, Banff Springs, Alberta.

Jameson, J.S. (1963). Comparison of tree growth on two sites in the Riding Mountain Forest Experimental Area. Canada Department of For., For. Res. Branch, Technical Note.

Jarvis, J.M. (1963). Some problems that affect white spruce silviculture in Western Canada. Master of Science Thesis, University of Manitoba, Winnipeg.

Jarvis, J.M., Steneker, G.A., Waldron, R.M. and J.C. Lees. (1966). Review of Silvicultural Research. White Spruce and Trembling Aspen Cover Types, Mixedwood Forest Region, Boreal Forest Region, Alberta - Saskatchewan - Manitoba. Forestry Branch, Department. Publication No. 1156.

Johnson, H.J. (1985). A Review of Forest Research Studies Conducted by the Canadian Forestry Service in Manitoba and Saskatchewan to 1970. Volumes 1 - 3. Northern Forestry Centre, Canadian Forestry Service, Edmonton, AB.

Johnson, Richard and Gouri Battacharyya. (1985). Statistics: Principles and Methods. John Wiley and Sons, New York.

Jungerius, P.D. (1969). Soil evidence of post-glacial tree line fluctuations in the Cypress Hills area, Alberta, Canada. Arctic and Alpine Research. 1(4): 235-246.

Kabzems, A. (1971). The Growth and Yield of Well-Stocked White Spruce in the Mixedwood Section in Saskatchewan. Dept. of Natural Resources, Forestry Branch, Saskatchewan. Tech. Bull. No. 5.

Kirk, Roger E. (1984). Elementary Statistics. 2 ed. Brooks/Cole Publishing Co., Monterey, California.

Krawchuk, W.A. (1990). The Riding Mountain Biosphere Reserve: A Synthesis of the Natural Resource Data Base. Practicum (M.N.R.M.), University of Manitoba, Winnipeg.

LaRoi, George H. and Thomas A. Babb. (1974). Canadian National Directory of IBP Areas, 1968 - 1974. Conservation of Terrestrial Biological Communities Subcommittee, Canadian Committee for the International Biological Programme. University of Alberta Printing Services, Edmonton, AB.

Lauenroth, W.K. and W.A. Laycock (eds). (1989). Secondary succession and the evaluation of rangelend conditions. Westview Press, Boulder, Colorado. In Friedel, M.H. 1991. Range condition and assessment and the concept of thresholds: A viewpoint. J. Range Manage. 44(5): 422-426.

Looman, Jan. (1969). The Fescue Grasslands of Western Canada. Vegetation 19: 128-145.

________, (1979). The Vegetation of the Canadian Prairie Provinces I., An overview. Phytocoenologia 5(3): 347-366.

________, (1980). The Vegetation of the Canadian Prairie Provinces II., The grasslands. Phytocoenologia 8(2): 153-190.

________, (1983). Grasslands as natural or semi-natural vegetation, in Holzner, W., M.J.A. Werger, and I. Ikusima (eds). Man's Impact in Vegetation. Dr. Junk Publishers.

Lothian, W.F. (1977). A History of Canada's National Parks. Volume II, Parks Canada, Ottawa.

________, (1979). A History of Canada's National Parks. Volume III, Parks Canada, Ottawa.

Malin, J.C. (1984). History and Ecology: Studies of the Grassland. University of Nebraska Press, Lincoln.

MacArtur, Robert H. and Edward O. Wilson. (1967). The Theory of Island Biogeography. Princeton University Press, Princeton, New Jersey.

McKim, W. (1968). Townsite Administration and Management in Canadian National Parks. p. 759-769. In Nelson, J.G. and R.C. Scace (eds.)(1968). The Canadian National Parks: Today and Tomorrow. Vol. II. Dept. of Geography, University of Calgary, AB.

McNaughton, S.J., Coughenour, M.B., and L.L. Wallace. (1982). Interactive Processes in Grassland Ecosystems. Pages 167-193 In Estes et al, Grasses and Grasslands, Systematics and Ecology.

