Effects of Timber Management Practices on the Use of Aquatic Feeding Areas by Moose (*Alces alces*) in the Great Lakes – St. Lawrence and Boreal Transition Forests of Central Ontario

By

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This thesis has been prepared
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The Undersigned certify that they have read, and recommended to the Graduate Studies Committee for acceptance of a thesis entitled “EFFECTS OF TIMBER MANAGEMENT PRACTICES ON THE USE OF AQUATIC FEEDING AREAS BY MOOSE (*ALCES ALCES*) IN THE GREAT LAKES – ST. LAWRENCE AND BOREAL TRANSITION FORESTS OF CENTRAL ONTARIO” submitted by Jennifer Chikoski in partial fulfillment of the requirement for the degree of Master of Science.

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Abstract

During spring and summer in Ontario, moose are commonly observed at sites known as moose aquatic feeding areas. Feeding on aquatic vegetation is thought to be an important source of sodium for moose at this time of year. The effects of different timber harvesting systems on the use of aquatic feeding areas by moose was studied in the Great Lakes – St. Lawrence and boreal transition forests of central Ontario. During June to September 2002, I compared the use of aquatic feeding sites by moose among selection cutting in the Algonquin Park Forest Management Unit (FMU), uniform shelterwood cutting in the French-Severn FMU, and clear-cutting in the Spanish FMU. At >50 sites within each harvesting system I studied the relationships between moose use and age of forest stands adjacent to aquatic feeding areas, proximity of timber harvest, and amount of shoreline affected. The locations of potential study sites in the three FMUs were initially identified using GIS data (cut history and reserve widths), moose aquatic feeding area survey data, and air photos. Sites were assessed for moose use by recording the characteristics of trails, tracks, pellet-groups, and browsing. Physiographic and vegetative attributes of the aquatic and terrestrial landscape were also measured. Overall, moose use of aquatic feeding areas was greatest in areas harvested by selection cutting, followed by shelterwood cutting, and clear-cutting, respectively. The reserve width and time since last cut influenced the use of aquatic feeding areas by moose in all three silvicultural systems. Within areas harvested by selection cutting, moose use was greatest adjacent to old cuts (>20 years) and large reserve widths (>120m). The shelterwood areas showed more moose use of sites adjacent to recent cuts (<5 years) with >120m reserves. The clear-cut areas showed more moose use adjacent to cuts >10 years of age with >120m reserves. The results of stepwise multiple regressions, indicated that habitat characteristics other than forest age and reserve width were also important for moose when selecting a site. The length of aquatic vegetation along the shore and midpoint basal area were important habitat variables within the selection cut system. Endpoint basal area was the only habitat variable important for moose use within the shelterwood system and there was no multiple regression model predicted in the clear-cut system. Subsequent correlation analyses indicated that the length of aquatic vegetation along the shore and reserve width were the only two variables related to moose use within all three silvicultural systems. Moose demonstrated both random and non-random patterns of use within reserves in all three systems. Random use was identified by an interconnection of moose trails within reserves that were not used repeatedly, indicating that sites were used less frequently. Non-random use was identified by a trail system heavily used within the reserve, indicating that trails were used repeatedly.

Because aquatic plants are an important source of nutrients for moose in spring and summer, forest management practices must ensure proper protection of these sites. This study shows that the time since last cut and the type of silvicultural system being used must be considered when applying a reserve around aquatic feeding areas, because the quality of the habitat within the adjacent reserve is important for moose using these sites. Although moose used aquatic feeding areas adjacent to narrow reserves (<60 m), the results of this study show that sites adjacent to 120-m reserves, as recommended in the *Timber Management Guidelines for the Provision of Moose Habitat*, were used the most and have the greatest potential of meeting the life history requisites of moose in all three silvicultural systems.

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Table of Contents

Page

Materials and Methods

Results

Discussion

List of Figures

List of Tables

List of Appendices

Introduction

Animals living in harsh northern environments experience great seasonal variation in both quality and quantity of available food and habitat. They have evolved physiological and behavioural adaptations to survive these seasonal changes in their food resources (OMNR 1990; VanBallenberghe and Miquelle 1990). Winter months can be particularly stressful, as foraging shifts from nutrient rich plants in summer to less nutritious vegetation in winter (Stewart et al. 1977; Jackson et al. 1991; Renecker and Schwartz 1998). The efficiency with which an animal chooses its habitat and obtains energy from its diet is critical to its survival during such stressful periods (Klein 1970). Animals that are more efficient in selecting suitable habitat, with all the necessary elements for survival, have a better chance of meeting their nutritional requirements, reproducing each year, and maximizing their individual fitness (Foxcroft 1980; OMNR 1990; Crete and Huot 1993; Saether et al. 1996).

Most northern ungulates demonstrate annual growth patterns in body weight (Klein 1970; Saether et al. 1996). To compensate for seasonal fluctuations in weight, these ungulates experience a decreased metabolic rate (Silver et al. 1969), narrow their habitat range, and shift their feeding habits to available sources (Jackson et al. 1991). Caribou (*Rangifer tarandus*), for example, undergo annual migration between the tundra and the boreal forest in North America (Williams and Heard 1986). In winter, caribou feed on lichens, which are replaced with graminoids in the spring, followed by deciduous leaves in the summer (Thompson and McCourt 1981; Gauthier et al. 1989). Elk (*Cervis elaphus*) also experience seasonal shifts in habitat use. They move to lower elevations in winter, where temperatures are warmer and their diets vary upon availability, plant diversity, and habitat type (Picton 1960; Miller et al. 1981; Marcum and Scott 1985). Moose (*Alces alces*) undergo seasonal elevation migrations in mountainous regions of British Columbia, Alaska, and Colorado. In all regions, moose migrate into forests in winter, adjacent to their summer home range, which should include all essential requirements for survival (Dunn 1976; Crossley and Gilbert 1983). As snow depths increase, forage becomes depleted (Weixelman et al. 1998) and moose feed on taller shrubs and trees (Milke 1969), therefore foraging characteristics may vary among habitats occupied in winter (Spencer and Hakala 1964; Miquelle et al. 1992). Regardless of their adaptability to winter, ungulates experience weight loss, expend energy searching for food, and rarely meet the nutrient levels required for proper maintenance (Edge et al. 1988). In summer, moose are at their greatest nutritional demand (Belovsky et al. 1973); they increase their forage intake to replenish fats and proteins after surviving a low quality forage intake over winter (Silver et al. 1969; Parker and Robbins 1984; Weixelman et al. 1998). These factors make the summer months an important foraging period and reinforce the need for optimal habitat availability.

The composition of moose diets varies seasonally within their geographic range. In winter, moose are limited in availability of browse and feed primarily on early successional woody vegetation (Renecker and Schwartz 1998). The nutritional value of winter forage is lower than in summer, so moose consume a mixture of coniferous and deciduous twigs to provide an optimal winter diet (Jackson et al. 1991; Renecker and Schwartz 1998). In Norway, willow (*Salix* spp.) dominates the winter diet of moose (Saether and Andersen 1990), whereas 89% of the diet in Finland is comprised of Scot's pine (*Pinus sylvestris* L.) (Heikkila and Mikkonen 1992). In late fall and early winter, moose in Maine (Peek 1974) and some parts of Europe feed on fallen deciduous leaves (Renecker and Hudson 1992) and in Alaska, 95% of the diet is comprised of willow, trembling aspen (*Populus tremuloides* Michx.), and cottonwood (*Populus* spp.) (Spencer and Chatelain 1953). Willow is also the primary food preference of moose in the western ranges and the Rocky Mountains of North America (Martin et al. 1946; Cole 1956). A mixture of coniferous vegetation and deciduous shrubs such as dogwood (*Cornus* spp.), mountain ash (*Sorbus americana*), and bog birch (*Betula pumila*) complements the willow diet. Because willow is limited in abundance on the east coast, moose rely heavily on balsam fir (*Abies balsamea* L.) and paper birch (*Betula papyrifera* Marsh.) (Pimlott 1953; Bergerud and Manuel 1968). Although the winter diet of moose in British Columbia is primarily willow, it resembles a diet on the east coast, including some fir and birch species (Ritcey 1965). Paper birch is the most palatable species in winter and is the principle food for moose throughout the boreal forest (Renecker and Schwartz 1998). In the boreal forest of Ontario, both coniferous and deciduous vegetation constitutes a winter diet for moose (Peterson 1953).

Moose limit their early summer foraging to preferred species and choose feeding sites that contain a greater diversity of plants than other times of the year (Edge et al. 1988). Food choices expand in summer to include leaf stripping and aquatic vegetation (Jordan et al. 1973; Fraser et al. 1980; Jackson et al. 1991). However, the abundance of aquatic plants is limited in some regions where moose occur (Peek 1974; Jordan 1987). Consequently, moose must rely on other vegetation with similar nutritional components (Murie 1934; Jordan 1987). In Norway, moose feed on deciduous trees and shrubs such as dwarf birch (*Betula pubescens*), billberry (*Vaccinium myrtillus*), and bog asphodel (*Narthecium ossifragum*) during summer (Renecker and Hudson 1992). In Alaska, the western ranges, and the Rocky Mountains, willow remains the dominant foraging species, comprising almost 75% of a moose's summer diet (Murie 1944; Hosley 1949; Peek 1974). Due to cold water temperatures and fast-flowing streams, aquatic vegetation can only provide up to 9.3% of a moose's diet in the western ranges (McMillan 1953). In British Columbia, moose will feed on aquatic vegetation such as swamp horsetail (*Equisetum* *fluviatile*), burrweed (*Sparganium augustifolium*), and pondweeds (*Potamogeton* spp.) when available (Ritcey and Verbeek 1969). Where aquatic vegetation is not available, such as along the Saskatchewan River delta, moose will forage on available shrubs similar to their winter diet (Ritcey 1965). In comparison, balsam fir and hardwood trees like paper birch and trembling aspen remain the principle food for moose in the eastern ranges (Pimlott 1961; Bergerud and Manuel 1968). In northern Maine, moose feed almost equally on aquatic and terrestrial vegetation and do not show a preference for specific habitats (Leptich and Gilbert 1989). In Ontario, conifers are almost completely avoided from late spring to fall (Peterson 1953), and during late spring and early summer (late May-July), moose concentrate their feeding at sites known as moose aquatic feeding areas (MAFAs) where they eat aquatic plants in greater abundance than terrestrial browse (deVos 1958; Fraser et al. 1980; Jackson et al. 1991). Even though a variety of aquatic plants are available in great abundance in Ontario, moose commonly choose the more palatable pondweeds (*Potamogeton* spp.) and pond lilies, such as yellow pond lily (*Nuphar variagatum*) and fragrant white water lily (*Nymphae tetragona*) (deVos 1958, Fraser et al. 1984).

Bergstrom and Danell (1986) suggest that moose try to consume foods high in magnesium and potassium during winter, whereas they focus their summer foraging on vegetation with high amounts of sodium (Belovsky 1981). Sodium is needed for hair replacement, antler growth, pregnancy, and lactation, and is thought to be desired when potassium (K^+) intake is high (Jackson et al. 1991). Terrestrial vegetation provides only 7 – 14% of the annual sodium (Na^+) requirements for moose (Botkin et al. 1973; Jordan et al. 1973). The sodium content of aquatic plants is 5-500 times richer than terrestrial browse (Jordan et al. 1973; Fraser et al. 1980) and, if eaten in adequate amounts, can provide the levels required for proper physiological functions (Botkin et al. 1973). Jordan et al. (1973) and Fraser et al. (1980) hypothesized that moose in Ontario focus their spring and summer feeding habits on receiving adequate amounts of sodium. Moose activity at sodium-rich springs and at sources of road salt (Peterson 1955; Fraser and Reardon 1980) provides evidence for this hypothesis.

Although moose populations exist across North America, aquatic plants may be sparse to non-existent in some areas, therefore aquatic vegetation is sometimes insignificant to a moose's diet. Some studies suggest that moose use aquatic feeding areas because aquatic plants are more palatable than woody vegetation (Murie 1934; Peterson 1955; deVos 1958) and also as a means of escaping insect attacks (Flook 1959; Ritcey and Verbeek 1969). It has been estimated that moose will travel up to 30 kilometers to reach a preferred feeding location (Fraser et al. 1980). A moose will feed at an aquatic site from a few minutes to several hours at a time (deVos 1958; Belovsky and Jordan 1978) and for up to three or more days (Fraser et al. 1980). Bulls enter aquatic feeding sites first, followed by cows. Cows spend 40-50% more of their time feeding at aquatic sites than bulls (Belovsky and Jordan 1978) because they must consume enough sodium for healthy reproduction and lactation (Jackson et al. 1991). Near the middle of August the abundance of aquatic plants decreases and moose again modify their feeding habits to available browse (Peterson 1955; Peek 1974; Jackson et al. 1991). This modification of food resources near the end of summer may also indicate sodium changes in plants or a change in the sodium requirements of moose.

Moose also meet their sodium requirements by attending mineral licks (Fraser and Reardon 1980; Jordan et al. 2000). Naturally occurring mineral licks and aquatic plants attract inland moose in northern ecosystems because they do not have the sodium supplements that are provided around marine coasts from salt deposits (Murie 1934; Botkin et al. 1973; Fraser and

Reardon 1980). In Alberta, moose were found detouring from their usual travel routes to attend mineral licks, and some moose favoured licks over other vegetation in certain areas (Best et al. 1977). The sodium content found in mineral licks is about 14 – 120 times higher than in vegetation (Fraser 1980). Mineral licks are not found in all parts of Ontario, and in the central region of the province moose rely mainly on aquatic plants for sodium (Jackson et al. 1991).

Because aquatic feeding is a prominent behaviour for moose in Ontario, defining the characteristics surrounding moose aquatic feeding areas is critical to ensure proper habitat protection for moose use of those sites. Habitat characteristics of preferred MAFAs are difficult to predict because limited knowledge is available on the factors that influence the ability of a moose to accurately measure available food within the habitat (Provenza and Balph 1987). In Ontario, these characteristics are not fully understood because research has been limited to small sample sizes within only a few areas of the province (deVos 1958; Fraser et al. 1980; Brusnyk and Gilbert 1983). Existing studies are specific to areas where timber harvest and hunting are non-existent, such as Sleeping Giant Provincial Park (Cobus 1972; Fraser et al. 1984; Timmermann and Racey 1989) and Chapleau Game Preserve (deVos 1958; Fraser et al. 1980). Most of the studies on the use of aquatic feeding areas by moose focus on plant selection (Fraser et al. 1984), activity (deVos 1958; Fraser et al. 1980), importance of shoreline characteristics with respect to vegetation type, entry points, slope and shoreline substrate (Fraser et al. 1980; Timmermann and Racey 1989), and consumption of aquatic vegetation for sodium (Belovsky et al. 1973; Botkin et al. 1973; Jordan et al. 1973; Franzmann et al. 1975). Nonetheless, studies on the use of MAFAs reveal some consistency in habitat preference. Favoured characteristics not only include preferred aquatic vegetation but also sufficient cover, preferably less than 200m away. Nearby cover provides a secure hiding and resting place and secure access to aquatic plants (Peterson 1977; Timmermann and Racey 1989; Jackson et al. 1991; Kunkel and Pletscher 2000). Adjacent cover minimizes heat stress from solar radiation by intercepting the sun's rays to provide shade. Moose tend to bed in cool, shady areas adjacent to aquatic feeding sites during summer (Jackson et al. 1991) because the moisture from the forest floor acts as a cooling source to reduce the amount of heat stress (Kelsall and Telfer 1974). Forest cover also minimizes strong winds, thereby reducing dispersal of scent, which could attract predators. The adjacent cover that allows moose to escape predators in case of an attack is referred to as 'escape cover' (OMNR 1990).

Moose aquatic feeding areas can be influenced by natural and human disturbances that alter their characteristics from year to year. Landscape disturbance resulting from forestry, roads, fire, and mining significantly alters the biotic and abiotic factors within available habitat (OMNR 1990; Kimmins 1997). As a result, ungulates may be forced to search over greater distances for suitable winter and summer habitat (Enns 1992). Forest practices are the largest land-based disturbance (OMNR 1990), and the main human activity (OMNR 1983) affecting the ability of many ungulates to meet their life history requirements and from reaching suitable habitat. Woodland caribou (*Rangifer tarandus*) habitat in British Columbia, for example, is decreasing from timber salvage operations. Lichens that comprise the primary winter food for caribou are in low density because they are sparse in regenerating immature forests, thereby increasing caribou starvation (Enns 1992). On Texada Island, blacktailed deer (*Odocoileus hemionus columbianus*) were suffering from nutritional stress because forage was limited in parts of their range from successional growth in older clear-cuts (Forbes et al. 1993). Because moose venture into mature forest in winter, moose in the Okanagan subregion are facing reduced browse in cut blocks that are treated with glyphosates. Glyphosates are herbicides that release conifer growth by inhibiting maturation of hardwood species (Lloyd 1990). Due to the potential impacts of forest practices on wildlife habitat at a large scale, timber harvesting in Ontario could have a negative effect on the use of MAFAs by moose.

