VEGETATION AND UNGULATE RESPONSE TO FOREST CLEARINGS IN THE DUCK MOUNTAIN, MANITOBA

A Thesis

Submitted to

The Faculty of Graduate Studies

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Anita Schewe

March 1981

"What this country needs are more ECO-ECO experts: ecologists who won't destroy the economy while saving the ecology, and economists who won't destroy the ecology while saving the economy."

-J. Kesner Kahn in "Line o'type,"
Chicago Tribune

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ABSTRACT

The vegetation and ungulate response to clear-cutting were investigated at four sites, Sarah Lake, Lidstone, Garland Canyon and Mink Creek along the Duck Mountain, Manitoba. The cleared plots ranged from 0.5 to 2 ha and were, in most instances, rectangular. The plot(cleared area), the edge of the plot and the control(mature stand) were examined.

The number and type of herbs, shrubs and trees were determined for the plot, edge and control. Species diversity, browse production and the abundance of herbs and shrubs were greatest along the edge of the plots. Most plots contained more individual plants and species of plants than the controls.

Dry weights of twigs predicted from dry diameters were used to estimate browse consumption by ungulates. The weight-diameter relations and the percent moisture of 10 browse species were monitored over the span of a year. High correlations of weight and diameter were found for twigs of red-osier dogwood(*Cornus stolonifera*), mountain maple(*Acer spicatum*), and trembling aspen(*Populus tremuloides*) throughout the year. Pincherry(*Prunus pensylvanica*), chokecherry(*P. virginiana*), beaked hazel(*Corylus cornuta*), balsam poplar(*P. balsamifera*), willow(*Salix* spp.), saskatoon(*Amelanchier alnifolia*) and low bush-cranberry(*Viburnum edule*) showed a greater variation in the weight-diameter relations with the highest correlations occurring in midwinter. The percent moisture of the twigs was at a maximum in the late spring.

Browse use determination, pellet group counts, rumen analysis,

track counts and general observations of moose(*Alces alces*), elk (*Cervus elaphus*) and white-tailed deer(*Odocoileus virginianus*) in the sites showed that these ungulates were using the plots more than the controls. Available cover, browse production, other environmental factors and man's disturbance affected the use of the plots by the ungulates. The edge, providing cover and food, was used more frequently than the plots and the controls.

The benefits of the habitat manipulation project in the Duck Mountain exceeded the costs when these benefits are evaluated in reference to hunter use of the areas. An increase in ungulate use of the plots provided the hunters with a greater probability of shooting some big game animals. Increased hunter use of the areas brought more revenue into the area.

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CHAPTER I

INTRODUCTION

A. General Introduction

A habitat manipulation project was undertaken by the Department of Natural Resources on the edge of the Duck Mountain, Manitoba, to increase the moose(*Alces alces*), elk(*Cervus elaphus*), and white-tailed deer(*Odocoileus virginianus*) use of large mature stands of trembling aspen(*Populus tremuloides*) and balsam poplar(*P. balsamifera*).[I]

The Duck Mountain is located in the northwest corner of southern Manitoba. The four sites(Sarah Lake, Lidstone, Garland Canyon and Mink Creek) selected for manipulation are on the edge of the Duck Mountain Forest Reserve. Between 1972 and 1978, 238 plots in the four sites were cleared with bulldozers and chainsaws.

The areas that have been cleared were formerly used for logging and agriculture. The main vegetation on these disturbed sites was mature poplar forest. The dense stands of aspen and balsam poplar provided little available browse for the ungulates. There were few shrubs under the dense tree canopy. The ground cover was made up of shade tolerant species such as wild lily-of-the-valley(*Maianthemum canadense*) and sarsaparilla(*Aralia nudicaulis*). Browse species such as red-osier dogwood(*Cornus stolonifera*), beaked hazel(*Corylus cornuta*) and cherry shrubs(*Prunus* spp.) were scarce.

Clearing opened up the forest canopy allowing light to penetrate to the ground surface. Pioneer species and species from the mature forest colonized the clearings. Aspen suckers, shoots of trees, shoots of shrubs and saplings soon dominated the vegetation in the cleared zone. The plots contained a wider diversity and a greater

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[I] Authorities for all binomials are found in Appendices A, B and C.

abundance of plant species.

The moose, elk and white-tailed deer were attracted to these early seral stages of succession because of the available and abundant food sources.

This thesis is divided into five chapters with a general conclusion and management recommendation section. The first chapter introduces the thesis topic and describes the necessary background information for the four study sites. The second chapter contains the results of the vegetation analysis. Chapter III outlines the seasonal changes in the twig weight-diameter relations of ten browse species. The regression equations generated in this chapter are used to determine the browse consumption of the ungulates in Chapter IV. Ungulate response to clearcuts and to the change in vegetation in clearcuts is discussed in Chapter IV. Chapter V outlines the costs and benefits of the habitat manipulation project.

B. Objectives

The objectives of this study were:

1) to compare and contrast the floristics and distribution of plant species within the cleared plots and mature forest stands of the four study sites.

2) to determine the best time of year to collect twigs of browse species in order to predict dry weight of browse from dry diameter of twigs.

3) to determine the food habits of white-tailed deer, elk and moose in the Duck Mountain study sites.

4) to determine the use of clearcuts near the Duck Mountain by moose, elk and white-tailed deer.

5) to assess the life span of cleared plots in terms of preferred browse species and ungulate use.

6) to determine if the benefits of the Duck Mountain Habitat Manipulation Project exceed the costs.

7) to recommend management procedures to maintain the mosaic of seral stages in the mature forest and to maintain or improve use of the clearcuts by the ungulates.

C. Site Description

(a) Location

The general study area is located along the Duck Mountain Periphery from $100^{\circ}30'$ to $101^{\circ}45'$ west longitude and $51^{\circ}15'$ to $52^{\circ}15'$ north latitude(Fig. 1.1). It rises above the surrounding Manitoba plains between two other prominent landscape features in the province: the Porcupine Mountain to the north and the Riding Mountain to the south. Most of the Duck Mountain is enclosed within the Duck Mountain Provincial Park and the Duck Mountain Forest Reserve.

The study sites are located in four areas along the Duck Mountain Forest Reserve. Three of the sites, Garland Canyon, Mink Creek, and Sarah Lake, are located on the Periphery Lands of the Forest Reserve(Inset of Fig. 1.1). The Lidstone site is located within the Forest Reserve. The locations of the plots within the Mink Creek, Garland Canyon, Lidstone and Sarah Lake sites are found in Fig. 1.2, Fig. 1.3, Fig. 1.4 and Fig. 1.5, respectively.

(b) Geomorphology

The Duck Mountain rises 350 meters to 500 meters above the lowlands with the greatest relief found on the eastern escarpment. Baldy Mountain at 831.2 meters, the highest elevation in Manitoba, is found within the Duck Mountain Provincial Park.

The area was under salt water in the Cretaceous period(50-100 million years B. P.). The North American continent began to form when the Precambrian rock core began to rise above the water. The uplifting of the shale formed by pressure on the sea bottom resulted

Fig. 1.1. The location of the Duck Mountain Forest Reserve in Manitoba and the location of the four study sites

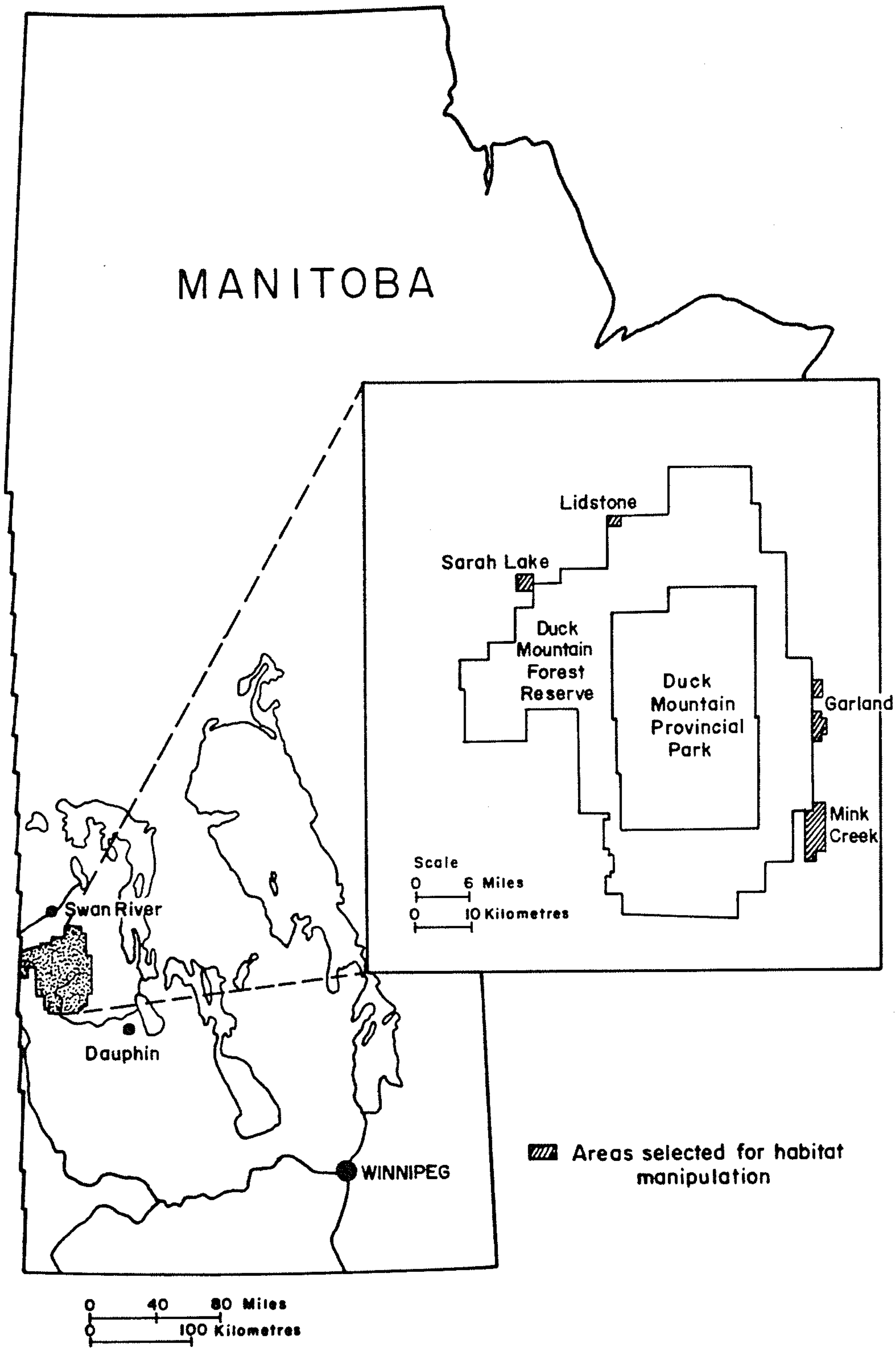
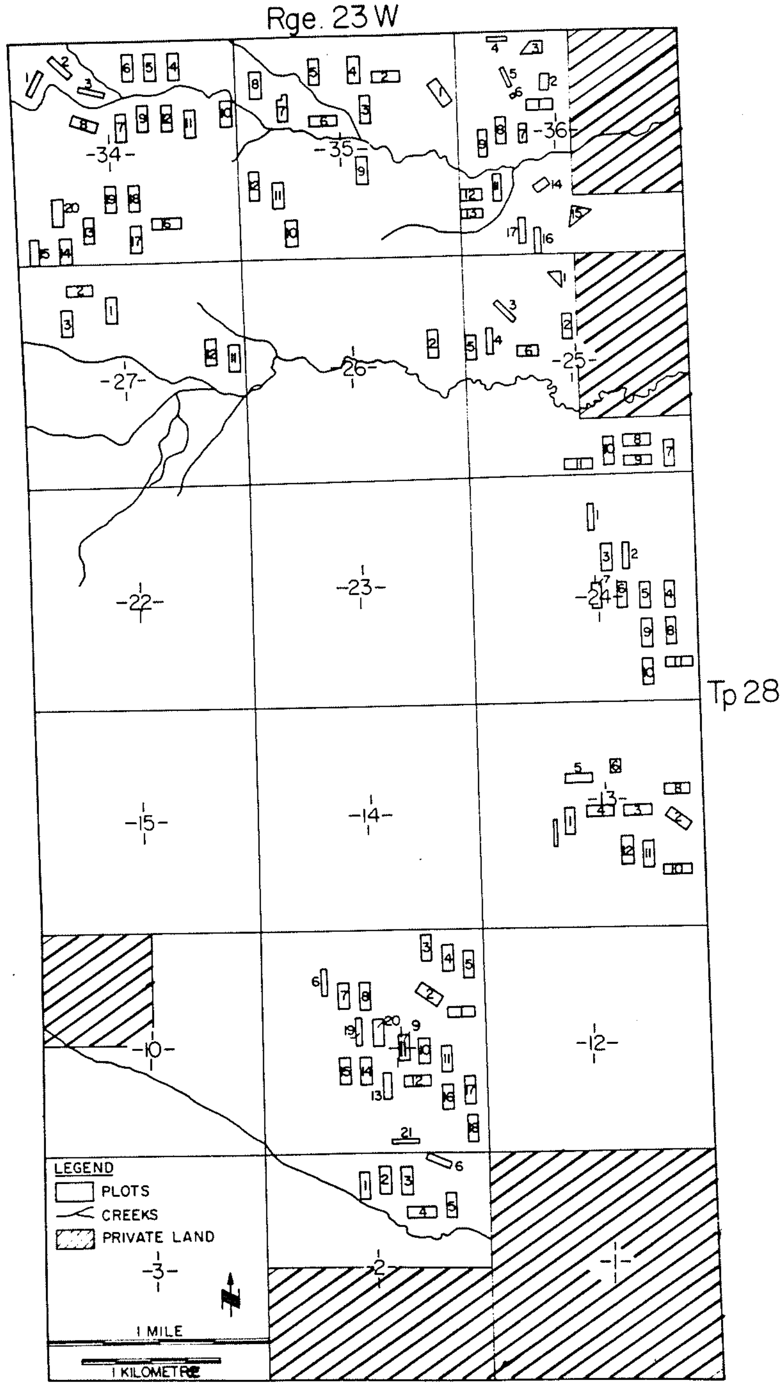

MANITOBA
Lidstone
Sarah Lake
Duck Mountain Forest Reserve
Duck Mountain Provincial Park
Garland
Mink Creek
Scale
0 6 Miles
0 10 Kilometres
Swan River
Dauphin
WINNIPEG
Areas selected for habitat manipulation
0 40 80 Miles
0 100 Kilometres

Fig. 1.2. Location of the study plots in the Mink Creek site



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LEGEND
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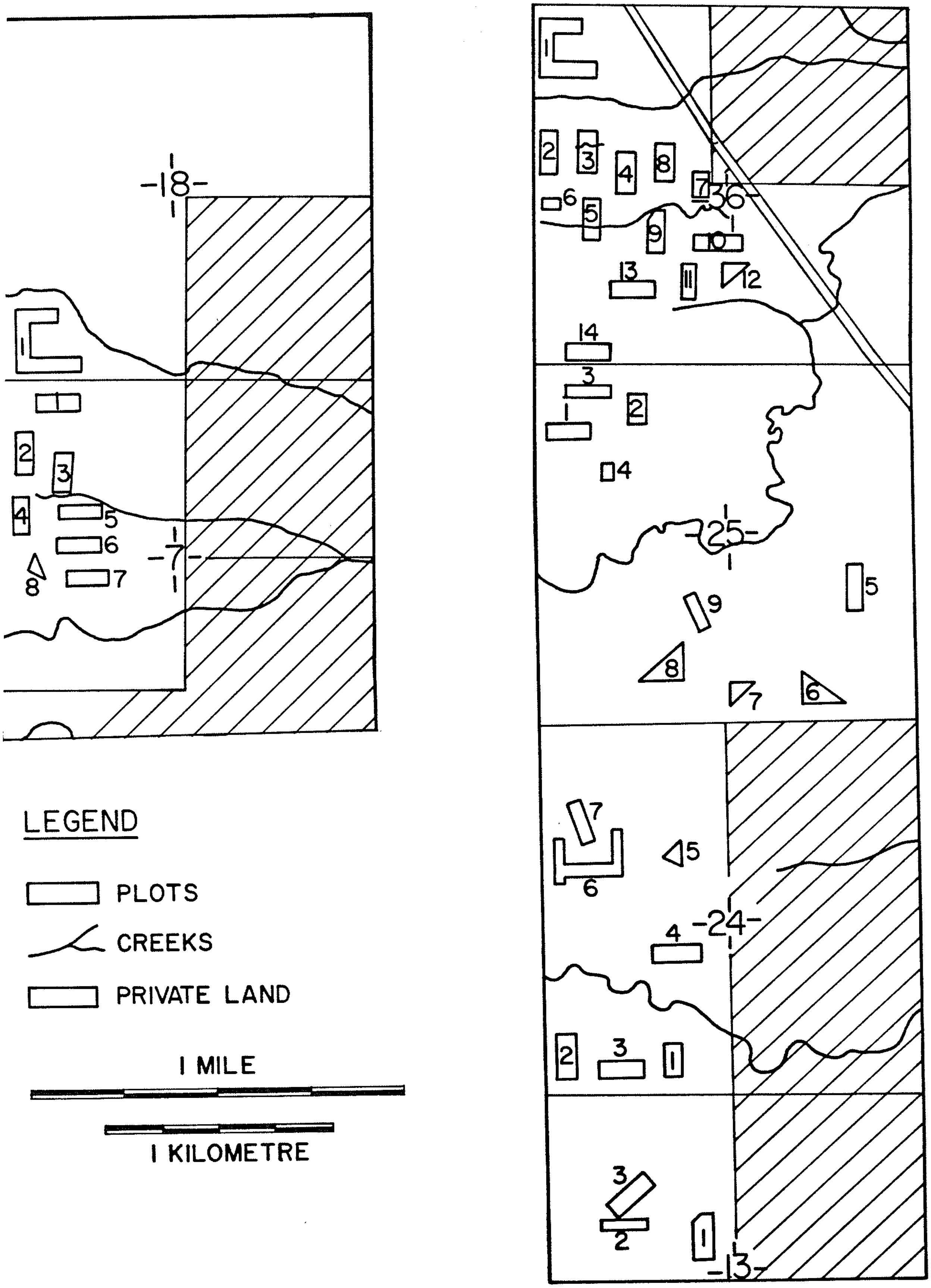
CREEKS
PRIVATE LAND
1 MILE
1 KILOMETRE

Fig. 1.3. Location of the study plots in the Garland Canyon site



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PLOTS
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1 MILE
1 KILOMETRE

Fig. 1.4. Location of the study plots in the Lidstone site

Sec. 31, Tp. 34, Rge. 26 W.

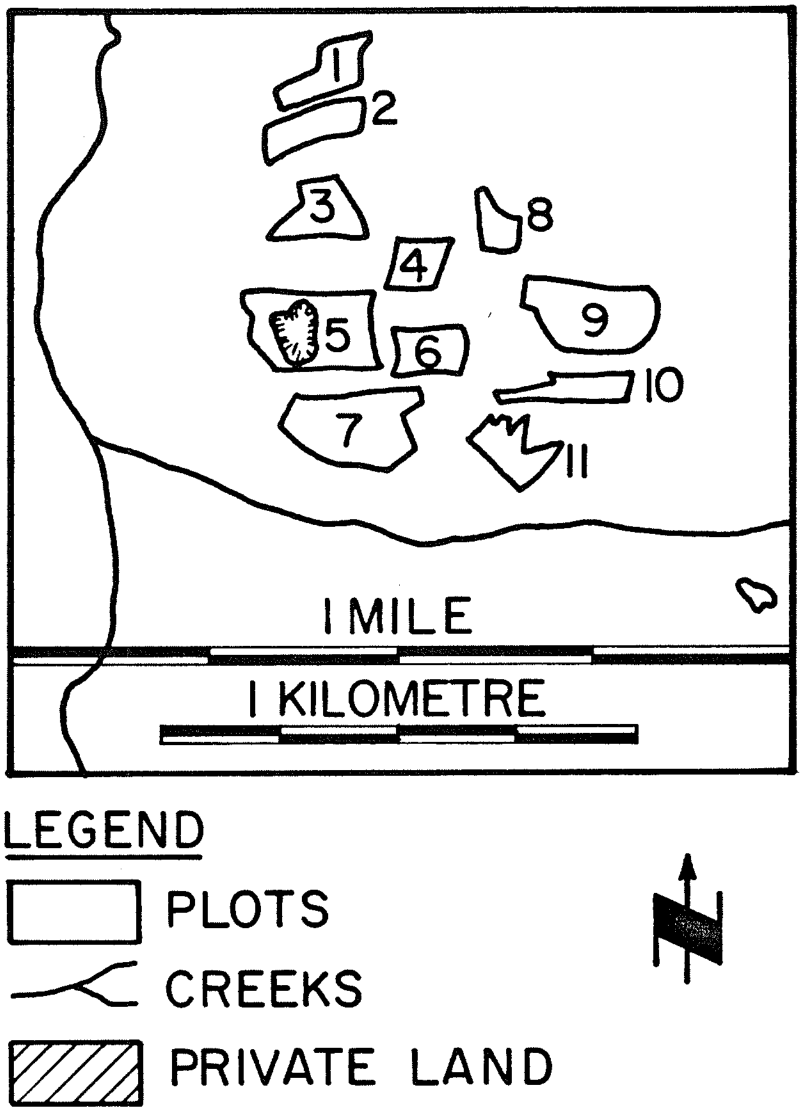
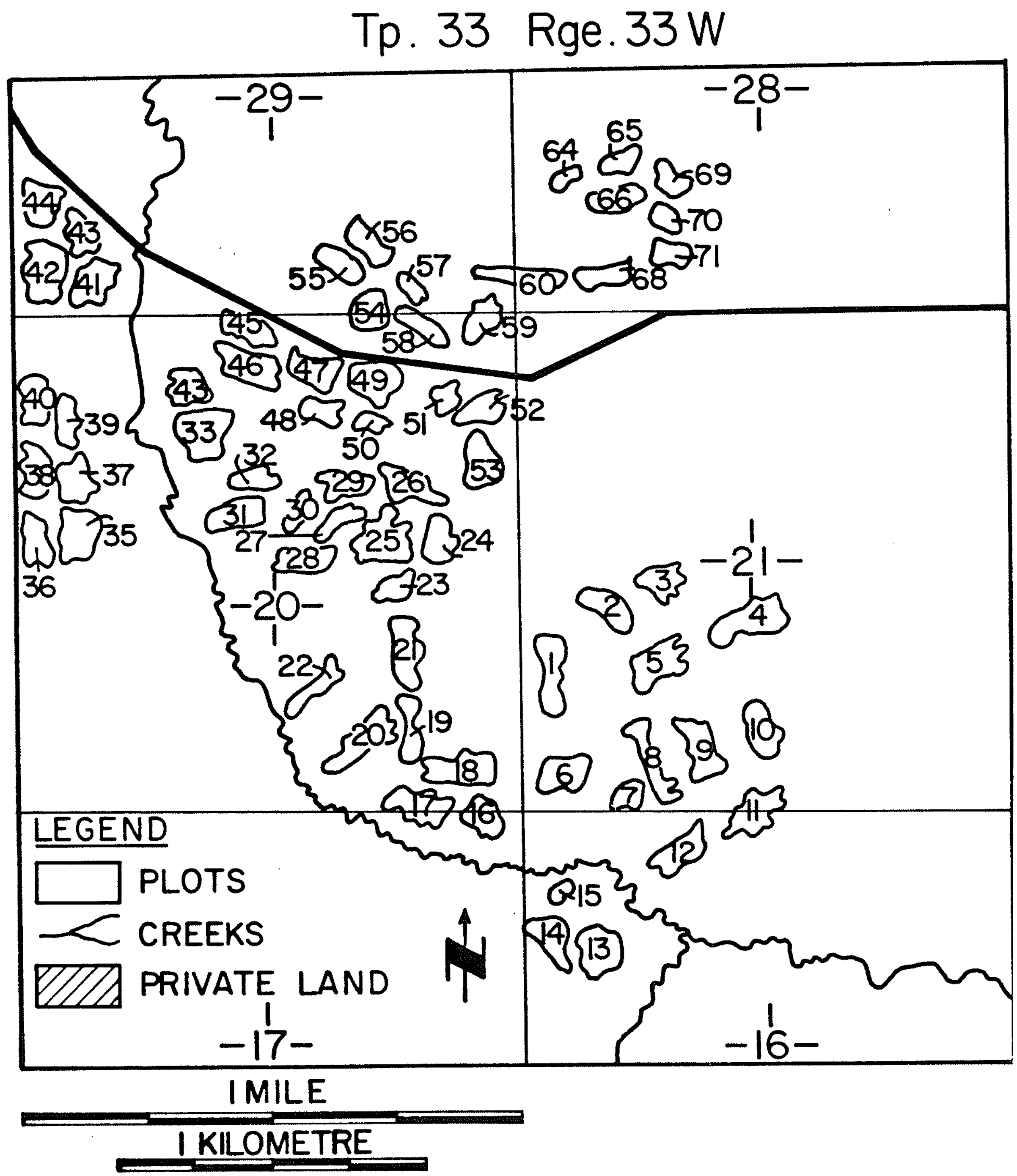


Fig. 1.5. Location of the study plots in the Sarah Lake site (found on following page).

Plate 1.1. The size and shape of the 71 plots at Sarah Lake in 1974 taken from aerial photograph (Department of Energy, Mines and Resources, Air Photo Number A 23350-84).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LEGEND
PLOTS
CREEKS
PRIVATE LAND
1 MILE
1 KILOMETRE

in the Riding Mountain Formation which includes the Duck Mountain. The eastern escarpment formed when the hard surface on the top of the formation did not erode as quickly as the underlying softer rocks. Where erosion was the greatest, in the Valley River and Swan River valleys large breaks were formed in the Riding Mountain Formation which separated the three mountain areas in the province: Duck, Riding and Porcupine.

In the Pleistocene, glaciers began to carve paths through the uplands. Other landscape features such as ground moraines and end moraines were deposited by the glacier. The original shale is now covered by glacial drift. The retreat of the Wisconsin Ice 20,000 to 30,000 years ago, and the formation of Lake Agassiz 10,000 years ago, added more features to Manitoba landscapes. Beaches and plateaus were formed giving gentle rises in elevation on the east side of the Duck Mountain escarpment. Heavier precipitation on the upland had resulted in the erosion of steep walls of shale by rivers. Steep river valleys and some small canyons now hold tiny streams.

(c) Soils

The general soil type for the Duck Mountain area is grey-wooded (Ellis 1959). The A and B horizons are generally well defined being slightly acidic to acidic. The glacial drift has resulted in the presence of boulders and stones in all layers of the soil profile. The yellow sandy clay and clay gravel mixtures predominate in the lower horizons.

The specific soil type varies in each of the four sites. In Mink Creek and Garland Canyon, there are four different soil types of which three only occur in significant amounts. The three major types are the Grifton Association, Peat and Eroded Slopes Complex. The Grifton Association covers most of the Mink Creek and Garland Canyon sites. Peats cover 800 hectares of the Mink Creek block while only small amounts of peat are found in the Garland area(Searle and Bukowsky 1973).

The Grifton Association is made up of sandy textured soils. Pockets of gravel and sand are common. Natural fertility of the soil is low but the soils are usually well to imperfectly drained.

The Eroded Slopes Complex occurs along the streams where slopes are relatively steep. The plots were not placed near erosion-prone slopes so there would be little soil of this type near the plots (Searle and Bukowsky 1973).

The Peat is largely dependent on the vegetation type covering its surface. The peat is slightly to strongly acidic and ranges from a few to 70 cm deep. The water table is generally high.

(d) Climate

The study area is in the Humid Microthermal Warm Summer Climate zone(Department of Tourism, Recreation and Cultural Affairs 1973). The temperature and precipitation vary greatly between upland and lowland. The precipitation is up to 50% higher in the upland with 3-4 degree F. cooler mean temperatures in July as well as in January. The onset of vegetative growth of the plant species is about 10-14 days later in the spring in the uplands as compared to the lowlands(Department of Tourism, Recreation and Cultural Affairs 1973).

In 1979 and 1980 there were some differences in the weather between the study sites on the east side(Garland Canyon and Mink Creek) and on the north side(Lidstone and Sarah Lake). There was a killing frost in early September 1979 on the north side of the Duck Mountain while the plants on the east side remained untouched by frost until a few weeks later. The winter snow depths also varied. Garland and Mink Creek had maximum snow depths of 40-45 cm while Lidstone and Sarah Lake recorded snow depths of 60 cm in 1980.

(e) Flora

The Mixed Woods section of the Boreal Forest is the primary vegetation type for the Duck Mountain(Rowe 1956) with aspen, balsam poplar, paper birch(*Betula papyrifera*) and white spruce(*Picea glauca*) the dominant trees. On the sandy ridges in the Garland area, jack pine(*Pinus banksiana*) is common. Tamarack(*Larix laricina*) and black spruce(*Picea mariana*) occur in the undrained areas. Aspen and balsam poplar are the dominant trees found in the disturbed areas where the plots are located.

Beaked hazel is the dominant shrub with red-osier dogwood, willow(*Salix* spp.), alder(*Alnus rugosa*) and high-bush cranberry (*Viburnum opulus* var. *americanum*) abundant in the moister areas. Chokecherry(*Prunus virginiana*), saskatoon(*Amelanchier alnifolia*), pincherry(*Prunus pensylvanica*) and rose(*Rosa* spp.) are common when light and soil conditions are suitable(Department of Tourism, Recreation and Cultural Affairs 1973).

The understory is typically made up of herbs such as sarsaparilla (*Aralia nudicaulis*), wild strawberry(*Fragaria virginiana*), wild lily-of-the-valley, Lindley's aster(*Aster ciliolatus*) and dewberry(*Rubus* *pubescens*). Very little light penetrates to the understory of the dense aspen and poplar stands thus providing an unsuitable environment for the growth of most herbs(Peterson 1955).

Appendix A contains a complete list of the plant species found in the Garland Canyon, Mink Creek, Lidstone and Sarah Lake sites. Authorities for all specific names are also found in the appendices.

(f) Fauna

White-tailed deer, moose, and elk are found in the study area. The average density per square mile for the ungulates(obtained from aerial surveys in 1977) is recorded in Table 1.1. Appendix B lists avian fauna while Appendix C lists the mammalian fauna found in the study sites. Other mammals common to the area include the snowshoe hare(*Lepus americanus*), red squirrel(*Tamiasciurus hudsonicus*). meadow vole (*Microtus pennsylvanicus*) and black bear(*Ursus americanus*).

Table 1.1. The density of white-tailed deer, moose and elk in the study sites in 1977.

Site	Density Per Square Mile		
	Deer	Moose	Elk
Lidstone	1.0	5.0	21.5
Sarah Lake	2.2	1.4	3.9
Garland	4.0	2.1	2.1
Mink Creek	4.0	2.0	1.0

A number of bird species are found in the study sites(Appendix B). Black-capped chickadees(*Parus atricapillus*), ruffed grouse(*Bonasa umbellus*), blue jays(*Cyanocitta cristata*), common ravens(*Corvus corax*) and gray jays(*Periosoreus canadensis*) are the common winter inhabitants of the Duck Mountain Forest. Additional birds,commonly seen in the summer, included chestnut-sided warblers(*Dendroica pensylvanica*), white-throated sparrows(*Zonotrichia albiocollis*) and American redstarts (*Setophaga ruticilla*).

(g) General History

Explorers and traders found the Duck Mountain more difficult to travel through than the surrounding plains. Therefore little is known about the area in pre-settlement times.

Fur trapping became the area's major industry when the North-west and the Hudson's Bay Companies began buying furs. As settlers became established in the area the fur industry declined but it is of minor importance today.

Settlement first took place in the lowlands where the terrain was even and the soils were rich. The building of the railroad to Cowan, on the northeast side of the Duck Mountain, opened up the area north of the mountain for settlement. The increase in settlement resulted in a demand for timber from the Duck Mountain forests. The demand was satisfied by the establishment of numerous sawmills, especially in the Grandview area. As the construction of houses declined, timber was diverted into the production of pulp and paper,

In 1906, the Duck Mountain Forest Reserve was set aside to serve the need for timber conservation. In 1961, the centermost part of the Reserve was declared a provincial park. Some of the land surrounding the Forest Reserve, although not part of the Reserve itself, is also owned by the Crown.

In 1973, 125 hectares are included within the provincial park, 245,000 hectares are included within the Provincial Forest Reserve and 25,000 hectares are included within other Crown lands(Department of Tourism, Recreation and Cultural Affairs 1973). The Crown lands or Periphery lands are being assessed to determine their best possible uses. They act as a "buffer zone" which can help to resolve the conflicts between agricultural and forestry operations.

(h) History of Plot Preparation

The 238 habitat manipulation plots were found in the Periphery lands(Sarah Lake, Garland Canyon and Mink Creek) and in the Duck Mountain Forest Reserve(Lidstone). The possible sites for the plots were flagged and then cleared manually or mechanically between 1972 and 1979.

In 1972 the clearing began in the eleven plots at Lidstone (Fig. 1.4) and in the 71 plots at Sarah Lake(Fig. 1.5). A bulldozer and a two man crew with chain saws felled the trees and left them where they fell. In 1974 the debris in the Lidstone plots was pushed into piles and burnt. Wet conditions at Sarah Lake hampered attempts to burn the slash in these plots.

In 1976-1977, 21 plots(Numbers 24, 51, 53-71 and half of plot 52) in Sarah Lake were recleared with bulldozers. The bulldozers pushed the logs into windrows. In 1978, 29 more plots(Numbers 1-8, 10-12, 31-

51 and half of plots 52, 9 and 28) were cleared again in the same manner as 1976.

The size of the Lidstone and Sarah Lake plots varies between 1 and 2 hectares. The shapes are also variable as can been seen in Plate 1 and in the maps(Fig. 1.4 and 1.5).

Beginning in 1974, the plots in the Mink Creek area(Fig. 1.2) and Garland Canyon(Fig. 3) on the east side of the Duck Mountain were cleared by pushing the logs into windrows with a bulldozer(Bukowsky 1974, Bigelow 1975). The windrows in some plots run parallel to one another while in others they are perpendicular(Plate 1.2). Most plots are rectangular averaging 0,5 to two hectares(Plate 1.2 and Fig. 1.2 and 1.3). Some are U-shaped and some are triangular(Plate 1.2).

All of the plots found in Sections 13, 24, 25 and 36 of Mink Creek(Fig. 1.2) as well as plots 1-12, 19 and 10 in Section 11 for a total of 63 plots were cleared in 1974(Minton 1975).

In 1975, the remaining 7 plots in Section 11(plots 13-18 and 21) and plots 1-6 in Section 2 were bulldozed. Also, in 1975, all 42 plots in the Garland Canyon block were cleared. The remaining Mink Creek plots, numbering 38(Sections 26, 27, 34 and 35), were bulldozed in 1976.

In plot preparation, careful attention was paid to the location of the plots. The following criteria were adhered to: 1) all plots were cleared in the winter, 2) all plots were flagged to avoid erosion-prone slopes, 3) all plots were prepared on land which had been disturbed by fire or agriculture resulting in mature aspen and balsam poplar cover and 4) to decrease erosion, a buffer zone of at least three meters on either side of small creeks was left in trees, if these creeks happened to cross a plot(Searle and Bukowsky 1973). Once flagged some plots did not meet the above criteria so they were not bulldozed(thus, the nonsequential numbering in some areas).

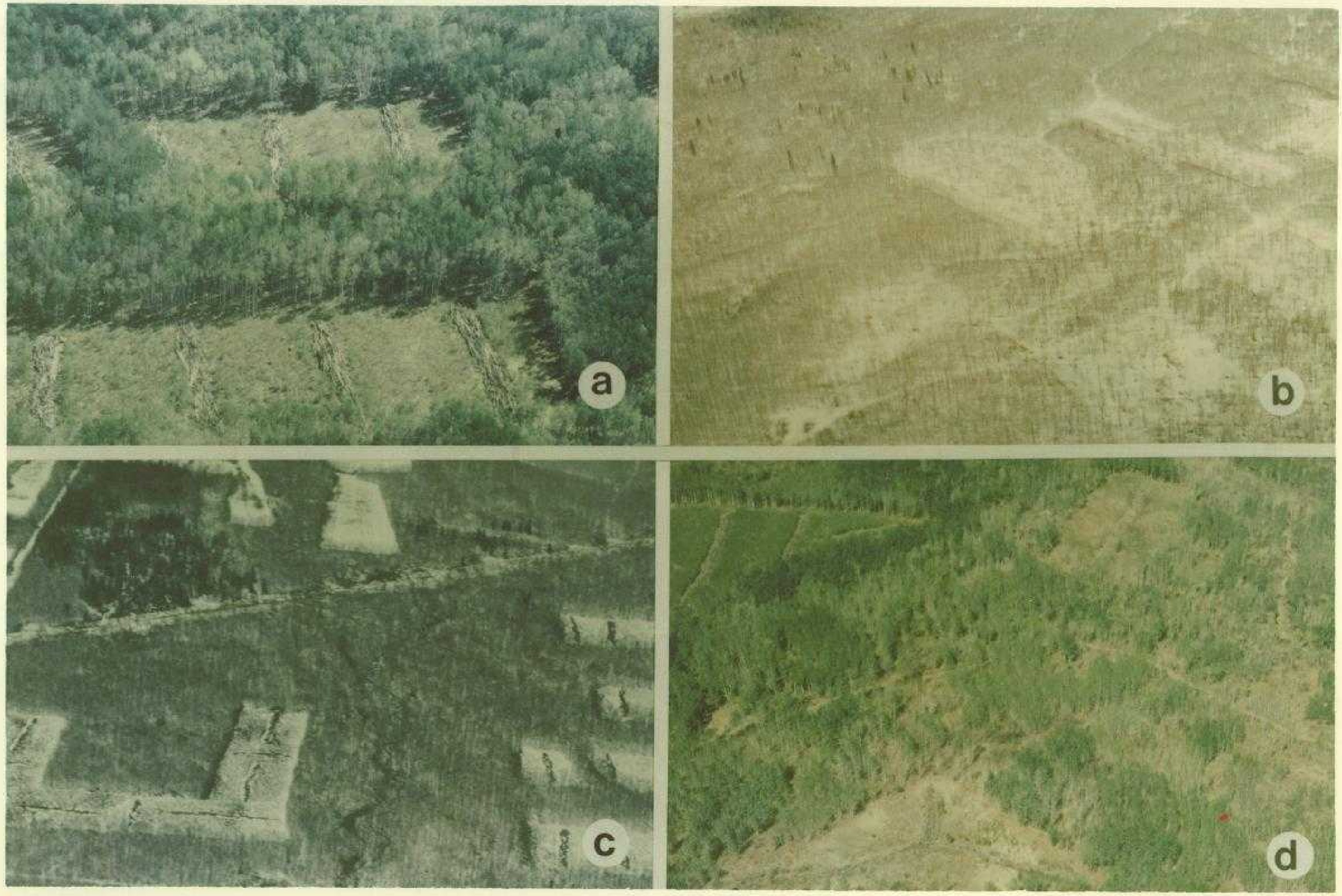
Plate 1.2 The shape and size of plots.

a) Rectangular plots (2 ha) with parallel windrows were the common ones in Mink Creek. The upper plot in the photo is divided in two by a residual stand of trees left growing beside a stream.

b) Variable sizes and shapes made up the Lidstone plots. Note the large trees still standing in the plots.

c) Some plots at Garland were U-shaped.

d) Other Garland plots were triangular.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CHAPTER II

A COMPARISON BETWEEN MATURE POPLAR FORESTS AND RECENTLY CLEARCUT STANDS IN THE DUCK MOUNTAIN, MANITOBA

A. Introduction

Many factors influence the recovery of vegetation in the boreal forest region after disturbance(La Roi 1967, Heinselman 1970 and 1973, Dix and Swan 1971, Rowe and Scotter 1973). Since clearcutting and fire in a forest result in similar vegetation changes they will be reviewed together.

The climax stage of the boreal forest is the black spruce or white spruce community(Rowe 1956). Before this stage is reached, the area goes through a number of seral stages. Poplar- poplar spruce-spruce poplar-spruce is one sequence suggested by Rowe(1956) for the Mixed Woods section of the Boreal Forest.

Clearcutting from logging is a common factor in the succession of twentieth century forests because fires have been suppressed. The end-product of clearcutting and burning is a mosaic of vegetation on the landscape(Cowan and Hatter 1950, Spencer and Chatelain 1953, Vierick 1973, Le Resche, Bishop and Coady 1974, Peek 1974b, Irwin 1975). Communities of different vegetation types or in different seral stages are found in close proximity to one another due to the patchiness of burning or clearing. Following logging and fires, the seed banks and rooting characteristics of some species allow some areas to return to their original species composition within a few growing seasons. The resulting mosaic in the boreal forest is prime habitat for some North American ungulates(See Chapter IV).

Many factors affect the rate of succession and the floristic composition of each seral stage. Precipitation, slope, soil type, root competition, litter accumulation, temperature, animal use and amount of sunlight are a few factors which have a direct effect on succession (Wright and Heinselman 1973). The amount of clearcutting and the intensity of burning affect the rate of succession (Cook 1939, Stelfox, Lynch and McGillis 1976, Usher 1978).

In addition to the gross changes in plant communities, fire and clearcutting affect the structure of each community. The opening of the forest canopy is one important aspect of clearing as light is a principal factor in controlling the growth of the lower strata(Rowe 1956). When the canopy is cleared the light can reach the soil surface. Tree-tall shrub-low shrub-tall herb-low herb-moss is a series which shows increasing tolerance to shade(Rowe 1956). With more light the species richness or species diversity(Whittaker 1975) of the strata is increased. As the tree canopy closes in, less light can reach the soil surface.

The effect of clearcutting on trees is dependent on the type of logging. It is a common forestry practice to thin stands of trees to promote the growth of certain species(Cook 1939, Graham, Harrison and Westell 1963, Patton and McGinnes 1964, Kneirim, Carvell and Gill 1971, Spurr and Barnes 1980). When there is a total clearcut, regeneration of the tree species is dependent on their growth form. Aspen is one tree whose regeneration is enhanced by fire or clearcutting(Graham et al. 1963). As the production of aspen suckers is controlled by apical dominance, the killing of the above ground portion results in numerous new aspen shoots (Farmer 1962). Winter cutting results in more vigorous growth of aspen shoots from suckering whereas summer cutting will result in the same growth but it will only occur the following summer (Galvin, Hoover and Avery 1979). For other tree species including birches, maples, and oaks, side shoots grow when the main branch of the tree is killed. These new sprouts of hardwoods are preferred by deer over the seedlings of the same species (Cook 1946).