Moss, E.H. 1952. Grasslands of the Peace River Region, Western Canada. Can. J. Bot. 30: 98-124.

Moss, E.H. and J.A. Campbell, (1947). The fescue grasslands of Alberta, Canada. Can. J. of Research. 25: 209-227.

National Vegetation Working Group. (1990). The Canadian Vegetation Classification System. National Vegetation Working Group of the Canada Committee on Ecological Land Classification. Strong, W.L., Oswald, E.J., and D.J. Downing. Ecological Land Classification Series, No. 25, Sustainable Development, Corporate Policy Group, Environment Canada, Ottawa, Canada.

Nienstedt, Hans. (1957). Silvicultural characteristics of White Spruce *Picea glauca*. U.S.D.A., Lake States For. Exp. Sta., Sta. Pap. No. 55.

Parks Canada, (1979). Parks Canada Policy. Parks Canada, Ottawa.

________, (1984). Riding Mountain National Park Resource Description and Analysis. Natural Resource Conservation Division, Parks Canada, Prairie Region, Winnipeg, Canada.

Pavlick, L.E. and Jan Looman. (1984). Taxonomy and nomenclature of rough fescues, Festuca altaica, F. campestris (F.scabrella var. major), and F. hallii in Canada and the adjacent part of United States. Canadian J. of Bot. 62: 1739-1749.

Peet, M., Anderson, R., and M. Adams. (1975). Effects of fire on big bluestem production. Am. Midl. Nat. 94: 15-37.

Pratt, M. (1978). Silvicultural Operations in the Riding Mountain Forest Research Area from 1961-1969. Northern Forest Research Centre, File Report NOR-17-071.

Roe, Eugene, I. (1952). Seed Production of a white spruce tree. U.S.D.A. Forestry Service, Lake States Forestry Experimental Station, Technical Note 373.

Rowe, J. Stan. (1955). Factors influencing white spruce reproduction in Manitoba and Saskatchewan. Canada Department N.A. and N.R., Forestry Branch, For. Res. Division, Technical Note 3.

________, (1956). Vegetation of the Southern Boreal Forest in Saskatchewan and Manitoba. Ph.D. Thesis, University of Manitoba.

________, (1958). Viable white spruce seed in the humus layer. Canada Department N.A. and N.R., For. Br., Forest Resource Division. Unpublished MS, Ottawa.

________, (1989). The Importance of Conserving Systems. Pages 228 - 235 in Hummel, M. (ed.), Endangered Spaces. World Wildlife Fund.

Scott, Geoffrey A.J. (1991a). World Vegetation: The Canadian Perspective. University of Winnipeg Print Shop, Winnipeg.

________, (1991b). Soils and Vegetation. A Laboratory Manual for the Geography of Soils and Vegetation. (2 ed)., Buchanan Printers, Winnipeg.

Sinton, H. (1980). Effects of burning and mowing on *Festuca hallii*. M.Sc. Thesis., University of Alberta, Edmonton, Alberta.

Smith, Freddy. (1919). Memorandum to District Forest Inspector, Oct.14, 1919. Dauphin, Manitoba. in Canada, (1918 - ?).

Spedding, C.R.W. (1971). Grassland Ecology. Clarendon Press, Oxford, England.

Spurway, C.H. (1941). Soil reaction (pH) preferences of plants. Michigan State College Agriculture, Experimental Station., Spec. Bull. 306.

Tabulenas, D.T. (1983). A narrative human history of Riding Mountain National Park and area: Prehistory to 1980. Unpublished report.

Tosczak, Deborah. (1989). The Status of the Chernozemic Soils and Native Grasslands in Riding Mountain National Park. Unpublished Report.

Trottier, Garry C. (1974). Range Studies, Riding Mountain National Park. Volumes 1 and 2. Canadian Wildlife Service, Edmonton, Alberta.

________, (1985). Evaluation of the Prescribed Burn Study, Prince Albert National Park. Canadian Wildlife Service, Edmonton.

________, (1986). Disruption of Rough Fescue, *Festuca hallii* grassland by livestock grazing in Riding Mountain National Park, Manitoba. Canadian Field Naturalist 100(4): 488-495.

