AN ASSESSMENT OF WINTER HABITAT FOR MOOSE ON HECLA ISLAND WITH EMPHASIS ON BROWSE PRODUCTION AND BROWSE UTILIZATION.

By

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AN ASSESSMENT OF WINTER HABITAT FOR MOOSE ON HECLA ISLAND WITH EMPHASIS ON BROWSE PRODUCTION AND BROWSE UTILIZATION.

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ABSTRACT

Range conditions were studied on Hecla Island, Manitoba from July, 1988 - June, 1989. The study area is located approximately 200 km north of Winnipeg on Lake Winnipeg. An assessment was conducted to determine browse composition, production and utilization levels in several habitat types which were identified using aerial photographs and Forest Cover Type maps. Using these data a first approximation for carrying capacity was made. Habitat relationships between moose (*Alces alces andersonii*), white-tailed deer (*Odocoileus virginianus*) and snowshoe hare (*Lepus americanus*) were evaluated using pellet group counts along fixed transects. Transects were located in each habitat type; browse species encountered were sampled using the corrected joint-point nearest neighbour technique. In the spring of 1989, an extensive survey using an ocular estimate classified the degree of browse use for Hecla range.

Several measures of habitat use were examined. Hypotheses tested revealed that moose used various habitats disproportionately in relation to their availability. Both pellet group and browse use surveys determined that mixedwood (s-h), immature deciduous and immature coniferous were preferred habitats. But willow-alder was most highly preferred for browsing. White-tailed deer preferred similar habitats but did not use willow-alder. Snowshoe hare preferred both mixedwood and deciduous types and avoided

willow-alder and marsh muskeg.

Total browse production (kg/ha) and use was greatest in the willow/alder habitat. Red-osier dogwood and willow contributed almost 80% of total browse production for that habitat. In estimating range capacity, ungulates were found to use only about one-third of available browse, but the condition of the most favoured species; red-osier dogwood, willow and mountain maple has deteriorated across all habitats as a result of high intensity browsing.

More information is needed for determining impacts of development on wildlife and due to the lack of natural events such as fire, additional, preferably long-term research on the successional trends of vegetation communities on Hecla Island should be pursued. Managing for both the maintenance of the ecosystem heterogeneity and maintaining the relative health of moose on Hecla Island may prove difficult. However, if the living resources can be responsibly and co-operatively shared by various interest groups, management objectives can be met.

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1.0 INTRODUCTION

1.1 BACKGROUND

Hecla Provincial Natural Park was established in 1969, and has recently been reclassified as Hecla Provincial Heritage Park, in recognition of its unique cultural aspects (DNR 1987). Set in the heart of Lake Winnipeg, Hecla (and Grindstone) are Provincial Parks that encompass some of the finest recreational lands in the Province (DNR 1988).

According to the Manitoba Provincial Park Lands Act (Anonymous 1972):

> "Provincial park lands are dedicated to the people of Manitoba and visitors of Manitoba, and may be used by them for healthful enjoyment, and for the cultural, educational and social benefits that may be derived therefrom."

Furthermore, "Provincial park lands shall be developed and maintained;

a) for the conservation and management of flora and fauna therein;

b) for the preservation of the specified areas, and objects therein that are of geological, cultural, ecological or other scientific interest and;

c) to facilitate the use and enjoyment of outdoor recreation therein."

Hecla Island had been labelled as "Manitoba's answer to Isle Royale" (Crichton, 1977) by virtue of the high density moose (*Alces alces andersonii*) population inhabiting an island within a large lake. However, Hecla Island has been developed to provide intensive recreational opportunities, unlike Isle Royale. In addition, Hecla has only a small transient population of gray wolves (*Canis Lupus*), that is, one or two family groups (B.Burgess, Manitoba Parks, pers. comm. 1990). Ever since the development of the causeway in 1972, populations of moose are not as isolated as they are on Isle Royale. Immigration and emigration is believed to occur to and from the island across winter ice. The real importance of this "label" is that Hecla Island, like Isle Royale, could be potentially available for research.

To be consistent with the Hecla-Grindstone Provincial Parks Management Plan, "there will be no regular hunting seasons on Hecla Island" (DNR 1988). However, special hunts may be allowed as required for management of the herd" (DNR 1988). There was a fall archery season and a one-week senior citizen (license awarded by draw) hunt in December, 1988. In addition, Treaty Indian hunting is still occurring. Also, there is an on-going, often controversial debate regarding making Hecla Island a "refuge" from all hunting.

The current decision for Hecla Island (1990) concerning hunting on Hecla had been made by the current Minister of Natural Resources, (Hon. H. Enns 1990) so that there was no moose hunting for the 1990 and 1991 seasons.

The Management Plan also stipulates that the moose population on Hecla Island will be managed to give priority to opportunities for viewing and interpretation and Treaty Indian hunting. It has been stated that moose habitat on

Hecla Island is being continuously reduced from both a qualitative and quantitative aspect by forest maturation and human development activities (Crichton 1977). The extent of the impact of forest maturation on moose populations on Hecla Island is to date not well known.

1.2 PROBLEM STATEMENT

The Parks Branch is working towards a Moose Management Plan for Hecla Island. At the present time, certain information is lacking. According to the Hecla/Grindstone Provincial Parks Management Plan (DNR 1988), "Information requirements include ongoing evaluation of moose distribution through the seasons, use of food plants, and interactions with park visitors. As an island, Hecla provides an interesting opportunity to study the interaction between wildlife and vegetation."

If the Parks Branch mandate is to provide viewing opportunities for Manitobans and visitors, then a sufficient moose population must be maintained in order to enhance viewing opportunities. It follows that at the same time moose habitat must also be maintained. In order for Parks to achieve these ends, information must be made available that will critically examine the habitat available for moose. This study attempted to examine and assess the current habitat conditions on Hecla Island, with specific emphasis on browse production and utilization. Based on these data, conclusions can be drawn on whether moose can maintain present or desired population levels given these habitat conditions.

1.3 RESEARCH OBJECTIVES

This study of moose habitat on Hecla Island had the following objectives:

1) To identify browse species used by moose;

2) To assess and estimate browse production within and between habitat types;

3) To assess and estimate winter browse utilization;

4) To identify available moose habitat and to evaluate the ungulate carrying capacity for future management;

5) To make recommendations for future management of moose habitat on Hecla, with particular emphasis on viewing enhancement.

1.4 RESEARCH PROGRAM

This study involved a three part program commencing in June, 1988. The first part of the study included map and aerial photograph interpretation for purposes of stratifying the available moose habitat on the basis of forest cover types, and identifying the study areas to be sampled. The habitat was then ground-truthed and tie-points were identified both on the ground and on aerial photographs for future reference. At this stage of the project, Landsat imagery was considered for enhancement of the delineation of habitat types. However, it was found to be unsuitable for this project, as the Forest Cover Type Inventory information had better resolution. Thematic mapping technology may have been used but was too expensive for this project.

The second portion of this study included a browse production study which occurred from August to November 1988. At this time, accurate forage production information on browse was obtained when forage production was at its peak. All woody browse species which were encountered and fell within the available vertical height range were sampled. Browse species which are less often utilized and thought to be unimportant to moose and deer were also sampled. The method used was the "corrected joint point-nearest neighbour technique" (Batcheler 1975).

The third part of this study examined browse utilization using a method described as the "nearest neighbour technique" (Cole 1963). This method effectively determines the frequency of browsing and hence, the degree of utilization of available habitat by moose and white-tailed deer (*Odocoileus virginianus*) on Hecla Island. The study ran from mid-May to mid-June, 1989 to take advantage of pre-leaf flush conditions of browse species. Leaf flush in 1989 was later than many years, and therefore, the required pre-leaf flush conditions were met, although in June, several species were beginning to flush. As well, to complement this portion of the study, a pellet group count was done to determine distribution of use by moose, white-tailed deer and snowshoe hare (*Lepus americanus*).

1.5 HYPOTHESIS STATEMENT

Moose populations can be sustained on Hecla Island given current and anticipated habitat conditions. Given this statement the hypothesis to be tested was:

> ***a)*** ***Browse use is directly proportional to the availability of browse species.***
>
> ***b)*** ***Habitat use is directly proportional to habitat availability***

It is expected that browse use will be closely correlated to the availability of browse species as they occur in various habitat types. In effect, browse utilization may be associated with other factors such as browse palatability or nutritional quality.

1.6 LIMITATIONS

Due to the nature of this study, where emphasis is on the production and utilization of browse species, it must be noted that the quality of browse species is not addressed. This, in fact, may be extremely important to the overall assessment of habitat conditions on Hecla Island. Future studies may be needed to address the adequacy of the nutritive value of browse to moose.

Due to the short length of the study period and relatively small sample size, measures reported cannot be taken as absolute. Variation of natural communities are inherently difficult to measure accurately as there are many variables which result from year to year.

Another limitation of this study is the fact that any shift in habitat use from season to season can not be detected by these sampling methods and that radio telemetry and aerial survey flights should be used to note any shifts in habitat use.

1.7 STUDY AREA

1.7.1 PHYSIOGRAPHY

Hecla Island is the largest island in Lake Winnipeg, with an area of approximately 162 km^2, measuring about 6.4 km wide and 25.6 km long. Hecla Island lies in the Interlake-Westlake Plain subdivision of the Manitoba Lowland, and represents a transition between the boreal forest and aspen parkland (Figure 1). The elevation varies between 218 m and 232 m above sea level (Weir 1960). Geologically, the island lies in the Red River Formation and the bedrock is limestone which was deposited during the Ordovician period.

1.7.2 DRAINAGE AND VEGETATION

The soil type is degraded rendzina which developed under grasses over high lime drift and was later altered by forest invasion. This soil is typified by fine textured clays, deposited when the area lay beneath glacial Lake Agassiz. On poorly drained soils, extensive marshes, bogs, fens and wet meadows have developed.

Major vegetation associations are described by the Manitoba Provincial Forest Inventory, (DNR, n.d. unpubl.) based on vertical photo-interpretation methods. This inventory bases its classification on site productivity for forested and non-forested areas.

Productive forest lands are designated by the major tree species found on various sites. For example, softwood species include black spruce (*Picea mariana*) and tamarack (*Larix laricina*) on poorly drained, wet sites and on higher ground with better drained sites, white spruce (*Picea glauca*) and balsam fir (*Abies balsamea*). Hardwood species include trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*) and green ash (*Fraxinus pensylvanica*).

Non-productive forests include treed muskeg and willow/alder associations.

1.7.3 CLIMATE

The climate on Hecla Island is classed as Humid Continental. The frost free period is approximately 110 days. The average July temperature is about 19 degrees Centigrade and the average January temperature is about -19 degrees Centigrade.(Environment Canada Normals, 1982). The average annual snowfall is 1.4 - 1.5 m (Environment Canada Normals, 1982).

1.8 DEFINITIONS

Basal Area	Cross-sectional area taken at the breast height (1.3 m) of a standing tree (Daniel *et al* 1972)
Even-aged stands	All trees within the stand are the same age or at least of the same age class. A stand is considered even-aged if the difference in age between the oldest and the youngest trees does not exceed 20% of the length of rotation (Smith 1962)

Tie-points	Points that are readily identifiable both on the ground as well as on a map or aerial photograph.
Uneven-aged stands	Contain at least three age classes intermingled intimately on the same area (Smith 1962)
Twig	That part of a branch distal to the point where branch diameters would, if air dried, equal the largest diameter observed for a stub of a browsed branch of that species (Telfer 1969)
Stems	That portion of woody growth which protrudes from the ground, or is a separate entity at ground level (Telfer 1969).

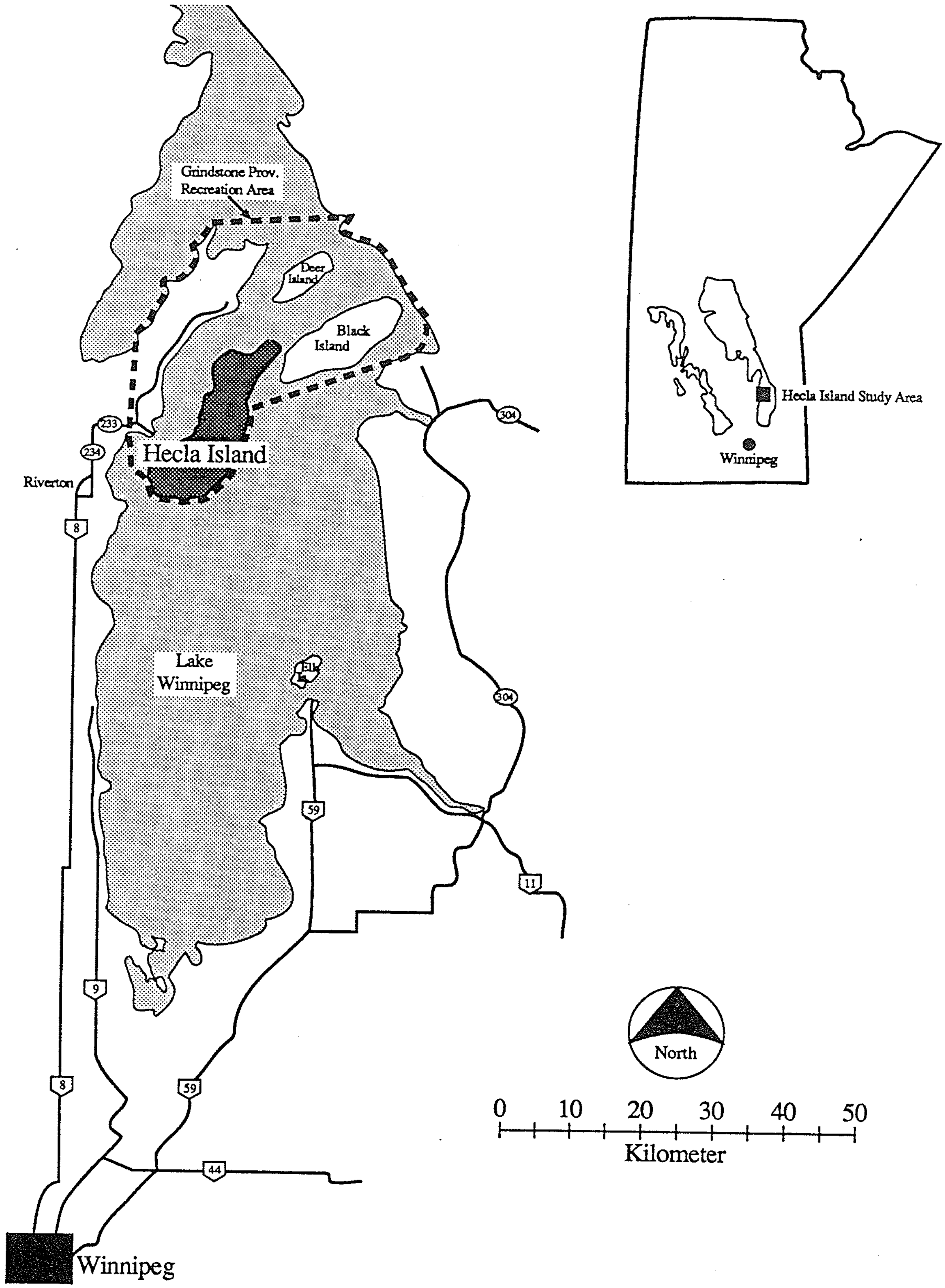


Figure 1. Hecla Island Study Area.

2.0 REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

The moose is primarily an inhabitant of the boreal forest. In North America, the most important habitat is mixed stands of conifer and hardwood where early seral stages of plant succession are present. Fire has historically maintained moose habitat but timber harvesting has now taken the place of fire in much of North America (Krefting 1974). Habitat is the essential ingredient dictating wildlife populations with the two primary components being food and cover, the former being the most critical to moose on Hecla (Crichton 1977).

2.2 COVER

Use of cover by moose was shown to be important in other studies: for predator avoidance (Stephens and Peterson 1984), thermal protection in northeast Minnesota (Van Ballenberghe and Peek 1971), and avoidance of deep or crusted snow in Thunder Bay, Ontario (McNicol and Gilbert 1980).

Moose use open habitat types such as shrublands, riparian habitats, muskeg, and clearcuts with some movement into upland aspen stands during late fall and early winter (Dorn 1970; Cairns and Telfer 1980; Rolley and Keith 1980; Mytton and Keith 1981; Nietfeld *et al* 1984; Risenhoover 1989). Eccles *et al.* (1986) noted high moose densities on the Peace-Athabasca delta in willow and alder habitats. In northwestern Alberta, Salter *et al.* (1986) and Eccles and Duncan (1988) in northeastern Alberta reported that treed bogs and shrubland habitats were the predominant habitats used in both early and late winter, although increased use of upland deciduous forests in late winter was noted. However, it should be noted that these habitats were the most common and widely distributed, and therefore not necessarily preferred habitats. Bog habitat on the Kenai Peninsula, Alaska apparently becomes more important when food abundance or quality declines in the early spring or as a burn matures (Bangs *et al* 1985). Moose were noted to be farthest from the forested edge while utilizing bog habitats (Bangs *et al* 1985).

Many authors have reported that as snow accumulates in more open habitat types, moose move closer to dense, closed canopy coniferous forests adjacent to open areas with large quantities of browse forage available (Rolley and Keith 1980, in Alberta; Doerr 1983, in Alaska; Nietfeld *et al* 1984, in Alberta; Pierce and Peek 1984, in Idaho). The distance moose move into openings from cover is apparently related to snow depth (Welsh *et al* 1980; Brusnyk and Gilbert 1983, in Ontario). One hundred metres is considered as a maximum distance that moose will move from the forest edge in deep snow conditions in northern Ontario (Hamilton and Drysdale 1975). In Alberta, Quinlan *et al* (1990) have stated that cow and calf groups rarely move further than 60 m from coniferous cover even during low snow accumulation.

In addition, Quinlan *et al* (1990) have attempted to quantify habitat requirements for moose as it relates to cover. They have reported that good early winter habitat consists of several small residual stands of mixed or coniferous trees with an average coniferous basal area of 9.5 m^2/ha and <10 m high. By late winter, dense coniferous cover which had a tree canopy closure of ≥75% and mean stand height of >6 m situated in close proximity to dense aspen with suitable available browse was preferred. As the proportion of coniferous trees increases the quality of the cover also increases.

2.3 FOOD

2.3.1 MOOSE FOOD HABITS

Moose are generalist herbivores that select a variety of preferred plant species (Miquelle and Gordon 1979). This pattern expands to include a number of less palatable species and increased use of preferred species (greater mean diameters at point of browse (dpb), bark stripping, as availability, related to snow accumulation, decreases during winter (Bonar 1985).

During the late fall/winter season, moose in western Canada use deciduous browse almost exclusively as a food item, although actual species composition of the diet may vary considerably between regions. Browse species use and availability may also be related to snow depth (Bonar 1985).

Various willow (*Salix* spp.) species have been shown by many authors to consistently be one of the most utilized shrubs throughout North America (Wolff and Cowling 1981, in Alaska; Goulet 1985, northern British Columbia; Irwin 1985, in Minnesota; Rudd and Irwin 1985, in Wyoming; Risenhoover 1989, in Alaska; Quinlan *et al* 1990, in Alberta). Goulet (1985) in British Columbia found that of 16 browse species which made up 97% of the diet of moose, willow alone made up 35% of that total. Other species which were preferred by moose included red-osier dogwood (*Cornus stolonifera*), mountain ash (*Sorbus americana*.), bog birch (*Betula glandulosa*), trembling aspen, paper birch and high-bush cranberry (*Viburnum opule*). Green alder (*Alnus crispa*), and saskatoon (*Amelanchier alnifolia*) were used in proportion to their availability. In Alberta, Nietfeld *et al* (1984) and Nowlin (1978) state that saskatoon, willow, aspen, red-osier dogwood, paper birch, balsam poplar, pin cherry (*Prunus pennsylvanica*), and chokecherry (*Prunus virginiana*) are the most important browse species to moose.

In most studies in western North America, even though coniferous shrubs such as western red cedar (*Thuja plicata*), lodgepole pine (*Pinus contorta*), larch (*Larix laricina*), and black spruce have been found to be browsed by moose (Bonar 1985; Stevens 1970; Goulet 1985; Matchett 1985; Rudd and Irwin 1985; Telfer 1969), they are not considered to be preferred.

In northeast Alberta, Renecker and Hudson (1985) state that moose had spent 39% of their foraging time during April stripping bark from aspen and balsam poplar. However, bark stripping became less important as leaves started to flush. This was also observed by Risenhoover (1989) near Fairbanks, Alaska and Miquelle and Van Ballenberghe (1989) in southeast Alaska, but the amount consumed was not significant.

2.3.2 TERMS

Terms or words frequently used in the literature often cause confusion for readers not familiar with the usage. Several terms are identified and defined below.

Principal foods can be the same as preferred foods, only when choices are equally available. Petrides (1975) states that principal foods of an animal population are those which it eats in greatest quantities, and which form the largest percentages of food items in the animals' diet. Calorific or other nutritive values are not involved here and whether an animal prefers those foods which comprise the greatest bulk of its diet is another matter.

Preferred foods are those actually favoured by the animal. Petrides (1975) defined preferred food species as those which are proportionally found more frequently in the diet of an animal than are available in the environment. Preference is a term used to describe animal reactions, usually behavioral, to certain food items (Hudson 1982). Gysel and Lyon (1980) suggest that preference refers to the selection of plants by animals and may vary by season or year.

Palatability is a term used to describe the characteristics which stimulate a selective response (Hudson 1982), or, in other words, palatability refers "to the attractiveness of plants to animals as forage" (Gysel and

Lyon 1980). Palatability is thought to be a function of taste, size, appearance, feel, work required per mouthful, and ease of swallowing (Giles 1978).

2.3.3 BROWSING INTENSITY

The ability of forage plants to withstand repeated browsing pressure has been documented by several authors (Westell 1954, in Michigan; Hunter *et al* 1979, in Pennsylvania; Hinds and Shepperd 1987, in Colorado; Peek *et al* 1976, in Minnesota; Campa et al 1992, in Michigan).

Browsing is not considered excessive until approximately 50% of available biomass is utilized (Peek *et al.* 1976). In Elk Island National Park, 60% browse use was considered to be acceptable (Blythe and Hudson 1987).

The relative ability of vegetation to respond to browsing has been studied extensively. Julander (1937) investigated effects of ungulate browsing and clipping on aspen tree height and production and found that trees browsed or clipped >75% showed a decrease in height and shoot production. This was contrary to the results of Campa *et al* (1992) where only minimal effects on aspen stand characteristics were reported. In northeast Minnesota, Peek *et al* (1976) reported that aspen sustained 63-70% utilization during the sensitive summer period, and winter use could have conceivably exceeded this value without destroying plants.

In the Lake States, Aldous (1952) found that mountain maple (*Acer spicatum*) can withstand heavy browsing (100%) for six to ten successive years without excessive damage. Beaked hazelnut (*Corylus cornuta*) and willow can withstand moderate to heavy use and balsam fir tolerates very heavy use. In a study in northeastern Minnesota, for the species present, only red-osier dogwood was sensitive to heavy repeated use (Peek *et al* 1976).

2.3.4 HECLA ISLAND MOOSE FOOD RELATIONS

The most critical component of the habitat requirements of moose on Hecla Island has been observed to be the food supply (Crichton 1977). It has been postulated that as forest succession on Hecla Island advances through the early seral stages (through lack of both fire and timber removal), cover increases while food decreases (Crichton 1977). Winter range on Hecla may not provide either adequate quality or quantity of browse. The abundance of coniferous forests and muskeg, and the lack and/or advanced age of existing early seral communities may place a qualitative limitation on spring, summer and fall ranges (Crichton and Wielgus 1981).

Recently disturbed areas and young forests on Hecla Island commonly possess an open canopy, but such areas are limited in number, size and distribution (Crichton and Wielgus 1981).

Food habits data on Hecla Island (Crichton 1977) revealed that moose used heavily timbered areas to a greater extent in the fall and early winter. Use of balsam fir, high-bush cranberry, mountain maple and red-osier dogwood increased in 1979. These browse species are characteristically found in mature forests (Wielgus 1980).

Conversely, species that grow in open areas decreased in the diet, e.g., willow, saskatoon, bog birch, cattail (*Typha latifolia*) and grasses (Graminaceae).

Browse species that are considered to be preferred by the Hecla moose are as follows: highly preferred: red-osier dogwood, trembling aspen; moderately preferred: beaked hazelnut (*Corylus cornuta)*, balsam fir, willow, high-bush cranberry and low preference: mountain maple (Crichton and Wielgus 1981). A later study by Zach *et al* (1982) on the early winter food habits of moose on Hecla Island and Manitoba Game Hunting Unit 26 identified 25 plant taxa in 86 rumen samples. In decreasing order of importance, moose fed mainly on red-osier dogwood, balsam fir, willow, mountain maple, trembling aspen, bog birch and balsam poplar. This partially concurs with Crichton and Wielgus (1981) but should be considered more reliable.

2.4 MOOSE AND WHITE-TAILED DEER RELATIONS

Moose and white-tailed deer have overlapping geographic ranges, along with general similarities in local distribution, habitat and food habits (Prescott 1974). Opportunities for interspecific competition may conflict with sympatric range. However, there have been relatively few studies concerned with interspecific relationships between the two cervids. More attention has been focussed on relationships between moose and white-tailed deer since the discovery of the nematode parasite *Parelaphostrongylus tenuis* as the causative agent of the moose disease (*cerebrospinal nematodiasis*).

In terms of habitat relationships, the moose is generally classified as a boreal-coniferous forest species, whereas the white-tailed deer is a deciduous brush forest inhabitant.(Prescott 1974). Broad differences in ecological adaptations and tolerance of environmental conditions are suggested by differing geographical ranges and dissimilar local distributions. The northern and altitudinal limits of deer are evidently set by winter characteristics (Kramer 1972). Moose seem to be limited primarily by the availability of browse plant species during the winter, though the excessive snow depths throughout parts of Quebec (Potter 1965) and elsewhere, may exceed their physical tolerance level (Formosov 1946; Kelsall 1969) and could also be a limiting factor.

In Nova Scotia, Telfer (1967, 1968, 1970a) concluded that although moose and deer used similar shelter-providing habitat types under deep snow conditions, they rarely used the same areas. Moose tended to remain near the more favorable feeding areas even when restricted by snow depths. In general, the habitat chosen by moose was composed of a mosaic of small forest patches of varying ages and species composition that averaged between 0.4 and 0.8 hectares (Telfer 1970b), while the habitat most utilized by white-tailed deer was a dense, continuous coniferous type with few openings (Telfer 1967).

Behavioral responses of moose and deer, particularly during winter, may have important bearings on interspecific relations. Moose are only occasionally restricted by snow depths over most of the overlapping moose-deer range. Des Meules (1964) found that moose shifted from cutover areas to closed canopy areas with small to medium openings when snow depth reached 76-86 cm. As snow depth increased, the moose became more and more confined to coniferous cover. He found that, in winter, moose selected habitat providing a snow depth between 60 and 100 cm.

Moose seldom occur in large groups (Houston 1971). In Quebec, Des Meules (1964) found that with increasing snow depth in mid-winter, the number of animals in each group decreased, averaging less than two animals. The quasi-solitary nature of moose also tends to lessen association of large numbers of moose and deer in similar wintering areas (Telfer 1968).

Deer habitat requirements in north-central Maine undergo a definite change with changing snow depths (Day 1963). Throughout the northern portion of their range, deer tend to concentrate, sometimes in large numbers, in areas with favorable climatic and shelter conditions (Prescott 1974), commonly referred to as "yards". Riewe (pers. comm. 1990) suggested that in Newfoundland moose will often yard with up to 100 animals present. With persistent deep snow, moose may be forced into areas similar to those used by yarded deer. Direct competition for food probably occurs if the same areas are used (Peterson 1955).

In terms of food relationships, Peterson (1955) noted a definite overlap between moose and white-tailed deer food habits in the central portion of the range with only white cedar and balsam fir, respectively, excluded from preferred diets of moose and deer. Also, four of eight species (red-osier dogwood, mountain maple, saskatoon and mountain ash heavily used by moose in northern Minnesota (Van Ballenberghe and Peek 1971) are preferred white-tailed deer foods (Erickson *et al* 1961). The other four (white birch, willow, trembling aspen, and balsam fir) are moderately preferred deer foods.

These studies suggest that moose and deer frequently, if not generally, use similar plant species as winter food on sympatric ranges. Utilization of the same habitat in large numbers could result in direct competition for available food supplies at least during winter. Peterson (1955) noted, "the most important ecological relationship between white-tailed deer and moose seems to be one of competition for food. Perhaps in a theoretically balanced population, these two species could occupy the same habitat without serious competition. In areas where either moose or white-tailed deer become abundant, there is little doubt that direct competition for available food takes place, especially in the winter months." However, the literature makes little reference to any area where deer or moose directly influenced the other through competition for available habitat or food supplies (Prescott 1974).

2.5 UNGULATE AND HARE RELATIONS

Moose occurrence coincides with that of the snowshoe hare throughout much of the northern hemisphere. There does seem to be considerable controversy over the extent of competition between these herbivores, despite the spatial and partial dietary overlap. Quantitative studies are few and the findings by no means unanimous.

Dodds (1960) reported definite similarities in the feeding patterns of both herbivores in Newfoundland, characterized by:

1) utilization of herbaceous material during summer and woody plants in winter;

2) browsing primarily of smaller and younger stems; and

3) the tendency to browse individual plants heavily.

Of the 30 woody species found on Dodd's study area, 27 were browsed to some degree by both moose and hare. Balsam fir was heavily utilized by moose and as a result reduced winter cover for hares. This eliminated any habitation by hares of cutover areas for several years. Competition for birch, the most important species for hares and the most important hardwood species for moose, increased only from the time hares began to inhabit cutovers. Dodds concluded that extensive competition for food occurred only in cutover areas with predominant fir regeneration. He suggested that in cutover areas moose browsing could moderate hare population fluctuations by maintaining near static low densities for 10 years or more. As well, Bergerud and Manuel (1968) suggested that damage to birch stems and coniferous cover by moose had reduced snowshoe hare densities in central Newfoundland.

Prescott (1968) emphasized the potential negative impact of snowshoe hares on moose in northeastern Nova Scotia. He noted direct dietary overlap, while only slight actual competition was observed. Twenty of the twenty-six woody species found on Prescott's study area were browsed both by moose and hare. Of considerably greater importance, most species browsed by moose were also utilized heavily by hares. Prescott suggested that deep snow could substantially increase the degree of competition. Fifty percent of the total stems of all species tallied were in the 0.0 to 0.6 metre height class. This class accounted for 57.6 percent of all hare-browsed stems, as compared to 16.4 percent of moose-browsed stems. Deep snow has a double effect by reducing the total forage availability for both species and by forcing hares to feed on taller stems, which comprised the bulk of moose browse.