Shrubs which sprout prolifically after a fire include saskatoon, hazel, alder, mountain maple, and willow (Leege and Hickey 1971, Wright and Heinselman 1973). The number of species of shrubs and trees which serve as browse for the ungulates increases after clearcutting or burning (Cowan et al. 1950, Halls and Alcaniz 1968, Dix and Swan 1971, Kneirim et al. 1971, Leege and Hickey 1971, Stelfox et al. 1976, Usher 1977 and 1978). In addition to the increased production of vegetative portions of shrubs, the production of fruit increases in forest clearings (Lay 1966, Halls and Alcaniz 1968, Wright and Heinselman 1973).

The herb layer changes significantly after a fire or logging. Pioneer species including thistles, goldenrods, fireweed, fleabanes, nettles and ragworts are the first to colonize the clearings (Daubenmire 1947, Wright and Heinselman 1973). Ferns, blueberries and grasses inhabit the clearings soon after the pioneer species (Galvin et al. 1979). The flowering of some shrubs and herbs such as fireweed is stimulated by fires (Wright and Heinselman 1973).

There is a change in the nutrient status of the herbs, shrubs and trees growing in the newly cleared areas. Einarsen(1946) found that a reduction in light intensity decreased the protein content in some shrubs and trees. Cowan et al.(1950) conclude that the nutritional value of woody plants vary with the successional stages of the vegetation. The vegetation in the oldest areas have high levels of carotene but the earlier stages of succession provide the most nutritious browse for moose(Cowan et al. 1950). They found that aspen and paper birch were high quality food. DeWitt and Derby(1955) also conclude that the protein content of their study shrubs increased after a fire while other nutrient levels did not change significantly.

The effect of clearcutting and fire on soil indirectly affects the vegetation and its response to disturbance. As there is little cover over the soil after a disturbance, the soil heats up and cools down much faster. The result is earlier growth of plants in spring (Daubenmire 1947). Fires also rid the soil surface of organic debris whereas logging contributes more to the debris.

The effect of clearcutting on the soil nutrient status has been studied in detail at the Hubbard Brook Experimental Forest. The greatest loss due to removal of the vegetation is the removal of the storage space for water resulting in greater runoff(Bormann and Likens 1969, Likens et al. 1970). There is a nitrate loss, which is followed by a loss of calcium, magnesium, sodium and potassium. There is less vegetation to take up the nutrients and to store them.

Even though there is an erosional problem after clearcutting, the rate of revegetation affects the rates of erosion and nutrient loss (Marks and Bormann 1972). The regeneration of the pincherry moderated the soil temperatures and modified the nutrient loss in the first few years after clearcutting. Thus the establishment of a complete canopy with fast-growing successional species is believed to reduce the negative effects of clearcutting on the ecosystem.

Before such potential impacts can be assessed, it is important to carry out an inventory of the floristic and browse resources of the study area; hence, the objectives of the plant study were to determine the composition of the vegetation in the different sites and the distribution of plant species in the clearings as compared to the mature forest.

B. Methods

Vegetation analysis began in May 1979 and continued throughout the summer of 1979 and 1980.

Each of the study sites was considered separately for the data analysis. The plots at Mink Creek and at Sarah Lake were grouped according to year of clearing. In total there were 8 treatment types: Lidstone(L-73), Garland(G-75), Sarah 1973(S-73), Sarah 1977(S-77), Sarah 1978(S-78), Mink Creek 1974(M-74), Mink Creek 1975(M-75) and Mink Creek 1976(M-76). In addition to the different treatment types, sample quadrats in the plot, the edge and the control were examined. The plot was composed of the actual bulldozed area. The edge was arbitrarily set at 3 m either side of the plot cut line. The control, the uncleared area around each plot, was chosen at 20 m in from the plot edge. The control was believed to best reflect the undisturbed vegetation which the plot now occupied. Environmental differences, not due to clearing, between the plot and the control would be minimized.

The quadrat method of vegetation sampling was used for the herbs and shrubs. The number of quadrats and the size of each quadrat was determined for each treatment type with species area curves(Ricklefs 1976). The tree density in the controls was calculated using the point-quarter method.

The quadrats for the herbs and shrubs and the points for the trees were randomly selected by compass directions. A random number of paces from the center of the plot located the position of the quadrat in the plot. Random number tables were used to obtain random numbers for

for compass degrees and number of paces.

The density, cover and frequency of all species of herbs were calculated for the plot, edge and control. The number of each species of shrub(where any woody plant between 0 and 250 cm constituted a shrub) was tabulated for the plot, edge and control The shrubs were categorized as shrubs below 50 cm(snow depth for the winter of 1978-79), shrubs between 50 and 250 cm, shrubs above 250 cm and the shrubs which had been browsed by ungulates. The density of the trees and their diameters were recorded for 5 points in each control(where any woody plant greater than 250 cm constituted a tree).

Soil was collected from the sites. Plot and control samples from the organic horizon, the A/B horizon and the C horizon were selected from the S-73, L-73, M-75 and G-75 treatments. One hundred and twenty samples were collected.

The vegetation data and soil data were analyzed using the analysis of variance in the General Linear Model program in SAS programs(SAS Institute Inc., 1979). An analysis of variance with an unbalanced design was used to determine if variations existed between the plot, edge and control with respect to the total number of herbs, the number of species of herbs, the number of alien plants(those species listed by Scoggan(1978) as naturalized), the number of shrub species, the total number of shrubs, the total number of shrubs which are preferred by the ungulates, the number of preferred shrubs less than 50 cm and the number greater than 50 cm and less than 250 cm.

The soil data were analyzed in terms of the depth of the organic matter, pH, nitrogen, phosphorus, potassium and sulphur contents, presence of carbonates and the percent organic matter in the O horizon(Soil Test Laboratory of the Manitoba Department of Agriculture). The data for the plot and the control for the above parameters were analyzed separately and combined for each horizon(O, A/B, and C horizons).

Plant species lists were compiled for Sarah Lake, Lidstone, Mink Creek and Garland Canyon(Appendix A). Scientific names follow Scoggan(1978) and common names follow Looman and Best(1979).

C. Results

(a) Comparisons of the vegetation between the plot, edge and control

Comparisons of the vegetation between the plot, edge and control revealed that some components of the vegetation differed in the three areas(Tables 2.1 and 2.2, Appendix D). For example, there is a significantly greater number of species of herbs in the plot and along the edge as compared to the control at L-73, G-75, S-77 and S-78. When the data for all the Sarah Lake plots are pooled, there is a significant difference between plot, edge and control for the number of species of herbs, the number of alien plants, the number of species of shrubs, the total number of shrubs and the number of low shrubs(0-50 cm). Fig. 2.1 graphically illustrates the differences in the total number of species of herbs in the plot, edge and control in the quadrats sampled for each of the treatments.

Even though there is a number of nonsignificant differences between the plot and the control, trends do show up. Generally, the control has the lowest number of species and individuals of each species as compared to the plot and the edge.

The control areas were under a dense canopy of aspen(Plate 2.1a). The denstiy of trees ranged from 13.58 to 20.13 trees per 100 m^2(Table 2.5). The ground cover was sparse(Plate 2.1c) with sarsaparilla(*Aralia nudicaulis*) dominating the tall herb stratum(Plate 2.2a).

Upon examination of the data on each species of plants, trends of habitat preference , either by actual preference for a set of

Table 2.1. The values for the number of species of herbs, the number of herbs, the number of alien plants, the number of species of shrubs, the number of shrubs, the number of browse shrubs, the number of browse shrubs between 0 and 50 cm, the number of browse shrubs between 50 and 250 cm for the plot, the edge and the control. The average value for each category is presented with its standard error of the mean.

Category	Treatment	Sites							
		S-78	S-77	M-76	G-75	M-75	M-74	S-73	L-73
Number of species of herbs	plot	9.73 ± 1.15	16.83 ± 2.56	12.25 ± 2.18	14.10 ± 0.83	19.33 ± 2.56	13.33 ± 1.04	10.50 ± 1.17	13.00 ± 1.41
	edge	11.00 ± 1.51	10.83 ± 0.31	8.50 ± 1.05	11.43 ± 0.84	15.83 ± 1.40	13.76 ± 0.99	11.00 ± 2.13	8.37 ± 1.27
	control	8.00 ± 1.04	7.33 ± 0.71	8.67 ± 0.73	9.43 ± 0.65	13.67 ± 1.61	12.28 ± 1.17	7.67 ± 0.76	4.87 ± 0.87
Number of herbs	plot	231.73 ± 73.29	136.00 ± 33.11	143.00 ± 24.87	205.29 ± 34.49	161.56 ± 35.14	106.61 ± 25.17	63.67 ± 14.38	84.33 ± 14.16
	edge	50.50 ± 11.81	83.33 ± 27.67	46.75 ± 8.18	102.19 ± 13.25	103.17 ± 21.87	77.47 ± 16.68	58.50 ± 16.54	59.75 ± 14.[illegible]8
	control	78.80 ± 17.55	74.67 ± 14.40	63.11 ± 7.83	77.95 ± 11.16	136.33 ± 61.39	96.67 ± 20.27	85.00 ± 9.49	18.50 ± 4.87
Number of aliens	plot	8.80 ± 3.87	5.50 ± 2.03	25.37 ± 8.27	8.71 ± 2.17	3.33 ± 1.20	1.17 ± 0.40	0.33 ± 0.33	7.42 ± 3.00
	edge	0.60 ± 0.34	0.17 ± 0.17	0.00	2.61 ± 1.22	1.17 ± 1.17	1.41 ± 0.67	0.17 ± 0.17	3.63 ± 3.08
	control	0.20 ± 0.20	0.00	0.00	0.10 ± 0.07	0.17 ± 0.17	0.11 ± 0.08	0.33 ± 0.33	0.00
Number of species of shrubs	plot	3.56 ± 0.38	5.40 ± 0.52	4.33 ± 0.43	6.96 ± 0.36	6.20 ± 0.71	6.60 ± 0.54	6.50 ± 0.42	6.50 ± 0.48
	edge	5.58 ± 0.47	4.80 ± 0.44	4.33 ± 0.54	5.81 ± 0.34	4.80 ± 0.66	6.21 ± 0.48	5.90 ± 0.43	6.33 ± 0.76
	control	3.08 ± 0.36	3.10 ± 0.50	3.46 ± 0.48	3.85 ± 0.36	4.10 ± 0.69	4.40 ± 0.56	5.42 ± 0.31	4.21 ± 0.35
Number of shrubs	plot	77.11 ± 12.04	53.90 ± 9.09	71.08 ± 14.27	76.19 ± 7.81	54.80 ± 8.77	75.75 ± 8.38	53.57 ± 5.37	98.44 ± 17.33
	edge	54.17 ± 9.10	36.90 ± 4.00	99.33 ± 12.29	69.89 ± 5.69	35.60 ± 10.98	66.84 ± 6.86	41.70 ± 8.28	60.75 ± 13.60
	control	37.50 ± 8.61	46.80 ± 12.90	40.00 ± 6.79	53.74 ± 7.16	78.40 ± 28.48	42.65 ± 9.06	36.71 ± 3.59	38.79 ± 5.61
Number of browse shrubs	plot	51.00 ± 12.52	32.20 ± 6.62	57.33 ± 11.71	53.14 ± 5.99	37.40 ± 5.73	57.70 ± 7.08	20.00 ± 3.75	52.33 ± 11.92
	edge	37.08 ± 9.73	24.10 ± 3.18	75.67 ± 10.84	43.56 ± 6.02	28.00 ± 10.31	45.53 ± 7.88	6.70 ± 1.87	37.33 ± 9.00
	control	21.92 ± 6.37	26.80 ± 12.32	37.67 ± 5.27	24.56 ± 5.22	45.60 ± 22.63	26.50 ± 7.51	18.36 ± 3.89	26.50 ± 5.11
Number of browse shrubs (0-50 cm)	plot	41.22 ± 10.77	14.30 ± 4.88	25.00 ± 6.98	14.07 ± 2.68	7.80 ± 4.79	6.35 ± 1.15	5.64 ± 1.56	10.78 ± 2.61
	edge	10.17 ± 3.62	7.30 ± 2.51	19.00 ± 4.57	8.89 ± 1.58	4.40 ± 0.88	7.21 ± 1.28	2.20 ± 0.68	12.42 ± 4.20
	control	5.92 ± 1.79	6.00 ± 2.40	17.41 ± 4.64	12.48 ± 4.13	8.80 ± 3.47	10.00 ± 2.81	4.85 ± 1.39	15.07 ± 3.77
Number of browse shrubs (50-250 cm)	plot	9.78 ± 2.47	17.90 ± 4.39	30.83 ± 11.85	39.07 ± 6.22	29.60 ± 5.94	51.35 ± 6.89	14.36 ± 2.59	41.78 ± 10.95
	edge	26.92 ± 7.84	16.80 ± 2.52	56.67 ± 10.70	34.78 ± 5.28	23.60 ± 9.94	39.89 ± 7.95	4.50 ± 1.60	24.92 ± 5.03
	control	15.67 ± 5.15	20.80 ± 12.61	20.25 ± 4.27	12.07 ± 2.88	28.40 ± 14.82	16.50 ± 5.19	13.21 ± 3.48	10.57 ± 2.14

Table 2.2. Significant differences for the vegetation parameters listed in Table 2.1 among plot, edge and control areas and among sites.

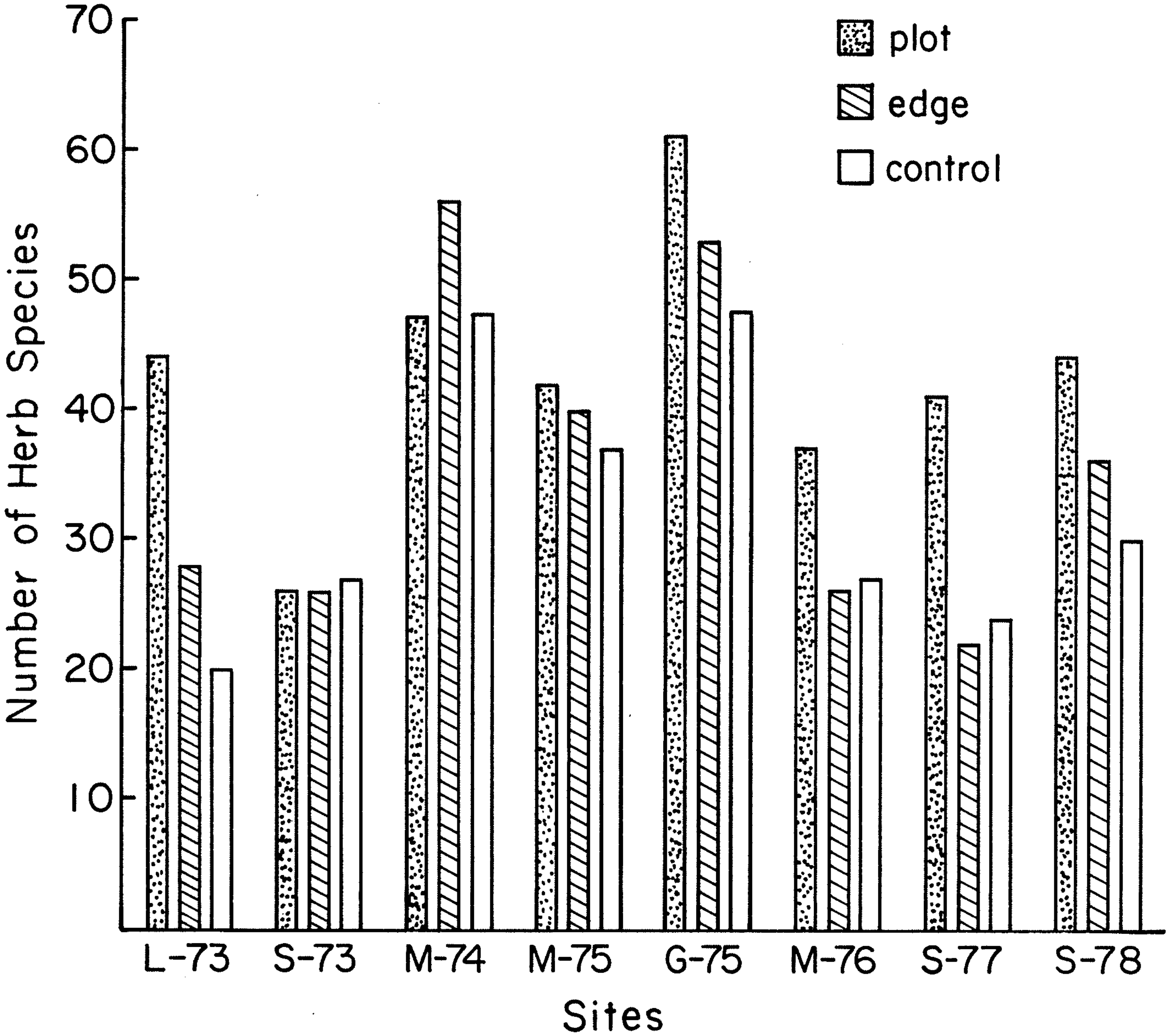
Site	# spp. herbs	# herbs	# aliens	# spp. shrubs	# shrubs	# browse shrubs	# browse (0-50 cm)	# browse (50-250cm)	% browse	kg browse /ha
Significant differences among plot, edge and control areas										
L-73	**	**	ns	**	**	ns	ns	**	**	**
G-75	**	**	**	**	*	**	ns	**	ns	**
S-77	**	*	ns	**	**	ns	**	*	**	-
S-78	**	ns	**	ns	**	ns	ns	ns	ns	ns
S-73	ns	ns	ns	ns	*	**	ns	*	ns	ns
M-74	ns	ns	*	**	**	**	ns	**	ns	ns
M-75	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
M-76	ns	ns	ns	ns	ns	**	ns	ns	ns	**
Sarah	**	ns	*	**	**	ns	**	ns	**	**
Mink	**	**	**	**	ns	ns	ns	**	ns	ns
North	**	*	**	**	**	**	**	ns	**	**
East	**	**	**	**	*	**	ns	**	ns	ns
All	**	**	**	**	**	**	**	**	**	**
Significant differences among sites										
Sarah	ns	ns	ns	**	ns	**	**	ns	ns	ns
Mink	**	ns	**	**	ns	*	**	ns	ns	**
North	ns	ns	ns	**	*	**	**	**	ns	*
East	**	*	**	**	ns	*	**	ns	ns	**
All	**	**	**	**	**	**	**	**	**	**

ns nonsignificant

** significant(α=0.10)

* significant(α=0.05)

Fig. 2.1. The total number of species of herbs in the plot, the edge and the control in the quadrats sampled for the different treatments.



plot
edge
control
Number of Herb Species
70
60
50
40
30
20
10
L-73
S-73
M-74
M-75
G-75
M-76
S-77
S-78
Sites

environmental factors or by lack of competition from other plants for these factors, show up in some plots. Appendix D contains the importance values (sum of relative density, frequency and dominence) for the herbs at all sites. Table 2.3 summarizes the plants which were more frequently found in the plot or along the edge, in the control or in the plot, edge and control.

A number of pioneer species including alien plants are found in the disturbed areas, the plot and the edge. Bicknell's geranium (*Geranium bicknelli*), alfalfa(*Medicago sativa*), white sweet clover (*Melilotus alba*), clover(*Trifolium* spp.), fire weed(*Epilobium angustifolium*), and stinging nettle(*Urtica dioica*) are some examples of invader or pioneer species which inhabit the plot and the edge areas (Plate 2.3b). Certain plants appear to be able to grow on or near the windrows. These plants included stinging nettle, Bicknell's geranium, ragwort(*Senecio* spp.) and strawberry blite(*Chenopodium capitatum*(Plate 2.3d).

Generally the number of herbs decreased as the plot aged(Table 2.1). In the first summer the herbs were most abundant(Plate 2.4a), In the second summer, shrubs began to dominate(Plate 2.4b and 2.4d) and by the fourth summer, the shrubs are dominant(Plate 2.4c). A sequence of successional stages over a 5-year span in one Garland plot is shown in Plate 2.5.

There was a greater diversity of shrubs in the plot and along the edge than in the control(Table 2.1). Certain shrubs appeared to be more abundant in the early stages of succession and others common in the late seral stages and in the control. Saskatoon(*Amelanchier alnifolia*), balsam poplar(*Populus balsamifera*) and aspen(*P. tremuloides*)

Plate 2.1. Mature forest stands before and after clearing.

a) The denseness of mature trembling aspen stands.

b) The canopy in the mature stands.

c) The sparse herb layer on the forest floor in the control.

d) The plot in early spring following winter clearing.


a
b
c
d

Table 2.3. Plants more frequent in the plot, the edge, the control or in a combination of these.

Species common to plot, edge and control	Species common to the plot and the edge
Aster ciliolatus	*Anemone canadensis*
Aralia nudicaulis	*A. riparia*
Bromus ciliatus	*Aster novae-angliae*
Cornus canadensis	*Calamagrostis canadensis*
Carex spp.	*Campanula rotundifolia*
Equisetum arvense	*Chenopodium hybridum*
Fragaria virginiana	*Cirsium arvense*
Galium boreale	*C. muticum*
G. triflorum	*Convolvulus sepium*
Lathyrus ochroleucus	*Carum carvi*
L. venosus	*Epilobium angustifolium*
Mertensia paniculata	*Geranium bicknellii*
Maianthemum canadense	*Geum aleppicum*
Oryzopsis asperifolia	*Lactuca tatarica*
Petasites palmatus	*Medicago sativa*
Rubus pubescens	*Melilotus alba*
Smilacina stellata	*Phleum pratense*
Sonchus arvensis	*Stachys palustris*
Solidago canadensis	*Streptopus roseus*
Steironema ciliatum	*Trifolium pratense*
Taraxacum officinale	*T. repens*
Viola canadensis	*Urtica dioica*

Table 2.3 continued

Species most common in the control
Actaea rubra
Comandra umbellatum
Circaea alpina
Pyrola asarifolia
Monotropa uniflora
Cypripedium calceolus

: 2.4. Density of the most abundant shrubs in the different plots and controls .

.es	Density of shrubs (/m^2) in the plot								Density of shrubs (/m^2) in the control			
	S-78	S-77	M-76	M-75	G-75	M-74	S-73	L-73	S	M	G	L
:nchier alnifolia	2.93	2.50	1.00	0.64	0.41	0.58	0.31	0.67	0.46	1.00	0.38	0.13
spicatum	-	-	-	-	0.02	-	-	0.81	-	-	0.83	4.88
is stolonifera	-	0.79	-	1.16	1.23	1.25	-	0.54	2.23	0.07	0.58	0.31
us cornuta	1.27	0.63	7.33	7.52	5.81	10.46	4.19	9.81	12.54	7.70	2.12	2.69
'era dioica	-	-	-	1.35	0.08	0.46	0.91	0.25	-	3.25	0.50	0.69
us balsamifera	1.67	1.04	-	1.21	1.20	0.54	0.12	0.48	-	-	0.04	0.13
'emuloides	4.47	2.46	1.50	1.89	2.11	1.25	0.41	1.04	0.33	0.17	0.33	0.63
s pensylvanica	-	0.25	0.17	0.11	0.66	0.20	0.31	0.04	0.25	0.42	-.04	-
rginiana	2.40	0.46	0.33	0.11	0.30	0.47	0.09	0.42	0.28	2.50	1.46	0.63
:us alnifolia	-	-	-	0.09	0.09	0.63	0.47	-	0.33	1.08	0.79	-
oxyacanthoides	-	-	-	2.02	0.23	0.19	0.13	0.25	0.08	0.25	0.83	-
spp.	1.33	4.50	0.33	0.91	1.55	0.40	0.09	0.40	2.17	1.00	1.67	0.25
idaeus	2.67	0.46	2.33	7.52	0.91	0.67	1.13	5.00	0.15	0.50	0.25	0.63
bebbiana	-	-	-	0.32	0.30	-	-	-	0.03	0.08	-	-
: spp.	-	-	-	0.51	1.48	0.02	-	-	-	-	0.08	-
ioricarpos albus	0.53	0.54	5.33	0.48	3.04	1.06	2.16	3.77	1.73	4.33	2.08	0.38
'num edule	0.07	-	0.50	0.34	0.02	0.20	0.19	0.67	0.04	-	0.25	0.38
oulus var. *americanum*	-	-	-	0.04	0.09	0.02	0.94	-	0.12	0.67	0.17	0.06

Plate 2.2. Plant response to clearing.

a) Wild sarsaparilla(*Aralia nudicaulis*) formed the ground vegetation in stands where light penetration was low.

b) Cherry trees(*Prunus* spp.) were common in the plot. Each tree produced more fruit in the plot than in the control as illustrated by the chokecherry(*P. virginianus*) growing along the windrow.

c) Hazel(*Corylus cornuta*) occurred along edges where light penetration was high.

d) An example of shrub density in the Mink Creek plots after 5 years of growth.

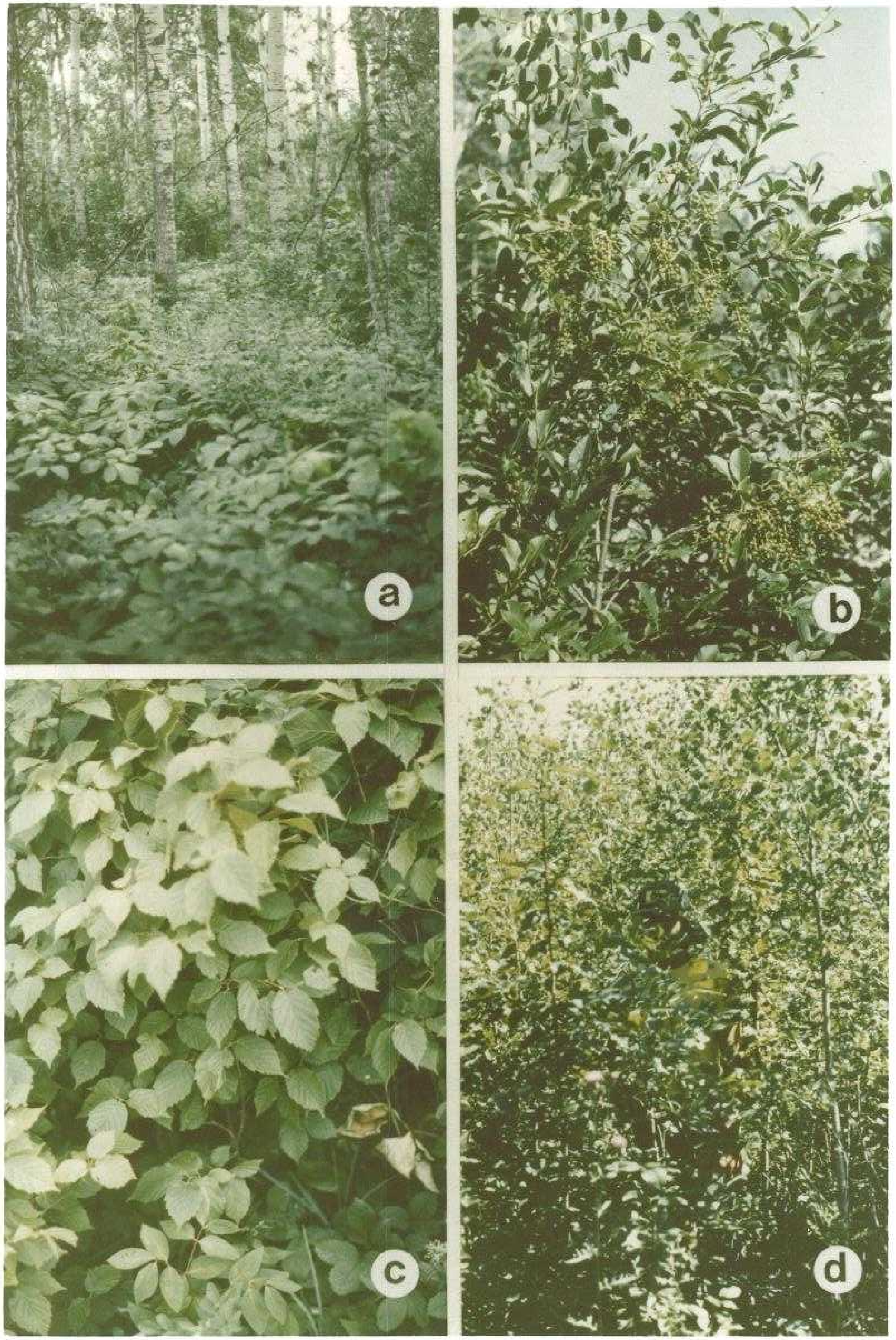

a
b
c
d

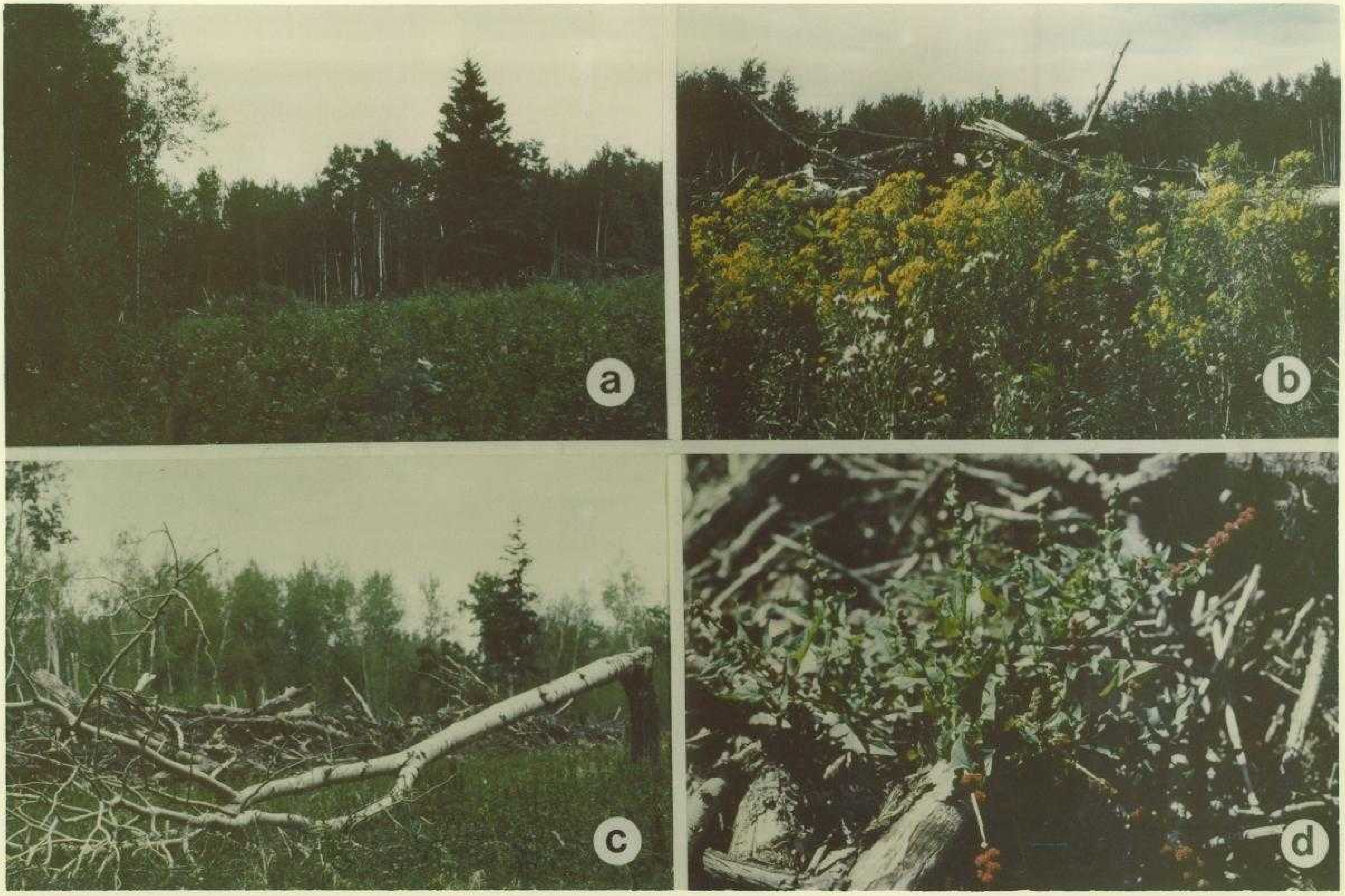
Plate 2.3. Plant response to clearing.

a) At the end of two summers' growth, the plot was colonized by numerous shrubs and herbs e.g. fireweed(*Epilobium angustifolium*).

b) Primary colonizers such as ragwort(*Senecio aureus*) and Canada thistle(*Cirsium arvense*) grew beside a windrow in a clearing.

c) In some plots, larger trees were left standing which left them exposed to wind damage.

d) Strawberry blite(*Chenopodium capitatum*) was common on the logs of the windrow.



tended to be more abundant in the early years of the plot(Table 2.4). Mountain maple(*Acer spicatum*) and high bush-cranberry(*Viburnum opulus* var. *americanum*) were found more often in the control. Beaked hazel (*Corylus cornuta*) was most abundant along the edges and in the plots of the older sites(Plate 2.3c). The other species were more variable in their tolerance to shading. Appendix D lists the abundance of less common shrubs.

Differences between the plot, the edge and the control were visible in the field especially in the first year of growth(Plate 2.1d). Although fruit production was not measured there was more fruit of pincherry, chokecherry, raspberry(*Rubus idaeus*) and high bush-cranberry(Plate 2.2b) shrubs in the plot. Herbs in the plot also appeared to suffer more from drought conditions. The leaves of some herbs were brown and shrivelled by the end of the summer.

(b) Comparisons of the vegetation between the four sites

The species and distribution of plants varied between the four sites with significant differences for all major parameters of the vegetation(Table 2.2).

Tables 2.5 and 2.6 list the density of the control trees and the importance values of the controls trees, respectively, for all sites. Trembling aspen was the most important tree species at all sites. The density of all trees at Lidstone was low in comparison to the other sites. Paper birch(*Betula papyrifera*) was much more abundant at this site than elsewhere.

Plate 2.4. Succession in the plots.

a) Little growth occurred in the Sarah Lake plots during the first spring after clearing.

b) Numerous shrubs and herbs colonized the soil surface during the first summer after clearing.

c) The Mink Creek plots showed the dominance of shrubs especially aspen after four years.

d) Some plots at Sarah Lake were prepared in two separate years. The left half of the plot in this photo was in its second year of growth while the right half was in its first season.


a
b
c
d

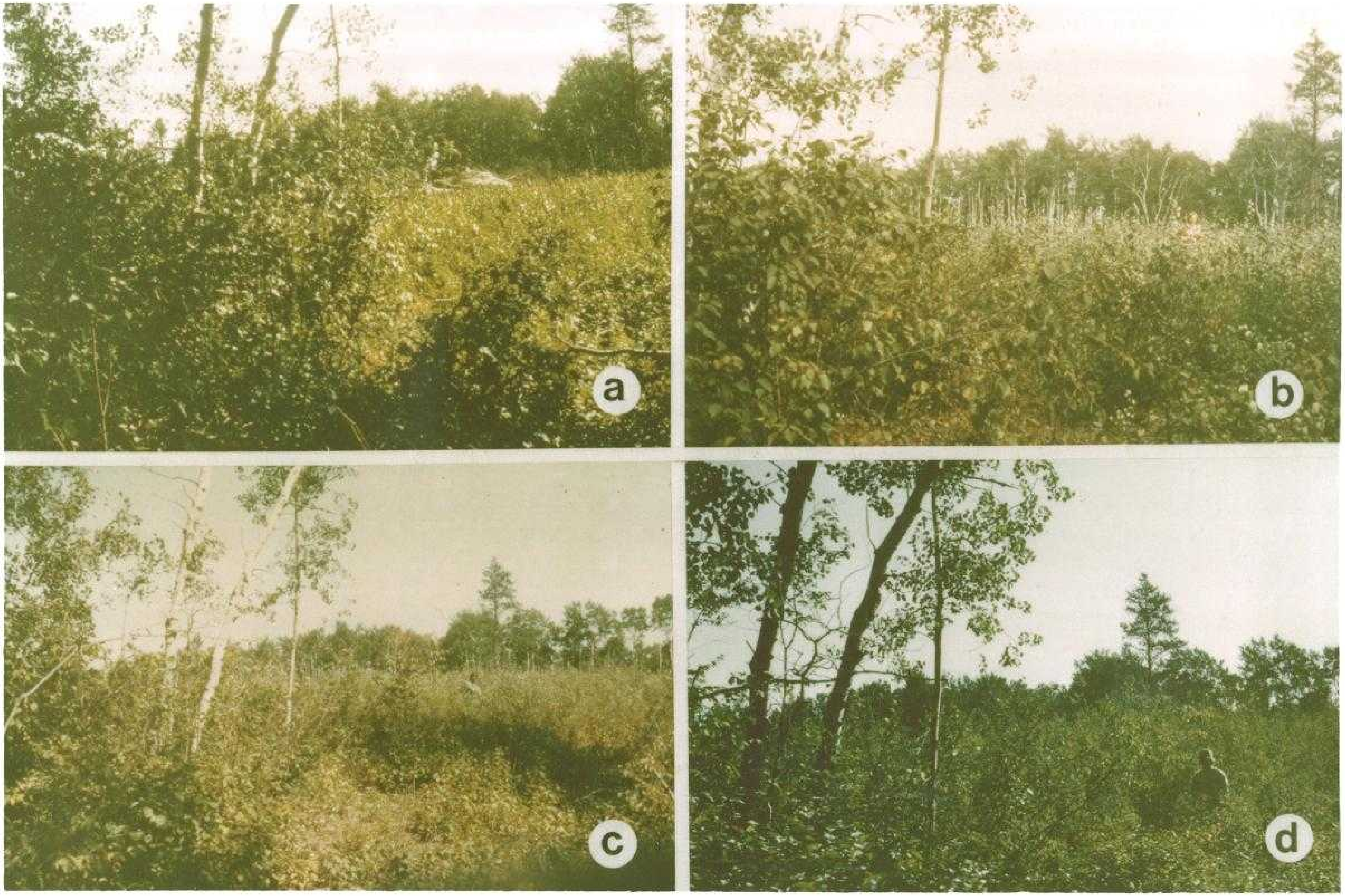
Plate 2.5. The successional stages in one plot.

a) After a summer's growth, Plot G-5(Section 25) was covered by numerous small shrubs and herbs(Photo by D. Bigelow).

b) By the second summer, the height of the shrubs was less than 3 m(Photo by D. Bigelow).

c) In the third summer, the height of the trees has increased but shrubs are still abundant. The number of tall herbs and medium herbs has decreased.

d) The height of the shrubs average 3 to 3.5 m after 5 years growth(Photo by D. Bigelow).


a
b
c
d

At Sarah Lake, Mink Creek and Garland the tree species were more varied but aspen was still the most important followed by balsam poplar and birch. A number of shrub species reached tree size(greater than 250 cm) at these sites. Even though the jack pine(*Pinus banksiana*) was present in the Garland area, it did not occur in sampled control.

The number of herbs differed between the sites. The species of herbs(Fig. 2.1), shrubs and trees also differed. At Lidstone, plants adapted to moist conditions such as wild ginger(*Asarum canadensis*), ostrich fern(*Matteuccia struthiopteris*), mountain maple, balsam poplar wild lily-of-the-valley(*Maianthemum canadense*), bishop's cap(*Mitella nuda*) and starflower(*Trientalis borealis*) were common. Plants at the other sites were more adapted to dry conditions. The Garland site had variations in plant species from dry jack pine sites with *Agastache foeniculum*, *Castilleja miniata*, *Lilium philadelphicum*, *Zizia aptera and Lathyrus venosus* to larch(*Larix laricina*) dominated sites with *Rhamnus alnifolia*, *Potentilla fruticosa*, *Geum rivale* and *Betula glandulosa*.

In addition to some differences in vegetation, some differences between the weather in the areas were noted. The Lidstone and Sarah Lake sites received a killing frost in early September 1979 but Mink Creek and Garland did not receive frost until 2 weeks later. The winter precipitation differed by 10 to 20 cm between the northern and southern sites(50-60 cm snow at Sarah Lake and Lidstone, 40 cm at Mink Creek and Garland).

(c) Soils

Table 2.7 outlines the average values for the soil carbonate

Table 2.5 Density of control trees (trees/100m^2)

Species	Site						
	Lidstone	Sarah	Mink	Garland	North	East	All
Populus tremuloides	5.90	12.65	11.03	8.41	11.11	10.28	10.50
P. balsamifera	2.47	4.48	3.50	2.55	4.05	3.26	3.54
Betula papyrifera	2.74	0.30	0.88	1.05	0.92	0.91	0.91
Alnus rugosa	0.00	0.84	0.35	1.35	0.64	0.42	0.52
Prunus pensylvanica	0.00	0.54	0.18	0.00	0.41	0.27	0.20
P. virginiana	0.00	0.16	0.35	0.01	0.11	0.29	0.20
Picea glauca	0.00	0.16	0.09	0.30	0.11	0.17	0.14
Salix sp.	0.00	0.08	0.18	0.15	0.06	0.20	0.14
Fraxinus pennsylvanica	0.00	0.00	0.05	0.60	0.00	0.20	0.12
Salix bebbiana	0.00	0.84	0.35	0.15	0.64	0.20	0.44
Amelanchier alnifolia	0.00	0.08	0.09	0.15	0.06	0.13	0.11
Quercus macrocarpa	0.00	0.00	0.18	0.00	0.00	0.17	0.11
Crataegus rotundifolia	0.00	0.00	0.00	0.15	0.00	0.03	0.02
Acer spicatum	2.06	0.00	0.00	0.00	0.52	0.00	0.19
Larix laricina	0.00	0.00	0.00	0.15	0.00	0.03	0.02
Viburnum opulus	0.41	0.00	0.05	0.00	0.11	0.02	0.00
TOTAL	13.58	20.13	17.28	15.02	18.74	16.39	17.46

Table 2.6 Importance values of control trees

Species	Site						
	Lidstone	Sarah	Mink	Garland	North	East	All
Populus tremuloides	113.0	180.1	187.3	160.9	165.2	180.2	173.4
P. balsamifera	92.0	71.8	59.6	65.5	78.5	62.6	69.1
Betula papyrifera	52.0	7.1	16.5	23.3	17.4	18.0	17.9
Alnus rugosa	0.0	10.6	5.8	21.8	8.1	8.6	9.3
Prunus pensylvanica	0.0	7.9	3.3	0.0	6.1	3.3	4.0
P. virginiana	0.0	1.9	6.6	2.3	1.3	5.5	4.0
Picea glauca	0.0	5.3	1.7	3.9	3.7	2.4	3.1
Salix sp.	0.0	1.4	3.9	2.2	0.9	3.8	2.6
Fraxinus pennsylvanica	0.0	0.0	1.0	8.3	0.0	2.9	1.8
Salix bebbiana	0.0	11.5	5.4	2.2	9.3	4.8	6.6
Amelanchier alnifolia	0.0	1.4	3.9	4.4	0.9	2.3	1.8
Quercus macrocarpa	0.0	0.0	4.7	0.0	0.0	3.2	1.9
Crataegus rotundifolia	0.0	0.0	0.0	2.3	0.0	0.6	0.4
Acer spicatum	33.0	0.0	0.0	0.0	6.7	0.0	2.6
Larix laricina	0.0	0.0	0.0	2.4	0.0	0.6	0.4
Viburnum opulus	10.0	0.0	0.9	0.0	1.9	0.6	1.1

content, pH, salinity, available nitrogen, available phosporus, available potassium, available sulphur, depth of the organic horizon and the percent organic content in the 0 horizon. No significant differences were found between the plot and control for these parameters. Even though there were no significant differences between the plot and the edge for the percent organic matter in the 0 horizon, there appeared to be a higher organic content in the control samples at Sarah Lake, Garland and Mink Creek (Plate 2.6c). No differences were detected in each of the soil parameters in the different layers of the soils. Appendix D contains the raw data for the soil analysis.