________, (1992). Conservation of Canadian Prairie Grasslands: A Landowner's Guide. Environment Canada, Canadian Wildlife Service (CWS). Edmonton, Alberta.

United States Parks. (1972). System Plan - U.S. National Parks, Vol.II. U.S. Dept. of Interior, National Park Service.

Waldron, R.M. (1962). Supply, Periodicity and dissemination of white spruce, Riding Mountain. Canada Department of Forestry, Forest Resource Branch, Mimeo 62-7.

Walker, Norman. (1987). White Spruce Transplant Stock Increases Yields, 59 Years After Planting. Forest Management Demonstration Note No.61. In Manitoba Forestry Demonstration Areas, Canada and Manitoba.

Willms, W.D. (1988). Response of rough fescue *Festuca scabrella* to light, water, temperature and litter removal, under controlled conditions. Can. J. Bot. 66: 429-434.

Appendix I

Record Groups and Files Consulted at National Archives

RG 39 Records of the Canadian Forestry Service, General Inventory Series

Volume	File	Name
227-228	93	Policy questions, 1928-1953
242	10585	Policy-Introduction to Visitors, 1928-1950
1	18374	Policy Resolutions, 1900-1946
248	28980	Forest Conditions, Prairie Provinces, 1910-1938
101	32674*	Riding Mountain, Nursery Station
	39715*	Riding Mountain, General
52	46371	Planting, Canadian National Parks, 1922-1941
413	A-3	"The Forests of Manitoba" manuscript, J.D.B. Harrison, 1931
365	48989	Nursery Sites

RG 84 Records of Parks Canada General Inventory Series

Volume	File	Name
1887	RM28-1 pt.1	RMNP-Landscaping, 1960-1967
168	RM181 pt.1	RMNP-Forest Operations, 1937-1951
175	RM343 pt.1	RMNP-Forest Experimental Station, 1937-1957
1915	RM343 Enclosure	RMNP-Forest Experimental Station, 1950-1954

* Researched only in part

Appendix II
Research Contacts During the Study

Dabney, Walter. Park Superintendent, Canyonlands National Park, Moab, Utah. June, 1992. (Written)

Domansky, Karl J. Retired Parks Canada Employee, Onanole, Manitoba. November, 1992. (Oral)

Gerling, H. Public Lands Division, Alberta Dept. of Forestry, Lands and Wildlife, Edmonton, Alberta. February, 1993. (Written)

Hernandez, Helios. Natural Resource Specialist, Parks and Natural Areas, Manitoba Dept. of Natural Resources, Winnipeg, MB. April, 1993. (Oral)

Howe, G. Manager, PFRA Shelterbelt Centre, Indian Head, Saskatchewan. Agriculture Canada. November, 1992. (Written)

Put, Margaret. Park Warden Service, Prince Albert National Park, Saskatchewan. December, 1992; January, 1993 (Written)

Park Resources Staff. Badlands National Park, South Dakota, United States. June, 1992. (Oral)

Svenson, Ray. Former mill owner-operator in Riding Mountain National Park. Onanole, MB. June, 1990. (Oral)

Toews, Clinton. Natural Resource Conservation, Canadian Parks Service, Prairie and Northern Region, Winnipeg, Manitoba. October, 1992. (Oral)

Trottier, G. Dept. of Environment, Canadian Wildlife Service, Edmonton, Alberta. August, 1992. (Oral)

Vanderschuit, Wybo. Park Warden Service, Riding Mountain National Park, Wasagaming, Manitoba. December, 1992. (Oral)

Waldron, Ross. Former Research Officer, Forestry Canada. Edmonton, Alberta. January, 1990. (Oral)