In Ontario, land is primarily managed for timber harvest and the Ontario Ministry of Natural Resources (OMNR) has used moose as a featured species for sustainable forest management over the last 20 years (McLaren 1998). In the Great Lakes – St. Lawrence and boreal transition forests of Ontario, MAFAs are the main attraction for moose in late spring, and many are situated within active Forest Management Units (FMUs). Within these forest regions, silvicultural systems try to emulate some aspects of natural disturbance to decrease the impact of harvesting on wildlife habitat (OMNR 1983). Timber harvest in this region is primarily, but not exclusively, limited to clear-cutting, shelterwood cutting, and selection cutting. The clear-cut silvicultural system is aimed at producing an even-aged stand, where new seeds become established in a fully exposed environment after most or all of the existing trees have been removed (OMNR 1983; Smith 1986). This can be done in blocks, strips, or patches. Clear-cutting may produce large forest openings with high light levels (OMNR 1983; Smith 1986). A clear-cut forest can produce sufficient habitat for moose in late winter because it creates an “edge effect” that allows moose to have cover as well as access to adjacent cut blocks to forage on early successional species. The shelterwood system also produces even-aged stands, but the trees in a block are harvested in a series of cuts for the purpose of obtaining natural regeneration under the shelter of the residual trees (OMNR 1983; Smith 1986). Selection cuts produce uneven-aged stands by removing only the mature and undesirable trees either individually or in small groups throughout an area. This allows the area to regenerate naturally (OMNR 1983; Smith 1986) and does not open the canopy enough to create large areas for moose habitat, as does clear-cutting (OMNR 1990). These three systems have been practiced in the Great Lakes – St. Lawrence region for at least three decades. As a result, forest composition has been modified throughout Ontario, significantly reducing the local abundance of some tree species and increasing the amount of fragmentation of the landscape (Bergerud 1981; Hunter 1990).

Because timber harvesting is the key approach to land management in Ontario, forest management practices must ensure proper protection of moose habitat. Evidence shows that moose numbers are greatest where the forest has been disturbed from fire, insect damage, and logging (OMNR 1990). However, along the shoreline of a MAFA, forest cover is critical for protection of moose as they feed in the open water. To that end, the Ontario Ministry of Natural Resources' *Timber Management Guidelines for the Provision of Moose Habitat* (OMNR 1988) recommend a minimum 120-m reserve in the boreal forest, and a modified 60-m reserve in the Great Lakes – St. Lawrence forest around all moderate to high use aquatic feeding areas to provide sufficient cover and reduce human disturbance. The level of potential moose use is determined by a system developed to rank aquatic feeding areas. The scale ranges from 0 (no potential use by moose) to 4 (high potential use by moose) based on the amount of preferred aquatic plant species, the size of the water body, accessibility to the site, and evidence of moose use (Ranta 1988). MAFAs are aerial surveyed and ranked between the first week of June and the second week of July when the aquatic plants are fully developed (Ranta 1988).

MAFAs are generally located on coolwater lakes and medium and shallow rivers (Ranta 1988), and are sometimes associated with beaver activity. Beaver activity is positively correlated with MAFAs and when present, the rank of a MAFA is reduced by one (Ranta 1988). For example, a site that would be given a rank of 4, would be reassigned a rank of 3 if beavers were present. Beavers cut down mature poplar and open the canopy to allow growth of early successional vegetation that moose feed on. It has been suggested that beaver dams alter the hydrology, energy flow, and nutrient cycling of aquatic systems (Naiman and Melillo 1984), helping to stabilize the flow of water (Scheffer 1938) and in turn, enhance the growth of aquatic vegetation. However, because beaver activity is ephemeral, once the dam collapses from abandonment, the pond is susceptible to draining and will reduce the potential for aquatic plant growth, reinforcing the rationale of reducing the rank of a MAFA with the presence of beavers (Ranta 1988).

Although timber harvesting may improve moose habitat (Peterson 1955; Payne et al. 1988), cutting to shoreline around moose aquatic feeding areas could contribute to decreased moose use. Because moose are selective in choosing their feeding sites, there may be features other than timber harvesting that will discourage a moose from using a particular site. For example, moose entering an aquatic feeding area may be influenced more by shoreline characteristics, such as distance to cover and substrate, than the width of forest cover around the site (Cobus 1972). Therefore, as suggested by Timmerman and Racey (1989), forest cover may only be needed in specific areas adjacent to aquatic vegetation such as where moose enter the site.

The 120m reserve around MAFAs has not been accurately tested to ensure that it is important for moose accessing aquatic feeding areas. The relevance of a 120m reserve has become an important issue to forest managers because merchantable timber is being withheld from harvesting in these reserves and companies may be losing the economic value of that timber. Along with the importance of protecting aquatic feeding areas, the frequency of moose use at a site and the number of moose that use a site are relevant when applying the 120m reserve. The outcome of the 120m recommendation (OMNR 1988) on moose use around

MAFAs is in need of evaluation, not only to determine if the 120m reserve is effective, but also to provide a better understanding of the immediate and long term impacts that forestry practices impose on moose populations.

There is limited published literature documenting the effects of stand age, reserve width, and use of shoreline reserves around aquatic feeding areas. This study examines the effects of timber harvesting on moose use of aquatic feeding areas in the Great Lakes – St. Lawrence and boreal transition forests of central Ontario. Three main objectives of this study were: (1) to determine the relationship between moose use around aquatic feeding areas and the adjacent reserve width; (2) to investigate the relationship between moose use and the time since last cut adjacent to MAFAs; and (3) to investigate the overall intensity of moose use of aquatic feeding areas within three silvicultural systems.

Study Area

The study area included three Forest Management Units (FMUs) located in the central region of Ontario (Figure 1), within the Great Lakes – St. Lawrence and boreal transition forests (Farrar 1995). A variety of forest management techniques are practiced in Ontario, but only three silvicultural systems are predominant in the study area: (1) selection cut (Algonquin FMU); (2) uniform shelterwood cut (French-Severn FMU); and (3) clear-cut (Spanish FMU). Both boreal coniferous softwoods and southern deciduous hardwoods characterize the forests in these three FMUs (Farrar 1995). Timber harvesting around all water bodies within these FMUs follows the *Timber Management Guidelines for the Provision of Moose Habitat* (OMNR 1988). The location of MAFAs used in this study varied among three forest stand ages: recent cuts (0-5 years), old cuts (10-15 years), and no cuts (no disturbance within the past 20 years). The proximity of harvesting to these sites was based on the width of the uncut reserve adjacent to each MAFA and fell into three classes; 0 – 60m, 61m – 120m, and greater than 120m. Timber harvesting was the last disturbance to occur at all sites examined.

The Algonquin FMU encompasses Algonquin Provincial Park (45°39’N, 78°39’W) with a total area of 7, 685 km^2 (Corbett 1993). Highway 60 is the only main access road that passes through the Algonquin FMU. Other existing roads are secondary and tertiary and can only be accessed by permit. The Algonquin FMU has rolling topography over granite bedrock (Department of Energy and Mines (DEM) 1985) with various mixedwood forests dominated by red maple (*Acer rubrum*), eastern hemlock (*Tsuga canadensis*), yellow-birch (*Betula lutea*), red pine (*Pinus resinosa*), and white pine (*Pinus strobus*) (Corbett 1993).

The French-Severn FMU is located in the Parry Sound District (45°45’N, 79°50’W). The landscape is rugged, with thick forests that lie on the Canadian Shield, covered primarily

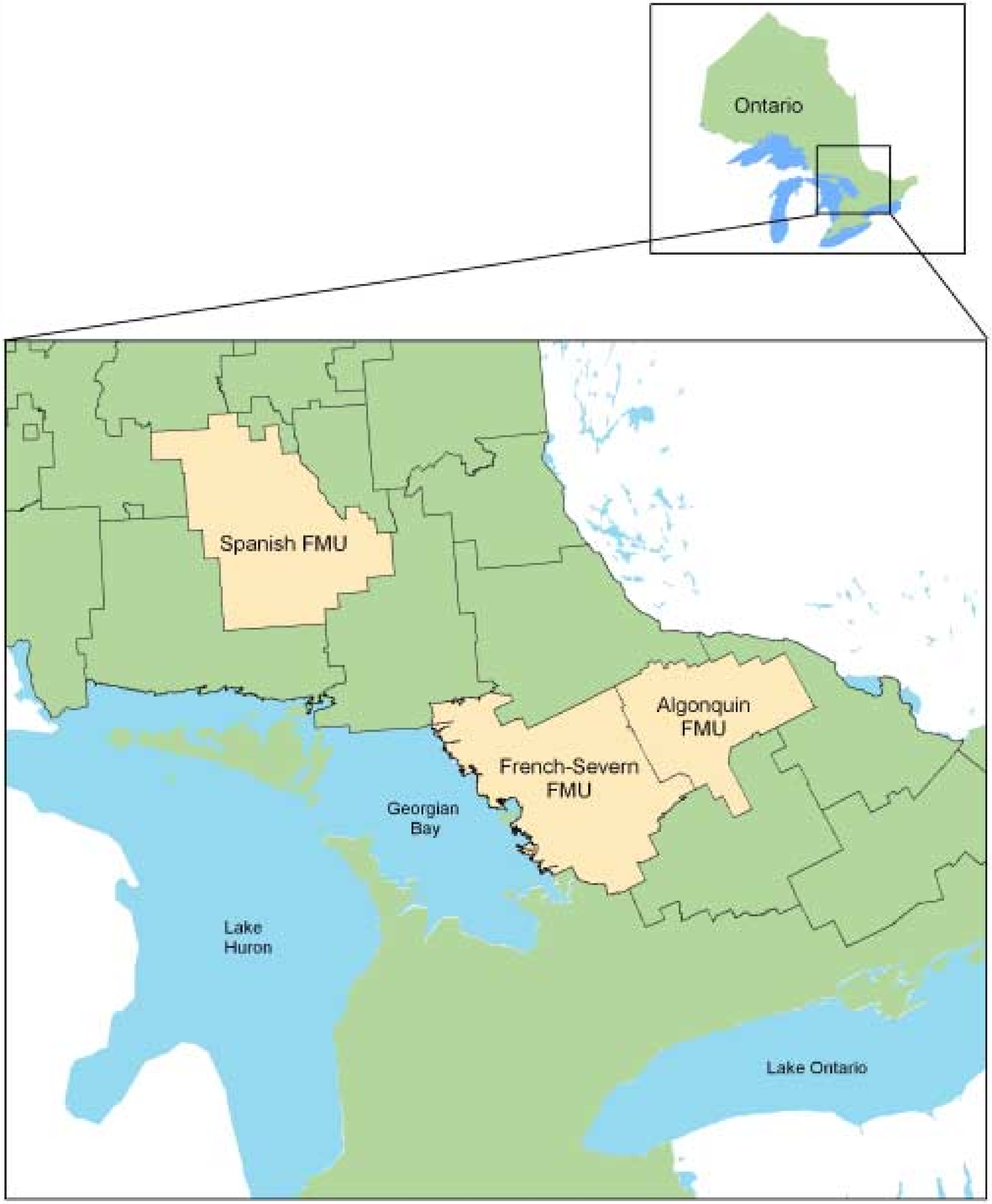


Figure 1. Locations of the 3 Forest Management Units (FMUs) in central Ontario. The Spanish FMU was subjected to clear-cutting, the French-Severn FMU was subjected to shelterwood cutting, and the Algonquin FMU was subjected to selection cutting.

with red and white pines, trembling aspen, and some paper birch (Rowe 1972).

The Spanish FMU is located just north of Espanola in the Lake Temagami Site Region (Rowe 1972) at 46°15’N and 81°46’W. This area is comprised of rolling topography, light soils, and has been logged since the 18th century. The southern part of the Spanish FMU is home to one of the largest concentrations of red and white pine stands in Ontario (Rowe 1972).

All three FMUs experience similar climatic factors with a monthly precipitation between 80mm and 160mm in July (DEM 1985). The mean summer temperature ranges from 5°C to 30°C (DEM 1985). Numerous water bodies, such as small lakes, rivers, and streams, exist in all FMUs and drain into the St. Lawrence System. The wetlands are classified as Low Boreal wetlands (DEM 1985) that typically have cold winters and warm summers. Glacial lakes Algonquin and Iroquois once covered these areas that lie on the Laurentian landscape and contributed to the bedrock and unconsolidated material (DEM 1985). Soils are predominantly podzolic with some rockland in the French-Severn FMU and some brunisols in the Spanish FMU (DEM 1985).

Materials and Methods

Site Selection

The locations of potential moose aquatic feeding areas sampled in this study were first identified using a Geographic Information System (GIS) (cut history and reserve widths), MAFA survey data, and air photos, as well as aerial and ground surveys in July and August 2001 and July 2002 to verify MAFA ranking and disturbance history. MAFAs were initially selected using the OMNR ranking system (Ranta 1988). The ranking system is a qualitative procedure that estimates the potential value of a wetland as a possible MAFA (Table 1).

MAFAs were not randomly selected for study from all potential ranks. Selected sites corresponded to ranks 3 and 4 (i.e., high and very high potential use by moose) of the OMNR ranking system because these sites routinely receive a 120m reserve. Final site selection was based on the observation of percent aquatic vegetation preferred by moose, accessibility to the site, influence of beaver activity, distance of aquatic vegetation from cover (Ranta 1988), and the size of the site (>1 hectare and <10 hectares). MAFAs easily accessible to observers were given highest preference.

Locations of previously ranked MAFAs in the French-Severn FMU were provided by Ron Black, OMNR District Biologist in Parry Sound. These sites were verified using colour aerial photography from 1999. Because there were not enough previously ranked MAFAs recorded on existing maps, the remaining potential sites for the French-Severn FMU were aerial selected by helicopter (Bell 206 Long Ranger) during July and August 2001. A total of 120 sites were selected in the French-Severn FMU.

Table 1. Summary of the OMNR ranking system for moose aquatic feeding areas (Ranta 1988).

RANK	POTENTIAL	WETLAND SIZE OR TYPE	VEGETATION
0	No	Lakes, creeks, rivers	None
1	Low	Bog lakes, areas where moose have difficulty accessing the vegetation	Sparse vegetation
2	Moderate	< 1 hectare in size	Some preferred aquatic plants, Dominated by graminoids, black spruce, and Jack pine along the shoreline
3	High	> 1 hectare in size	< 50% preferred aquatic species, > 50% graminoids
4	Very High	Large areas (>1 hectare)	> 50% preferred aquatic species, < 50% graminoids

Previous MAFA data pertaining to the Algonquin FMU were not available; therefore, more than 300 potential sites were aerial surveyed using a Turbo Beaver fixed-wing plane during July and August 2001 and ranked according to the OMNR ranking system (Ranta 1988). Sites were selected based on their potential as a protected MAFA.

Preliminary sites were selected in the Spanish FMU using previous MAFA data provided by the OMNR district biologist, Christine Selinger, in Espanola. Aerial surveys could not be completed during the summer of 2001 due to time constraints. These sites were aerial surveyed by helicopter (Bell 206 Long Ranger) in the first week of July 2002, with the help of the Area Technician Ken Johnson and Area Forester Paul Leale (OMNR, Espanola), to verify MAFA ranking and disturbance history.

Three hundred and sixty MAFAs were originally selected (120 MAFAs in each FMU), to allow for seasonal changes (i.e., drought, fire, not accessible) that may alter the characteristics of some sites to the point that they would no longer be suitable for sampling. The final sites in each FMU to be studied were distributed among three age categories (recent, 0-5 years; old, 10-15 years; no cut (control), no disturbance in the last 20 years) and three proximity (i.e., distance from the MAFA to timber harvest) classes (0-60m, 61-120m, greater than 120m).

Sampling Methods

A total of 159 moose aquatic feeding areas were sampled between June and September 2002: 56 in the Algonquin FMU (Appendix I), 55 in the French-Severn FMU (Appendix II), and 48 in the Spanish FMU (Appendix III).

Each site was ground surveyed for evidence of moose use to determine differences among proximity class, age class, and reserve width in the three FMUs. Surveys were completed during the hours of 0700 – 1600 and 0500 – 1400. Each survey crew consisted of two people. At each site, the observers recorded their name, date, time, site number, Universal Transverse Mercator (UTM) coordinates (North American Datum 1983), and weather conditions. Photocopied maps were provided with data sheets to record all observations. Occasionally, a reserve did not completely encircle a pond and only the side with the aquatic vegetation had a reserve, therefore surveying took place on the side of the pond adjacent to the aquatic vegetation.

Each crew walked three transects, equal distance apart, one at each end of the aquatic vegetation boundary and one in the middle (Figure 2). All transects were perpendicular to the shoreline. Each transect continued for the width of the reserve or until the edge of the adjacent cutblock was reached. The length of each transect was recorded on the data sheets. The number of transects remained equal within proximity classes and the location and direction of each transect was marked on the map. Sampling began at the shoreline, although this area was not included in the reserve width. The area between the shoreline and trees >2m in height was identified as the transition zone between water and forest. Measurement of the reserve width began at trees >2m in height in order to test for the importance of the treed reserve in providing access to the site. Sampling continued into the trees for the remainder of the reserve width.