Table 2.7. Average values for the soil parameters for plot and control in the 4 sites.[I]

Site		Carbonate content (range)	pH	Salinitiy mm hos/cm	Avail. N ppm	Avail. P ppm	Avail. K ppm	Avail. S ppm	Depth. of Org. (cm)	% Org.[II]
Mink Creek	Plot	Absent	7.1	0.3	2.3	9.1	345	10+	12.2	23.7
	Control	Absent	6.7	0.4	2.8	12.3	315	10+	8.0	43.8
Garland Canyon	Plot	Absent-high	7.0	0.2	2.3	5.3	209	5.8	8.6	49.0
	Control	Absent-low	6.9	0.2	5.4	3.7	203	4.9	11.5	70.5
Lidstone	Plot	Absent-very low	6.5	0.2	1.4	18.4	396	6.6	8.7	55.0
	Control	Absent-very low	6.3	0.2	2.1	17.9	377	4.6	11.0	56.2
Sarah Lake	Plot	Very low	6.1	0.2	14.6	14.1	482	6.1	7.5	34.8
	Control	Very low	5.8	0.1	1.3	3.2	395	5.4	8.0	56.8
Average	Plot	Absent-high	6.8	0.2	4.1	9.6	301	6.3	8.9	40.6
	Control	Absent-low	6.4	0.2	4.1	6.6	265	5.6	10.4	55.7

[I]averages all horizons

[II]for 0 horizon only

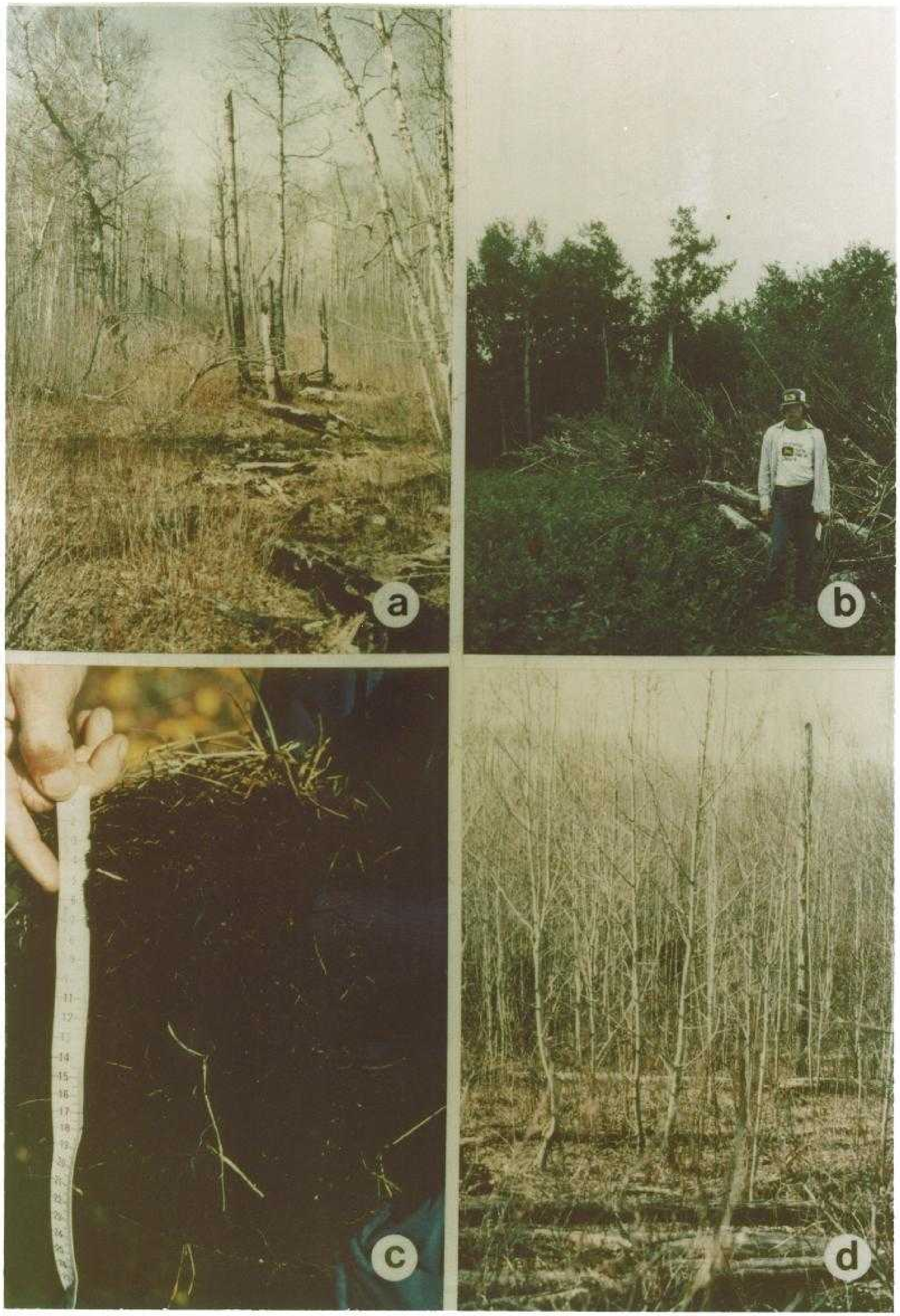
Plate 2.6. Types of plots and sampling techniques.

a) The plots at Lidstone were cleared using a bulldozer. Later, the fallen trees were pushed into windrows and burnt. Mountain maple and raspberry preferred the habitat along these windrows.

b) The plots at Garland, Sarah Lake (1977 and 1978) and Mink Creek were cleared with the trees pushed into windrows. The windrows were 1.5 to 2 m high.

c) Soil samples, with particular emphasis on the organic layer, were collected in some study areas (L-73, S-73, M-75 and G-75).

d) Debris consisting of rotting logs (cleared by hand and pushed over by bulldozer) made up the S-73 plots. Density of the new growth and height of the aspen reflected the seven years of growth after the treatment.


a
b
c
d

D. Discussion

(a) Comparisons of the vegetation between the plot, edge and control

The vascular flora of the plot and the edge was richer in species composition than the mature stands, even though many species were in common. Corns and La Roi(1976) attribute the similarity of species composition of the plots to the controls to the fact that most plant species in the control survive in the plot. They attribute the species diversity of the plot to the influx of invader species. In this study a greater number of invader species was found in the plot as compared to the control. The invaders were able to take advantage of the increased light penetration and the decreased competition for other essential elements. A number of species were common in the plot, edge and control(Table 2.3).

There was a rapid change in the clearcuts in the first few years of the study(Plate 2.4). After 7 years changes were still occurring but the changes were in species abundance and not in species diversity. In the first year or part of the first year, herbs dominated the vegetation; however, by the end of the summer, the shrub and sapling density had increased. The density of the shrub stratum continued to increase until the seven-year stage.

Aspen achieved the highest density on the plots, especially in Mink Creek, Garland, and Sarah Lake where the original composition of the tree stratum was mainly aspen. Graham et al.(1963) found that the number of aspen suckers was dependent on the original density of the aspen stand. In this study the results resemble those obtained by

Graham et al.(1963).

The plot edges contained a greater variety of plants than most plots and controls. Strelke and Dickson(1980) found that the edge had a greater number of foliage layers. Plate 2.3c illustrates the productivity of the edge habitats and the number of foliage layers.

In some plots the edge vegetation was not as dense due to the piling of some logs and other litter along the edge of the clear-cut. In these areas, primarily at Sarah Lake, the density of herbs and shrubs was not as great along the edge as in the plot.

The soils in this study did not appear to be affected by clearcutting. Only one parameter, the percent organic matter in the O horizon, was greater in the control than in the plot. There would be less organic matter left to be incorporated into the O horizon because the removal of the trees removed a large source of the litter.

As the plots sampled for soil were 5 to 7 years old, the decrease in the leaf litter should be noticeable. Other soil parameters were not expected to be different after clearcutting since the regeneration of the plants occurred quickly. As the data were variable, these results could be due to insufficient sampling.

The early stages of succession last from 10 to 20 years(Usher 1978). As the plots still contained a greater diversity of ungulate food plants than the controls, the life of the plots can only be discussed with reference to other studies and to the results in the Duck Mountain study to date. The Lidstone site which was 7 years old contained a greater abundance of plants in the plots. Fifty percent more shrubs were growing in the plot as compared to the control. Extrapolation from these results and from other studies results in the prediction of plot life to be 5 to 10 years. The plot life would be increased if ungulate use was high enough to retard succession.

The plots provided a greater diversity of plant species which would be able to support a greater diversity of animal life. Ungulates (See Chapter IV), snowshoe hare(Usher 1978) and songbirds(Strelke and Dickson 1980) are some animals which can benefit from the plots. There is nearby cover, a greater food supply and a habitat diversity providing numerous niches for plants and animals.

A cycle of clearcutting should be implemented so that a diversity of habitats and a series of successional stages are provided. Plots of 0.5 to 2 hectares are recommended in order to limit damage to the ecosystem, especially to soils and the vegetation. Since the mature forest is growing beside the clearcuts, the plants and animals can exploit the resources offered by both areas. In this study the edge was used more by the ungulates(Chapter IV) than the controls.

There are some disadvantages in the clearing of the plots. Trees left standing are more subject to wind damage(Plate 2.3c). The trees contain many nutrients which would not be released to the environment for many years.

(b) Comparisons of the vegetation between the 4 sites

Variation in the results is partially dependent on site differences. The sites are separated by a distance of 80 km, and located on different slopes and aspects of the Duck Mountain. As many factors affect the successional sequence in the boreal forest (Vierick 1973), the vegetation response to clearcuts would be dependent on the same factors. These factors could be acting differently in the plot and the mature stand modifying the effects of clearing.

The sites can be described according to Rowe's classification scheme(1956). The Lidstone site falls into the moist to very moist forest category while the vegetation at the other sites can be classified as dry forest, fresh forest and moist forest. A few plots belong to the very moist to wet forest classes.

The diversity of plant species was greater at Mink Creek, Garland and Sarah Lake because these sites covered a larger area encompassing small creeks and a variety of microhabitats.

CHAPTER III

SEASONAL VARIATION IN TWIG WEIGHT-DIAMETER RELATIONSHIPS FOR 10 BROWSE SPECIES

A. Introduction

Twig weight-diameter relationships for browsed plant species have been used to estimate browse consumption by ungulates (Crete and Bedard 1975, Telfer 1978). High correlations between dry diameter and dry weight for a number of browse species have been recorded (Shafer 1963, Basile and Hutchings 1966, Telfer 1969, Lyon 1970, Crete and Bedard 1975). Telfer (1969) concluded that factors such as site, time of collection, part of plant sampled, extreme site conditions and composition of twigs affected the relationship between twig weight and diameter. Basile and Hutchings (1966) found that the relationship between twig weight, length and diameter for bitterbrush (*Purshia tridentata*) differed in two different sites. Peek et al. (1971) did a more detailed study on the effects of site variations on the weight-diameter relationships of eight species of shrub. They found that twig weights derived from the different regression equations for each site differed by more than 20% in half of the cases.

The purpose of this study was (1) to monitor seasonal variation in weight-diameter relationships for 10 most commonly browsed shrub species in the study area, (2) to determine in which month the highest correlations between diameter and weight of the 10 species occur, (3) to monitor the variation of the weight-diameter relationships for one species in four sites around the Duck Mountain Forest Reserve, and (4) to monitor the change in moisture content of the twigs throughout the year.

B. Methods

The following plants, browsed frequently by ungulates, were used in this study: saskatoon (*Amelanchier alnifolia)*, red-osier dogwood (*Cornus stolonifera)*, beaked hazel (*Corylus cornuta*), balsam poplar (*Populus balsamifera*), trembling aspen (*P. tremuloides*), pincherry (*Prunus pensylvanica*), chokecherry (*P. virginiana*), beaked willow (*Salix bebbiana*), low bush-cranberry (*Viburnum edule*), and mountain maple (*Acer spicatum*). The latter species was found only in significant quantities at the Lidstone site. Red-osier dogwood was collected at Sarah Lake, Lidstone, Garland and Mink Creek (Fig. 1. 1). All other species were collected at Sarah Lake.

Two hundred twigs from each species were collected in the field from ground level or snow level up to 250 cm wherever they were found. A twig is defined as "that part of a branch distal to the point where branch diameter would, if air dried, equal the largest diameter observed for a stub of a browsed branch of that species" (Telfer 1969).

Twigs of varying diameters were collected including both new and old growth. In the summer, the leaves constituted part of the twig weight. The diameters of twigs which were browsed by ungulates were measured with calipers. The range of the diameters at the point of browse was the range used in harvesting the twigs in the field. Fifty of the 200 twigs were selected at random in the laboratory to further randomize the sampling.

Twigs were obtained during the first week of every month for April to December inclusive. Since it was assumed that the relationships did not change drastically over the mid-winter period only one collection (February 15, 1980) was made between December and April.

The fresh weights and diameters (at the point of clipping) of the 50 twigs (to the nearest 0.01 g and 0.05 mm respectively) were recorded before and after drying at 70°C. (Telfer 1969). Percent moisture was calculated (1 - dry weight/fresh weight x 100).

The correlation coefficients, regression equations, scattergrams and general statistics were generated using the BMDP computer package (Brown 1977). All combinations of dry weights (DW) fresh weights (FW), dry diameters (DD), and fresh diameters (FD) were plotted. Additionally, natural logarithms of dry weight and dry diameter were calculated in an attempt to increase the accuracy of the prediction.

Telfer (1969) fitted a curve to the weight-diameter data. In this study, the natural logarithmic transformations did not enhance the predictive accuracy. In some cases, there was a greater correlation coefficient value for the transformed data as compared to the untransformed. The correlation coefficients (r) were not significantly higher. So, the simpler method of predicting dry weights from dry diameters was chosen. The range of values used in Telfer's study (1969) is greater than in this study. Basile and Hutchings (1966) also fitted a stright line to the bitterbrush twig weight and diameter data. Similarly, the equation used in this study is of the general linear form: oven dry weight = b + m (oven dry diameter) where b and m are constants for a sample.

Collections of twigs provided within-site comparisons(96) and between site comparisons(32) for 10 study species and 10 harvest times.

C. Results and Discussion

Figures 3.1 and 3.2 graphically illustrate the linear relationship between dry weight and dry diameter for beaked willow (r = 0.940) and trembling aspen (r = 0.929). Appendix E contains the graphs for the other study species. Logarithmic transformation of these data points decreased the correlation coefficient in both cases.

The correlation coefficients for the dry weight versus the dry diameter were recorded for each species for each sample date in Table 3.1. Correlations for some species were high throughout the year e.g. mountain maple, red-osier dogwood and trembling aspen (r = 0.600 -0.92). Some species such as balsam poplar have correlations which were low (r = 0.090) in one month but they were higher (r = 0.774) in another month. Pincherry, chokecherry, low bush-cranberry, beaked hazel, saskatoon, and balsam poplar showed the greatest seasonal variation in the twig weight-diameter relationship.

Correlation coefficients greater than 0.288 (at $\alpha = 0.05$) were significant. All but four of the correlation coefficients were greater than 0.288 (Table 3.1). These were recorded for balsam poplar and chokecherry. Higher correlations than 0.288 would be desirable for more accurate prediction of dry weights from dry diameters.

The results suggested that there was a seasonal variation in the weight-diameter relationships of the ten browse species studied. The highest correlations were recorded in the winter months. These data corresponded with the phenology of the species. As there was a greater variation in the morphological characteristics such as leaf number, there was a greater variation in twig weights thus producing

Fig. 3.1. Twig weight-diameter relationship for beaked willow for October 1979 in the Duck Mountain, Manitoba ($r = 0.940$).

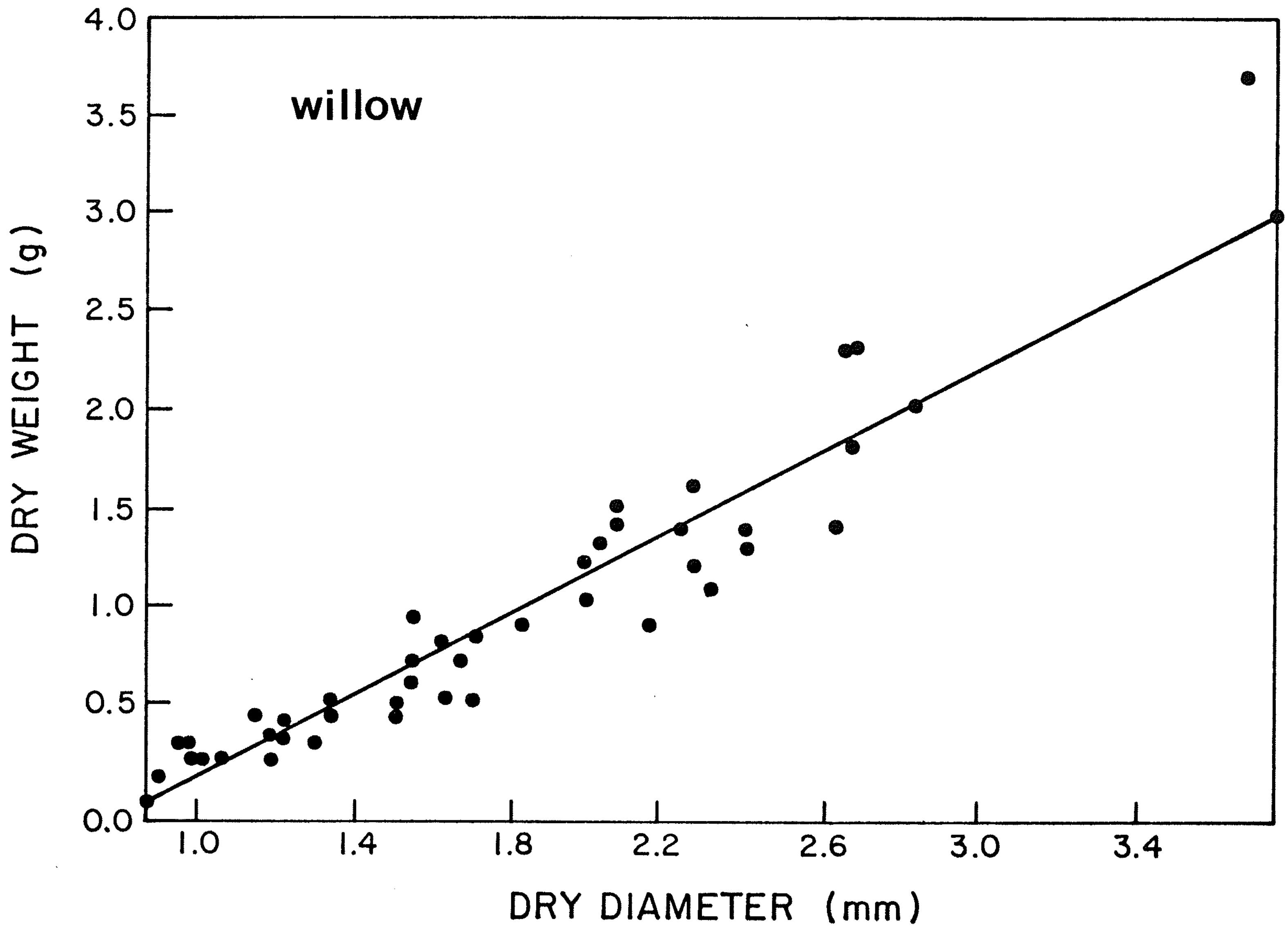
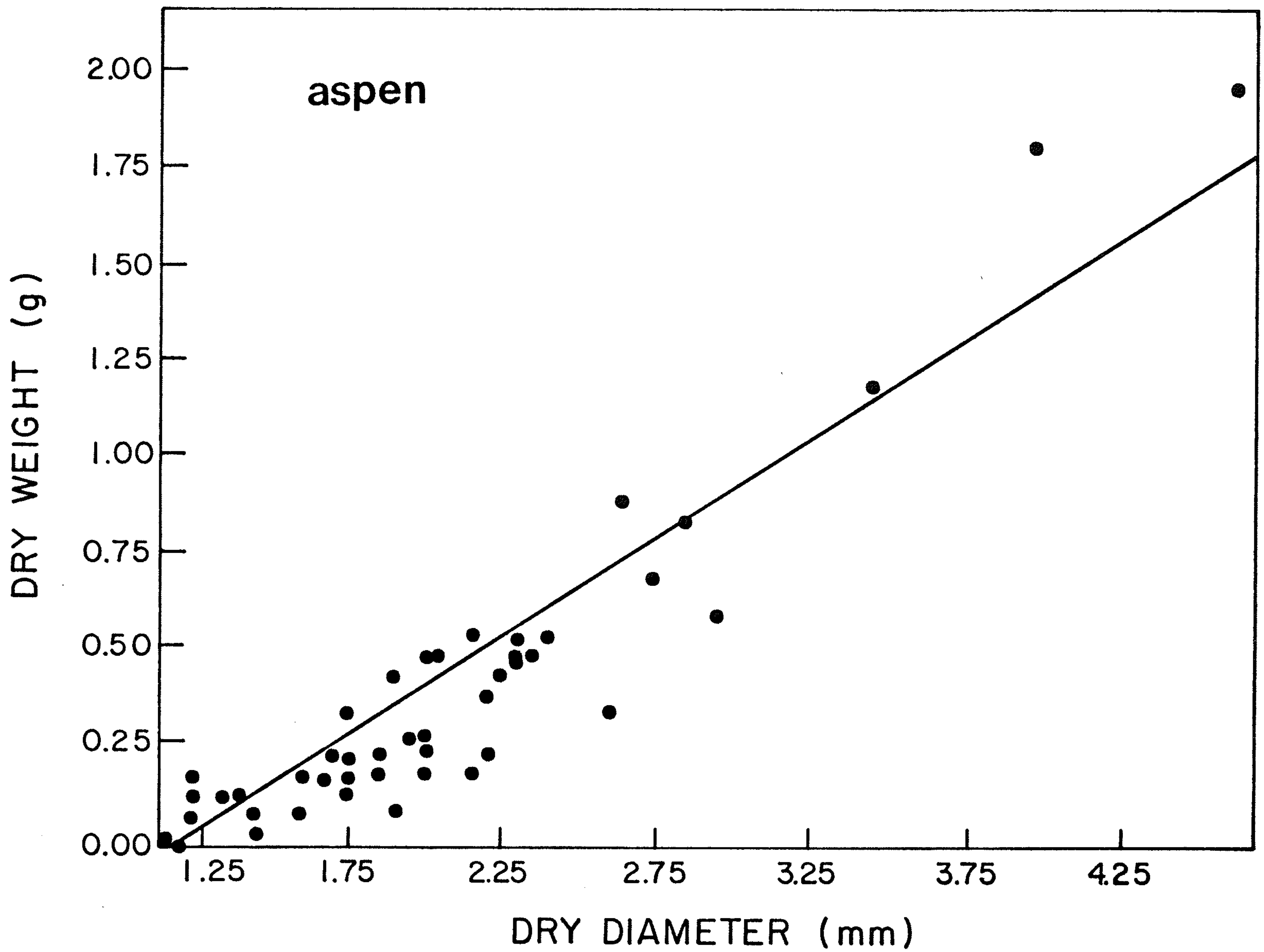

willow
DRY WEIGHT (g)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.0
1.4
1.8
2.2
2.6
3.0
3.4
DRY DIAMETER (mm)

Fig. 3.2. Twig weight-diameter relationship for trembling aspen for April 1980 in the Duck Mountain, Manitoba ($r = 0.929$).



aspen
DRY WEIGHT (g)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1.25
1.75
2.25
2.75
3.25
3.75
4.25
DRY DIAMETER (mm)

Table 3.1. Correlation coefficients for twig dry diameter and dry weight for 10 browse species and for 10 collection periods(1979-1980).[I]

SPECIES	CORRELATION COEFFICIENTS FOR EACH COLLECTION PERIOD									
				1979					1980	
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Feb.	April	May
Mountain maple	-	-	0.753	0.808	0.870	0.862	0.846	0.743	0.911	0.840
Saskatoon	0.650	0.657	0.640	0.756	0.853	0.873	0.599	0.845	0.831	0.794
Red-osier dogwood	0.773	0.607	0.788	0.883	0.808	0.889	0.835	0.772	0.873	0.940
Beaked hazel	0.543	0.818	0.706	0.658	0.850	0.754	0.390	0.656	0.900	0.711
Balsam poplar	0.410	0.685	0.090	0.271	0.665	0.708	0.774	0.639	0.200	0.757
Trembling aspen	-	0.792	0.797	0.886	0.794	0.606	0.792	0.639	0.929	0.830
Pincherry	0.627	0.713	0.389	0.728	0.623	0.869	0.868	0.924	0.779	0.823
Chokecherry	0.210	0.615	0.794	0.625	0.877	0.862	0.914	0.886	0.930	0.652
Beaked willow	0.529	0.827	0.587	0.940	0.795	0.860	0.786	0.810	0.705	0.812
Low bush-cranberry	0.562	0.561	0.646	0.738	0.561	0.616[II]	0.792	0.923	-	0.902

[I] n=50 for all samples
[II] n=24 for this sample only

lower correlations between twig weight and twig diameter. Table 3.2 gives the month in which the highest correlation for each species occurs. Also given are the values for the regression equations and the range of diameters for the selected month. The most accurate prediction of dry weight from dry diameter would be in the month in which the highest correlation was found. The predictive equation would be in the form of predicted oven dry weight = b + m (measured oven dry diameter).

Table 3.3 outlines the between-site variations in the predicted values of dry weight (predicted from mean dry diameter values) for red-osier dogwood. The predicted dry weight values from the individual sites do not differ significantly. The greatest percent difference is less than 20%. This suggests that the relationship between diameter and weight for red-osier dogwood does not vary greatly between the four sites along the edge of the Duck Mountain Forest Reserve.

The percent moisture in the twigs (Fig. 3.3) closely followed the phenology of the species. In mid-winter (December) the moisture levels were the lowest as was found for shrub iomass experiments by Ohmann, Grigal and Brander (1974). In spring, the buds burst and the leaves expanded thus increasing moisture levels; however, there was variation between species. Willow had the highest level of moisture in the late spring when the catkins were out while balsam poplar had the highest level of moisture in June when the leaves were fully expanded.

The moisture levels of most species were greater in May 1980 than in June 1979. This was due to the late spring in 1979 and the

Table 3.2. Highest correlations for twig diameters and twig weights.

SPECIES	Month	CORRELATION COEFFICIENTS(r) FW/FD	FW/DD	DW/FD	Ln DD/ Ln DW	DW/DD	Values for b	m	Range of dry diameters (mm)
Mountain maple	April	0.898	0.927	0.890	0.882	0.911	0.536	-0.882	1.53-4.55
Saskatoon	Nov.	0.891	0.870	0.887	0.925	0.873	0.615	-0.655	0.93-3.53
Red-osier dogwood	Nov.	0.924	0.890	0.920	0.880	0.889	0.398	-0.514	1.00-2.80
Beaked hazel	April	0.896	0.885	0.893	0.902	0.900	0.257	-0.253	1.15-3.00
Balsam poplar	Dec.	0.805	0.752	0.827	0.758	0.774	0.929	-1.812	2.05-4.90
Trembling aspen	April	0.901	0.893	0.942	0.856	0.929	0.509	-0.670	1.23-4.65
Pincherry	Feb.	0.908	0.906	0.921	0.917	0.924	0.274	-0.217	0.85-2.85
Chokecherry	April	0.942	0.919	0.954	0.935	0.930	0.482	-0.646	1.00-3.67
Beaked willow	Sept.	0.932	0.936	0.934	0.956	0.940	1.060	-0.980	0.90-3.67
Low bush-cranberry	Feb.	0.854	0.887	0.898	0.907	0.923	0.368	-0.533	1.55-3.87

Table 3.3. Summary of the dry weights predicted from mean dry diameters of red-osier dogwood for each of the 4 sites as compared to all 4 sites combined.

DATE	Dry diameter (mm) mean	range	Predicted values of dry weight(g) All sites	Sarah	Garland	Lidstone	Mink Creek	Greatest % difference
August 1979	1.67	0.95-3.00	0.78	0.79	0.72	0.87	0.74	11.5
September 1979	2.24	1.23-427	1.73	1.45	1.79	1.78	1.70	16.2
October 1979	2.25	1.10-4.27	0.40	0.44	0.36	0.41	0.37	10.0
November 1979	2.09	1.00-3.80	0.34	0.32	0.33	0.32	0.40	17.6
December 1979	2.12	1.20-3.65	0.39	0.40	0.38	0.41	0.35	10.3
February 1980	2.11	1.00-5.45	0.42	0.39	0.40	0.42	0.41	7.1
April 1980	2.13	1.00-3.67	0.34	0.35	0.32	0.39	0.32	14.7
May 1980	2.05	0.93-3.85	0.50	0.47	0.48	0.44	0.47	12.0

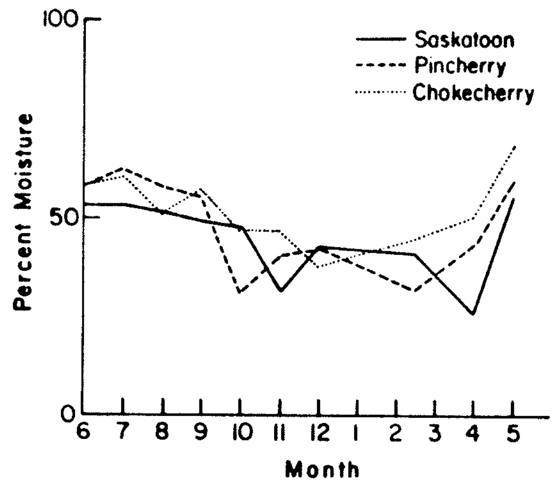
early spring in 1980. The seasonal changes of the species studied in 1980 were a month and few days ahead of the previous year's records.

The percent moisture affected the relationship between dry and fresh weight and diameter. As there was increased variability in the relationship between fresh diameter and fresh weight in the summer due to variability in moisture levels, they were not used in the predictive equations. Dry weight and dry diameter gave the most consistent results and the most accurate results in determining browse consumption in the field.

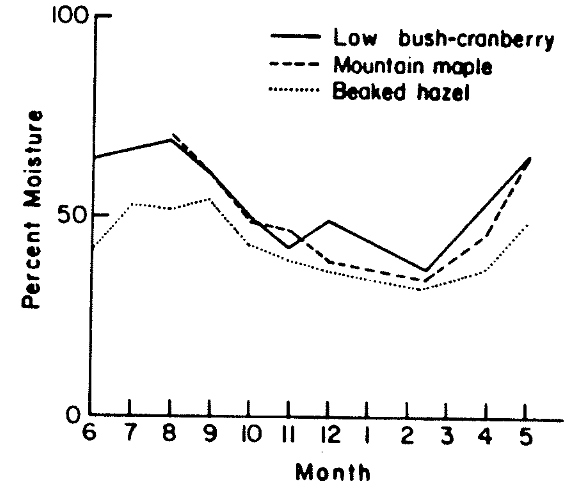
Fig. 3.3 also illustrates the difference in moisture levels of the red-osier dogwood in the four sites. From analysis of variance, it was found that the moisture levels did differ significantly between sites for August, September, November and March. Slight changes at the sites could be the cause of differences in moisture levels. For example, in early September a killing frost occurred at the Lidstone and Sarah Lake sites while the other two sites did not receive frost until two weeks later.

The data suggest that the dry weight of browsed twigs can be predicted by the dry diameters using the regression equation for twig weight and diameter. Greater accuracy in the prediction can be obtained by using twigs which have been collected in the winter months. If values for biomass of a year's growth on a species is needed, the winter collections would be the most accurate. Some species such as mountain maple, red-osier dogwood, and trembling aspen have high correlations between twig weight and diameter throughout the year so browse consumption can be estimated year round. The growth of twigs of these

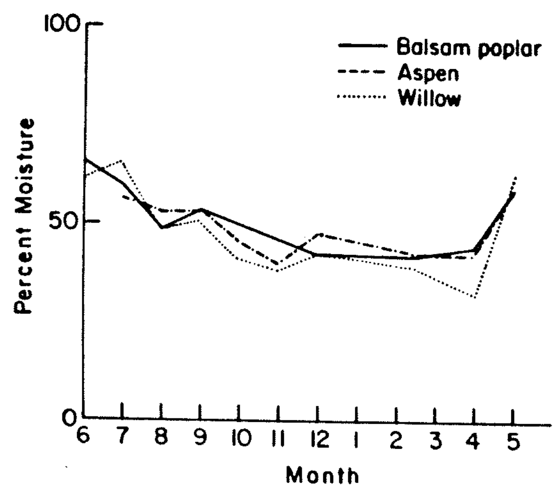
Fig. 3.3. Monthly values for percent moisture for saskatoon, pin-cherry, chokecherry, low bush-cranberry, mountain maple, beaked hazel, balsam poplar, trembling aspen, beaked willow, and red-osier dogwood (at Sarah, Garland, Lidstone, and Mink Creek) for 1979-1980. The maximum standard error of the mean is 3%.



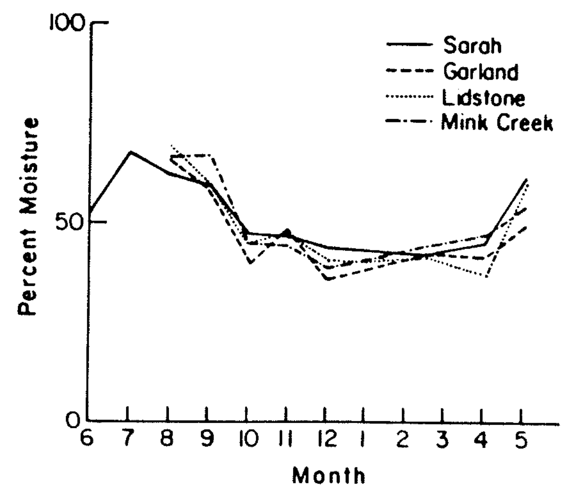
100
50
0
6 7 8 9 10 11 12 1 2 3 4 5
Month
Percent Moisture
Saskatoon
Pincherry
Chokecherry



100
50
0
6 7 8 9 10 11 12 1 2 3 4 5
Month
Percent Moisture
Low bush-cranberry
Mountain maple
Beaked hazel



100
50
0
6 7 8 9 10 11 12 1 2 3 4 5
Month
Percent Moisture
Balsam poplar
Aspen
Willow



100
50
0
6 7 8 9 10 11 12 1 2 3 4 5
Month
Percent Moisture
Sarah
Garland
Lidstone
Mink Creek

species through the spring and summer can be quantified by weight.

The regression equations can be useful in predicting browse consumption in the areas and under the conditions studied. Factors such as site differences and composition of the twigs would still affect the relationship between twig weight and diameter as Telfer (1969) suggests. The predictive equation would yield similar results for the different areas. Collection of twigs at the right time of year and use of the dry diameters for predicting the dry weights in the areas sampled would decrease error in the calculations of browse consumption by ungulates in the field. Growth of these browse species can also be measured throughout the year keeping in mind the assumptions made in this and other studies.

The twig diameter-weight relations were used to estimate browse consumption by the ungulates (Chapter IV). In the field, browsed twigs were measured at the point at which they were eaten. The measured diameter was used to predict the dry weight of the material consumed by the animal by intrapolating from the predictive equation.

CHAPTER IV

UNGULATE RESPONSE TO FOREST CLEARING IN THE DUCK MOUNTAIN, MANITOBA

A. Introduction

The literature on the food habits of ungulates is large. Peterson(1955), Peek(1974a) and Krefting(1974) cover in some detail the habitat selection and food habits of the North American moose (*Alces alces*). Murie(1951), Kufeld(1973) and Banfield(1974) review the habits of elk(*Cervus elaphus*) in various regions of the continent. The habits of the white-tailed deer(*Odocoileus virginianus*) are documented by many authors(Schenck, Linder and Richardson 1972, Schneeweis, Severson and Peterson 1972, Banfield 1974). During the past five years, research data on ungulate response to clearcutting and burning has been published by a number of authors(Vallee, Joyal and Couture 1976, Stelfox, Lynch and Gillis 1976, Ffolliott et al. 1977, Short, Evans and Boeker 1977, Drolet 1978, Telfer 1978, Usher 1978).

Studies by Green(1933), Banfield(1949), Trottier and Samoil (1978) and Rounds(1979; 1980) in Riding Mountain National Park, by Cairns and Telfer(1980) in Elk Island National Park, by MacLennan (1975) and Hunt(1976; 1979) in the Porcupine Forest in southeastern Saskatchewan, by Usher(1977; 1978) in east central Alberta, by Scaife (1980) in north central Manitoba and by Hamilton and Drysdale(1975) in western Ontario, provide information on those ungulates occupying similar habitats to those occurring in the Duck Mountain, Manitoba.

This literature review is divided into (a) food habits of the ungulates and (b) ungulate responses to clearing.

(a) Ungulate food habits

Moose, elk and white-tailed deer often prefer similar habitats but the use of each is stratified to some extent by season, food plants (Cairns and Telfer 1980), area(Trottier and Samoil 1978) and height of browse(Rounds 1979). Moose feed on aquatic vegetation in the summer, whereas elk and deer increase their consumption of forbs and grasses in the summer. All three ungulates eat a large amount of woody browse in the winter and smaller amounts in the other seasons.

Moose food habits, habitat selection and general ecology are well reviewed by Peterson(1955) and Krefting(1974). Moose prefer habitats which are in the early stages of succession as there is an abundant food supply(Peteron 1955, Peek 1974b, Irwin 1975, Cairns and Telfer 1980). In the winter, moose in Riding Mountain National Park use a number of plant resources including willow, aspen, tamarack, black spruce, white spruce and mixtures thereof(Trottier and Samoil 1978). Young willow and aspen stands are prime moose habitat(Berg and Phillips 1974) in Minnesota. Sedge meadow is also deemed important moose habitat in Elk Island National Park(Cairns and Telfer 1980). Between June and October, the moose in Ontario move to areas where the aquatic vegetation is abundant(Vos 1958). Moose also move to better ranges if the opportunity so arises(Telfer 1978).

Peterson(1955) covers the food plants eaten by moose throughout the year. Peek(1974a) gives an update of the studies on the moose's food habits in North America. As the moose is a generalist in its food selection, diversity of forages aid in its selection of habitat (Peek 1974b). Trottier and Samoil(1978) found that moose feed on hazel and willow in early winter but the moose then shift to a higher ratio of willow to hazel by late winter. In southern Ontario, moose feed on the following food species(in order of preference): cherry, willow, aspen, saskatoon, hazel, alder, mountain maple, paper birch and jack pine(Hamilton and Drysdale 1975).

Elk inhabit upland sites with a preference for an open habitat. In Elk Island National Park, elk choose the upland grasslands(Cairns and Telfer 1980) and other studies show that elk like the early to mid-successional stands(Trottier and Samoil 1978, Singer 1979). In Riding Mountain, Manitoba, Trottier and Samoil(1978) suggest that the intensive use of shrubland by elk because there is a lack of numerous grasslands in the park.

The elk feed on forbs and grasses throughout the seasons but woody browse makes up the largest proportion of its diet; increasingly so as the winter progresses(Trottier and Samoil 1978). In north-eastern Saskatchewan, Hunt(1979) ranked the preferred foods of elk as aspen, willow, rose, raspberry, red-osier dogwood, saskatoon, jack pine, chokecherry and pincherry. Hunt also found that the elk's autumn diet included a large proportion of agricultural crops. Saskatoon, willow and aspen were highly preferred in late winter(Trottier and Samoil 1978).

White-tailed deer food habits have been studied in various parts of the continent(Colbentz 1970, Schenck et al. 1972, Schneeweis et al. 1972, Wetzel et al. 1975, Anthony and Smith 1977). Browse from various shrubs and trees is the primary food source for deer (Banfield 1974). Hazel was the preferred browse species in Riding Mountain

National Park in late winter(Trottier and Samoil 1978). Other winter foods include mountain maple,cherry, aspen and red-osier(Banfield). Their summer diet includes woody browse as well as goldenrods, asters, lambs quarters, jewelweed and mushrooms(Banfield 1974).

(b) Ungulate response to burning and clearcutting

Controlled burns and small clearcuts have been used to increase the use of an area by ungulates. There are many limitations as to size, type, location and successional stages of the burn or clear-cut which are important to the choice of habitats by ungulates.

Fire and clearcuts open up the forest canopy to light which can penetrate to the understory(See Chapter II). In addition to the increase in plant diversity and numbers, the quality of the forage in the openings is increased(Cowan et al. 1950, Dix and Swan 1971). After a fire, browse plants are richer in protein and in other nutrients(Einarsen 1946, DeWitt and Derby 1955).

The use of clearcuts by ungulates has been well documented by Patton(1974), Telfer(1974a), Hamilton and Drysdale(1975), Stelfox et al.(1976), Hunt(1976), Prescott(1968), Davis(1977), Ffolliott et al.(1977), and Drolet(1978) in terms of forage cover, traditional use patterns and sizes of clearcuts.