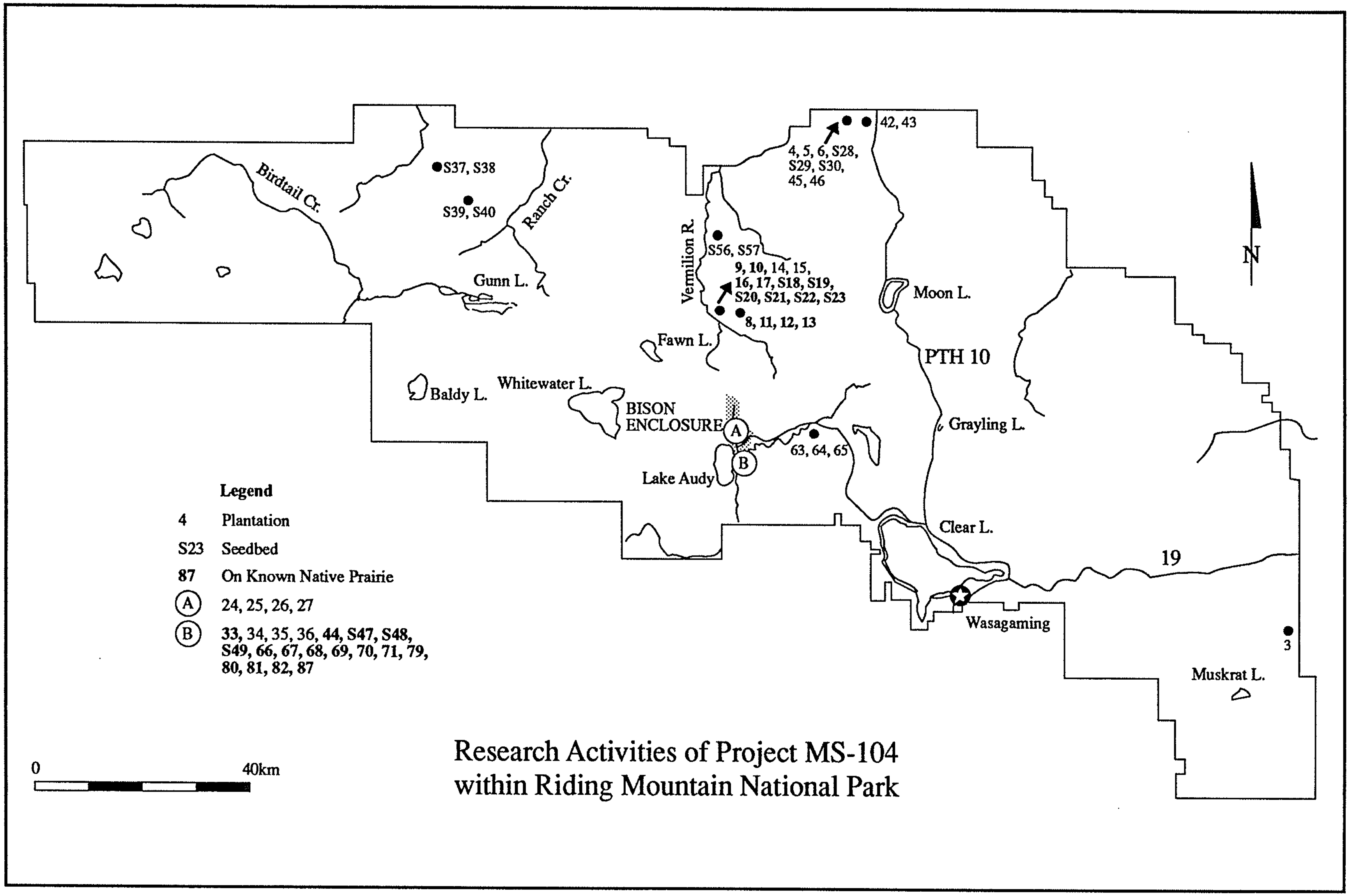
Watt, R.A. Park Warden Service, Waterton Lakes National Park, Alberta. May, 1992. (Written)

Contacts made but not included in study

Schiller, Robert. Resource Conservation, National Parks Service, Rocky Mountain Regional Office, Lakewood, Colorado. August, 1992.