Munroe (1969) studied the effects of high snowshoe hare populations on forest vegetation in New Brunswick. Moose and deer were present only in limited numbers, whereas hare populations were believed representative of densities elsewhere in the province. Browsing by hares and ungulates on regenerating shoots, especially balsam fir, was greater in clear cutovers than in partial cutovers. Browsing on all species was most severe in the one to two meter height class. Browsed balsam fir showed a 35 percent reduction in growth over those not currently browsed. Munroe concluded that repeated browsing would allow spruce to replace fir as the dominant species in the forest association.

Ritcey (1965) reported that the browse preferences of snowshoe hares, which were moderately abundant on moose winter range in Wells Gray Park, British Columbia differed from those of moose. Competition was found to be most important on marginal moose range, and that the most productive moose range supported few hares. The immediate impact of hare competition was outweighed by the long-term beneficial effect of selective hare browsing, which retarded coniferous forest succession.

Telfer (1972a) reported a high degree of adaptation by hares to utilization of available browse species. He suggested the potential for serious competition would appear to be greater in the simpler, more northern ecosystems with inherently lower plant diversity. Considering the hare's propensity for periodic high population densities, at least localized competition for food undoubtedly occurs, this being contingent upon snow conditions and the availability of alternate food species.

2.6 HECLA ISLAND MOOSE MANAGEMENT: SPECIFIC LITERATURE

Many previous studies and public submissions have pointed out that the Hecla Island moose herd affords somewhat unique opportunity, be it for recreational hunting or for non-consumptive use, in view of its location on an island, high population density and proximity to Winnipeg. The existing management plan for Hecla/Grindstone Park has addressed the direction for moose management.

Until this study, moose management planning has largely been short term and based on limited data. That available data are inadequate for long term management has repeatedly been pointed out in the many studies reviewed. A look at some of the past "studies" will clarify the extent of this short term "snapshot-in-time" data collection approach on Hecla Island. The principal findings of past efforts (in chronological order) are presented below. This review (internal memo) was prepared by Resource Management Planning staff of the Manitoba Department of Natural Resources and was not intended to be exhaustive of browse studies in general, but only to focus specifically on Hecla Island.

Moose habitat was classified in four broad classes using forest inventory maps, Canada Land Inventory data, aerial surveys, and field checks (Weatherill 1970). In this, the Tentative Moose Management Plan for Hecla Island Provincial Park, no detailed evaluation of browse conditions or status was provided. It concluded that some habitat manipulation was necessary to increase carrying capacity. It was suggested that browse plots need not be large or continuous; and that clearings of 5-10 acres would be heavily used. It also suggested that the most important use of moose on Hecla should be non-consumptive.

Thompson (1973) in an unpublished memo discussed a limited browse survey which was conducted in February 1973. Significant stem use (45-67%) was observed for beaked hazelnut, poplar, dogwood, and willow. Highly preferred species including red-osier dogwood showed severe hedging. Birch, poplar and beaked hazelnut had a high percentage of permanent damage. Moose yard areas displayed evidence of breaking of main leaders of willow, poplar and birch. Concerning methodology, survey areas were not representative of heavy use areas, and the study was done partway through winter, not at the end as is normally the accepted procedure.

Crichton (1977) estimated that 9% (7.7 square kilometres) of Hecla Island's moose habitat was lost directly to development of park facilities and indirectly through making areas less attractive to moose. In The Moose of Hecla Island, Crichton points out that habitat manipulation programs recommended by Weatherill (1970) were never initiated but two small (5 acres) plots were clearcut in winter 1974-75. These clearcuts regenerated to poplar, aspen, mountain maple, white birch and green ash. All but the ash were heavily browsed. Browse surveys began in spring 1976 with two sites sampled (near the park entrance) and seven more sites added in spring 1977 (throughout the island). Sites were selected to sample different habitat types, not on the basis of known moose concentration. All live and dead stems within ten 2 m x 2 m plots at each site were counted, along with live and dead twigs 15-210 cm above ground on each stem.

Data from 1976 were of limited value in extrapolating to the rest of the island. Red-osier dogwood was the most abundant species in both plots, and was used the most with 80-85% of the stems browsed. In 1977, where dogwood was present, it was again utilized the most. Aspen, dogwood, willow and mountain maple were the most widely distributed species. Aspen and dogwood generally had a large percentage of stems browsed wherever they grew. Dogwood displayed hedging with most twigs browsed. For management purposes, one could consider dogwood twig use to be complete. Significant mortality of some clumps had occurred. Distribution of saskatoon, pincherry and beaked hazelnut was more sporadic with a substantial number of dead stems and twigs. Balsam fir was used extensively in some areas but not in others. Mountain maple was occasionally heavily used, but usually only after other species. Use of willow varied with species. According to Crichton (1977), the main problem facing moose on Hecla was lack of suitable browse habitat. Carrying capacity was judged to be 100 - 120 moose and was likely to decrease as vegetation matured. With yearly habitat manipulations, it was thought that carrying capacity could be increased to maintain the herd at 180 - 200.

Failure to improve habitat would lead to over-browsing and high moose mortality in a severe winter. Habitat manipulation was recommended to start in the fall of 1977-78 by selectively cutting mature trees or clearcutting plots 150 m x 615 m. In this work, various alternatives were proposed for reducing moose population numbers, with other recommendations included: annual population surveys, and annual browse quantity and quality surveys.

In a study by Pastuck (1978), moose sign and browse use were noted during a survey for dead moose in the spring of 1978. Favoured areas were upland sites with an understory of young aspen, red-osier dogwood, mountain maple, beaked hazelnut and white birch. Wet areas (alder swamps, spruce bogs) were crossed but not used for active feeding. Clipping of dogwood, small aspen and birch was estimated at 90-100%. Mountain maple twigs were clipped 40-80% depending on presence of other species.

In 1981, Crichton and Wielgus used methodology which had been considered slightly more reliable. No habitat improvement had been implemented to that date. Hunting reduced the population from 260 animals in 1978 to 140 ± 20 in the spring of 1980. Browse use was measured at seven sites (largely not the same as Crichton 1977) throughout the island in winter 1979-1980. Road accessible sites were selected from aerial photos. Forty branches of known browse species of proper height (55-210 cm) were marked before winter and resurveyed in spring at each site. Browse use was determined by comparing length of new growth and number of browsed and unbrowsed twigs. Browsing was heavy in mature mixedwood sites. There was high use of aspen, moderate use of beaked hazelnut, balsam fir and red-osier dogwood and low use of mountain maple. Little use of browse was noted in cutover mixedwoods, young deciduous forest and willow marshes, although dogwood appeared to be used consistently but only to a limited extent. Overall, browsing did not appear to be excessive.

Factors affecting observed patterns of browse could include the early and severe winter which restricted moose to the more protected sites (e.g. mature mixedwood), and possible localized population reductions by previous hunts with no recolonization having yet occurred. Browse quantity, overall, did not appear to be limiting. Physiological data suggested that the moose population was in poor health, and possibly nutritionally stressed, suggesting that browse quality may be a limiting factor. It was again suggested that habitat rejuvenation should take place. Studies were recommended to determine the nutritional quality of seasonal ranges, and the effects of roads and human use on moose distribution.

As previously mentioned, Zach *et al* (1982), studied early winter food habits of moose from Hecla Island and Manitoba Game Hunting Unit 26 in Southeastern Manitoba in 1978 and 1979. Three methods of food habit determination were used: presence/absence, abundance score, and dry weight. All three methods yielded very similar results.

In the spring of 1986, spot sampling to get an impression of browse conditions was conducted by department staff. Although not a rigorous or statistically valid study the following observations were made. Red-osier dogwood was browsed virtually wherever it grew, particularly in the north end of the island. Aspen and mountain maple were used heavily in some local areas where they were dominant and moose presence was high due to the abundance of nearby thermal winter cover. Alder (*Alnus spp.*) showed the least sign of use and moose presence. Only a few balsam fir trees showed any sign of being browsed, with most of these only having a twig or two nipped off.

While a substantial quantity of unused browse appeared to remain available, many confounding factors (e.g. severity of winter, distributional changes, browse quality) existed that made it impossible to conclude whether or not the winter range is over-browsed.

That data are inadequate for long term management has repeatedly been pointed out in the many efforts reviewed above. Each author also identified the additional work needed. Since people and branches within the Department of Natural Resources of Manitoba differ in their concept of what the long-term objectives should be and particularly when data are lacking, many questions arise when such "best-guess" decisions are made. The same data could equally be interpreted to arrive at opposing conclusions.

From the above related studies, a few recurring observations have been made. First, there is a need to quantify or define explicitly what is meant by such terms as "severe", "significant", "excessive", "substantial", "high", "moderate", "low", etc. when used to describe the amount of browse use or shrub mortality on Hecla range. Second, that red-osier dogwood, is the most preferred woody browse species for moose on Hecla Island. Perhaps more importantly, it has been suggested that Hecla Island moose are physiologically stressed (Crichton 1977). Hence, a study which extensively analyzed browse conditions on Hecla Island would supplement past data towards a framework for a Hecla Island Moose Management Plan in the future.

3.0 METHODS

3.1 PRELIMINARY MAP WORK AND SAMPLING DESIGN

Black and white aerial photographs (1:15840) were obtained from Manitoba Parks Branch and Forest Cover Type maps obtained Manitoba Forestry Branch, from May to July 1988. An initial interpretation of the habitats was made and following this, ground-truthing verified the interpretation. Habitats were stratified into various types on the basis of forest cover types and were sampled accordingly. Bailey (1967) and the Manitoba Forestry departments Forest Inventory were used.to describe habitat types.

3.2 DESCRIPTION OF HABITAT TYPES

3.2.1 PURE DECIDUOUS(IMMATURE) (Imm.dec.)

These forests were described as, "understocked, very open to moderately stocked". This forest cover type is dominated by trembling aspen, with some balsam poplar and the occasional pure stand of ash and white birch.

This type was primarily dominated by young aspen (>50%) ranging in age from 10-20 years. Numerous openings were found both among widely spaced trees and between groves of trees. Shrub growth occurred in direct relationship to sunlight with extensive development noted along the margins of the treed areas. Tree height averages varied from 8-15 m. Further succession trends to young aspen is evident by numerous saplings and generally low growth even in well treed areas.

Plate 1. Pure deciduous (immature). Young trembling aspen with scattered understory.

Plate 2. Pure deciduous (mature). Typically has dense beaked hazelnut understory.

3.2.2 PURE DECIDUOUS (MATURE) (Mat.dec.)

These forests were fully stocked to over-stocked. Canopy coverage may be close to 100% and height ranges from 15 to 20 m. Dense tree growth is often complemented by an obvious shrub layer dominated by beaked hazelnut. In over-mature stands, which frequently have openings, the shrub layer may be impenetrable

Trembling aspen was the major tree species found in this type.

3.2.3 MIXEDWOOD (HARDWOOD-SOFTWOOD) (H-S)

This forest cover type includes all stands where the basal area of all coniferous species is between 26 and 50% of the total basal area. This type made up approximately 10% of the total area of Hecla Island.

The major tree species of this type include associations of trembling aspen and black spruce, larch, and/or balsam fir. White birch could also combine with black spruce or balsam fir.

3.2.4 MIXEDWOOD (SOFTWOOD-HARDWOOD) (S-H)

This forest cover type includes all stands where the basal area of all the coniferous species is between 51 and 75% of the total basal area.

The major coniferous tree species could be any of the following: white spruce, black spruce, or balsam fir in association with trembling aspen or other deciduous tree species.

3.2.5 WILLOW-ALDER (w-a)

This type consists of low-lying areas with a saturated water table presently supporting willow and/or alder growth. At least 51% of the area must be shrub covered. Shrub morphology was typically large clumps, often reaching 3-4 m in height.

3.2.6 MIXED PURE CONIFEROUS (M.conif.)

This habitat type consists of pure coniferous tree species where 40-70% of the total basal area is made up by one major species, with the remaining component being a second or third coniferous species. These types usually had a moderate shrub layer with a variety of overstory characteristics, such as even-aged or uneven-aged, and some windthrow.

3.2.7 PURE CONIFEROUS (MATURE) (Mat.con.)

This habitat type consists of stands where 76-100% of the total basal area are made up of coniferous tree species. The majority of these stands were of pure black spruce, with larch (tamarack) or balsam fir contributing a small component of the same habitat. This type had a rather sparse shrub understory, with typical components being Labrador tea (*Ledum groenlandicum*), feather mosses (*Hylocomium splendens*), and horsetail (*Equisetum* spp.), alder and bunchberry (*Cornus canadensis*). Sphagnum (*Sphagnum* spp.) was often found on the forest floor.

Plate 3. Mixedwoods (hardwood-softwood). Note the hardwood dominance in the overstory.

Plate 4. Mixedwoods (softwood-hardwood). Note coniferous dominance in overstory.

Plate 5. Willow-alder habitat. Note close proximity to dominant conifer cover in background on right side.

Plate 6. Pure mixed coniferous.

3.2.8 PURE CONIFEROUS (IMMATURE) (Imm.conif.)

This type consists of stands where 76-100% of the total basal area are made up of coniferous tree species. The major distinction between this type and mature coniferous is the age distinction and the physical characteristics of the stand. That is, there are more small openings, more regeneration on the ground and an increase in shrub species present. The increase in shrub species present is directly related to the increase in light reaching the forest floor as a result of the openings in the overstory.

3.2.9 TREED MUSKEG (tr.musk.)

This cover type is similar to open muskeg, except that the area is supporting semi-stagnated or stagnated trees. It is typified by the presence of black spruce and sphagnum which forms spongy hummocks on the surface. At least 10% of the area is covered with trees. Other common constituents of this type include Labrador tea, bog cranberry (*Vaccinium vitis-ideae*) and blueberry (*Vaccinium myrtilloides*). Various lichens, bunchberry and the three-leaved Solomon's-seal (*Smilacina trifolia*) are common constituents of the black spruce forest floor.

3.2.10 UNCLASSIFIED (unclass.)

This habitat type consists of many components including rights of way (ROW.), roads, gravel pits or borrow pits, summer resorts, beaches, etc. Included as a right of way are the hydro-line clearings which traverse Hecla Island. This type was not included in the browse production study (Fall

1988) but was included in the broader browse utilization study in the spring (1989).

According to the forest cover type map estimates, only a small proportion of the island falls within this type, so in terms of browse production, it may not represent a substantial amount. However, this does not suggest that this habitat type is not important to ungulates on Hecla Island. Data from the spring survey will be discussed later.

3.2.11 MARSH MUSKEG (mar.musk.)

The marsh component of this type is a wetland completely or partially covered with tall grass, rushes or sedges. The muskeg component of this type is a wetland complex which can have a vegetative cover consisting mainly of sphagnum and heath plants with very scattered brush. Marsh was generally found on the periphery of the island, with the muskeg component generally found in the interior or adjacent to treed types. Often found on these lower areas were shrub species like willow and swamp birch (*Betula pumila*).

3.2.12 MINOR TYPES

The following types were encountered along the sample traverses but were not mapped on the Forest Cover type maps.

(a) Clear cuts

- make up a very small percentage of the total area and were not sampled in the fall survey.

(b) Habitat enhancement plots

- moose habitat enhancement was attempted by mechanical removal of mature deciduous cover on 12 plots from one to two acres in size to promote new plant growth. Although few browse production survey plots were placed in these types, nothing conclusive can be reported.

Plate 7. Pure coniferous (mature) habitat. Photo taken from side of highway which traverses the entire island. Note the club tops of black spruce.

Plate 8. Pure coniferous (immature) habitat type.

Plate 9. Treed muskeg. Note sparse overstory with bog birch understory.

Plate 10. Unclassified habitat type. Large borrow pit. Several of these pits were scattered adjacent to the highway.

Plate 11. Unclassified habitat type. Hydroline right of way (RoW) traversed the length of Hecla Island.

Plate 12. Marsh muskeg. This type was dominated by two browse species; willow (*Salix* spp.) and swamp birch (*Betula pumila*).

Plate 13. Other miscellaneous types included the habitat manipulation plots which were mechanically cleared in 1984 in Pure deciduous (mature). Note dense browse understory.

3.3 BROWSE PRODUCTION AND UTILIZATION SURVEYS

With the use of the most recent aerial photographs (1976) and forest cover type maps of Hecla Island, habitat was differentiated and systematically surveyed. Tie points were marked on the aerial photos and identified on the ground. Habitat types were described on the basis of major cover type associations. Parameters which determined the differentiation of habitat types were major/minor tree species, basal area, and age.

It must be recognized that forests are dynamic ecosystems and that aerial photographs represent a "snap-shot in time" and subsequent maps derived from photos will be dealing with seral (or changing) vegetation (Kimmins, 1987). Many of the boundary lines drawn on vegetation maps do not actually exist in nature. One community or vegetation type will typically change gradually into an adjacent one through a broad ecotone. The line on the map may represent the mid-point of that ecotone (Barbour *et al*, 1987). If the ecotone is unusually large, or if several types coexist in some complex mosaic, then the ecotone or mosaic may be mapped as a separate unit in its own right. (Barbour *et al*, 1987).
This survey attempted to:

- determine the annual yield of browse in terms of weight per unit area (kg/ha) in the habitat types.
- determine the annual utilization of browse in terms of weight per unit area (kg/ha) in the habitat types.

For the sample design, the island was divided into habitat types. A color coded habitat type map was produced (See foldout map #1). A series of transect lines of varying lengths were assigned to each of the habitat types (also on foldout map #1). The total number of sample points were roughly assigned on the basis of disproportional allocation (stratification). This meant that some habitat types were sampled more heavily than others. The transect lines were drawn on forest cover type maps (1:15,840) and on black and white aerial photographs (1:15,840). They were drawn so that there was an identifiable start point for later relocation and ran the length of the stand/stands (habitat types). To eliminate some of the location bias introduced, transect lines were placed prior to field sessions and were not altered in the field. Obviously, some transects were more accessible or easier to locate than others.

The chosen method was a plotless sampling method, "The Corrected Joint-Point Nearest Neighbor Technique" (Batcheler 1971, 1973). This method involved establishment of sample points every 20 m along a transect line.

At each sample point three distance measurements were taken:

1) distance from the point to the nearest shrub (Ip) or centre of a "clump".

2) distance to the nearest neighbor of Ip (In).

3) distance from In to its nearest neighbor (Im) excluding (Ip). (Batcheler, 1975).

At each point, a temporary stake was placed in the ground. These measurements were used to determine stem density. See Appendix A Table 1 for stem density formulas.

Twigs of shrub species sampled along transect lines browsed by moose, deer, and snowshoe hare were counted, provided that they fell within the vertical range of browse occurrence (55-250 cm for moose).

At the upper height limit twigs up to 3 m are available to moose in regions of deep snow (Telfer 1974, Potvin 1978). Deer will use twigs to a height of 2.25 m (Potvin, 1978). In regions with softer, shallower snow, mixed cervid species use browse to about 2.5 m. Snowshoe hares, when supported by snow, can browse over the height range used by cervids (Dodds 1960, Telfer 1974). Hares also gain access to twigs above their reach by clipping entire stems off shrubs and saplings and then eating the twigs.

Browse species include willow, trembling aspen, balsam poplar, white birch, speckled alder (*Alnus rugosa*), red-osier dogwood, hazelnut, mountain maple and green ash. However, since the purpose of this survey is to provide a general overview of browse production on Hecla Island and to give an extensive list of browse species, additional species were sampled. Some of these included prickly wild rose (*Rosa acicularis*), chokecherry, wild red raspberry (*Rubus idaeus*), high-bush cranberry (*Viburnum opulus*), saskatoon, and black currant (*Ribes americana*).

Application of the corrected joint-point nearest neighbor method to hydro-lines and other components was considered less useful for sampling narrow vegetation zones associated with ROW edges. Distance methods, which involve measuring distances from a sample point to a series of shrubs, sample an undefined area that varies in relation to the density of shrubs around the sample point (Brusnyk and Westworth 1985).

Using Batcheler's method,

1) At each point:

- only live stems of shrub species were selected for temporary sampling.
- using this method, the basic sampling unit was the "clump". A "clump" may consist of one or more stems depending on the nature of the species being sampled. For example, trembling aspen was a single stem as opposed to red-osier dogwood, which usually had more than one stem).
- species and number of stems in each clump were recorded.
- shrubs were defined as any browse species greater than 50 cm tall and less than 3.8 cm dbh (diameter at breast height).
- stems shorter than 50 cm would probably be unavailable to moose during the winter because of snow cover (Telfer 1972b). To allow for comparison of other studies, 50 cm was chosen for consistency.
- twigs on these stems were counted up to a height of three metres which is approximately the maximum height of moose browsing
- twigs and stems were counted in the sample for those occasions when tips of sample stems were ridden-down, trampled or sheared

off as long as they were within the vertical range of ungulates and still alive

- twigs less than 2.5 cm in length were not considered in this study

2) Twig measurements

To make weight estimates, measurements were taken to allow the calculation of an average diameter at:

- the base of the twig growth of the previous year, the diameter of current growth (dcg). The most recent year's growth is usually a different (lighter) color and the bark smoother than the older part.

- the point where twigs are bitten off by browsing animals are called the diameter at point of browsing (dpb).

At least 50 to 100 measurements of these points for each shrub in each habitat type were necessary (Telfer 1972b). It was difficult to get 50 for some less abundant species. However, for some of the major known browse species, over 100 measurements were taken. Diameter measurements were made in millimetres with Vernier calipers, recording several from each transect for each species present. On the selected stems, all unbrowsed and browsed (by moose, deer and hares) twigs were counted. Generally speaking, moose browse can be distinguished from hare browse by the "nipping" of terminal buds with incisors, leaving a sharp cut effect by hare. Moose do not possess incisors, so browsing leaves a torn or ragged twig tip. Also, hare generally browse the lower 1.5 m of browse species, where moose will browse the upper 1.5 m. It was deemed impossible to differentiate between white-tailed deer and moose browsing.

3) Twig weights

To obtain an estimate of twig weights (grams) from diameters at the base, it was necessary to collect twigs over the range of dcg's and dpb's usually found. The basal diameter of the twigs were measured when they were cut. This provided the "green diameter" corresponding to diameters on unbrowsed twigs, which were used to estimate BROWSE PRODUCTION, that is, estimating weight of last year's (1988) production. The twigs were dried for approximately two weeks and measured again to provide the "air dried" diameters needed to estimate BROWSE UTILIZATION. Dpb's were air dry diameters because browsed twigs were bitten off some time before allowing time for drying and radial shrinkage.

Twigs were dried in a laboratory oven at a temperature of 70°C for 48 hours in a convection oven. After drying, twigs were taken from the oven individually and weighed to the nearest 0.01 grams (Mettler PE360 Delta Ranger).

Only certain coniferous species were not sampled when encountered in the survey. These were black spruce and white spruce. According to Telfer (1984) these species do not contribute significantly to ungulate diets.

Weights of twigs produced and utilized per hectare in each habitat type was obtained from the following calculation

Total weight = *(mean number of twigs per stem of browse species)* x *(mean weight* *per twig of browse species)* x *(number of stems of browse species per hectare).*

Approximate weights of browse consumed by moose per day were obtained from the literature and then compared with the amounts of browse available to obtain information on the carrying capacity, that is, the number of "ungulate days" of browse available. This estimate of net annual yield is perhaps the most useful measure of habitat carrying capacity for moose (Telfer 1978).

Regression equations for each browse species were developed by statistically relating twig weights to twig diameters. Logarithmic transformations were applied to both the dependent (twig weight) and independent (twig diameter) variables because of heterogeneous variances and non-normal distributions. These equations were used to predict weights produced and utilized.

Following Telfer (1969), regression equations of the form $LN\ Y = a + b\ LN\ X$ were generated for:

a) oven-dry weight of twigs as the dependent variable compared to green diameter of the twig as the independent variable

b) oven-dry weight of twigs as the dependent variable compared to air-dry diameter

3.3.1 DETERMINATION OF BROWSE PREFERENCE

Browse preference was determined by comparing the twig diameters at the point of browse (dpb) with twig diameters of current years growth (dcg). Comparing the relationship of diameters at point of browsing (dpb) with the diameters of current year's growth (dcg) can be important if an estimate of the effect of browsing intensity upon the plant is to be made (Peek *et al* 1971). If the dpb/dcg ratio is greater than 1.0 (or utilization >100% of dcg), the suggestion is that either more than the current year's growth has been removed or that the larger twigs were preferred. This has been shown to be dependent on browse species (Peek 1971).

3.4 SPRING BROWSE USE STUDY

In May and June 1989 prior to green-up (leaf flush), a technique described by Cole (1963) as the "nearest neighbor technique" was used. The exact timing of this survey was determined by the previous winter. The critical period is the pre-leaf flush period, sometime between March and June.

The optimum time to measure the degree of browse utilization by moose was after the majority of winter usage. This technique was used to determine the frequency of browsing and the degree of utilization of available habitat by moose on Hecla Island. A series of transects were established on aerial photographs and forest cover type maps, using randomly generated start points. Each transect consisted of a 3000 m triangular transect, that is, each side was 1000 m in length. At 200 points (every 5 m) along each transect leg, the following data were collected, using an ocular estimate;

a) the nearest clump was assigned a utilization class, based on the ratio of browsed twigs to the total number of browsed and unbrowsed twigs:

utilization class	%
0	0-20
1	21-40
2	41-60
3	61-80
4	81-100
5	100+

b) distance from plot centre to nearest neighbour

c) identification of shrub species

The resulting summary of data from a large sample indicated the percentage of use of each plant species from the total sample. Any biases introduced by the ocular estimate were more than compensated for by the large number of sample points. An ocular estimate of 100+ indicated that all of the annual growth was removed plus some of last years growth. Analysis of the results, coupled with known food requirements of moose, enabled the determination as to whether Hecla Island was being over-browsed.

3.5 PELLET GROUP COUNT AND DISTRIBUTION SURVEY

This method has been used to estimate ungulate population densities, to obtain trend and distribution data and to measure habitat use (Riney 1957, Cairns and Telfer 1980, Henry 1981, Tilton and Willard 1982, Van Etten and Bennett 1965, Neff 1968, Stelfox and McGillis 1977, Collins and Urness 1981, and Rowland *et al.* 1984). The standard method for determining habitat use involves counting the number of pellet groups deposited within defined sampling areas between leaf fall and snow melt. It provides a relatively unbiased estimate of cumulative winter use by various species of ungulates within different habitat types.

The primary purpose for including this survey was to complement the browse survey in determining degree of browse use of various habitat types by moose and white-tailed on Hecla Island on a broad scale. No attempt to distinguish browsing between them were made. The pellet group survey was conducted simultaneously with the spring browse survey in April-May 1989, along the same line transects. Plots consisted of a two metre wide swath, one metre on either side of the transect line for ten metres, such that plot size was 20 m^2 in area. Plot intensity was one pellet group plot for every five ocular plots, or 40 pellet group plots for the 1000 m transect length The total area covered by the 10m x 2m (0.002 ha) plots was 1.382 ha.

At each plot the following data were tallied:

1) number of pellet groups found in each rectangular 20 m^2 plot.

2) identification of the animal species responsible for pellet group(s).

The following assumptions were applied to the survey:

1) that counts made in the spring (May and June) included only those pellets deposited since leaf-fall (October) or that pellets deposited prior to October were identifiable as such. Also, that pellets persisted from October to April.

2) that all groups were correctly identified as such and that none were missed.

3) that a 20 m^2 plot was a sufficient sampling unit for this study.

4) that pellet groups on the border of the plot, were counted if half or more of the pellets were within the plot (Neff, 1968).

3.6 DATA ANALYSIS

The relationship between browse availability and utilization was examined using a variety of tests. Chi Square statistics of Independence were used to test both hypotheses separately. Expected proportions were compared to observed proportions based on availability of habitat to ungulates. Bonferroni confidence intervals were used to determine which habitat types were preferred. Student's t-tests were used to compare each variable (stem density, twig weights produced and utilized, twig numbers produced and utilized, twig diameters produced and utilized, and mean browse production and utilization) between different forest categories (Van Egmond 1990). In all cases, the null hypothesis (i.e. no significant difference between communities) was rejected at the 95% confidence level if the level of significance was less than 0.05.

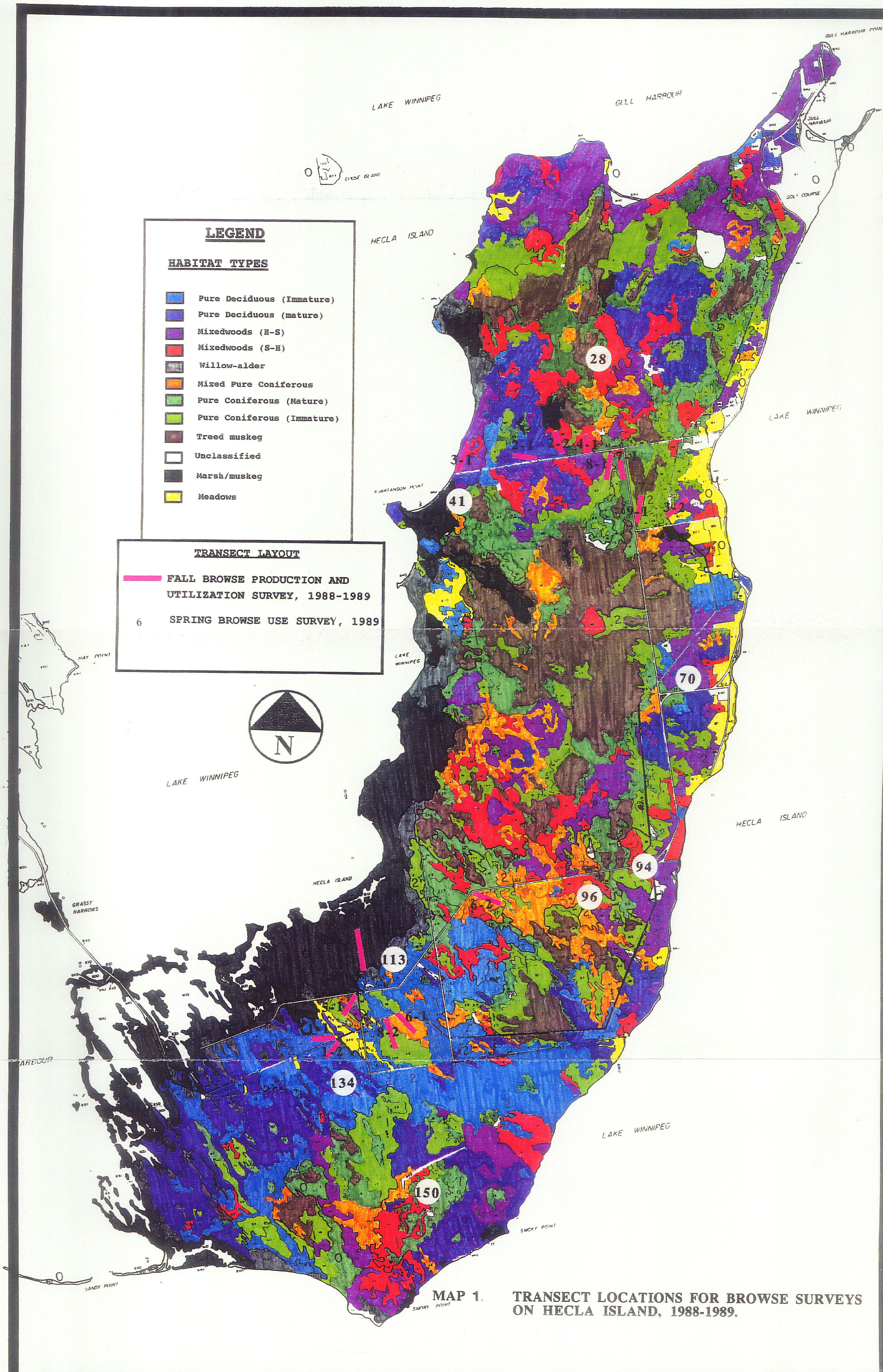
Mean availability and use indices per habitat were calculated for each habitat, without regard to plant species. Chi square tests were used to determine relative habitat preference of moose, white-tailed deer and snowshoe hare. All analysis was done by statistical packages available to Macintosh users. They included Statwork ", Statview " and Excel ". Graphics were generated by Cricket " Graphics.