Forage production(Corns and La Roi 1976, Stelfox et al. 1976, Halls and Alcaniz 1968, Vallee et al. 1976, Usher 1977; 1978) is one important aspect of clearcuts. The increased forage production can result in increased production and twinning in moose populations(Peek 1974b). Elk and mule deer used areas along burnt windrows where forage is succulent and green(Ffolliott et al. 1977). A particular aspect of the increased forage is the production of more fruit of shrubs and herbs in the clearings(Halls and Alcaniz 1968, Lay 1966). The fruit is often used by deer, elk and especially black bears(Banfield 1974).

Cover is one factor used to assess the use of clearcuts by moose, elk and white-tailed deer, and often is more important than food variety(Davis 1977). The ungulates need adequate cover for shelter in winter and for concealment from predators throughout the year. Standing timber left after logging or left after a fire can provide sufficient cover(McCulloch 1969, Telfer 1974a, Davis 1977). For complete clearing, the shrubs and trees do not always provide adequate winter cover for elk and deer even after 5 years of growth; however, adequate summer cover is present(Stelfox et al. 1976).

Deer are not attracted to areas with no cover(Short et al. 1977). Deer are more affected by lack of cover than are moose and elk(Cairns and Telfer 1980, Drolet 1978, Ffolliott et al. 1977, MacLennan 1975). Of the three ungulates studied, elk preferred to spend the most time in openings(MacLennan 1975, Cairns and Telfer 1980).

The size, shape and treatment of clearcuts determines their use by wildlife. As deer stay within 1 km of cover(Short et al. 1977), they occupy only those clearcuts where cover is nearby. The following sizes of clearcuts are suggested for deer: 200 m widths(Hamilton and Drysdale 1975), 0.5-3.5 ha(Ffolliott et al. 1977), and 60 ha (Drolet 1978). Moose use clearcuts up to 1.3 square km(Telfer 1974a); however, a 100 square km area with small clearcuts interspersed with mature forest would be suitable to increase the population size of the moose. Patton(1974) suggest that many plots of varying sizes or fewer plots being long, narrow and contouring would be the most beneficial to the game animals.

The clearcuts do not remain at the early stage of succession very long. Deer in eastern Canada use clearcuts for about 6 years (Drolet 1978). Usually the benefits of the clearcut plot last for 15 to 20 years(Reynolds 1969, Stelfox et al. 1976, Vallee et al. 1976, Usher 1978). The best type of habitat manipulation includes plots at various stages of succession rotated on a long term cycle. The animals can use the different seral stages in the plots and still be near to cover within the mature stands.

Deep snow hampers movement of deer and elk and, to a lesser degree, moose. Often snow depths are greater in the plots(Eastman 1974) and use by all ungulates is terminated when depths reach 60-70 cm(Kelsall and Prescott 1971, Stelfox et al. 1976, Drolet 1978). Wind chill is another factor to consider in the plots as it is greater in the openings(Moen 1973). Human disturbance through hunting and from traffic on the roads has a detrimental effect on wildlife(Rost and Bailey 1979); however, trails can provide moose with easier access to browse plants(Hamilton and Drysdale 1975). Some other aspects of the plots which are beneficial to wildlife are the earlier growth of vegetation in the clearcuts and the relief from insects in the openings.

Edges are important to wildife since they provide simultaneous access to different habitats at one time(Strelke and Dickson 1980).

The proximity to cover is maintained as well as the availability of food along the edge between the forest and the clearcut. Le Resche et al.(1974) expanded on the importance of the ecotonal edge in Alaska. Many small islands of trees left after a fire provided a larger area of edge. The increase of moose in this area was attributed partially to the amount of edge. The greater use of edges of large clearcuts has been documented by Hunt(1976), MacLennan (1975) and Hamilton and Drysdale(1975).

The main objective of this study is 1) to determine the food habits of the moose, elk and white-tailed deer for the study sites and 2) to assess the ungulate response to clearing through browse studies, pellet group counts, rumen analysis and track counts.

B. Methods

The ungulate-use study of clearcuts was initiated in the spring of 1979. It was conducted concurrently with the vegetation analysis of the plots. Each treatment type(differentiated by year of clearing and by clearing procedure) was examined.

The four major methods of gathering ungulate data included pellet group counts, track counts, rumen analysis and browse utilization assessment. A restricted random sampling procedure was employed for the pellet group counts, track counts and browse utilization. Each treatment type was sampled on a random basis. The number of plots sampled for each treatment type is outlined in Appendix F.

Pellet groups can be used as an index of ungulate population size through calculations using the defecation rates of the animals (Eberhardt and Van Etten 1956, Franzmann et al 1976). In this study the pellet counts provided information on relative use of cleared versus uncleared areas at the different sites. This study takes into account the following assumptions as made by Neff(1968) and Eberhardt and Van Etten(1956): 1) the number of pellet groups is related to the number of animal-hours spent in an area, 2) the counts only include pellets deposited since leaf fall, 3) groups are identified correctly and none are missed, 4) the belt transects are sufficient sampling units and 5) valid estimates of sampling error are obtained. In addition to these basic assumptions, it was assumed that similar errors would be made on all transects.

Line transects were used to count pellet groups(Short et al. 1977, Eberhardt and Van Etten 1956). Although Neff(1968) and Robinette et al.(1958) report that small circular plots were the most efficient, line transects were deemed more practical for this study. The transects ran parallel to one another in the plot, along the edge and in the control so that topographic changes such as creeks and biological changes such as game trails were included in all three transects.

Transects were run the length and width of the plot with their positions within the plot randomly chosen. The transects along the edge were the same length and width. The width of each transect belt was 3 m and was determined by the use of a 1.5 m pole carried by the observer.

All pellet groups within the transect belt were identified as to source by the size and shape of the pellets(Plate 4.1b). All groups consisting of 30 or more pellets and with more than half of their mass inside the transect belt were counted(Neff 1968). Only those pellets dropped since the fall of leaves from the previous autumn were recorded.

Track counts were made in February 1980 after a fresh snowfall. The number of fresh tracks and the number of old tracks in the plot and the control were counted along two transects(one the width of the plot and the other the length of the plot). The length of the transects in the plot equalled the length of those in the control. Ten plots were randomly sampled.

Rumen samples were collected by conservation officers from 10 hunter-killed animals(4 moose, 6 elk) from the 1979-1980 hunting season in the Duck Mountain. The animals were killed within the plot areas of the two northern sites, Lidstone and Sarah Lake. The

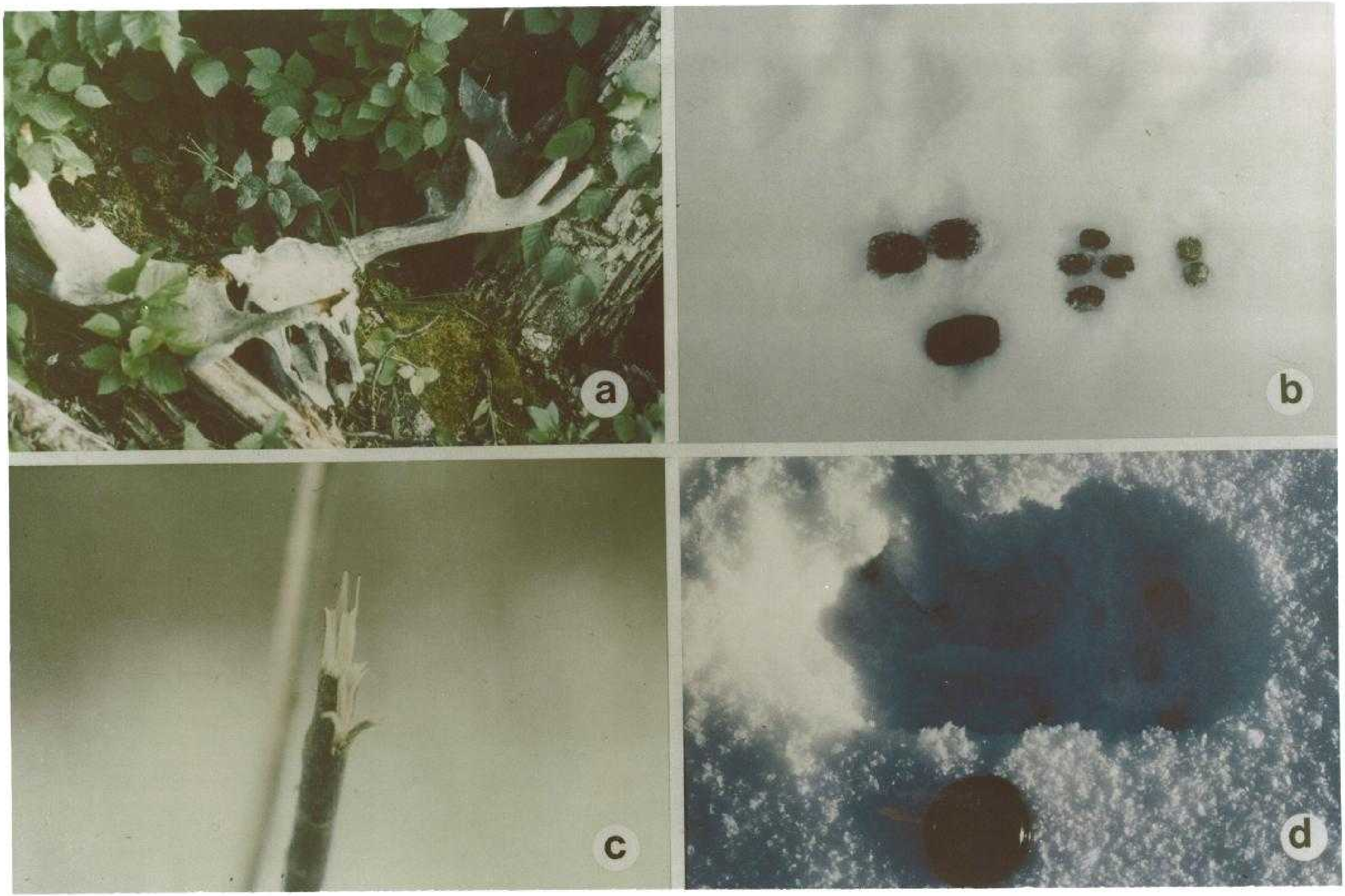
Plate 4.1 Animal signs.

a) Partial remains of moose skeleton found at the edge of a Garland plot.

b) Pellet groups were identified to species. From left to right above: elk, white-tailed deer and snowshoe hare below, moose.

c) The tip of this chokecherry had been browsed by ungulates.

d) Moose track found at a Sarah Lake site in late fall 1979.


a
b
c
d

rumen material was collected and then frozen(Korschgen 1971).

One liter aliquots from the collected rumen material were washed through a 2 mm sieve(Dirschl 1962). The material less than 2 mm was oven dried and weighed. The material greater than 2 mm was placed in a large pan which was divided into 16 small quadrats. Three of the 16 quadrats were randomly selected. All material within each sampled quadrat was identified as to genus and species when possible. Grasses and sedges could not be differentiated so they were labelled as such. All species as well as the unknown plant material were oven dried individually for 24 h at 70°C (Dirschl 1962). Dry weights of all identifiable material and all unidentifiable material were tabulated.

Browse utilization data in the plots, edges and controls from the previous winter were collected the same time as other vegetation data (Chapter II). Browse is defined as that plant material actually or potentially consumed by ungulates. Throughout the field program, plant species which had been browsed by moose, elk and deer were noted. The percent of the total available shrubs which were browsed and the browse consumption were calculated.

The percent of the total available shrubs which were browsed in the quadrats(the same quadrats used in the vegetation analysis) was the number of browsed plants of a species divided by the available plants of that species multiplied by 100. The plants, which would be available in the winter, would be those plant parts between 50 and 250 cm(between average snow depth for 1978-79 winter and the average upper reach of the ungulates(Trottier and Samoil 1978, Usher 1978)).

Browse consumption was calculated using the twig weight-diameter relations(Telfer 1974c, Usher 1978). Diameter at the point of browsing was measured with calipers. The weight of plant material which had been browsed was interpolated from the regression curve of the twig weight versus twig diameter graphs by filling in the values for the predictive equation(See Chapter III). Browse consumption was compared for the plot, edge and control.

Other observations of animal use were recorded during the course of the study. The animal signs recorded included bedding sites, pellet group locations, skeletal remains(Plate 4.1a), tracks (Plate 4.1d), feeding craters(Plate 4.2b), animal sightings and browse evidence(Plate 4.1c).

Lists of bird species and mammal species were compiled for all study sites. All scientific names and common names of birds and mammals follow Godfrey(1966) and Banfield(1974) respectively (Appendices B and C).

Analysis of variance was used to determine if there were any statistically significant differences between the plot, edge and control or between treatment types.

C. Results

(a) Pellet groups

Fig. 4.1, 4.2 and 4.3 illustrate the differences between the number of pellet groups deposited by moose, elk and white-tailed deer, respectively, in the plot, edge and control.

Although there is a general trend of more moose pellet groups in the plot or along the edge for the 1979 pellet group count, these differences are not statistically significant(α= 0.05). Only in S-78 were there significantly more pellet groups in the edge area or in the plot area as compared to the control. The S-73 plots were the only ones where there were more moose pellets groups in the control. Contrary to the 1979 data there were more pellet groups in the S-73 plots than in the controls and there were less pellet groups in the S-78 plots than in the controls in 1980.

Elk pellet groups were more numerous in the plot area or edge area for L-73, G-75, M-74 and S-78 for the plots sampled in 1979 (Fig. 4.2a). In S-77 the control had more pellets than the plot or edge while the control and plot pellet counts for S-73 were equal.

In 1980, the elk pellet group counts produced quite different results from those in 1979. L-73, G-75, S-73 and S-77 had more pellet groups in the plot or along the edge; however, the opposite was true for the rest of the treatments. None of these differences were significantly different.

In both 1979 and 1980, deer pellet groups were more numerous in the control in some cases(Fig. 4.3). In 1979, there were more

Plate 4.2 Animal effects on and use of the vegetation.

a) Logging was carried out in all the study sites. Sometimes logging debris covered the control and the plots. Here logs were temporarily stored in a plot.

b) Elk feeding craters were found in the Mink Creek plots in February 1980. Elk fed on the dormant herbaceous and woody plant material.

c) The candlelabra growth form of the red-osier dogwood was a common result of browsing. The ungulates ate the apical shoots allowing subapical buds to flourish the next growing season.

d) The snowshoe hare, abundant in 1979 and 1980, killed a number of shrubs (especially hazel) by girdling the plants during feeding. The S-73 plots made excellent hare habitat as the fallen logs provided hideouts from predators and the clearings provided more food.

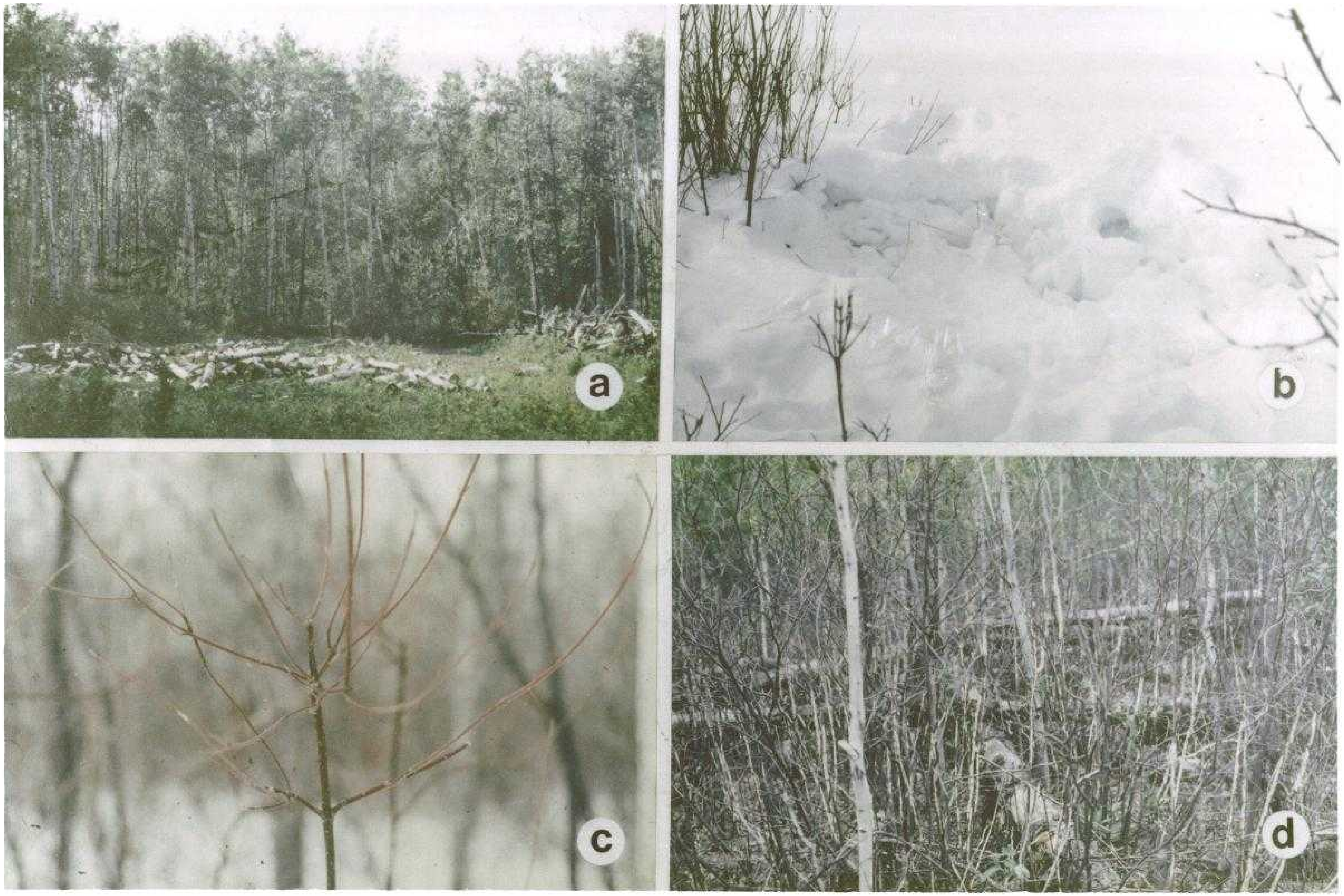

a
b
c
d

Fig. 4.1a. The average number of moose pellet groups in the plot, the edge and the control for the eight treatments in 1979.

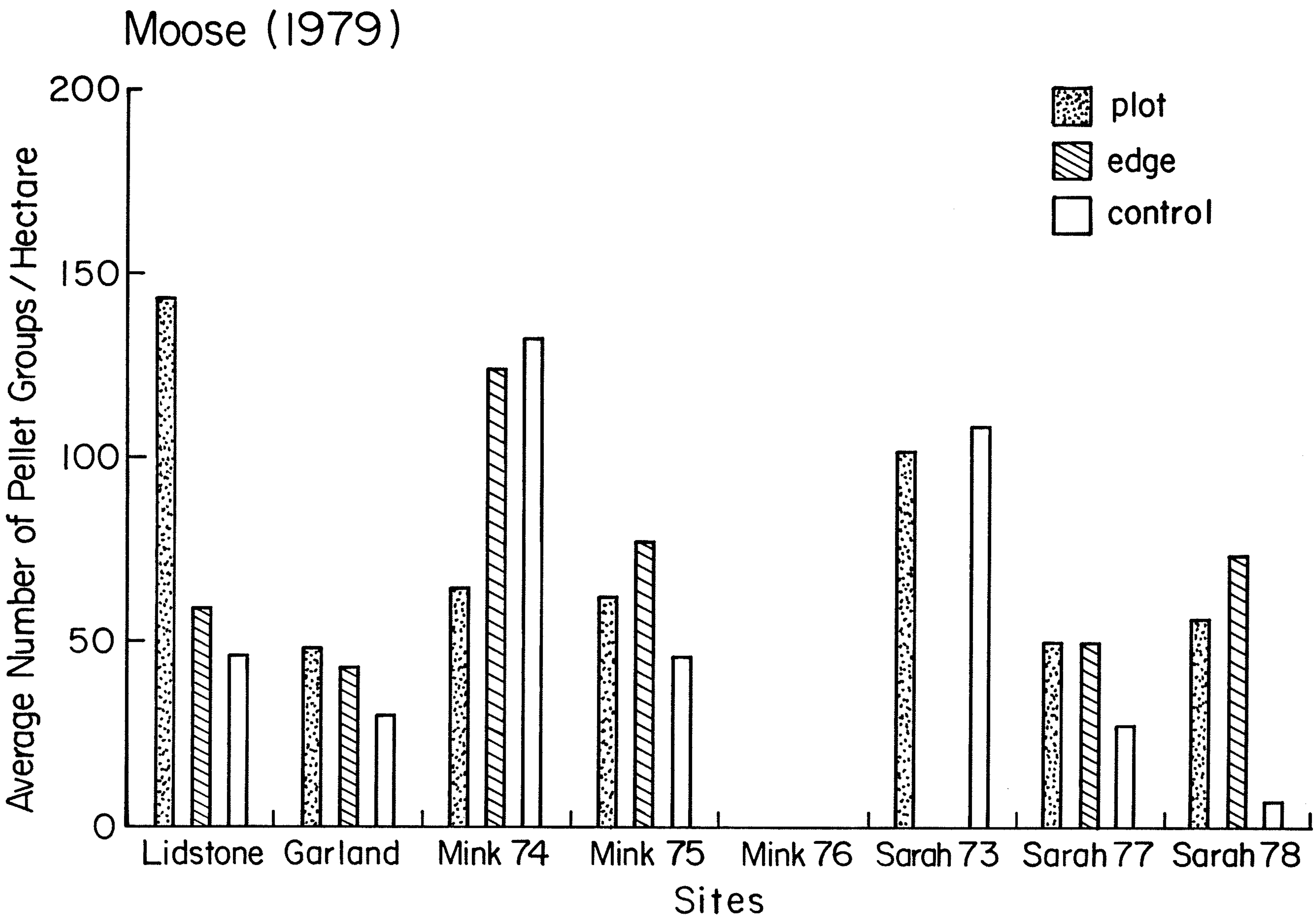

Moose (1979)
plot
edge
control
Average Number of Pellet Groups / Hectare
200
150
100
50
0
Lidstone
Garland
Mink 74
Mink 75
Mink 76
Sarah 73
Sarah 77
Sarah 78
Sites

Fig. 4.1b. The average number of moose pellet groups in the plot, the edge and the control for the eight treatments in 1980.

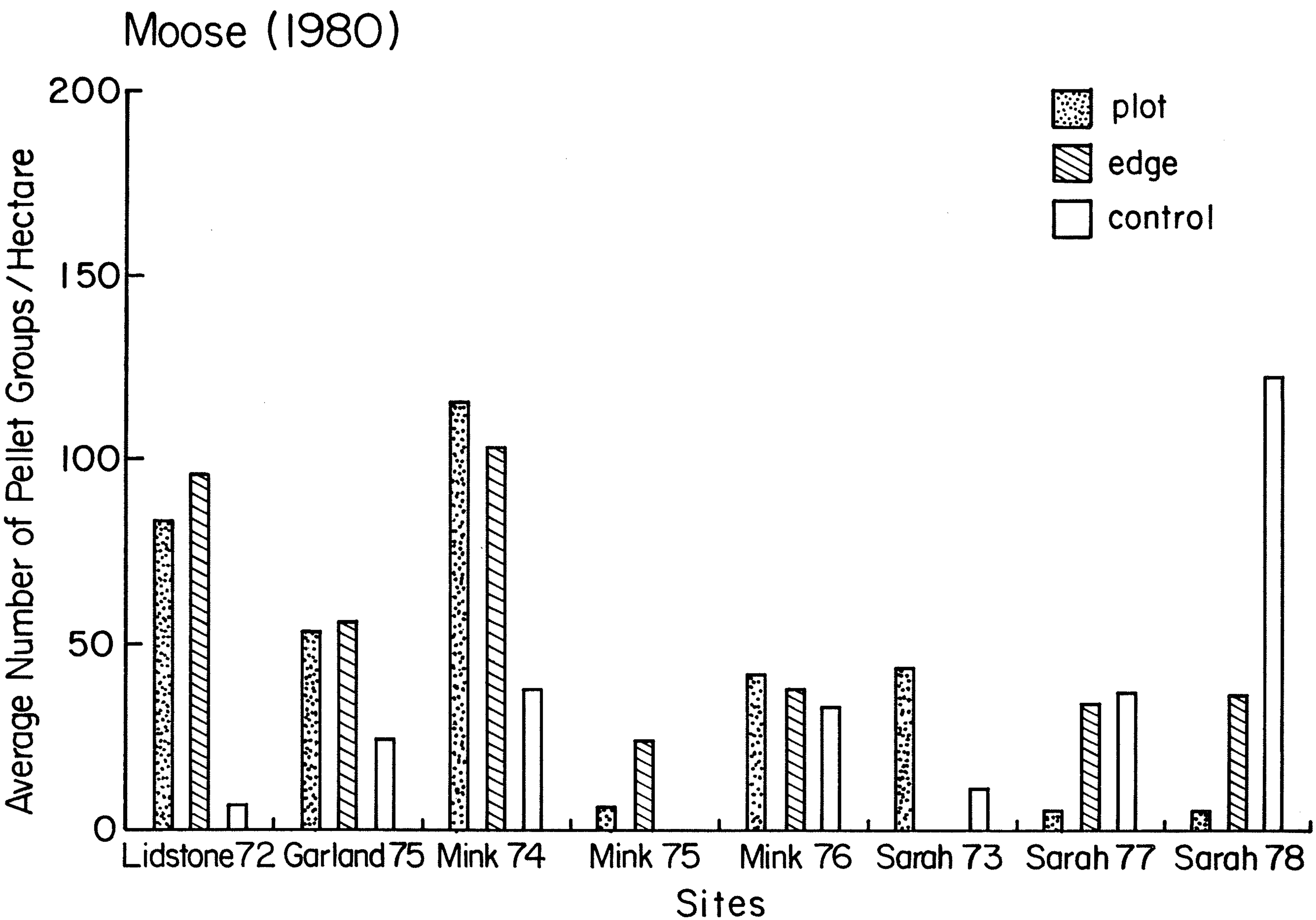

Moose (1980)
200
150
100
50
0
Average Number of Pellet Groups / Hectare
plot
edge
control
Lidstone 72
Garland 75
Mink 74
Mink 75
Mink 76
Sarah 73
Sarah 77
Sarah 78
Sites

Fig. 4.2a. The average number of elk pellet groups in the plot, the edge and the control for the eight treatments in 1979.

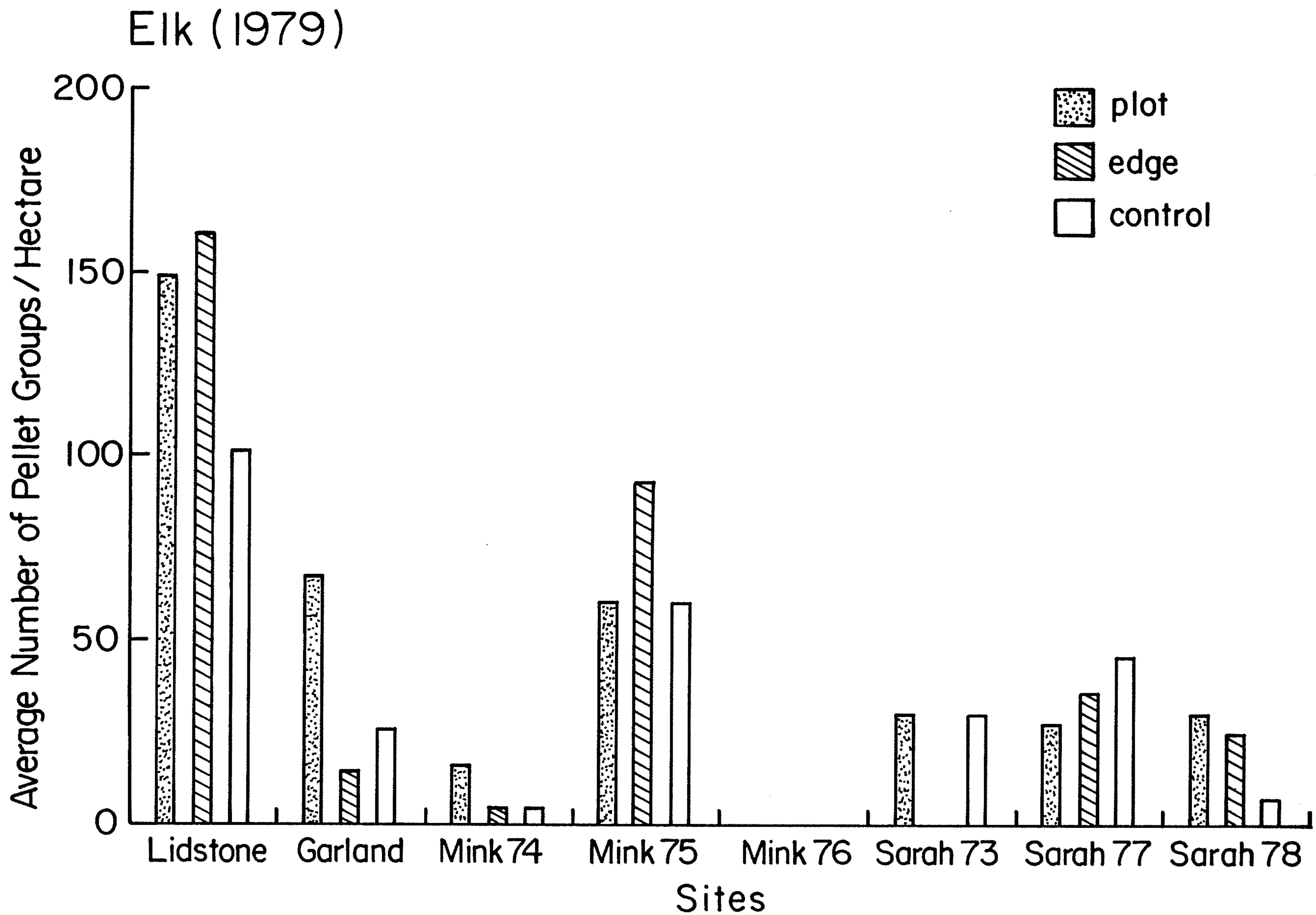
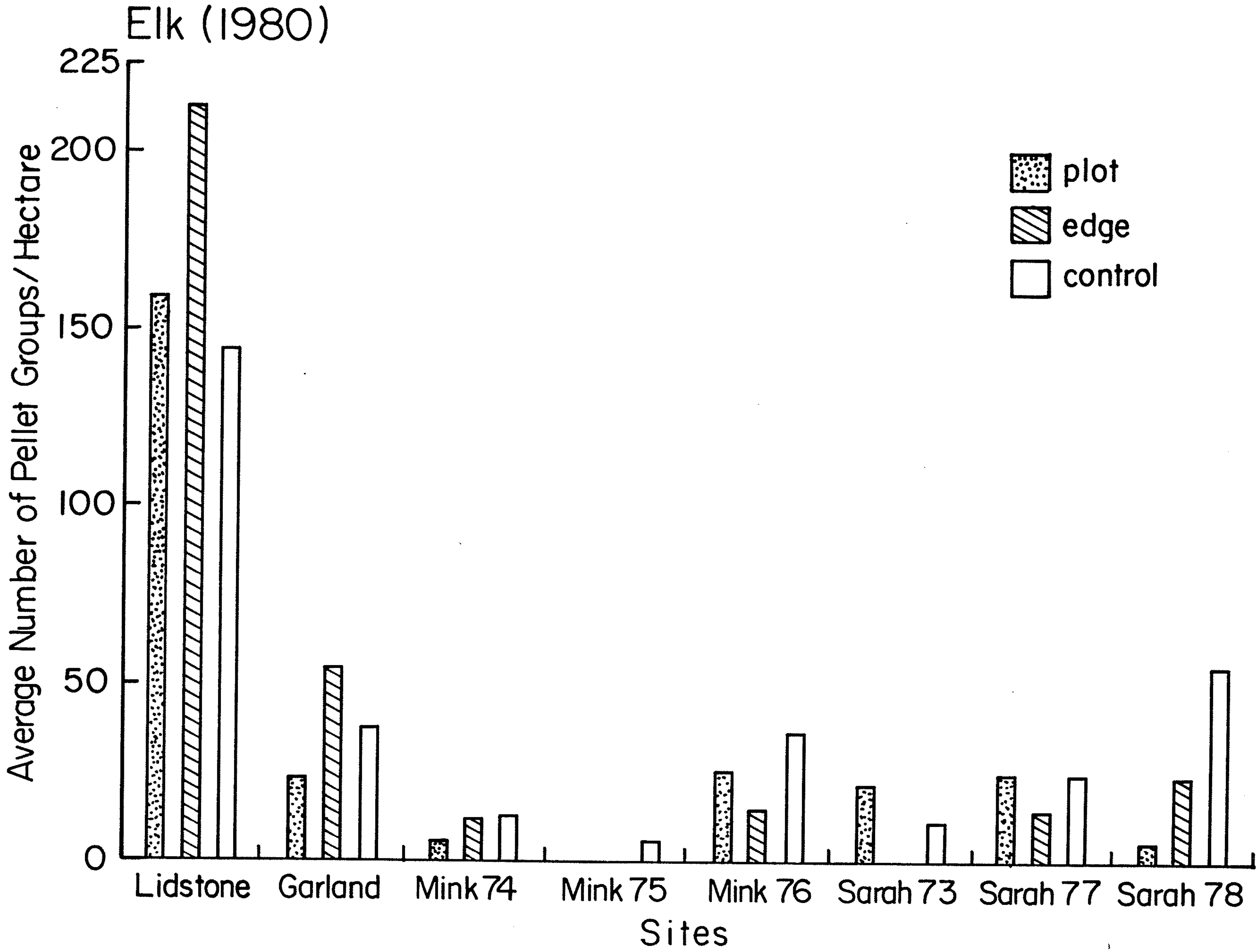
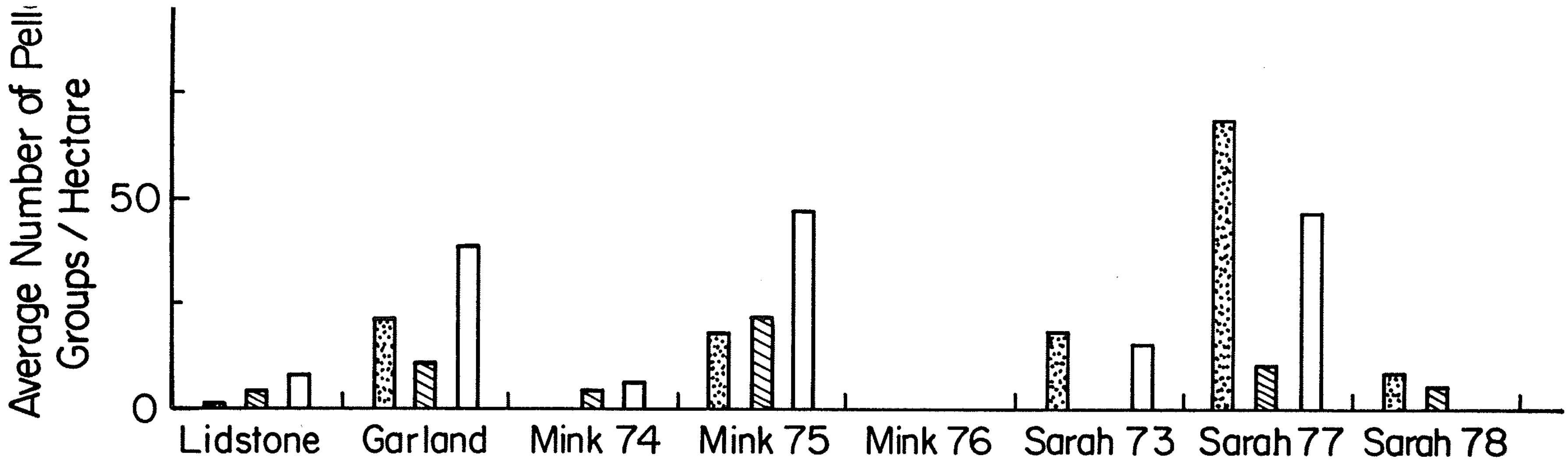

Elk (1979)
200
150
100
50
0
Average Number of Pellet Groups / Hectare
plot
edge
control
Lidstone
Garland
Mink 74
Mink 75
Mink 76
Sarah 73
Sarah 77
Sarah 78
Sites

Fig. 4.2b. The average number of elk pellet groups in the plot, the edge and the control for the eight treatments in 1980.

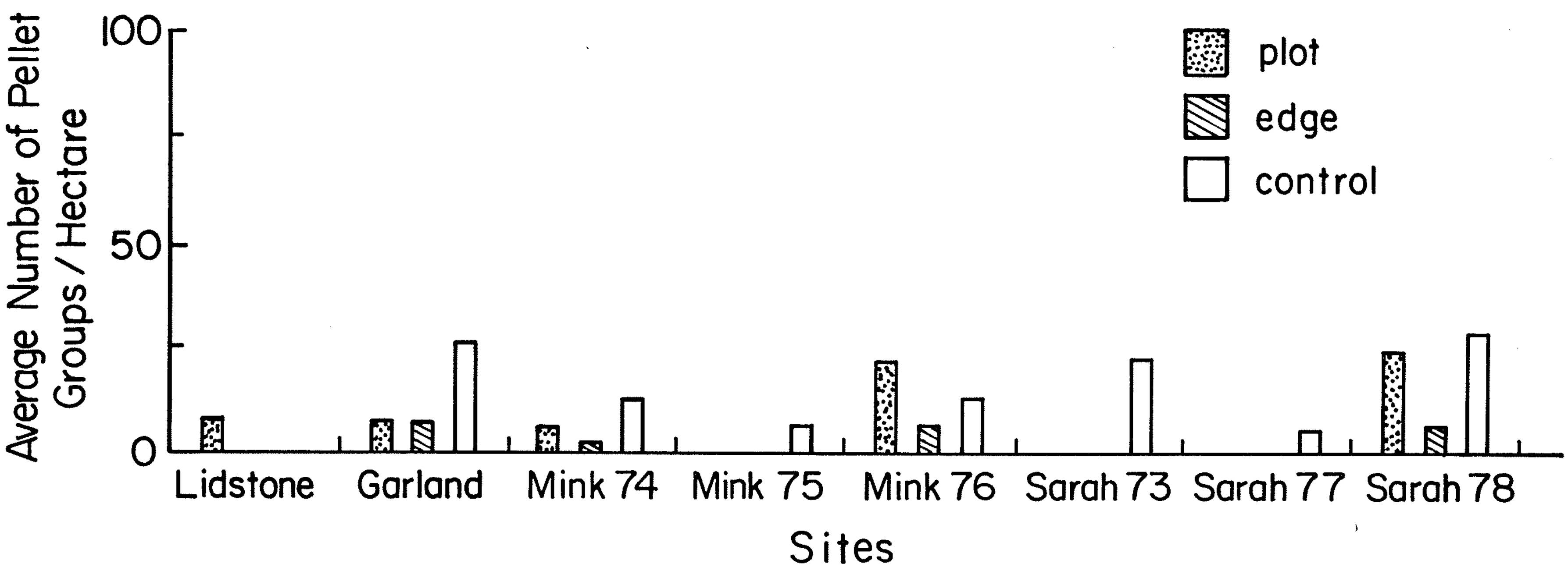


Elk (1980)
225
200
150
100
50
0
Average Number of Pellet Groups/ Hectare
plot
edge
control
Lidstone
Garland
Mink 74
Mink 75
Mink 76
Sarah 73
Sarah 77
Sarah 78
Sites

Fig. 4.3. The average number of white-tailed deer pellet groups in the plot, the edge and the control for eight treatments in (a) 1979 and (b) 1980.


Average Number of Pell
Groups / Hectare
50
0
Lidstone
Garland
Mink 74
Mink 75
Mink 76
Sarah 73
Sarah 77
Sarah 78

Deer (1980)


Average Number of Pellet
Groups / Hectare
100
50
0
plot
edge
control
Lidstone
Garland
Mink 74
Mink 75
Mink 76
Sarah 73
Sarah 77
Sarah 78
Sites

in the plot in M-74, S-77 and S-78 but in the 1980 survey there were more groups found in the control. The Lidstone plots differed from the rest as there were more pellet groups in the control in the 1979 survey and more in the plot in the 1980 survey. Again no statistically significant differences(α= 0.05) were found between the plot, the edge and the control for the deer pellet group counts.

Fig. 4.4, 4.5, 4.6 and 4.7 combine the pellet group count data for each of the sites for the 1979 survey.

No pellet group counts were made in the M-76 plots in 1979 because these plots were not included on the original maps; however, the vegetation analysis and the 1980 pellet group counts were conducted for this treatment. Edge counts were not made for the S-73 plots because the edge was too difficult to determine.

(b) Track counts

The track counts showed that the plot was used more often than the control for Lidstone and Sarah Lake(Fig. 4.8). The same percentage of total tracks was found in the plot and control for Garland and Mink Creek.