Appendix III

Map of Research Activities Conducted under Project Ms-104
Within Present Day Boundary of RMNP



Research Activities of Project MS-104 within Riding Mountain National Park

Appendix IV

Testing Criteria for Carbonates after Adding 10% HCl Acid to Soil (Scott, 1991b)

$\%CaCO_3$	Audible effects	Visible effects
< 0.1	none	none
0.5	faintly audible increasing to lightly (listen up close in a quiet room)	none
1.0	faintly audible increasing to moderate	slight effervescence confined to individual grains. just visible
2.0	moderate to distance, heard away from ear	slightly more general effervescence visible at close inspection
5.0	easily audible	moderate effervescence, bubbles to 3 mm across easily visible
>10.0	easily audible	generally strong efferves. ubiquitous bubbles to 7 mm easily visible

Appendix V

Silvicultural History of Lake Audy Plantations (Canada, 1918 - ?)

Plantation 33-22

Notes by:

Planting date: May, 1922

Size(ha): 0.16

Species planted: Pj / Ps
No/ha: 3154 / 3089
Age of stock:
Spacing:
Origin of stock: ? / I.H.
Preparation of site: Furrows were ploughed in east - west direction
Planting method: Trees planted with grub hoe and set out in alternate rows.
Forest/Plant type: prairie
Topography and situation:

Soil

Litter:
Sub-soil:

Unleached soil:
Ground cover:

Survival and growth information

	1923	1926	1957
Trees/ha	778 / 1091	721 / 936	531 / 44
% survival	24.7 / 35.3	22.9 / 30.3	14.3 / 1.2
Ave.ht.(m.)	.46 / .37	.43 / .40	7.65 / --

Plantations 66-27 / 67-27

Notes by:

Planting date: 1st week of May, 1927

Size(ha): 0.87/2.15

Species planted: Sw / Sw
No./ha: 2714 / 2810
Age of stock: 2 - 3 Smaller grade stock planted in 66-27 and larger planted in 67-27.
Spacing:
Origin of stock:
Preparation of site: Site burned over prior to planting. Furrows were ploughed in an east-west direction.
Planting method: Planting spade
Forest/Plant type: Grass cover and prairie herbs

Soil

Litter:
sub-soil:

Unleached soil:
Ground cover:

Survival and growth information

	1928	1945	1957
Trees/ha	2203 / 2758	1111 / 1272	908 / 931
% survival	81.1 / 98.1	40.9 / 45.2	33.5 / 33.1
Ave.ht.(m.)	20 / .33	4.3 / 4.9	6.8 / 7.5

Plantations 68-28 / 69-28 Notes by: Bedell

Planting date: May 11 and 12, 1928 Size(ha): 1.01 / 1.23
Species: Sw
No./ha: 4406 / 3383
Spacing: 1.8 - 1.6 m
Age of stock: 3-0 / 2-2
Origin of stock: Lake Audy Nursery
Preparation of site: Grass burned over and furrows ploughed in an east-west direction.
Planting method: Planting spades proved most effective. One man and team ploughing furrows. Men worked in pairs, one man making holes and the other setting and tamping plants.
Forest/Plant type: Prairie

Soil
Litter: Nil Unleached soil: 20 cm. black loam
sub - soil: Gravel patches of clay
Ground cover: Complete cover of sod.

Survival and growth information

	1930	1945	1957
Trees/ha	1652 / 2116	741 / 1111	214 / 219
% survival	37.5 / 62.6	16.8 / 32.8	4.9 / 6.5
Ave.ht.(m.)	.18 / .21	3.0 / 3.4	6.1 / 6.6

Plantation 79 - 29 Notes by:

Planting date: May 1 - 8, 1929 Size(ha): 0.81
Species planted: Sw
No./ha: 2749
Age of stock: 3 - 0
Spacing: 1.8 - 2.0m.
Origin of stock: Lake Audy Nursery
Preparation of site: Furrows ploughed in an east - west direction.
Planting method: Planting spades
Forest/Plant type: Prairie

Soil
Litter: Unleached soil:
sub - soil: Ground cover:

Survival and growth information

	1930	1945	1957
Trees/ha.	891	617	59
% survival	32.4	22.5	2.2
Ave.ht.(m.)	0.12	3.05	--