4.0 RESULTS

For the purposes of this study, the habitat types and their abbreviations listed in Table 1 will be used throughout this document. Refer to foldout map #1 for color-coded habitat types found on Hecla Island.

Table 1. Habitat types found on Hecla Island based on Forest Cover Type information.

Habitat Types	Abbreviations
Pure deciduous (Immature)	imm.dec.
Pure deciduous (Mature)	mat.dec.
Mixedwood (hardwood-softwood)	h-s
Mixedwood (softwood-hardwood)	s-h
Willow/alder	w-a
Mixed pure coniferous	m.conif.
Pure coniferous (mature)	mat.con.
Pure coniferous (immature)	imm.con.
Treed muskeg	tr.musk.
Unclassified (RoW, gravel pits, hydro-lines, roads, beaches)	unclass.
Marsh-muskeg	mar.musk.



MAP 1. TRANSECT LOCATIONS FOR BROWSE SURVEYS ON HECLA ISLAND, 1988-1989.

Table 2. Approximate areas of habitat types on Hecla Island.

Habitat	**Number of Stands** (% of total)	**Area (Ha.)**	(% of total area)
Pure deciduous (immature)	**91** (11.8)	**1735.7**	10.7
Pure deciduous (mature)	**91** (11.8)	**1471.1**	9.1
Mixedwood (H-S)	**100** (13.0)	**1618.7**	10.0
Mixedwood (S-H)	**80** (10.4)	**1009.3**	6.2
Willow/alder	**9** (1.2)	**433.5**	2.7
Mixed Pure Coniferous	**62** (8.1)	**812.6**	5.0
Pure Coniferous (mature)	**128** (16.6)	**1544.1**	9.5
Pure Coniferous (Immature)	**164** (21.3)	**1877**	11.6
Treed muskeg	**10** (1.3)	**1835.2**	11.3
Unclassified	**7** (0.9)	**677.9**	4.2
Marsh/muskeg	**12** (1.6)	**2388.4**	14.7
<u>Miscellaneous</u>			
Field (Agriculture)	**5** (0.65)	**490**	3.0
Meadow	**5** (0.65)	**254.3**	1.6
Water	**5** (0.65)	**52.2**	0.3
TOTAL	**769** (100.0)	**16199.7**	100.0%

Table 2 summarizes the areal proportion (%) of the habitat types found on Hecla Island. The marsh/muskeg type had the largest proportion area (14.7%), while willow/alder had the smallest proportion area (2.7%). All other habitat types had approximate areal proportions of between 5% and 11%.

In terms of frequency of occurrence or number of stands expressed as a percent of the total number of stands, Unclassified habitat type, which includes R.O.W., roads, beaches, etc. had the lowest number of stands with seven (<1.0%). Willow/alder had a low frequency of occurrence (9 stands) which is only 1.2% of the total number (769 stands). Treed muskeg and marsh/muskeg types also had very low numbers of stands, 10 and 12 respectively, but had large area proportions. This means that the stands were quite large where they occurred.

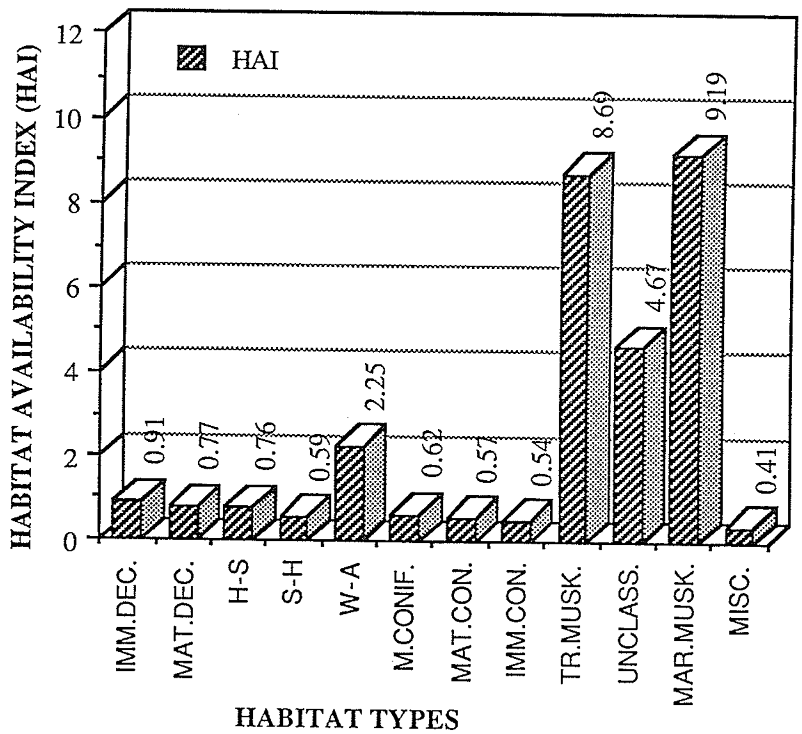
The relationship of area (%) and frequency (%) of the habitat types occurring on Hecla Island was used to create a Habitat Availability Index (HAI). The HAI number for any of the habitat types was calculated using the following simple formula:

$$\mathbf{HAI}_i = \frac{\textbf{Percent of total area of habitat } i}{\textbf{Percent of total number of stands represented by habitat } i}$$

Therefore, derived HAI numbers that are less than 1 simply mean that the relative area (% of total area) represented by this habitat type is less than the relative frequency of occurrence. Values that are greater than 1, will mean the opposite. However, the ratio presented here does not explain anything about the interspersion or relative position of the various habitat types to each other.

Examples of these relationships can be verified by both Table 2 and Figure 2.

Figure 2. Habitat availability index for habitat types found on Hecla Island.



Because the aerial photographs and therefore the forest cover type inventory maps were created in 1976, they did not take into account the effects of human development (golf courses, highway widening, hydrolines, and other linear and areal features such as trails and borrow/gravel pits, respectively) over approximately 15 years (1976-1991). Newer aerial photographs were not available for this study, therefore all areas calculated and summarized in the results are based on 1976 aerial photographs and forest cover type inventory maps.

4.1 GROUND-TRUTHING

Verification of habitat type classification was done by visiting (walk through) various cover types. This was necessary because interpretation of forest cover types was done by Forest Inventory personnel of the Forestry Branch using aerial photographs, often with no ground-truthing (G.Becker, pers.comm.,1988) All available timber cruise data was used to verify typing in conjunction with actual visits. For the most part, the typing proved to be quite accurate with few major discrepancies. Type lines on Forest Cover Type maps were taken to represent an ecotone between two or more forest stands in which a moderate discrepancy was accepted, in recognition of successional processes occurring on the island, as described earlier.

In areas where massive windthrow and stem breakage occurred in various locations on Hecla Island, forest cover type interpretation were inaccurate, mostly as a result of changes in stand characteristics. These kinds of problems were a result of old (1976) aerial photograph coverage and subsequent interpretation on maps.

In this study, unmapped changes in cover types due to successional changes had very little effect on the Browse Production Survey and only a moderate effect on the following Spring Browse Use Survey.

Table 3. Inventory of transects for browse production and utilization on Hecla Island, 1988-1989.

Habitat Type	Number of Transects	Total (m)	Number sample points
imm. dec.	2	700	35
mat.dec.	2	900	45
h-s	2	900	45
s-h	1	400	20
w-a	1	400	20
m. conif.	2	1000	50
mat. con.	1	200	10
imm. con.	1	400	20
tr. musk.	1	200	10
Unclass.	NOT SAMPLED		
Mar.musk.	1	540	27
Total	**14**	**5640**	**272**

4.2 BROWSE PRODUCTION

Results from the 1988 fall browse production survey are summarized by the various component factors (stem density, twig counts, twig weights, and twig diameters) which were used to estimate browse production. They are summarized by the use of a series of tables, figures, and text. For the purposes of this document, reference will be made to several tables which can be found in the Appendix A. It should be noted that many of the entries in the tables represent the mean values for a given browse species in a given habitat type, and that gaps in data occur; these should be considered a limitation of this study.

4.2.1 STEM DENSITY

Stem densities varied considerably among the 10 habitat types sampled. Pure coniferous (immature) had the highest total stem density per hectare of 60527, comprised of bog birch (28.5%), alder (23.6%), willow (20%), dogwood (15%), and raspberry (10%). Browse species which represent a minor component include trembling aspen (0.71%), balsam fir (1.43%) and balsam poplar (0.71). The Coefficient of Variation (CV) for stem density in this habitat was 88.1%.

Pure coniferous (mature) had the lowest total stem density per hectare of 122 stems/hectare and a CV of 41.2%. Only three species contributed to the total: alder (48.9%), balsam fir (24.4%) and dogwood (26.7%).

Pure deciduous (immature) had the highest diversity (16) in terms of browse species, in which four species were found to have less than one percent of the total stems. Mixedwood (h-s) had 15 species sampled. Treed muskeg, as might be expected, showed the least diversity (one shrub species, bog birch), but quite a high combined stem count of 30477. Marsh/muskeg had only two species tallied, willow and swamp birch, but had 41765 stems per hectare and a CV of 10.7%.

Figure 3 compares the total stem density per hectare per habitat type.

Figure 3. Total stem density per hectare for woody species per habitat type on Hecla Island, 1988.

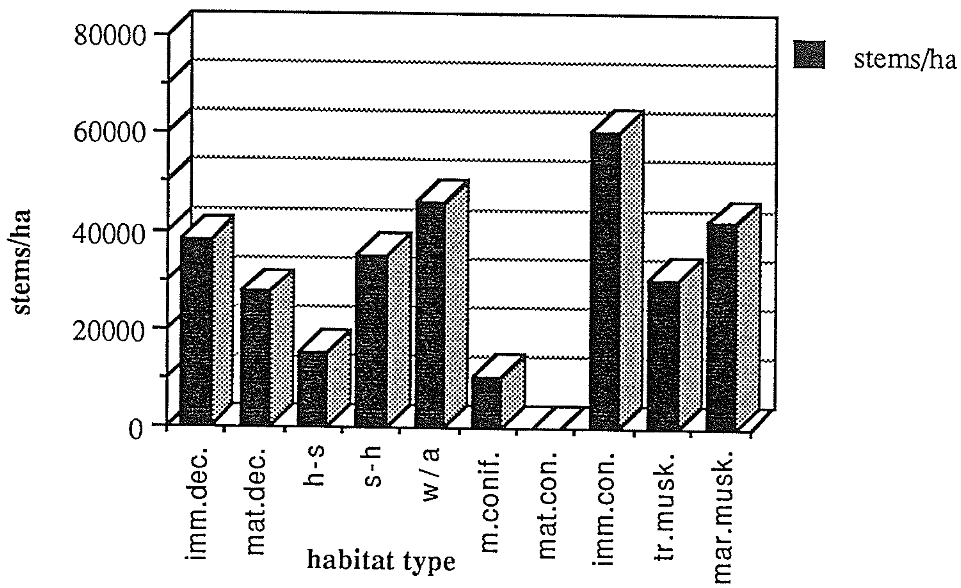


Table 1 in Appendix A summarizes the stem densities by habitat type, relative stem densities (%) of each browse species and a summary of stem density formulas used to make estimates. Descriptive statistics for each habitat type are also shown in Table 1.

Statistically significant differences ($p<0.05$) in total stem densities were found when comparing the following;

a) h-s to s-h, w-a, imm.dec., and mat.dec.,

b) h-s to imm.con., and

c) all habitats compared with mar.musk.

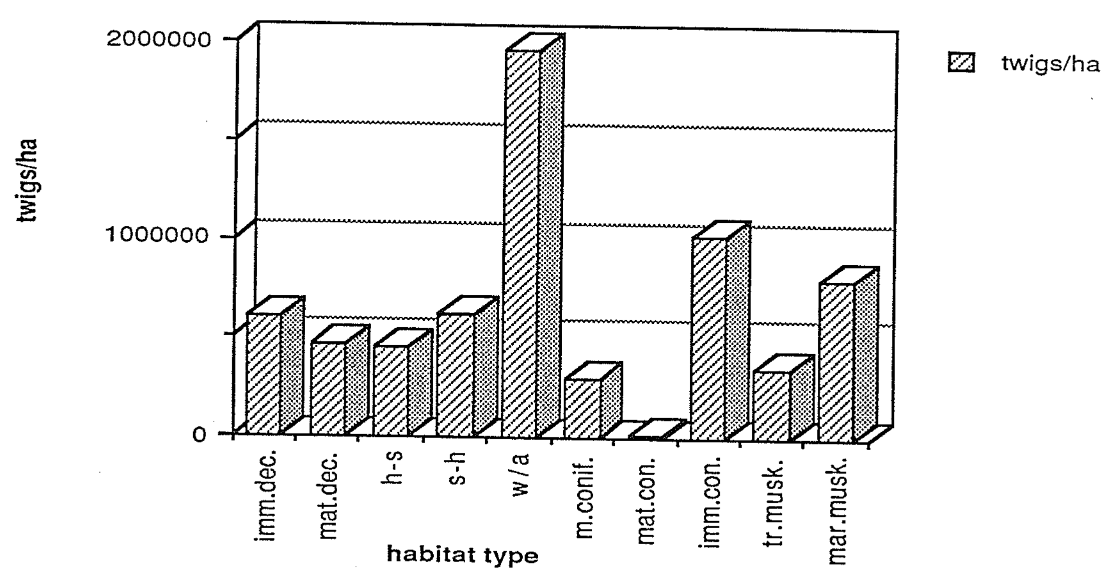
Table 2 in Appendix B summarizes all combinations of stem density comparisons using the T statistic for comparing means.

4.2.2 TWIG COUNTS

Willow/alder produced the highest number (1,969,735) of twigs compared to the other habitat types. Mature coniferous produced the least number of twigs. In Willow/alder, 53.7% of all twigs produced were by dogwood, followed by willow with 24.67%.

Coefficients of variation show high variability about the mean twig production per hectare. In pure deciduous (immature) the range of twig production per browse species varied from 139 twigs/ha for both arrowwood and nannyberry to 221361 twigs/ha for dogwood. Figure 4 shows the number of twigs produced per ha per habitat type on Hecla Island, 1988. Table 2 in Appendix B summarizes the twig production data for all browse species in all habitat types.

Figure 4. Number of twigs per hectare per habitat type produced, Hecla Island, 1988.



Significant differences in twigs produced were found between the following communities;

a) imm.dec.and h-s to w-a;

b) imm.dec., mat.dec. and h-s compared to imm.con., and;

c) all habitat types compared to mar.musk., except w-a.

Table 3 in Appendix B summarizes all the comparisons made between habitat types.

4.2.3 MEAN TWIG DIAMETERS (DCG)

The smallest mean diameter for any of the browse species sampled was 1.13 mm for balsam fir in pure coniferous (mature). The largest mean diameter for any browse species sampled was 4.3 mm for ash in pure deciduous (immature). Balsam poplar had the next largest mean twig diameter measured, 4.25 mm in mixedwood (s-h).

The mean CV across all habitat types was less than 30%, which indicates quite a small variation about the mean diameter of current growth for all species. Table 3 in Appendix A summarizes mean diameters (mm) of twigs at the base of current years growth (dcg) which was used in determining twig biomass on a per browse species per habitat type basis.

When the means were compared, no significant differences were found between habitat types as summarized in table 4 Appendix B.

4.2.4 TWIG WEIGHTS

The largest mean weight per twig for all browse species within a habitat type was 0.26 g in pure mixed coniferous and the smallest mean weight was 0.01 g in pure coniferous (mature). Balsam poplar had the largest mean weight per twig across all habitat types (0.44 g) and raspberry had the smallest mean weight per twig (0.003 g).

Coefficients of variation for twig weights averaged 58% across all habitat types, ranging from a low of 15.7% in marsh/muskeg to a high of 97.2% in mixedwood (s-h). Table 4 Appendix A summarizes the mean weight (g, oven dry) of twigs for current years growth, by habitat type and browse species for Hecla Island during the 1988 growing season. No significant differences were found between the habitat types when comparing mean twig weights. Table 5 in Appendix B summarizes calculated T-statistics and significance values for each pair of habitats compared.

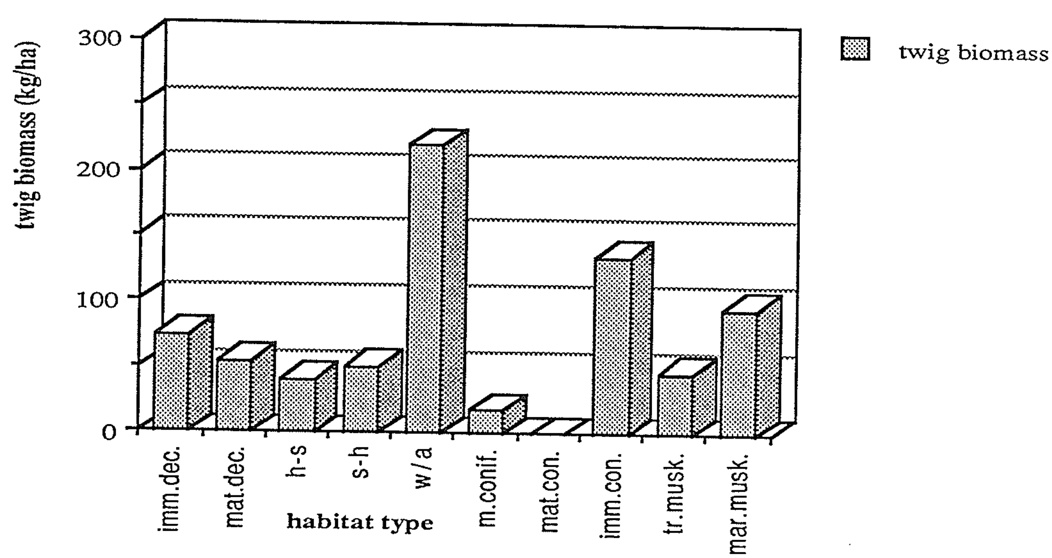
Twig weights were calculated by applying the regression equations, (Table 5 Appendix A), which summarizes the constants for the linear equations, range of twig diameters, r^2 values, and sample sizes for each species. Regression equations were derived for 21 browse species. Two species, raspberry and Manitoba maple, were lost due to mold found on twig samples rendering them useless for this study. A raspberry regression equation from Telfer (1969) was used to estimate browse yield in this study, but an equation for

Manitoba maple was not found and therefore browse yield could not be calculated.

For this Hecla Island study, relatively high correlations between twig weights and diameters can be reported for the majority of the more preferred browse species sampled. An overall r^2 range of 0.30 to 0.94 for browse species on Hecla Island have been reported in Table 8 of Appendix 1. Less preferred browse species account for lower r^2 values; nannyberry, arrowwood, and gooseberry all have low r^2 values of 0.51, 0.30, and 0.48, respectively.

Table 6 Appendix A, summarizes all of the previous data in the form of available twig biomass or yield (kg/ha) per habitat type on Hecla Island in 1988. Figure 5 illustrates these data below with no regard to browse species.

Figure 5. Available twig biomass per hectare on Hecla Island, 1988.



Willow/alder had the highest total twig yield of all the habitat types (219.85 kg/ha) of which dogwood and willow contributed 50.36% and 28.3% respectively and pure coniferous (mature) had the lowest total twig yield (0.592 kg/ha). Marsh/muskeg had the highest mean twig biomass production (47.436 ± 5.87 kg/ha).

Dogwood (20.81 ± 14.195 kg/ha) and willow (20.23 ± 8.968 kg/ha) were the highest mean producing species across all habitat types. Raspberry (0.090 ± 0.050 kg/ha) produced the least across all habitats in which it occurred. Mountain maple produced a significantly greater amount of available browse in the two mixedwood types than in any other. Hazelnut was found to produce the greatest amount in the mature deciduous type accounting for 48.7% of the total yield. Alder accounted for 44.7% of all browse produced in immature deciduous habitat type and was one of the top five producers wherever it occurred.

Coefficients of variation were very high for most habitat types. Pure mixed coniferous had the highest (239.6%) and Marsh/muskeg had the lowest (17.5%). The mean CV across all habitat types was 120%. When habitat types were compared statistically, significant differences were found for the following;

a) h-s to w-a, imm.dec.;

b) h-s to imm.con.;

c) and all habitats compared to mar.musk. except w-a and imm.con.

Table 6 in Appendix B summarizes all the statistical comparisons of the habitat types.

4.3 BROWSE UTILIZATION

4.3.1 NUMBER OF TWIGS UTILIZED

Twigs browsed were counted on the same ribboned stems surveyed in the fall survey to determine use during the winter 1988-1989. Willow/alder had the greatest number of twigs utilized (1,041,580 twigs/ha) and Pure coniferous (mature) had the least number of twigs utilized. Figure 6 shows this graphically. Dogwood consistently showed high use across and within all habitat types wherever it occurred. Mountain maple showed high twig counts in both Mixedwood types.

Coefficients of variation ranged from 280.2% in Pure deciduous (immature) to 56.0% in Pure coniferous (mature). The overall average CV across all habitat types was 132.3%. Table 7 in Appendix A summarizes the twig count for browsed twigs found on stems.

Significant differences in number of twigs utilized were found between the following habitat types;

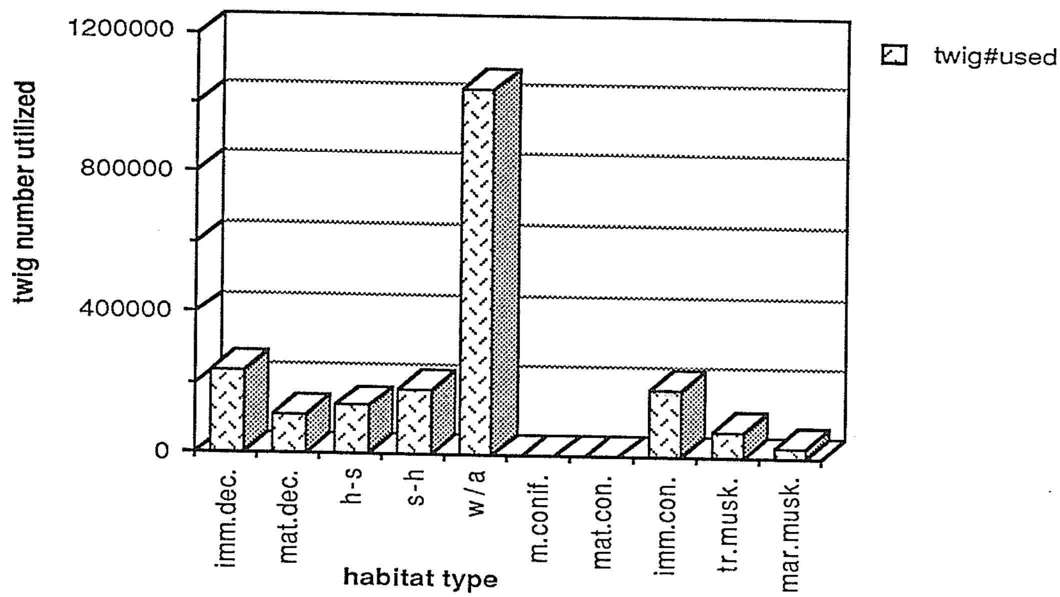
a) h-s and w-a;

b) h-s and imm.con., and

c) m.conif. and mar.musk.

Table 7 Appendix B summarizes t-statistics and significance values.

Figure 6. Number of twigs utilized per habitat type, Hecla Island, 1988-1989.



4.3.2 MEAN TWIG DIAMETERS (DPB)

In some cases an increase in consumption over the current years growth occurred (as summarized in Table 3 Appendix A). For example, the average dogwood twig diameter produced across all habitat types from Table 3 was 2.1 mm and the average diameter utilized from Table 8 Appendix A, was 2.6 mm, approximately 24% greater than what was produced. Mountain maple, willow, and trembling aspen are all browse species which have this characteristic. Of course, this is not true for all browse species in all habitats and this difference was reflected in the twig weights removed over the course of the winter season. Table 8 Appendix A summarizes the mean diameter at point of browse.

No significant differences were found in twig diameters between habitat types. Table 8 in Appendix B summarizes the comparisons of twig diameters.

4.3.3 MEAN TWIG WEIGHTS

As was the case for estimating browse production based on estimating twig weights, it was necessary to generate prediction equations to estimate the mean twig weight utilized.

Relatively high correlations between twig weights and diameters can be reported for the majority of the more preferred browse species sampled. An r^2 range of 0.64 to 0.97 has been reported in Table 9 Appendix A. Nannyberry, arrowwood, and gooseberry all have low r^2 values of 0.002, 0.36, and 0.54, respectively.

Pure deciduous (immature) had the highest mean twig weight (0.43 g oven dry). Large mean twig weights for chokecherry contributed to this (4.47 g). The second highest mean twig weights (0.40 g) were found in pure mixed coniferous. Trembling aspen had very high measures for mean twig weight removed. Marsh/muskeg had the smallest mean twig weight utilized (0.294 g). Rose had the smallest mean twig weight (0.001 g) removed in pure deciduous (mature), chokecherry had the largest (4.47 g).

It was stated earlier that large dpb's would be reflected in the mean twig weight removed data. Dogwood is a good example. In Table 4, the mean twig weight produced is

0.09 g ± 0.003 g and in Table 10, the mean twig weight utilized is 0.174 g ± 0.023 g, almost double.

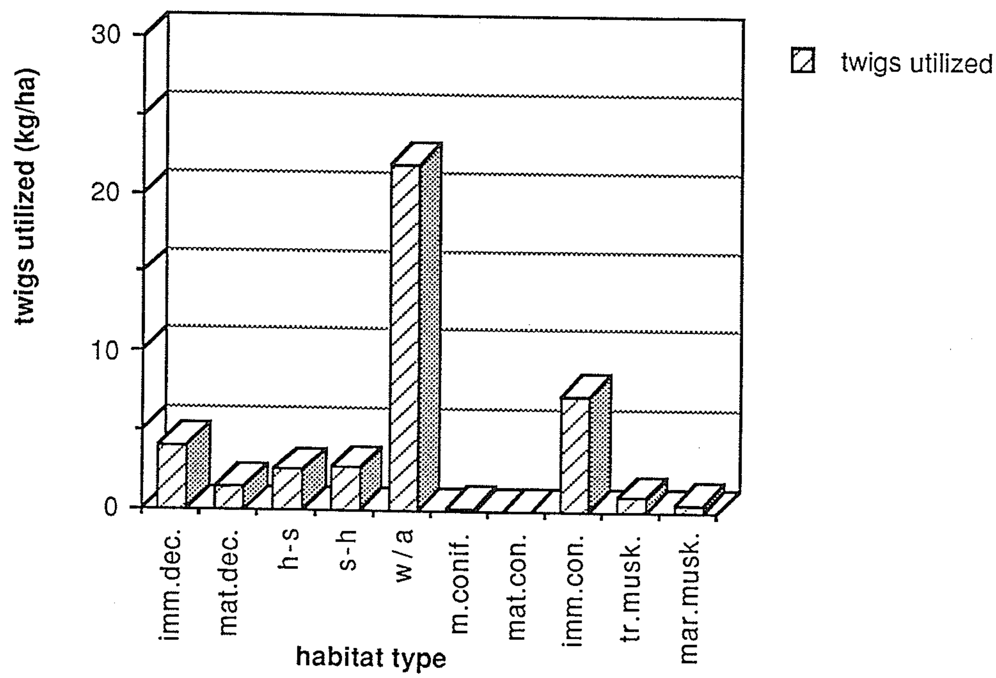
Coefficients of variation ranged from 6.2% in marsh/muskeg to 251.2% in pure deciduous (immature). The overall mean CV was 78.0%. Table 9 and Table 10 Appendix A summarizes the results of using those equations in predicting mean twig weights utilized by ungulates. A significant difference was found when mat.con. was compared to mar.musk. Table 9 Appendix B summarizes the t-statistics and significance values.

4.3.4 BROWSE BIOMASS UTILIZED

Willow/alder had the highest utilization with 162.7 kg/ha. Dogwood accounted for 56% of the use, willow (24.5%), swamp birch (11%) and alder (8.9%). Pure coniferous (mature) had the lowest utilization of 0.067 kg/ha. In pure deciduous (immature), dogwood use accounted for 88% of all use in the type. In pure deciduous (mature) where beaked hazelnut is dominant in the shrub layer, only 14% was used. In mixedwood (s-h), mountain maple accounted for 50.5% of biomass removed of browse species. In pure coniferous (immature), bog birch and dogwood combined to make up 83% of browse use.

Coefficients of variation ranged from 287.2% in pure deciduous (immature) to 81.4% in pure coniferous (immature), and overall mean CV of 139.2% across all habitat types. Table 11 Appendix A summarizes the browse utilization data obtained. Figure 7 summarizes the browse use (kg/ha) per habitat without regard to browse species.

Figure 7. Twig biomass utilized on Hecla Island, 1988-1989.