(c) Rumen analysis

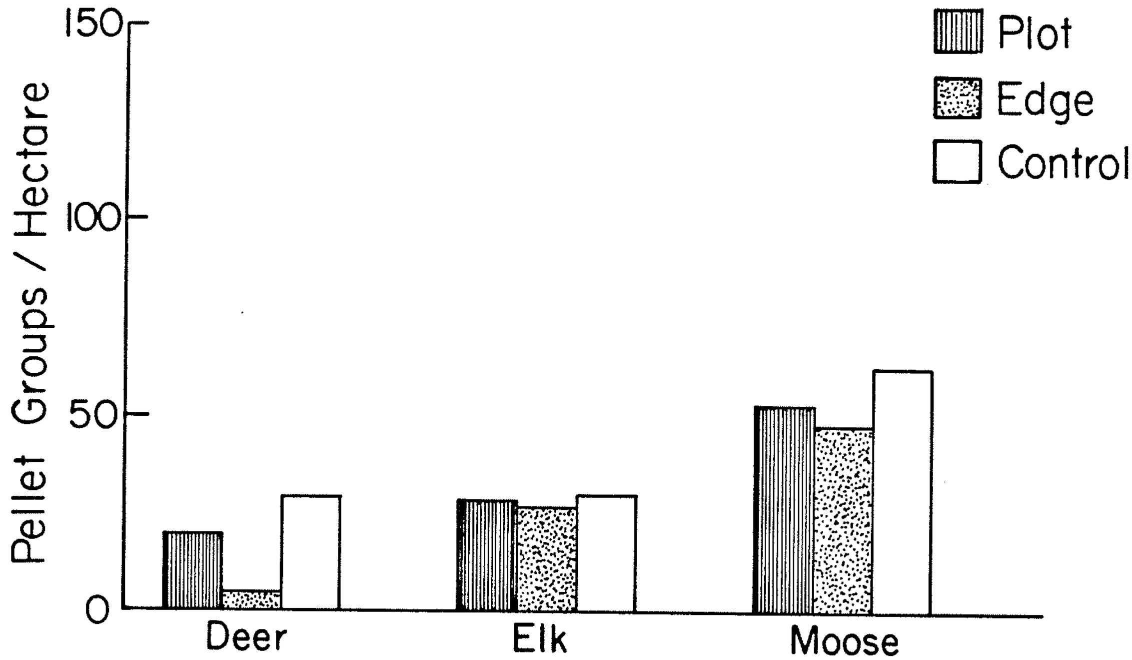
The rumen analysis gave further information on the actual food habits of elk and moose. The moose rumens contained a high percentage of trembling aspen(Fig. 4.5a). Other shrubs and trees which provided some of the moose's diet were willows, saskatoon, balsam fir and hazel. Grain provided the bulk of the diet for elk during the early winter as nearly half of the rumen contents were barley and rapeseed(Fig. 4.9b). Shrubs and grasses made up a smaller portion

Fig. 4.4. (a) The average number of pellet groups for the plot, edge and control for all the Sarah Lake plots sampled during 1979.

(b) The percent browse for some shrubs in the plot, edge and control at Sarah Lake during 1979.

SARAH LAKE

Pellet Group Counts



Browse Percentage

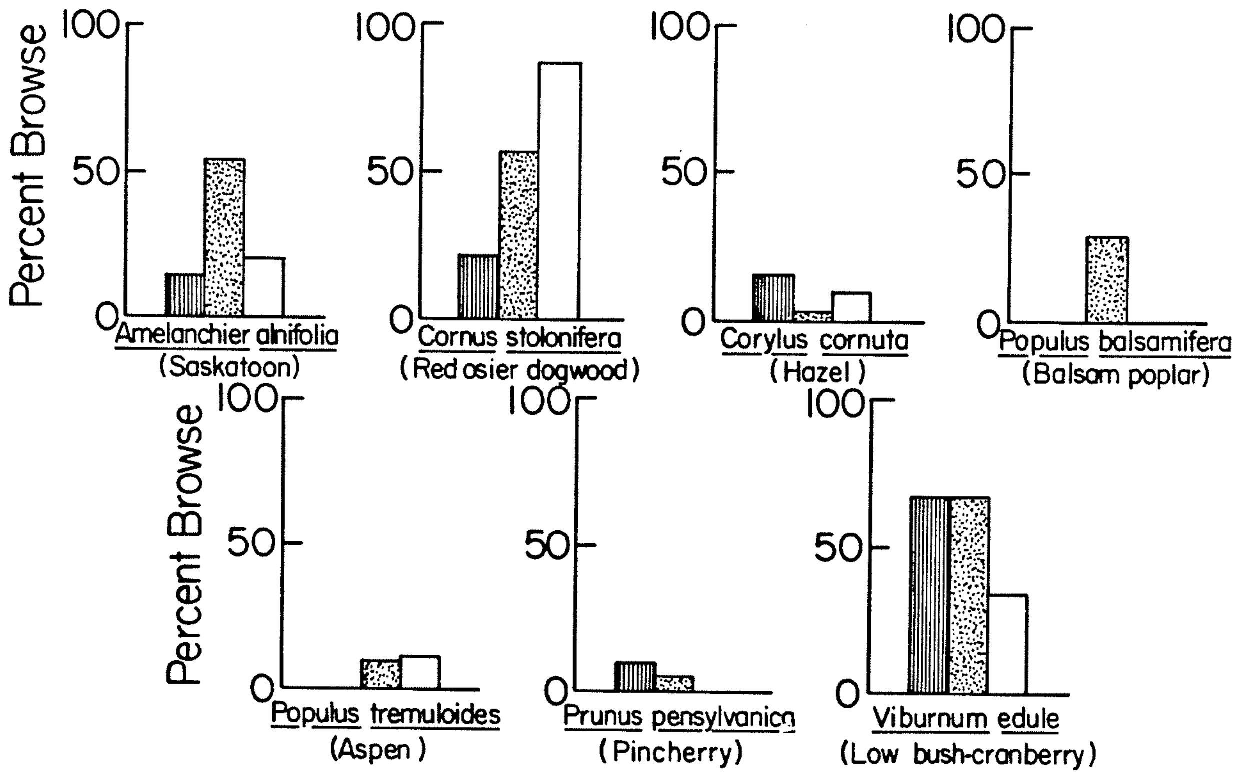
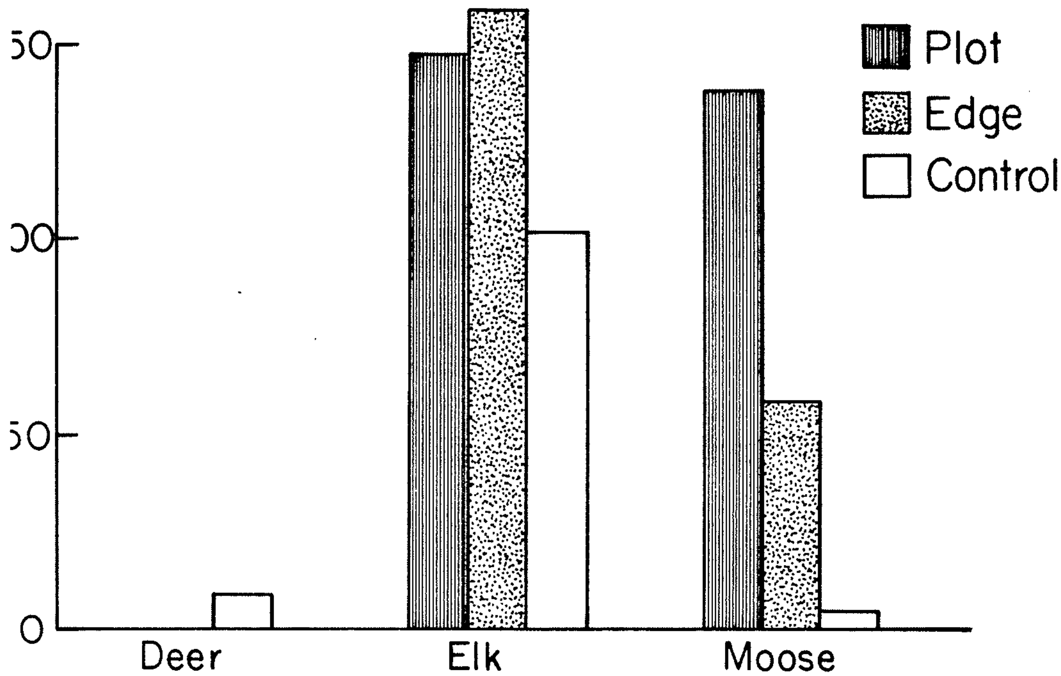


Fig. 4.5. (a) The average number of pellet groups for the plot, edge and control at the Lidstone site during 1979.

(b) The percent browse for some shrubs in the plot, edge and control at Lidstone during 1979.

LIDSTONE

Pellet Group Counts



Browse Percentage

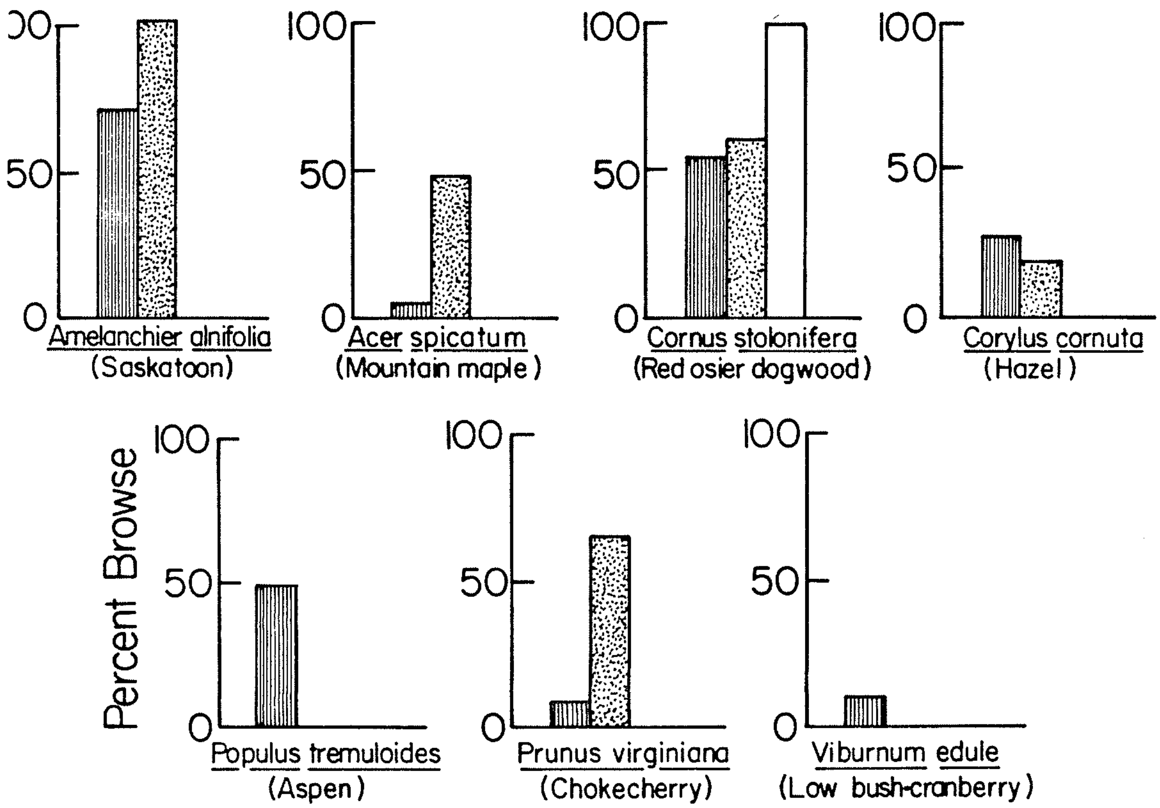


Fig. 4.6. (a) The average number of pellet groups for the plot, edge and control at the Garland site during 1979.

(b) The percent browse for some shrubs in the plot, edge and control at Garland during 1979.

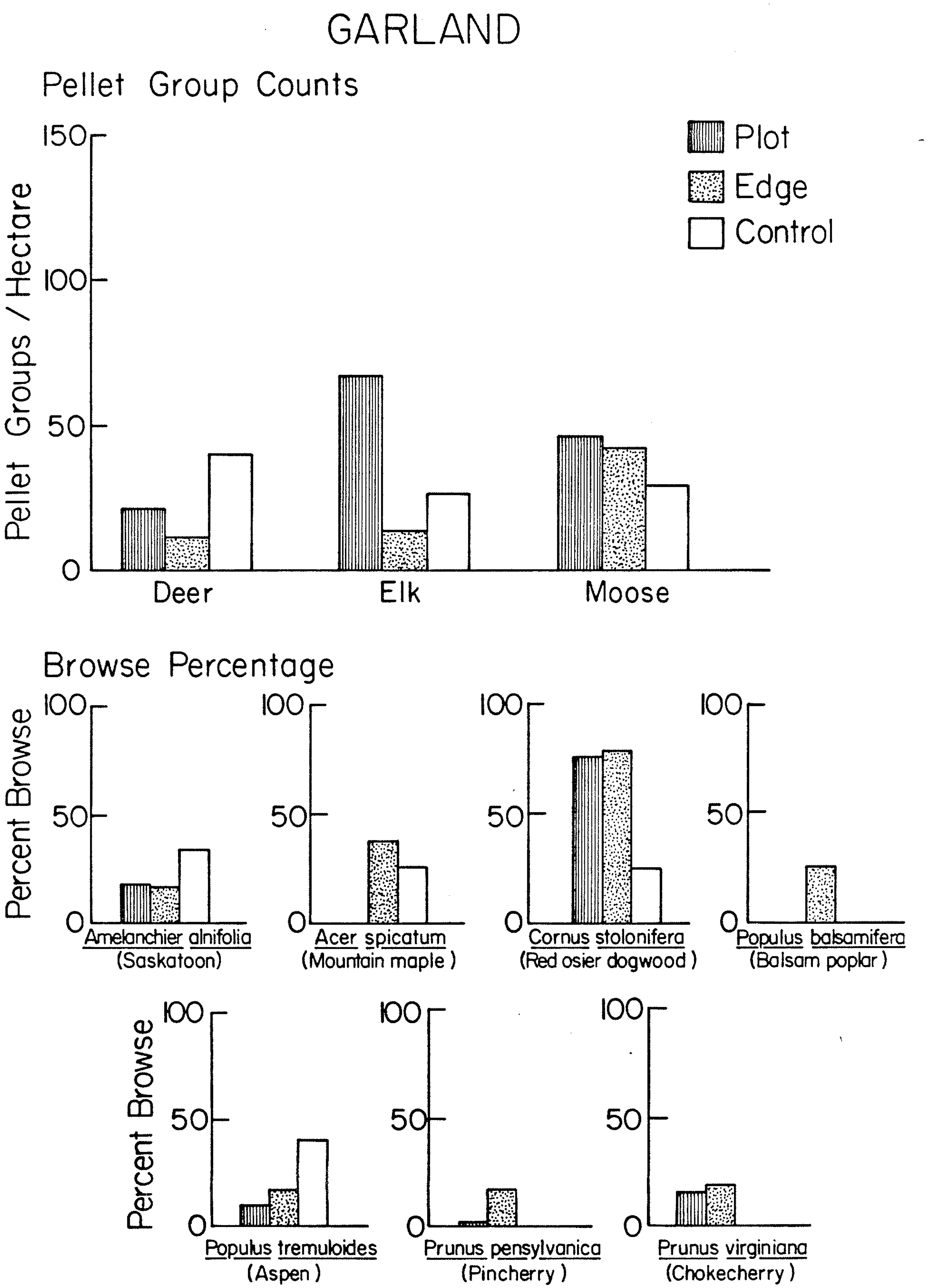

GARLAND
Pellet Group Counts
Pellet Groups / Hectare
150
100
50
0
Plot
Edge
Control
Deer
Elk
Moose
Browse Percentage
Percent Browse
100
50
0
Amelanchier alnifolia
(Saskatoon)
Acer spicatum
(Mountain maple)
Cornus stolonifera
(Red osier dogwood)
Populus balsamifera
(Balsam poplar)
Populus tremuloides
(Aspen)
Prunus pensylvanica
(Pincherry)
Prunus virginiana
(Chokecherry)

Fig. 4.7. (a) The average number of pellet groups for the plot, edge and control at all the Minkcreek plots sampled during 1979.

(b) The percent browse for some shrubs in the plot, edge and control at Minkcreek during 1979.

MINKCREEK

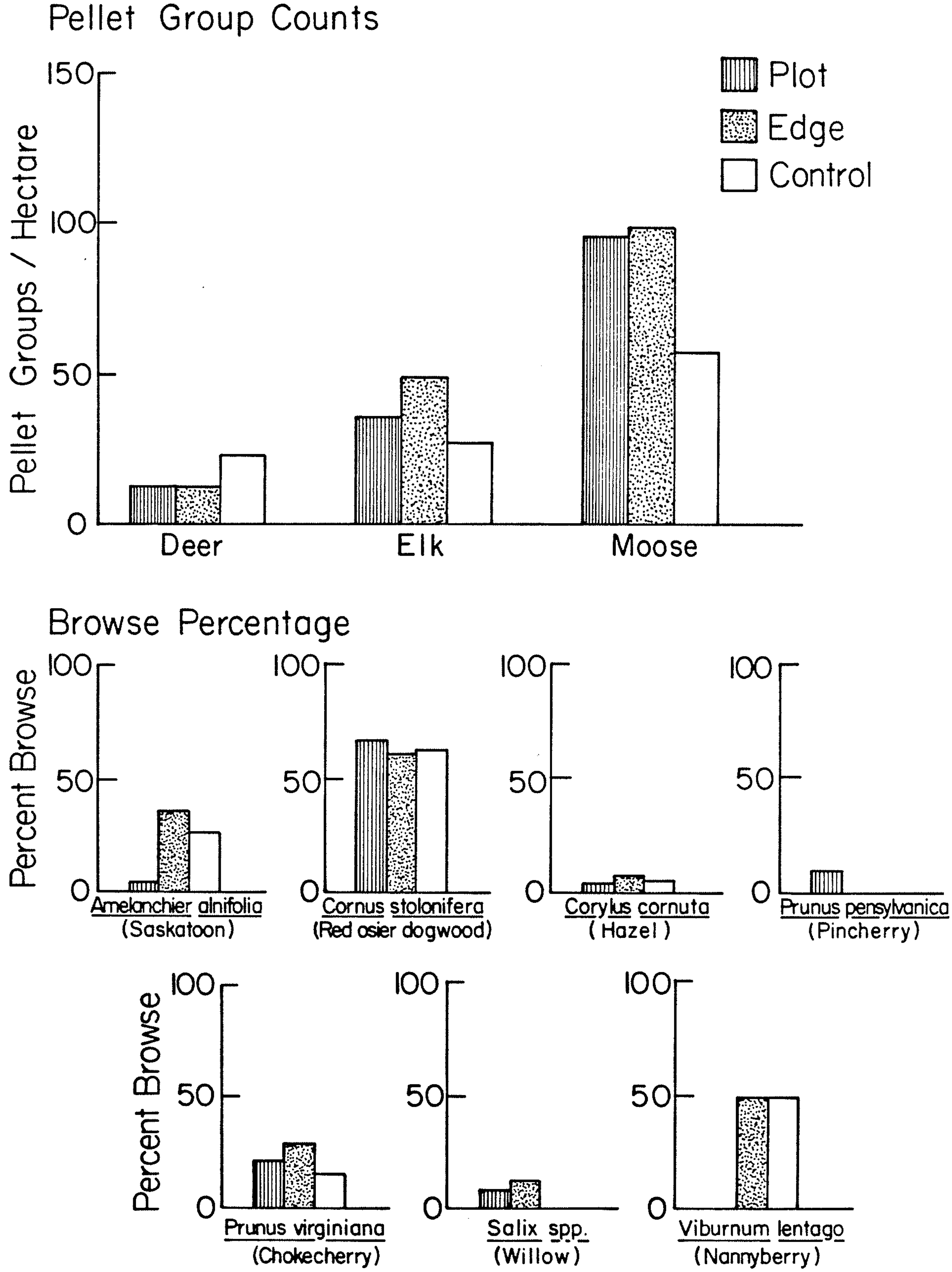
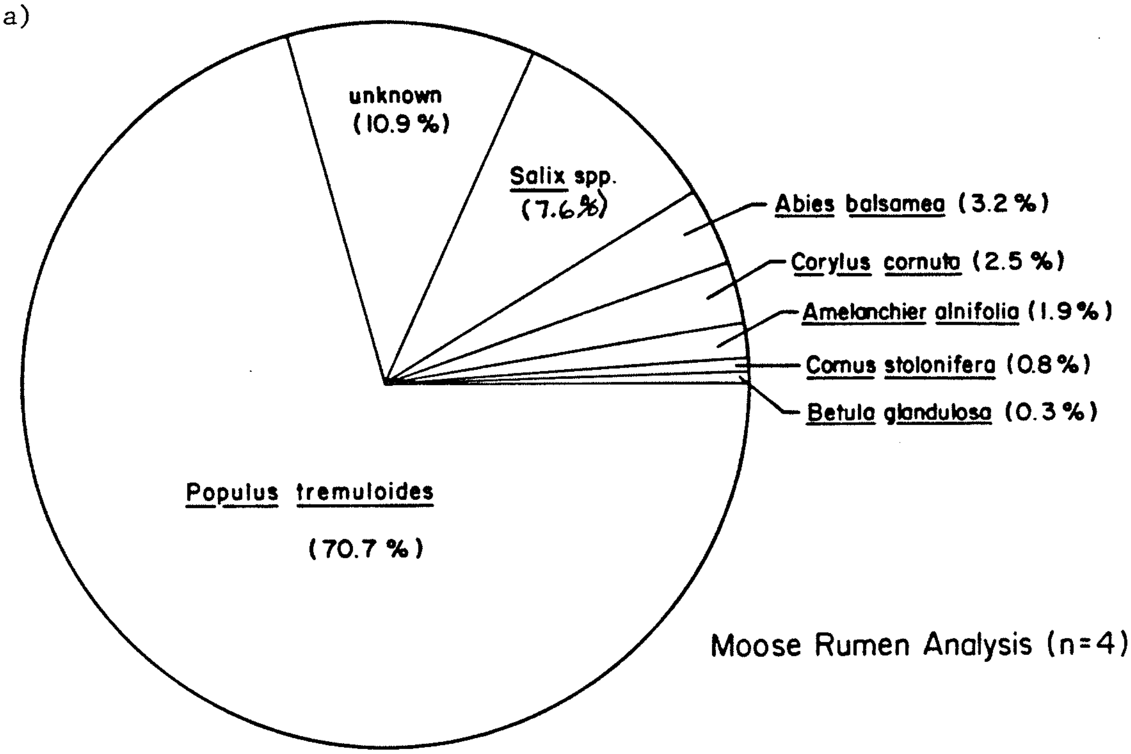

Pellet Group Counts
Pellet Groups / Hectare
150
100
50
0
Plot
Edge
Control
Deer
Elk
Moose
Browse Percentage
Percent Browse
100
50
0
Amelanchier alnifolia
(Saskatoon)
Cornus stolonifera
(Red osier dogwood)
Corylus cornuta
(Hazel)
Prunus pensylvanica
(Pincherry)
Prunus virginiana
(Chokecherry)
Salix spp.
(Willow)
Viburnum lentago
(Nannyberry)

Fig. 4.8. The average percent of the total dry weight made up by each plant or groups of plants in (a) the moose rumens and (b) the elk rumens.

(a)


unknown
(10.9 %)
Salix spp.
(7.6%)
Abies balsamea (3.2 %)
Corylus cornuta (2.5 %)
Amelanchier alnifolia (1.9 %)
Cornus stolonifera (0.8 %)
Betula glandulosa (0.3 %)
Populus tremuloides
(70.7 %)
Moose Rumen Analysis (n=4)

(b)

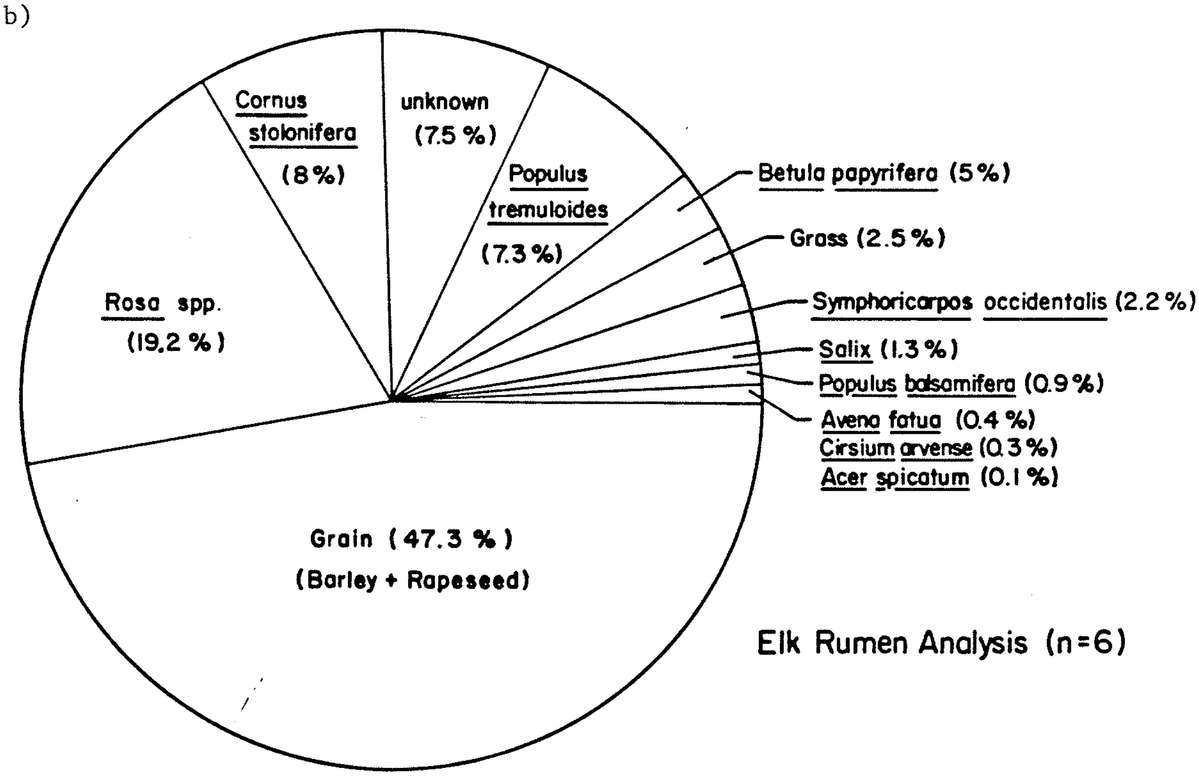
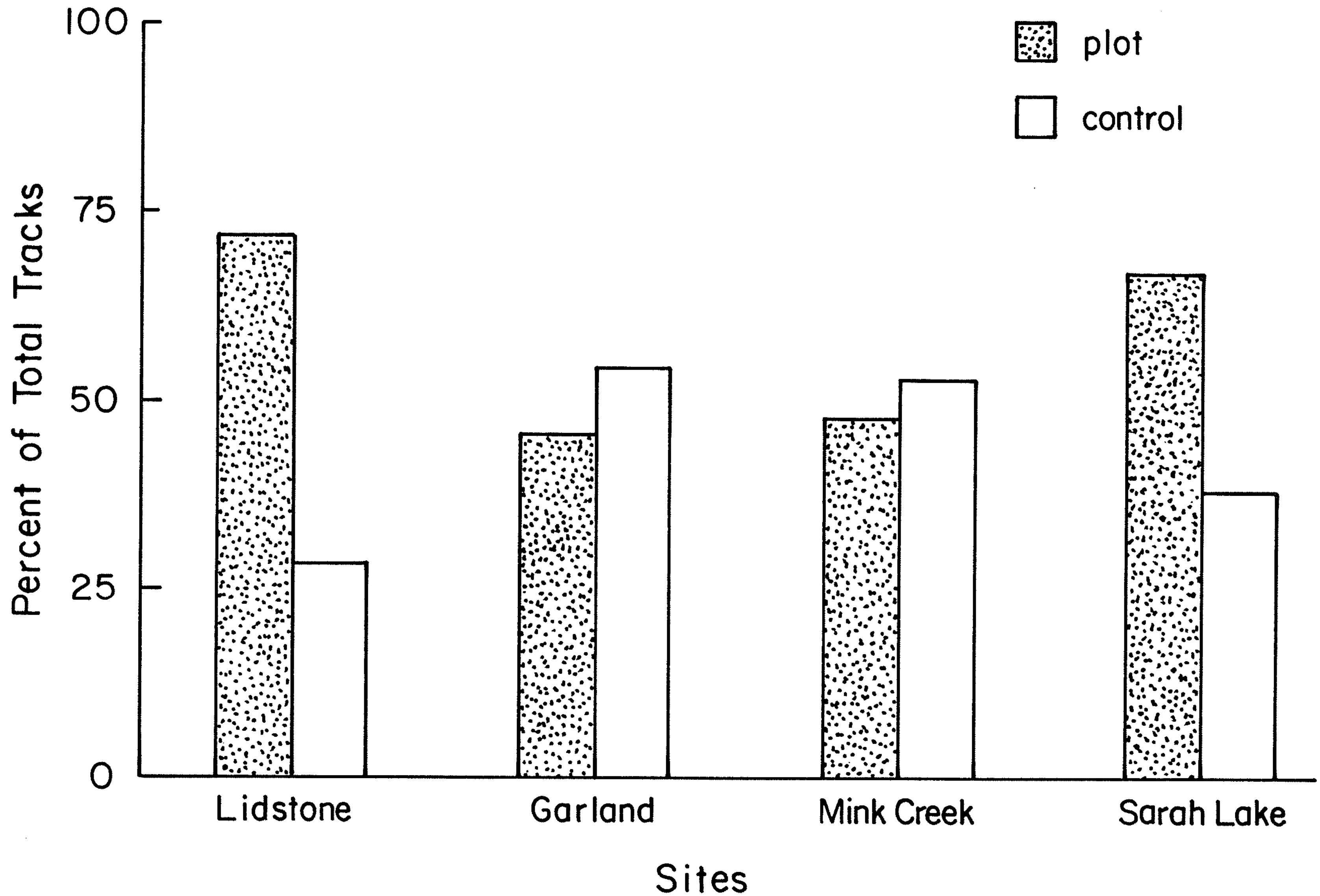

Cornus
stolonifera
(8%)
unknown
(7.5 %)
Populus
tremuloides
(7.3%)
Betula papyrifera (5%)
Grass (2.5 %)
Symphoricarpos occidentalis (2.2 %)
Salix (1.3 %)
Populus balsamifera (0.9 %)
Avena fatua (0.4 %)
Cirsium arvense (0.3 %)
Acer spicatum (0.1 %)
Rosa spp.
(19.2 %)
Grain (47.3 %)
(Barley + Rapeseed)
Elk Rumen Analysis (n=6)

Fig. 4.9. The percent of total ungulate tracks found in the plot as compared to the control for the four sites.



100
75
50
25
0
Percent of Total Tracks
plot
control
Lidstone
Garland
Mink Creek
Sarah Lake
Sites

while some alien plants(wild oats and Canada thistle) made up a small amount.

(d) Browse utilization

Table 4.1 and Table 4.2 list plant species which have been noted as browsed by the ungulates in the summer and in the winter, respectively. The percent browse for some of the shrub species which received a significant use is graphed in Fig. 4.4, 4.5, 4.6 and 4.7 for Sarah Lake, Lidstone, Garland, and Mink Creek respectively.

At Sarah Lake, saskatoon, hazel, balsam poplar, pincherry, and low bush-cranberry were browsed more in the plot or edge areas than in the control(Fig. 4.4). Contrarily, the red-osier dogwood shrubs and aspen seedlings or shoots in the control were browsed more intensively by the ungulates.

There was a significant difference($\alpha = 0.05$) in the percent browse of the total number of browse shrubs between the plot, edge and control at Sarah Lake(Table 4.3). Browse consumption of saskatoon, willow, balsam poplar and aspen was high along the edge as compared to the plot and the control; however, browse consumption of beaked hazel was the greatest in the control and pincherry was greatest in the plot. Total browse consumption did not differ significantly. Table 4.3 lists the average values for plot, edge and control for the number of available shrubs, the percent total browse and the browse consumption for all sites.

At Lidstone the percent browse was greatest in the plot and along the edge for all shrubs except for red-osier dogwood(Fig. 4.5). The availability of saskatoon and red-osier dogwood was very low in

Table 4.1. The plant species which had been browsed by the ungulates in the summers of 1979 and 1980 for all sites.

Scientific name	Common name
Abies balsamea	Balsam fir
Acer spicatum	Mountain maple
Amelanchier alnifolia	Saskatoon
Aster ciliolatus	Lindley's aster
A. novae-angliae	New England aster
A. pansus	Many-flowered aster
A. simplex	Small blue aster
Avena fatua	Wild oats
Betula glandulosa	Swamp birch
B. papyrifera	White birch
Calamagrostis canadensis	Marsh reed grass
Caltha palustris	Marsh-marigold
Carex spp.	Sedges
Chenopodium hybridum	
Cirsium arvense	Canada thistle
C. muticum	Swamp thistle
Cornus stolonifera	Red-osier dogwood
Corylus cornuta	Beaked hazel
Diervilla lonicera	Bush-honeysuckle
Epilobium angustifolium	Fireweed
Lonicera dioica	Twining honeysuckle
Petasites saggittatus	Arrow-leaved colt's-foot

Table 4.1 continued

Populus balsamifera	Balsam poplar
P. tremuloides	Trembling aspen
Prunus pensylvanica	Pincherry
P. virginiana	Chokecherry
Ribes americanum	Wild black currant
Rosa spp.	Roses
Rubus idaeus	Wild red raspberry
Salix bebbiana	Beaked willow
S. interior	Sandbar willow
Salix spp.	Willows
Symphoricarpos albus	Snowberry
Urtica dioica	Stinging nettle
Viburnum edule	Low bush-cranberry
V. opulus var. americanum	High bush-cranberry

Table 4.2. The plant species which had been browsed by the ungulates in the winter of 1979.

Scientific name	Common name
Abies balsamea	Balsam fir
Acer spicatum	Mountain maple
Amelanchier alnifolia	Saskatoon
Betula glandulosa	Swamp birch
B. papyrifera	White birch
Cornus stolonifera	Red-osier dogwood
Corylus cornuta	Beaked hazel
Populus balsamifera	Balsam poplar
P. tremuloides	Trembling aspen
Prunus pensylvanica	Pincherry
P. virginiana	Chokecherry
Rosa spp.	Roses
Rubus idaeus	Wild red raspberry
Salix bebbiana	Beaked willow
S. interior	Sandbar willow
Salix spp.	Willows
Symphoricarpos albus	Snowberry
Viburnum edule	Low bush-cranberry
V. opulus var. *americanum*	High bush-cranberry

comparison to the percent browse(Table 4.4). The percent browse was relatively high for hazel but the percent availability was over 50 percent. The browse consumption for all species including red-osier dogwood was highest in the edge quadrats or in the plot quadrats. The differences between the plot, edge and control were statistically significant.

At Garland the percent browse for the shrubs did not show significant differences between plot, edge and control. For 5 species including mountain maple, red-osier dogwood, balsam poplar, pincherry and chokecherry, the lowest browse was recorded in the control(Fig. 4.6). Contrary to the results at the Lidstone site, the percent browse of saskatoon was low and the percent browse for red-osier dogwood was higher even though their availability remained the same (Table 4.5). The dry weight of browse was higher along the edge and in the plot for all species.

Even though there were no significant differences between the percent browse between the plot, edge and control for Mink Creek, all species provided the least browse in the control(Fig. 4.7). Similar results were found for browse consumption whereby the differences between the plot and control were nonsignificant but the lowest consumption occurred in the control.

(e) General observations

Bedding sites of moose, elk and white-tailed deer were found in the plots and controls of all sites. Pellet groups for moose, elk and deer were found at all sites and in all seasons. Game trails (Plate 4.3b and 4.3c) were found along the perimeter of all plots

Table 4.3. The average values for available browse, percent browse and browse consumption for the plot, edge and control for the 8 treatments.[1]

Treatment	Available browse (Number of individuals)			Percent browse (Percent)			Browse consumption (Dry weight in grams)		
	plot	edge	control	plot	edge	control	plot	edge	control
S-78	9.77	26.92	15.67	0	30	11	0.00	15.82	42.45
S-77	17.90	16.80	20.80	3	32	28	0.37	11.58	172.32
M-76	30.83	56.67	20.25	0	5	9	0.00	8.41	11.88
G-75	39.07	34.78	12.07	12	15	10	5.86	4.10	0.43
M-75	29.60	23.60	28.40	9	15	2	23.25	15.82	9.67
M-74	51.35	39.89	16.50	15	6	5	5.09	6.08	5.08
S-73	14.36	4.50	13.21	16	29	19	4.62	5.79	10.60
L-73	41.77	24.92	10.57	37	38	9	11.06	15.88	0.60

[1]The standard error of the mean for each average value is given in Appendix F.

able 4.4. The percent of the total number of individual shrubs ompared to the percent of the total number hich have been browsed in the Lidstone site.

	Plot		Edge		Control	
pecies	% total	% browse	% total	% browse	% total	% browse
melanchier alnifolia	2.7	70.0	2.1	100.00	5.1	-
cer spicatum	3.3	4.0	25.4	47.9	28.8	-
'ornus stolonifera	1.2	55.5	9.8	60.7	3.4	100.00
'orylus cornuta	57.4	27.8	28.2	19.8	52.5	-
'opulus balsamifera	2.9	-	7.3	-	1.7	-
'. tremuloides	6.0	48.9	2.1	-	-	-
'runus pensylvanica	0.6	-	1.7	10.0	-	-
'. virginiana	1.5	9.1	6.6	57.9	3.4	-
!osa spp.	0.9	-	0.7	-	-	-
!ubus idaeus	20.8	2.5	-	-	-	-
'iburnum edule	1.2	11.1	1.0	-	1.7	-
'. opulus	-	-	-	-	3.4	-
!ibes americanum	0.9	-	-	-	-	-
!. triste	0.1	-	-	-	-	-
,onicera dioica	0.5	-	-	-	-	-

Table 4.5. The percent of the total number of individual shrubs compared to the percent of the total number which have been browsed in the Garland site.

Species	Plot		Edge		Control	
	% total	% browse	% total	% browse	% total	% browse
Amelanchier alnifolia	3.0	16.1	2.4	15.4	2.7	33.3
Acer spicatum	-	-	3.1	36.8	3.6	25.0
Cornus stolonifera	8.5	74.1	11.3	76.7	3.6	25.0
Corylus cornuta	43.6	4.2	42.2	2.4	49.5	-
Populus balsamifera	7.6	-	1.3	28.6	-	-
P. tremuloides	17.4	9.9	5.9	17.1	4.5	40.0
Prunus pensylvanica	5.9	1.6	0.9	16.7	0.9	-
P. virginiana	1.9	15.0	4.1	19.0	0.9	-
Rosa spp.	2.3	-	2.6	-	9.0	-
Rubus idaeus	2.1	-	3.4	-	0.9	-
Symphoricarpos albus	-	-	-	-	6.3	-
Viburnum opulus	0.5	-	4.7	-	1.8	-
Alnus rugosa	0.2	-	4.1	-	2.7	-
Salix spp.	4.8	2.0	3.9	-	3.6	-
Rhamnus alnifolia	-	-	0.8	-	12.6	-
Lonicera dioica	-	50.0	1.5	-	-	-
L. villosa	0.4	-	-	-	-	-
Fraxinus pennsylvanica	0.6	-	-	-	-	-
Ribes oxyacanthoides	1.0	-	0.2	-	-	-

except for two of those examined. Trails in Lidstone and Sarah Lake went through the plot beside windrows(but seldom went between windrows).

Animals were sighted in some plots at all sites. Feeding craters made by elk were found in some plots in February 1980(Plate 4.2b).

A few aspen saplings appeared to serve as rubbing posts for the antlered ungulates. Wallows made by the hooves of elk were found in one of the Sarah Lake plots. Skeletal remains were found in the plots and controls(Plate 4.1a).

Although there was an emphasis on the winter use of the plots, qualitative data on use by the ungulates was documented throughout the summer. Elk and deer were seen in the plot throughout the summer. Fresh elk and deer droppings were found in some plots at all sites in all seasons. Many herbs including those in Table 4.1 were eaten by the ungulates(Plate 4.3a and 4.3d).

Trails crossed the Lidstone plots at various places as the windrows which were burnt did not hamper movement(Plate 2.6a). A greater amount of red-osier dogwood, raspberry and invader species grew along the windrows. From afar the shrubs along the windrow appeared to be cropped off to the same height by ungulates. Trails along or within the burnt rows were common.

During the course of the field work, showshoe hares were abundant and were seen daily. Hares used the windrows for resting in winter and summer. The S-73 plots also provided the hares with abundant forage and adequate hiding places from predators underneath the deadfall. Numerous signs of girdling of shrubs by hares were found in these plots(Plate 4.2d). Hazel was the preferred food for

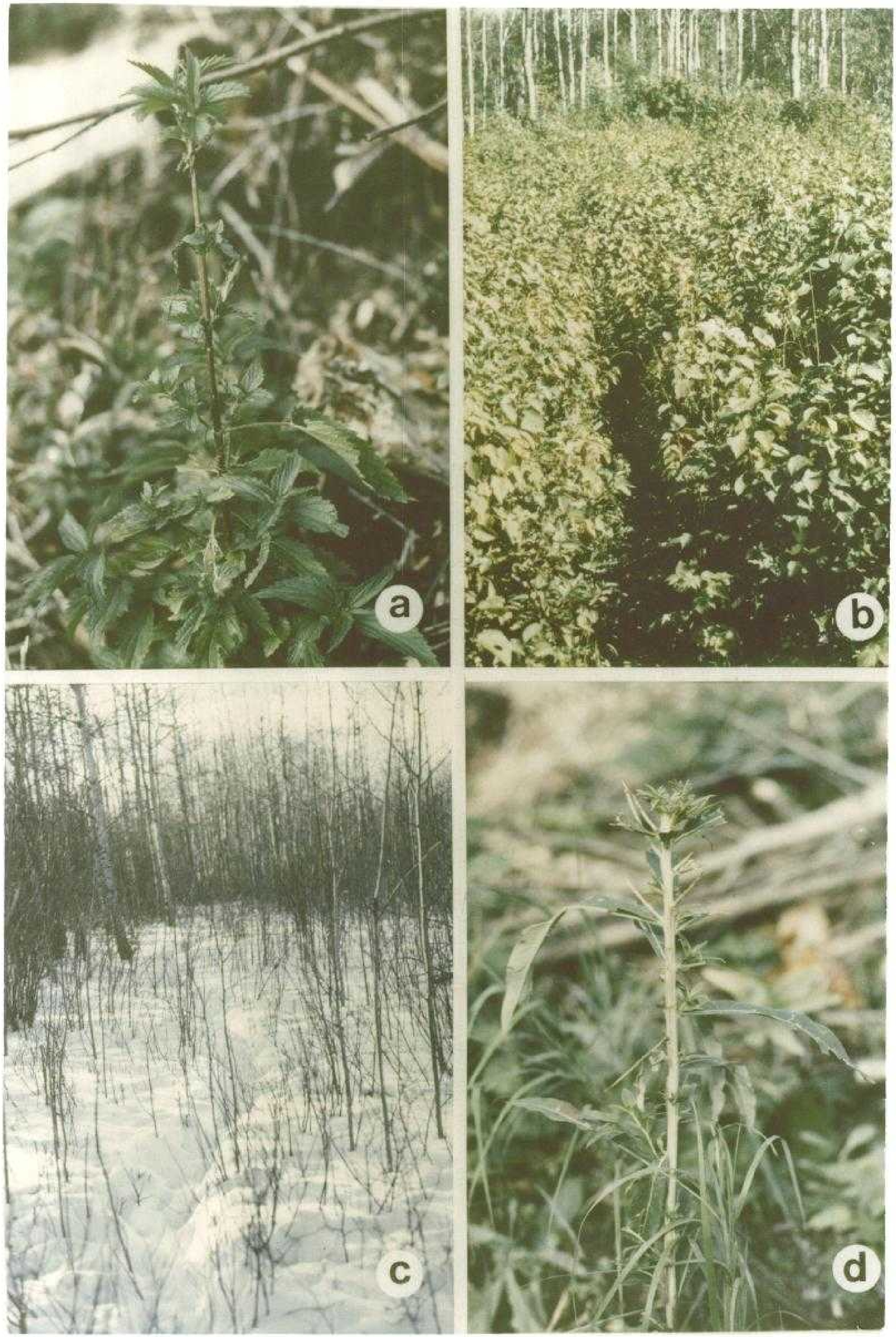
Plate 4.3. Ungulate use of the plots.

a) Stinging nettle(*Urtica dioica*) was eaten by elk in the summer.

b) A game trail in a Lidstone plot.

c) A game trail along the edge of a plot.

d) Fireweed(*Epilobium angustifolium*) which had been browsed by an ungulate.


a
b
c
d

snowshoe hares followed by rose. Other forage included aspen, speckled alder, chokecherry, mountain maple, saskatoon, low bush-cranberry, raspberry, red-osier dogwood, high bush-cranberry, pincherry, balsam poplar and wild gooseberries.