Plantation 80 - 29

Notes by:

Planting date: May 1 - 8, 1929

Size(ha): 5.07

Species: Sw
No./ha: 2576
Spacing: 1.8 - 2.1 m
Age of stock: 60% ,3-0 / 40% ,2-2
Origin of stock: Lake Audy Nursery
Preparation of site: Furrows planted in an east - west direction.
Planting method: Planting spades
Forest/Plant type: Prairie

Soil

Litter: Sod
sub - soil: gravel

Unleached soil: Sandy loam
Ground cover: Grass

Survival and growth information

	1930	1945	1957
Trees/ha	659	469	79
% survival	25.6	18.2	3.1
Ave.ht.(m.)	0.12	3.05	5.5

In May 1930, 15% of the living plants have dead tops.

Plantation 87-30

Notes by:

Planting date: May, 1930

Size(ha): * 24.17

Species: Sw
No./ha: 2276
Age of stock: 2 - 2
Spacing:
Origin of stock:
Preparation of site: Furrows made in an east - west direction.
Planting method: Planting spades
Forest/Plant type: Prairie

Soil

Litter: Sod
sub - soil: Gravel

Unleached soil: Light loam
Ground cover: Grass and scattered cinquefoil.

Survival and growth information

	1945	1957
Trees/ha.	432	390
% survival	16	14
Ave.ht.(m.)	1.2	6.2

* Original plantation was 34.2ha.in size. However, with development of the Bison enclosure, 10.0ha of trees were removed.

Appendix VI

Detailed Account of Forest Research Activities under Project MS-104

Endeavour -Year (1)	Spp. (2)	Nature of Activity (3)	Age of Stock (4)	Origin (5)	Status (Cause/Mortality/Year) (6)	Area (ha) (7)
1-18	Sw	Plantation	5	I.H.	Replanted May 19, 1922. See 41-22	.41
2-18	Sw	Plantation	5	I.H.	Failure(destroyed by fire in 1925,100% dead)	.10
3-18	Sw	Plantation	5	I.H.	Failure(badly chewed by rabbits,90% dead,1926)	.10
*4-18	Sw	Plantation		I.H.		.38
5-18	Sw	Plantation	5	I.H.	Failure(Large% living, many badly chewed by rabbits,1926)	.10
6-18	Sw	Plantation		I.H.	Failure(Large% living, many badly chewed by rabbits, 1926)	.01
7-18	Sw	Plantation	5	I.H.	Failure(Trees destroyed by fire in 1929)	.41
8-20	Sw	Plantation	3	I.H.	Failure(Very poor shape, smothered by grass & weeds, 1926)	.10
9-20	Pj	Plantation	3	I.H.	Failure(93% of plants dead, September/1927)	.10
10-20	Ps	Plantation	3	I.H.	Failure(Choked by grass & winter killed, almost all dead	.10
11-20	Sw	Plantation	3	I.H.	Failure(Choked by grass, 100% dead, Fall/1925)	.10
12-20	Pj	Plantation	3	I.H.	Failure(Choked by grass, 100% dead, Fall/1925)	.10
13-20	Pj	Plantation	3	I.H.	Failure(Choked by grass, 93.9% dead, Fall/1925)	.10
14-20	Sw	Plantation	3	I.H.	Failure(Cancelled/1927)	.10
15-20	Pj	Plantation	3	I.H.	Failure(Choked out by grass, 100% dead, 1926)	.10
16-20	Sw	Plantation	3	I.H.	Failure(Most plants dead, 1926)	.10
17-20	Pj	Plantation	3	I.H.	Failure(Cause uncertain, 100% dead)	.10
S18-20	Sw	Seedbed	N/A		Complete failure(No germination, grass & weeds, 1926)	.10
S19-20	Pj,Sw	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	.10
S20-20	Sw	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	.10
S21-20	Pj	Seedbed	N/A			.10
S22-20	Sw	Seedbed	N/A			.10
S23-20	Pj	Seedbed	N/A			.10
S24-20	Sw	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	
S25-20	Pj	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	
S26-20	Sw	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	
S27-20	Pj	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	
S28-20	Sw	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	
S29-21	Sw	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	
S30-22	Sw	Seedbed	N/A		Complete failure (No germination, grass & weeds, 1926)	
31-22	Pj	Plantation	5	I.H.	Failure(Rabbits & dense shade, 100% dead, Sept./1924)	.10