Direct evidence of moose use included observations of moose present and indirect evidence included the number of tracks, pellet groups, trails, and aquatic and terrestrial browsing. Evidence of other wildlife (i.e., waterfowl, bird nests, predator tracks, etc.) was identified and recorded for both the aquatic and terrestrial components of the sites

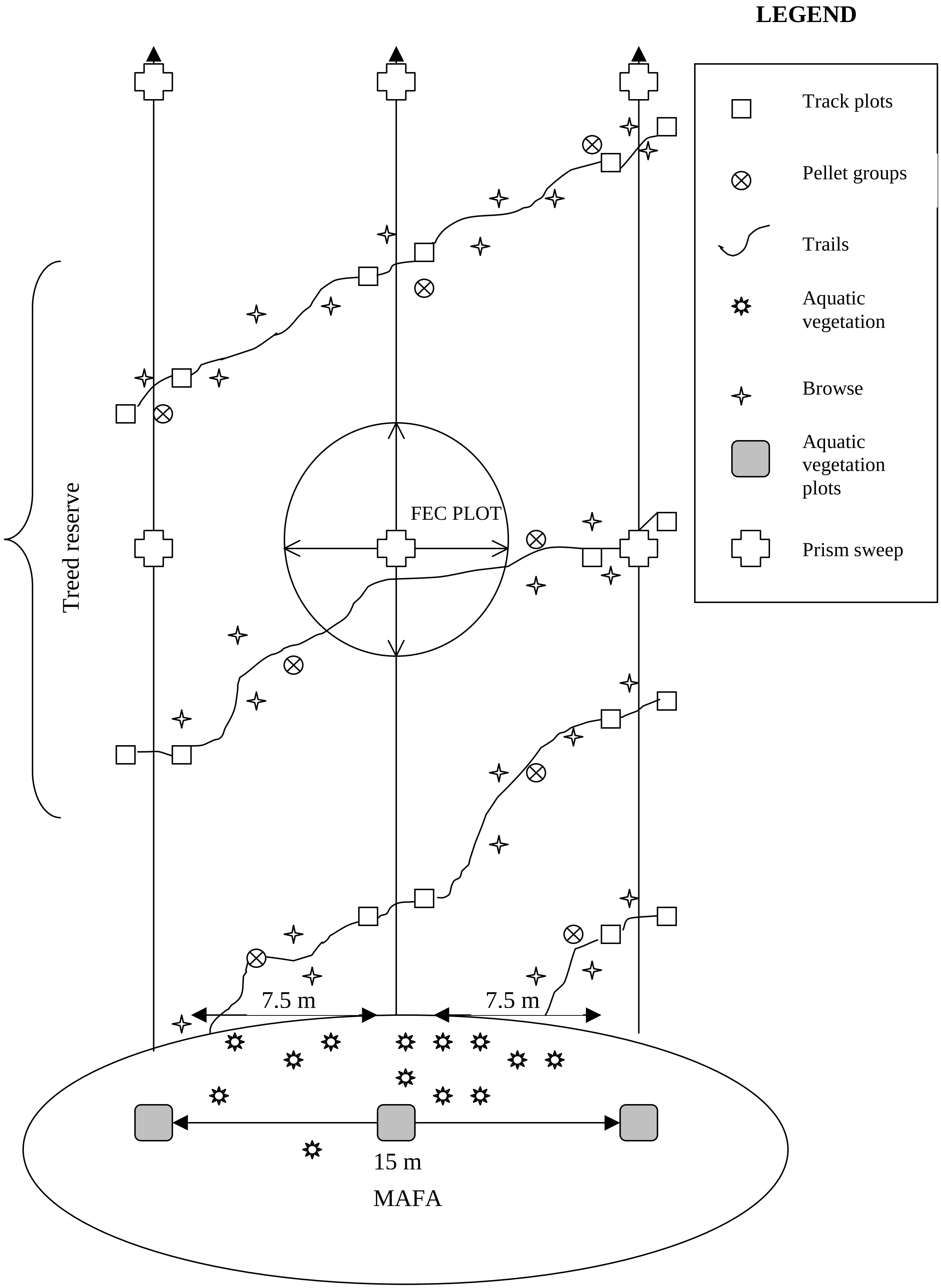


Figure 2. The layout of the sampling design used for data collection at each moose aquatic feeding area (MAFA).

(Fraser et al. 1982). Aquatic and terrestrial habitat characteristics such as slope, aspect, and substrate of the shoreline, pond size, canopy cover, vegetation, and the distance of aquatic plants from forest cover were used to develop statistical models to predict use of aquatic feeding areas by moose.

Measuring Intensity of Moose Use

Game trails were used to determine the relative frequency of moose use at sites by measuring track and browse intensity and the number of pellet groups along each trail. The field crew walked along each of the 3 perpendicular transects at each site and recorded the locations of each intersecting trail (Figure 2). This established the number of trails in each reserve width. The trails were followed from 5m outside the end transect line to 5m outside the other end transect line, if the trail crossed all three transects. If the trail went to the water, it was walked from the start (5m outside the first transect it intersected) to the water line. After flagging the start of the trail, a measuring tape and a compass were used to determine the length and direction of the trail (Timmermann and Racey 1989). Changes in the direction of the trail, and any obstacles that might have forced a moose to change direction (e.g., slope, rock cliff, roads), were recorded and mapped (Timmermann and Racey 1989). A general impression of trail use was estimated by a rank from 0 (no tracks) to 5 (a wide, heavily rutted trail) (Fraser et al. 1984).

Because moose tend to follow each other’s tracks when foraging together (i.e., cow and calf) (Shipley et al. 1998), tracks need to be fresh to determine the number of moose using a trail and the frequency of moose use. Along each trail, 2m x 2m track plots were set out at 5m on either side of the three perpendicular transects (Figure 2). There were a maximum of 6 track plots and a minimum of 2 track plots per trail. These plots were used to determine the number of tracks/m^2 in a reserve. Any signs of pairs (cow-calf), the estimated age of the moose tracks, and the direction of trails were recorded.

Pellet-group surveys were also used to indicate moose use in an area. Pellet groups were counted along each trail within 1m on either side of the trail (Figure 2). This provided a measure of pellet groups/m^2 in each reserve.

Browse was measured in a similar manner to the method for counting pellet groups (Figure 2). Along each trail, stems within 1m on either side of the trail that showed evidence of browsing (leaf/bark stripping) were recorded by species (shrub/tree). Recording each species browsed indicated the species richness of browse available within the reserve. A count of the number of times each species was browsed along the trail indicated the intensity with which each species was used by moose. These data provided a measure of the number of twigs browsed/m^2 for each species of browse within the reserve.

If observers encountered moose at a site, they marked their own location on the map and the location of the moose. The number of moose present, if they were alone (i.e., cow and calf), sex of the moose, approximate age (by body size and antler growth), and any interactions between moose were recorded (deVos 1958; Fraser et al. 1984). The arrival and departure time of moose, as well as their behavioural and physical characteristics (antlers, markings), were also noted. Any evidence of moose mortality was documented with the cause of death, if it could be determined. Any evidence of deer use at a site was recorded on the data sheets and marked on the map. UTM coordinates and other locations marked on the map were determined using a handheld Global Positioning System (GPS) (Model Plus II, Garmin Inc., Olathe, Kansas).

Aquatic Sampling

The aquatic sites were observed for evidence of moose browsing on aquatic plants and uprooted vegetation. Trails and tracks entering the water and bedding sites and pellet groups around the site were also recorded. Beaver activity (chewing, dams, lodges) was recorded and mapped according to the location observed. The length of aquatic vegetation along the shoreline was measured to determine the extent of aquatic vegetation at each site and subsequent placement of transect lines. At the end of each transect line, a 1m x 1m plot was set in the water, no further than 2m from shore (Figure 2), to identify the type of aquatic vegetation (emergent, submergent, floating-leafed) and percent coverage at the site (Fraser et al. 1980). The distance of aquatic vegetation from the shoreline was measured and recorded. The boundary of the entire aquatic community and distribution of aquatic plants according to each type (emergent, submergent, floating-leafed) were sketched on the map.

The substrate along the shoreline and at the bottom of the water (bare rock, soil, peat, stone, muck) (Fraser et al. 1984) was identified. The slope was measured, using a compass, by an observer standing at the shoreline facing the trees. Shoreline aspect was also determined using the compass. In the absence of a similar reference for south – central Ontario, the wetland type of each site was established using the *Field Guide to the Wetland Ecosystem Classification for Northwestern Ontario* (Harris et al. 1996) and was identified by class (palustrine, lacustrine, riverine). The number of dead standing trees and an estimate of the water depth at 1m from shore was also recorded.

Lateral cover for moose provided by the reserves was indexed by sightability distance. One observer held a 1m x 0.5m painted red board at the shoreline, while the other observer walked back into the trees until the red board was no longer visible (Welch et al. 2000). The distance between the observers was recorded. This was done twice, once at 1m high (calf height) and again at 2m high (adult height). The distance of the aquatic vegetation from the shoreline to the shrub layer (>2m and <5m in height) and from the shoreline to the treed cover (>5m in height) was also measured.

The width of the transition zone (i.e., the distance from the waterline to trees >2m in height) was measured using a measuring tape. The type of transition zone was identified by vegetation characteristics: sedge, grass, floating bog, shrub, or a combination of vegetation types.

Collection of Terrestrial Habitat Data

The *Field Guide to Forest Ecosystems of Central Ontario* (Chambers et al. 1997) was used to determine the vegetation-type (V-type) of the forest adjacent to each site. A 10m radius plot was set in the middle of the reserve at the midpoint along the center transect (Figure 2). Two 20m transect lines bisecting the center of the plot (north, east, south, west) were used to record the number and species of woody vegetation. An observer walked the transect line holding a 1-m ruler at waist height, with 50cm on each side, and recorded the species of woody vegetation that touched the ruler. The main stem of individual plants that touched the ruler was counted once, and not the number of branches that touched the ruler because shrubs usually have more than one branch. Woody vegetation that did not touch the ruler (e.g., *Vaccinium myrtilloides*), because it was lower than the height of the ruler, was also recorded. The vegetation was grouped into shrubs (>0.5m and <2m) and understorey trees (>2m and <5m). These measurements were used to quantify the number and species of woody vegetation available for browsing in the reserve. Canopy cover was estimated using a 5cm x 5cm cardboard tube as an ocular lens. At 10m from the center of the plot in 4 directions (north, east, south, west) canopy cover was estimated for understorey (<2m) and overstorey (>2m and <5m) vegetation. The four estimates were averaged to get one measure of canopy cover for the reserve. The dominant tree and shrub species were subjectively recorded as the most prevalent species within and around the FEC plot. Soil within the plot was identified by category: rocky (>2.5mm diameter), mucky (water-logged soil), gravel (<2mm diameter), or sand (fine sediment). Topographical features such as stumps, snags, surrounding cliffs, and hilly terrain were recorded. Any disturbances in the area such as roads, people, boats, vehicles, fires, canoe routes, and camping sites were also recorded.

Basal area measurements were obtained at each site using a 2-m^2 wedge prism; one for the middle of the reserve and one at the end of the reserve (Figure 2). A total of 6 prism sweeps were completed at each site (two along each transect). The three midpoint measurements were averaged together and the three endpoint measurements were averaged together to get two basal area measurements/site.

If no aquatic vegetation was present at the site or the site had become a meadow, it was not sampled. In these cases, the site number and UTM coordinates were recorded and a substitute from the original 120 MAFAs for the FMU was used as a replacement.

Statistical Analysis

I tested for normality of data using Kolmogorov-Smirnov tests (Zar 1999). Log, square root, and arcsine transformations were performed when data were not normally distributed. All tests were completed using the Statistical Package for the Social Sciences (Version 11.5, SPSS Inc., Chicago, Illinois).

A Principal Components Analysis (PCA) was performed on the ten dependent variables (Table 2) to combine these measures into one dependent measure representing the intensity of moose use of individual sites in each FMU.

Variables removed from the PCA included shoreline trail intensity (Appendix IV), shoreline track intensity (Appendix V), and aquatic browsing (Appendix VI). These variables were measured subjectively on ordinal scales and, therefore, equal assessments may not have been applied across all sites by all observers. The intensity of shoreline browsing was also eliminated from the PCA due to a high number of zero values ($\geq$ 90% of sites). Terrestrial browsing measures (Appendix VII) were excluded from the PCA because terrestrial browsing represented use of the treed reserve and not direct use of the aquatic feeding area.

The dependent variable with the highest factor loadings from the PCA was used in a Pearson Correlation Coefficient Analysis (Zar 1999) to test the strength of associations between the dependent variable and reserve width, time since last cut adjacent to the MAFA, and other habitat characteristics. Statistically significant relationships detected by the Pearson Correlation Analysis were checked in a scatterplot to detect outliers or skewed results. Highly intercorrelated variables (those with $r \geq 0.8$) were removed, retaining those with the highest correlation with moose use. This process resulted in 15 independent variables (Table 3) for all three FMUs that were subsequently refined by Stepwise Multiple Linear Regression (SMR) for each FMU using the PCA scores as the dependent variable. The SMR was used to extract the independent variables most related to moose use of surrounding habitat characteristics or combinations of them, other than reserve width and time since last cut, that were important factors for moose selecting an aquatic feeding area.

Table 2. Dependent variables measured as indicators of moose use.

Dependent Variables Indicators of Moose Use
Total number of moose trails
Total length of moose trails
Number of tracks
Number of pellet groups along trails
Number of shoreline pellet groups
Number of stems summer browsed
Number of moose beds
Shoreline track intensity
Shoreline trail intensity
Intensity of aquatic browsing

A two-way Analysis of Variance (ANOVA) was completed to look at the interaction of the reserve width and time since last cut on the use of aquatic feeding areas by moose.

Table 3. Independent variables associated with moose use as determined by Pearson Correlation Coefficient Analysis.

Independent Variables Habitat Characteristics
Length of aquatic vegetation along the shore
Reserve width
Time since last cut
Midpoint basal area
Endpoint basal area
Distance of aquatic vegetation from shore
Number of dead standing trees
Percent cover trees >5m
Percent cover trees >2m and <5m
Distance to trees >5m
Sightability at 2m
Sightability at 1m
Distance to trees >2m
Canopy cover overstorey
Canopy cover understorey

Results

Selection Cut Silvicultural System

The Principal Components Analysis performed on the moose use variables (Table 4) extracted one component with an eigenvalue of 2.775, accounting for 55.5% of the standardized variance among moose use variables. The total length of moose trails, number of pellet groups along trails, number of beds, and number of tracks had positive loadings on the components (0.876, 0.844, 0.322, and 0.616 respectively); however, the total number of moose trails had the highest positive loading (0.901).

The dominant site characteristics of all sites sampled in the selection cut silvicultural system are summarized in Table 5. Mean values (± 1 standard error) of other site characteristics sampled in the selection cut silvicultural system are summarized in Table 6. Pearson Correlation Coefficients showed a significant correlation between the total number of moose trails and reserve width, as well as time since last cut (Figure 3). The total number of trails increased as reserve width increased and in older cuts. However, the length of aquatic vegetation along the shore had a higher correlation with moose use than reserve width or time since last cut (Table 7). Midpoint basal area was also positively correlated with moose use of sites (Table 7). The remaining 11 habitat variables were not significantly correlated with the total number of moose trails at sites (Table 7).

A 2-way ANOVA indicated that the number of moose trails differed significantly between reserve groups (0-60m, >60m; $p<0.05$) but there was no difference among age groups (0-10 years, 10-20 years, >20 years; $p>0.05$). There was no significant interaction between reserve width and time since last cut with moose use ($p>0.05$).

Table 4. Summary of the dependent variables at all sites (n = 56) sampled in the selection cut silvicultural system.

Dependent Variables Indicators of Moose Use	Mean ± 1 Standard Error
Total number of moose trails	7.7 ± 4.6
Total length of moose trails	264.7m ± 239.6m
Number of tracks	6.0 ± 10.5
Number of pellet groups along trails	1.75 ± 4.6
Number of shoreline pellet groups	0.5 ± 1.4
Number of stems summer browsed	12.9 ± 61.1
Number of moose beds	0.5 ± 1.4

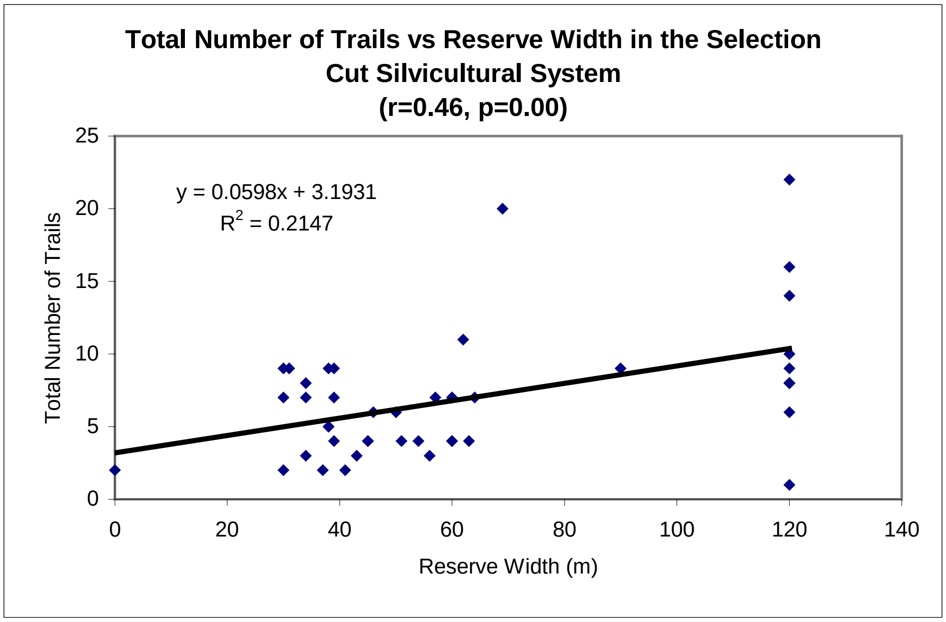
Table 5. Dominant site characteristics of all sites (n = 56) in the selection cut silvicultural system.