D. Discussion

(a) Food habits

The habitats for ungulates are dependent on the availability of the preferred plant species in the plots, along the edges and in the controls. Determination of browse use in this study provides information on the abundance of plant species with reference to the food habits of the ungulates.

Although hazel was not the most preferred food for the ungulates, it did provide a large proportion of the browse. These results are similar to those obtained by Trottier and Samoil(1978) in Riding Mountain, where hazel provided food for moose, elk and deer. Saskatoon, red-osier dogwood and aspen were also eaten in large quantities, the former two species being less available but more preferred. Saskatoon provided the bulk of the elk diet in Riding Mountain while red-osier dogwood was not an important part of the wildlife forage due to its low availability(Trottier and Samoil 1978).

Rumen sampling is another method used to determine feeding preferences of the ungulates; however, the results document the feeding preference of one animal at one point in time. The presence of certain plant species in a rumen sample documents use of the species in the area. Even though the sampling is limited, the results support the browse studies.

The results of the moose rumen sampling suggest that the moose in the Duck Mountain feed heavily on the aspen in mid-winter. The importance of aspen in the diet of the moose has been documented by Nowlin(1978) in northeastern Alberta. Aspen was also found to be an important browse species in the browse analysis.

The food species found in the elk rumens correspond well with other studies. A large proportion of the elk's fall diet in the Porcupine Forest(Saskatchewan) consists of agricultural crops(Hunt 1979) as was found in this study. Some of the elk's diet is made up of forbs(Blood 1966, Hunt 1979) and shrubs(Trottier and Samoil 1978). Often invader species are found in the elk rumens(Hunt 1979). Wild oats and Canada thistle were two invader species found in the elk rumens from the Duck Mountain.

(b) Ungulate response to clearing

(i) Comparisons of ungulate use between plot, edge and control

The differences between plot, edge and control are discussed with reference to the type of treatment and the successional stage of the plot. Some of these differences can be attributed to clearing; however, factors including human disturbances and weather also affected the use of the areas by ungulates.

Ungulate use of the clearcuts as determined by pellet group counts, track counts and browse utilization was generally greater in the plot and along the edge as compared to the control. Each index gives information on some aspect of the way ungulates use the plots. Pellet group counts and browse utilization give an index of the best foraging areas while track counts give a better idea of the use of the habitats for cover, shelter and travel routes(Bennett et al. 1940).

The use of the plots, the edges and the controls depended on the successional stage of the areas. In general, plot use increased from 0 to 7 years after treatment.

The most recently bulldozed plots(S-78) showed the least use by the ungulates. At the beginning of the field study, in the spring of 1979, the S-78 plots were devoid of vegetation. The 1979 pellet group counts did show use of the area. The ungulates could have used the pre-plot vegetation in early winter before bulldozing took place. They could use the plots as travel routes which could provide them easier movement along or between the windrows. As a number of the pellet groups were found beside the windrows and signs of browsing were found on the trees in the windrows, the ungulates probably used the windrows to provide them with palatable browse in the first winter.

After one year's growth, some of the shrubs in the plot attained a height which were above snow level. They would serve as available winter food for the ungulates. Still, the abundance of tall shrubs was low and the energy expended by an ungulate per unit of forage would have been great.

These results corresponded to those obtained in central Alberta (Usher 1978). One of the two study sites was used less than the other even though they both had two years of growing time since clearing (Usher 1978). Usher attributed the differences to the height of the shrubs. The less used site had less available winter browse due to the shorter shrubs.

Generally, the pellet group counts at Sarah Lake showed a decline in ungulate use for the winter of 1979-1980. This can be attributed to the logging which was carried out in the Sarah Lake site. Trees had been cut within a few feet of some of the plots and the plots were used to store logs(Plate 4.2a). Hunting pressure was also a factor. Before the hunting season very little snow fell and the trails were readily accessible to regular road vehicles. The general increase in traffic would be enough to move ungulates from the area(Rost and Bailey 1979).

Moose appeared to be least affected by the human disturbances but elk and deer appeared to be more prone to disturbance effects. Rost and Bailey(1979) also found that elk and mule deer were suceptible to human disturbances such as traffic. Moose have been cited as inhabiting roadside communities as snow depths are decreased due to snow ploughing(Van Ballenberge and Peek 1971).

In the S-77 plots, the logging traffic was more frequent as these plots lie directly north of the main road(Fig. 4.5). Logging was greatest in this part of the Sarah Lake site.

In S-73 the trees were cut down and allowed to fall at random. The use of these plots was greater for moose and elk than for deer. Deer have shorter legs and could not traverse the criss-crossed logs. Even though seven years had past, the logs still remained solid. Reynolds(1969) found that the deer used areas more frequently if no slash was deposited. If access to forage is easy, ungulates will feed in the area(Short et al. 1977).

Higher use of S-73 plots by snowshoe hare could be attributed to the abundant food supply and the good hiding places from predators. As the snowshoe hare populations were high throughout the sampling period, their observed use of the plots would not be the same when their populations were lower.

Few differences were found between M-74, M-75 and M-76 plots. These differences only reflected slight differences in site locations especially regarding the traditional use of the areas and the amount of human disturbance. M-76 would be least affected by humans as it is farther away from the main roads (Fig. 1.2).

The plants in the controls were similar in diversity and abundance. The plants in the plots were also similar between the

3-, 4- and 5-year stands(M-74, M-75 and M-76), as the treatments were applied only a year apart. Vallee et al.(1976) found that the number of stems did not differ significantly between 5- and 12-year old stands in clearcuts in Quebec. So differences among 3-, 4- and 5-year stands would be less noticeable.

The Garland site showed a similar use of plots versus controls as did the Mink Creek site. The site differences were not great and the year of treatment was the same as one of the Mink Creek treatments.

The edge effect was noted in this study where the ungulates preferred the edges more than the rest of the plot. The larger the clearcut, the more deer use the edges(Drolet 1978). In smaller ones the edge effect is hardly noticed. Cairns and Telfer(1980) conclude that elk also prefer the edges of plant communities. Le Resche et al.(1974) attribute an increase in the moose population to an increase in ecotonal edge. Deer, elk and moose used the edges more in the Duck Mountain clearcuts than the plots or controls in this study even though the plots were small.

The edge effect was noted especially along the bulldozed trails between plots. The trails were, in fact, long narrow winding plots. Ungulate use, with special reference to travel routes, was high along the trails. Drolet(1978) found that deer used roads through a plot more than the rest of the plot. Hamilton and Drysdale(1975) and Scaife(1980) reached similar conclusions for moose. The moose used the roadside vegetation because of the ease of access. MacLennan(1975) and Hunt(1976) discovered that moose tend to remain closer to the edges of large clearcuts.

The preparation of windrows for storing the clearing debris is controversial in light of the animal use of the plots. In this study it was found that the windrows provided better access to the plots than did the S-73 treatment where logs were strewn across the plot. The windrows themselves did not put up a barrier to travel as trails were found throughout; however, the windrows did prevent random movement in the plot. Usher(1978) found a number of windrows, that after settling, were crossed at low points when the snow was deep. Usher(1978) concluded that the windrows prevented random movement of the ungulates in the plot.

Windrows are recommended by some to rid the area of debris (Usher 1978). Availability of forage would be increased if the area was free of logging debris. In this study, use of the vegetation near the burnt rows at Lidstone was greater than the use of the ungulates of the vegetation in the surrounding plot. Nutrients from burnt logs could enter the ecosystem faster and could result in vigorous plant growth for the first few years after burning.

The size and shape of the plots were suitable for ungulate use. As most plots range from 0.5 to 2 ha, their use was not determined by their sizes. Previous authors have recommended even greater maximum plot size(Telfer 1974b; 1978, Hamilton and Drysdale 1975, Ffolliott et al. 1976, Stelfox et al. 1976, Short et al. 1977, Usher 1977; 1978, Drolet 1978).

Although U-shaped, triangular and irregular-shaped plots were not studied in detail, no obvious differences were noted. The shape of the plot would alter the amount of edge present(Patton 1974).

From the ungulate use study, it appears that some plot types are used more than others. For example, the Lidstone were used more frequently than the other study sites. The reasons for this high use could be the result of a) the large standing trees providing cover; b) the irregular-shaped plots providing a greater edge area; c) the burnt windrows providing random access to all parts of the plot; d) the past traditional use of the area providing animals to inhabit the disturbed sites; and e) the small clearcuts providing mature forest nearby for cover and an abundant food supply in the clearing. All the above attributes of the plots would contribute in part to the ungulate use. Focus on any one factor would be simplifying the interrelationships between plants and animals.

(ii) Comparisons of ungulate use between sites

The ungulate use of the plots was reflective of traditional use of the sites. Lidstone has the largest population of elk. Sarah Lake, Garland Canyon and Mink Creek have higher populations of deer but the total ungulate populations are lower than at Lidstone. The areas on the southeast side of the Duck Mountain Forest Reserve support less elk, moose and deer than the rest of the Duck Mountain(Searle and Bukowsky 1973). The data from the pellet group counts and the browse use reflected these differences.

The data collected on ungulate use showed other differences among the sites. The 1980 pellet group counts showed significant differences for elk and deer between Sarah Lake and Lidstone but not differences for moose. There were no significant differences between the deer counts at Garland and Mink Creek but the moose and elk data did differ significantly. In all cases the southeast (Mink Creek and Garland) and the northeast(Lidstone and Sarah Lake) differed signicantly($\alpha = 0.05$).

The browse consumption differed significantly between all sites but the percent browse values were similar for Mink Creek and Garland and for Sarah Lake and Lidstone.

The availability of browse and the percent browse reflected the high population of elk in the Lidstone site if one examines regional results on ungulate food habits. The preference for saskatoon was higher than red-osier dogwood at Lidstone but at

Garland saskatoon rate much lower. Elk, whose population was much higher at Lidstone, prefer saskatoon(Trottier and Samoil 1978) and moose, whose population was higher at Garland, prefer red-osier dogwood(Crichton 1977, Usher 1978).

Some of the ungulate use differences can be attributed to the floristic differences at the sites(Chapter II). Plant species composition and plant species density differed between all sites: however, plant chacteristics such as the number of species of herbs, the number of herbs and the number of alien plants in the plot did not differ between Sarah Lake and Lidstone. Differences were found beteen Garland and Mink Creek.

In addition to the floristic differences, northwestern sites are on the north slope while the southeastern sites are on the east slope of the Duck Mountain. Although the elevation changes are not drastic, environmental changes were apparent. Snow depths in 1980 were greater on the north slope by 10 cm. Frost killed the plants on the north slope 3 weeks before those on the east slope in September 1979. These differences could account for some of the variation between sites.

The characteristics of each site play an important role in the ungulate use of the plots, edges and controls. Even if the plots are being used significantly more than the controls, other contributing factors could decrease or increase ungulate use. Yet, on the span of sites and treatments examined it can be concluded that ungulate use was higher in the plots and along the edges than in the controls.

CHAPTER V

BENEFIT-COST ANALYSIS FOR THE DUCK MOUNTAIN HABITAT MANIPULATION PROJECT

A. Introduction

Benefit-cost analysis is being used by a number of government agencies to determine economic feasibility of natural resource projects (Mishan 1973). The purpose of a benefit-cost analysis is defined by Mishan (1973) as 1) to determine, before undertaking projects, which project will yield higher returns and 2) to determine when undertaking one project whether or not the benefits will outweigh the costs. The purpose of this benfit-cost analysis is to determine if the benefits of the Duck Mountain Habitat Manipulation Project are greater than the costs.

The economic value of wildlife must be defended against competing resources (Bart et al. 1979). Sometimes, as is the case for most natural resources, the price of goods is often meaningless. In their article on economics and wildlife, Bart et al. (1979) discuss methods which give economic values to wildlife and wilderness. They use a definition of economic value as quoted from Clawson and Knetson (1966) namely: "Economic values are measured basically by what people are willing to give up; a relevant economic measure of recreation value is, therefore, the willingness on the part of consumers to pay for outdoor recreation services."

Another aspect of economic value determination is shadow pricing. A shadow price is the price tag attached to goods which is more appropriate in economic terms than the actual value of those goods (Michan 1971). For example, the value of a moose is difficult to assess if one considers its role in the ecosystem. Meat, aesthetic value and its role in nature are only some of its worth. Its real price may be the price hunters will pay for a licence. If a hunter uses moose meat as a beef alternative, moose meat would be worth the equivalent in beef.

A second important aspect of benefit-cost analysis is the discount rate. Costs today will be more than the costs for a year from now but the opposite is true for benefits. Benefits are worth less in the future than they are today (West and Miller 1978). By using a discount rate one can see the actual balance of benefits and costs in today's value of the dollar (or at some specific point in time).

The money which is invested in a government project today could also be invested in the private sector. If one receives a higher rate of return from investing in the private sector rather than in a government project, it would be economically sound to do so. If a government spends money on a project it must benefit the people. If they would benefit more from investment of the government money in the private sector, the government should invest privately. The government has to make decisions which maximize profits for present generations but it must take into account future generations. A government must decide what is economically beneficial for society as a whole (Mera 1968).

B. Background Information

According to aerial surveys (1972 - 1977), the increase in the ungulate population has been higher than the pretreatment population by an average of 49 animals (11 moose, 11 elk and 27 deer).Therefore there are 49 animals more in the 40 sq. miles of the plots in a given year as compered to pre-plot years. From the previous chapters it appears that the plots are producing significantly more browse than in surrounding areas. The animals are using the plots more than the controls. No one will ever know if the plots actually caused the increase in animals but the evidence does support the theory. The surveys do cover a number of years, both good and bad years for ungulate populations. Thus, the estimate is not biased towards a very good year.

The hunter use of the plots is a little more tangible. The hunters do use the area more frequently. Firstly, there is ease of access for the hunters. Secondly, the animals are in the plots and they are more easily spotted there.

C. Costs

The costs as found in Table 5.1 were encountered in the first five years of the project. After these initial outlays of capital, no further costs would be needed to upgrade the project. The costs include the salaries paid to Natural Resource personnel who surveyed the plots (estimates only) and the actual bulldozing costs. Part of these costs are benefits as they provide salaries for the caterpillar operators who are local farmers. Thus, the project provided local employment. As the costs are incurred over a five-year period the discount rate applies to them. The costs paid in 1973 were more of a burden in 1973 than the same costs in the following years (ie. dollar for dollar). The costs unlike the benefits are quite easily calculated.

Table 5.1. Costs and Benefits for the Duck Mountain Habitat Manipulation Project in dollars of the year they occurred.[I]

YEAR	COSTS ($)			BENEFITS ($)		
	Operators	Bulldozing	Surveying	Wages	Hunter use	Animal prices
1973	6842	8708	3280	6842	0	0
1974	5741	7307	2320	5741	4768	8220
1975	7432	9458	2440	7432	5298	7181
1976	7004	8914	1480	7004	5887	6973
1977	1760	2240	0	1760	6541	8012
1978	0	0	0	0	7268	11545
1979	0	0	0	0	8076	13545
1980	0	0	0	0	8973	14664
1981	0	0	0	0	9870	15738
1982	0	0	0	0	10857	16812
1983	0	0	0	0	11943	17886
1984	0	0	0	0	13137	18960
1985	0	0	0	0	14451	20034
1986	0	0	0	0	15896	21108
1987	0	0	0	0	17485	22182
1988	0	0	0	0	19235	23256

[I] Appendix G contains more details on calculations of the prices prices found in the table.

D. Benefits

Some of the benefits were easy to calculate in monetary terms such as the benefits to the two caterpillar operators. Other benefits are not so readily assessed in monetary terms.

Shadow prices are used to evaluate the worth of a moose, elk or white-tailed deer. There is no existing price for a moose. Yet it must be worth something as hunters are willing to pay to go moose-hunting. A shadow price for a moose would be \$619.96, \$10.00 for its hide (Sidney I. Robinson fur and hides price list) and \$609.96 for its meat (69¢/pound multiplies by 884 pounds-average weight of a moose from Banfield (1974). There are other monetary values which could be attached to a moose depending on the person assessing the values.

The benefits of the Duck Mountain Habitat Manipulation Project are calculated in two ways: hunter costs and the price of the meat produced by the animals. Table 5.2 outlines these benefits. The first method uses the costs that hunters will incur in order to get animals. The extra animals that the plots maintain entice more hunters. The plots themselves provide easier access to the animals for the hunters. Signs of browse, pellet groups, bedding sites and the animals number greater in the plots as compared to the controls. The hunters have a greater probability of shooting one animal in the plots as compared to areas outside the plots.

If the plots were not present, some moose, elk and deer would still be at the sites. There also would be hunters. For the plots to be beneficial, they would have to entice more hunters than if the plots were not there. In the calculation, a value of ten hunters

Table 5.2. Benefits[I] of the Duck Mountain Habitat Manipulation

Year	Benefits in 1973 dollars (discount rate is 7%)	
	Hunter costs	Price of the animals
1973	-11988	-11988
1974	-4049	-1172
1975	-4583	-3282
1976	-2608	-1980
1977	2074	2783
1978	2729	4640
1979	2614	4562
1980	2504	4092
1981	2358	3660
1982	2221	3258
1983	2091	2889
1984	1969	2552
1985	1854	2247
1986	1746	1973
1987	1644	1728
1988	1548	1509
Total benefits	2124	29459

[I] Costs are included as negative benefits.

more than the pre-manipulation years (1972) was used. This figure is more than likely a underestimation as the plots are well known in the immediate vicinity. Ten rumen samples were also taken from the plot area suggesting that the hunters definitely are using the plots.

The second means of computing benefits is the worth of the animals. This is described above in shadow-pricing. The actual worth of the animals is calculated (Appendix A and B give more details on the calculations).

E. Discount Rates

What particular discount rate should be used for the project? As costs are high in the present and benefits are less beneficial in the future (West and Miller 1978), a discount rate must be used to determine tomorrow's wealth in today's prices.

Since the project was begun in 1972-73, all costs and benefits are calculated in 1973 dollars. A net benefit-cost ratio will be used.

Prest and Turvey (1965) use a 5-6 percent discount rate in the United States in the 1950's. Ramsay and Anderson (1972) quote a 4 percent rate for a government health project. Mishan (1971) quotes rates of 4 percent, 6 percent and 8 percent for projects in the 1960's. Foster (1963) state that discount rates between 4 and 8 percent do not make much differences in project assessments (as found in Prest and Turvey 1965) and from the aforementioned studies, a discount rate of 7 percent was chosen. In total 20 percent was discounted from the benefits as in Table 5.2 where 13 percent is the rate of inflation. Table 5.2 outlines the benefits of the Duck Mountain Habitat Manipulation project in discounted rates.

F. Benefit-Cost Analysis

A net benefit-cost ratio is used in Table 2 in order to determine the feasibility of the Duck Mountain Project. If the net benefit-cost ratio is greater than zero, the project is economically feasible (Mishan 1971). The calculations for the net benefit-costs are as follows:

$$\sum_{t=0}^{t=n} \frac{B_t}{(1 + r)^2}$$

where B = benefits
n = 15 years (project length)
r = rate of discount (7%)
t = time (years)

Costs are considered negative benefits.

The net benefit-cost for the hunter use is $2124.00 while the price of the animals gives a net benefit-cost of $29459.00 As both these values are larger than zero, the Duck Mountain Habitat Manipulation Project is economically feasible (ie. within the context of the assumptions made).

G. Problems with Benefit-Cost Analysis

Some of the problems involved in benefit-cost analysis have been discussed above. The two larger problems involve attaching price tags to some benefits and determining a suitable rate of discount. These assessments are more subjective in their estimation. In this project I tried to underestimate values.

More problems also lie within the project itself and not within benefit-cost analysis. It is very difficult to determine the benefits of projects when so many factors other than the project affect the animal populations; however, a crude estimation may be better than no estimation. Again it gives the public some idea as to the effectiveness of government spending.

More exact information could be obtained for benefits and costs if more time was used. Surveys could have been carried out in questionnaire form asking the hunters if they actually used the plot areas as did an Alaskan study (Buckley 1957) and the Delta Marsh Technical Committee (Development of the Delta Marsh 1967). Questions such as the following would have been useful:

1) When did you start hunting?
2) Where do you hunt? (section, township and range)
3) Do you use the plot areas to hunt?
4) Do you think the plots are useful to hunt in?
5) Did you shoot any moose, elk and deer?
6) How much did you spend on food, transportation, equipment, licenses and accomodation?

This study only looks at the value of wildlife in terms of the hunters. If one considers the values of nonhunters, the economic value of the animals would increase. Arthur and Wilson (1979) did three surveys on the public's attitude toward wildlife. Hunters and nonhunters were considered separately. Nonconsumptive uses of wildlife were the highest ranked in the importance rating for both hunters and nonhunters. The order of importance (overall) of all the wildlife uses were: 1) maintaining nature's balance, 2) enjoyment from knowing the animals exist,

3) viewing, 4) food, 5) hunting and 6) furs. Even though the hunters are willing to pay highly for their sport, they still find nonconsumptive uses of wildlife more enjoyable. Although it is easier to determine the economic value of wildlife in terms of hunting, the majority of the public do not do so.

Other benefits are not considered, such as the decrease in crop damage as the plots rather than the farmers' fields provide available food for the ungulates. The benefits could also be quantified by searching through the statistics on ungulate crop damage near the plots.

Other problems with benefit-cost analysis and with this particular study are the costs and benefits of goods. Wildlife could be assessed in terms of its meat value, its scientific value, or its aesthetic value. Bart et al. (1979) discuss economic value as the value which people are willing to give up in order to pursue their activities in the wilderness. Powell (1980) and Fried (1980) commented on the article by Bart et al. (1979). Powell (1980) states that it is impossible to place a value in dollar terms on wildlife and wilderness. Fried (1980) believes that there is no simple scale to assess aesthetic value. Although there is no simple way to determine the economic value of wildlife and wilderness, people are paying for the use of these resources. There is a value but it is difficult to determine. In the 'political arena,' wildlife managers have to use all the tools they can get, including economic values of wildlife, to preserve wildlife as wildlife competes with other resources (Bart et al. 1980).

The monetary values of other benefits are intangible. The windrows into which the trees are bulldozed deny access by the ungulates to all parts of the plot. The windrows do provide dens for bears and coyotes and resting places for grouse and snowshoe hare. The hare population increased because of more browse, more hiding places from predators and being at the top of their population cycle, which in turn increases the coyote and lynx populations (spillover effects). There would be an increase in the trapping potential of the area.

There is an increase in species diversity with bulldozing thus increasing the carrying capacity of the area. All these and many other benefits are a result of the Habitat Manipulation Project. However, one can not place monetary values on all of them.

The positive aesthetic value of the animals would be counteracted by the negative value of the disturbed land. One value which is not priced is the scientific value. The Duck Mountain Project is important to the field of wildlife management because other research on the ungulate and plant interactions is carried out at the same time as the effect of cutovers on populations of plants and animals. If one could add up all the benefits of the project, one would find an even greater net benefit-cost ratio.

CHAPTER VI

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

A. General Summary and Conclusions

The impact of clearcutting on the vegetation and of grazing and browsing by moose, elk and white-tailed deer in the Duck Mountain Forests was determined through a vegetation survey and an ungulate use survey. Numerous factors affected the plant growth and ungulate use of the clearcuts. The major results of these studies are summarized below.

1. Species richness or diversity of the flora was greater in the clearcuts than in the mature stands. The number of invader species is greater in the plots than in the controls thereby increasing the diversity of the former.
2. After seven years of regeneration, the density of the shrubs in the plot is double that of the shrubs in the control.
3. Leaching and erosion were not problems in the small clearcuts but the % organic matter in the O horizon was greater in the controls at some sites. Revegetation occurred rapidly so the soils were soon protected.
4. Moose, elk and white-tailed deer used the plots more than the controls. The plots three to seven years old received the most ungulate use. The plots at Lidstone which were seven years old received the heaviest use by moose and elk.
5. The edges of the plots and the trails to the plots were well used by the ungulates. The edges and trails provided more ecotonal regions where cover and food availability are greater. The abundance of a number of shrubs especially browse species like beaked hazel and aspen was greatest

along the edge.

6. A benefit-cost analysis of the Duck Mountain Habitat Manipulation Project (using a seven percent rate of discount over a 15-year period) reveals that the benefits in terms of hunter use or the benefits in terms of animal production are greater than the costs. The project is economically feasible when judging the project in the light of the aforementioned criteria (Chapter V).

B. Management Recommendations

The results of these studies are useful in suggesting recommendations for the management of the plant communities and the ungulates in the Duck Mountain, Manitoba. Some recommendations follow:

1) Small cutovers (0.5-2 ha) are useful to increase plant species diversity and ungulate use of an area.
2) The trees in the cleared areas should be pushed into windrows so access by moose, elk and deer is made easier. To further increase access to the entire plot and to allow random movement throughout a plot, the windrows should be burnt; however, this could lead to loss of nutrients from the ecosystem.
3) The edge is most beneficial in terms of browse quality and quantity to moose, elk and deer. An increase in edge area can be produced by the preparation of irregular shaped plots or long narrow plots or by the presence of residual stands in a larger clearcut.
4) A series of seral stages provides a greater mosaic of plant communities and correspondingly an increase in the diversity of browse species. Even if there are a number of plots in the first stage of regeneration, other plots in more advanced stages would be available to the ungulates.
5) A rotation of cutting is recommended every 12 to 15 years, as was suggested by Usher (1978) but in addition a staggered cutting program in Duck Mountain is considered to be more beneficial. A selective thinning could also produce

favorable results in terms of browse species.

6) Before future clearing is undertaken, it is strongly recommended that studies on browse quality and ungulate use take place. After clearing, reassessment of these factors would provide more detailed information on the use of plots.

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APPENDICES

Appendix A. Plant Species List

PLANT SPECIES LIST

	Garland	Mink	Lidstone	Sarah
EQUISETACEAE				
Equisetum arvense L.	x	x	x	x
Equisetum fluvatile L.				x
Equisetum scirpoides Michx.	x	x	x	x
LYCOPODIACEAE				
Lycopodium complanatum L.				x
OPHIOGLOSSIACEAE				
Botrychium virginianum (L.) Sw.	x	x	x	x
POLYPODIACEAE				
Dryopteris cristata (L.) Gray	x			x
Matteuccia struthiopteris (L.) Todaro	x	x	x	x
PINACEAE				
Abies balsamea (L.) Mill.	x			
Larix laricina (Du Roi) K. Koch	x	x		x
Picea glauca (Moench) Voss	x	x	x	x
Pinus banksiana Lamb.	x			
TYPHACEAE				
Typha latifolia L.				x
ALISMATACEAE				
Alisma plantago-aquatica L. var. *americanum* Schultes & Schultes			x	
Sagittaria latifolia Willd.				x
GRAMINEAE				
Agrostis stolonifera L.	x			
Agropyron pectininiforme R. & S.				x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Agropyron trachycaulum(Link) Malte.	x	x	x	x
Agropyron trachycaulum var. *glaucum*(Pease & Moore) Malte.		x		
Avena fatua L.				
Beckmannia syzigachne(Steud.) Fern.	x	x	x	x
Bromus ciliatus L.	x	x	x	x
Bromus inermis Leyss.	x	x	x	x
Calamagrostis canadensis(Michx.) Nutt.	x	x	x	x
Cinna latifolia(Trev.) Griseb.		x		
Deschampia caespitosa(L.) Beauv.				x
Elymus canadensis L.	x	x		x
Elymus innovatus Beal	x	x		x
Glyceria grandis Wats.	x			
Glyceria pulchella(Torr.) Trin.			x	
Hierochloe odorata(L.) Beauv.		x		
Hordeum jubatum L.	x	x		x
Koeleria cristata(L.) Pers.	x	x	x	x
Oryzopsis asperifolia Michx.	x	x	x	x
Oryzopsis pungens(Torr.) Hitchc.	x			
Phalaris arundinacea L.	x			
Phleum pratense L.	x		x	
Poa palustris L.	x	x	x	x
Poa pratensis L.	x	x	x	x
Schizachne purpurascens(Torr.) Swallen			x	
Setaria viridis(L.) Beauv.	x	x	x	x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
CYPERACEAE				
Carex spp.	x	x	x	x
Carex atherodes Spreng.				x
Carex aurea Nutt.			x	
Carex bebbii Olney	x			x
Carex granularis Muhl.		x		
Carex lasiocarpa Ehrh. var. *americana* Fern.	x			
Carex retrorsa Schw.	x	x	x	x
Carex rostrata Stokes			x	
Carex stipata Muhl.	x		x	x
Scirpus microcarpus Presl.	x			
Scirpus lacustre L. ssp. *validus* (Vahl) Koyama	x			x
LEMNACEAE				
Lemna minor L.				x
JUNACEAE				
Juncus balticus Willd. var. *littoralis* Engelm.	x			x
Luzula acuminata Raf.	x			
LILICEAE				
Disporum trachycarpum (S. Wats.) B. & H.	x	x	x	x
Lilium philadelphicum L. var. *andinum* (Nutt.) Ker	x	x	x	x
Maianthemum canadense Desf. var. *interius* Fern.	x	x	x	x
Smilacina stellata (L.) Desf.	x	x	x	x
Smilacina trifolia (L.) Desf.		x		
Streptopus amplexifolia (L.) DC. var. *americanus* Schutes				x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Streptopus roseus Michx. var. *perspectus* Fassett		x		x
Trillium cernuum L.			x	x
Zigadenus elegans Pursh		x		
IRIDACEAE				
Sisyrinchium montanum Greene	x	x		x
ORCHIDACEAE				
Corallorhiza striata Lindl.		x		x
Cypripedium calceolus L. var. *parviflorum* (Salisb.) Fern.	x	x	x	x
Cypripedium reginae Walt.		x		
Habenaria hyperborea (L.) R.Br.		x		
Malaxis unifolia Michx.		x		
SALICACEAE				
Populus balsamifera L.	x	x	x	x
Populus tremuloides Michx.	x	x	x	x
Salix amygdaloides Anderss.	x		x	
Salix bebbiana Sarg.	x	x	x	x
Salix exigua Nutt. ssp. *interior* (Rowlee) Cronq.	x			
Salix interior Rowlee	x			
Salix lutea Nutt.	x			x
Salix pellita Anderss.	x			x
Salix petiolaris Sm.		x		
BETULACEAE				
Alnus rugosa (Du Roi) Spreng. var. *americana* (Regel) Fern.	x	x	x	x
Betula glandulosa Michx.		x		

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Betula occidentalis Hook.	x	x		
Betula papyrifera Marsh. var. *neoalaskana* (Sarg.) Raup	x	x	x	x
Corylus cornuta Marsh.	x	x	x	x
FAGACEAE				
Quercus macrocarpa Michx.	x	x		x
ULMACEAE				
Ulmus americana L.	x			
URTICACEAE				
Urtica dioica L. var. *procera* (Muhl.) Wedd.	x	x	x	x
SANTALACEAE				
Comandra umbellatum (L.) Nutt. var. *pallida* (DC.) Jones	x	x		x
Comandra umbellatum (L.) Nutt. var. *umbellatum*		x		
ARISTOLOCHIACEAE				
Asarum canadense L.			x	
POLYGONACEAE				
Fagopyrum sagittatum Gilib.		x		
Polygonum amphibium L.				x
Polygonum aviculare L.			x	
Polygonum erectum L.	x		x	x
Polygonum lapathifolium L.	x		x	x
Rumex crispus L.		x		
CHENOPODIACEAE				
Axyris amaranthoides L.		x		

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Chenopodium album L.	x	x		x
Chenopodium capitatum (L.) Aschers.	x	x	x	x
Chenopodium hybridum L.		x	x	x
CARYOPHYLLACEAE				
Arenaria lateriflora L.	x	x		x
Arenaria stricta Michx. var. *dawsonensis* (Britt.) Scoggan	x			
Cerastium arvense L.		x		
Silene cucubalus Wibel	x	x		
Silene noctiflora L.		x		
RANUNCULACEAE				
Actaea rubra (Ait.) Willd.	x	x	x	x
Actaea rubra (Ait.) Willd. Forma *neglecta* (Gillman) Robins.	x	x	x	x
Anemone canadensis L.	x	x	x	x
Anemone cylindrica Gray	x	x		
Anemone quinquefolia L.	x	x		
Anemone riparia Fern.	x	x	x	x
Aquilegia canadensis L.	x	x	x	x
Caltha palustris L.	x	x	x	x
Ranunculus abortivus L.			x	
Ranunculus acris L.		x		
Ranunculus cymbalaria Pursh		x		
Ranunculus gmelinii DC. var. *hookeri* (Don) Benson			x	
Ranunculus macounii Britt.			x	x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Ranunculus rhomboideus Goldie		x		
Thalictrum dasycarpum Frisch. & Lall.	x			x
Thalictrum venulosum Trel.	x			x
FUMARIACEAE				
Corydalis aurea Willd.		x		x
CRUCIFERAE				
Arabis glauca (L.) Bernh.	x	x		
Erysimum cheiranthoides L.	x		x	x
Erucastrum gallicum (Willd.) O. E. Schulz	x			
Rorippa islandica (Oeder) Borbas		x		
Thlaspi arvense L.	x	x	x	x
SAXIFRAGACEAE				
Chrysosplenium alternifolium L.				x
Heuchera richardsonii R. Bv.	x			
Mitella nuda L.	x	x	x	x
Parnassia palustris L. var. *neogaea* Fern.	x	x		
Ribes americanum Mill.	x	x	x	x
Ribes glandulosum Grauer		x	x	x
Ribes oxyacanthoides L.	x	x	x	x
Ribes oxyacanthoides L. var. *hirtellum* (Michx.) Scoggan	x	x	x	x
Ribes triste Pallas	x	x	x	x
ROSACEAE				
Agrimonia striata Michx.	x		x	
Amelanchier alnifolia Nutt.	x	x	x	x
Crataegus rotundifolia Moench	x	x		

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Fragaria virginiana Dcne.	x	x	x	x
Geum aleppicum Jacq.	x	x	x	x
Geum macrophyllum Willd. var. *perincisum* (Rydb.) Raup		x		
Geum rivale L.	x	x	x	
Potentilla anserina L.		x		
Potentilla arguta Pursh	x			
Potentilla fruticosa L.	x	x		
Potentilla gracilis Dougl. var. *glabrata* (Lehm.) Hitchc.	x			
Potentilla norvegica L.	x	x	x	x
Prunus americana Marsh.	x	x	x	x
Prunus pensylvanica L.	x	x	x	x
Prunus virginiana L.	x	x	x	x
Rosa acicularis Lindl.	x	x	x	x
Rosa woodsii Lindl.			x	
Rubus idaeus L. var. *strigosus* (Michx.) Maxim.	x	x	x	x
Spiraea alba Du Roi				x
LEGUMINOSAE				
Astragalus adsurgens Pallas	x	x		x
Astragalus alpinus L.	x	x		
Astragalus canadensis L.	x			x
Astragalus striatus Nutt.	x			
Hedysarum alpinum L. var. *americanum* Michx.	x	x		
Lathyrus ochroleucus Hook.	x	x	x	x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Lathyrus venosus Muhl.	x	x	x	x
Medicago lupulina L.	x	x	x	x
Medicago sativa L.	x	x	x	x
Melilotus alba Desr.	x	x	x	x
Melilotus officinalis (L.) Lam.	x	x	x	x
Oxytropis campestris (L.) DC. var. *gracilis* (Nels.) Barneby	x	x		
Trifolium hybridum L.	x	x	x	x
Trifolium pratense L.	x	x	x	x
Trifolium repens L.	x	x	x	x
Vicia americana Muhl.	x	x	x	x
LINACEAE				
Linum usitatissimum L.				x
GERANIACEAE				
Geranium bicknelli Britt.	x	x	x	x
POLYGALACEAE				
Polygala paucifolia Willd.	x	x		
Polygala senega L.		x		
ACERACEAE				
Acer negundo L.	x	x		
Acer spicatum Lam.	x	x	x	x
BALSAMINACEAE				
Impatiens capensis Meerb.	x		x	x
RHAMNACEAE				
Rhamnus alnifolia L'Her.	x	x	x	x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
CORNACEAE				
Cornus canadensis L.	x	x	x	x
Cornus stolonifera Michx.	x	x	x	x
PYROLACEAE				
Monotropa uniflora L.	x	x	x	x
Pyrola asarifolia Michx.	x	x	x	x
Pyrola secunda L.	x	x	x	x
Pyrola virens Schweigger		x	x	
ERICACEAE				
Arctostaphylos uva-ursi (L.) Spreng.	x	x		x
Ledum groenlandicum Oeder	x	x		
PRIMULACEAE				
Androsace septentrionalis L.	x	x		
Primula mistassinica Michx.		x		
Steironema ciliatum (L.) Raf.	x	x	x	x
Trientalis borealis Raf.	x	x	x	x
OLEACEAE				
Fraxinus pennsylvanica Marsh.	x	x	x	x
GENTIANACEAE				
Gentianella amerella (L.) Börner	x	x	x	x
Gentianella crinita (Froel.) Don		x		
Halenia deflexa (Sm.) Griseb.	x	x	x	x
APOCYNACEAE				
Apocynum androsaemifolium L.	x	x		x
ASCELPIADACEAE				
Asclepias speciosa Torr.	x			x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
VIOLACEAE				
Viola adunca Sm.	x	x	x	
Viola canadensis L.	x	x	x	x
Viola macloskeyi Lloyd	x	x	x	x
Viola nephrophylla Greene		x		
ELAEAGNACEAE				
Shepherdia canadensis (L.) Nutt.	x	x		x
ONAGRACEAE				
Circaea alpina L.	x	x	x	
Epilobium angustifolium L.	x	x	x	x
Epilobium glandulosum Lehm.	x	x	x	x
Epilobium glandulosum Lehm. var. *adenocaulon* (Haussk.) Fern.			x	x
Oenothera biennis L.	x			
HALORAGACEAE				
Myriophyllum spicatum L.				x
ARALIACEAE				
Aralia nudicaulis L.	x	x	x	x
UMBELLIFERAE				
Carum carvi L.	x	x		
Cicuta maculata L.	x		x	x
Heracleum lanatum Michx.	x	x	x	x
Sanicula marilandica L.	x	x	x	x
Sium sauve Walt.		x		
Zizia aurea (L.) Koch		x		

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
CONVOLVULACEAE				
Convolvulus sepium L.	x		x	x
Cuscuta umbrosa Beyrich	x	x		
POLEMONIACEAE				
Collomia linearis Nutt.	x	x	x	x
BORAGINACEAE				
Lithospermum canescens (Michx.) Lehm.	x	x		
Mertensia paniculata (Ait.) Don	x	x	x	x
LABIATAE				
Agastache foeniculum (Pursh) Ktze.	x	x	x	x
Dracocephalum formosius (Lunell) Rydb.	x			
Dracocephalum nuttallii Britt.		x	x	
Galeopsis tetrahit L. var. *bifida* (Boenn.) Lej. & Court.			x	
Lycopus americanus Muhl.	x	x	x	
Mentha arvensis L.	x	x	x	x
Moldavica parviflora (Nutt.) Britt.				x
Monarda fistulosa L.	x	x		
Scutellaria epilobifolia Hamilton	x		x	
Scutellaria lateriflora L.	x			x
Stachys palustris L. var. *pilosa* (Nutt.) Fern.	x	x		x
SOLANACEAE				
Chamaesaracha grandiflora (Hook.) Fern.		x		
SCROPHULARIACEAE				
Castilleja miniata Dougl.	x	x		x
Pedicularis canadensis L.		x		

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Penstemon albidus Nutt.	x			
Veronica americana Schwein	x		x	
PLANTAGINACEAE				
Plantago major L.	x	x	x	x
RUBIACEAE				
Galium aparine L.			x	
Galium boreale L. var. *boreale*	x	x	x	x
Galium trifidum L.	x			x
Galium triflorum Michx.	x	x	x	x
Houstonia longifolia Gaertn.		x		
CAPRIFOLIACEAE				
Diervilla lonicera Mill.				x
Linnaea borealis L. var. *longifolia* Torr.	x	x		x
Lonicera dioica L. var. *glaucescens* (Rydb.) Butters	x	x	x	x
Lonicera villosa (Michx.) R. & S.	x	x	x	x
Symphoricarpos albus (L.) Blake	x	x	x	x
Symphoricarpos occidentalis Hook.	x	x		x
Viburnum edule (Michx.) Raf.	x	x	x	x
Viburnum lentago L.		x		
Viburnum opulus L. var. *americanum* Ait.	x	x	x	x
CAMPANULACEAE				
Campanula rotundifolia L.	x	x		x
COMPOSITAE				
Achillea millefolium L.	x	x	x	x
Achillea sibirica Ledeb.	x		x	x