Endeavour - Year (1)	Spp. (2)	Nature of Activity (3)	Age of Stock (4)	Origin (5)	Status (Cause/Mortality/Year) (6)	Area (ha) (7)
32-22	Pj	Plantation	5	I.H.	Failure(Rabbits & dense shade, 100% dead, Sept./1924)	.08
*33-22	Pj,Ps	Plantation				.17
34-22	Sw	Plantation	5	I.H.	Failure(Badly chewed by rabbits, 95.2% dead, Fall/1925)	.08
35-22	Sw	Plantation	5	I.H.	Failure(Badly chewed by rabbits, 95.3% dead, Fall/1925)	.08
36-22	Sw	Plantation	5	I.H.	Failure(Badly chewed by rabbits, 87% dead, Fall/1925)	.08
S37-22	Pj	Seedbed	N/A		Failure(No seedlings observed, 1927)	
S38-22	Sw	Seedbed	N/A		Failure(No seedlings observed, 1927)	
S39-22	Sw	Seedbed	N/A			
S40-22	Pj	Seedbed	N/A			
41-22	Sw	Formerly 1-18			Uncertain(Over rich soil,plot not located in 1945)	
42-23	j	Plantation	4T	I.H.	Failure(100% dead, October/1924)	.41
43-23	Pj	Plantation	4T	I.H.	Failure(100% dead, October/1924)	.30
44-24	Pj,Ps	Plantation	5T, 5T	I.H.	Failure(Some living, fair shape, 1926)	.20
45-24	Pj	Plantation	5T	I.H.	Failure(Rabbits & wet conditions, 94.6% dead, Fall/1925)	.10
46-24	Sw	Plantation	3	I.H.	Failure(Severe damage by rabbits,80% dead, April/1930)	.10
S47-24	Sw	Seedbed	N/A			
S48-24	Sw	Seedbed	N/A			
S49-24	Sw	Seedbed	N/A			
50-25	Sw	Plantation	5	RMR	Failure(Rabbits and competition, 83% dead, 1930)	.01
51-26	Sw	Plantation	5	RMR	Uncertain(Some rabbit damage, 44% dead, 1930)	.01
S52-26	Sw	Seedbed	N/A			
S53-26	Sw	Seedbed	N/A			
S54-26	Pl	Seedbed	N/A			
S55-26	Pj	Seedbed	N/A			
S56-26	Sw	Seedbed	N/A			
S57-26	Sw	Seedbed	N/A			
58-21	Pj	Pj thinning plots	N/A			
59-21	Pj	Pj thinning plots	N/A			
60-21	Pj	Pj thinning plots	N/A			
61-21	Pj	Pj thinning plots	N/A			
62-22	Pj	Pj thinning plots	N/A			