Water body type	Water level	Aquatic substrate	WEC[1]	Shoreline substrate	Dominant shoreline spp. <2m	Dominant shoreline spp. >2m and <5m	Dominant shoreline spp. >5m	Transition zone type	Vegetation type[2]	Disturbance type
Ponds	Moderate (>1m and <2m)	Muck	W3/W4	Muck	Sweetgale	Black spruce	White pine	Sedge, floating bog	V18	Roads

[1] *Field Guide to the Wetland Ecosystem Classification for Northwestern Ontario* (Harris et al. 1996)
[2] *Field Guide to Forest Ecosystems of Central Ontario* (Chambers et al. 1997)

Table 6. Mean values (± 1 SE) of site characteristics at all sites (n = 56) in the selection cut silvicultural system.

Site Characteristic	Mean Value (± 1SE)
Length of aquatic vegetation along the shore (m)	107.08 (8.53)
Distance of aquatic vegetation from shore (m)	1.05 (0.25)
Distance from shore to trees >2m in height (m)	8.99 (3.24)
Distance from shore to trees >5m in height (m)	11.69 (3.14)
Sightability at 1m in height (m)	23.43 (1.03)
Sightability at 2m in height (m)	27.10 (1.07)
Transition zone width (m)	7.41 (0.96)
Canopy cover overstorey (%)	61 (20.8)
Canopy cover understorey (%)	37 (20.5)
Average number of dead standing trees	11 (21)
Midpoint basal area	45.6 (13.9)
Endpoint basal area	41.9 (14.4)
Dominant species Percent cover, trees > 5m	Balsam fir 47 (27)
Dominant species Percent cover, trees >2m and <5m	Sugar maple 48 (26)



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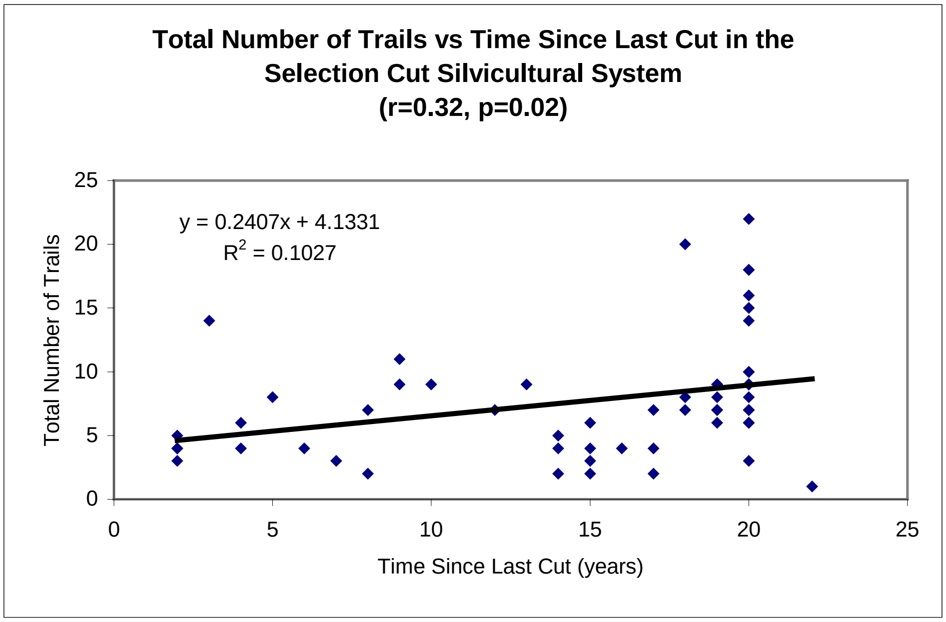

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Figure 3. The relationship between the total number of moose trails and reserve width (A) and the total number of moose trails and the time since last cut (B) in the selection cut silvicultural system.

Table 7. Correlation coefficients between the total number of moose trails and site characteristics in the selection cut silvicultural system.

Site Characteristic	Correlation
Length of aquatic vegetation along shore	0.621*
Reserve width	0.464*
Time since last cut	0.320*
Midpoint basal area	0.304*
Endpoint basal area	0.185
Distance of aquatic vegetation from shore	0.171
Number of dead standing trees	0.138
Percent cover trees >5m	0.126
Percent cover trees >2m and <5m	0.120
Distance to trees >5m	0.025
Sightability at 2m	-0.005
Sightability at 1m	-0.016
Distance to trees >2m	-0.020
Canopy cover overstorey	-0.074
Canopy cover understorey	-0.130

* Significant at $p < 0.05$

The Stepwise Multiple Regression (SMR) of data from the selection cut sites included two variables highly correlated with the intensity of moose use (the length of aquatic vegetation along the shoreline ($R^2 = 0.328$, $p = 0.00$) and midpoint basal area ($R^2 = 0.378$, $p = 0.00$). The overall model was statistically significant (PCA = 2.360 (length of aquatic vegetation along shoreline) + 0.018 (midpoint basal area) – 5.484 (constant)). Figure 4 shows the relationship between the PCA scores for moose use and the length of aquatic vegetation along the shore and basal area for the middle of the reserve. As the length of aquatic vegetation along the shore increased and the midpoint basal area increased, the intensity of moose use (PCA scores) increased.

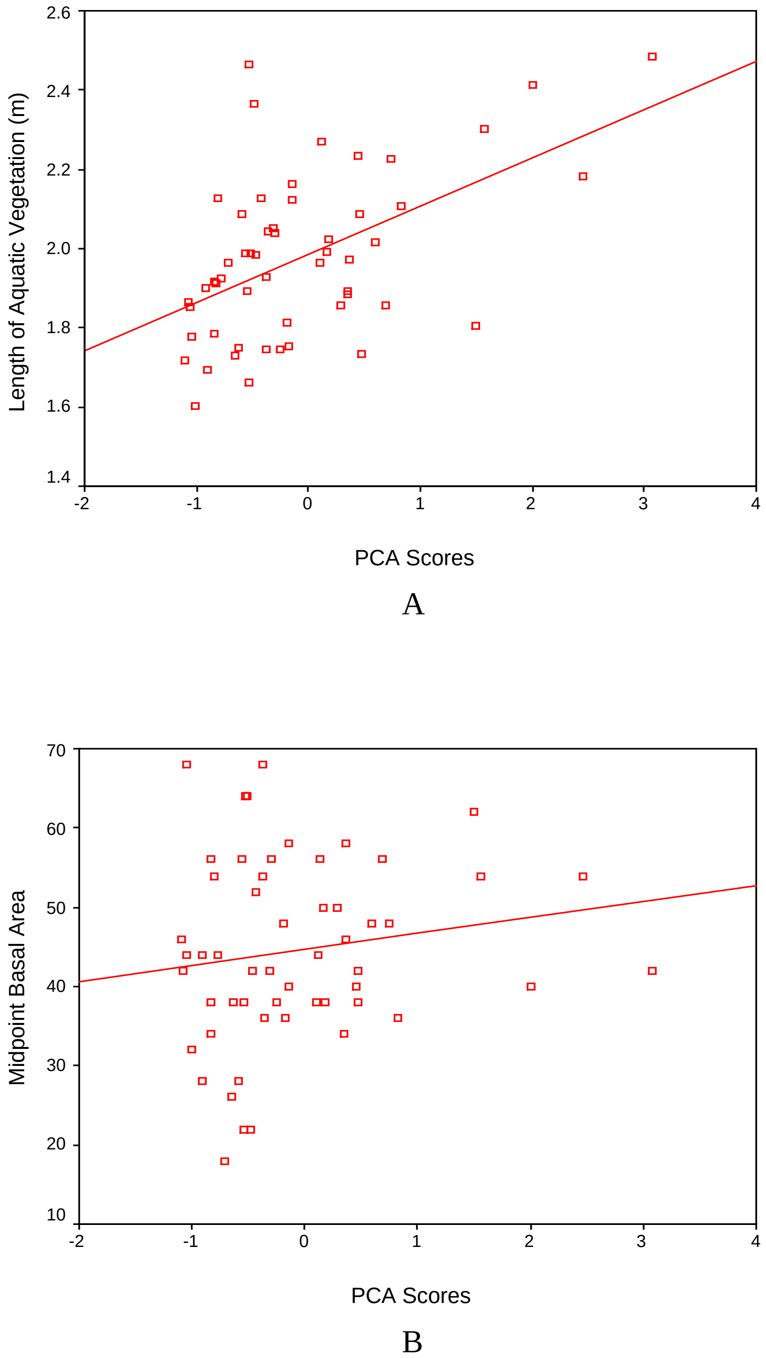


Figure 4. The relationship between the PCA scores for moose use and the length of aquatic vegetation along the shore (A) and midpoint basal area (B) in the selection cut silvicultural system.

Shelterwood Cut Silvicultural System

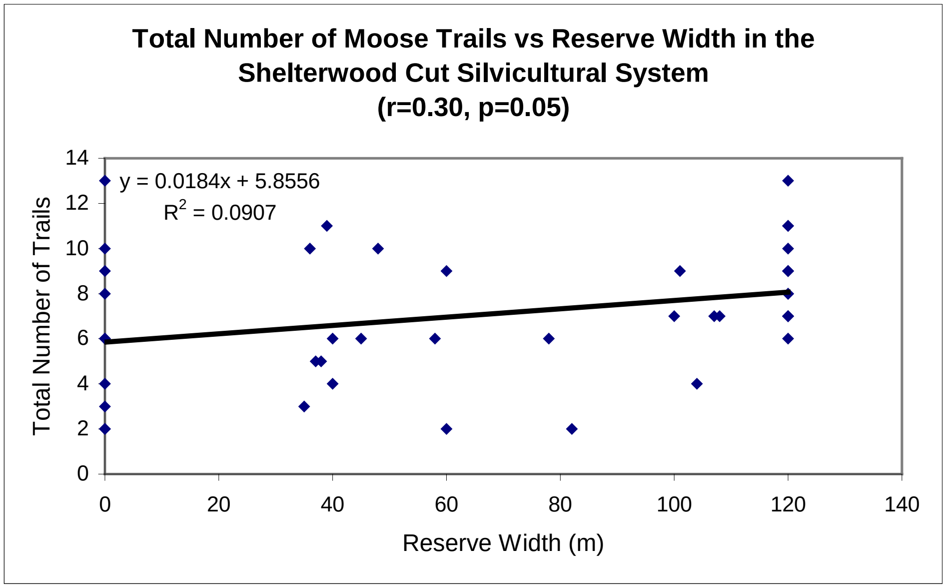
The Principal Components Analysis performed on the moose use variables (Table 8) extracted one component with an eigenvalue of 1.901, accounting for 48% of the standardized variance among moose use variables. PCA scores indicated that factor loadings on the dependent variables were highest on the total number of moose trails within reserves (0.892). The total length of moose trails, number of shoreline pellet groups, and number of pellet groups along moose trails also had positive loadings on the components (0.824, 0.523, and 0.391, respectively).

Pearson Correlation Coefficients indicated no significant correlation between the total number of moose trails and the time since last cut ($r = -0.105$, $p = 0.45$) (Figure 5B). However, the correlation between the total number of moose trails and reserve width was marginally significant ($r = 0.302$, $p = 0.052$) (Figure 5A). There was a slight decrease in the total number of moose trails from recent to older cuts but the total number of moose trails increased as reserve width increased.

The dominant site characteristics of all sites sampled in the shelterwood cut silvicultural system are summarized in Table 9. Mean values (± 1 standard error) of other site characteristics sampled in the shelterwood cut silvicultural system are summarized in Table 10. Pearson Correlation Coefficients showed no significant correlations between the total number of moose trails and any site characteristic other than reserve width sampled in the shelterwood silvicultural system (Table 11).

Table 8. Summary of the dependent variables at all sites (n = 55) sampled in the shelterwood cut silvicultural system.

Dependent Variables Indicators of Moose Use	Mean ± 1 Standard Error
Total number of moose trails	6.8 ± 2.7
Total length of moose trails	211.8m ± 137.9m
Number of tracks	5 ± 6.2
Number of pellet groups along trails	1.5 ± 2.2
Number of shoreline pellet groups	0.5 ± 1.2
Number of stems summer browsed	14.9 ± 22.5
Number of moose beds	0.5 ± 1.2



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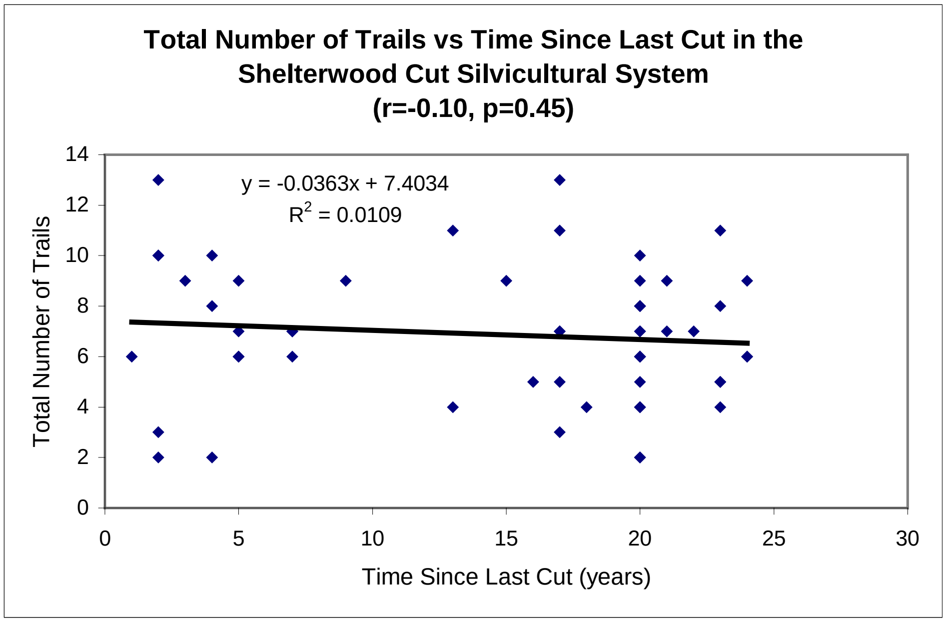


B

Figure 5. The relationship between the total number of moose trails and reserve width (A) and the total number of moose trails and the time since last cut (B) in the shelterwood cut silvicultural system.

Table 9. Dominant characteristics of all sites (n = 55) in the shelterwood cut silvicultural system.

Water body type	Water level	Aquatic substrate	WEC[1]	Shoreline substrate	Dominant shoreline spp. <2m	Dominant shoreline spp. >2m and <5m	Dominant shoreline spp. >5m	Transition zone type	Vegetation type[2]	Disturbance type
Ponds	Moderate (>2m and <5m)	Muck	W4	Muck	Sedges	White Pine	White Pine	Sedge, grass	V29	Roads

[1] *Field Guide to the Wetland Ecosystem Classification for Northwestern Ontario* (Harris et al. 1996)
[2] *Field Guide to Forest Ecosystems of Central Ontario* (Chambers et al. 1997)

Table 10. Mean values (± 1 SE) of site characteristics at all sites (n = 55) in the shelterwood cut silvicultural system.

Site Characteristic	Mean Value (± 1SE)
Length of aquatic vegetation along the shore (m)	140.08 (10.4)
Distance of aquatic vegetation from shore (m)	1.04 (0.3)
Distance from shore to trees >2m in height (m)	6.73 (0.83)
Distance from shore to trees >5m in height (m)	8.58 (0.96)
Sightability at 1m in height (m)	27.71 (1.11)
Sightability at 2m in height (m)	32.07 (1.3)
Transition zone width (m)	7.41 (0.96)
Canopy cover overstorey (%)	56 (20.2)
Canopy cover understorey (%)	30 (21.6)
Average number of dead standing trees	31 (28)
Midpoint basal area	31.7 (11.7)
Endpoint basal area	29.1 (11)
Dominant species Percent cover, trees >5m	White pine 43.8 (24.2)
Dominant species Percent cover, trees >2m and <5m	Red maple 65 (26.7)

Table 11. Correlation coefficients between the total number of moose trails and site characteristics in the shelterwood cut silvicultural system.

Site Characteristic	Correlation
Reserve width	0.302*
Canopy cover overstorey	0.214
Distance to trees >2m	0.202
Endpoint basal area	0.200
Distance to trees >5m	0.166
Sightability at 1m	0.153
Sightability at 2m	0.122
Number of dead standing trees	0.105
Length of aquatic vegetation along shore	0.054
Midpoint basal area	-0.009
Percent cover trees >2m and <5m	-0.069
Percent cover trees >5m	-0.077
Distance of aquatic vegetation from shore	-0.087
Time since last cut	-0.105
Canopy cover understorey	-0.105

*Significant at $p < 0.05$

A 2-way ANOVA showed that the total number of moose trails differed significantly among reserve groups (0-60m, 61-120m, >120m; $p<0.05$). There was no significant difference in the number of moose trails among age groups (0-10 years, 10-20 years, >20 years; $p>0.05$). The interaction between reserve width and the time since last cut was not statistically significant.