Significant differences in twig utilization were found when comparing the following habitat types;

a) imm.dec., mat.dec., h-s, and s-h to w-a;

b) w-a to m.conif.; and

c) mat.dec., h-s, m.conif. to imm.con.

Table 10 in Appendix B summarizes all the statistical comparisons.

Table 4 summarizes data as a ratio expressed as a percentage of browse use to browse produced for weight (kg/ha) and in terms of twig numbers. This relative index summarizes browse use on Hecla Island.

The following formulas were used to calculate each entry in Table 4:

$$\text{Weight} = \frac{(\text{kg/ha utilized})}{(\text{kg/ha produced})} \times 100\%$$

$$= \text{Relative \% use biomass}$$

$$\text{Twig number} = \frac{(\text{number of twigs utilized}) \times 100}{(\text{number of twigs produced})}$$

$$= \text{Relative \% use of number of twigs.}$$

Across all habitats, dogwood had consistently high use (mean = 145%) in terms of weight (kg/ha) and to a lesser extent, the number of twigs used. Alder had low use in all habitat types except in willow/alder where 141% of current (1988) twig biomass were used and 98.3% of current twigs were taken by ungulates (both moose and white-tailed deer). Mountain maple had very high use in pure deciduous (immature) with 314% of current growth used and 85.9% of all twigs used. This high use was found to be high in all other habitat types wherever it occurred except in pure mixed coniferous where only 20% of twig weight was used and 18.6% of the number of twigs of current growth were removed. Rose had extremely large percentage of twig weight (1868%) removed in pure deciduous (mature) and 100% of current twigs used. All other species in all habitat types showed fairly low use.

Figure 8 compares browse production to browse utilization on a per habitat basis.

Figure 8. Browse production (kg/ha) compared to browse use (kg/ha).

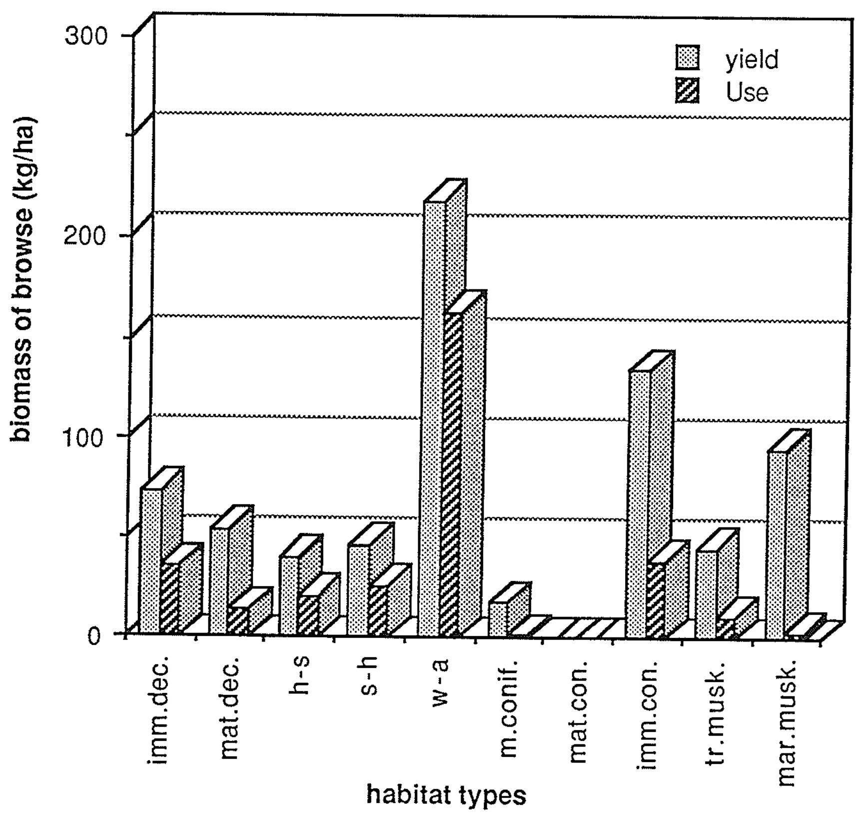


Table 4. Browse utilization as percentage of browse production and number of twigs per habitat type, Hecla Island, Manitoba, 1988-1989.

	Habitat Types																			
SPECIES	IMM.DEC.		MAT.DEC.		H-S		S-H		W-A		M.CONIF.		MAT.CON.		IMM.CON.		TR.MUSK.		MAR.MUSK.	
	weight*	number*	weight	number	weight	number	weight	number	weight	number	weight	number	weight	number	weight	number	weight	number	weight	number
alder	45.2	3.48			6.32	1.13	0.33	2.32	226	98.3	10.4	2.57	3.89	13.00	2.88	0.87				
arrowwood																				
ash					31.3	46.3					11.5	12								
aspen	5.08	0.38	16.5	12.2	167	27.8	204	20.4									35.6	20.7		
balsam fir					15.4	6.94	16.7	24.1					15.2	0.74						
bog birch															83.3	41.7	27.7	20.7		
balsam poplar	0.93	2.11			39.2	28.9									34.9	50				
chokecherry			1.88	32.7	290	5.81														
currant	0.42	29.6																		
dogwood	373	89.5	392	85.3	388	91.6	338	72.1	177	44.8	769	32.7	500	60.3	280	73.5				
elm					20	77.4														
gooseberry	5.25	4.16							42	47.5										
hazel	0.53	0.41	4.74	12.7	4.59	6.9	12	45.7												
high-bush cran.	13.5	37.3																		
Manitoba maple						61.9														
mountain maple	1733	85.9	126	47.5	885	77.6	376	66.6			25.6	18.6								
raspberry							15.8	17.4			2.92	0.56								
rose	0.91	39	250	100	2.19	25.6	1.37	25		50										
saskatoon			20.3	16.6			432	87.5												
swamp birch									95.1	51.1										
nannyberry																				
willow	20.2	7.75	448	25.9	198	50			247	57.8	112	30.2			65	67			18.1	7.1

* Weight and number of twigs are expressed as ratios and are described in results section.

To test the hypothesis that browse use is directly proportional to the availability of browse to ungulates, a Chi Square test was performed. The hypothesis was rejected at the 0.05 level meaning that browse use is not proportional to availability. A statistically significant difference was found between utilization on browse resources and availability of the habitat types. Bonferroni confidence intervals were used to determine which habitat types were preferred (Neu *et al* 1974; Byers and Steinhorst 1984). A preference index was also calculated by dividing the observed occurrence by the expected occurrence (Cairns and Telfer 1980). A preference index of 1.0 indicates that a given habitat was used in the proportion in which it is available. Preference indices greater or lesser than 1.0 indicate preference or avoidance.

The table below summarizes the preference ratings for the habitat types with Bonferroni confidence intervals.

The Bonferroni intervals (Table 5) show that the following habitat types are utilized less than would be expected by chance; m.conif., mat.con., tr.musk. and mar.musk. Whereas habitat types imm.dec.,s-h, w-a, and imm.con. are utilized more than would be expected by chance.

Table 6 summarizes the survey in terms of browse yield and browse use for the whole island. It must be understood that the unclassified habitat type was not sampled during the fall survey, therefore, there may be an inherent inaccuracy in these figures.

Table 5 Preference Index and Simultaneous confidence intervals using the Bonferroni approach for utilization of habitat types, p_i

HABITAT TYPES	Observed prop'n of usage[1]	Expected prop'n of usage[2]	Preference Index[3]	Bonferroni intervals for p_i[4] (Byers and Steinhorst 1984)
imm.dec.	0.200	0.118	1.70	$0.1981 \leq p_i \leq 0.2020$*
mat.dec.	0.067	0.100	0.67	$-0.6348 \leq p_i \leq 0.7688$
h-s	0.104	0.110	0.94	$0.1025 \leq p_i \leq 0.1045$
s-h	0.086	0.068	1.26	$0.0846 \leq p_i \leq 0.0874$*
w-a	0.223	0.030	7.43	$0.2209 \leq p_i \leq 0.2251$*
m.conif.	0.002	0.055	0.04	$0.0018 \leq p_i \leq 0.0022$
mat.con.	0.0001	0.105	0.001	$0.00005 \leq p_i \leq 0.00015$
imm.con.	0.234	0.128	1.83	$0.2319 \leq p_i \leq 0.2361$*
tr.musk.	0.065	0.124	0.52	$0.0638 \leq p_i \leq 0.0622$
mar.musk.	0.020	0.162	0.123	$0.0193 \leq p_i \leq 0.0207$

1 Observed proportions are weighted totals calculated by area (ha) and browse use (kg/ha).

2 Expected values are based on proportion of browse expected to be used by ungulates given available habitat areas.

3 Preference index of 1.0 indicates that a given habitat was used in the proportion in which it is available. Preference indices greater or lesser than 1.0 indicate relative preference or avoidance.

4 Bonferroni simultaneous confidence intervals for Pi were calculated using:

$$p_i - z_{\alpha/2k}[p_i(1-p_i/n)]^{-1/2} \leq p_i \leq p_i + z_{\alpha/2k}[p_i(1-p_i/n)]^{-1/2}$$

* Indicates a difference at the 0.05 level of significance.

Table 6. Total browse yield and browse use on Hecla Island, 1988-1989.

Habitat Type	Yield (kg/ha)	Use (kg/ha)	Area (ha)	YIELD Total (kg)	USE Total (kg)
imm.dec.	73.1	36.4	1735.7	126880	63179
mat.dec.	54.3	14.3	1471.1	79881	21037
h-s	40.4	20.2	1618.7	65395	32698
s-h	50.5	26.9	1009.0	50954	27142
w-a	219.8	162.7	433.5	95283	70530
m.conif.	18.2	0.8	812.6	14788	650
mat.con.	0.6	0.01	1544.1	926	15
imm.con.	134.0	39.3	1877.0	251518	73761
tr.musk.	46.4	11.1	1835.2	84603	20371
Unclass.		NOT SAMPLED IN FALL SURVEY			
mar.musk.	94.9	2.6	2388.4	226659	6210
TOTAL	732.2	314.3	16199.7[1]	996887	315593
MEAN	73.22	31.43		99688.7	31559.3
S.E.	20.17	15.25		26048.2	8912.6

[1] This area (162 km^2) represents the entire Hecla Island and therefore includes areas which were not sampled, i.e. road sides, development areas, etc.

In Table 6, highest browse yield was in the pure coniferous (immature) habitat type (251518 kg) over the whole island. The lowest browse yield was found in Pure coniferous (mature) with only 926 kg. The highest browse use was found in pure coniferous (immature) with 73761 kg. The next highest was in willow/alder with 70530 kg. The habitat type which had the lowest browse utilization (15 kg) was pure coniferous (mature).

In comparing the total yield (996,887 kg) with total browse use (315,593 kg), it would appear that ungulates (moose and white-tailed deer) only use about 30% of available winter browse species.

4.3.5 BROWSE PREFERENCE

An attempt to identify those browse species which are preferred by moose and white-tailed deer has been made in Table 7. By comparing the twig diameters at the point of browse (dpb) with twig diameters of current years growth (dcg), a ratio is established. Those browse species with ratios of greater than 1.0 are considered to be highly preferred by ungulates.

Highly preferred browse species as indicated by ratios found in Table 7 are chokecherry, balsam fir, aspen, dogwood, willow, alder and mountain maple. Moderate preference was shown for swamp birch, gooseberry, bog birch, saskatoon, balsam poplar, raspberry, ash, beaked hazelnut, currant and high-bush cranberry. Low preference was shown for rose. No use was shown for arrowwood, elm, Manitoba maple, and nannyberry.

Table 7. Browse species preference shown by ungulates by the comparison of the ratio of dpb to dcg.

Browse species	Mean dcg[1] (mm)	Mean dpb[2] (mm)	ratio dpb/dcg (mm/mm)	Preference rating*
chokecherry	2.25	4.20	1.87	1
balsam fir	1.40	2.42	1.73	2
aspen	2.24	3.50	1.56	3
dogwood	1.85	2.50	1.35	4
mountain maple	2.25	2.57	1.14	5
willow	2.33	2.54	1.09	6
alder	2.46	2.68	1.09	7
swamp birch	1.72	1.60	0.93	8
gooseberry	2.22	2.00	0.90	9
bog birch	2.02	1.80	0.89	10
saskatoon	2.00	1.75	0.875	11
balsam poplar	3.76	3.25	0.86	12
raspberry	1.87	1.60	0.86	13
ash, green	3.87	3.20	0.83	14
hazelnut	2.11	1.70	0.81	15
currant	2.65	1.70	0.75	16
high bush cran	2.81	2.00	0.71	17
rose	2.12	1.13	0.53	18
arrowwood	1.54	0.00	0	19
elm	1.69	0.00	0	19
Manitoba maple	2.74	0.00	0	19
nannyberry	2.03	0.00	0	19

1 and 2 Diameters were averaged across habitat types wherever they occurred.

* This preference rating is a relative measure, based on diameters sampled. A small occurrence of large diameters may distort this value, and therefore, the preference rating.

4.3.6 ESTIMATION OF CARRYING CAPACITY OF AVAILABLE BROWSE

Browse carrying capacity was calculated for Hecla Island and summarized in Table 8. The proportion of browse utilized (%) was determined by estimating the number of ungulate-days per ha which were utilized relative to the carrying capacity or ungulate-days per ha that a habitat type could support based on browse production.

Table 8 summarizes the results and indicates that marsh-muskeg had the lowest use (2.6%) of available browse. Willow-alder had the highest use (73.9%). Three types: pure immature deciduous, mixedwoods (h-s), and mixedwoods (s-h) had approximately 50% of available browse removed by ungulates (50.0%, 49.9%, and 53.5%, respectively). Remaining types had only about 30% of available browse removed.

Given reliable information on populations of ungulates, one can make some conclusions as to whether or not Hecla Island is being over-browsed.

Table 8. Browse carrying capacity of available browse and utilization by moose on Hecla Island, 1988-1989.

Habitat Types	Carrying Capacity[1] (m-d/ha)[2]	Utilization (m-d/ha)	Available browse utilized (%)
imm.dec.	14.6	7.3	50.0
mat.dec.	10.9	2.9	26.6
h-s	8.1	4.0	49.9
s-h	10.1	5.4	53.5
w-a	44.0	32.5	73.9
m.conif.	3.6	0.2	5.6
mat.con.	0.12	0.01	8.3
imm.con.	26.8	7.9	29.5
tr.musk.	9.3	2.2	23.7
unclass.	-	-	-
mar.musk.	19.0	0.5	2.6

1 Carrying capacity is defined as the maximum number of days 1 moose can feed on the forage available on 1 hectare of habitat. Calculations are based on the consumption rate of 5 kg/moose/day (dry weight) (Gasaway and Coady 1974). See discussion for variation of consumption rates by moose.

2 moose days per hectare

4.4 SPRING SURVEY

4.4.1 BROWSE USE SURVEY

The Spring 1989 Browse Use Survey attempted to determine the degree of browse utilization to complement the Fall Browse Production Survey. This extensive survey will only suggest a relative degree of use across the habitat types, as opposed to the intensive nature of the previous survey. Further identification of key browse species were made, by estimating the degree of use of each shrub that was sampled at each point. The degree of utilization observed on each species indicates preference and to some extent palatability (DeVos and Mosby 1969). The condition of all browse species on the range is indicative of the existing (or recent) relationship between the ungulate population and range capacity.

Table 9 shows just under 18 km of transects were laid out and 3575 plots were sampled using the ocular method of estimating browse use as described in the methods section. The highest proportion (14.1%) of sample plots in pure deciduous (immature) and the lowest proportion (3.9%) was found in pure mixed coniferous. Refer to foldout map #1 for transect layout.

Table 9. Summary of transect layout for spring browse survey, Hecla Island, 1989.

Habitat	Number of plots	Transect Length (m)	Proportion plots and length (%)
imm.dec.	506	2530	14.1
mat.dec.	261	1305	7.3
h-s	415	2075	11.6
s-h	504	2520	14.1
w-a	181	905	5.1
m.conif.	138	690	3.9
mat.conif.	362	1810	10.1
imm.conif.	276	1380	7.7
tr.musk.	236	1180	6.6
Unclass.	217	1085	6.1
mar.musk.	446	2230	12.5
clearcut	17	85	0.5
other	16	80	0.4
TOTAL	3575	17875	100.0

Table 10. 1989 Hecla Island spring browse use by habitat types.

Habitat	Degree of use (%)						
	0-20	21-40	41-60	61-80	81-100	100+	TOTAL
imm.dec.	268	59	30	31	61	57	506
mat.dec.	123	35	16	25	26	36	261
h-s	282	38	31	12	17	33	413
s-h	319	44	36	22	39	42	502
w-a	119	23	11	9	11	8	181
m.conif.	96	13	8	5	6	10	138
mat.con.	152	8	7	9	19	9	204
imm.con.	152	12	6	7	15	35	227
tr.musk.	109	3	11	1	6	6	136
unclass.	83	8	3	3	1	3	101
mar.musk.	304	56	39	11	14	8	432
sub-total	2007	299	198	135	215	247	3101
no browse species							334
clearcut							17
other							123
sub-total							474
Grand total							3575

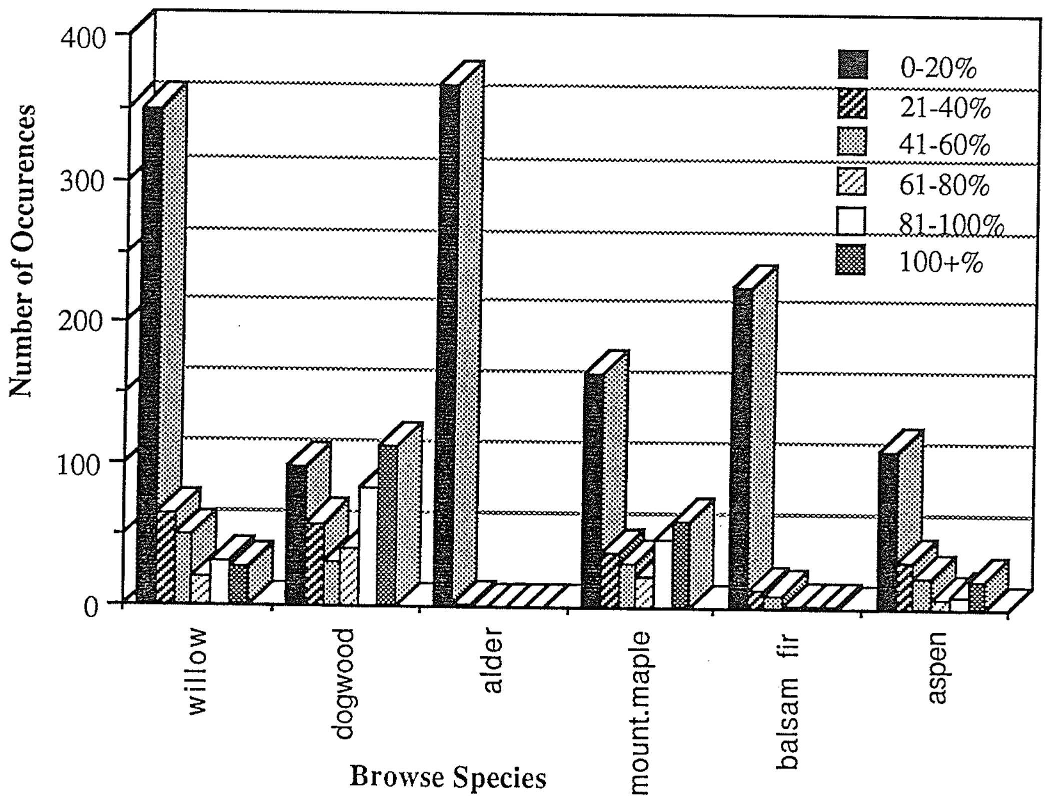
Table 10 is presented as a general summary of the degree of browse use on the basis of 3575 sample plots with no regard to browse species. Sixty five per cent of all plots sampled in the habitat types had <20% of twigs on shrubs browsed. Only 8% of all shrubs sampled had over 100% of current growth browsed. Only 19.2% of sample shrubs across all habitat types had over 60% of current growth browsed by ungulates.

Table 11. Spring browse use by browse species on Hecla Island, 1988-1989.

Browse Species	no. samples	0-20	21-40	41-60	61-80	81-100	100+
willow	545	350	64	51	21	32	27
dogwood	425	98	59	31	41	83	113
alder	373	366	3	1	1	1	1
mount.maple	370	166	40	32	23	49	60
balsam fir	257	226	12	10	3	3	3
aspen	208	110	34	24	8	11	21
swamp birch	157	123	13	13	3	4	1
white birch	136	56	17	17	13	23	10
raspberry	134	127	5	0	2	0	0
ash	117	113	3	0	0	0	0
balsam poplar	94	62	14	3	3	2	10
larch	89	85	2	1	0	1	0
hazelnut	80	38	18	7	13	4	0
rose	50	38	7	3	1	0	1
bog birch	26	15	2	1	4	4	0
gooseberry	23	19	2	1	1	0	0
chokecherry	14	5	4	2	2	1	0
saskatoon	9	4	0	2	1	2	0
buffaloberry	6	6	0	0	0	0	0
h-b cranberry	4	4	0	0	0	0	0
Manitoba maple	1	0	1	0	0	0	0
Sub-total	3118	2011	300	199	140	220	248
nbs	333						
other	124						
Grand total	3575						

In Table 11, willow, dogwood, alder, mountain maple, balsam fir and aspen account for 70% of all species encountered during the spring browse use survey. Alder had very low use; in fact 98% of all alder sampled had less than 20% of current growth browsed. Figure 9, below, summarizes six of the most abundant major species found on Hecla Island and their relative use.

Figure 9. Browse utilization (%) of six major species on Hecla Island, 1988-1989.



Dogwood and mountain maple had the highest proportion of current growth over 100% used, 26.6% and 16.2% of any browse species. Beaked hazelnut had 30% of shrubs sampled with >60% browse use, but none with 100%+. All other browse species sampled had a low degree of browse use.

Browse Use Summaries for all habitats are presented in Tables 12-22, found in Appendix A.

In Table 12, pure deciduous (immature) habitat a total of 19 browse species were tallied on 506 points. Dogwood was the most prevalent browse species with 161 samples. Seventy per cent of dogwood shrubs tallied had 60% or greater of current growth used.

In Table 13, pure deciduous (mature), of the 16 different browse species sampled, dogwood, trembling aspen, hazelnut, willow and ash accounted for 71.6% of the 261 sample points. Hazel, which dominated the understory showed moderate use with only 27% of the sample shrubs having 60%$^{+}$ browse used.

In mixedwoods (h-s), Table 14, mountain maple, trembling aspen, balsam fir, ash and balsam poplar account for 80% of all sample points. Mountain maple had 22% of the shrubs browsed at 60%+. Balsam fir had very low use, with <1% of its shrubs >60% browsed. Trembling aspen had 15% of the sampled shrubs over 60% browsed.

In mixedwood (s-h), Table 15, mountain maple, balsam fir, trembling aspen, alder and dogwood accounted for 84% of the 504 sample points and 15 different browse species tallied. Mountain maple and willow had 41.7% and 43.9%, respectively,of all shrubs tallied over 60% browsed. Balsam fir had very low use.

In willow/alder, Table 16, only 7 species were tallied for a total of 181 samples. Willow, dogwood, and alder accounted for 85% of sampled browse species. Willow and alder both had low use, and dogwood had 47.3% over 60% use, but only 14% over 100% use.

In Table 17, pure mixed coniferous, 13 different browse species were sampled. Mountain maple, alder, dogwood, ash, and raspberry made up 78% of the 139 samples. Mountain maple had 33% of the shrubs sampled over 60% browsed, and only 16% over 100%.

Table 18, pure coniferous (mature) had nine browse species sampled. Alder, white birch, balsam fir, larch, and willow made up 54% of 362 sample points. No high use was evident in this habitat type.

Table 19, pure coniferous (immature) had 11 different browse species sampled and 276 points. Alder, balsam fir, dogwood, white birch and larch accounted for 67% of all shrubs measured. Only dogwood had extensive over-browsing with 61% of the 33 shrubs over 60% browsed and 54% of that 100%+ current growth browsed. Eighteen per cent of all sample points had no browse species tallied.

Table 20, treed muskeg had 9 browse species tallied. Larch, alder, willow, bog birch and swamp birch accounted for over half (55%) of the sample points. Only willow had any evidence of browse over 60% utilized. Fourty two per cent of the sample points had no browse species tallied.

Unclassified habitat type (Table 21) had 217 sample points on roads, borrow pits, hydro-lines, trails and gravel pits. Only 12.4% of these points were on or along hydro-lines. Borrow pits had the greatest proportion of sample points (56%). Thirteen browse species were tallied. Raspberry, willow, balsam poplar, trembling aspen and dogwood all had low use.

Marsh/muskeg (Table 22) had 446 sample points. Willow and swamp birch made up 87% of all sample shrubs of which relatively low use was made.

4.4.2 COMPARISON OF SNOWSHOE HARE AND UNGULATE BROWSE SELECTION

Based on the number of plants which were browsed by ungulates and hare, and summarized in Table 12, approximately 70% were dogwood, mountain maple, willow, trembling aspen and white birch. Hazelnut, swamp birch, balsam fir and balsam poplar were moderately used by ungulates, while the remaining browse species accounted for approximately 5% of the total use by ungulates.

The major browse species used by ungulates are also used by hare, but rarely did ungulates and hare browse on the same plants. Only 1.2% of total plants browsed were browsed by both.

Table 12. List of browse species which were browsed by both snowshoe hare and ungulates during winter on Hecla Island, 1988-1989.

Browse	# plants browsed by ungulates	# plants browsed by hares	# plants browsed by both	% of plants browsed by hares
dogwood	320	6	1	2.2
mountain maple	190	11	4	7.9
willow	189	5	3	4.2
trembling aspen	92	5	1	6.5
white birch	80	7	2	11.2
hazelnut	39	2	1	7.7
swamp birch	34	0	0	0 0
balsam fir	30	3	0	10.0
balsam poplar	28	5	1	21.4
rose	12	1	0	8.3
chokecherry	9	0	0	0.0
raspberry	7	0	0	0.0
bog birch	5	0	0	0.0
gooseberry	5	1	0	20
saskatoon	5	0	0	0.0
alder	4	2	0	50
larch	4	0	0	0.0
ash	4	2	0	50
Manitoba maple	1	0	0	0.0
Total	1058	49	13	
% of total	94.4	4.4	1.2	

4.4.3 PELLET GROUP COUNT AND DISTRIBUTION SURVEY

No attempt was made to estimate population of animals using pellet groups for this study. Only relative distribution of pellet groups found in each habitat type for each herbivore surveyed were determined, as illustrated by Figure 10. In Figure 11, pellet group densities are estimated for three herbivores found in the various habitat types on Hecla Island.

The total number of pellet groups counted along 17,875 m of transects across 11 habitat types was 691. Of those plots, only 323 plots (0.646 ha) had pellet groups of moose, white-tailed deer, and/or snowshoe hare counted. Table 23 in Appendix A summarizes the pellet group distribution of moose, white-tailed deer, and snowshoe hare across all habitat types on Hecla Island.

Figure 10 Comparative pellet group distribution by moose, white-tailed deer, and snowshoe hare during winter 1988-89 on Hecla Island, Manitoba.

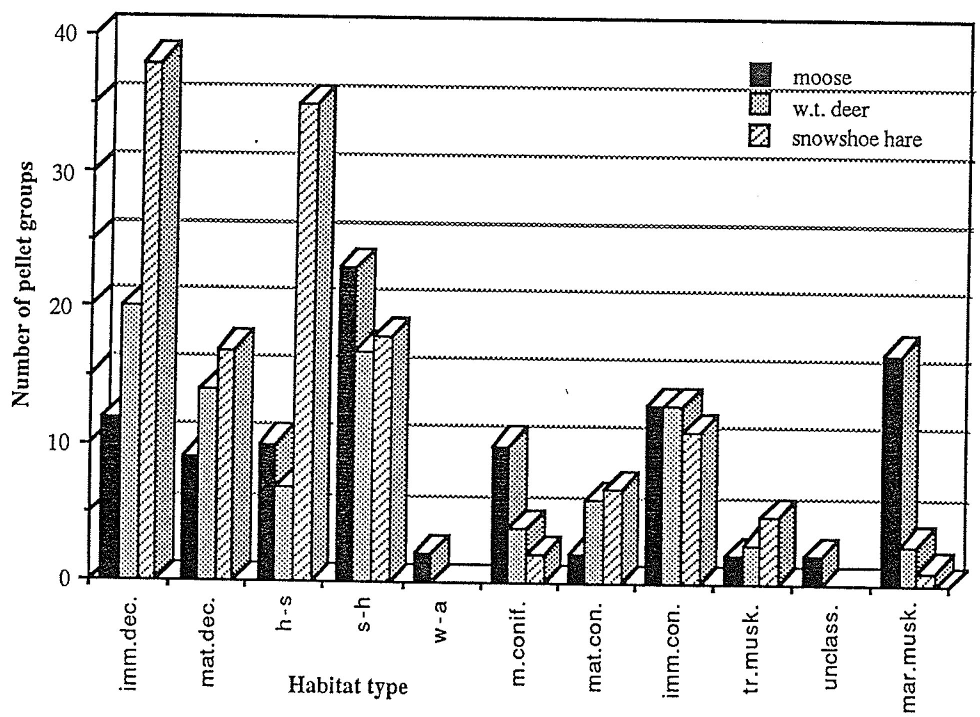
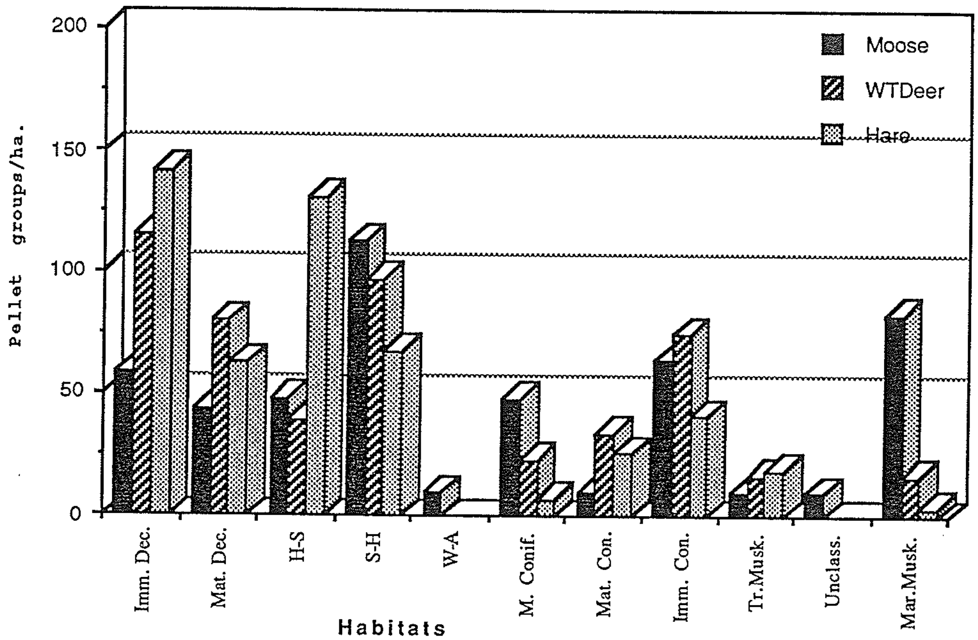


Figure 11 Pellet group densities (p.g./ha.) for three species of herbivores across all habitat types on Hecla Island.