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Agoseris glauca (Pursh) Raf.				x
Antennaria neglecta Greene	x	x		x
Antennaria parviflora Nutt.	x	x		x
Arctium minus (Hill) Bernh.		x		
Artemisia biennis Willd.	x	x		
Artemisia ludoviciana Nutt. var. *gnaphalodes* (Nutt.) T. & G.	x	x		
Aster ciliolatus Lindl.	x	x	x	x
Aster ericoides L.	x	x		
Aster laevis L.	x	x	x	x
Aster novae-anglaie L.	x		x	x
Aster puniceus L.	x	x	x	x
Aster simplex Willd.	x	x		x
Aster umbellatus Mill.	x	x		
Bidens cernua L.	x		x	
Chrysanthemum leucanthemum L.		x		
Cirsium arvense (L.) Scop.	x	x	x	x
Cirsium flodmanii (Rydb.) Arthur		x		
Crepis tectorum L.	x			
Erigeron canadensis L.	x	x		
Erigeron glabellus Nutt.	x	x		
Erigeron philadelphicus L.	x	x	x	x
Eupatorium purpureum L. var. *maculatum* (L.) Darl.	x	x		x
Helianthus annuus L.		x		
Helianthus tuberosum L.	x			

Plant Species List - continued

	Garland	Mink	Lidstone	Sarah
Hieracium canadense Michx.	x	x	x	x
Lactuca tatarica (L.) Meyer	x			x
Liatris ligulistylis (Nels.) Schum.		x		
Matricaria matricarioides (Less.) Porter	x	x	x	x
Petasites palmatus (Ait.) Gray	x	x	x	x
Petasites sagittatus (Banks) Gray	x	x	x	x
Petasites vitifolius Greene	x	x	x	
Prenanthes alba L.	x	x		x
Prenanthes racemosa Michx.	x		x	
Rudbeckia hirta L.	x	x		x
Senecio aureus L.	x	x		
Senecio eremophilus Richards.	x	x	x	
Solidago canadensis L.	x	x	x	x
Solidago gigantea Ait. var. *serotina* (Ait.) Cronq.	x	x		x
Solidago graminifolia (L.) Salisb. var. *major* (Michx.) Fern.	x	x		
Solidago hispida Muhl.	x	x		x
Solidago juncea Ait.		x		
Solidago missouriensis Nutt.	x	x		
Solidago rigida L.	x			
Sonchus arvensis L.	x	x	x	x
Tanacetum vulgare L.	x		x	
Taraxacum officinale Weber	x	x	x	x

Appendix B. Bird Species List

BIRD SPECIES LIST

		Garland	Mink	Lidstone	Sarah
Anas platyrhynchos (L.)	Mallard				x
Buteo jamaicensis (Gmelin)	Red-tailed Hawk	x	x	x	x
Bonasa umbellus (L.)	Ruffed Grouse	x	x	x	x
Pedioecetes phasianellus (L.)	Sharp-tailed Grouse			x	
Charadrius vociferus L.	Killdeer	x	x		
Capella gallinago (L.)	Common Snipe				x
Zenaidura macroura (L.)	Mourning Dove	x	x	x	x
Bubo virginianus (Gmelin)	Great Horned Owl	x	x		
Chordeiles minor (Forster)	Common Nighthawk	x	x		x
Archilochus colubris (L.)	Ruby-throated Hummingbird		x	x	x
Colaptes auratus (L.)	Common Flicker	x	x	x	x
Dendrocopos villosus (L.)	Hairy Woodpecker	x	x	x	
Tyrannus tyrannus (L.)	Eastern Kingbird		x		
Sayornis phoebe (Latham)	Eastern Phoebe		x		x
Empidonax minimus (Baird and Baird)	Least Flycatcher		x		
Contopus sordidulus Scalter	Western Wood Pewee		x		
Hirundo rustica L.	Barn Swallow		x	x	
Perisoreus canadensis (L.)	Gray Jay	x	x	x	x
Cyanocitta cristata (L.)	Blue Jay	x	x	x	x
Corvus corax L.	Common Raven	x	x	x	x
Corvus brachyrhynchos Brehm	Common Crow	x	x	x	x
Parus atricapillus L.	Black-capped Chickadee	x	x	x	x
Troglodytes aedon Vieillot	House Wren		x		x
Cistothorus platensis (Latham)	Short-billed Marsh Wren				x
Toxostoma rufum (L.)	Brown Thrasher		x		
Turdus migratorius L.	American Robin	x	x	x	x
Bombycilla cedrorum Vieillot	Cedar Waxwing		x		x
Lanius ludovicianus L.	Loggerhead Shrike	x	x	x	
Mniotilta varia (L.)	Black-and-white Warbler		x		
Dendroica coronata (L.)	Yellow-rumped Warbler	x	x		x
Dendroica pensylvanica (L.)	Chestnut-sided Warbler	x	x	x	x
Seiurus aurocapillus (L.)	Ovenbird	x	x	x	x
Oporornis philadelphia (Wilson)	Mourning Warbler		x		
Geothlypis trichas (L.)	Common Yellowthroat		x	x	x
Setophaga ruticilla (L.)	American Redstart	x	x	x	x
Agelaius phoeniceus (L.)	Redwinged Blackbird			x	x
Quiscalus quiscula (L.)	Common Grackle	x	x	x	
Pheucticus ludovicianus (L.)	Rose-breasted Grosbeak	x	x	x	x
Carpodacus purpureus (Gmelin)	Purple Finch			x	
Spinus tristis (L.)	American Goldfinch	x	x	x	x
Spizella passerina (Bechstein)	Chipping Sparrow	x	x	x	x
Spizella pallida (Swainson)	Clay-colored Sparrow		x		
Zonotrichia albicollis (Gmelin)	White-throated Sparrow	x	x	x	x
Melospiza georgiana (Latham)	Swamp Sparrow		x		
Melospiza melodia (Wilson)	Song Sparrow		x		

Appendix C. Mammal Species List

MAMMALS SPECIES LIST

		Garland	Mink	Lidstone	Sarah
Alces alces (L.)	Moose	x	x	x	x
Canis latrans Say	Coyote	x	x	x	x
Canis lupus L.	Grey wolf				x
Castor canadensis Kuhl	American beaver	x			x
Cervus elaphus L.	Wapiti or elk	x	x	x	x
Clethrionomys gapperi (Vigors)	Gapper's redback vole	x	x	x	x
Erthizon dorsatum (L.)	American porcupine	x	x		
Eutamias minimus (Bachman)	Least chipmunk	x			x
Lepus americanus Erxleben	Snowshoe hare	x	x	x	x
Marmota monax (L.)	Woodchuck			x	x
Microtus pennsylvanicus (Ord)	Meadow vole	x	x	x	x
Mephitis mephitis (Schreber)	Striped skunk	x	x		
Odocoileus virginianus (Zimmerman)	White-tailed deer	x	x	x	x
Ondatra zibethicus (L.)	Muskrat	x			x
Procyon lotor (L.)	Raccoon	x	x	x	
Spermophilus tridecemlineatus (Mitchell)	Thirteen-lined ground squirrel	x	x		
Tamias striatus (L.)	Eastern chipmunk	x	x		
Tamiasciurus hudsonicus (Erxleben)	American red squirrel	x	x	x	x
Ursus americanus Pallas	Black bear	x	x	x	x
Vulpes vulpes (L.)	Red fox	x	x	x	x
Zapus hudsonius (Zimmerman)	Meadow jumping mouse	x	x		

Appendix D. Appendix for Chapter II

(a) Plot sampling intensity

(b) Shrub density/100m^2

(c) Importance values of herbs

(d) Combined data for vegetation parameters

(e) Raw data for the soil analysis

(a) Plot Sampling Intensity

Table D.1. Summary of work completed in the Duck Mountain periphery for ungulate use and vegetation analysis.

Work type	Number of plots in each treatment type							
	L-73	G-75	S-73	S-77	S-78	M-74	M-75	M-76
Pellet Group Counts	7	8	7	7	9	10	5	3
Track Counts	2	2	1	1	1	3	-	-
Vegetation Analysis	6	10	6	6	7	10	5	6
Total Number of Plots	11	42	17	21	33	65	10	39

(b) Shrub density/100m^2

Table D.2. Shrub density (/ 100 m^2) for all shrubs (0 to 250 cm).

Species	S-78			S-77			M-76			M-75			G-75			M-74			S-73			L-73		
	P	E	C	P	E	C	P	E	C	P	E	C	P	E	C	P	E	C	P	E	C	P	E	C
Abies balsamea															004									
Acer spicatum									017			007	002	085		083						081	266	487
Alnus rugosa		034									020	107	003	033	021				041	058				
Amelanchier alnifolia	293	144	0013	250	072		100	0067	167	064	148	164	041	031	037	0058	0040	0100	031	021	013	067	019	013
Arctostaphlos uva-ursi																	0017							
Betula occidentalis												029												
B. papyrifera											004													
Cornus stolonifera		337		079	021	633		0167	117	116	066	029	123	144	058	0125	0073	0071		071	013	054	094	031
Corylus cornuta	127	628	3350	063	054		733	1333	567	752	438	321	581	602	213	1046	1152	1325	419	063	413	981	384	269
Cretaegus rotundifolia											002													
Fraxinus pensylvanica													007	002	087									
Ledum groenlandicum															050									
Lonicera dioica								0083	017	052	014	043	008	069	050	0046	0079	0325	091	046		025		068
L. villosa											018		007	004	025			0017					013	
Picea glauca															004									
Populus balsamifera	167			104				0017	017	121	034	007	120	033	004	0054	0033		013	017		048	075	013
P. tremuloides	467	050	0013	246	133	050	350	0150		189	093		211	067	033	0125	0056	0017	041	046	029	104	019	006
Potentilla fruticosa										005				004	013		0042	0008						
Prunus pensylvanica		019	0013	025	083	017	017	0033		011	002	066	066	014	004	0021	0048	0042	031		008	004	019	
P. virginiana	240	044	0050	046	037	033	033	0083	417	011	004	050	030	090	146	0048	0013	0250	009	008		042	094	063
Quercus macrocarpa										021														
Rhamnus alnifolia										136	034	136	009	023	079	0063	0013	0108	047					
Ribes americanum	093			008	067					004		014	001	002	021							019	025	
R. oxycanthoides										009		157	023	042	083	0019	0008	0025	013	041	025	025	066	
R. triste											004	007	002	035				0008				015		019
Rosa spp.	133	140	0213	450	192	283	033	0083	083	091	075	193	155	165	167	0040	0100	0100	009	196	154	040	016	025
Rubus idaeus	267	059	0025	046	063	017	233			034	050	014	091	081	025	0067	0031	0050	113	029	004	500	244	006
Salix bebbiana		013								032	021	007	030	027			0008	0008			008			
Salix spp.								0136		048	004	064	148	025	008	0002								
Shepherdia canadensis										004	017		003	083										
Symphoricarpos albus	053	219	0275	054	008	017	533		117	202	139	079	304	192	208	0106	0154	0433	216	108	229	377	297	037
S. occidentalis																		0025		008				
Viburnum edule	007	003			067		050	0200	133	004	004	079	002	023	035	0021			019		013	067	075	037
V. lentago											014	014					0002						028	006
V. opulus var. *americanum*			0037						050	009	019	021	009	063	017	0002	0029	0067	009	100				
V. rafinesquianum																	0006							

(c). Importance values of herbs

able D.3. Importance values of herbs.

ECIES	Plot								Edge								Control							
	L-73	S-73	M-74	M-75	G-75	M-76	S-77	S-78	L-73	S-73	M-74	M-75	G-75	M-76	S-77	S-78	L-73	S-73	M-74	M-75	G-75	M-76	S-77	S-78
hillea millefolium	--	--	--	--	2.3	--	2.3	--	--	--	--	--	0.55	--	0	--	--	--	--	--	2.1	--	0	--
hillea sibirica	--	--	--	--	1.3	--	1.3	--	--	--	--	--	0.7	--	0	--	--	--	--	--	0.9	--	0	--
taea rubra	--	--	--	3.2	0	1.2	1.3	--	--	--	0.5	3.0	0	0	0	--	--	--	0.7	2.2	0.8	2.1	0	--
astache foeniculum	--	--	--	--	--	--	--	1.0	--	--	--	--	--	--	--	1.2	--	--	--	--	--	--	--	0
ropyron trachycaulum	1.6	0	1.9	0	1.6	--	21.4	1.9	C	0	0	6.4	2.1	--	0	2.4	0	11.1	0	3.4	0	--	0	7.5
aranthus retroflexus	--	--	--	--	--	--	--	1.0	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0
emone canadensis	3.2	3.6	2.2	10.1	5.6	7.3	3.1	1.0	0	1.8	2.4	10.4	2.8	0	0	3.6	0	0	0	4.4	0	0	0	0
cylindrica	--	--	--	--	0.7	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--	--	--
guinquefolia	--	--	0.9	0	0.6	1.2	--	--	--	--	1.1	3.5	0	2.8	--	--	--	--	1.6	0	0	2.1	--	--
riparia	--	--	0	1.2	--	--	--	--	--	--	0.5	0	--	--	--	--	--	--	0	0	--	--	--	--
tennaria neglecta	--	--	0	--	--	--	--	--	--	--	0.6	--	--	--	--	--	--	--	0	--	--	--	--	--
ocynum androsaemifolium	--	0	0	--	--	--	4.0	2.4	--	1.8	1.4	--	--	--	0	0	--	0	0	--	--	--	3.2	0
alia nudicaulis	18.5	39.8	14.6	5.4	9.0	4.8	12.7	18.5	14.7	40.3	16.4	13.7	14.3	10.5	34.3	26.7	35.6	39.4	21.6	19.9	11.0	9.3	51.9	30.2
ctostaphylos uva-ursi	--	--	3.1	--	--	--	--	--	--	--	8.2	--	--	--	--	--	--	--	13.2	--	--	--	--	--
enaria lateriflora	--	--	--	--	0	--	--	1.0	--	--	--	--	1.8	--	--	1.2	--	--	--	--	0	--	--	0
arum canadense	0	--	--	--	--	--	--	--	3.5	--	--	--	--	--	--	--	6.4	--	--	--	--	--	--	--
ter ciliolatus	20.5	21.6	18.9	19.6	14.5	15.4	11.7	14.1	24.0	14.0	23.1	13.1	21.9	12.7	23.1	18.8	25.0	12.1	20.1	15.7	17.7	21.5	16.2	15.5
ter novae-angliae	3.0	--	0.6	1.2	--	--	--	--	0	--	0	1.6	--	--	--	--	0	--	0	0	--	--	--	--
ter ericoides	--	--	--	1.5	1.0	2.8	--	--	--	--	--	0	0.55		0	--	--	--	--	0	0	0	--	--
umbellatus	--	5.1	--	1.5	--	--	0	1.3	--	2.3	--	3.5	--	--	0	1.5	--	0	--	1.7	--	--	3.2	0
ter spp.	--	--	--	2.5	0	--	--	2.0	--	--	--	1.7	2.3	--	--	0	--	--	--	0	1.7	--	--	0
tragalus sp.	--	--	--	--	3.4	--	--	--	--	--	--	--	3.1	--	--	--	--	--	--	--	1.3	--	--	--
omus ciliatus	7.3	37.3	11.6	14.6	4.8	3.3	21.9	9.9	0	30.0	5.5	25.1	0	21.3	26.4	16.0	0	42.6	9.6	7.1	3.5	0	11.9	16.3
trychium virginianum	--	0	0	2.3	0.4	--	--	0	--	1.8	0.5	1.6	0.7	--	--	1.2	--	0	1.8	1.7	0	--	--	0
lamagrostis canadensis	--	4.1	35.2	38.7	48.3	5.5	4.6	36.6	--	17.3	4.3	0	13.2	0	0	12.6	--	0	1.3	0	2.3	0	0	0
ltha palustris	--	--	2.0	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--	--	--	--	--
moanula rotundifolia	--	--	0	--	1.0	--	--	--	--	--	0.5	--	1.4	--	--	--	--	--	0	--	0	--	--	--
rex spp.	16.3	0	16.6	14.2	20.1	14.7	24.4	19.7	14.3	0	19.5	3.6	29.5	15.1	0	3.6	0	10.1	10.5	40.8	23.6	3.9	0	7.1
stellija miniata	--	--	--	1.2	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--	--	--	--
enopodium hybridum	--	--	--	--	--	--	--	4.5	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0
rcea alpina	2.2	--	0	0	0	--	--	--	6.4	--	0	0	0	--	--	--	0	--	0.7	1.8	0.9	--	--	--
rsium arvense	12.4	--	0.5	6.0	2.8	10.1	2.3	3.1	7.7	--	1.2	1.6	1.1	0	0	0		--	0	0	0	0	0	0
rsium muticum	--	--	0	0	0.4	--	--	--	--	--	1.1	2.6	0	--	--	--	--	--	0	0	0	--	--	--
cuta maculata	--	--	--	--	--	--	4.6	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--
mandra umbellatam	--	--	2.1	--	--	--	--	--	--	--	5.4	--	--	--	--	--	--	--	4.2	--	--	--	--	--
nvolvulus sepium	3.6	--	0.7	--	0.9	--	--	--	3.5	--	0.6	--	0	--	--	--	0	--	0	--	0	--	--	--
rnus canadensis	8.5	12.6	8.4	0	4.6	2.2	7.6	3.9	16.9	10.3	10.0	4.8	8.7	13.1	3.6	6.9	0	0	14.5	6.6	11.6	21.6	32.0	7.8
pripedium calceolus	--	--	--	0	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	1.8	--	--	--	--
rum carvi	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	1.5	--	--	--	--	--	--	--	0
ervilla lonicera	--	--	--	--	--	--	0	0	--	--	--	--	--	--	0	1.5	--	--	--	--	--	--	11.0	1.6
sporum trachycarpum	1.6	--	0.6	--	0.4	2.5	0	0	0	--	0.5	--	1.1	2.1	2.5	1.2	0	--	0.9	--	0	4.2	3.8	0
ilobium angustifolium	--	4.6	0	3.0	0.4	--	10.6	12.4	--	15.3	0	0	0	--	9.2	8.6	--	6.5	0.7	0	2.0	--	9.0	3.0
uisetum arvense	--	0	0	1.2	7.8	--	9.7	6.6	--	1.8	0.6	3.2	5.5	--	0	0	--	2.5	0.8	0	7.7	--	3.2	3.4
uistum scirpoides	--	--	0	0	0.9	0	--	--	--	--	0.7	8.0	3.1	0	--	--	--	--	0	5.1	3.7	2.9	--	--
igeron philadelphicus	--	--	--	--	2.7	--	--	1.3	--	--	--	--	1.1	--	--	0	--	--	--	--	1.3	--	--	0
patorium purpureum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
agaria virginiana	16.4	12.1	17.3	26.1	21.2	39.8	16.5	4.9	20.9	14.8	19.7	29.5	20.8	15.4	34.7	19.8	22.8	16.7	14.6	19.3	19.7	5.0	52.1	32.6
lium boreale	11.4	25.2	13.1	9.5	10.8	13.0	18.5	15.9	17.3	18.2	15.4	2.6	19.0	53.3	23.7	22.2	8.9	3.9	13.4	17.9	18.1	13.8	29.1	21.7
lium triflorum	18.3	0	4.0	1.8	4.0	16.8	6.2	3.8	12.1	3.6	4.2	4.7	4.7	2.1	0	2.8	16.7	4.4	1.9	2.9	2.0	14.0	0	3.0
ntianella amerella	--	--	--	--	0.9	--	1.3	--	--	--	--	--	1.8	--	0	--	--	--	--	--	0.7	--	0	--
ranium bicknelli	--	--	--	--	--	1.2	--	1.3	--	--	--	--	--	0	--	0	--	--	--	--	--	0	--	0
um aleppicum	1.2	--	0	--	--	--	--	--	0	--	1.1	--	--	--	--	--	0	--	0	--	--	--	--	--
um rivale	--	--	--	--	0.4	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--	--	--
lenia deflexa	--	0	0.5	--	0	0	--	--	--	3.6	0	--	0	3.4	--	--	--	2.5	0	--	0.7	0	--	--
racleum lanatum	--	6.4	1.0	1.5	--	--	1.3	2.2	--	0	1.9	0	--	--	0	1.5	0	7.6	3.0	0	--	--	0	1.6

SPECIES	Plot								Edge								Control							
	L-73	S-73	M-74	M-75	G-75	M-76	S-77	S-78	L-73	S-73	M-74	M-75	G-75	M-76	S-77	S-78	L-73	S-73	M-74	M-75	G-75	M-76	S-77	S-78
Hieracium canadense	--	2.5	0.6	1.5	0.4	--	--	--	--	0	0	0	0	--	--	--	--	0	1.6	1.7	0	--	--	--
Impatiens capensis	4.8	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--
Lactuca tatarica	--	--	--	--	--	--	7.7	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	--	0
Lathyrus ochroleucus	9.1	2.5	0.9	0	2.0	--	6.3	0	7.4	9.4	2.1	0	0	--	2.2	3.9	0	0	1.3	3.3	0	--	0	0
Lathyrus venosus	3.9	7.1	6.1	2.3	5.1	8.1	7.3	13.5	0	8.6	5.8	6.4	12.2	7.5	25.0	19.9	0	5.0	6.4	2.7	5.1	6.9	18.4	8.[illegible]
Linnaea borealis	--	--	1.2	0	1.3	1.2	--	0	--	--	3.1	3.0	1.2	0	--	5.5	--	--	2.4	0	3.5	5.9	--	0
Lycopus americanus	--	--	--	--	0.5	--	--	--	--	--	--	--	0.9	--	--	--	--	--	--	--	0	--	--	--
Maianthemum canadense	17.4	7.5	21.7	3.9	12.8	13.4	7.3	7.4	17.7	12.9	21.0	16.2	30.0	27.8	47.3	22.0	71.5	29.6	25.3	10.9	39.7	23.5	12.6	39.[illegible]
Mattaceucia struthiopteris	5.6	--	--	--	--	--	3.2	0	0	--	--	--	--	--	0	0	0	--	--	--	--	--	4.3	2.2
Medicago sativa	0	--	--	--	--	--	--	3.3	16.4	--	--	--	--	--	--	0	0	--	--	--	--	--	--	0
Melilotus alba	--	--	--	--	0.4	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--	--	--
Mentha arvensis	5.5	--	0.5	--	1.4	0	--	3.7	0.5	--	0	--	2.2	0	--	0	0	--	0	--	0.7	4.3	--	0
Mertensia paniculata	20.8	21.2	13.3	7.4	7.8	10.4	9.1	10.8	31.7	13.0	12.3	10.4	3.1	5.4	2.2	11.8	0	11.8	12.0	4.3	4.2	13.8	4.3	9.8
Mitella nuda	3.2	2.5	0	0	0	--	--	--	0	0	3.3	0	2.6	--	--	--	27.9	10.7	0	1.8	13.6	--	--	--
Monotropa uniflora	--	0	--	--	0	--	--	0	--	0	--	--	0	--	--	0	--	3.2	--	--	1.2	--	--	2.2
Oryzopsis asperifolia	2.4	3.6	7.6	1.7	6.5	12.9	0	0	0	0	5.7	7.6	12.4	38.7	7.6	1.2	0	4.0	16.4	15.8	14.3	64.0	0	2.8
Petasites palmatus	16.2	10.5	12.1	4.0	8.0	6.2	11.7	7.5	11.6	16.8	15.9	12.1	4.5	7.0	10.1	14.0	0	6.9	15.3	13.8	0.9	20.3	10.4	14.3
Petasites sagittatus	--	--	0	--	0.4	0	--	--	--	--	0.5	--	0	2.3	--	--	--	--	0	--	0.7	3.7	--	--
Petasites vitifolius	--	--	1.0	1.7	3.6	--	--	--	--	--	0.7	0	2.1	--	--	--	--	--	1.9	1.7	0.7	--	--	--
Phleum pratense	1.6	--	--	--	0.6	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--
Poa palustris	--	--	--	3.4	--	0	--	--	--	--	--	0	--	0	--	--	--	--	--	7.2	--	8.4	--	--
Poa pratensis	1.2	--	0.5	--	0.9	--	2.4	--	0	--	0	--	2.9	--	0	--	0	--	0	--	0	--	0	--
Polygala paucifolia	--	--	0	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	1.7	--	--	--	--	--
Prenanthes alba	5.0	--	1.2	--	0	0	1.3	0	0	--	0	--	0.5	2.1	0	0	0	--	1.1	--	0.7	0	0	1.6
Pyrola asarifolia	--	0	2.6	0	2.5	1.6	0	1.0	--	0	5.0	1.6	3.9	2.5	5.7	5.8	--	9.5	12.2	1.7	14.6	4.3	0	7.2
Pyrola secunda	--	0	0.5	0	0	0	2.3	0	--	0	1.6	1.6	0.5	0	2.2	2.4	--	9.5	0	3.3	0	3.7	0	5.7
Ranunculus sp.	--	--	--	--	--	--	2.9	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	0	--
Rubus pubescens	19.4	16.5	16.5	16.3	11.3	12.8	13.9	14.0	19.0	16.5	14.5	20.2	8.3	10.6	9.7	14.3	6.4	20.4	13.5	15.4	24.9	12.2	9.9	21.1
Rudbeckia hirta	--	--	0.9	--	1.6	1.2	--	--	--	--	2.2	--	0	0	--	--	--	--	1.3	--	0	0	--	--
Sanicula marilandica	--	0	9.2	8.4	3.3	6.6	0	2.2	--	6.8	10.9	9.5	7.6	20.5	6.4	9.6	--	0	19.2	15	8.1	4.8	0	3.0
Smilacina stellata	--	5.0	4.9	8.1	3.6	1.2	1.5	0	--	4.7	5.5	9.9	5.1	2.1	0	3.2	--	2.5	4.9	10.9	7.4	6.8	0	1.6
Solidago canadensis	--	10.6	7.7	10.7	5.3	8.1	5.1	3.8	--	6.2	7.9	6.5	4.5	0	2.7	4.8	--	14.9	1.5	3.8	2.4	2.1	3.2	4.7
Sonchus arvensis	15.4	--	4.4	8.1	15.5	41.7	6.2	4.7	6.9	--	0.7	0	6.6	0	0	0	0	--	0	0	0.7	0	0	0
Stachys palustris	--	--	--	--	2.2	--	2.9	5.0	--	--	--	--	2.0	--	0	0	--	--	--	--	0.7	--	0	0
Steironema ciliatum	--	--	4.5	12.5	5.7	5.7	--	0	--	--	5.6	11.3	5.5	2.1	--	1.2	--	--	4.4	4.7	0.9	0	--	0
Stellaria sp.	--	--	--	--	--	--	0	--	--	--	--	--	--	--	2.2	--	--	--	--	--	--	--	0	--
Taraxacum officinale	6.0	2.5	5.9	7.6	3.7	8.6	10.6	4.4	0	1.8	6.4	3.3	1.0	0	2.2	4.0	0	2.5	2.1	1.7	1.4	0	0	3.4
Thalictrum dasycarpum	1.2	--	0	--	0.7	--	2.1	5.4	0	--	0.7	--	1.0	--	0	5.4	0	--	0	--	2.5	--	0	1.6
Thalictrum venulosum	--	12.6	10.8	12.2	2.0	4.2	--	2.0	--	15.9	15.0	19.1	2.6	4.5	--	0	--	0	10.4	13.8	6.5	0	--	0
Trientalis borealis	1.2	--	--	--	0.6	0	--	--	3.5	--	--	--	1.3	2.1	--	--	55.9	--	--	--	0	0	--	--
Trifolium pratense	--	--	--	--	1.0	--	--	--	--	--	--	--	1.2	--	--	--	--	--	--	--	0	--	--	--
Trifolium repens	2.5	--	0.6	1.2	0.7	--	1.3	--	0	--	0.5	0	0	--	0	--	0	--	0	3.8	0	--	0	--
Trillium cernuum	3.6	--	--	--	--	--	0	0	0	--	--	--	--	--	0	0	0	--	--	--	--	--	3.2	1.6
Urtica dioica	3.6	--	--	--	--	--	--	3.3	0	--	--	--	--	--	--	0	0	--	--	--	--	--	--	0
Vicia americana	4.2	11.0	2.7	10.0	8.5	9.3	7.5	10.1	16.7	9.5	3.1	7.3	8.6	0	11.3	4.3	0	0	3.5	0	2.7	0	0	3.4
Viola adunca	--	--	0.9	--	--	--	--	--	--	--	0.5	--	--	--	--	--	--	--	0	--	--	--	--	--
Viola sp.	--	--	0	--	--	--	--	--	--	--	0.7	--	--	--	--	--	--	--	0.2	--	--	--	--	--
Viola canadensis	4.1	9.0	3.4	0	5.0	2.9	3.0	0	25.1	0	0.5	1.6	1.7	8.7	0	11.4	20.0	9.5	7.1	1.7	1.9	13.2	6.5	12.6
Zigadenus elegans	--	--	--	0	--	--	--	--	--	--	--	1.6	--	--	--	--	--	--	--	0	--	--	--	--

(d) Combined data for vegetation parameters

Table D.4. Combined data for the vegetation parameters.

Treatment
- 1=plot
- 2=edge
- 3=control

Site
- 1=Lidstone
- 2=Garland
- 3=Sarah Lake 1973
- 4=Sarah Lake 1977
- 5=Sarah Lake 1978
- 6=Mink Creek 1974
- 7=Mink Creek 1975
- 8=Mink Creek 1976

Plot
- Numbers as in Fig. 1.2, 1.3, 1.4 and 1.5

Section
- Land section which plot is in as in above figures.

TREATMENT	SITE	PLOT	SECTION	# SPP. HERBS	# HERBS	# ALIENS	# SPP. SHRUBS	# SHRUBS	# BROWSE SHRUBS	# LOW SHRUBS	# HIGH SHRUBS	% BROWSE	KG OF BROWSE
1	1	01		12	0092	000	06	077	070	005	065	000	00000
1	1	01		19	0154	016	05	050	022	001	021	000	00000
1	1	01		17	0138	036	08	051	041	004	037	003	00073
1	1	04		21	0161	004	08	080	032	015	017	047	01941
1	1	04		08	0015	002	06	050	006	003	000	000	00205
1	1	04		05	0053	000	03	051	002	000	004	025	00529
1	1	07		12	0079	003	08	316	208	012	196	010	01205
1	1	07		14	0053	009	09	200	124	036	088	086	01038
1	1	07		09	0018	001	05	192	104	012	092	057	05828
1	1	08		08	0051	003	03	157	011	000	011	100	
1	1	08		15	0093	002	07	082	034	012	022	100	
1	1	08		16	0105	013	08	110	064	025	039	074	
1	1	02					10	053	045	021	024	005	01200
1	1	02					06	028	018	005	013	000	00000
1	1	02					06	048	023	005	018	000	01251
1	1	02					06	065	048	000	049	022	
1	1	02					04	068	062	032	030	050	
1	1	02					09	094	028	006	026	085	
2	1	01		07	0068	025	04	024	022	007	015	100	01410
2	1	01		06	0021	000	07	024	022	001	021	033	01037
2	1	04		12	0066	000	08	115	034	018	016	063	03881
2	1	04		12	0079	000	08	085	035	009	026	008	00289
2	1	07		03	0005	000	11	177	130	054	076	032	05343
2	1	07		06	0022	000	04	026	022	011	011	000	00000
2	1	08		13	0094	001	09	068	049	017	032	028	01176
2	1	08		08	0123	003	04	031	017	000	017	006	00128
2	1	02					09	078	049	017	032	028	02517
2	1	02					04	031	017	000	017	006	00101
2	1	02					03	034	028	007	021	090	
2	1	02					05	036	023	008	015	060	
3	1	01		08	0028	000	03	050	048	040	008	050	00720
3	1	01		06	0017	000	05	044	038	020	018	000	00000
3	1	04		03	0008	000	05	072	042	026	016	000	00000
3	1	04		05	0015	000	05	076	066	042	024	000	00000
3	1	07		01	0002	000	03	030	030	008	022	000	00000
3	1	07		03	0009	000	06	064	044	026	018	000	00000
3	1	08		08	0045	000	05	048	020	008	012	050	
3	1	08		05	0024	000	03	030	018	006	012	025	
3	1	02					05	032	024	018	006	000	00000
3	1	02					04	012	004	000	004	000	00000
3	1	02					05	032	018	006	000	000	
3	1	02					04	012	004	000	004	000	
3	1	02					05	017	015	011	004	000	00000
3	1	02					01	024	000	000	000	000	00000
1	2	07	36	17	0241	032	09	043	032	006	026	000	00000
1	2	07	36	17	0270	024	08	067	041	026	015	007	00153
1	2	07	36	21	0196	021	11	091	078	021	057	009	00721
1	2	12	36	14	0187	000	06	028	010	001	009	033	02706
1	2	12	36	13	0066	002	04	102	102	012	090	040	02611
1	2	12	36	16	0159	007	07	084	064	004	060	000	00000
1	2	01	36	16	0072	010	08	135	122	011	111	014	01989
1	2	01	36	15	0055	005	10	124	082	015	067	006	01404
1	2	01	36	10	0063	007	06	072	060	004	056	000	00000
1	2	06	25	11	0065	003	06	119	099	012	087	000	00000
1	2	06	25	14	0126	000	07	151	017	002	015	000	00000
1	2	06	25	12	0115	003	05	152	114	000	114	003	00170
1	2	03	07	18	0621	001	08	053	024	004	020	075	00910
1	2	03	07	19	0541	029	05	016	014	005	009	000	00000
1	2	03	07	15	0160	012	09	067	055	016	039	023	02050
1	2	05	25	07	0083	000	06	075	050	030	020	000	00000
1	2	05	25	14	0226	001	07	149	041	006	035	000	00000
1	2	05	25	05	0165	000	05	066	065	005	060	006	00772
1	2	01	18	13	0404	005	07	033	017	016	001	000	00000
1	2	01	18	12	0370	005	08	044	030	012	018	000	00000
1	2	01	18	17	0126	016	07	042	041	012	029	000	00000
1	2	01	25				08	050	044	012	032	000	
1	2	01	25				06	047	046	009	037	005	
1	2	01	25				05	037	020	013	007	086	
1	2	01	13				08	067	052	024	028	021	00584
1	2	01	13				03	036	036	034	002	000	00000
1	2	01	13				09	107	079	068	011	000	00000
2	2	07	36	13	0072	005	05	102	086	010	076	018	00710
2	2	07	36	09	0079	000	07	076	024	008	016	013	01062
2	2	07	36	14	0065	017	09	120	096	042	054	019	00981
2	2	12	36	11	0048	000	06	094	060	014	046	000	00000
2	2	12	36	11	0079	000	04	140	128	022	106	011	01427
2	2	12	36	13	0126	000	05	068	056	010	046	070	08051
2	2	01	36	13	0084	000	05	050	020	008	016	075	04182
2	2	01	36	10	0034	000	06	056	044	006	038	000	00000
2	2	01	36	07	0051	000	07	060	028	006	022	009	00169
2	2	06	25	18	0108	008	09	102	066	014	052	031	02491
2	2	06	25	07	0086	000	05	050	012	010	002	000	00000
2	2	06	25	11	0079	000	06	102	016	010	006	000	00000
2	2	03	07	15	0188	000	05	060	042	004	038	058	03697
2	2	03	07	16	0242	000	06	038	030	002	028	021	01096
2	2	03	07	14	0094	000	07	090	000	000	000	000	00000
2	2	05	25	06	0141	000	05	084	078	006	072	011	00499
2	2	05	25	04	0048	000	03	092	066	006	060	000	00000
2	2	05	25	05	0056	000	01	092	092	006	086	000	00000
2	2	01	18	13	0260	019	06	042	022	014	008	000	00000

TREATMENT	SITE	PLOT	SECTION	# SPP. HERBS	# HERBS	# ALIENS	# SPP. SHRUBS	# SHRUBS	# BROWSE SHRUBS	# LOW SHRUBS	# HIGH SHRUBS	% BROWSE	KG OF BROWSE
2	4	66		12	0209	000	06	032	028	012	016	006	00637
2	4	66		10	0109	000	02	013	013	003	010	000	00000
2	4	59					06	049	031	003	028	079	
2	4	59					05	038	019	001	018	100	
2	4	55					05	050	043	024	019	005	
2	4	55					05	043	024	018	006	000	
3	4	52		06	0018	000	04	064	032	012	020	100	36460
3	4	52		09	0096	000	01	012	000	000	000	000	00000
3	4	54		10	0106	000	01	004	000	000	000	000	00000
3	4	54		06	0088	000	03	016	008	004	004	000	00000
3	4	66		07	0044	000	05	148	132	000	132	082	66935
3	4	55					05	056	024	020	004	000	
3	4	66		06	0096	000	02	032	004	000	004	000	00000
3	4	55					05	048	024	016	008	000	
3	4	59					02	052	032	008	024	100	
3	4	59					03	036	012	000	012	000	
1	5	29					07	042	036	011	025	012	00929
1	5	29					07	071	044	009	035	046	02763
1	5	09		09	0048	000	09	098	022	003	019	000	00000
1	5	09		15	0084	000	05	028	005	000	005	000	00000
1	5	13		13	0066	000	07	044	016	002	014	000	00000
1	5	13		08	0032	000	05	040	023	005	018	000	00000
1	5	14		08	0030	000	10	068	019	001	018	000	00000
1	5	14		10	0122	002	06	046	015	004	011	000	00000
1	5	17					6	068	043	020	023	013	
1	5	17					6	076	029	013	016	075	
1	5	20					04	027	001	000	001	000	
1	5	20					06	051	008	004	004	000	
1	5	06					07	039	002	000	002	000	
1	5	06					06	052	017	007	010	080	
2	5	09		02	0006	000	06	038	004	001	003	000	00000
2	5	09		10	0032	001	03	021	004	002	002	050	00110
2	5	13		10	0057	000	06	025	004	001	003	000	00000
2	5	13		12	0045	000	06	036	007	007	000	100	00831
2	5	29					07	032	007	001	006	033	00596
2	5	29					07	040	022	005	017	035	01646
2	5	14		17	0114	000	05	017	008	002	006	033	00364
2	5	14		15	0097	000	08	044	008	001	007	043	01087
2	5	06					05	109	002	002	000	000	
2	5	06					06	055	001	000	001	000	
3	5	09		07	0056	002	04	018	004	000	000	000	00000
3	5	09		07	0054	000	03	036	027	011	016	019	00523
3	5	13		06	0100	000	05	046	039	002	037	019	02423
3	5	13		10	0100	000	05	031	002	001	001	050	
3	5	14		06	0100	000	05	046	039	002	037	019	02423
3	5	14		10	0100	000	05	031	002	001	001	050	
3	5	20					05	043	026	010	016	000	
3	5	20					06	032	011	008	003	000	
3	5	17					05	067	012	004	008	000	
3	5	17					07	050	043	018	025	036	
3	5	06					06	025	006	006	000	000	
3	5	06					07	021	009	001	008	037	
3	5	29					07	024	012	002	010	030	00837
3	5	29					06	044	025	002	023	009	00153
1	6	08	11	14	0225	002	10	122	103	002	101	000	00000
1	6	08	11	13	0036	001	09	107	076	001	075	000	00000
1	6	01	36	13	0115	000	07	042	019	003	016	000	00000
1	6	01	36	18	0056	001	09	097	069	006	063	087	00829
1	6	11	25	19	0070	004	05	031	030	004	026	073	03260
1	6	11	25	12	0023	000	01	012	012	004	008	000	00000
1	6	14	36	08	0016	000	07	087	078	011	067	003	00446
1	6	14	36	13	0079	001	06	078	069	009	060	004	00134
1	6	02	13	13	0048	001	04	080	052	003	049	000	00000
1	6	02	13	12	0045	000	04	087	087	011	076	000	00000
1	6	06	24	09	0272	001	06	049	037	001	036	000	00000
1	6	06	24	15	0070	002	10	055	028	001	027	025	00998
1	6	01	11	15	0205	000	06	058	025	008	017	000	00000
1	6	01	11	06	0017	000	07	182	125	010	115	000	00000
1	6	07	25	24	0388	006	11	063	043	016	027	002	00280
1	6	07	25	17	005 08	06	08	063	049	017	032	000	00000
1	6	01	24	12	0050	001	06	089	086	012	074	000	00000
1	6	01	24	07	0199	000	05	035	013	000	013	054	01392
1	6	03	13				06	103	082	002	080	006	00440
1	6	03	13				05	075	071	006	065	037	02410
2	6	01	24	13	0064	000	08	076	031	007	054	015	03850
2	6	01	24	14	0048	002	07	028	005	001	004	000	00000
2	6	07	25	18	0310	009	07	060	026	018	008	000	00000
2	6	01	11	12	0142	000	03	018	013	013	000	000	00000
2	6	01	11	14	0118	000	09	061	029	017	012	000	00000
2	6	06	24	15	0057	000	07	068	021	009	012	000	00000
2	6	06	24	17	0087	000	07	054	007	000	007	029	00464
2	6	02	13	12	0036	000	03	124	108	008	100	000000000	
2	6	02	13	11	0030	000	04	141	138	004	134	000	00000
2	6	14	36	18	0075	001	04	058	051	004	047	000	00000
2	6	14	36	17	0063	002	07	036	016	003	013	013	00232
2	6	11	25	05	0007	001	08	052	043	009	034	012	00681
2	6	11	25	09	0022	000	02	039	037	004	033	000	00000
2	6	01	36	21	0081	001	07	070	050	010	040	014	04104
2	6	01	39	17	0066	008	07	060	053	008	045	009	01248