The Stepwise Multiple Regression of data from the shelterwood sites included one positively correlated variable, endpoint basal area, with the intensity of moose use ($R^2 = 0.10$, $p = 0.02$). The model was statistically significant (PCA = 0.032 (endpoint basal area) – 0.954 (constant)). Figure 6 shows the relationship between the PCA scores for moose use and basal area measurements for the edge of the reserve.

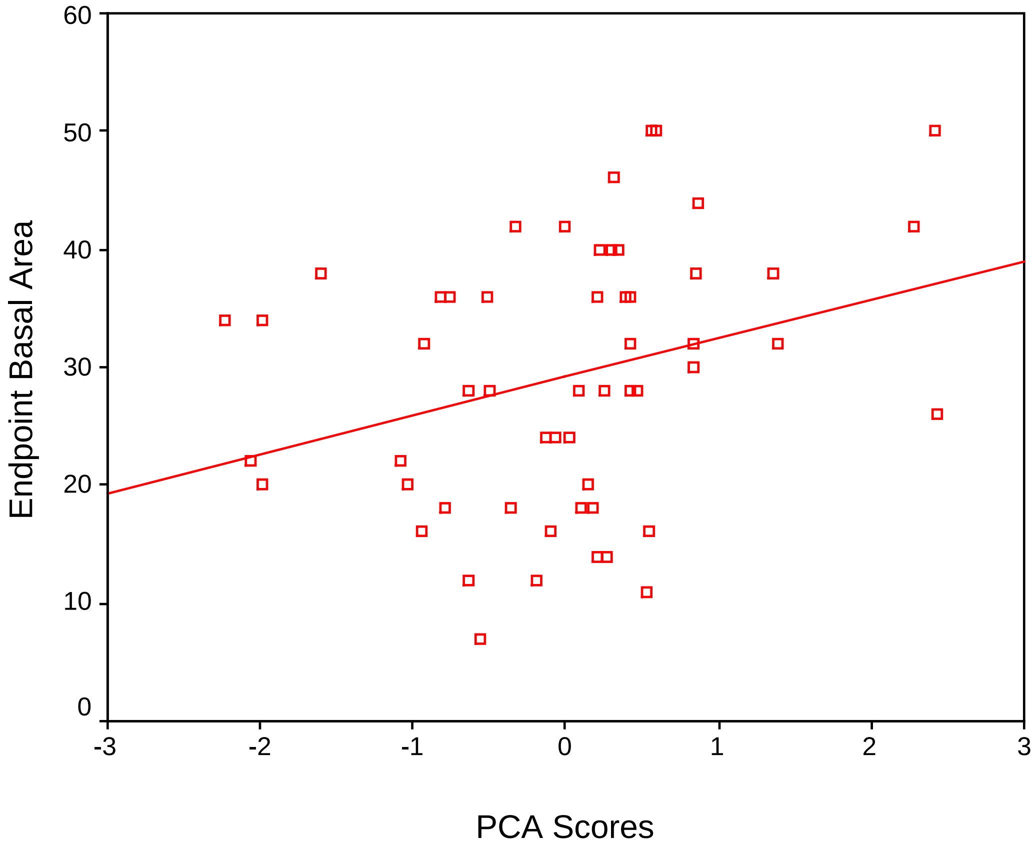


Figure 6. The relationship between the PCA scores for moose use and the endpoint basal area in the shelterwood cut silvicultural system.

Clear-cut Silvicultural System

The Principal Components Analysis performed on the moose use variables (Table 12) extracted one eigenvalue (2.759) explaining 55.2% of the standardized variance among moose use variables. The PCA scores indicated that factor loadings on the dependent variables were highest for the number of pellet groups counted along moose trails within reserves (0.863). The number of tracks, number of beds, total number of trails, and total length of trails also had positive loadings on the components (0.598, 0.505, 0.833, 0.841, respectively).

There was little difference in the factor loadings for the number of pellet groups and total number of moose trails (0.863 vs. 0.833), therefore I used the total number of moose trails as the dependent variable in the Correlation Analysis for consistency with other analyses.

The dominant site characteristics of all sites sampled in the clear cut silvicultural system are summarized in Table 13. Mean values (± 1 standard error) of other site characteristics sampled in the clear cut silvicultural system are summarized in Table 14. Pearson Correlation Coefficients indicated no significant statistical relationship between the total number of moose trails and reserve width (r=0.211, p=0.224) or time since last cut (r=0.130, p=0.390) (Figure 7). However, there was a trend towards an increase in the total number of trails as reserve width increased, and in older cuts. There was no significant correlation between the total number of moose trails and any other habitat characteristic sampled in the clear-cut silvicultural system (Table 15).

A 2-way ANOVA indicated that the number of moose trails differed significantly among reserve groups (p = 0.002). The number of moose trails was marginally significant among age groups (p = 0.061). However, the interaction between age groups and reserve groups was not statistically significant.

Table 12. Summary of the dependent variables at all sites (n = 48) sampled in the clear-cut silvicultural system.

Dependent Variables Indicators of Moose Use	Mean ± 1 Standard Error
Total number of moose trails	4.7 ± 3.8
Total length of moose trails	164.1 ± 160.8
Number of tracks	2.3 ± 5.4
Number of pellet groups along trails	1.3 ± 3.1
Number of shoreline pellet groups	0.8 ± 3.5
Number of stems summer browsed	1.5 ± 5.9
Number of moose beds	0.4 ± 1.0

Table 13. Dominant characteristics of all sites (n = 48) in the clear-cut silvicultural system.

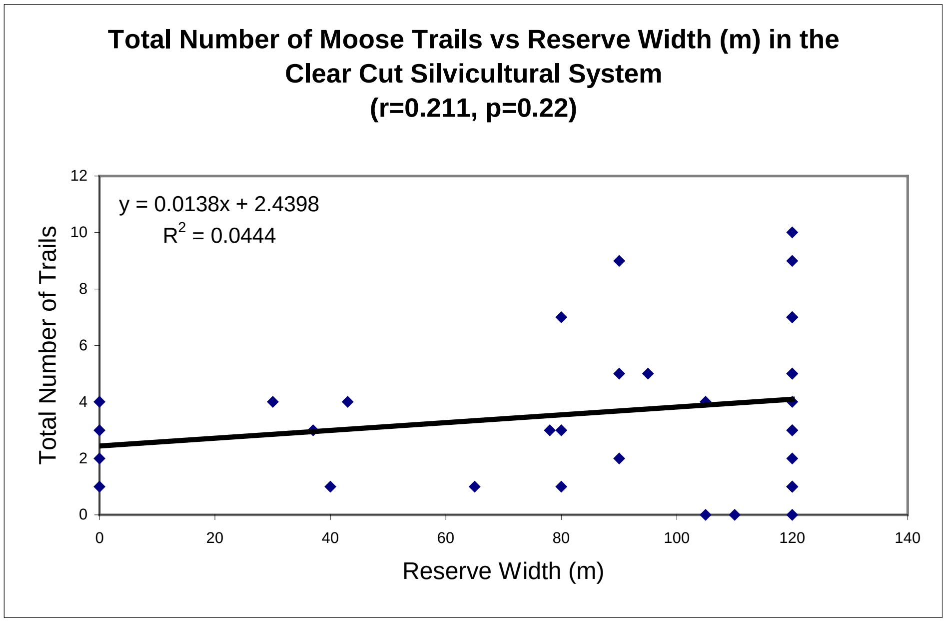
Water body type	Water level	Aquatic substrate	WEC[1]	Shoreline substrate	Dominant shoreline spp. <2m	Dominant shoreline spp. >2m and <5m	Dominant shoreline spp. >5m	Transition zone type	Vegetation type[2]	Disturbance type
Ponds	Moderate (>2m and <1m)	Muck	W3	Muck	Sweetgale	Black Spruce	Black Spruce	Sedge	V39	Roads

[1] *Field Guide to the Wetland Ecosystem Classification for Northwestern Ontario* (Harris et al. 1996)

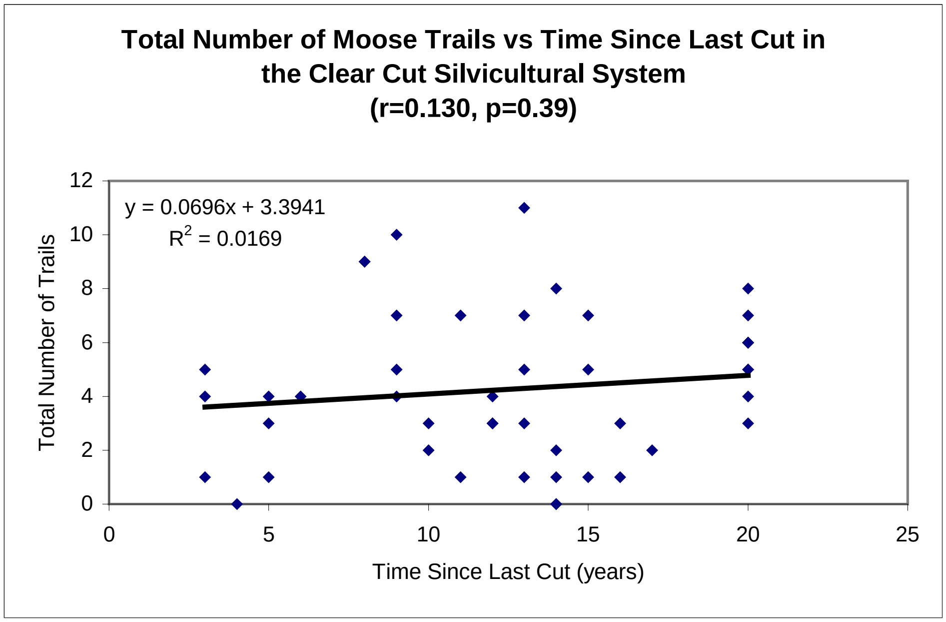
[2] *Field Guide to Forest Ecosystems of Central Ontario* (Chambers et al. 1997)

Table 14. Mean values (± 1 SE) of site characteristics at all sites (n = 48) in the clear-cut silvicultural system.

Site Characteristic	Mean Value (± 1SE)
Length of aquatic vegetation along the shore (m)	108.99 (7.65)
Distance of aquatic vegetation from shore (m)	1.05 (0.21)
Distance from shore to trees >2m in height (m)	8.61 (2.39)
Distance from shore to trees >5m in height (m)	12.40 (2.39)
Sightability at 1m in height (m)	33.72 (3.16)
Sightability at 2m in height (m)	37.46 (3.65)
Transition zone width (m)	12.41 (2.42)
Canopy cover overstorey (%)	36 (21.8)
Canopy cover understorey (%)	24 (23)
Average number of dead standing trees	3 (6.4)
Midpoint basal area	25 (21.7)
Endpoint basal area	24.3 (19)
Dominant species Percent cover, trees >5m,	Black spruce 43 (24.2)
Dominant species Percent cover, trees >2m and <5m	Low-sweet blueberry 45 (19.6)



A



B

Figure 7. The relationship between the total number of moose trails and reserve width (A) and the total number of moose trails and the time since last cut (B) in the clear-cut silvicultural system.

Table 15. Correlation coefficients between the total number of moose trails and site characteristics in the clear-cut silvicultural system.

Site Characteristic	Correlation
Reserve width	0.211
Time since last cut	0.130
Length of aquatic vegetation along shore	0.127
Canopy Cover overstorey	0.113
Percent cover trees >5m	0.020
Midpoint basal area	0.013
Sightability distance 1m	-0.007
Distance to trees >5m	-0.008
Distance to trees >2m	-0.024
Canopy cover understorey	-0.037
Distance of aquatic vegetation from shore	-0.041
Sightability distance 2m	-0.071
Endpoint basal area	-0.093
Number of dead standing trees	-0.096
Percent cover trees >2m and <5m	-0.177

There was no model predicted with the Stepwise Multiple Regression for the clear cut silvicultural system.

Overall Data

Among the three silvicultural systems, moose used reserves in the selection cut more intensively (mean number of trails ± 1 SE = 7.7 ± 4.7) than in the shelterwood cut (mean number of trails ± 1 SE = 6.8 ± 2.7), and reserves in the shelterwood cut more intensively than in the clear-cut (mean number of trails ± 1 SE= 4.7 ± 3.8) silvicultural system (Figure 8).

However, the way moose used sites was more similar between the selection cut and clear-cut silvicultural systems than the shelterwood cut silvicultural system. There were more common variables correlated with the level of moose use in the selection and clear-cut silvicultural systems than in the shelterwood sites (Tables 7, 11, and 15). As well, the patterns of use among reserve widths and time since last cut were more similar between the selection and clear-cut systems than the shelterwood cut system. Moose use increased with wider reserves and older cuts in the selection and clear-cut systems, whereas moose use increased with wider reserve widths but declined as the time since last cut increased in the shelterwood system. However, the length of aquatic vegetation along the shore, and reserve width were positively correlated with moose use in all three silvicultural systems. Therefore, there was more moose use at larger aquatic sites and, as reserve width increased, the total number of trails increased.

The dominant wetland type (W3, W4) among all sites sampled was similar among the three Forest Management Units (Tables 5, 9, and 13). W3 is an open water marsh with mixed organic substrate (Harris et al 1996). The water is < 2m deep with emergent, submergent, and floating-leaved aquatic plant species. There are only a few plant species (sometimes only one)

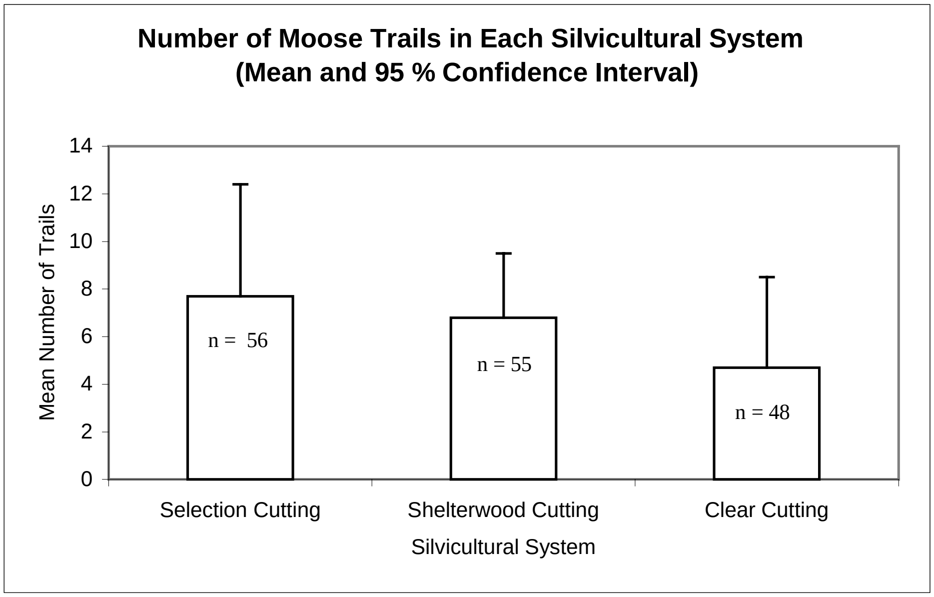


Figure 8. Mean number of moose trails at sites in each silvilcultural system.

present in these wetlands (Harris et al. 1996). W4 is an open water marsh with floating-leaved plants covering >50% of the water surface. Few plant species are present and species composition is variable. Aquatic plant species at these sites include watershield (*Brasneria schreberi*), white water lily (*Nymphaea tetragona*), and large-leaf pondweed (*Potamogeton amplifolius*).

Discussion

The three harvesting systems used in this study have differing effects on the landscape, which results in a difference in reforestation (i.e., a monoculture or a mixed wood) and the type of habitat available to moose. However, this study has shown that reserve width, time since last cut, and type of silvicultural system practiced all had an association with the use of aquatic feeding areas by moose.

Reserve Width

Reserve width was found to be statistically important in both the selection cut and shelterwood cut systems (Figure 3A, 5A) but not in the clear-cut system (Figure 7A). However, the same pattern of moose use was evident in all three silvicultural systems; moose use increased with an increase in reserve width. The lower number of sites sampled and the lower density of moose in the clear-cut system compared to the others may have affected the significance of reserve width in the study. Nonetheless, wider reserves (>120m) were used more frequently than narrower reserves (<120m) in the clear-cut system (Figure 7A).

Reserves around aquatic feeding areas are important to moose because they offer more available habitat. A moose's home range encompasses more than a single clear-cut patch (Potvin et al. 1999) and, therefore, reserve widths become important because there are few areas left that offer security. Timmermann and Racey (1989) discussed the importance of shoreline reserves for allowing moose free access to and from aquatic feeding sites. Moreover, reserves adjacent to aquatic feeding areas offer more than just a travel corridor to the water. Larger treed reserves provide more entry points to the water (Timmermann and Racey 1989), a diversity of both terrestrial and aquatic browse (Belovsky et al. 1973), greater area to support more than one moose (deVos 1958; Fraser et al. 1980), and they may help with thermoregulation (Peterson 1977; Jackson et al. 1991). If moose avoid areas of timber harvest, and insufficient treed reserves are available around aquatic feeding areas, moose may not use them. By lowering the number of MAFAs available to moose, this also decreases the availability of aquatic plants to satisfy their nutritional requirements in spring and summer (Belovsky et al. 1973).