The Chi square statistic for independence was used to test the null hypothesis that habitat use by moose, white-tailed deer and snowshoe hare was proportional to the area (or availability) of that habitat type on Hecla Island, that is, they have no preference for any given habitat type.

Although habitat preference cannot be determined absolutely, relative preference for habitats can be iterated from preference indices. Table 13 summarizes habitat preference by comparing the proportion of observed pellet groups to the number of pellet groups expected by chance if habitat use is considered to be related to availability.

Table 13. Habitat use and preference as determined by comparing observed versus expected proportions of pellet groups.

HABITAT TYPES	MOOSE	WHITE-TAILED DEER	SNOWSHOE HARE
imm.dec.	1.08	2.10	2.60
mat.dec.	0.95	1.73	1.36
h-s	0.96	0.78	2.55
s-h	3.60	3.09	2.14
w-a	0.71	0.00	0.00
m.conif.	0.192	0.91	0.29
mat.con.	0.20	0.71	0.53
imm.con.	1.08	1.26	0.69
tr.musk.	0.17	0.30	0.32
unclass.	0.45	0.00	0.00
mar.musk.	1.11	0.23	0.05

From this data it is apparent that moose will utilize the following habitats:

(a) In less proportion than their availability:

- w-a, m conif , mat.con., tr.musk. and unclass.

(b) In greater proportion to there availability:

- s-h

(c) In approximately equal proportion to their availability:

- imm.dec., mat.dec., h-s, imm.con. and mar.musk.;

White-tailed deer pellet group distributions indicated that the following habitat types were used according to their availability:

(a) In less proportion than their availability:

- h-s, w-a,mat. con., tr.musk., unclass. and mar.musk.

(b) In greater proportion to there availability:

- imm.dec., mat.dec., s-h and imm.con.

(c) In equal proportion:

- m.conif.

Snowshoe hare pellet distribution indicated that the following habitats were used according to their availability:

(a) In less proportion:

- w-a, m.conif., mat.con., imm.con., tr.musk., unclass. and mar.musk.

(b) In greater proportion:

- imm.dec., mat.dec., h-s and s-h.

(c) Data did not suggest equal proportional use of habitat types for snowshoe hare.

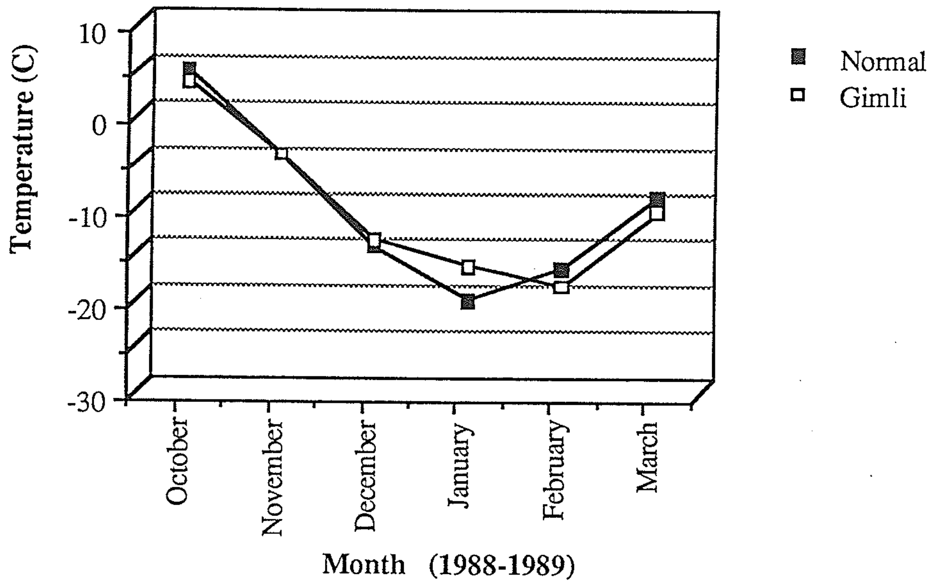
Table 1 in Appendix B summarizes the results of the Chi Square tests.

4.5 WEATHER SEVERITY DATA FOR HECLA ISLAND, 1988-1989.

Weather severity data was summarized using Canadian Climate Normals, 1951-1980. Temperature and snowfall at both Gimli (50 38'N 97 3'W at 221 m mgl) and Fisher Branch (51 6'N 97 33'W at 247 m mgl) were used to approximate Hecla Island weather conditions during the 1988-1989 winter season.

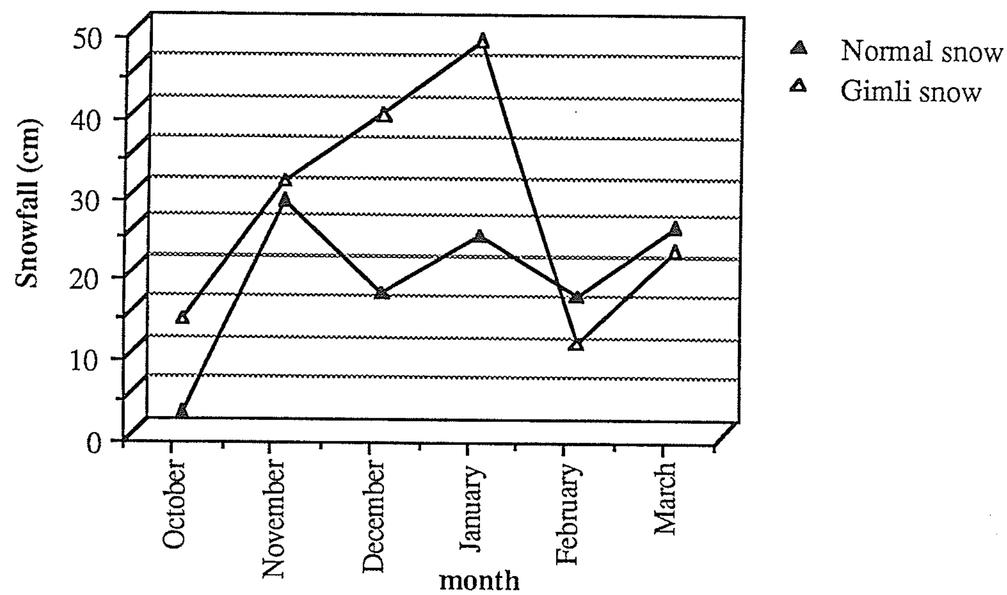
Figure 12 below compares the normal temperature to 1988-1989 temperatures on Hecla Island (as measured at Gimli). Hecla Island had very close to normal temperatures (mean daily temperatures), with January being slightly warmer than normal.

Figure 12. Temperature (°C) comparison for Hecla Island during the winter of 1988-1989.



Snow measures were obtained in the same manner and are summarized in Figure 13 below. Because more reliable snow depth data for Hecla Island was not available, data from Gimli was used to approximate snow depths. Typically Hecla Island receives more snow than Gimli (B. Cameron, Manitoba Wildlife Branch, pers.comm. 1992). It appears that December and January had substantially more snow than what typically falls on Hecla Island and late winter (February and March) had less than normal snow.

Figure 13. Snow comparison for Hecla Island for the winter, 1988-1989.

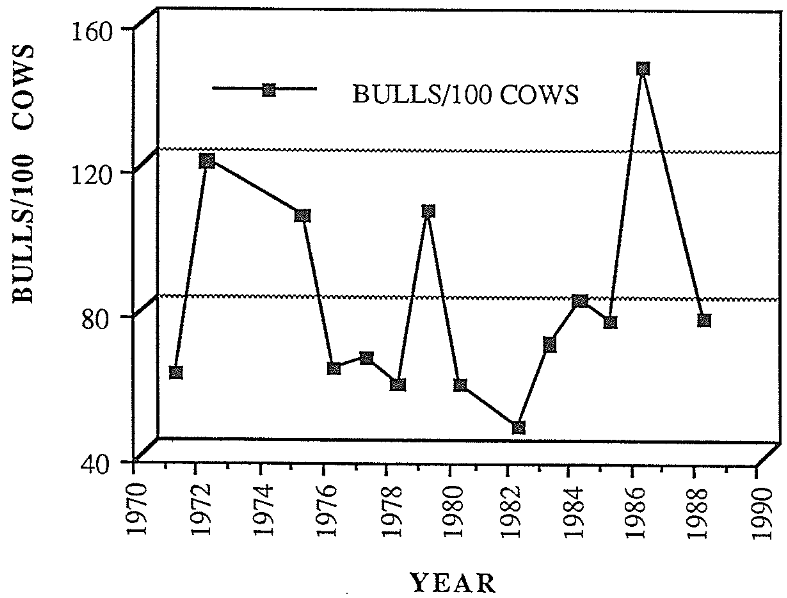


4.6 HERD STRUCTURE ON HECLA ISLAND

Based on information provided by Manitoba Wildlife Branch, characteristics of population structure including sex, age, and cow:calf ratios are presented here and in Table 12 Appendix B. Data presented are taken from moose age/sex aerial survey data taken from 1971 to 1989.(Manitoba Wildlife Branch, Unpubl. n.d.)

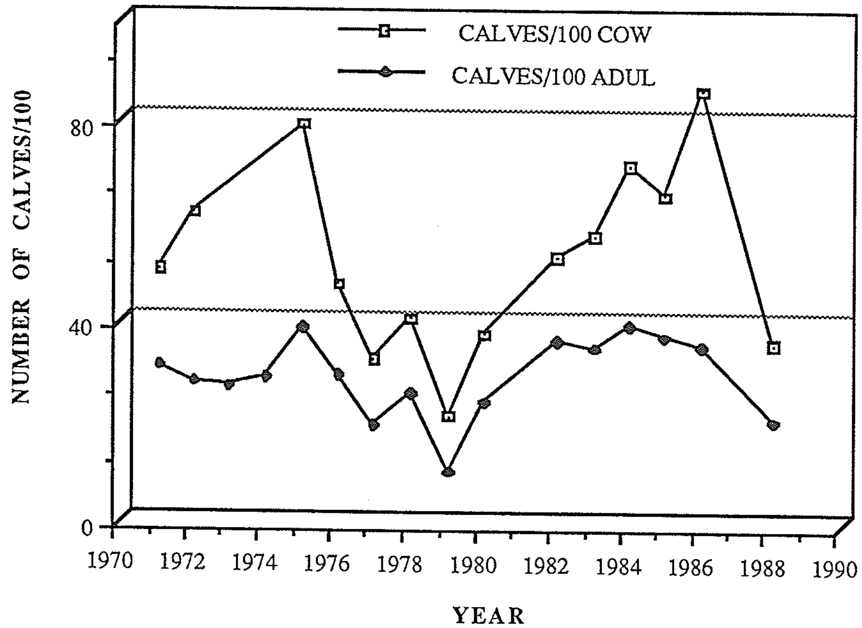
The sex ratio (males:100 females) has fluctuated from a low 47.2:100 in 1982/1983 to a high of 147.2:100 in 1986/87. The overall average ratio maintained over the 18 year period was 81.3:100. Over the majority of the period stated, the sex ratio has appeared to favour females. This can probably be attributed to the bull only hunts that have traditionally occurred during the above period. Figure 14 shows the fluctuating male:100 female ratio on Hecla Island from 1971/72 to 1988/89.(Manitoba Wildlife Branch, Unpubl. n.d.)

Figure 14. Bulls:100 cows on Hecla Island, 1971-1989.



A second aspect of population structure is that of pregnancy rates and cow:calf ratios. Cow:calf ratios have been summarized in Table 12 of Appendix B and Figure 15 below. Some data on twinning rates have also been obtained.

Figure 15. Calves:100 cows and Calves:100 Adults on Hecla Island, 1971-1989.



On Hecla Island, between 1971 and 1989 the number of calves:100 cows averaged 52.5:100, with a range from 20.8:100 in 1979/80 to a high of 86.1:100 in 1987/88. During this same period twinning had occurred, the number of sets of twins reported ranged from no twins in 1980/81 to a high of 8 sets in 1975/76.(Manitoba Wildlife Branch, Unpubl. n.d.). Proportionally, the per cent of calves which represented twins was calculated to vary from a low of 0% to a high of 20%, with an overall mean of 10% for the same period. This means that 1 cow in 10 cows on Hecla Island will have had a set of twins.

Reliable age data were limited, and has been obtained by proxy evidence derived from moose harvest data for 1978.

This data indicated for females and bull moose respectively, mean ages of 6.6 ± 4.2 years and 5.7 ± 2.3 years.(Manitoba Wildlife Branch, Unpubl. n.d.)

Mean weights for females and bulls were obtained from the same data as above in 1978. Females had an average estimated live weight of 382 ± 53 kg and for bulls, 422 ± 14 kg. was reported. Average weights correspond to the average ages for females and bulls as reported earlier.(Manitoba Wildlife Branch, Unpubl. n.d.)

Having summarized all the data, a discussion of the various important components will follow in the next section, with supporting or contradictory findings from other researchers.

5.0 DISCUSSION

This study was initiated to provide resources managers with a first approximation of browse yield and utilization on Hecla Island. This preliminary browse resource data was used to determine a relative measure of the food carrying capacity for moose and white-tailed deer during months when they are exclusively dependent on browse. Specific discussion on habitat use and ultimately preference with reference to the significance of the tested hypotheses in relation to browse use and habitat availability. Secondly, habitat use and availability will be discussed in order to supplement existing information on the identification of important moose habitat on Hecla Island. This information is supplementary to Hecla Island resource information which resource managers already have and is not intended to preclude previous work by others.

Although most of the discussion will focus on moose as the primary user of the browse resource, it must be recognized that white-tailed deer and snowshoe hare may play a significant role in the range condition and resource partitioning.

5.1 ASSESSMENT OF BROWSE RESOURCES

5.1.1 BROWSE PRODUCTION

Analysis of moose range commonly stresses production, abundance and the use of large woody shrubs (Aldous and Krefting 1946, Krefting 1951, Spencer and Chatelaine 1953, Spencer and Hakala 1964, Houston 1968). This emphasis occurs because browse is the primary food available to moose in winter over much of its range. Browse availability has classically been considered a limiting factor for moose populations. In addition, range survey methods have traditionally depended on the ease by which one can visually estimate browse conditions (Cole 1963).

Although not many studies (Crichton and Wielgus 1981; Zach *et al.* 1982) have been done on Hecla Island specifically, many other studies across western North America have indicated wide ranges of data for browse availability (twigs/ha). While browse availability alone provides some information on the relative abundance of various browse species, it does not incorporate the widely used measure of twig weight for determining carrying capacity.

Since little was known about browse biomass production on Hecla Island prior to the present study and because of the variability in browse abundance and species composition, the importance of annual production levels to ungulates was first examined on a habitat basis. This would provide accurate baseline information on existing browse resources for each habitat type and may be useful for assessing potential impacts on ungulates if further developments on Hecla Island continue.

Browse production estimates were expressed as the product of mean twig weight, mean number of twigs/stem and stem density for each species in each habitat type.

Variation in yield may have been related to many factors, including species composition and diversity, site quality due to nutrient and moisture availability, and the history of browsing or other disturbances to the browse plants. Relatively small sample sizes in the fall survey may account for some of the reported variation.

Several species in each habitat type were responsible for the majority of the browse production. For example, in willow-alder habitat, willow and dogwood were responsible for the high production. The growth forms of these shrubs were usually in clumps, up to and often greater than 20 stems per clump. Dogwood represented approximately 49% of all stems in this type. However, in most other habitat types, clump sizes were considerably smaller, usually not exceeding 10 stems per clump. The nature of the habitat types (closed versus open) have a profound effect on shrub form. As a result of the large clumps in willow-alder, biomass was very localized. Another reason for the high production figures are the approximately 2 million twigs/hectare produced on these dogwood (and willow) stems. Many of the large willow and dogwood clumps found in this habitat type were over 4 m high, and quite often outside the effective feeding range of ungulates.

When the two pure deciduous habitat types were compared, species diversity of each were quite similar; 16 species for pure deciduous (immature) and 12 for Pure deciduous (mature). However, the five major contributors to the total browse yield were different within each type. In the immature deciduous type, dogwood, alder, willow, raspberry, and hazelnut were the five major browse species contributing to stem density (Table 1 Appendix A). However, in terms of twig yield (Table 6 Appendix A), these same species take the following order; willow, dogwood, alder, balsam poplar, and hazelnut. Raspberry, was one of the lowest producers of biomass because of the small twig count and very small average diameter of current growth (dcg). In contrast, for the mature deciduous type, the five browse species with the highest stem densities were hazelnut, dogwood, willow, aspen, and arrowwood. In terms of twig yield, however, hazelnut, chokecherry, dogwood, saskatoon, and arrowwood were highest.

There were habitat types which did not produce large quantities of browse in the 1988 growing season. For example, Pure coniferous (mature) where black spruce was the dominant overstory component, species diversity and browse yield were very low. Treed muskeg had similar characteristics to Pure coniferous (mature). The browse yield survey for this habitat type, revealed only one browse species in the shrub layer, (bog birch). This contrasted with the spring browse utilization survey, in which several browse species were sampled, but, for the most part had quite a low species diversity. One possible reason for this discrepancy may be the small sample size in the fall survey (10 points or 30 clumps) and a significantly larger sample size in the spring survey. Variation in production figures were therefore expected.

5.1.2 BROWSE USE

Methods using the proportion of browsed stems to unbrowsed stems do not provide a good indication of the severity or intensity of utilization (Baskerville 1972) because diameters are not used. Using this proportion may force one to conclude that the degree of browsing intensity would be the same in various habitats, which in fact may not be true. On the other hand, if one uses the proportion of all available browse that was effectively removed, one may conclude that the impact by moose was much greater in one habitat type than another, when in fact the estimate was over-influenced by the utilization of one species.

Although this study has seen examples of both situations, there were attempts to minimize the inherent biases of these methods by using an intensive method in which proportions of both browsed and unbrowsed twigs were tallied. Samples were measured, weighed both dry and fresh, diameters were measured, and equations were derived to arrive at browse production and utilization figures. As well, to arrive at some estimation of the degree of browse use across the habitat types on Hecla Island, an extensive method using ocular estimates of browse use was utilized.

The use of regression equations to estimate browse utilization by moose and white-tailed deer has been used in many studies (Shafer 1963; Basile and Hutchings 1966; Telfer

1969, 1972c; Lyon 1970; Peek *et al.* 1971). High correlations between twig weight and twig diameter have been reported. Baskerville (1972) stated that the use of regression equations proved quite useful, provided consideration is given to the possible biases inherent in the method.

Telfer (1969) recognized that his equations might not give oven dry weights that corresponded with the variation of twig weights inherent under different climatic and site conditions. As well, this study recognizes the limited use of the regression equations. Lyon (1970) reported that twig length and diameter of saskatoon varied significantly between sites, by size of plant, location of twigs on the plant and other categories. He found that such differences would not necessarily preclude the use of a weight-diameter regression developed for many sites to predict utilization on a specific site. Lyon concluded that game animals do not browse small percentages of individual twigs, and as utilization of an individual twig increases the potential error decreases. Further, Lyon (1970) reports that "utilization on twigs that are browsed will always be high enough to prevent gross errors in utilization estimates associated with site variability".

Peek (1971) found that a sample of 50 twigs was adequate to give an estimated regression coefficient within 20% of the true coefficient at 95% level of confidence. In this study, all species across all habitat types were lumped, ignoring the variation in twig weights and diameters for different sites, and vertical location on individual stems. This was especially true for those species that were relatively rare and quite habitat specific, for example, downy arrowwood (*Viburnum rafinesquianum*).

Upon closer scrutiny, a few observations were made on utilization. First, alder appeared to be a little used browse species in every habitat type except in willow/alder where 226% of biomass was used and 98.3% of twigs were browsed (See Table 4). This suggested that almost all stems were being selected by ungulates (very likely moose), and that more than the current years growth was being removed. This was strange because other habitat types did not have such high alder use. The spring survey confirmed this point, alder was one of the most numerous (high availability) species across many habitats, but only very low to non-use occurred (Table 11). The discrepancy within the data may be indicative of the two differing methods for determination of browse use. Due to small sample sizes in the fall survey, an exaggeration of the importance of alder may be concluded, but based on past research on browse use and the results of the spring browse use survey, I would conclude that (a) quality of browse provided by alder is low and therefore should not be considered an important browse species by resources managers and (b) willow-alder represents critical winter habitat in terms of its capacity to provide large quantities of important browse for moose.

Secondly, across all habitat types, dogwood was consumed as the most highly preferred browse species as indicated by the high consumption of twig weight. Numbers occur in the range of 82% for willow-alder to 182% in Pure deciduous (mature). Browse use (by weight (kg)) consumed was averaged at 145% across all habitat types. This reflected the larger dpb's found on dogwood stems, and also explains much of the dying back of dogwood stems found throughout the entire island from both surveys reported in this document. This trend was most notable in the large 30+ stem clumps found in the more open habitat types like willow/alder. The importance of this browse species is consistent with past Hecla Island studies, observations and other measures of browse preference used in this study.

Thirdly, mountain maple, a close resemblance to dogwood (in appearance) seemed to be over-browsed in selected habitat types. Pure deciduous (immature) exhibited 314% of twig weight removed and 85.9% of twigs browsed. A similar situation was found in mixedwood (h-s) and mixedwood (s-h), with 122% of twig weight used and 77.6% twigs used, and 142% of twig growth removed and 66.6% of twigs browsed, respectively. Peek (1971) found that mountain maple, which grew in open areas and produced long twigs, was browsed only on current year's growth, whereas plants which grew under a conifer canopy were often browsed in late winter and sometimes had more than the current annual growth removed.

Based on the above figures, though, it does not appear that moose on Hecla Island differentiate the use of mountain maple between habitat types, that is, that wherever it occurs, moose use it. Moose may shift to mountain maple as an alternate (although nutritionally inferior choice for ungulates) source of browse as a result of over-utilized dogwood stems that have been subjected to many successive years of heavy browsing. It may indicate that Hecla Island range is stressed in those habitat types which are important to moose and white-tailed deer during the winter months.

Another interesting finding was that of rose use in Pure deciduous (mature). In this habitat, rose had 250% of current year's growth removed and 100% of the twigs bitten. This may have been a local phenomenon, where the sampling transect may have fallen on a pocket of high rose use. Literature was not found to accommodate such findings. It could be that white-tailed deer use was very high as a result of finding favourable browsing conditions in one particular area. Therefore the significance of this finding could be disregarded to some extent in terms of identifying important browse species on Hecla Island. Once again, small sample sizes may seriously affect the validity of such an observation. The spring survey, however, also indicates very low use and availability (Table 11) and therefore validate the observation. Similar findings were consistent with other species of low abundance like raspberry.

Browse resources on Hecla Island are disproportionately used in relation to availability (area). As indicated by the Bonferroni statistics in Table 5, those habitats which are browsed by ungulates to a greater extent than there availability ($p<0.05$) (31.3% of Hecla Island) are as follows: willow-alder, immature coniferous, immature deciduous and mixedwood (s-h). These habitats represent important sources of browse and are considered to be critical for the maintenance of the Hecla Island moose herd.

Those habitats which are used to a lesser extent ($p>0.05$), or avoided (mature coniferous, mixed coniferous, treed muskeg and marsh muskeg) are all habitat types with some similar characteristics; lower species diversity, lower browse production, increased overstory closure, and large degree of availability in relation to use for browse. These types are represented by 40.5 % of the island, but are not considered to be important sources of browse resources.

5.1.2.1 Analysis of diameters at point of browse

Comparing the relationship of diameters at point of browsing (dpb) with the diameters of current year's growth (dcg) can be important if an estimate of the effect of browsing intensity upon the plant is to be made (Peek *et al* 1971). In fact he suggested that complete removal of current annual growth from each browsed twig would severely retard a plants ability to produce new growth the following season. If the dpb/dcg ratio is greater than 1.0 (or utilization

>100% of dcg), the suggestion is that either more than the current year's growth has been removed or that the larger twigs were preferred. This has been shown to be dependent on browse species (Peek 1971). In the eastern slopes of Alberta, Brusnyk and Westworth (1985) reported that high mortality and stunted growth forms of preferred browse species was likely influenced by high levels of browsing intensity in preferred habitats.

In that study, dpb's averaged 107% of the dcg's indicating that ungulates were removing the previous years growth in addition to the current annual growth. This relationship can suggest plant preference by browsers. Results from this study (Table 7) also indicate high usage of over 100% for many species, including many of the principle species considered to be important to ungulates. Preferred species (by this method) include chokecherry, balsam fir, aspen, dogwood, mountain maple, willow, and alder.

This method indicates that alder is preferred , however, further analysis (comparison of weight available to weight used) indicates that this must be a local phenomenon, primarily within the willow-alder complex and immature deciduous type. Chokecherry has a high preference rating but this ratio was based on a small sample size. The true significance is primarily a statement of this shrubs availability on Hecla Island. It turns out that it is not one of the most abundant species, therefore the high rating only indicates local high use and not really high preference.

Balsam fir is another species which has a habitat type effect on preference. Balsam fir is predominantly found as an understory shrub, where the dominant overstory is also coniferous and therefore is most abundant in only a few types such as the two mixedwood types and both immature and mature coniferous.

Those browse species which have very high preference are also those species which are available in all habitats. Included in this category are willow, dogwood, mountain maple and to a lesser extent aspen.

Limitations of this method of browse preference are related to several factors. First, the sample from which this ratio is derived is very critical. For example, if the diameter at point of browse is taken from a small sample of twigs which has unusually high diameters, the ratio can be affected and will tend to be an over-estimate of the preference.

Mechanical parameters related to mouth size, texture, shape, length of current annual growth which is variable with climate, topography and habitat type may affect the ratio. However, this is only conjecture and any significant analysis of this is well beyond the scope of this document.

5.1.2.2 Degree of Browse Use on Hecla Island Range

In the spring of 1989, during the month of May and June, before leaf flush, an extensive browse use survey was done over the Hecla Range, in an attempt to determine if the range was being over-utilized by the existing ungulate population. This survey was done to supplement the previous intensive browse production survey done the previous year. The degree of use of the Hecla Island range on the basis of 3575 sample plots across all eleven habitats was summarized (Table 20). It is relatively apparent that the majority (74.4%) of browse species were less than 40% utilized, and only a relatively small proportion represented use above 80% (7.0%). Only 8.0% of the sampled plots showed over-use of 100%+. Again, this high use (15%) is primarily a result of the highly preferred browse species being selected and sought after by ungulates.

On a habitat basis, generally it was found all habitats were not over-utilized, in fact, a weighted average use was calculated to be only 29%, without regard to browse species. But in virtually every habitat, high levels of dogwood and mountain maple were found. Because the preferred species are over-utilized, perhaps beyond which the shrub can maintain from one growing season to the next, it can be suggested that browsing resources between some specific habitats are stressed beyond the food carrying capacity.

Unlike the fall browse production survey hazelnut was found to have 30% of shrubs sampled with >60% browse use. This was found to occur primarily in the mature deciduous type where hazel is the dominant understory species.

Intensity of browse (% use) on various species found on the range were also summarized. In descending order of occurrence, the ten most abundant species represent 87% of all plots sampled. The remaining browse species (last 11 species) represents approximately 13% of the sampled plots of which relatively sparse use was determined.

By way of explanation, the entry of 333 plots (9.0%) which had "no browse species" measured, simply referred to the fact that a "no tally" was given if a potential shrub was not found within a 10 m radius. When this occurred, the investigator simply proceeded to the next sample point along the transect line. This occurred in those habitats which had low relative shrub densities. Treed bog and mature coniferous habitats had the largest per cent occurrence of no tallies. The "other" designation referred to points that landed on areas which were unable to be sampled, for example, water (large borrow pits) or highways. These points really testify to the rapid development of the island, and the further reduction of available moose habitat, although a quantitative comparison cannot be made in this document.

5.1.2.3 Hare Browse Use

To investigate the degree of browse use by snowshoe hare, those browse species which were selected are summarized. It is recognized that hares are capable of foraging in the same vertical range as ungulates (Telfer 1972a, Dodds 1960, Boukhout 1965, Samoil 1979). This investigation determined that hare infrequently browsed above 1.8 metres, and for the most part, the majority of browsing was below 1 metre.

In this study, snowshoe hare are browsing on the same shrub species. The most palatable and most preferred species for ungulates (dogwood, willow, trembling aspen, mountain maple) are also the most preferred by hare. These findings are consistent with several authors that also found that snowshoe hares use the same food items as ungulates (Samoil 1978; Trottier and Samoil 1978; Leonard 1979). The percent of hare browsed stems are very low for all important species, suggesting to me that the contribution of snowshoe hare to total utilization during 1988-1989 was very low. In the absence of any snowshoe hare population trend data, I would suggest that snowshoe hare population was not at a critical level where direct competition for browse resources were shown.

One interesting note, however, was the diameters at point of browse (dpb) for hare. Dpb's were consistently larger for snowshoe hare than for ungulates, although not significantly different. For example, balsam poplar was browsed on by both hare and ungulates in pure deciduous, mixedwood (h-s), mixedwood (s-h), the mean diameters for hare browsed balsam poplar was 4.1 mm and that for ungulates was 3.05 mm. Although the difference in browse diameters was not significant ($p < .05$), the comparison may suggest that this species is preferred where it occurs. The same can be said for trembling aspen ($p < .05$) in the same habitats as mentioned above. In the mixedwood (h-s) type, mountain maple was browsed by hare considerably, having an average dpb of 6.1 mm.

5.2 CARRYING CAPACITY

Ricklefs (1979), Odum (1959), Moen (1973) and many others have all discussed the concept of carrying capacity. Other terms which have been used are ecological carrying capacity (Ferrar et al. 1983), subsistence density (Dasmann 1981), environmental carrying capacity (Clark 1976), potential carrying capacity (Riney 1982) and K carrying capacity (McCullough 1979). Although the carrying capacity of an environment for a population is partly dependent upon the resource requirements of individuals, most variation in the population density of a species in different habitats, or of similar species in a community, can be related to the availability of resources. Dasmann (1959) defined carrying capacity as the number of animals of each species that can be supported by the available range without detriment to either the animals or the range. In this study, several highly preferred browse species (dogwood, mountain maple, and willow) have been over-utilized where current growth as well as previous years growth have been taken.