Endeavour - Year (1)	Spp. (2)	Nature of Activity (3)	Age of Stock (4)	Origin (5)	Status (Cause/Mortality/Year) (6)	Area (ha) (7)
63-26	Po	Po thinning	N/A			
64-26	Po	Po thinning	N/A			
65-26	Po	Po thinning	N/A			
*66-27	Sw	Plantation		I.H.		.89
*67-27	Sw	Plantation		I.H.		2.19
*68-28	Sw	Plantation		LAN		1.03
*69-28	Sw	Plantation				2.86
70-28	Ls,Sw	Plantation	2-1,2-2	LAN	Lost to Bison Enclosure	3.40
71-28	Sw	Plantation	3-0	LAN	Lost to Bison Enclosure	.31
72-28	Ls,Sw	Plantation	2-1,2-2			.54
S73-28	Sw	Seedbed	N/A			
S74-28	Sw	Seedbed	N/A			
S75-28	Pj	Slash disposal	N/A			
76-28	Pj	Slash disposal	N/A			
77-28	Pj	Slash disposal	N/A			
78-28	Pj	Slash disposal	N/A			
*79-28	Sw	Plantation		LAN		.82
*80-29	Sw	Plantation				5.17
81-29	Ls,Sw	Plantation	2-2,2-2	LAN	Failure(No larch, some spruce, 1945)	
82-29	Sw	Plantation	2-2	LAN	Uncertain(Unusually dry weather in 1930, 79%dead, Sept/1945)	
83-29	Sw	Plantation**	2-2,3-0	LAN	Uncertain (64% dead, April/1930)	.65
84-29	Sw	Plantation**	2-2,3-0	LAN	Uncertain (Unusual weather condition,73% dead,May/1930)	1.99
85-29	Sw	Plantation**	2-2,3-0	LAN	Failure(Unusual weather conditions, 83% dead, April/1930)	1.02
86-29	Sw	Plantation**	2-2,3-0	LAN	Failure(Unusually dry weather, 86% dead, April/1930)	.46
*87-30	Sw	Plantation		LAN		34.86

Key: I.H. - Indian Head Pj - Jack pine Po - Poplar (Trembling aspen) Ps - Scots pine RMR - Riding Mountain Reserve
RMR - Riding Mountain Reserve Sw - White spruce
* Lake Audy Plantations
** The planted stock consisted of 75%, 2-2 and 25%, 3-0.

Appendix VII

Summary of Hypotheses Testing and Corresponding p-values

pH:

pooled estimate of σ

Test Ho:μ(Ah - Fescue)-μ(Ah - Plantation) = 0

vs Ha:μ(Ah - Fescue)-μ(Ah - Plantation) > 0

Sample mean(Ah - Fescue) = 6.7125 Sample mean(Ah - Plantation) = 5.9375

t-statistic = 4.014 with 14 d.f.

Reject Ho at alpha = 0.05

pooled estimate of σ

Test Ho:μ(Bm - Fescue)-μ(Bm - Plantation) = 0

vs Ha:μ(Bm - Fescue)-μ(Bm - Plantation) > 0

Sample mean(Bm - Fescue) = 6.9375 Sample mean(Bm - Plantation) = 6.6500

t-statistic = 1.670 with 14 d.f.

Fail to reject Ho at alpha = 0.05

Moisture Content (MC%):

pooled estimate of σ

Test Ho:μ(Ah - Fescue)-μ(Ah - Plantation) = 0

vs Ha:μ(Ah - Fescue)-μ(Ah - Plantation) $\neq$ 0

Sample mean(Ah - Fescue) = 39.531 Sample mean(Ah - Plantation) = 23.883

t-statistic = 5.128 with 14 d.f.

Reject Ho at alpha = 0.05

pooled estimate of σ

Test Ho:μ(Bm - Fescue)-μ(Bm - Plantation) = 0

vs Ha:μ(Bm - Fescue)-μ(Bm - Plantation) $\neq$ 0

Sample mean(Bm - Fescue) = 14.733 Sample mean(Bm - Plantation) = 10.433

t-statistic = 1.876 with 13 d.f.

Fail to reject Ho at alpha = 0.05

Organic Matter (OM%):

pooled estimate of σ

Test Ho:μ(Ah - Fescue)-μ(Ah - Plantation) = 0

vs Ha:μ(Ah - Fescue)-μ(Ah - Plantation) > 0

Sample mean(Ah - Fescue) = 14.375 Sample mean(Ah - Plantation) = 9.9825

t-statistic = 2.602 with 12 d.f.

Reject Ho at alpha = 0.05

pooled estimate of σ

Test Ho:μ(Bm - Fescue)-μ(Bm - Plantation) = 0

vs Ha:μ(Bm - Fescue)-μ(Bm - Plantation) > 0

Sample mean(Bm - Fescue) = 11.224 Sample mean(Bm - Plantation) = 4.6780

t-statistic = 3.539 with 8 d.f.

Reject Ho at alpha = 0.05

Appendix VIII
Distribution of Carbonate Values Using Box-plot Method