Moose feed on both aquatic plants and terrestrial vegetation in spring and summer. Belovsky et al. (1973) studied the diets of moose in two different study areas (one area was more boreal, the other offered coastal vegetation characteristics) on Isle Royale and found them to be similar. They suggested that the diversity of browse available within these areas influenced the selection of habitat by moose (Belovsky et al. 1973). Areas that offer a diversity of browse enhance the overall quality of the habitat and when moose can forage on both terrestrial and aquatic browse they will use those areas more frequently (Belovsky et al. 1973; Peek et al. 1976). Therefore moose may prefer to use aquatic feeding areas if the adjacent reserve can also supplement a summer diet rich in terrestrial browse.

Brusnyk and Gilbert’s (1983) study of the use of shoreline reserves by moose in the Chapleau Game Preserve found that in winter moose preferred reserves over cut areas. These reserves were correlated with the proximity of adequate coniferous cover and an abundant source of browse. They found that 70% of browsing at sites occurred within the shoreline reserves. I found terrestrial browsing at sites within all silvicultural systems (Appendix VII) and sites with more available browse had higher intensities of moose use in summer. My results support Joyal and Scherrer (1978) who suggest that terrestrial browsing adjacent to aquatic feeding areas is an important factor in the use of a site by moose.

The shoreline reserves studied by Brusnyk and Gilbert (1983) had both summer and winter pellet groups present. I also found that many of the reserves sampled had both summer and winter pellet groups. This indicates that these reserves are being used in winter as adjacent cover to cut blocks, as moose forage in cutover areas at that time (Brusnyk and Gilbert 1983).

Timmermann and Racey (1989) suggested that a treed reserve might only be needed adjacent to the actual feeding area or main entry points that moose use. In this study, trails were present from beyond the shoreline of aquatic vegetation but were only followed up to 5m outside the aquatic vegetation boundary. Therefore, I cannot verify the extent of shoreline that would actually require a reserve for moose using these sites.

My study found that the use of aquatic feeding areas by moose is not solely based on the width of the adjacent reserve. Habitat characteristics within the reserve, the time since last cut adjacent to the reserve, and the amount of disturbance at a site jointly influence a moose in selecting a foraging area. These results are supported by studies of deVos (1958), Jordan et al. (1973), Peek et al. (1976), Fraser et al. (1980), and Timmermann and Racey (1989).

Time Since Last Cut

The time since last cut adjacent to aquatic feeding areas was statistically important in the selection cut system (Figure 3B) but not in the shelterwood cut (Figure 5B) or the clear-cut systems (Figure 7B). Joyal and Scherrer (1978) studied summer movements and feeding by moose in western Quebec where they considered a 10-year-old logged area to be good moose range. This was similar to the pattern of moose use in the selection cut and clear-cut systems that I studied, in which moose use increased with older cuts (i.e., cuts >10 years). Older forests provide better habitat for moose; there is more available browse and protective cover, which enhance the overall security for moose. Courtois et al. (1998) found that although moose in Quebec increased their daily movements immediately after a clear-cut, they detoured around clear-cut patches because moose rarely use recent clear-cuts (Brusnyk and Gilbert 1983). On the other hand, Potvin et al. (1999) found that moose density decreased immediately in areas after logging, suggesting that moose tend to avoid recent disturbances.

The pattern of use in the shelterwood cut system was different compared to that in the selection cut and clear-cut systems. As the time since last cut increased in the shelterwood cut system, the use of aquatic feeding areas by moose decreased. In this study area, the type of cut pattern together with the age of the cut may influence moose activity. A shelterwood cut might be different than a selection cut or a clear-cut in that it may produce high quality habitat with sufficient cover at a younger age than other harvesting systems. After studying the forest management planning process in Ontario, Payne et al. (1988) suggested that certain cutting patterns improve moose habitat. A seed tree shelterwood cut system leaves dispersed uncut timber throughout the harvested area thereby improving natural regeneration. This creates a more valuable ‘edge effect’ hence improving moose habitat (Payne et al. 1988) and may explain why moose were using sites adjacent to recent cuts more in the shelterwood system than in the selection or the clear-cut systems. This also indicates that the site selection process by moose includes consideration of the quality of habitat within the reserve, as well as the characteristics of the adjacent cutover (Peek et al. 1976).

Reserve Width and Time Since Last Cut

Although the 2-way ANOVAs indicated that reserve width and the time since last cut influenced moose use independently, there is evidence that the interaction of the two variables had an effect on how moose chose to use an aquatic feeding area. In the selection cut and clear-cut systems, there was greater use of aquatic feeding areas by moose where the reserve width was >120m regardless of the time since last cut. There was also more variation in the use of reserve widths around aquatic feeding areas in these two systems when the adjacent cut was >10 years old. Under natural conditions, stand age regulates forest characteristics. The vertical structure and spatial arrangement of the vegetation begins to blend with age, regardless of buffers left by harvesting (Kimmins 1997). Thus, the interaction of age and reserve width is important in the response by moose to an area, because once a stand reaches a certain age (approximately 10-20 years) it acts as a continuous piece of habitat regardless of reserve width.

Moose demonstrated a slightly different pattern of use in the shelterwood cut silvicultural system. Reserve width was statistically related to, and positively correlated with, moose use (Table 11). However, time since last cut was not statistically important and was negatively correlated with moose use in the shelterwood cut system (Table 11). Time since last cut had a different effect on the use of aquatic feeding areas by moose in the shelterwood cut system. As the time since last cut increased, the level of moose use declined. In this system, greater moose use occurred in recent cuts with reserve widths >120m.

During summer months in northeastern Minnesota, Peek et al. (1976) found that moose commonly used aquatic communities and sparsely stocked stands with a dense shrub understorey. Shelterwood cuts do not remove the entire canopy and therefore provide a rich understorey of vegetation along with a diversity of available browse. The recent cut blocks (0-10 years) in the shelterwood cut system, adjacent to reserves, could be supporting more available terrestrial browse and attracting moose to the terrestrial browse on their way to feed on aquatic vegetation. In this study, over 50% of the sites sampled had evidence of terrestrial browsing within the adjacent reserve (Appendix VII). In the selection and clear-cut systems there was more evidence of aquatic browsing than terrestrial browsing. Cutovers were not sampled for evidence of moose use and therefore I cannot confirm the intensity of use, if any, of the cutover areas.

Patterns of Moose Use of Reserves

The patterns of moose use of reserves in this study are based on indirect evidence of moose use (trails, tracks, pellet-groups, browsing). Therefore, I am unable to determine how many aquatic feeding areas were used by one moose or how many moose used the same MAFA. However, I am able to describe patterns of moose use based on the direction of travel by moose with respect to physical features and habitat characteristics within adjacent reserves and silvicultural system.

Timmermann and Racey (1989) found that shoreline characteristics had the strongest influence on where moose entered the water at Joeboy Lake, Sleeping Giant Provincial Park, yet Costain and Matchett (1992) found it difficult to summarize the preferred characteristics surrounding aquatic feeding areas. These observations were shared by deVos (1958), Cobus (1972), and Fraser et al. (1980). There is much debate on the different feeding behaviours of moose at aquatic feeding areas. deVos (1958) observed moose feeding at one MAFA while other MAFAs had no moose. Fraser et al. (1980) observed moose in the Chapleau Game Preserve and found that feeding locations by some moose throughout the summer did not change. He observed one moose using Cooke Lake intensely for a few days and then it departed while another moose was observed in the same lake for two days and then never seen again. Costain and Matchett (1992) suggest that moose may be attracted to feeding sites by something other than the presence of aquatic plants. When they observed moose selecting aquatic feeding sites in British Columbia, they reported that one moose walked past a number of MAFAs before settling to feed at the Yaak River; other moose chose to stop at those same aquatic sites to feed. Fraser et al. (1980) reported that moose were attracted to a lake in the Chapleau Game Preserve when there was abundant woody vegetation in logged areas nearby. This suggests that moose are attracted to aquatic feeding areas when the adjacent reserve can also provide quality habitat.

Typically, there were two main moose trails leading to shore in the shelterwood cut silvicultural system. In more recent cuts (0-10 years old), one trail usually followed the edge of the cut block with trails leading off perpendicular through the reserve to the water. Secondary trails led into the cut block from this edge trail, suggesting that moose were using the entire reserve for cover while feeding in the cutover, and as protective cover in accessing the water. The other main trail lay parallel to the shoreline and had multiple trails leading off into the water. With narrower reserves (<120m), it was more common for moose to enter the reserve from a trail parallel to the shoreline. The main trail along the edge of a cut block was not always present at sites with narrower reserves in the shelterwood cut system.

Moose had many entry points to aquatic feeding areas in the selection cut system. At older cut sites, moose use was variable. Moose entered the MAFA from the cut block into the reserve and walked perpendicular to the water’s edge. On occasion, moose traveled parallel to the shoreline until they reached the aquatic vegetation. In recent cuts, it was more common for moose to enter the MAFA from the side of the reserve paralleling the shoreline and on occasion they would walk through a recent cut block into the reserve. There was often a heavily used trail that paralleled the shoreline with smaller trails leading into the water.

The pattern of moose use of reserves was similar between the clear-cut and selection cut systems. In no cut areas (>20 years) moose entered MAFAs from the cut block to the shore. In recent (0-10 years) and older cuts (10-20 years), it was more common for moose to enter a MAFA parallel to the shore. The avoidance of cut blocks in recent and older cuts suggests that moose are affected by the disturbance caused by timber harvest.

Timmermann and Racey (1989) identified a combination of trail use patterns. They found individual trails leading to shore, trails that were well spaced with only one interconnection, and found that the longest and most used trails were often associated with old logging roads (Timmermann and Racey 1989). I found the same interconnection of trails, as well as a main trail system, in most areas. Roads were the most common disturbance type in all three FMUs. I found that old roads (primary, secondary, and tertiary) might have enhanced moose use of the area. In the clear-cut system, roads often split reserves due to the physical features of the landscape. These roads were used as a main trail and moose walked off the road perpendicular to the shore.

In their study at Joeboy Lake, Sleeping Giant Provincial Park, Timmermann and Racey (1989) found that moose trails were influenced by slope. They found moose trails ran perpendicular to shore when the slope was <30% but where slopes were >30%, moose trails followed the contour of the slope before entering the MAFA. This same pattern was evident in all three silvicultural systems that I studied. However, because I used the OMNR MAFA ranking system (Ranta 1988) in the site selection process, characteristics such as slope, aspect, pond size, and aquatic vegetation were already taken into consideration. Therefore, there were only a few sites with a slope >30%. There were more sites with slopes >30% in the clear-cut system than the shelterwood or clear-cut areas due to differences in physical landscape features of each area. Where slopes were <30% there were more trails perpendicular to shore compared to sites with a slope of >30%, where trails ran more parallel to the water's edge.

Overall, there was more use of aquatic feeding areas by moose where reserve widths were >120m. The pattern of use among sites was specific to age, reserve width, and the type of cut that occurred in the area. The general pattern of reserve use among all three silvicultural systems indicates that moose were avoiding the disturbance of timber harvest and walked from areas that had not been disturbed. Moose also followed the shoreline, depending on shoreline characteristics, until they reached the aquatic vegetation. In areas that had been disturbed, moose returned to those sites approximately 10-15 years after the cut. This suggests that once a preferred age of the forest is reached, reserve width becomes less important as the cut block and reserve blend into one continuous forest (Kimmins 1997); approximately >15 years.

Silvicultural System

There has been little research done in the Great Lakes – St. Lawrence forest region detailing the response to partial cutting practices by moose throughout their seasonal habitat. Without studying the three silvicultural systems in one geographic area, direct comparisons of harvesting systems on the use of aquatic feeding areas by moose cannot be made. Because each silvicultural system leaves a different pattern on the landscape, it can be expected that moose will alter their pattern of use according to the type of disturbance.

Each Forest Management Unit that I studied is in a distinct geographic area that offers unique physical and vegetative characteristics. Although the areas lie within a transition zone of two forest regions (Farrar 1995), certain tree species become more dominant the more north or south of the transition. Therefore, as the Spanish FMU (clear-cut) is more northerly, it is representative of more northern boreal conifer communities, while the Algonquin FMU (selection cut) is more southerly and representative of more southern deciduous tree species (Farrar 1995). Moose densities in each FMU are also at different capacity, with higher moose densities in the Algonquin FMU followed by the French-Severn FMU and Spanish FMU, respectively (A. Rodgers, OMNR, personal communication). With these factors combined, I cannot accurately explain why there were higher levels of intensity of moose use in the selection cut followed by the shelterwood cut and clear-cut, respectively, although the pattern of use appears to correspond with moose density. Although the silvicultural system was different in each FMU, a comparison can be made of the site-specific characteristics that were measured across all sites, such as canopy cover, shrub density, and sightability distance.

The clear-cut and selection cut systems were used in similar ways by moose. Moose use was positively correlated with basal area, sightability distance, percent shrub cover, and understorey canopy cover. These four habitat characteristics represent a measure of protective cover. Vegetative cover is an important habitat component during all seasons for moose (Timmermann and McNicol 1988). Lateral cover helps with thermoregulation by providing shade, blocking the wind and sun, and acts as concealment to protect from predators (Timmermann and McNicol 1988) by providing a secure hiding and resting place (Timmermann and Racey 1989; Jackson et al. 1991). Moose are more vulnerable to predation when open areas are nearby, such as roads and trails, because they allow for easier travel by predators (Kunkel and Pletscher 2000) and exposure to hunters (Rempel et al. 1997).

Endpoint basal area measurements were smaller than the midpoint basal area due to adjacent cut blocks. Using basal area as an estimate of tree cover is helpful because it is directly linked to the contribution of individual trees in providing protective cover (Cade 1997). Canopy closure is a useful measure of the contribution of tree crowns to providing thermal cover (Cade 1997). The percent canopy cover for both understorey and overstorey was positively correlated with moose use in the shelterwood cut and clear-cut systems and negatively correlated with moose use in the selection cut system. These relationships are due to the type of cut practiced. A selection cut may be dominated by remaining hardwood trees (yellow birch, maple, aspen) that suppress browse species in the understorey (Jackson et al. 1991).

The length of aquatic vegetation along the shore was positively correlated with moose use in all three silvicultural systems. Moose may use the longer shoreline of aquatic vegetation to compensate for a narrower reserve. A greater length of aquatic vegetation along the shore also allows for greater abundance, distribution, and diversity of aquatic plants available at one site (deVos 1958; Belovsky et al. 1973; Fraser et al. 1984), and allows for more entry points to the water (Timmermann and Racey 1989). Because the Timber Management Guidelines (OMNR 1988) recommend a 120m reserve only adjacent to aquatic vegetation, the longer the aquatic shoreline, the more protective cover left after harvesting.

Timber harvest can reduce the quality of habitat for wildlife by changing the distribution and type of food and shelter available (Jackson et al. 1991; Kimmins 1997). However it has also been suggested that timber harvest can enhance habitat available for moose (Payne et al. 1988). Moose are highly adaptable and can cope with varying disturbances including timber harvest and fire (Spencer and Hakala 1964; Costain and Matchett 1992; Potvin et al. 1999), insect outbreaks, herbicide spraying, and blowdown (Germain et al. 1990). Moose have demonstrated this by colonizing new areas where fire or logging has disrupted the landscape, or simply moving to new areas with more available browse (Costain and Matchett 1992). Timber harvest creates an “edge effect” that borders two ecotones; the cut area and the uncut area. Moose have adapted to using this edge effect and research has shown that harvesting systems such as a clear-cut or a shelterwood cut with adjacent cover nearby can provide good moose habitat (Payne et al. 1988). Potvin et al. (1999) found that moose avoided clear-cut patches, preferring uncut patches with dense shrub layers and conifer regeneration within their home range. In early winter, moose have been observed using cutovers with adjacent cover nearby for browsing (Jackson et al. 1991). Although, clear-cuts may quickly produce sufficient regeneration for moose browse, the negative effect of clear-cutting may last from 10-15 years; the time needed for lateral cover to grow (Potvin et al. 1999). New, clear-cut patches are not suitable for many wildlife species such as ruffed grouse, marten, snowshoe hare, and moose, unless cutovers provide necessary requirements such as large trees, snags, and coarse woody debris (Courtois et al. 1998; Potvin 1998).

Importance of Reserves for Other Wildlife

Although reserves are left around aquatic feeding areas to protect their use by moose, other animals are also using the reserves. While observing moose at aquatic feeding areas, deVos (1958) observed the abundance of other animals present including beavers, muskrats, waterfowl, and other big game species that were also feeding at these sites. I also observed other wildlife such as birds (Appendix VIII) and other mammals (Appendix IX) using both the aquatic and terrestrial areas. The riparian area of these sites, ‘the transition between the aquatic environment of a wetland and the upland terrestrial environment that is subject to periodic flooding’ (Molles 1999), also provides habitat for many amphibians and reptiles such as frogs, salamanders, and turtles; which is supported by my observations (Appendix X). Species richness at sites sampled varied among the three silvicultural systems. Higher numbers of other mammals and amphibians were present in the selection cut (12 mammal species, 6 amphibian species) and shelterwood cut (11 mammal species, 6 amphibian species) systems compared to sites sampled in the clear-cut system (7 mammal species, 3 amphibian species). There were few reptiles found among all three silvicultural systems. The shelterwood cut system had the highest number of avian species observed (32 species), followed by the clear-cut (29 species) and the selection cut (21 species), respectively.