The above definition has traditionally been accepted. But a distinction should be made depending on whether carrying capacity is viewed as a threshold, equilibrium or a target (Blythe and Hudson 1987).

Traditionally, it had been believed that a threshold carrying capacity would have vegetation resources drastically decline and an ungulate population would immediately crash to extinction. This view is no longer accepted (Blythe and Hudson 1987).

Three factors which are important in regulating herbivore populations when discussing carrying capacity as an equilibrium are food depletion, dispersal and predation. Food depletion results in lower fecundity and higher mortality rates as populations increase to a point where they exceed the available food supply (Blythe and Hudson 1987). This has been postulated to be true for moose and range on Hecla Island although not fully tested. Birth rate and juvenile survival both decline as populations increase and deplete resources. With an increase in age of reproductive maturity these factors result in lowered productivity. For ungulate populations, density dependent changes in adult survival usually occur close to carrying capacity.

Dispersal of free ranging ungulates occurs in two ways. First, populations can disperse into surrounding areas which may have artificially low numbers, largely as a result of man's activities. This tends to continuously reduce population levels and therefore the equilibrium level (Blythe and Hudson 1987). Barriers such as fences also tends to reduce dispersal (such as is found at Elk Island National Park in Alberta). On Hecla Island there are no natural barriers to animal dispersal. Moose have even been spotted on the causeway entering Hecla Island and water does not present a true barrier to dispersal for moose.

The third factor regulating ungulate populations is predation. Generally, the predator impact on prey populations is largely dependent on the size of the prey population and the effectiveness of predators. With an efficient predator and alternative prey sources available, both prey and predator populations may stabilize at a point where prey populations are high. Therefore, little impact on the prey population will occur or at a low population where predators may severely deplete the prey population (Blythe and Hudson 1987). An inefficient predator will cause a stable position only when prey populations are relatively high.

On Hecla Island the black bear (*Ursus americana*) and the grey wolf seem to have little impact on the present moose population even though they are considered to be relatively efficient predators. It is known that wolves on Hecla Island do hunt and are somewhat successful in making moose kills by the presence of kill sights (B.Burgess, 1990). However, it is not known what the kill/effort ratio might approach Several examples of ungulate populations on islands (Isle Royale and Hecla Island) where essentially the only regulating factor is food availability indicates that if left alone the ungulate population can eventually reach an equilibrium level. It is this authors opinion that predators do not play a limiting role in ungulate populations on Hecla Island although predator/prey relations should be studied in the future.

Carrying capacity as a target level is the last . Often systems are managed as production ecosystems and therefore carrying capacity is considered as the stocking density at which maximum animal production is achieved.

Hecla Island has never been managed to maximize animal production. This is especially true, given the more recent approach to Parks Management, emphasizing the non-consumptive use (viewing, and trail development) of wildlife and other resources. Even if it was, legal native hunting could upset management goals.

5.2.1 ESTIMATION OF BROWSE REQUIREMENTS OF EXISTING POPULATIONS AND STOCKING LEVELS.

Using the following assumptions (Hudson 1982, Telfer, unpubl. 1981), the total theoretical biomass requirements for moose were calculated.

As described by Hudson (1982), initial estimates can be derived from a two-step procedure involving:

1) measurement of allowable offtake of available forage (about 60% of annual production) at the leanest time of year followed by,

2) division by animal forage requirements (approx. 2.2% body weight, $W^{0.75}$).

This procedure using plant criteria is assumed to approximate in a crude way, optimal stocking levels based upon characteristics of the animal population.

Consider the following calculation of carrying capacity for moose on Hecla island which assumes that the population is limited by winter browse supplies.

Vegetation

Browse supply at the end of the growing season (averaged across all habitat types) ....61.3 kg/ha

Proper use factor 60%

Browse available for consumption (100 x 0.60) .....36.78 kg/ha

Animal Requirements

Daily forage requirements .... 8 kg/animal/day

Proportion of browse in the diet 95%

Daily browse requirement (8 x 0.95) ..... 7.6 kg/animal/day

Period of dependence on standing crop of browse ....200 days

Browse requirement over winter ....1520 kg/animal

Stocking Rate for Hecla Island

Area required to support 1 moose over winter (1520/36.78) ....41.3 ha ($0.413\ km^2$)

Carrying capacity (1/0.413) 2.42 moose/km^2

If a conservative 9% loss of available habitat to moose can be assumed (Crichton 1977), then based on the area of Hecla Island (162 km^2), the following calculation should determine the maximum theoretical number of moose that can be supported by the browse resource, given similar conditions to the winter of 1988-1989 with no differentiation of habitats and the above assumptions:

> 2.42 moose/km^2 x [162 km^2 - (9% of total area)] = 356 moose for Hecla Island.

Of course, this rather crude calculation provides only an order of magnitude estimate of actual carrying capacity since factors such as daily requirement and diet composition change in response to environmental conditions have not been considered. Also, the effect of removal of foliage, the main summer diet of moose, on browse production and no accommodation for white-tailed deer and other herbivore winter browse requirements have been made in this calculation. Another important variable which has be initially neglected is the area proportion of the island that represents unusable habitat in terms of browse. Those habitats would include treed muskeg and mature coniferous which represent about 21%. Recalculated the formula now looks like the following:

> 2.42 moose/km^2 x [162 km^2 - (9% of total area)-(21% of unusable habitat)] = 274 moose for Hecla Island.

Further, known counts for moose on Hecla were 102 moose and an estimation of 69 white-tailed deer (Pers. comm, D. Roberts, 1989 Gimli, DNR) based on aerial surveys. If 102 moose inhabit Hecla Island, and based on the above calculated winter browse requirement of 1520 kg over 200 day period, total browse required would be 155040 kg per year. This study indicates that almost twice this amount (315593 kg) is utilized by both moose and white-tailed deer, and to a lesser extent snowshoe hare. Compared to the 996887 kg produced in 1988, I would conclude that quantity of browse resources are not the absolute limiting factor on Hecla Island.

It was quite apparent that the total browse yield can accommodate the theoretical requirements (as per the above calculations) of the ungulates on Hecla Island. Findings from this study indicate that ungulates use more than their theoretical requirement using this very simple model.

To adequately assess the carrying capacity of a given area, it is important to have knowledge of all nutritional and energy requirements of the species involved for all life processes and activities. Moen (1973) suggested that such an assessment requires not only knowledge of the population structure, but also knowledge of the habitat with regard to the production of required materials. DeVos and Mosby (1969) stated that the delimitation of carrying capacity for extensive ranges had also proven difficult, especially when more than one species of large ungulates was present.

Another approach for this study was used to estimate range capacity on a per habitat type basis. Having calculated both browse production and browse utilization, and knowing the consumption rates of moose from literature, the number of moose-days that any one habitat type could support was calculated.

This estimation was summarized in Table 8 ..An average use of about 32% was determined, with a range of use of 2.6% in marsh-muskeg to a high of 73.9% in willow-alder. This figure is quite significant since we are treating all habitats as equal in the calculation of average use. A higher average use would be found if those habitats that do not contribute greatly to browse production were ignored. Higher average use (between 40 and 50%) was also found in the immature deciduous type and both mixedwood types. Discussion of habitat preference may be implied by this reported estimation. By this estimation from a browse use perspective, willow-alder habitat type represents the most important critical moose habitat on Hecla Island in terms of browse use.

5.2.2 BROWSE CONSUMPTION

Estimation of daily browse consumption had been rather crude (prior to 1970) and one reason for this had been the poor reliability of estimates of defecation rates available in literature. Variation of this parameter was reported by Crete and Bedard (1975). A range between 10.3 - 32.2 pellet groups per day has been given.

Gasaway and Coady (1974) arrived at estimates for browse consumption of 1.3 to 5.4 kg-dry weight/moose/day at Kenai. They also estimated daily energy needs in moose using classical curves of metabolic rate versus body weight together with known caloric value of browse, and obtained an estimate of 4.5 to 5.5 kg (dry weight) for winter daily browse consumption.

Variation between sex and age had also been reported. Des Meules (1965) estimated daily consumption (from cow and calf) to be 10 kg for the cow, and 6.7 kg for the calf. Bergerud and Manuel (1968) obtained comparable figures for a fenced bull fed on balsam fir only consumed 14.5 to 18.6 kg (fresh weight) per day. Balsam fir, which has an estimated moisture content of 53% (Crete and Bedard 1975) produces a daily consumption estimate of 7.7 to 9.9 kg (dry weight) per moose per day. Crete and Bedard's estimate of 2.5 kg/moose/day was considerably smaller than both of the previous authors, but is quite comparable to the theoretical (basal metabolic rate) estimate of Gasaway and Coady (1974).

5.2.3 BROWSE QUALITY

It is universally accepted that carrying capacity as a concept is very difficult to define and use on a practical management basis. Browse quality, palatability, and digestibility are as much a function of habitat capability as browse quantity and availability. Under the best conditions, woody browse usually contains <10% crude protein, 1-7% crude fat, 40-60% carbohydrates and 20-40% cellulose (crude fiber) (Kelsall 1968, Milke 1969, Houston 1968). In protein levels, at least, the woody parts of all common browse species provide barely adequate maintenance levels of nutrition as judged from domestic ruminants (Swenson 1970) and other wild cervids (Ullrey et al 1969, Luick et al. 1971).

Several authors have studied food quality for ungulates. Mautz *et al.* (1974) compared digestibility of hazelnut and six other browse species and found that beaked hazelnut had the best protein digestibility and highest net energy. Rations containing large proportions of hazelnut were consumed by deer in excess of other rations offered. Crude protein was 8.0 % in Minnesota (Peek et al. 1976) and 11.8% in New Hampshire (Mautz *et al.* 1974). In comparison, McNamara (1979) found 3.9 to 4.7% crude protein in aspen twigs from the Rocky Mountains of Colorado while in Saskatchewan, Stewart and MacLennan (1977), determined values of 7.9% for aspen, 6.0% for red-osier dogwood, 6.6% for willow, 5.8% for saskatoon, 7.6% for balsam poplar, and 8.9% for chokecherry. It is likely that any disproportional use of browse which may have occurred is correlated to browse quality.

Therefore, populations of moose confined to woody browse for long periods during winter may suffer. Depletion or virtual elimination of some browse species, such as dogwood, willow, mountain maple, may not only reduce the proportion of higher protein forage, but also reduces variety available during winter. Mellenberger et al. (1971) suggests that variety itself is important to ruminants for digestibility of forage is sometimes altered strikingly by addition of other material to one species diet.

It appears from this study, that ungulates have no shortage of variety of woody browse available for consumption. Shrubs which have been classically referred to as favored foods (aspen, chokecherry and saskatoon) were in fair to poor condition at many sites, but I do not feel these species are good indicators of range condition because they are not abundant and because together they account for a fairly low proportion of the available browse to herbivores. However, it is quite obvious that some of the most highly preferred species, for example, dogwood and mountain maple may be suffering from intensive, long term impacts of herbivory as evidenced by the observed level of use and stem dieback.

5.2.4 RESPONSE OF SHRUBS TO HERBIVORE ACTIVITY

Several researchers have commented on this topic. Aldous (1952), Krefting et al. (1966), Willard and McKell (1978) agree that although a reasonable level of twig removal in winter, stimulates plant growth and maintains growth of saplings and shrubs within the reach of moose, that defoliation during the growing season decreases carbohydrate reserves, increases twig dieback, and reduces foliage production in subsequent years (Giese et al. 1964, Kulman 1971, Garrison 1972, Hodson 1981). Mountain maple and aspen, both preferred species, are quite able to revegetate following ungulate defoliation (Rose 1958, Skilling 1964, Hodson 1981). Mountain maple and dogwood were two species that showed a fair proportion of stem dieback on Hecla Island, although no quantitative data for dead stems per hectare were reported. Continuous high use of key browse species will stress the ungulate populations in the future if the assumption that browse availability is the single most important limiting factor for moose on Hecla Island.

5.3 WINTER HABITAT USE AND SELECTION

Determining habitat selection is a difficult problem and has several perspectives. Statements about selection for or against habitats are quite relative. Underlying mechanisms for habitat 'choices' are not fully understood (Matchett 1985). That is, ecological variables such as social interactions, plant phenology, forage quality or availability, temporal changes, physiological changes, and many other factors are all important. Moose use that is greater or less than availability does not mean preference or avoidance, only that there is a relative difference (Matchett 1985). For example, if a given habitat component is abundant (e.g. 75% of the available area), but only used 50% of the time, avoidance may be implied when in fact 50% use suggests this is an important habitat.

However, in Neff's (1968) summary of the pellet group count method, he suggested that it was assumed that pellet groups were deposited most heavily in those places in which moose and white-tailed deer, as well as other ungulates spend the greater part of there time. Van Etten (1959) reported that pellet group densities would vary between different vegetation types and in fact this was the case (Figure 11) for habitat types found on Hecla.

In studying the pellet group distribution of moose, white-tailed deer and snowshoe hare, it was assumed that a higher count of pellet groups tended to show a relative preference of one habitat type to another. In this study, it was only postulated that moose, white-tailed deer and snowshoe hare utilize the habitat in approximate proportion to habitat availability. This was done using comparative pellet group distribution data. However, there was no way in this study to differentiate ungulate activity (feeding, standing, bedding) in the habitat types by pellet group distribution information. Extensive browse use data from this study may help to explain ungulate habitat selection in relation to the browse resource on Hecla Island.

5.3.1 MOOSE

From the pellet group distribution data and statistical analysis it was determined that moose used mixedwood (s-h), immature coniferous, immature deciduous, and marsh-muskeg greater than availability. Other researchers (Crichton 1977, Wielgus 1980) on Hecla Island have also found that mixedwoods (although not differentiated) are important to moose in winter. This can most likely be explained by the softwood or coniferous content of the overstory and therefore the increased thermal cover. Ozoga (1968) suggested that the mature state and coniferous components of various stands likely offered adequate cover. Greater coniferous cover could reduce energy expenditures and increase efficient use of the shrub understory (Moen 1968, Ozoga 1968, VanBallenberghe and Peek 1971).

Habitat preference based on browse use indicated that moose prefer willow-alder, immature coniferous, immature deciduous and mixedwood (s-h). There is some discrepancy between the two measures (pellet distribution and browse use) but an explanation can be made. Pellet group distributions imply that a greater length of time is spent in a particular habitat. Moose will often deposit pellets and urinate at a bedding site in those habitats which provide the most protection from wind and cold weather. All of the above habitats except immature deciduous have a significant conifer content. Immature deciduous is most likely only marginally preferred based on pellets alone. It is obvious that moose will use those habitats which will meet their maintenance requirements as well as remaining close to the foraging resources. Results indicate that the mixedwood (s-h) is more highly preferred because of its superior thermal characteristics.

Crichton and Wielgus (1981) suggested the significance of winter cover was further illustrated by utilization of red-osier dogwood. They found dogwood to be utilized to a greater extent in deciduous and mixedwoods than that found in open areas (willow-alder), which likely had deeper snow cover, greater wind exposure and colder temperatures. Peek et al. (1976) suggested that moose used dogwood in fall and early winter as a preferred browse but as soon as it was depleted, other species would then be utilized. While this may have been true in 1978-79, very high use of dogwood was found in willow-alder. This would follow because the winter of 1988-89 had lower than normal temperatures and snowfall except in December when snow was deeper than normal.

Rounds (1981) found somewhat similar winter habitat selection patterns for moose in Riding Mountain National Park, Manitoba. He found that moose showed preference for immature aspen forest but rejection of shrublands and bog communities. He also found that moose neither preferred nor rejected mature aspen forest. This was also found to be true in this study based on pellet group distribution only. The only deviation from Rounds (1981) study is that moose showed a relative preference for marsh-muskeg habitat. This finding is somewhat atypical for most studies, but once again the relatively warm winter may explain moose venturing out into the peripheral edges (west side) of the island.

This study found that dogwood was a highly preferred browse species and was browsed heavily in all habitat types, and over-browsed in selected types. The postulation made by Peek et al. (1976) might be supported by data from this study, as mountain maple, a less preferred browse species, was used heavily wherever it occurred, quite possibly as a second choice.

Willow-alder habitat does not appear to be used preferentially by moose during winter, however, when snow conditions are favourable, heavy browsing may occur.

Literature suggests that thermal cover and snow depth along with browse requirements supercede the browse requirements alone (Peek et al.1971). This is somewhat confounding since browse utilization in this type was 73% of all available browse, the highest of any habitat type sampled. Once again, the conclusion that moose used this habitat type only until weather and snow depth became excessive, and then moved into areas which provided more cover and suitable browse may explain this observation. Berg and Phillips (1974) in a study of moose in willowed areas in NW Minnesota found that areas of tall willow (up to 3m in height) were extensively used from January to April. However, these authors make no statements concerning the proximity of forest cover to the willowed areas which may act as thermal and security habitats.

Rounds (1981) found that bog communities were rejected by moose in Riding Mountain National Park, Manitoba. This would include pure mature coniferous types and treed muskegs on Hecla Island. This is understandable because of the poor production of browse species in the understory. This study concurs with Crichton and Wielgus (1981) who found that moose only frequently moved through these areas, very likely to move to better foraging areas. Light use of browse within these types occur as these forests contribute little to moose habitat requirements unless they were found in conjunction with or adjacent to superior forage producing habitats (Crichton and Wielgus, 1981). The extensive tracts of pure coniferous species found in these habitats contribute very little to the habitat and nutritional requirements of moose. They were used to a lesser extent than to what was available on Hecla Island. VanBallenberghe and Peek (1971) and Peek et al. (1971) reported these habitats were used for cover, but areas like pure immature coniferous which had available browse were invariably associated with their use. On Hecla Island, immature coniferous types were used in greater proportion than they were available because of the combination of available browse and thermal characteristics.

The use of Unclassified habitat type by moose during winter suggests, largely from this study, that moose do not spend a lot of time along hydro-lines, in open borrow pit areas, or along roads and highways. Probably for the same reason that moose are not usually found in the low lying marsh-muskeg areas during most winters. Under normal snow and temperature conditions for the climate regime on Hecla Island, thermal maintenance can not usually be met by these open areas. Berg and Phillips (1974) found that moose shifted use of habitat to lower, more open sites like marsh-muskeg after April when conditions were more favourable, and also for the duration of the summer months. In 1988-89 these favourable temperature and snow conditions were probably met earlier than normal.

5.3.2 WHITE-TAILED DEER

In this study, white-tailed deer generally used mixedwood (s-h) type, immature coniferous type and to a lesser extent the two deciduous habitats proportionally more than their availability ($p < 0.05$). Treed muskeg, willow-alder, unclassified and marsh-muskeg type were noted to be used in lesser proportion ($p > 0.05$) than what was available. These habitat selections are similar to moose and therefore interactions between the two species is expected.

The ability of a land unit to provide the highest possible quality winter food to combat energy loss is of primary importance to deer during late fall/early winter. However, efficient use of energy is also significant because of the poorer quality food source (browse). Thermal cover and escape cover become very important as a result of poorer food selection, poorer (i.e. colder) conditions, and increased susceptibility to predators after leaf fall. The relative interspersion of hiding cover with foraging habitat is of prime importance in determining the quality of escape cover. Generally, woody cover types which are diverse in height and species composition and occur in close proximity to farmland are ideal white-tailed deer habitat. During the study, white-tailed deer on Hecla Island had been observed towards the south end of the village in late fall where mixedwoods and deciduous types meet at farmstead boundaries (pers. obs.). Well developed understory vegetation has been reported to be preferred for winter ranges but not for summer ranges. As well, edge or ecotonal areas associated with transition zones between treed and non-treed areas, also bring suitable food and cover types into close association with each other and are productive in terms of good browse species. In addition, deep snow can severely limit the available high quality forage for deer. Based on the pellet group surveys, one can conclude that several habitats provide adequate food, thermal and/or security (escape) cover.

Winter behaviour of white-tailed deer as influenced by snow depth has been recorded by several authors (Day 1963, Prescott 1974, Peterson 1955) and may have an important bearing on interrelations with moose. Willow/alder and marsh-muskeg are no doubt avoided by white-tailed deer as they may represent those habitat types which have deep snow throughout the winter because they do not have adequate coniferous content for interception of snow. Generally, if winters are severe and snow depths exceeds 50 cm, deer will aggregate and remain in dense stands of conifer or mixedwood (Telfer 1970). The need for adequate thermal cover (i.e. energy conservation) is very important and availability of forage becomes a secondary consideration. Treed muskeg has adequate thermal cover, but definitely lacks the browse resources which can maintain a deer population.

Limiting factors for white-tailed deer are somewhat difficult to pinpoint in some areas and not for others. However, snow depth is probably the factor that limits deer movement most (Telfer 1970). Deer mobility is restricted by snow depths greater than 38 cm, therefore areas in the northern boreal forest dictate that traditional winter ranges with shallow snow are critically important. Because snow depths were shallower on Hecla Island and unseasonably warm, early spring conditions probably made for a relatively easy winter (1988-89) for white-tailed deer.

5.3.3 SNOWSHOE HARE.

Snowshoe hare use the two deciduous types,and the two mixedwood types in greater proportion to habitat availability ($p<0.05$) as indicated by the winter pellet group distribution. All other types were used less than availability (or avoided).

These findings are not new, habitat selection by snowshoe hare is highly variable from region to region. In their review of snowshoe hare habitat use, Tompkins and Woehr (1979) state that, "The snowshoe hare appears to accept a variety of habitat types, ranging from predominantly coniferous to predominantly deciduous forests".

The association of hares with coniferous habitats is well documented (Grange 1932; Adams 1959, northwestern Montana; Telfer 1972, in Nova Scotia; Dolbeer and Clark, central Rocky Mountains 1975; Walski and Mautz 1977). Other researchers found that hares use predominantly deciduous habitats (Keith and Surrendi 1971). Dodds (1960) found hares using deciduous woods for both cover and food in areas where the distribution of conifers was severely limited due to heavy browsing by moose.

It is widely accepted that all habitats which continually support hares contain low, dense shrubby cover, although the apparent overstory preferences of hare can be highly variable from region to region. The common denominator across the variety of habitat types utilized by hare is a brushy understory, deciduous or coniferous, that provides both cover and winter food (Keith and Surrendi 1971; Keith et al. 1984). Several other studies have reached similar conclusions (Adams 1959, in Montana; Dolbeer and Clark 1975, in Colorado and Utah; Green 1980, in northeastern Alberta; Wolfe *et al.* 1982, in Utah).

An apparent preference for immature pure coniferous over other types by hare has been documented as well (Orr and Dodds 1982, Bakuzis and Hansen 1965) where it was determined that hare preferred low coniferous cover that was associated with deciduous shrubs. Although the pellet distribution survey for this study did not concur with these particular findings, it was found that immature coniferous was only weakly rejected by snowshoe hare. This particular type was found to have these characteristics, with ample light reaching the forest floor, enough cover and a matrix of overstory, openings, and food. Orr and Dodds (1982) reported that hare use was lower where trees are taller than 12 m and where canopies are denser than 60 per cent.

5.4 RESOURCE USE RELATIONSHIPS WITHIN THE HECLA ISLAND HERBIVORE GUILD

This study has produced considerable data on resource use among the major terrestrial herbivores, moose, white-tailed deer, and snowshoe hare. Attempts to identify foraging and habitat dimensions of the niches of these herbivores has been done while others (Samoil 1978; Leonard 1979 have undertaken similar studies for snowshoe hare. The data from this study should try to compare relationships which may explain species co-existence, or alternately, the presence of antagonistic interaction.

For the purposes of Hecla park management and planning, this portion of the study is important because "management of multi-species systems requires clear knowledge of the manner in which members of the herbivore community utilize and partition resources available to them. Such information is basic to determination of appropriate combinations of animals that would meet various management objectives" (Hudson 1976).

Resource partitioning (Schoener 1974) and competition (Pianka 1976, Cole 1958) are two important concepts which provide a theoretical as well as biologically relevant background for comparing niches. Niche differentiation among co-existing species usually involves separation along the dimensions of habitat or space, food, and time. All these dimensions are discussed in this report, although the short term nature of this study can really only imply relationships without being taken as absolute.

Birch (1957) defined competition as being "utilization of common resources in short supply". Cole (1958) stated the parameters to be evaluated for detection of competition as follows:

1. Potentially competing species must use the same area;

2. They must use the same forage plants;

3. The forage plants used must be important sources of food for the species;

4. The forage plants being used must be in limited supply or deteriorating as a result of combined use.

Leonard (1979) suggested several additional conditions after there study comparing the interactions between ungulates and snowshoe hares. They asked:

1. Do hares possess the behavourial and physical adaptations to interact, in a dietary sense, with ungulates?;

2. Do the species use the same feeding space (that is, the same feed sites and plants?; and

3. The given species possesses the energetic potential to compete with its contemporaries?

Competitive exclusion is not necessarily implied by Birch's (1957) definition which does imply that competition can occur either at the same time or sequentially and for any length of time. Of course, another possible result is that both species may be reduced as the result of competitive coactions controlled by external environmental factors like snow thickness, duration of snow cover, and changes in range productivity due to climate (Trottier and Hutchison 1981).

Given the above seven pre-conditions for interspecific competition, discussion will assess data concerning moose, white-tailed deer and snowshoe hare for this study.

The first condition of the mutual use of the habitat by potentially competing animals is quite easily answered by the pellet group distribution study where pellets for all three species showed preference (to different degrees) for the mixedwood (s-h) habitat type and to a lesser extent the deciduous (both mature and immature) types. In very difficult winters this overlap of habitat use could compress the availability of browse for all three herbivores species. Although this study cannot determine the absolute extent of habitat overlap, it can suggest that it exists on Hecla Island.

For example, data obtained on hare track transects in Riding Mountain National Park (Leonard 1979) in late winter in 1978 indicated that severe snow conditions forced elk out of deciduous and open habitats. Elk activity was then restricted to coniferous cover, the preferred habitat of deer (in that study), while moose continued to move unrestricted mostly in the deciduous forest cover. A similar scenario could exist on Hecla Island if the winter was severe enough. During this study, I believe that this did not occur to any great extent, as a great deal of browse was taken from the more open willow-alder habitat, where moose would go freely to browse, unrestricted by snow depth. White-tailed deer and hare would most likely be feeding in similar areas with more cover and therefore would most likely be overlapping in resource use.

In 1979, Leonard felt that the current hare population was in the expansion phase. In 1989 (ten years later) if cycles follow, Hecla Island may have experienced similar hare population conditions based on only coincidental use of plants for food by hares and ungulates that was recorded for this study. Data suggest little interaction between the three species, except that very likely hare and deer feeding sites were occupied by both as opposed to hares sharing moose sites. This conclusion seems plausible given the documented similarity in white-tailed deer and snowshoe hare habitat preferences.

The second condition regarding sympatric species using the same forage plants has essentially been answered. This study indicates that ungulates (moose and deer) and hare share the same preferred species. Other authors (Samoil 1978; Trottier and Samoil 1978; Leonard 1979) have also shown that snowshoe hares use the same food items as ungulates with the greatest diet overlap being realized during late fall and winter when all three species feed almost exclusively on the shrub forage class (Trottier and Hutchison 1981).

The third condition considers the importance of forage plants as sources of food for the three species. Because the shrub layer is used almost exclusively by moose, deer, and hares during winter, I would conclude that preferred species of the ungulates are also preferred by snowshoe hares. Although diet studies were not done, the evidence for this statement is found in data summarized in Table 12 and thereby satisfying this condition.

The fourth condition asks if forage plants are being used in limited supply or deteriorating as a result of combined use. Data for this question was generated through the study of browse utilization by ungulates and hares at the temporary transects. Although analysis should continue to get long term trend data, this study provides short term baseline data which was needed.

Trottier and Hutchison (1981) believed that hazelnut was a key range condition indicator because of its importance in herbivore diets and relative abundance in their study area in Riding Mountain National Park. Using that same line of thinking, red-osier dogwood and willow can be considered to be good indicators on Hecla Island. Condition of these species have been observed to be severely hedged and utilization of current growth to be nearly complete. Beaked hazelnut appeared to be in good condition, but primarily in the mature deciduous habitat type.

The fifth condition asks if species use the same feeding space. The only indicator for this study comes from the pellet group distribution survey, which indicate that all the herbivores overlap in the deciduous types and the mixedwood (s-h) types. Under severe winter conditions it is expected that all three would use the same areas. Trottier and Hutchison (1981) found the use of ungulate feeding sites by hare was low. Those sites were shown to be mostly openings in the forest with poor cover for hares if snow was thick. As hare numbers increase such marginal sites may be occupied by dispersing individuals because the food supply would be attractive (Trottier and Hutchison 1981).

Several authors (Samoil 1978; and Leonard 1979) have reported that the percentage of plants browsed by hares and ungulates increased as the winter progressed, although some discrepancy was found. In this study, the percentage of plants browsed by ungulates that had been browsed by hares was only 1.2% and therefore negligible. Ungulate use was not differentiated between moose and white-tailed because it is not possible.

In terms of vertical overlap, snowshoe hares are capable of competing at the same level with ungulates depending on snow thickness and shrub stem diameter. Also, girdling of stems by hares kills the plant and constitutes an additional mode of vertical overlap. But in this study, although some girdling was observed, the observations were mostly coincidental and therefore not a true measure of the resource by hare.

The scope of this study does not allow for an accurate assessment of the energetic requirements for the members of the herbivore guild because of the difficulty in obtaining site specific data on populations and their energy requirements. Although some assumptions regarding daily consumption of moose have been made in this study, only other literature can answer the question fully. Caloric intake by deer would be slightly higher than for moose due to greater body surface/volume ratio. Hares, on the other hand, because of their high metabolic rate and propensity to periodically over-populate their range (Keith and Windberg

1978) possess the potential for seriously depleting forage resources (Leonard 1979); however, it is not known what their forage intake is and therefore what their impact on the vegetation would be under natural conditions at peak population levels. High ungulate densities, however, may affect hares in two ways. First, by depleting cover for hares (Van Camp and Telfer 1975) and secondly, by consuming most of the current growth of shrubs in intensive feeding areas.