TREATMENT	SITE	PLOT	SECTION	# SPP. HERBS	# HERBS	# ALIENS	# SPP. SHRUBS	# SHRUBS	# BROWSE SHRUBS	# LOW SHRUBS	# HIGH SHRUBS	% BROWSE	KG OF BROWSE
2	2	01	18	15	0103	000	07	088	036	000	036	005	00263
2	2	01	18	15	0103	006	08	046	022	006	016	000	00000
2	2	01	25				07	054	040	010	030	000	
2	2	01	25				05	046	034	002	032	000	
2	2	01	25				05	034	026	008	016	013	
2	2	01	13				08	040	018	002	016	006	00673
2	2	01	13				06	032	029	009	020	045	04586
2	2	01	13				04	029	005	005	001	000	00000
3	2	07	36	13	0094	000	04	072	028	024	004	000	00000
3	2	07	36	10	0067	000	05	032	016	008	008	100	
3	2	07	36	08	0057	000	06	124	020	012	008	000	00000
3	2	12	36	11	0162	000	02	040	040	004	036	000	00000
3	2	12	36	13	0080	000	003	032	016	012	004	000	0000
3	2	12	36	11	0086	000	07	124	072	012	060	000	00000
3	2	01	36	06	0013	000	06	060	040	036	004	000	00000
3	2	01	36	09	039	000	04	044	040	012	028	000	00000
3	2	01	36	08	0029	000	04	056	044	004	040	000	00000
3	2	06	25	10	0039	000	07	092	028	016	012	000	00000
3	2	06	25	10	0133	001	02	068	000	000	000	000	00000
3	2	06	25	05	0057	000	04	132	128	112	016	000	00000
3	2	03	07	11	0117	000	06	108	024	012	012	000	00000
3	2	03	07	13	0126	000	06	096	000	000	000	000	00000
3	2	03	07	10	0215	000	03	016	012	008	004	000	00000
3	2	05	25	07	0099	000	03	024	016	008	008	000	00000
3	2	05	25	11	0067	000	04	052	020	016	004	000	00000
3	2	05	25	01	0007	000	02	044	044	012	032	000	00000
3	2	01	18	13	0065	001	04	024	004	004	000	000	00000
3	2	01	18	10	0056	000	06	052	004	004	000	000	00000
3	2	01	18	08	0029	000	04	028	004	000	004	000	00000
3	2	01	25				05	034	026	006	020	000	
3	2	01	25				02	020	018	006	012	025	
3	2	01	25				02	006	002	000	002	000	
3	2	01	13				2	028	016	008	008	050	00933
3	2	01	13				03	016	016	012	004	100	00058
3	2	01	13				01	056	000	000	000	000	00000
1	3	09		11	0776	008	06	080	078	050	028	000	00000
1	3	09		13	0244	000	03	036	024	008	016	000	00000
1	3	09		10	0084	004	05	108	068	048	020	000	00000
1	3	52		09	0232	060	03	032	008	008	000	000	00000
1	3	52		07	0084	000	02	004	000	000	000	000	00000
1	3	52		05	0028	008	03	100	036	036	000	000	00000
1	3	40		04	0044	000	02	084	084	080	004	000	00000
1	3	40		06	0048	000	05	224	216	188	028	000	00000
1	3	40		02	0020	000	03	032	012	012	000	000	00000
1	3	35		09	0112	004	03	124	120	096	024	000	00000
1	3	35		14	0200	008	05	048	028	024	004	000	00000
1	3	35		10	0104	012	02	036	028	024	004	000	00000
1	3	07		17	0984	004	04	084	024	024	000	000	00000
1	3	07		17	0388	016	07	104	060	040	020	000	00000
1	3	07		12	0128	008	01	024	000	000	000	000	00000
1	3	49					05	112	080	064	016	000	
1	3	49					03	060	012	004	008	000	
1	3	49					02	096	040	036	004	000	
2	3	09		02	0006	000	06	038	004	001	003	000	00000
2	3	09		10	0032	001	03	021	004	002	002	050	00110
2	3	52		11	0022	000	07	051	032	003	029	076	06035
2	3	52		11	0058	000	04	020	008	002	006	050	00277
2	3	40		10	0027	002	08	098	087	017	070	001	00148
2	3	40		16	0122	000	05	078	075	023	052	000	00000
2	3	35		07	0028	000	07	056	038	001	037	016	00980
2	3	35		12	0077	000	06	101	086	009	077	004	00832
2	3	07		11	0035	000	06	091	069	039	030	000	00000
2	3	07		20	0098	003	07	056	032	023	009	067	07437
2	3	49					05	021	004	002	002	100	
2	3	49					03	019	006	000	006	000	
3	3	09		07	0056	002	04	018	004	000	000	000	00000
3	3	09		07	0054	000	03	036	027	011	016	019	00523
3	3	52		06	0018	000	04	064	032	012	020	100	36460
3	3	52		09	0096	000	01	012	000	000	000	000	00000
3	3	40		13	0180	000	03	108	068	012	056	000	00000
3	3	40		06	0052	000	05	056	048	012	036	000	00000
3	3	35		09	0118	000	03	012	004	000	004	000	00000
3	3	35		13	0150	000	03	016	008	000	008	000	00000
3	3	07		02	0050	000	04	060	036	004	032	009	05465
3	3	07		08	0014	000	04	040	032	016	016	000	00000
3	3	49					02	012	004	004	000	000	
3	3	49					01	016	000	000	000	000	
1	4	52		26	0288	014	04	011	007	000	007	000	00000
1	4	52		22	0109	008	08	091	063	025	038	000	00000
1	4	54		12	0083	001	06	072	044	011	033	000	00000
1	4	54		09	0063	002	04	089	024	004	020	000	00000
1	4	66		16	0115	002	08	053	048	019	029	007	00220
1	4	66		16	0158	006	03	011	009	002	007	000	00000
1	4	55					05	039	014	004	010	020	
1	4	55					05	040	013	011	002	000	
1	4	59					06	073	046	015	031	006	
1	4	59					05	060	054	052	002	000	
2	4	52		11	0022	000	07	051	032	003	029	076	06035
2	4	52		11	0058	000	04	020	008	002	006	050	00277
2	4	54		11	0055	001	04	037	020	004	016	000	00000
2	4	54		10	0047	000	04	036	023	003	020	000	00000

TREATMENT	SITE	PLOT	SECTION	# SPP. HERBS	# HERBS	# ALIENS	# SPP. SHRUBS	# SHRUBS	# BROWSE SHRUBS	# LOW SHRUBS	# HIGH SHRUBS	% BROWSE	KG OF BROWSE
2	6	08	11	13	0077	000	09	072	037	003	034	000	00000
2	6	08	11	08	0034	000	06	092	088	016	072	000	00000
2	6	03	13				5	081	054	002	052	013	00696
2	6	03	13				08	080	058	001	057	002	00286
3	6	08	11	14	0193	000	02	005	000	000	000	000	00000
3	6	08	11	05	0105	000	02	032	032	010	022	000	00000
3	6	01	36	11	0024	001	03	022	010	004	006	000	00000
3	6	01	36	07	0032	000	03	026	020	016	004	000	00000
3	6	11	25	11	0041	000	09	092	042	004	038	010	01520
3	6	11	25	18	0100	000	07	046	024	008	016	000	00000
3	6	14	36	13	0045	000	02	006	004	004	000	000	00000
3	6	14	36	06	0027	000	02	006	000	000	0000000		00000
3	6	02	13	09	0040	000	03	030	022	014	008	000	00000
3	6	02	13	11	0031	000	04	028	002	000	002	000	00000
3	6	06	24	14	0072	000	05	036	012	004	008	000	00000
3	6	06	24	14	0042	000	03	006	002	002	000	000	00000
3	6	01	11	12	0172	000	03	036	026	026	000	000	00000
3	6	01	11	15	0176	000	03	016	008	006	002	000	00000
3	6	07	25	25	0302	001	08	072	024	002	022	016	00222
3	6	07	25	18	0251	000	07	158	120	036	084	003	00400
3	6	01	24	06	0016	000	08	124	116	046	070	003	01520
3	6	01	24	12	0071	000	08	048	010	000	010	040	01520
3	6	03	13				01	020	020	006	014	000	00000
3	6	03	13				05	044	036	012	024	028	04972
1	7	18	11	13	0300	001	02	016	013	001	012	000	00000
1	7	18	11	15	0174	009	06	067	055	050	005	000	00000
1	7	06	02	19	0064	001	06	034	015	000	015	007	00044
1	7	06	02	31	0095	003	04	038	034	006	028	000	00000
1	7	03	02				08	039	028	002	026	000	
1	7	03	02				04	065	060	000	060	000	
1	7	01	02				09	038	019	004	015	000	
1	7	01	02				08	073	059	004	055	000	
1	7	05	02	18	0211	003	07	114	046	010	036	052	09422
1	7	05	02	20	0125	003	08	064	045	001	044	029	04481
3	7	18	11	09	0101	000	04	024	000	000	000	000	00000
3	7	18	11	11	0038	000	04	016	008	000	008	000	00000
3	7	06	02	11	085	001	02	012	008	004	004	000	0000
3	7	06	02	15	0066	000	02	012	004	000	004	000	00000
3	7	03	02				01	008	008	000	008	000	00000
3	7	03	02				05	032	012	004	008	000	00000
3	7	01	02				04	192	176	032	144	000	00000
3	7	01	02				04	060	020	012	008	000	00000
3	7	05	02	19	0088	000	07	204	184	020	080	020	09670
3	7	05	02	17	0440	000	08	224	036	016	020	000	00000
2	7	06	02	18	0136	000	05	016	013	001	012	000	00000
2	7	06	02	17	0122	000	03	006	004	002	002	000	00000
2	7	18	11	12	0036	000	02	018	018	008	010	006	00086
2	7	18	11	11	0045	000	03	008	002	002	000	000	00000
2	7	03	02				06	034	020	004	016	055	02551
2	7	03	02				05	032	018	007	011	000	
2	7	05	02	18	0106	000	07	122	110	007	103	056	12330
2	7	05	02	19	0174	007	09	057	046	002	044	035	09360
2	7	01	02				04	048	044	008	036	000	00000
2	7	01	02				04	015	005	003	002	000	00000
1	8	05	34	14	0156	018	04	192	144	008	136	000	00000
1	8	05	34	12	0129	010	06	080	032	028	004	000	00000
1	8	04	35	17	0256	058	04	122	084	080	004	000	00000
1	8	04	35	0066	017	05	05	088	060	024	036	000	00000
1	8	05	35	10	0048	007	07	026	088	056	032	000	00000
1	8	05	35	10	0104	021	06	033	068	048	02	000	0000
1	8	01	35	21	0186	066	02	032	008	008	000	000	00000
1	8	01	35	14	0122	018	04	032	008	008	000	000	00000
1	8	12	34				03	052	040	012	028	000	00000
1	8	12	34				03	100	088	016	072	000	00000
1	8	02	34				03	032	012	012	000	000	00000
1	8	02	34				05	064	056	000	056	000	00000
2	8	05	34	10	0032	000	04	204	168	012	156	000	00000
2	8	05	34	13	0066	000	06	060	024	000	024	000	00000
2	8	04	35	06	0037	000	07	136	108	016	092	000	00000
2	8	04	35	12	0064	000	04	092	044	012	032	000	00000
2	8	05	35	09	0086	000	03	100	092	024	068	000	00000
2	8	05	35	05	0044	000	08	116	092	056	036	000	00000
2	8	01	35	06	0018	000	04	064	056	024	032	032	09256
2	8	01	35	07	0027	000	03	088	088	032	056	000	00000
2	8	12	34				04	060	052	012	040	000	00000
2	8	12	34				02	068	064	000	064	031	
2	8	02	34				05	072	060	032	028	000	00000
2	8	02	34				02	060	060	008	052	000	00000
3	8	05	34	12	0052	000	01	028	028	024	004	000	00000
3	8	05	34	06	0041	000	04	036	032	024	008	000	00000
3	8	04	35	11	0096	000	07	076	052	020	032	000	00000
3	8	04	35	07	0035	000	03	052	052	020	032	038	11743
3	8	05	35	11	0084	000	04	052	052	008	044	015	02511
3	8	05	35	07	0081	000	05	02					
3	8	05	35	07	0081	000	05	092	076	060	016	000	00000
3	8	01	35	09	0064	000	04	027	024	023	001	000	00000
3	8	01	35	08	0034	000	02	007	004	002	002	000	00000
3	8	12	34				01	036	036	000	036	000	00000
3	8	12	34				03	036	032	004	028	000	00000
3	8	02	34				02	040	036	008	028	000	00000
3	8	02	34				04	036	028	016	012	000	00000

(e) Raw data for the soil analysis

Table D.5. Raw data for the soil analysis

Coding:

Site
1=Lidstone
2=Garland
3=Sarah Lake
4=Mink Creek

Horizon
1=O horizon
2=A/B horizon
3=C horizon

Salinity in mm hos/cm

N=Available nitrogen(ppm)

P=Available phosphorus(ppm)

K=Available potassium(ppm)

S=Available sulphur(ppm)

depth=depth of the organic layer(cm)

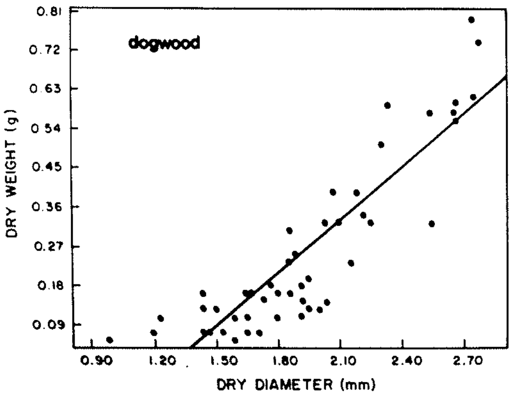
% organic=the % organic matter

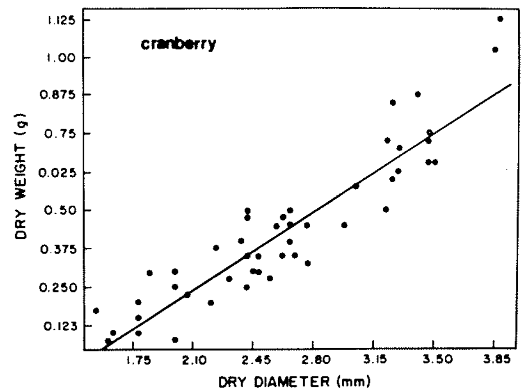
treatment
1=plot
2=control

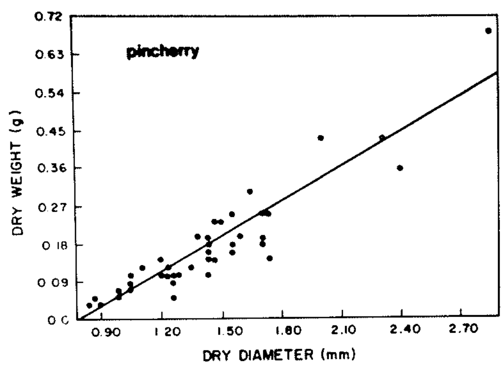
site	horizon	pH	salinity	N	P	K	S	depth	% organic	treatment
1	1	66	02	566	200	472	31	03	520	1
1	1	63	02	006	480	700	50	03	503	1
1	1	65	02	152	460	700	50	05	812	1
1	1	63	02	214	214	570	10	07	310	1
1	1	60	03	342	222	700	10	08	604	1
2	1	65	02	024	148	461	10	08	623	1
2	1	66	01	136	226	700	39	005	775	1
2	1	65	02	076	250	390	35	05	762	1
2	1	69	02	018	222	453	32	10	076	1
2	1	66	03	014	238	444	10	07	213	1
3	1	71	03	032	036	188	10		461	1
3	1	66	02	116	174	192	04	06	121	1
3	1							9	820	1
3	1	69	03	022	038	223	10	12	449	1
3	1							7	201	1
3	1	66	02	010	184	305	12	05	191	1
3	1	68	03	024	058	262	10	08	196	1
4	1	67	03	014	158	395	10	15	096	1
4	1	69	02	000	106	378	19	03	275	1
4	1	70	01	008	066	294	18	03	393	1
4	1	69	02	000	106	378	19	03	275	1
4	1	75	02	022	076	255	07	04	186	1
1	1							08	596	2
1	1							08	792	2
1	1	68	01	022	296	654	32	02	668	2
1	1	60	02	026	410	700	50	05	705	2
1	1	68	02	196	340	620	23	02	463	2
2	1	64	03	052	398	700	10	11	751	2
2	1	65	02	040	164	535	44	05	782	2
2	1	64	02	020	162	690	32	10	654	2
2	1	59	01	042	190	665	30	05	632	2
3	1							12	711	2
3	1							9	641	2
3	1							13	757	2
3	1							11	174	2
3	1	61	62	010	138	317	10	10	203	2
3	1	68	02	502	080	317	10	20	722	2
3	1	65	01	016	122	460	10	10	592	2
3	1	69	03	010	006	127	10	13	741	2
4	1	63	03	066	086	419	20	03	327	2
4	1	66	02	006	198	700	50	02	277	2
4	1	71	02	004	148	687	50	04	483	2
4	1	69	04	048	114	335	10	08	666	2

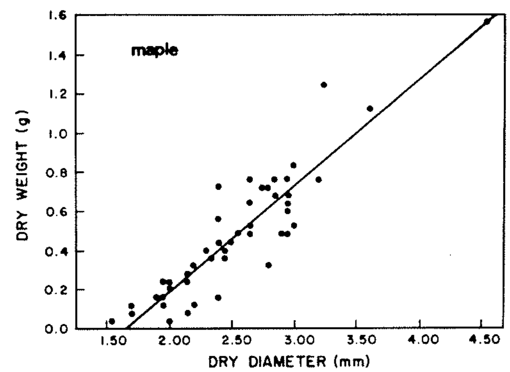
site	horizon	pH	salinity	N	P	K	S	% organic	treatment
1	2	64	02	014	210	592	04	085	1
1	2	65	01	002	338	588	08	321	1
1	2	60	01	028	152	320	20	408	1
1	2	64	01	016	070	309	01	303	1
2	2	57	01	242	098	302	27	739	1
2	2	67	02	006	176	295	07	171	1
2	2	64	61	030	110	217	17	356	1
2	2	67	01	002	038	140	01	043	1
2	2	64	03	024	416	700	10	672	1
3	2	72	03	010	200	490	10	720	1
3	2	73	02	006	004	177	03	046	1
3	2			010	008	177	10	441	1
3	2	74	04	028	002	197	05	053	1
3	2	67	02	008	012	285	02	048	1
4	2	75	02	002	020	075	06	046	1
4	2	80	02	020	008	075	02	025	1
4	2	72	04	032	050	295	10	513	1
4	2	81	02	008	062	045	03	020	1
1	2	53	01	012	008	372	06	116	2
1	2	59	01	008	082	568	06	515	2
1	2	62	02	018	006	245	05	024	2
1	2	67	02	090	200	440	50	210	2
1	2	67	01	008	286	550	17	621	2
1	2	60	10	080	360	512	20	210	2
2	2	71	01	040	046	285	20	336	2
2	2	65	02	006	068	411	19	215	2
2	2	63	02	034	084	300	27	608	2
2	2	60	01	008	134	285	02	757	2
2	2	65	01	004	004	129	02	035	2
3	2	73	03	022	044	234	10	087	2
3	2	74	02	012	004	137	04	047	2
3	2	65	01	004	024	090	01	015	2
3	2	64	02	008	004	274	03	055	2
3	2	67	01	012	012	164	02	069	2
3	2	73	03	074	054	145	10	076	2
4	2	68	02	002	012	117	06	046	2
4	2	80	02	020	008	075	02	025	2
4	2	65	02	008	132	295	10	058	2
4	2	69	02	000	022	103	09	080	2
1	3	66	01	004	000	217	02	087	1
1	3	68	02	020	070	305	02	058	1
1	3	62	01	004	042	327	02	019	1
1	3	62	01	002	042	290	02	034	2
1	3	63	01	004	228	420	02	028	2
1	3	61	01	012	100	400	05	069	2
1	3	59	01	012	060	349	03	027	2
2	3	68	01	004	148	250	22	055	1
2	3	65	02	012	010	153	04	107	1
2	3	63	01	018	062	300	03	070	1
2	3	64	01	016	070	309	01	303	1
2	3	65	02	010	026	195	05	039	2
2	3	53	01	000	002	165	01	046	2
2	3	62	01	016	046	135	02	059	2
3	3	76	02	016	008	072	02	002	1
3	3	70	02	016	004	079	02	021	1
3	3	74	02	020	008	049	02	026	1
3	3	76	02	010	004	072	01	024	1
3	3	68	01	008	004	250	02	026	1
3	3	65	01	002	140	057	01	016	2
3	3	74	03	008	004	225	02	032	2
3	3	70	01	010	004	060	01	022	2
3	3	71	01	010	006	127	02	041	2
3	3	73	02	012	008	062	02	041	2
4	3	75	02	002	020	075	06	046	1
4	3	80	02	020	008	075	02	025	1
4	3	72	04	032	050	295	10	513	1
4	3	81	02	008	002	045	03	020	1
4	3	68	02	002	012	117	06	046	2
4	3	80	02	020	008	075	02	025	2
4	3	65	02	008	132	295	10	058	2
4	3	69	02	000	022	103	09	080	2

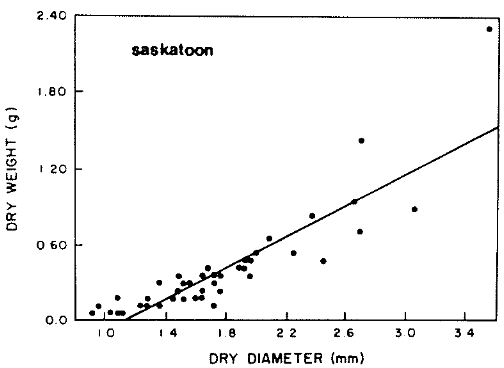
Appendix E. Twig weight-diameter relationship for red-osier dogwood, low bush-cranberry, pincherry, mountain maple, saskatoon, chokecherry, balsam poplar and beaked hazel(Chapter III)

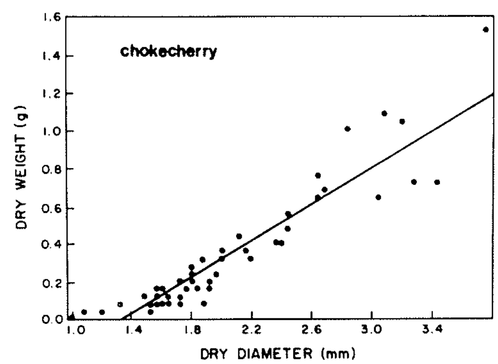

dogwood
DRY WEIGHT (g)
0.81
0.72
0.63
0.54
0.45
0.36
0.27
0.18
0.09
0.90
1.20
1.50
1.80
2.10
2.40
2.70
DRY DIAMETER (mm)

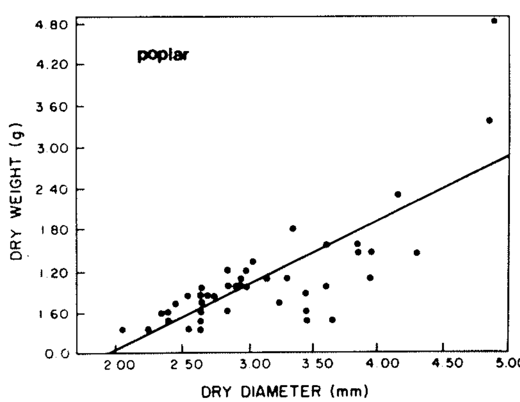

cranberry
DRY WEIGHT (g)
1.125
1.00
0.875
0.75
0.025
0.50
0.375
0.250
0.123
1.75
2.10
2.45
2.80
3.15
3.50
3.85
DRY DIAMETER (mm)

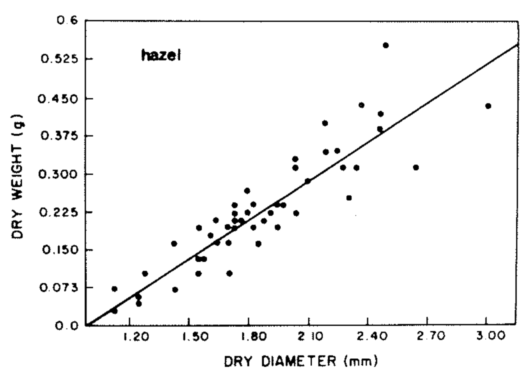

pincherry
DRY WEIGHT (g)
0.72
0.63
0.54
0.45
0.36
0.27
0.18
0.09
0.0
0.90
1.20
1.50
1.80
2.10
2.40
2.70
DRY DIAMETER (mm)


maple
DRY WEIGHT (g)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.50
2.00
2.50
3.00
3.50
4.00
4.50
DRY DIAMETER (mm)


saskatoon
DRY WEIGHT (g)
2.40
1.80
1.20
0.60
0.0
1.0
1.4
1.8
2.2
2.6
3.0
3.4
DRY DIAMETER (mm)


chokecherry
DRY WEIGHT (g)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.0
1.4
1.8
2.2
2.6
3.0
3.4
DRY DIAMETER (mm)


poplar
DRY WEIGHT (g)
4.80
4.20
3.60
3.00
2.40
1.80
1.20
1.60
0.0
2.00
2.50
3.00
3.50
4.00
4.50
5.00
DRY DIAMETER (mm)


hazel
DRY WEIGHT (g)
0.6
0.525
0.450
0.375
0.300
0.225
0.150
0.073
0.0
1.20
1.50
1.80
2.10
2.40
2.70
3.00
DRY DIAMETER (mm)

Appendix F. Appendix for Chapter IV

(a) Raw data for pellet group counts

(b) Browse preference and browse availablility for shrubs in Mink Creek and Sarah Lake plots

(c) Dry weights for material found in the rumen analysis

(d) The average values for available browse, percent browse and browse consumption for the plot, edge and control for the 8 treatments(the standard error of the mean for each value is also given)

(a) Raw data for pellet group counts

Table F.1 Pellet group counts for 1979 and 1980. (Coding is the same as Table D.4).

1979 PELLET GROUP COUNTS

site	trt.	deer	elk	moose
1	1	0	15	19
1	1	0	10	18
1	1	0	10	7
1	1	0	16	1
1	1	0	10	2
1	2	0	50	18
1	2	0	4	2
1	2	0	2	0
1	2	0	8	0
1	2	0	2	4
1	3	2	32	2
1	3	0	0	0
1	3	0	8	0
1	3	0	2	0
1	3	0	0	0
2	1	4	5	4
2	1	4	15	7
2	1	1	7	4
2	2	1	1	2
2	2	3	1	5
2	2	0	3	9
2	3	3	2	0
2	3	11	3	4
2	3	1	5	7
3	1	0	0	0
3	1	0	0	0
3	1	0	0	0
3	1	0	0	1
3	1	0	4	4
3	2	1	1	13
3	2	0	4	4
3	2	0	0	6
3	2	1	2	0
3	2	0	4	11
3	3	0	0	6
3	3	0	8	6
3	3	2	3	1
3	3	0	0	2
3	3	2	3	10
4	1	4	4	1
4	1	1	2	0

site	trt.	deer	elk	moose
4	1	5	4	2
4	1	4	4	4
4	1	0	0	1
4	2	2	3	8
4	2	0	0	2
4	2	1	1	1
4	2	6	7	4
4	2	0	0	0
4	3	14	2	5
4	3	0	3	4
4	3	4	2	5
4	3	2	1	0
4	3	0	0	1
5	1	0	2	7
5	1	1	4	12
5	1	2	1	7
5	1	4	8	25
5	1	1	1	5
5	3	0	4	18
5	3	0	3	4
5	3	8	3	18
5	3	2	13	10
5	3	0	0	1
6	1	0	3	14
6	1	1	0	11
6	1	1	2	18
6	2	0	1	6
6	2	0	0	15
6	2	1	0	10
6	3	0	0	0
6	3	0	0	11
6	3	0	1	5
7	1	1	2	4
7	1	1	6	3
7	1	3	4	8
7	2	0	4	1
7	2	2	10	5
7	2	3	8	12
7	3	1	9	0
7	3	7	1	8
7	3	3	2	4

1980 PELLET GROUP COUNTS

site	trt.	deer	elk	moose
1	1	1	8	1
1	1	0	11	10
1	1	0	2	0
1	2	0	6	8
1	2	0	12	0
1	3	0	5	0
1	3	0	7	1
1	3	0	7	0
2	1	1	1	6
2	1	2	6	0
2	1	0	1	4
2	1	0	0	8
2	1	0	1	4
2	2	1	7	7
2	2	1	7	2
2	2	0	0	3
2	2	1	7	5
2	2	0	1	6
I	3	2	6	0
2	3	5	3	2
2	3	1	0	1
2	3	2	2	1
2	3	1	0	6
3	1	2	1	1
3	1	0	0	0
3	1	1	0	0
3	1	2	0	0
3	2	0	1	9
3	2	1	2	1
3	2	0	1	0
3	2	0	1	0
3	3	0	1	5
3	3	3	5	19
3	3	0	0	2
3	3	3	6	0
4	1	0	0	0
4	1	0	3	1
4	1	0	1	0
4	1	0	1	0
4	2	0	2	2
4	2	0	1	1
4	2	0	3	3
4	2	0	1	1
4	3	1	3	3
4	3	0	2	2
4	3	0	2	2
4	3	0	1	1

site	trt.	deer	elk	moose
5	1	0	0	2
5	1	0	1	2
5	1	0	2	2
5	3	1	1	0
5	3	1	0	1
5	3	1	1	1
6	1	2	2	6
6	1	0	0	10
6	1	1	0	9
6	1	0	1	13
6	1	0	0	1
6	1	0	1	14
6	1	0	0	10
6	2	0	2	6
6	2	0	2	10
6	2	0	0	8
6	2	0	1	6
6	2	0	0	3
6	2	0	0	1[illegible]
6	2	1	1	11
6	3	0	1	1
6	3	2	3	5
6	3	3	0	14
6	3	0	1	1
6	3	1	1	2
6	3	1	1	2
6	3	0	0	2
7	1	0	0	0
7	1	0	0	1
7	2	0	0	4
7	2	0	0	0
7	3	0	0	0
7	3	1	1	0
8	1	0	1	8
8	1	1	2	5
8	1	6	2	9
8	1	0	4	2
8	2	1	0	5
8	2	1	2	4
8	2	0	1	3
8	2	0	2	1
8	3	1	1	4
8	3	2	5	4
8	3	0	6	3
8	3	1	1	0

(b) Browse preference and availability for shrubs in Mink Creek and Sarah Lake plots

Table F.2. The percent of total shrubs that each species makes up compared to the percent of the total browse that each species makes up in the Sarah Lake (S-73) site.

	Plot		Edge		Control	
Species	% total	% browse	% total	% browse	% total	% browse
Amelanchier alnifolia	3.3	-	4.3	4.3	1.7	1.7
Cornus stolonifera	-	-	12.3	7.0	1.7	1.7
Corylus cornuta	38.5	5.8	9.6	1.8	66.7	10.0
Populus balsamifera	1.1	-	3.5	0.9	-	-
P. tremuloides	4.4	-	7.9	3.5	4.2	1.7
Prunus pensylvanica	3.6	0.4	-	-	-	-
P. virginiana	0.7	-	1.8	-	1.7	-
Rosa spp.	16.0	-	24.6	-	16.7	-
Rubus idaeus	8.4	-	5.3	-	-	-
Viburnum edule	1.1	0.7	-	-	2.5	0.8
Alnus rugosa	4.7	-	12.3	-	-	-
Lonicera dioica	5.5	-	2.6	-	-	-
Viburnum opulus	8.0	-	15.8	-	-	-
Ribes oxyacanthoides	1.1	0.7	-	-	-	-
Rhamnus alnifolia	3.6	-	-	-	-	-
Salix spp.	-	-	-	-	1.7	1.7
Symphoricarpos occidentalis	-	-	-	-	3.3	-

Table F.3. The percent of the total shrubs that each species makes up compared to the percent of the total browse that each species makes up in the Sarah Lake(S-77) site.

	Plot		Edge		Control	
Species	% total	% browse	% total	% browse	% total	% browse
Amelanchier alnifolia	26.0	-	18.7	12.2	-	-
Cornus stolonifera	5.1	1.1	4.1	2.4	77.8	71.1
Corylus cornuta	3.4	-	8.1	-	-	-
Populus balsamifera	11.3	-	-	-	-	-
P. tremuloides	24.3	-	20.3	-	4.4	-
Prunus pensylvanica	1.7	-	13.0	-	2.2	-
P. virginiana	1.1	-	4.9	-	4.4	-
Rosa spp.	24.3	-	22.8	-	8.9	-
Rubus idaeus	2.8	-	2.4	-	-	-
Viburnum edule	-	-	9.8	6.5	-	-
Ribes americanum	-	-	0.8	-	2.2	-

Table F.4. The percent of total shrubs that each species makes up compared to the percent of the total browse that each species makes up in the Sarah Lake(S-78) site.

Species	Plot		Edge		Control	
	% total	% browse	% total	% browse	% total	% browse
Amelanchier alnifolia	31.7	9.8	5.9	1.4	11.3	1.6
Cornus stolonifera	-	-	0.7	0.3	3.2	-
Corylus cornuta	-	-	82.1	2.1	72.6	9.7
Populus balsamifera	14.6	-	-	-	-	-
P. tremuloides	26.8	-	2.4	-	1.6	-
Prunus pensylvanica	-	-	1.0	0.3	1.6	-
P. virginiana	26.8	-	1.4	-	3.2	-
Rosa spp.	-	-	4.1	-	6.5	-
Rubus idaeus	-	-	1.0	-	-	-
Salix spp.	-	-	1.4	1.4	-	-

Table F.5. The percent of total shrubs that each species makes up compared to the percent of the total browse that each species makes up in the Mink Creek(M-74) site.

	Plot		Edge		Control	
Species	% total	% browse	% total	% browse	% total	% browse
Amelanchier alnifolia	4.3	-	13.2	5.0	6.3	1.6
Cornus stolonifera	7.2	5.1	7.8	3.0	6.9	3.7
Corylus cornuta	48.9	0.3	44.0	7.8	50.8	2.6
Populus balsamifera	5.6	0.4	3.9	0.2	-	-
P. tremuloides	12.9	0.5	8.2	0.2	-	-
Prunus pensylvanica	0.7	0.1	-	-	2.1	-
P. virginiana	0.5	0.1	-	-	6.3	1.1
Rosa spp.	2.7	-	4.1	0.4	1.6	-
Rubus idaeus	0.5	-	4.1	-	3.2	-
Viburnum edule	-	-	-	-	2.6	-
V. opulus	0.4	-	1.1	-	1.1	-
Salix spp.	1.4	-	2.8	0.4	4.2	-
Rhamnus alnifolia	8.7	-	2.2	-	5.8	-
Ribes oxyacanthoides	0.4	-	-	-	1.1	-
Symphoricarpos occidentalis	-	-	-	-	0.5	-
Alnus rugosa	0.7	-	2.2	-	3.7	-
Lonicera villosa	-	-	1.1	-	0.5	-
L. dioica	1.3	-	0.2	-	2.1	0.5
Viburnum lentago	-	-	1.5	0.9	1.1	0.5
Quercus macrocarpa	1.3	-	-	-	-	-
Symphoricarpos albus	0.3	-	0.9	-	-	-
Shepherdia canadensis	0.3	-	2.0	-	-	-
Potentilla fruticosa	0.4	-	-	-	-	-
Cretaegus rotundifolia	-	-	0.2	0.2	-	-
Betula papyrifera	-	-	0.4	-	-	-

Table F.6. The percent of total shrubs that each species makes up compared to the percent of the total browse that each species makes up in the Mink Creek (M-75) site.

Species	Plot % total	Plot % browse	Edge % total	Edge % browse	Control % total	Control % browse
Amelanchier alnifolia	3.5	0.4	2.3	1.1	13.0	3.7
Cornus stolonifera	10.2	6.3	3.8	1.8	1.9	1.9
Corylus cornuta	59.6	4.0	77.9	3.8	64.8	3.7
Populus balsamifera	4.4	0.2	2.0	-	-	-
P. tremuloides	11.1	-	3.7	0.6	-	-
Prunus pensylvanica	1.1	-	-	-	-	-
P. virginiana	2.8	0.5	0.5	0.3	1.9	-
Rosa spp.	1.1	-	1.4	-	1.9	-
Rubus idaeus	1.8	-	1.4	-	1.9	-
Betula occidentalis	-	-	-	-	7.4	-
Viburnum opulus	0.2	0.2	1.4	-	7.4	-
Salix spp.	0.2	0.2	0.6	-	-	-
Rhamnus alnifolia	4.0	-	0.9	-	-	-
Ribes oxyacanthoides	-	-	0.6	-	-	-
Lonicera dioica	0.2	-	0.8	-	-	-
Viburnum lentago	-	-	0.2	-	-	-
Symphoricarpos albus	-	-	0.6	-	-	-
Potentilla fruticosa	-	-	1.5	-	-	-
Viburnum rafinesquianum	-	-	0.5	-	-	-

Table F.7. The percent of the total shrubs that each species makes up compared to the percent of the total browse that each species makes up in the Mink Creek (M-76) site.

	Plot		Edge		Control	
Species	% total	% browse	% total	% browse	% total	% browse
Amelanchier alnifolia	11.1	-	2.5	-	-	-
Cornus stolonifera	-	-	8.8	8.8	13.5	10.8
Corylus cornuta	14.8	-	71.2	-	70.3	2.7
Populus balsamifera	-	-	1.2	-	2.7	-
P. tremuloides	59.3	-	5.0	-	-	-
Prunus pensylvanica	-	-	2.5	-	-	-
P. virginiana	-	-	1.2	-	2.7	-
Rosa spp.	-	-	1.2	-	-	-
Rubus idaeus	14.8	-	-	-	-	-
Viburnum edule	-	-	6.2	-	2.7	-
Viburnum opulus	-	-	-	-	8.1	-

(c) Dry weights for material found in the rumen analysis.

Table F. 8. The dry weights of the material found in the moose rumen samples.

Plant	Dry weight(g) in samples									
	1	2	3	4	5	6	7	8	9	10
Populus tremuloides	3.66	2.93	0.50	0.24	0.50	0.45	0.82	0.56	0.55	0.57
Unknown	-	-	0.09	0.08	0.08	0.16	0.17	0.10	0.18	0.14
Salix sp.	-	-	0.02	-	-	-	-	-	0.45	0.55
Betula glandulosa	-	-	-	0.01	-	-	-	-	-	-
Corylus cornuta	-	-	-	0.09	-	0.06	-	-	-	-
Abies balsamea	-	-	-	-	-	0.08	0.10	0.17	-	0.04
Cornus stolonifera	-	-	-	-	-	-	0.11	-	-	-
Amelanchier alnifolia	-	-	-	-	-	-	-	-	0.11	0.09

Table F.9. The dry weights of the material found in the elk rumen samples.

Plant component	Dry weight (g) in samples																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Grain	0.86	0.69	0.86	0.06	0.15	0.06	0.40	0.20	0.29	1.07	1.65	-	-	-	0.42	0.31	0.20
Graminoids	0.03	-	-	0.03	0.02	0.04	0.01	0.03	-	-	-	0.01	0.02	0.02	-	0.02	0.01
Populus tremuloides	0.03	0.13	-	0.06	0.07	0.22	0.28	0.06	0.09	-	-	-	0.01	0.05	-	-	-
Rosa spp.	-	-	-	0.35	0.21	0.20	0.01	-	-	-	-	0.06	0.22	0.51	0.29	0.17	0.13
Cirsium arvense	-	-	-	-	0.03	-	-	-	-	-	-	-	-	-	-	-	-
Cornus stolonifera	-	-	-	-	0.05	0.05	-	-	0.05	-	-	0.08	0.15	0.03	0.21	0.26	-
Unknown	-	-	-	-	-	-	0.01	0.03	-	-	0.01	0.07	0.09	0.04	0.33	0.18	0.40
Populus balsamifera	-	-	-	-	-	-	0.01	-	0.09	-	-	-	-	-	-	-	-
Salix spp.	-	-	-	-	-	-	0.02	-	-	-	-	0.04	0.03	-	-	-	-
Betula papyrifera	-	-	-	-	-	-	0.06	0.10	0.12	0.02	-	-	-	-	-	-	-
Acer spicatum	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-
Avena fatua	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.04	-
Symphoricarpos occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	0.05	0.29

Table F.10. The average values for available browse, percent browse and browse consumption for the plot, edge and control for the 8 treatments (the standard error of the mean for each average value is also given).

Treat-ment	Available Browse			Percent Browse			Browse Consumption		
	plot	edge	control	plot	edge	control	plot	edge	control
S-78	9.77 ± 2.46	26.92 ± 7.84	15.67 ± 5.15	0.00	30.33 ± 10.48	10.67 ± 8.29	0.00	15.82 ± 8.72	42.45 ± 36.20
S-77	17.90 ± 4.39	16.80 ± 2.52	20.80 ± 12.62	3.30 ± 2.04	31.60 ± 12.73	28.20 ± 14.44	0.37 ± 0.37	11.58 ± 9.81	172.32 ± 115.87
M-76	30.83 ± 11.85	56.67 ± 10.70	20.25 ± 4.27	0.00	5.25 ± 3.54	8.92 ± 7.65	0.00	8.41 ± 8.41	11.88 ± 9.82
G-75	39.07 ± 6.22	34.78 ± 5.28	12.07 ± 2.88	12.14 ± 4.32	15.00 ± 4.24	10.18 ± 5.38	5.86 ± 1.82	4.10 ± 4.10	0.43 ± 0.40
M-75	29.60 ± 5.94	23.60 ± 9.94	28.40 ± 14.82	8.80 ± 5.59	15.20 ± 7.54	2.00 ± 2.00	23.25 ± 15.96	15.82 ± 15.82	9.67 ± 9.67
M-74	51.35 ± 6.85	39.89 ± 7.95	16.50 ± 5.19	14.55 ± 5.99	5.63 ± 1.89	5.00 ± 2.44	5.09 ± 2.01	6.08 ± 2.84	5.08 ± 2.65
S-73	14.36 ± 2.59	4.50 ± 1.60	13.21 ± 3.47	16.14 ± 7.70	29.40 ± 10.06	19.21 ± 5.00	4.62 ± 3.48	5.79 ± 2.07	10.60 ± 4.47
L-73	41.77 ± 10.95	24.92 ± 5.03	10.57 ± 2.14	36.88 ± 9.00	37.83 ± 9.66	8.93 ± 4.98	11.06 ± 4.68	15.88 ± 5.70	0.60 ± 0.60

Appendix G. Appendix for Chapter V
(Benefit-cost Analysis)

Calculations of costs and benefits

Costs- 44% of the bulldozing costs go to pay the operators. This value varies with the region but the operators receive aproximately $10.00/hour.

-surveying costs were estimated. The survey of a plot was given a day value. At the average wage of the technician at $5.00/hour and 8 hours per plot, each plot would cost $40.00 (including map preparation).

Benefits- Hunter use- The selection of 10 hunters was chosen as a minimum value. The costs were determined on the basis of the hunters giving information on the ten rumen samples received from the area. The costs were as follows:

Transportation to the area-$620

Daily transportation-

3 days x 30 minles x 2 trips=$756

Of the 10 hunters whose moose or elk rumens were sampled, 4 were local, 2 from Swan River, 2 from Brandon, 1 from Virden and 1 from Winnipeg).

(a rate of 21¢/mile) was used in assessing transportation costs)

Licenses (@$20.00)-$200
Guns (@$500)- $5000
Accomodation- $480

(Most hunting licenses are good for 3 days or a hunter usually spends a minimum of 3 days hunting if he is allowed to hunt longer).

Food	$432
Clothing	$300
Ammunition	$100
Missed work@$3.39 /hour x 4 days	$1085
Total costs	$9973

(Total costs are in 1980 prices. From information over the years a 13% inflation rate was added to the costs).

<u>Animal economic value in meat price terms:</u>

	average weight	x	price of beef	+	hide price
elk	598		60¢/lb. (1980)		$7.00
moose	884		"		$10.00
deer	166		"		$5.00