Summary

This study indicates that both reserve width and the age of adjacent timber are important in determining moose use of aquatic feeding sites, regardless of the silvicultural system practiced. There was more use of sites by moose in the selection cut than in the shelterwood cut and more use of sites in the shelterwood cut than in the clear-cut. In all three silvicultural systems, there was more use of sites with greater reserve widths as well as access to both terrestrial and aquatic browse.

The reserves sampled in this study show evidence of use annually by moose; they browse in adjacent cutover areas in winter, and use reserves as a secure travel route to feed on aquatic vegetation in summer. Because aquatic plants are an important source of nutrients for moose in spring and summer, forest management practices must ensure proper protection of these sites. This study has shown that when applying a reserve, the time since last cut and the type of silvicultural system being used must be considered because the quality of the habitat within the adjacent reserve is important for moose using these sites. Although moose used aquatic feeding areas adjacent to narrow reserves (<60 m), the results of this study show that sites adjacent to 120-m reserves, as recommended in the *Timber Management Guidelines for the Provision of*

Moose Habitat, were used the most and have the greatest potential of meeting the life history requisites of moose in all three silvicultural systems.

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APPENDICES

Appendix I

Locations, proximity of cuts, reserve widths, and year of last cut of sites sampled in the Algonquin Forest Management Unit.

Site Number	Easting	Northing	Proximity of Cut (m)	Reserve Width (m)	Year of Last cut
1	0723247	5065355	50	50	1983
2	0710791	5059090	60	60	1990
3	0710235	5069598	30	30	1992
4	0713243	5065741	120	120	1982
5	0719372	5068374	57	57	1985
6	0726642	5062672	110	120	1982
7	0716834	5020843	38	38	1988
8	0716056	5021667	44.7	44.7	1988
9	0716139	5022739	37.3	37.3	1987
10	0715892	5021727	38.7	38.7	1985
11	0715854	5022367	43	43	1987
12	0714995	5024002	41	41	1988
13	0713867	5025138	62.7	62.7	1986
14	0701740	5062377	53.7	53.7	1998
15	0708678	5057521	98	120	1984
16	0718040	5025323	45	45	1987
17	0697909	5066279	120	120	1982
18	0711010	5028963	55	60	1996
19	0711784	5029433	56	56	2000
20	0712100	5029234	50.7	50.7	2000
21	0697419	5034700	56.3	60	1983
22	0691570	5036278	120	120	1998
23	0693456	5036573	36.7	30	1994
24	0692390	5038173	30	30	1994
25	0698685	5032537	120	120	1999
26	0699496	5033051	60	60	2000
27	0695766	5033895	38.7	38.7	1983
28	0697116	5035060	34	34	1983
29	0698092	5036676	66.7	120	1980
30	0698618	5037832	120	120	1997
31	0709727	5061231	39.3	39.3	1989
32	0701586	5050385	120	120	1982
33	0697481	5040762	37.7	37.7	2000
34	0711312	5028253	34.3	34.3	1995
35	0713123	5028098	120	0	1985
36	0716014	5031624	90.3	90.3	1983
37	0718937	5017030	31	31	1983

Site Number	Easting	Northing	Proximity of Cut (m)	Reserve Width (m)	Year of Last cut
38	0720306	5016313	54.3	120	1982
39	0701640	5044744	120	120	1982
40	0701826	5055852	37.7	37.7	1993
41	0701519	5055900	62	62	1993
42	0693716	5036856	120	120	1982
43	0696098	5034258	33.7	33.7	1984
44	0703660	5050290	180	180	1982
45	0703991	5057708	180	180	1982
46	0701292	5057394	69	69	1984
47	0679803	5048212	120	120	1982
48	0685273	5047408	120	120	1982
49	0701651	5058430	63.7	63.7	1982
50	0701785	5056452	45.7	45.7	1987
51	0678307	5049277	120	120	1982
52	0708542	5052262	120	120	1982
53	0703436	5050696	120	120	1982
54	0712728	5048726	120	120	1982
55	0678835	5048651	120	120	1982
56	0712670	5048603	120	120	1982

Appendix II

Locations, proximity of cuts, reserve widths, and year of last cut of sites sampled in the French-Severn Forest Management Unit.

Site Number	Easting	Northing	Proximity of cut (m)	Reserve Width (m)	Year of Last Cut
1	0546947	5081466	120	0	1998
2	0542347	5078724	120	0	2000
3	0541844	5079584	36	36	2000
4	0542953	5079286	48.3	48.3	2000
5	0543878	5079505	120	0	1998
6	0547613	5081868	120	0	1997
7	0548465	5081201	115	0	1997
8	0548020	5080664	120	0	1997
9	0548504	5081921	120	100	1997
10	0553870	5081965	120	120	1985
11	0553172	5080011	36.7	36.7	1985
12	0553108	5079161	106.6	106.6	1985
13	0556389	5095471	100.7	100.7	1993
14	0557184	5095912	97	97	1989
15	0558773	5096408	40	40	1995
16	0558252	5096756	107.7	107.7	1995
17	0559642	5095875	120	120	1995
18	0534849	5076863	120	120	1982
19	0546296	5081243	120	0	1998
20	0547268	5079232	120	0	1979
21	0537912	5078320	120	120	1982
22	0537628	5077784	44.7	44.7	2001
23	0556530	5078562	120	120	1987
24	0552283	5078556	36.3	36.3	1982
25	0555998	5078354	37.7	37.7	1986
26	0555272	5077312	120	120	1985
27	0556573	5078805	39	39	1989
28	0551520	5059357	120	120	1982
29	0551511	5055624	120	120	1982
30	0549743	5054188	120	120	1979
31	0551617	5059110	45	120	1979
32	0549436	5054293	120	120	1979
33	0552967	5048874	120	60	2000
34	0537227	5077589	34.7	34.7	2000
35	0552974	5049185	120	0	1999
36	0552018	5055346	120	120	1985
37	0554965	5094852	90	90	1985
38	0553293	5053717	51.7	120	1978
39	0547213	5079710	39.3	120	1981

Site Number	Easting	Northing	Proximity of cut (m)	Reserve Width (m)	Year of Last Cut
40	0553501	5053575	45	120	1981
41	0553628	5053743	78.3	78.3	1978
42	0553371	5053168	48.3	120	1978
43	0551775	5059111	51.3	120	1982
44	0560087	5039880	103.7	103.7	1982
45	0550608	5055785	120	120	1980
46	0551411	5059134	40	40	1984
47	0548310	5055612	120	0	1982
48	0549968	5053345	120	120	1979
49	0549763	5052574	120	120	1982
50	0549959	5051794	120	120	1982
51	0549944	5051650	120	120	1982
52	0550289	5055937	120	120	1982
53	0569358	5035304	58	58	1982
54	0567852	5032052	120	120	1982
55	0551642	5058705	81.7	81.7	1982

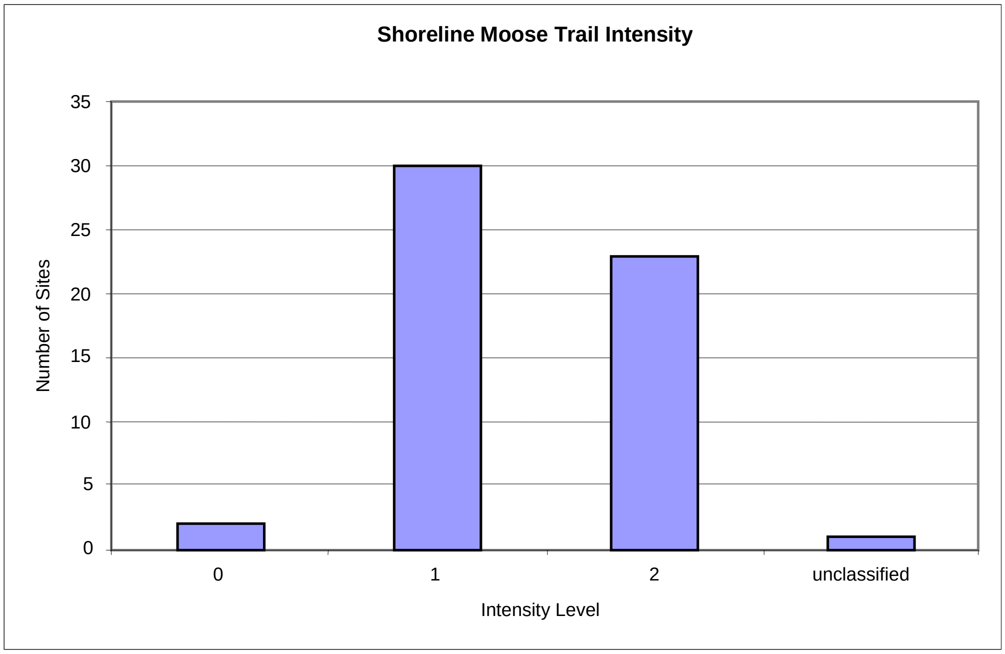
Appendix III

Locations, proximity of cuts, reserve widths, and year of last cut of sites sampled in the Spanish Forest Management Unit.

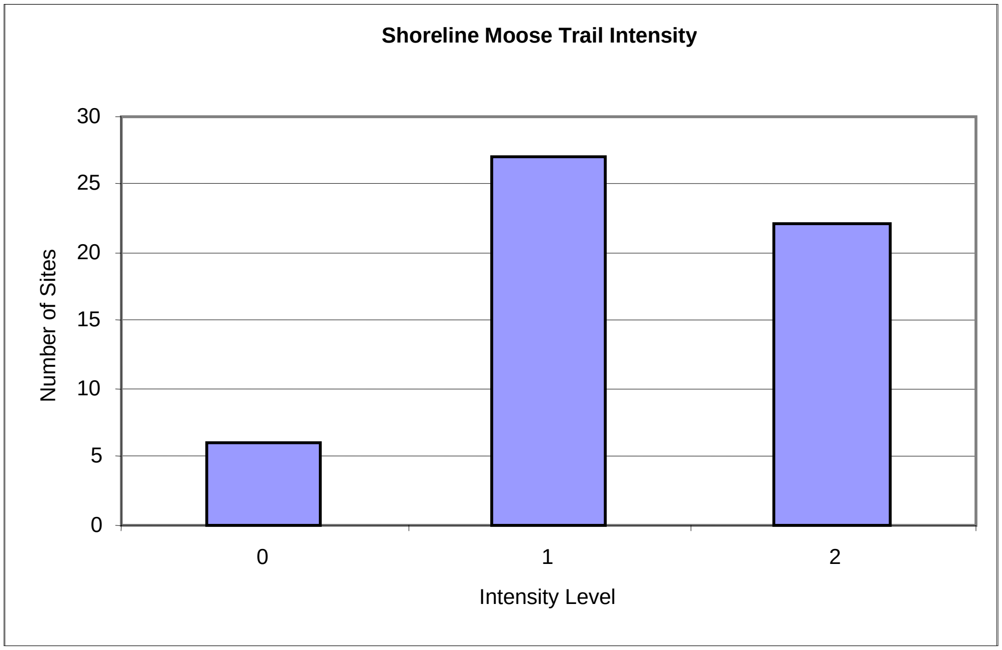
Site Number	Easting	Northing	Proximity of Cut (m)	Reserve Width (m)	Year of Last Cut
1	0403700	5204493	120	0	1992
2	0407159	5206095	90	90	1993
3	0407177	5195530	120	120	1982
4	0393242	5211266	80	80	1989
5	0392608	5212672	120	120	1986
6	0402609	5202050	120	120	1993
7	0399068	5220484	120	120	1989
8	0398721	5220578	64.7	120	1986
9	0390477	5206906	120	120	1987
10	0392929	5209397	120	120	1985
11	0394656	5207023	120	95	1987
12	0394845	5206589	105	105	1988
13	0395523	5206145	120	120	1988
14	0389270	5205791	120	120	1988
15	0395748	5219713	120	0	1999
16	0402896	5204811	86	80	1991
17	0406670	5201666	38.3	30	1993
18	0405504	5203794	120	120	1993
19	0405213	5203853	120	120	1982
20	0405964	5207983	109.7	110	1998
21	0403734	5206690	120	120	1992
22	0403972	5210727	40	40	1987
23	0417402	5175616	120	0	1988
24	0422591	5166269	120	120	1999
25	0408472	5182756	120	0	1989
26	0411226	5202210	120	90	1994
27	0411572	5201853	120	120	1994
28	0416504	5176904	120	9999	1988
29	0430638	5169047	120	120	1982
30	0430836	5169401	120	120	1982
31	0408255	5182793	81.7	80	1989
32	0411507	5181172	42.7	43	1990
33	0404908	5187942	78.3	78	1997
34	0411322	5180518	67.3	65	1991
35	0406152	5186016	120	120	1997
36	0427845	5164927	120	120	1982
37	0428357	5165353	120	120	1982
38	0428885	5175413	120	120	1982

Site Number	Easting	Northing	Proximity of Cut (m)	Reserve Width (m)	Year of Last Cut
39	0430946	5175030	120	120	1999
40	0425216	5176114	120	120	1982
41	0426095	5175655	120	120	1982
42	0415723	5171306	120	0	1990
43	0417459	5177578	120	0	1992
44	0416155	5170365	120	0	1990
45	0416173	5170951	36.7	36.7	1990
46	0417592	5171377	120	120	1989
47	0406637	5186515	105	105	1996
48	0436500	5172503	120	0	1997

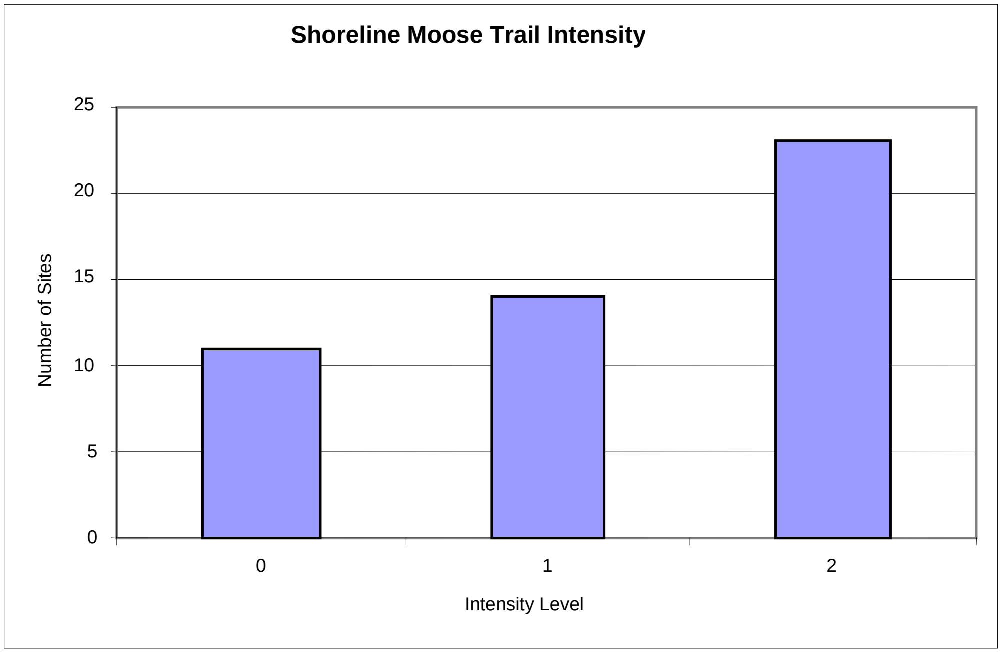
Appendix IV



Intensity levels of shoreline moose trails at sites (n=56) in the selection cut silvicultural system (0=not present, 1=less than 5 trails, 2=more than 5 trails along the shoreline, or trails heavily used).

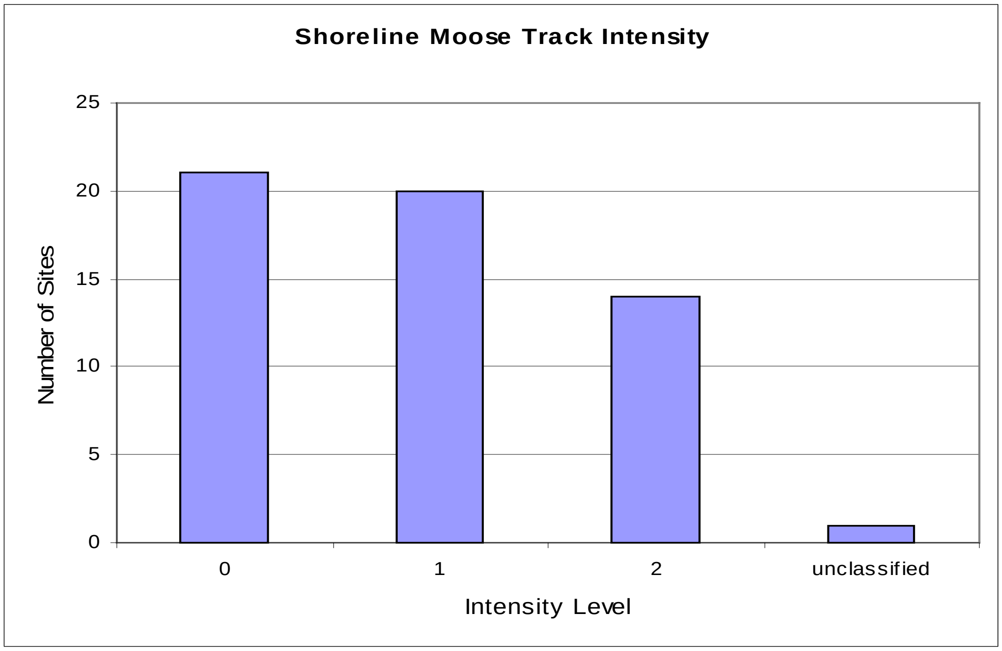


Intensity levels of shoreline moose trails at sites (n=55) in the shelterwood cut silvicultural system (0=not present, 1=less than 5 trails, 2=more than 5 trails along the shoreline, or trails heavily used).