Although most of the conditions have been met to suggest competition between herbivores within the guild, I am not totally comfortable making broad sweeping statements about theoretical implications based solely on this short term study. However, based on my data, I would conclude that some areal and vertical overlap does occur between moose, white-tailed deer and snowshoe hare.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Although only a few studies have been attempted on Hecla Island, it was felt that insufficient information existed which described browse production and utilization by moose specifically, and to a lesser extent other herbivores, namely white-tailed deer and snowshoe hare. This study concentrated on measuring those levels by collecting data to test two hypotheses

The first of those hypotheses asked if browse use was proportional to availability. Statistical procedures were used to compare total browse use to the proportional areas of the habitats found on Hecla Island. It was found that disproportional browse use was found in relation to habitat availability. Willow-alder was considered a highly preferred critical foraging habitat for moose during winter. In addition, immature coniferous, mixedwood (s-h) and immature deciduous were also preferred. These same habitats also indicate that relative levels of browse produced is relatively high.

Hecla Island appears to have no absolute shortage of browse produced on an annual basis. Of course, annual variation in production does occur but could not be addressed in this study. For winter 1988-89 moose and other herbivores were not limited by browse quantities available, as has been noted by other authors (Crichton 1977, Crichton and Wielgus 1981) in previous studies.

However, several of the highly preferred species are over-browsed. On Hecla Island, there is stem mortality directly attributable to over-browsing. Evidence of this occurred on stems of dogwood, mountain maple, willow, and to some extent, trembling aspen in various habitats. This report concurs with findings that dogwood use was complete for management purposes.

Several factors affect carrying capacity. Although not described in this study, chronic disease or parasite infestations may preempt food related density dependence. The result in the case of moose may be a reduction in mean sustainable yield (MSY) density to a lower level. Secondly, vegetation succession from open shrubland to closed forest may have lowered population levels at or near MSY for moose. It could be that moose are more affected by slaughters from hunting, winter ticks, and native harvest than vegetation succession.

Care must be taken in the interpretation of such simple estimation of the number of moose-days supported by any given habitat on Hecla Island. As a first approximation, however, the results of this report may help to provide a framework for ungulate management on Hecla Island, as well for other similar areas in Manitoba. However, it should be recognized that this document is not a management plan. Because of limitations of this study (short term) and the baseline nature of data presented, it is evident that knowledge of more than browse quantity must be taken into account. Browse quality, physical health of the animals, digestibility and palatability of plants, sex ratios, presence of predators and interspecific competition are all important in making complete assessments of habitat requirements of ungulates.

Niche differentiation and competitive (co-existence or antagonistic interaction) relationships between the three herbivores were explored. Based on data and arguments presented, it was concluded that moose, white-tailed deer, and snowshoe hare all have similar habitat preferences (mixedwoods, and deciduous types) and browse preferences (willow, dogwood, and mountain maple) during the winter months. Some feeding on similar plant species occurred between all three, although not to an excessive extent. During years in which heavier snow depths accumulate during winter months the degree of competition can be intensified among the three herbivores. If hare populations are approaching a peak level, then additional pressure on resources can be assumed. The degree of barking, girdling, and combined browse use can be noted in the field.

Certain habitat types will contribute very little to the winter maintenance of ungulates. Mature coniferous types are not favoured by ungulates and therefore habitat manipulation should not concentrate on these areas. Hydro-lines may serve as unobstructed transportation corridors for ungulates but do not otherwise appear to play a role in ungulate habitat selection during winter as they are not expected to provide minimal life requirements (i.e. cover and/or food).

Ecological theory and other practical application suggests that if a system is maintained at a particular state or condition (artificially stabilized), the systems resilience decreases through loss of diversity, heterogeneity and the processes of change that allow recovery from disturbance. Aspen parkland in a natural state is an example of a very resilient, highly dynamic system.

The system on Hecla Island exists both temporally and spatially between two very different vegetation conditions (Boreal Mixedwoods and grassland). Typically, fire, moisture regimes, beaver activities and large ungulate vegetation consumption are all forces or processes capable of creating change, increasing diversity and over a large scale increasing heterogeneity. Because of Hecla Island's relative isolation as an island, fire has not had a major influence on vegetation community succession through rejuvenation, so that other natural processes are still primarily responsible for maintenance of heterogeneity of the island vegetation communities and systems.

Theoretically, fluctuations are more extreme for populations which occur in small areas. The effects of harvests in place of predation has not been studied directly, but a comparison of Hecla Island with Isle Royale (both with a semi-enclosed moose population with a primary predator; the wolf, indicates that both populations have followed a cyclical path of similar frequency and timing. It appears that Hecla Island is experiencing similar dynamics that Isle Royale experienced prior to the re-introduction of wolves. That is, that the vegetation and large ungulate interaction is much stronger than that of the predator and prey.

Future resources managers will require a clear understanding of objectives, carrying capacity, and especially the role that ecological dynamics, diversity and heterogeneity play in system resilience, in order to allow for the equally complex cause and effect of management actions to be predicted. Ungulate management programs should not be based solely by specific population targets, but should be controlled by natural processes such as native hunters, predators, animal migration patterns, and fire if it has historically been a part of the Hecla Island system. Management should be based on yearly and long term monitoring of ungulate and vegetation dynamics.

In addition, Provincial regulatory organizations (Parks Branch; Fish and Wildlife; Tourism, etc.) must work together in a cooperative manner with traditional native users. Because native hunters utilize the living resources on Hecla Island, it is important for the following to be determined: Who uses the resources, what is the number of active hunters, and to what extent or level of harvest the population of animals biologically sustain over time.

RECOMMENDATIONS

1. Monitoring and Prediction.

Vegetation should be monitored and future changes predicted in order to assess the accomplishment of management objectives and provide management control of resource protection, enhancement and intervention actions. A recommended sampling strategy is found below.

> Sampling strategies most appropriate for estimates of annual browse production and utilization should be consistent from one year to the next. The inventory should be stratified to reduce variability of estimates for browse production and utilization within strata. Secondary sample units should be clustered at primary sample units, such as the joint-point nearest neighbour or point quarter methods, and selected randomly within the strata. Within each secondary sample unit, plots for estimates of browse production and utilization should be located systematically along transects.
>
> Annual browse production should be clipped when information is most suitable for estimates of carrying capacity, such as peak browse production or the beginning of the winter period. Utilization should be measured following seasonal browsing by ungulates or if wildlife leaves the winter range. In Hecla Islands case, range remains the same for summer, although a shift in habitat types may occur from winter to summer. Estimates of annual browse production should be based on at least three years of data, unlike this study. Utilization should be measured approximately once every five years, within plots on permanently marked transects.
>
> The above sampling regime is primarily based on experimental results. Preliminary sampling is therefore desirable to confirm relationships among twig diameters, crown canopy volume (not used in this study), and annual browse production and utilization. Preliminary sampling can also be used to determine the optimal numbers of primary and secondary sampling units, and allocation of clipped browse production plots (fixed area) or shrubs (based on joint-point nearest neighbour or point quarter methods) according to variable probability proportional to size (if fixed

area) or distance to nearest shrub (distance methods). Preliminary data may be collected simultaneously with initial stages of the shrub inventory program, and analyzed prior to the second field season of inventory so that revised sampling and measurement techniques can be incorporated.

This preliminary data can establish whether desired levels of accuracy and precision can be attained at acceptable cost. Shrub measurements vary significantly among a variety of factors, including shrub species, genetic variability within species, plant phenology, moisture content, site conditions, annual growing conditions, position of twigs on shrubs, canopy closure and response to browsing intensity. In many situations, therefore, accurate and precise estimates of browse production and utilization may be economically prohibitive.

Field personnel undertaking shrub inventories should receive a minimum of one week to minimize variability among samplers. Annual browse production and utilization estimates should be limited to shrub species considered to be important to ungulates and other herbivores for managerial expediency.

Surveys of the following nature should be conducted annually.

1. A survey of the past winter's browse use and previous years production should be conducted each spring.
2. A survey of the summer herbage production, use and winter carry-over should be conducted each fall.
3. Vegetation and ungulate fecal samples should be collected each month and analyzed to assess the quality of forage produced by the vegetation and consumed by the ungulates.

2. Vegetation Succession Monitoring and Prediction.

Vegetation succession and the resultant diversity of plants and interspersion of plant communities should be monitored by the following measures.

i. Historic aerial photography should be compared to present aerial photography to establish in a rather crude fashion the rate of vegetation succession.

ii. Air photography should be interpreted to document relative changes in vegetation physiognomy every ten (10) years.

iii. Photographs should be taken every five years at stations to be permanently located in representative examples of each biophysical vegetation unit. These stations should be situated in the same cells identified for tree stand age and air photo interpretation of vegetation succession.

iv. In concordance with the above, a new biophysical inventory should be conducted every 20 years and should be compared to previous inventories to assess change in species/vegetation occurrence and pattern.

v. Geographic Information System (GIS) technology should be utilized for vegetation resource planning that can monitor vegetation succession and land use changes.

3. The impacts of prescribed, natural and accidental fire should be monitored to document the following:

   i. vegetation succession,

   ii. non-native plant invasion and,

   iii impacts and benefits to wildlife.

4. Interpretation Needs

The public should be provided with information which presents the management of Hecla Island and how this management contrasts with areas outside the park. The key topics which should be included are as follows:

i. The character of the Boreal/Aspen Parkland Vegetation Transition zone within the park that may result from the herbivory of the native ungulate populations which may no longer exist outside the park;

ii. The differing objectives for range management at Hecla Island as compared to surrounding lands;

iii. The concepts of managing a small ecological island within a greater region of agricultural and urban development.

Recommendations to continue existing programs which include;

i. Moose ecology theatre presentations

ii. Interpretive trail enhancement

iii. Viewing towers

iv. Education programs on winter ecology of moose, white-tailed deer and snowshoe hare; predator-prey relations, moose tick biology, and wildlife management techniques of all wildlife species.

v. Future trail development should be carefully planned so as to optimize viewing opportunities, however, consideration for ungulate energy maintenance requirements should be a greater priority. That is, those habitats which are important to moose and white-tailed deer during the critical winter months, when the physiological stresses of winter combine (temperature, wind chill, and snow depths) to force ungulates into a negative energy balance should be avoided to a certain extent.

5. Research Needs

Research which has the potential to provide better interpretation, clearer management objectives, and/or advancements to science should be encouraged and supported with funding through cooperation of the Provincial regulatory bodies. Research of the following should be undertaken.

i. provide further clarification of paleobotanical history of Hecla Island area.

ii. Autecological research which may provide important information on aspects of key representative plants, rare plants, or important large ungulate food species.

iii. Synecological research which may provide a better understanding of representative and rare plant communities, which may provide information on the natural heterogeneity of the park's vegetation.

iv. Research which can significantly improve the understanding of the use and production of browse and herbage. This includes the effects of environment on productivity, better techniques of measurement, and the impacts of herbivory on plant succession.

v. Research which will advance the level of understanding of the dynamics of ungulate and herbivore guilds including resource partitioning, population regulation, and disease or parasite relationships.

vi. Further research is required to solve important resource management problems and which will provide significant improvements in active vegetation management should be considered. In particular, research which provides a better understanding of man's influence on the natural processes of change effecting vegetation should be given priority.

7.0 LITERATURE CITED

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8.0 APPENDICES

APPENDIX A Summary tables used to calculate browse production and utilization

Table 1. Relative stem density per hectare for woody species per habitat type on Hecla Island, 1988.

BROWSE SPECIES	HABITAT TYPES																			
	imm. dec.		mat. dec.		h-s		s-h		w-a		m.conif.		mat. con.		imm. con.		tr. musk.		mar. musk.	
	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)	stems per/ha	(%)
alder	4999	13.5			871	5.82	1642	4.7	829	1.79	6951	66.18	60	48.89	14276	23.59				
arrowwood	139	0.37	1418	5.2																
ash	1041	0.19			2179	14.6					182	1.73								
aspen	1455	3.93	1771	6.49	1597	10.68	3696	10.59							432	0.71				
balsam fir					872	5.83	2875	8.23			1032	9.83	30	24.44	866	1.43				
bog birch					145	0.97	411	1.18			365	3.47			17261	28.5	30477	100		
balsam poplar	694	1.87			508	3.4	411	1.18							432	0.71				
chokecherry	139	0.37	1063	3.9	436	2.91														
currant	1041	2.82							129	0.28	30	0.29								
dogwood	12680	34.2	3780	13.9	1670	11.16	4517	12.94	22646	49	789	7.51	32	26.67	9084	15				
elm					73	0.49														
gooseberry	762	2.06							388	0.84	61	0.58								
hazel	3336	9.01	12751	46.75	2542	17	4534	12.99												
high-bush cran.	486	1.31																		
Manitoba maple					1162	7.77														
mountain maple	553	1.49	827	3.03	1888	12.6	13541	38.79			152	1.45								
raspberry	3462	9.35	118	0.43			1643	4.7	4921	10.6	789	7.51			6057	10				
rose	2221	6	118	0.43	726	4.85	1232	3.52	518	1.12	61	0.58								
saskatoon			1772	6.5	218	1.46	411	1.18												
swampbirch									6862	14.8									22468	53.8
nannyberry	139	0.37	237	0.87																
willow	4853	13.1	3302	12.1	73	0.49			9972	21.6	91	0.87			12119	20.02			19297	46.2
TOTAL	38000	100	27157	100	14960	100	34913	100	46265	100	10503	100	122	100	60527	100	30477	100	41765	100
MEAN	2375		2468		997		3174		5783		955		41		7566				20882	
SD	3194		3618		807		3780		7720		2020		16.8		6666				2242	
CV	134.5		147		81		119		133		211		41.2		88.1				10.7	
N	16		11		15		11		8		11		3		8		1		2	

* Data based on "Joint-point nearest neighbour" survey (Batcheler 1971,1973)

Cont'd from Table 1.

Stem density formula:

density (stems/ha) or d = $\frac{n}{\pi[\Sigma(r1)^2 ... rn^2] + (N-n)R^2} \times 10{,}000$ Equation 1

Corrected for clumpiness:

corrected density (d) or log true density = log d - $(0.1416 - 0.1613\ \Sigma r_p \Sigma r_n)$ Equation 2

where:

d = estimated density (per unit area in the same units used to measure "r")
n = the number of sample points at which a woody plant clump as found within the distance R of the point
$r_1 ... r_n$ = distances from sample points 1...n to the nearest woody plant clumps (where one was within R distance of the point)
N = total number of sample points in the survey
R = A predetermined distance. If no plants were this close to the sample point (or to the first or second clumps selected) the survey moves to the next sample point (R = 20)
10,000 = a factor to bring values to a per hectare basis where "n" and "R" are in metres

Estimated density was then corrected for clumpiness to get better estimates of the true density as follows:

log true density = log d - $(0.1416 - 0.1613\ \Sigma r_p / \Sigma r_n)$ where:

d = estimated density from equation 1 above.
rp = distance from sample points to nearest clump (same as ri...rn values in equation 1).
rn = distance between the clump nearest the sample point and the second nearest clump.

Table 2. Number of twigs per hectare produced per habitat type on Hecla Island, Manitoba, 1988.

BROWSE SPECIES	HABITAT TYPES									
	imm.dec.	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	tr.musk.	mar.musk.
alder	73879		25706	35306	55762	11824	940	299377		
arrowwood	139	50800								
ash	275	1421	17721			759				
aspen	68853	32837	14380	44355				14262		
balsam fir			166283	273097		263258	9418	317269		
bog birch			1816	821		5938		155740	348944	
balsam poplar	13188		5521	411				864		
chokecherry	139	37912	5011							
currant	3748				55762	486				
dogwood	221361	56235	53591	55852	1177919	3248	368	133666		
elm			2252							
gooseberry	8341				5180	273				
hazel	49281	213487	72589	62030						
high-bush cran.	19714									
Manitoba maple			16776							
mountain maple	7568	11696	48507	135148		2125				
raspberry	7899	1421		9445	103322	5344		53652		
rose	11730	355	9658	3285	2330	1123				
saskatoon		38380	2250	6568						
swamp birch					273337					410038
nannyberry	139	5479								
willow	125260	6370	5376		546123	2215		43284		399692
total	611484	456393	447437	626318	1969735	294358	10726	1018114	348944	809730
mean	38219.625	38032.75	29829.133	56938	277466.88	26963	3575.3333	127264.25	348944	404865
standard deviation	58550.173	56392.969	41993.426	78341.146	381031.52	74792.733	4137.9835	116078.87		5173
C.V.*	158.22	154.87	145.7	144.31	146.81	290.9	141.75	97.5		1.807

Table 3. Mean twig diameters of current years growth (DCG) of browse species for estimation of browse production on Hecla Island, 1988.

BROWSE SPECIES	imm. dec.	mat. dec.	HABITAT TYPES h-s	s-h	w-a	m. conif.	mat. con.	imm. con.	tr. musk.	mar. musk.
alder	2.34		2.15	2.32	2.51	2.67	2.4	2.86		
arrowwood		1.54								
ash	4.3	3.13	3.98			4.05				
aspen	2.04	2.52	2.71	2.03				1.89		
balsam fir			1.28	1.66		1.45	1.13	1.46		
bog birch				2.11		2.18		2.03	1.75	
balsam poplar	3.72		3.31	4.25						
chokecherry		2.47	2.03							
currant	2.34					2.97				
dogwood	1.8	1.82	1.91	1.95	1.89	1.7	1.7	2.01		
elm			1.69							
gooseberry	2.31				2.33	2.02				
hazel	1.93	2.2	1.99	2.33						
high-bush cran.	2.81									
Manitoba maple			2.74							
mountain maple	1.6	2.21	2.4	2.29		2.75				
raspberry	1.89	1.7		1.89	1.89	1.96		1.89		
rose	2.51	1.49	2.21		2.26					
saskatoon		2.02	1.94	2.03						
swamp birch					1.6					1.83
nannyberry		2.03								
willow	2.23	2.26	2.34		1.93	2.37		3.34		1.85
total	31.82	25.39	35.17	22.86	14.41	24.12	5.23	15.48	1.75	3.68
mean	2.45	2.12	2.34	2.29	2.06	2.41	1.74	2.21		1.84
standard deviation	0.772	0.463	0.661	0.721	0.317	0.75	0.64	0.65		0.014
C.V.*	31.6	21.9	28.2	31.6	15.4	31	36.5	29.42		0.77

Table 4. Mean weight of twigs of current years growth (dcg), by habitat type for selected species, Hecla Island, Manitoba, 1988 (grams).

BROWSE SPECIES	HABITAT TYPES imm. dec.	mat. dec.	h-s	s-h	w-a	m. conif.	mat. con.	imm. con.	tr. musk.	mar. musk.
alder	0.175		0.165	0.174	0.183	0.191	0.178	0.2		
arrowwood		0.03								
ash	0.28	0.198	0.257			0.262				
aspen	0.069	0.113	0.133	0.068				0.058		
balsam fir			0.046	0.057		0.051	0.042	0.052		
bog birch			0.235	0.18		0.19		0.169	0.133	
balsam poplar	0.424		0.335	0.555				0.445		
chokecherry		0.276	0.162							
currant	0.111	0.17			0.14	0.247				
dogwood	0.086	0.088	0.096	0.099	0.094	0.078	0.078	0.105		
elm			0.041							
gooseberry	0.095				0.096	0.082				
hazel	0.089	0.124	0.096	0.143						
high-bush cran.	0.109									
Manitoba maple										
mountain maple	0.034	0.066	0.079	0.071		0.104				
raspberry	0.003	0.003		0.003	0.003	0.003		0.003		
rose	0.264	0.053	0.178	0.172	0.191			0.172		
saskatoon		0.125	0.114	0.127						
swamp birch					0.101					0.13
nannyberry		0.055								
willow	0.156	0.16	0.172		0.114	0.177		0.368		0.104
total	1.895	1.461	2.109	1.649	0.922	1.385	0.298	1.572		0.234
mean	0.146	0.112	0.151	0.15	0.115	0.26	0.01	0.175		0.117
standard deviation	0.111	0.076	0.08	0.146	0.059	0.087	0.07	0.148		0.018
C.V.*	76.4	67.9	55.1	97.2	51.4	62.7	70.9	84.5		15.71

Table 5. Values of constants for the prediction equations of 22 woody plant species, Hecla Island, Manitoba, 1988, used to estimate browse production.

BROWSE SPECIES	CONSTANTS a	b	Range of twig dia. in the sample (mm)	r2	Sample size N	n
alder	-2.30351	0.659139	1.4 - 4.8	0.396248	294	17
arrowwood	-3.78819	0.674327	1.0 - 3.0	0.304716	78	10
ash	-2.87243	1.096606	2.2 - 9.0	0.868999	100	11
aspen	-4.3104	2.301696	1.1 - 6.1	0.778246	307	20
balsam fir	-3.26062	0.781433	0.7 - 3.2	0.376046	249	14
bog birch	-2.91034	1.600809	0.8 - 4.1	0.813728	103	16
balsam poplar	-3.51873	2.025575	1.5 - 7.3	0.720329	107	24
chokecherry	-3.73863	2.710242	1.2 - 6.2	0.86157	111	15
currant	-5.03779	3.344852	1.9 - 4.1	0.722955	20	11
dogwood	-3.45815	1.720557	1.1 - 4.0	0.638928	271	13
elm	-4.53221	2.564995	1.0 - 2.6	0.920973	43	8
gooseberry	-3.30169	1.135787	1.2 - 4.3	0.482045	71	15
hazel	-4.09552	2.543722	1.1 - 4.0	0.92676	240	16
high-bush cranberry	-4.71113	2.410661	2.2 - 4.3	0.729844	19	7
Manitoba maple	-	-	-	-	-	-
mountain maple	-4.34392	2.058146	1.5 - 5.3	0.724807	166	13
raspberry	-	-	-	-	-	-
rose	-4.18036	3.096906	0.8 - 4.8	0.941614	123	17
saskatoon	-3.6856	2.286607	1.0 - 3.9	0.941376	125	15
swampbirch	-3.18847	1.908065	0.9 - 3.5	0.887861	143	14
nannyberry	-3.35757	0.653598	1.4 - 2.7	0.512835	65	7
willow	-3.56978	2.130937	1.0 - 5.5	0.934884	311	21

Prediction equation is of the form:

LN oven dry wt. = a + b(LN fresh twig dia.)

Table 6. Available twig yield per habitat type on Hecla Island, 1988-1989.

BROWSE SPECIES	HABITAT TYPES									
	imm. dec.	mat. dec.	h-s	s-h	w-a	m. conif.	mat. con.	imm. con.	tr. musk.	mar. musk.
alder	12.929		4.241	6.143	10.204	2.258	0.167	59.875		
arrowwood	0.004	1.524								
ash	0.077	0.281	4.554			0.199				
aspen	4.75	3.71	1.912	3.016				0.827		
balsam fir			7.649	15.566		13.426	0.396	16.498		
bog birch			0.427	0.148		1.128		26.32	46.41	
balsam poplar	5.592		1.85	0.228				0.384		
chokecherry	0.03	10.464	0.812							
currant	0.416				7.807	0.12				
dogwood	19.037	4.949	5.145	5.529	110.72	0.253	0.029	14.035		
elm			0.092							
gooseberry	0.792				0.497	0.022				
hazel	4.386	26.472	6.968	8.87						
high-bush cran.	2.148									
Manitoba maple										
mountain maple	0.257	0.772	3.832	9.596		0.221				
raspberry	0.024	0.004		0.028	0.31	0.016		0.161		
rose	3.097	0.019	1.719	0.565	0.445	0.193				
saskatoon		4.798	0.256	0.834	0.0515					
swamp birch					27.607					53.305
nannyberry	0.008	0.301								
willow	19.54	1.019	0.925		62.258	0.346		15.928		41.568
total	73.087	54.313	40.382	50.523	219.85	18.182	0.592	134.028	46.41	94.873
mean	4.568	4.526	2.884	4.593	27.482	1.653	0.197	16.754		47.436
standard deviation	6.662	7.567	2.516	5.094	39.68	3.96	0.185	19.842		8.299
C.V.*	145.8	167.2	87.21	110.91	144.4	239.6	93.9	118.4		17.5

Coefficient of Variation (C.V) = Standard deviation x 100/mean

Table 7. Number of twigs per hectare utilized per habitat type, Hecla Island, Manitoba, 1988-1989.

BROWSE SPECIES	HABITAT TYPES imm. dec.	mat. dec.	h-s	s-h	w-a	m. conif.	mat. con.	imm. con.	tr. musk.	mar. musk.
alder	2548		290	821	54790	304	122	2596		
arrowwood										
ash			8206			91				
aspen	263	4016	3994	9035						
balsam fir			11547	10677	91		70			
bog birch						346		64892	72261	
balsam poplar	278		1598							
chokecherry		12401	291							
currant	1111									
dogwood	198098	47965	49089	40247	527762	1062	222	98195		
elm			1744							
gooseberry	346				2460					
hazel	200	27153	5011	28337						
high-bush cran.	7358									
Manitoba maple			10385							
mountain maple	6501	5553	37616	89942		395				
raspberry				1643		30				
rose	4576	355	2469	821	1165					
saskatoon		6377		2874						
swamp birch					139579					
nannyberry										
willow	9707	1651	2688		315733	668		29000		28372
total	230986	105471	134928	184397	1041580	2896	414	194683	72261	28372
mean	20998.73	13183.875	10379.08	20488.56	148797.1	413.714	138	48670.75	72261	28372
standard deviation	56094.08	15377.244	14657.45	27773.45	187360.5	328.044	63.077	36144.16		
C.V.*	280.17	124.69	146.99	143.78	136	85.64	55.9	85.75		

Table 8. Mean twig diameters at point of browse (DPB) for browse species used for estimation of browse utilization, Hecla Island, 1988-1989.

BROWSE SPECIES	imm. dec.	mat. dec.	h-s	s-h	w-a	m. conif.	mat. con.	imm. con.	tr. musk.	mar. musk.
	HABITAT TYPES									
alder	4.1	3.7		1.3	2.7		1.6			
arrowwood										
ash	3.6	2.4		3.1		3.6				
aspen	2.8	2.6	3.3	2.7		6.2				
balsam fir	4.2	2.1	1.7	2.4		1.2	2.9			
bog birch									1.8	
balsam poplar	2.9	3	3.3	3.8						
chokecherry	6.8	1.6								
currant	1.7									
dogwood	2.3	2.4	2.5	2.6	2.4	3.5			1.7	
elm										
gooseberry	2.1	2	1.9							
hazel	1.8	1.7	1.7		1.6					
high-bush cran.	2									
Manitoba maple										
mountain maple	2.7	2.4	2.7	3		2.6		2		
raspberry	1.5				1.7					
rose	1.4	0.5		1.5						
saskatoon	1.7	1.8								
swamp birch							1.8			1.4
nannyberry										
willow	2.4	3.5		2.1	2.3		2.7	2.9	2.4	2
total	44	29.7	17.1	25.2	10.7	17.1	9	4.9	5.9	3.4
mean	2.8	2.3	2.4	2.5	2.1	3.4	2.2	2.4	2	1.7
standard deviation	1.4	0.84	0.7	0.74	0.47	1.8	0.64	0.64	0.38	0.42
C.V.	50	36.8	28.6	29.4	22.1	53.4	28.7	28.7	2	25

Table 9. Values of constants for the prediction equations of 22 woody plant species, Hecla Island, 1988-1989, used to estimate browse use.

BROWSE SPECIES	CONSTANTS a	b	Range of twig dia. in the sample (mm)	r2	Sample size N	n
alder	-3.02464	1.699529	1.4 - 4.8	0.777088	300	14
arrowwood	-3.64605	0.824997	1.2 - 2.6	0.361007	78	8
ash	-2.8312	1.114695	2.0 - 7.7	0.828099	100	9
aspen	-4.01238	2.339891	1.0 - 4.9	0.819714	307	19
balsam fir	-3.39232	1.36879	0.7 - 2.8	0.643327	249	11
bog birch	-2.77410	1.522712	0.6 - 3.4	0.771748	103	15
balsam poplar	-3.20547	1.87645	1.4 - 7.1	0.68102	107	23
chokecherry	-3.79789	2.762217	1.0 - 5.1	0.871336	111	15
currant	-5.05854	3.932738	1.6 - 3.4	0.746637	20	9
dogwood	-3.11266	1.541712	0.8 - 3.4	0.642496	205	14
elm	-4.52837	2.767683	1.1 - 2.2	0.931313	48	7
gooseberry	-3.36409	1.385321	1.2 - 4.1	0.540376	71	12
hazel	-3.92971	2.558973	1.1 - 4.0	0.919412	240	15
high-bush cranberry	-4.59279	2.766036	1.9 - 3.3	0.661588	19	6
Manitoba maple	-	-	-	-	-	-
mountain maple	-3.94243	1.870358	1.1 - 4.2	0.733389	166	13
raspberry	-	-	-	-	-	-
rose	-4.15645	3.417022	0.8 - 4.4	0.965067	123	15
saskatoon	-3.44289	2.413989	1.1 - 3.3	0.957361	125	12
swampbirch	-2.84774	1.684698	0.8 - 3.4	0.919188	143	12
nannyberry	-2.97676	0.027631	1.3 - 2.6	0.001842	65	6
willow	-3.94243	2.234353	0.9 - 5.5	0.934101	311	20

Prediction equation is of the form:

LN Oven dry twig wt. = a + b(LN air dry twig dia.)

Table 10. Mean weight of twigs at point of browse for browse species for estimation of browse utilization, Hecla Island, 1988-1989.

	HABITAT TYPES									
BROWSE SPECIES	imm. dec.	mat. dec.	h-s	s-h	w-a	m. conif.	mat. con.	imm. con.	tr. musk.	mar. musk.
alder	0.534	0.449	0.33	0.076	0.263		0.108			
arrowwood										
ash	0.246	0.156	0.214	0.208		0.246				
aspen	0.201	0.169	0.296	0.185		1.29				
balsam fir	0.24	0.093	0.07	0.111		0.043	0.144			
bog birch				0.283					0.153	
balsam poplar	0.299	0.318	0.381	0.496						
chokecherry	4.47	0.082								
currant	0.051									
dogwood	0.161	0.172	0.183	0.194	0.172	0.307			0.101	0.101
elm			0.017							
gooseberry	0.097	0.091	0.084							
hazel	0.088	0.076	0.076		0.065					
high-bush cran.	0.069									
Manitoba maple										
mountain maple	0.124	0.1	0.124	0.151		0.116		0.071		
raspberry	0.013				0.023					
rose	0.049	0.001		0.063						
saskatoon	0.115	0.132								
swamp birch							0.156			0.102
nannyberry										
willow	0.137	0.319		0.102	0.125		0.178	0.209	0.137	0.091
total	6.894	2.158	1.775	1.869	0.648	2	0.586	0.28	0.391	0.294
mean	0.43	0.17	0.18	0.19	0.13	0.4	0.15	0.14	0.13	0.098
standard deviation	1.08	0.124	0.124	0.128	0.094	0.51	0.029	0.097	0.03	0.006
C.V.	251.2	74.9	70.1	68.4	72.3	127	20	69.7	20.4	6.2

Table 11. Twig biomass utilized per habitat type on Hecla Island, Manitoba, 1988-1989. (Kg/Ha)

BROWSE SPECIES	HABITAT TYPES imm. dec.	mat. dec.	h-s	s-h	w-a	m. conif.	mat. con.	imm. con.	tr. musk.	mar. musk.
alder	1.361		0.096	0.062	14.41	0.1	0.013	0.637		
arrowwood										
ash			1.756			0.091				
aspen	0.052	0.679	1.182	1.671						
balsam fir			0.808	1.185			0.01			
bog birch						0.098		14.146	11.056	
balsam poplar	0.083		0.609							
chokecherry		1.017								
currant	0.057									
dogwood	31.894	8.25	8.983	7.808	90.775	0.326	0.044	18.477		
elm			0.03							
gooseberry	0.034									
hazel	0.018	2.064	0.381	2.161						
high-bush cran.	0.508									
Manitoba maple			1.277							
mountain maple	0.806	0.555	4.664	13.581		0.046				
raspberry				0.03		0.006				
rose	0.224	0.355	0.004	0.052	0.044					
saskatoon		0.842		0.355						
swamp birch					18.006					
nannyberry										
willow	1.33	0.527	0.459		39.467	0.114		6.061		2.582
total	36.367	14.289	20.249	26.905	162.7	0.781	0.067	39.321	11.056	2.582
mean	3.306	1.786	1.687	2.989	32.5	0.111	0.022	9.83		
standard deviation	9.495	2.665	2.625	4.663	35.5	0.102	0.018	8		
C.V.*	287.2	149.2	155.5	156	109	91.2	84.3	81.4		

Table 12. Browse Use for Pure Deciduous (Immature) on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%)					
		0-20	21-40	41-60	61-80	81-100	100+
dogwood	161	23	17	8	17	50	46
willow	73	56	4	7	5	1	0
trembling aspen	45	18	12	8	1	3	3
alder	44	41	2	0	1	0	0
raspberry	38	36	2	0	0	0	0
ash	28	28	0	0	0	0	0
hazel	22	7	6	2	3	4	0
balsam poplar	21	12	7	1	0	0	1
rose	19	12	5	0	1	0	1
gooseberry	13	12	0	0	0	1	0
white birch	11	7	1	1	0	1	1
balsam fir	7	2	0	1	2	0	2
mountain maple	7	0	2	0	1	1	3
buffaloberry	4	4	0	0	0	0	0
saskatoon	4	2	0	2	0	0	0
chokecherry	3	2	1	0	0	0	0
high-bush cranberry	3	3	0	0	0	0	0
swamp birch	2	2	0	0	0	0	0
larch	1	1	0	0	0	0	0
TOTAL	506	268	59	30	31	61	57

Table 13. Browse Use Summary for Pure Deciduous (Mature) on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%)					
		0-20	21-40	41-60	61-80	81-100	100+
dogwood	58	10	6	2	7	12	21
trembling aspen	40	17	10	3	4	2	4
hazel	37	13	9	5	10	0	0
willow	30	25	2	0	0	0	3
ash	22	21	1	0	0	0	0
mountain maple	21	4	2	1	1	7	6
rose	14	12	1	1	0	0	0
chokecherry	10	3	2	2	2	1	0
balsam poplar	6	4	1	0	0	1	0
balsam fir	5	3	0	1	0	1	0
alder	4	3	0	0	0	0	1
saskatoon	4	1	0	0	1	2	0
raspberry	3	3	0	0	0	0	0
white birch	3	1	1	0	0	0	1
buffaloberry	2	2	0	0	0	0	0
gooseberry	2	1	0	1	0	0	0
TOTAL	261	123	35	16	25	26	36

Table 14. Browse Use Summary for Mixedwoods (H-S) on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%)					
		0-20	21-40	41-60	61-80	81-100	100+
mountain maple	163	96	17	14	5	15	16
trembling aspen	52	33	5	6	1	2	5
balsam fir	43	38	1	3	1	0	0
ash	37	37	0	0	0	0	0
balsam poplar	36	23	3	2	2	0	6
dogwood	31	13	7	5	2	0	4
hazel	14	12	2	0	0	0	0
alder	8	8	0	0	0	0	0
raspberry	7	7	0	0	0	0	0
white birch	7	5	0	1	0	0	1
gooseberry	5	3	1	0	1	0	0
rose	4	4	0	0	0	0	0
willow	3	2	0	0	0	0	1
chokecherry	1	0	1	0	0	0	0
saskatoon	1	1	0	0	0	0	0
Manitoba maple	1	0	1	0	0	0	0
No Browse species (nbs)	2						
TOTAL	415	282	38	31	12	17	33

Table 15. Browse Use Summary for Mixedwoods (S-H) on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%)					
		0-20	21-40	41-60	61-80	81-100	100+
mountain maple	127	47	14	13	12	20	21
balsam fir	112	104	6	2	0	0	0
trembling aspen	57	33	7	6	2	3	6
alder	45	44	0	0	0	1	0
dogwood	41	11	6	6	2	6	10
white birch	30	16	4	6	2	2	0
raspberry	21	20	1	0	0	0	0
ash	17	14	2	0	0	0	1
balsam poplar	15	9	1	0	1	1	3
bog birch	14	6	2	1	2	3	0
rose	10	7	1	2	0	0	0
willow	7	2	0	0	1	3	1
hazel	4	4	0	0	0	0	0
larch	1	1	0	0	0	0	0
high-bush cranberry	1	1	0	0	0	0	0
No Browse species (nbs)	2						
TOTAL	504	319	44	36	22	39	42

Table 16. Browse Use Summary for Habitat #5, willow/alder on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%)					
		0-20	21-40	41-60	61-80	81-100	100+
willow	76	58	12	5	1	0	0
dogwood	57	17	8	6	7	11	8
alder	21	20	1	0	0	0	0
raspberry	18	16	1	0	1	0	0
swampbirch	7	7	0	0	0	0	0
gooseberry	1	0	1	0	0	0	0
bog birch	1	1	0	0	0	0	0
TOTAL	181	119	23	11	9	11	8

Table 17. Browse Use Summary for Pure Mixed Coniferous on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%)					
		0-20	21-40	41-60	61-80	81-100	100+
mountain maple	31	13	5	3	2	3	5
alder	30	30	0	0	0	0	0
dogwood	26	8	6	3	3	2	4
ash	11	11	0	0	0	0	0
raspberry	10	10	0	0	0	0	0
swampbirch	10	10	0	0	0	0	0
white birch	7	6	0	1	0	0	0
balsam fir	4	3	0	1	0	0	0
trembling aspen	3	1	0	0	0	1	1
willow	3	2	1	0	0	0	0
hazel	1	1	0	0	0	0	0
rose	1	1	0	0	0	0	0
balsam poplar	1	0	1	0	0	0	0
TOTAL	138	96	13	8	5	6	10

Table 18 Browse Use Summary for Pure Coniferous (Mature) on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%)					
		0-20	21-40	41-60	61-80	81-100	100+
alder	86	86	0	0	0	0	0
white birch	33	10	7	4	3	7	2
balsam fir	31	26	1	2	0	1	1
larch	23	23	0	0	0	0	0
willow	22	3	0	0	4	9	6
bog birch	4	1	0	0	2	1	0
swampbirch	3	1	0	1	0	1	0
mountain maple	1	1	0	0	0	0	0
raspberry	1	1	0	0	0	0	0
no browse species (nbs)	158						
TOTAL	362	152	8	7	9	19	9

Table 19. Browse Use Summary for Pure Coniferous (Immature) on Hecla Island, 1988-1989.

Browse Species	Count per species	Degree of Browse Use (%) 0-20	21-40	41-60	61-80	81-100	100+
alder	62	62	0	0	0	0	0
balsam fir	48	45	2	0	0	1	0
dogwood	33	7	5	1	1	1	18
white birch	23	5	2	3	3	6	4
larch	19	15	2	1	0	1	0
willow	16	8	1	0	0	3	4
mountain maple	15	1	0	1	2	3	8
raspberry	7	6	0	0	1	0	0
swampbirch	2	2	0	0	0	0	0
ash	1	1	0	0	0	0	0
trembling aspen	1	0	0	0	0	0	1
no browse species (nbs)	49						
TOTAL	276	152	12	6	7	15	35

Table 20. Browse Use Summary for Treed muskeg on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%) 0-20	21-40	41-60	61-80	81-100	100+
larch	45	45	0	0	0	0	0
alder	43	43	0	0	0	0	0
willow	30	5	2	11	1	6	5
bog birch	7	7	0	0	0	0	0
swampbirch	4	4	0	0	0	0	0
balsam fir	3	2	1	0	0	0	0
dogwood	2	1	0	0	0	0	1
gooseberry	1	1	0	0	0	0	0
white birch	1	1	0	0	0	0	0
no browse species (nbs)	100						
TOTAL	236	109	3	11	1	6	6

Table 21. Browse Use Summary for Unclassified, RIGHTS OF WAY on Hecla Island, 1988-1989.

Browse Species	Count per Species	Degree of Browse Use (%) 0-20	21-40	41-60	61-80	81-100	100+
raspberry	28	28	0	0	0	0	0
willow	24	16	4	2	2	0	0
balsam poplar	14	13	1	0	0	0	0
trembling aspen	10	8	0	1	0	0	1
dogwood	6	3	1	0	1	0	1
mountain maple	5	4	0	0	0	0	1
white birch	5	3	1	0	0	1	0
hazel	2	1	1	0	0	0	0
alder	2	2	0	0	0	0	0
rose	2	2	0	0	0	0	0
gooseberry	1	1	0	0	0	0	0
ash	1	1	0	0	0	0	0
balsam fir	1	1	0	0	0	0	0
Sub-Total	101						
no browse species (nbs)	8						
SUB-TOTAL	109	83	8	3	3	1	3

SAMPLE BREAKDOWN		
	Highway or road	39
	water or borrow pit	122
	hydro-line	27
	trail	5
	old gravel pit	24
	TOTAL	217

Table 22. **Browse Use Summary for Marsh/Muskeg on Hecla Island, 1988-1989.**

Browse Species	Count per Species	Degree of Browse Use (%) 0-20	21-40	41-60	61-80	81-100	100+
willow	261	173	38	26	7	10	7
swamp birch	129	97	13	12	3	3	1
alder	28	27	0	1	0	0	0
dogwood	10	5	3	0	1	1	0
white birch	2	1	1	0	0	0	0
raspberry	1	0	1	0	0	0	0
balsam poplar	1	1	0	0	0	0	0
no browse species (nbs)	14						
TOTAL	446	304	56	39	11	14	8

Table 23. Pellet group distribution of moose, white-tailed deer, and snowshoe hare across all habitat types on Hecla Island.

Habitat type	moose	white-tailed deer plots	snowshoe hare	sub-total	total pellet group
imm.dec.	12	20	38	70	99
mat.dec.	9	14	17	40	51
h-s	10	7	35	52	83
s-h	23	17	18	58	98
w-a	2	0	0	2	38
m.conif.	10	4	2	16	29
mat.con.	2	6	7	15	71
imm.con.	13	13	11	37	56
tr.musk	2	3	5	10	45.
unclass.	2	0	0	2	35
mar.musk	17	3	1	21	86.
Total	102	87	323	323	691

APPENDIX B Statistical information and summary tables

Table 1. Chi Square statistics for pellet groups survey.

Habitat Type	% area	Frequencies: observed (expected) moose	w.t. deer	hare	sub total	number pellet group plots
imm.dec.	10.9	12 (11.1)	20 (9.5)	38 (14.6)	70	99
mat.dec.	9.3	9 (9.5)	14 (8.1)	17 (12.5)	40	51
h-s	10.2	10 (10.4)	7 (8.9)	35 (13.7)	52	83
s-h	6.3	23 (6.4)	17 (5.5)	18 (8.4)	58	98
w-a	2.75	2 (2.8)	0 (2.4)	0 (3.7)	2	38
m.conif.	5.1	10 (5.2)	4 (4.4)	2 (6.8)	16	29
mat.con.	9.7	2 (9.9)	6 (8.4)	7 (13.0)	15	71
imm.con.	11.8	13 (12.0)	13 (10.3)	11 (15.8)	37	56
tr.musk.	11.5	2 (11.7)	3 (10.0)	5 (15.4)	10	45
Unclass.	4.3	2 (4.4)	0 (3.7)	0 (5.8)	2	35
mar.musk.	15	17 (15.3)	3 (13.0)	1 (20.1)	21	86
sub-total		102	87	134		Total 691
Chi square Statistic		63.757	60.476	125.5		
DF		10	10	10		
alpha		0.05	0.05	0.05		
Table value		18.307	18.307	18.307		

Table 2. T-statistics and significance values found in comparing the stem densities of woody species in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	mar.musk.
imm.dec.	t = -0.071 sign. = 0.944	t = 1.621 sign. = 0.116	t = -0.593 sign. = 0.559	t = -1.546 sign. = 0.136	t = 1.302 sign. = 0.205	t = 1.236 sign. = 0.233	**t = -2.610 sign. = 0.016**	**t = -7.850 sign = 0.000**
mat.dec.		t = 1.535 sign. = 0.138	t = -0.447 sign. = 0.660	t = -1.256 sign. = 0.226	t = 1.212 sign. = 0.240	t = 1.129 sign. = 0.281	**t = -2.151 sign. = 0.046**	**t = -6.814 sign. = 0.000**
h-s			**t = -2.179 sign. = 0.039**	**t = -2.426 sign. = 0.024**	t = 0.074 sign. = 0.941	t = 2.004 sign. = 0.062	**t = -3.843 sign. = 0.001**	**t = -27.203 sign. = 0.000**
s-h				t = -0.978 sign. =0.342	t = 1.717 sign. = 0.101	t = 1.394 0.189	t = -1.829 sign. = 0.085	**t = -6.283 sign. = 0.000**
w-a					t = 2.002 sign. = 0.061	t = 1.246 sign. = 0.244	t = -0.494 sign. = 0.629	**t = -2.629 sign. = 0.030**
m.conif.						t = 0.761 sign. = 0.461	**t = -3.128 sign. = 0.006**	**t = -12.700 sign. = 0.000**
mat.con.							t = -1.891 sign. = 0.091	**t = -17.635 sign. = 0.000**
imm.con.								**t = 2.680 sign. = 0.028**

NOTE: Values in bold indicate significant differences between habitat types.

Table 3. T-statistics and significance values found in comparing the number of twigs of woody species in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	mar.musk.
imm.dec.	t = 0.008 sign. = 0.944	t = 0.441 sign. = 0.663	t = -0.683 sign. = 0.501	**t = -2.350** **sign. = 0.028**	t = 0.421 sign. = 0.677	t = 0.969 sign. = 0.346	**t = -2.392** **sign. = 0.026**	**t = -8.345** **sign = 0.000**
mat.dec.		t = 0.417 sign. = 0.680	t = 0.638 sign. = 0.530	t = -2.032 sign. = 0..057	t = 0.385 sign. = 0.704	t = 0.985 sign. = 0.343	**t = -2.171** **sign. = 0.044**	**t = -8.511** **sign. = 0.000**
h-s			t = -1.091 sign. = 0.286	**t = -2.378** **sign. = 0.027**	t = 0.119 sign. = 0.906	t = 1.020 sign. = 0.323	**t = -2.784** **sign. = 0.011**	**t = -11.852** **sign. = 0.000**
s-h				t = -1.765 sign. =0.095	t = 0.875 sign. = 0.392	t = 1.092 0.296	t = -1.490 sign. = 0.154	**t = -5.775** **sign. = 0.000**
w-a					t = 2.010 sign. = 0.061	t = 1.1.126 sign. = 0.289	t = 0.998 sign. = 0.335	t = -0.423 sign. = 0.683
m.conif.						t = 0.501 sign. = 0.625	**t = -2.163** **sign. = 0.045**	**t = -6.570** **sign. = 0.000**
mat.con.							t = -1.669 sign. = 0.129	**t = -74.344** **sign. = 0.000**
imm.con.								**t = -3.024** **sign. = 0.016**

NOTE: Values in bold indicate significant differences between habitat types.

Table 4. T-statistics and significance values found in comparing mean twig diameters of current years growth of browse species in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	mar.musk.
imm.dec.	t = 1.289 sign. = 0.210	t = 0.404 sign. = 0.689	t = 0.512 sign. = 0.614	t = 1.264 sign. = 0.222	t = 0.111 sign. = 0.912	t = 1.458 sign. = 0.167	t = 0.687 sign. = 0.501	t = 1.078 sign = 0.301
mat.dec.		t = -0.936 sign. = 0.356	t = -0.670 sign. = 0.511	t = 0.289 sign. = 0.776	t = -1.139 sign. = 0.268	t = 1.170 sign. = 0.263	t = -0.375 sign. = 0.713	t = 0.815 sign. = 0.431
h-s			t = 0.167 sign. = 0.869	t = 1.003 sign. = 0.328	t =-0.264 sign. = 0.794	t = 1.369 sign. = 0.191	t = 0.394 sign. = 0.698	t = 0.991 sign. = 0.338
s-h				t = 0.777 sign. =0.449	t =-0.384 sign. = 0.706	t = 1.167 sign. = 0.268	t = 0.218 sign. = 0.830	t = 0.841 sign. = 0.420
w-a					t = -1.171 sign. = 0.260	t = 1.088 sign. = 0.308	t = -0.559 sign. = 0.586	t = 0.930 sign. = 0.383
m.conif.						t = 1.395 sign. = 0.190	t = 0.573 sign. = 0.575	t = 1.042 sign. = 0.322
mat.con.							t = -1.049 sign. = 0.325	t =-0.204 sign. = 0.852
imm.con.								t = 0.769 sign. = 0.467

NOTE: Values in bold indicate significant differences between habitat types.

Table 5. T-statistics and significance values found in comparing mean weight of twigs of current years growth (dcg) in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	mar.musk.
imm.dec.	t = 0.871 sign. = 0.393	t = -.126 sign. = 0.900	t = -0.078 sign. = 0.939	t =0.687 sign. = 0.500	t = 0.165 sign. = 0.870	t = 0.656 sign. = 0.522	t = -0.515 sign. = 0.612	t = 0.340 sign = 0.739
mat.dec.		t = -1.250 sign. = 0.223	t = -0.811 sign. = 0.426	t = -0.091 sign. = 0.928	t = 0.771 sign. = 0.449	t = 0.273 sign. = 0.789	t = 1.305 sign. = 0.207	t = -0.084 sign. = 0.935
h-s			t = 0.016 sign. = 0.987	t = 1.057 sign. = 0.303	t = 0.346 sign. = 0.732	t = 0.990 sign. = 0.338	t = -0.502 sign. = 0.621	t = 0.555 sign. = 0.588
s-h				t = 0.623 sign. =0.536	t = 0.215 sign. = 0.832	t = 0.570 0.579	t = -0.376 sign. = 0.711	t = 0.308 sign. = 0.764
w-a					t = -0.644 sign. = 0.528	t = 0.380 sign. = 0.713	t = -1.062 sign. = 0.305	t = -0.040 sign. = 0.969
m.conif.						t = 0.707 sign. = 0.494	t = -0.600 sign. = 0.518	t = 0.336 sign. = 0.744
mat.con.							t = -0.833 sign. = 0.424	t = -0.331 sign. = 0.763
imm.con.								t = 0.530 sign. = 0.609

NOTE: Values in bold indicate significant differences between habitat types.

Table 6. T-statistics and significance values found in comparing available twig yield (kg/ha) per habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	mar.musk.
imm.dec.	t = 0.016 sign. = 0.988	t = 0.890 sign. = 0.381	t = -0.011 sign. = 0.992	t = -2.057 sign. = 0.051	t = 1.297 sign. = 0.206	t = 1.110 sign. = 0.282	**t = -2.256** **sign. = 0.034**	**t = -8.436** **sign = 0.000**
mat.dec.		t = 0.766 sign. = 0.451	t = -0.025 sign. = 0.981	t = -1.773 sign. = 0.092	t = 1.125 sign. = 0.273	t = 0.963 sign. = 0.353	t = -1.953 sign. = 0.067	**t = -7.363** **sign. = 0.000**
h-s			t = -1.100 sign. = 0.283	**t = -2.130** **sign. = 0.045**	t = 0.948 sign. = 0.353	t = 1.803 sign. = 0.092	**t = -2.627** **sign. = 0.016**	**t = -17.937** **sign. = 0.000**
s-h				t = -1.713 sign. =0.104	t = 1.511 sign. = 0.146	t = 1.451 sign. = 0.172	t = -1.965 sign. = 0.066	**t = -10.201** **sign. = 0.000**
w-a					t = 1.976 sign. = 0.064	t = 1.063 sign. = 0.313	t = 0.509 sign. = 0.618	t = -0.814 sign. = 0.437
m.conif.						t = 0.618 sign. = 0.548	**t = -2.483** **sign. = 0.024**	**t = -13.146** **sign. = 0.000**
mat.con.							t = -1.397 sign. = 0.196	**t = -10.794** **sign. = 0.002**
imm.con.								t = -2.065 sign. = 0.073

NOTE: Values in bold indicate significant differences between habitat types.

Table 7. T-statistics and significance values found in comparing number of twigs utilized in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.
imm.dec.	t = 0.363 sign. = 0.721	t = 0.398 sign. = 0.695	t = 0.154 sign. = 0.879	t = -1.997 sign. = 0.063	t = 0.915 sign. = 0.374	t = 0.596 sign. = 0.562	t = -0.856 sign. = 0.407
mat.dec.		t = 0.398 sign. = 0.695	t = -0.375 sign. = 0.713	t = -1.899 sign. = 0.080	t = 2.045 sign. = 0.062	t = 1.329 sign. = 0.217	t = -2.172 sign. = 0.055
h-s			t =-0.754 sign. = 0.460	**t = -2.513** **sign. = 0.022**	t = 1.706 sign. = 0.105	t = 1.132 sign. = 0.277	**t = -2.897** **sign. = 0.011**
s-h				t = -1.936 sign. =0.073	t = 1.517 sign. = 0.152	t = 0.985 sign. = 0.348	t = -1.541 sign. = 0.152
w-a					t = 1.940 sign. = 0.076	t = 1.229 sign. = 0.254	t = 0.937 sign. = 0.364
m.conif.						t = 1.292 sign. = 0.232	**t = -3.195** **sign. = 0.011**
mat.con.							t = -1.966 sign. = 0.107
imm.con.							

NOTE: Values in bold indicate significant differences between habitat types.

Table 8. T-statistics and significance values found in comparing the twig diameters at point of browse in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	tr.musk.	mar.musk.
imm.dec.	t = 1.060 sign. = 0.299	t = 0.551 sign. = 0.588	t =0.495 sign. = 0.626	t = 0.951 sign. = 0.353	t = -0.877 sign. = 0.391	t = 0.691 sign. = 0.498	t = 0.296 sign. = 0.771	t = 0.951 sign. = 0.355	t = 1.039 sign = 0.314
mat.dec.		t = -0.424 sign. = 0.677	t = -0.606 sign. = 0.551	t = 0.359 sign. = 0.724	t = -1.846 sign. = 0.083	t = 0.075 sign. = 0.941	t = -0.263 sign. = 0.796	t = 0.627 sign. = 0.540	t = 0.943 sign. = 0.363
h-s			t = -0.151 sign. = 0.882	t = 0.836 sign. = 0.423	t = -1.307 sign. = 0.221	t = 0.451 sign. = 0.663	t = -0.013 sign. = 0.990	t = 1.087 sign. = 0.309	t = 1.388 sign. = 0.208
s-h				t = 0.924 sign. =0.374	t = -1.335 sign. = 0.207	t = 0.554 sign. = 0.591	t = 0.083 sign. = 0.936	t = 1.104 sign. = 0.295	t = 1.354 sign. = 0.209
w-a					t = -1.516 sign. = 0.168	t = -0.296 sign. = 0.776	t = -0.727 sign. = 0.500	t = 0.536 sign. = 0.612	t = 1.136 sign. = 0.308
m.conif.						t = 1.207 sign. = 0.267	t = 0.699 sign. = 0.516	t = 1.319 sign. = 0.235	t = 1.249 sign. = 0.267
mat.con.							t = -0.359 sign. = 0.738	t = 0.669 sign. = 0.533	t = 1.062 sign. = 0.348
imm.con.								t = 1.103 sign. = 0.351	t = 1.387 sign. = 0.300

NOTE: Values in bold indicate significant differences between habitat types.

Table 9. T-statistics and significance values found in comparing mean weight of twigs at dpb in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.	tr.musk.	mar.musk.
imm.dec.	t = 0.873 sign. = 0.390	t = 0.730 sign. = 0.472	t = 0.703 sign. = 0.489	t = 0.610 sign. = 0.549	t = 0.060 sign. = 0.953	t = 0.514 sign. = 0.614	t = 0.369 sign. = 0.717	t = 0.469 sign = 0.645	t = 0.519 sign = 0.610
mat.dec.		t = -0.220 sign. = 0.828	t = -0.395 sign. = 0.697	t = 0.610 sign. = 0.549	t = -1.614 sign. = 0.126	t = 0.305 sign. = 0.765	t = 0.279 sign. = 0.784	t = 0.482 sign. = 0.637	t = 0.922 sign. = 0.372
h-s			t = -0.167 sign. = 0.870	t = 0.755 sign. = 0.464	t = -1.355 sign. = 0.198	t = 0.482 sign. = 0.639	t = 0.397 sign. = 0.700	t = 0.634 sign. = 0.539	t = 1.073 sign. = 0.306
s-h				t = 0.883 sign. = 0.393	t = -1.294 sign. = 0.218	t = 0.611 sign. = 0.552	t = 0.484 sign. = 0.639	t = 0.739 sign. = 0.475	t = 1.167 sign. = 0.268
w-a					t = -1.172 sign. = 0.275	t = -0.343 sign. = 0.742	t = -0.132 sign. = 0.901	t = -0.013 sign. = 0.990	t = 0.565 sign. = 0.593
m.conif.						t = 0.984 sign. = 0.358	t = 0.682 sign. = 0.526	t = 0.891 sign. = 0.407	t = 0.998 sign. = 0.357
mat.con.							t = 0.137 sign. = 0.898	t = 0.749 sign. = 0.487	**t = 2.761** **sign. = 0.040**
imm.con.								t = 0.175 sign. = 0.872	t = 0.813 sign. = 0.475
tr.musk.									t = 2.050 sign. = 0.110

NOTE: Values in bold indicate significant differences between habitat types.

Table 10. T-statistics and significance values found in comparing browse utilization in each habitat type.

	mat.dec.	h-s	s-h	w-a	m.conif.	mat.con.	imm.con.
imm.dec.	t = 0.437 sign. = 0.667	t = 0.569 sign. = 0.576	t = 0.091 sign. = 0.928	**t = -2.632** **sign. = 0.020**	t = 0.880 sign. = 0.392	t = 0.582 sign. = 0.572	t = -1.218 sign. = 0.245
mat.dec.		t = 0.082 sign. = 0.935	t = -0.641 sign. = 0.531	**t = -2.509** **sign. = 0.029**	t = 1.653 sign. = 0.122	t = 1.108 sign. = 0.296	**t = -2.671** **sign. = 0.023**
h-s			t = -0.815 sign. = 0.425	**t = -3.140** **sign. = 0.007**	t = 1.568 sign. = 0.135	t = 1.305 sign. = 0.305	**t = -3.224** **sign. = 0.006**
s-h				**t = -2.543** **sign. =0.026**	t = 1.620 sign. = 0.128	t = 1.067 sign. = 0.311	t = -1.973 sign. = 0.074
w-a					**t = 2.468** **sign. = 0.033**	t = 1.537 sign. = 0.175	t = 1.239 sign. = 0.255
m.conif.						t = 1.459 sign. = 0.183	**t = -3.356** **sign. = 0.008**
mat.con.							t = -2.072 sign. = 0.093
imm.con.							

NOTE: Values in bold indicate significant differences between habitat types.

Table 11. Hecla Island moose herd structure and population summary from 1971-1989.

YEAR	MALE	FEMALE	CALVES	TOTAL	SETS TWINS	# SPIKE MALES	UNANTLERED MALES	MALES 1 ANTLER	CALVES/100 COWS	CALVES/100 ADULTS	BULLS/100 COWS
1971/72	22	36	18	76	3				50	31	61.1
1972/73	47	39	24	111	2				61.5	27.6	120.5
1973/74	53	27	29	137	0					26.9	
1974/75	22	18	29	130	3					28.7	
1975/76	61	58	46	167	8	8			79.3	38.6	105.2
1976/77	32	51	24	107	3	5	4		47.1	28.9	62.7
1977/78	35	53	17	105	3	6	4		32.1	19.3	66
			29	169	4						
1978/79	52	89	36	177	2	4	11	2	40.4	25.5	58.4
1979/80	51	48	10	109	1	12	28		20.8	10.1	106.3
1980/81	25	43	16	84	0	3	12		37.2	23.5	58.1
1981/82	NO DATA										
1982/83	17	36	19	73	1				52.8	35.9	47.2
1983/84	20	29	17	69	2	2	7		56.7	34.7	70
1984/85	45	55	39	141	3	13	19		70.9	39	81.8
1985/86	48	63	41	152	4	6	33		65.1	36.9	76.2
1986/87	53	36	31	120	3	10	23		86.1	34.8	147.2
1988/89	37	48	17	102	2	6	9		35.4	20	77

APPENDIX C.

Woody plant species occurring on Hecla Island, 1988-1989.

Common names	Scientific names
speckled alder	*Alnus rugosa*
arrowwood, downy	*Viburnum rafinesquianum*
ash, green	*Fraxinus pennsylvanica*
aspen, trembling	*Populus tremuloides*
fir, balsam	*Abies balsamea*
birch, bog	*Betula glandulosa*
birch, paper	*Betula papyrifera*
birch, swamp (dwarf)	*Betula pumila*
balsam poplar	*Populus balsamifera*
buffaloberry	*Shepherdia canadensis*
chokecherry	*Prunus virginia*
currant, black	*Ribes americanum*
dogwood, red-osier	*Cornus stolonifera*
elm, american	*Ulmus americanum*
gooseberry	*Ribes oxycanthoides*
hazelnut, beaked	*Corylus cornuta*
high-bush cranberry	*Viburnum opulus*
Manitoba maple	*Acer negundo*
mountain maple	*Acer spicatum*
nannyberry	*Viburnum lentago*
raspberry, wild red	*Rubus idaea var. strigosus*
rose, wild	*Rosa* spp.
saskatoon	*Amelanchier alnifolia*
willow	*Salix* spp.