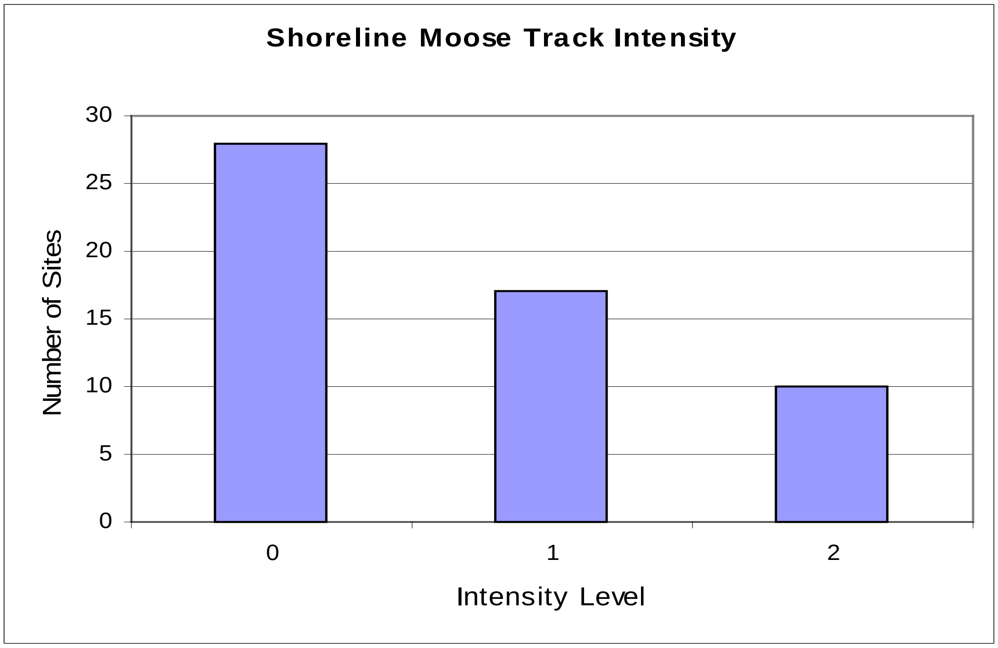


Intensity levels of shoreline moose trails at sites (n=48) in the clear-cut silvicultural system (0=not present, 1=less than 5 trails, 2=more than 5 trails along the shoreline, or trails heavily used).

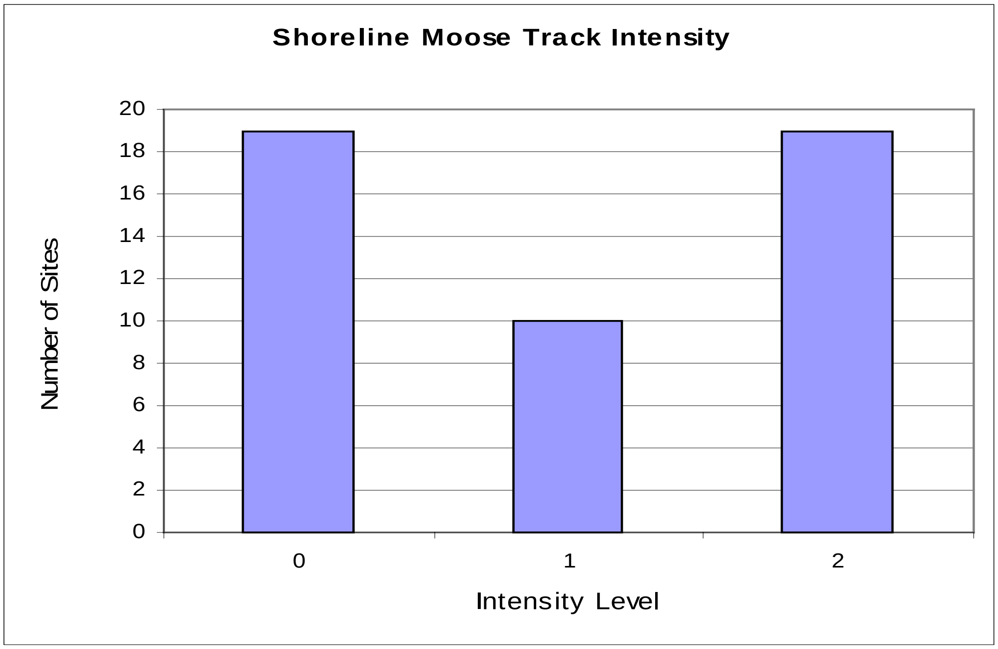
Appendix V



Intensity levels of shoreline moose tracks at sites (n=56) in the selection cut silvicultural system (0 = not present, 1 = less than 3 sets of tracks, 2 = more than 3 sets of tracks).

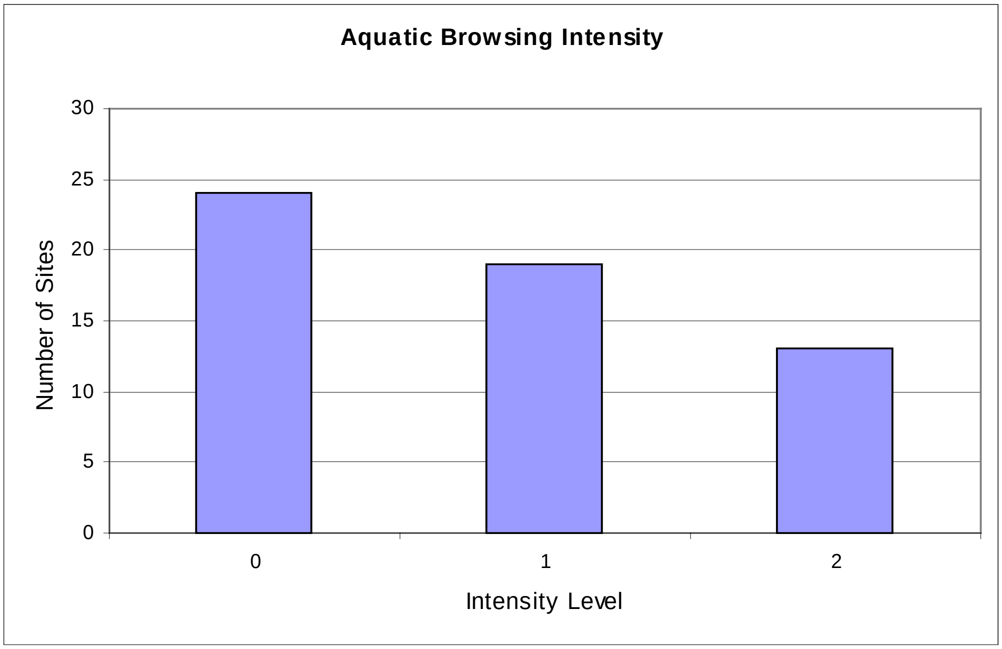


Intensity levels of shoreline moose tracks at sites (n=55) in the shelterwood cut silvicultural system (0 = not present, 1 = less than 3 sets of tracks, 2 = more than 3 sets of tracks).

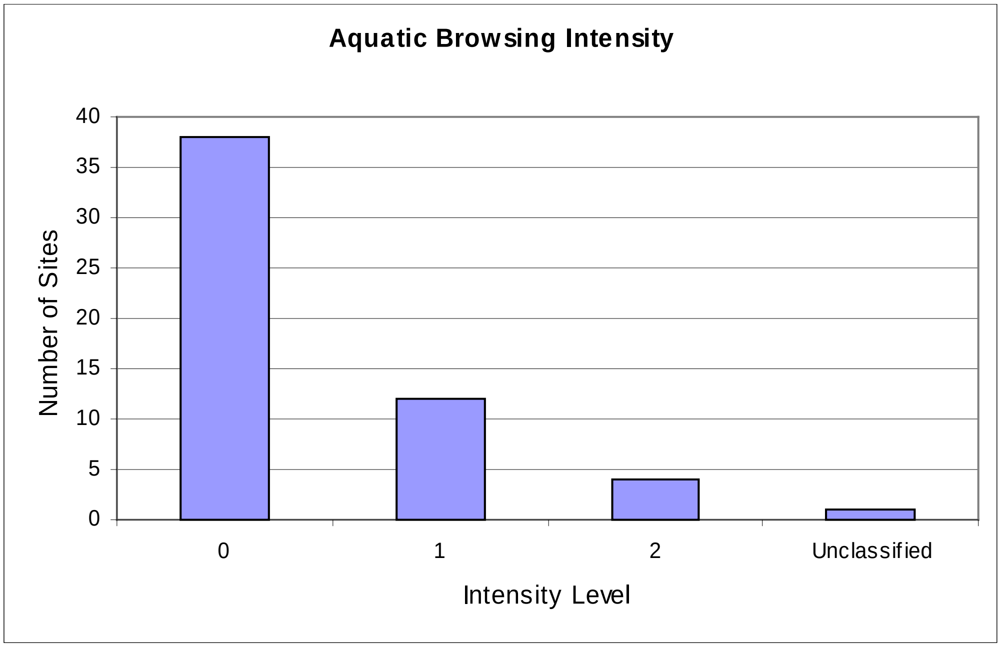


Intensity levels of shoreline moose tracks at sites (n=48) in the clear-cut silvicultural system (0 = not present, 1 = less than 3 sets of tracks, 2 = more than 3 sets of tracks).

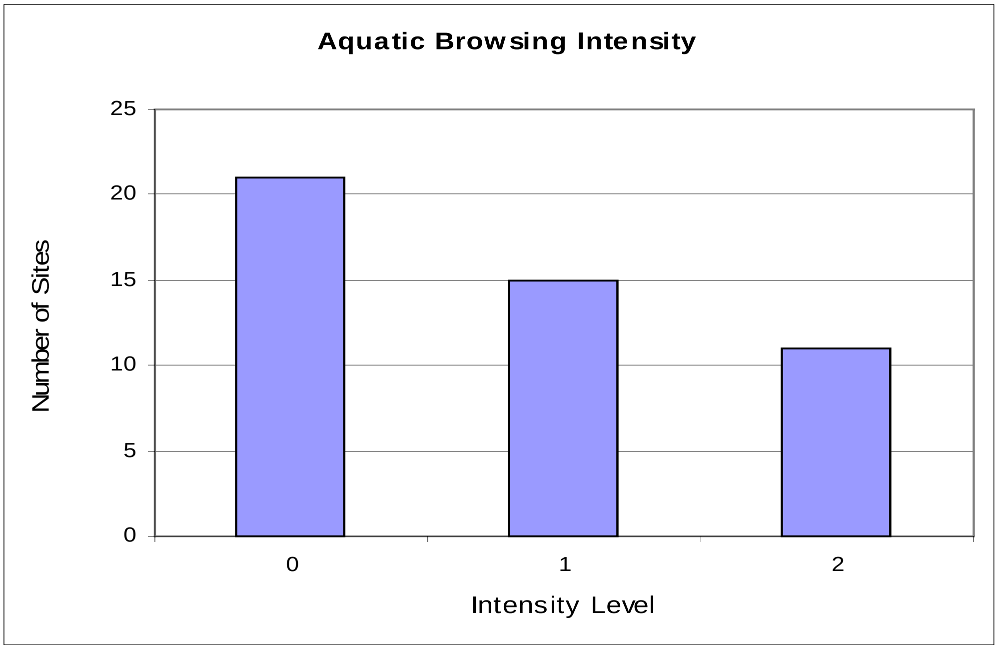
Appendix VI



Intensity levels of aquatic browsing by moose at sites (n=56) in the selection cut silvicultural system (0= not present, 1 = less than half of the shoreline aquatics were browsed, 2 = more than half the shoreline aquatics were browsed).

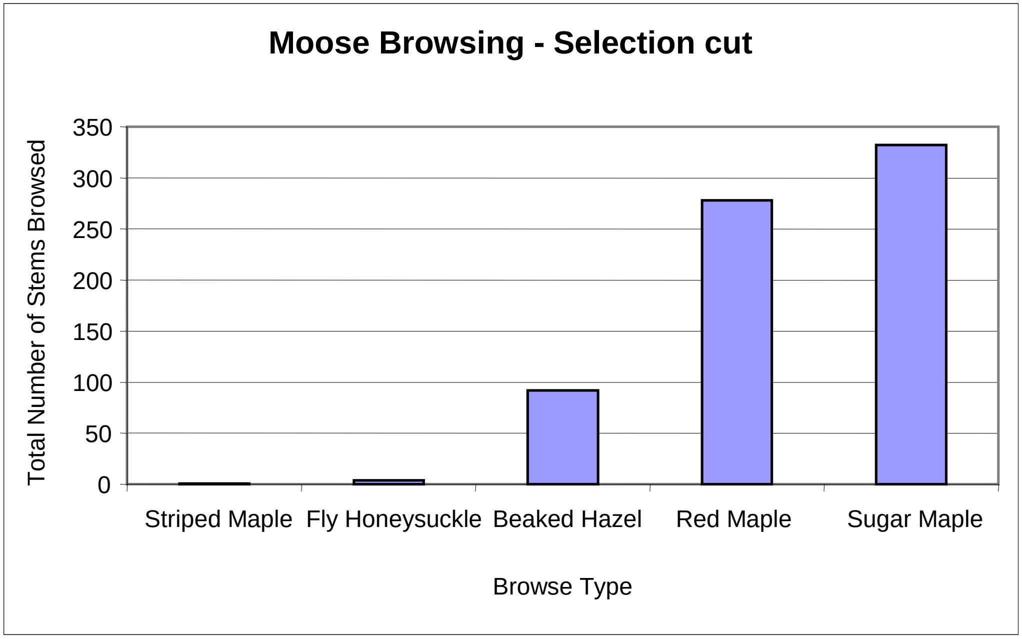


Intensity levels of aquatic browsing by moose at sites (n=55) in the shelterwood cut silvicultural system (0= not present, 1 = less than half of the shoreline aquatics were browsed, 2 = more than half the shoreline aquatics were browsed).

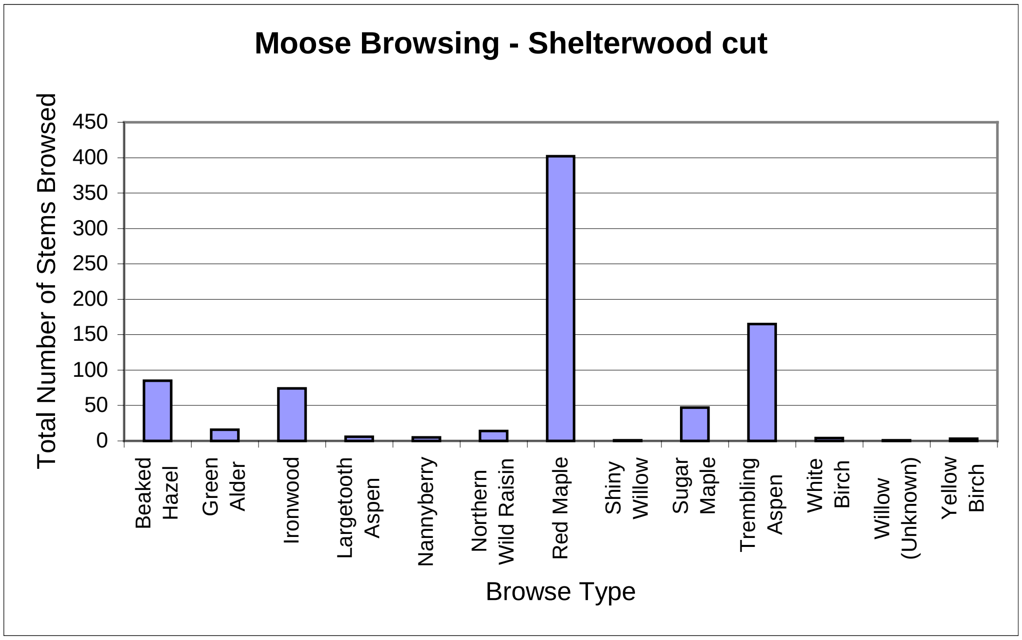


Intensity levels of aquatic browsing by moose at sites (n=48) in the clear- cut silvicultural system (0= not present, 1 = less than half of the shoreline aquatics were browsed, 2 = more than half the shoreline aquatics were browsed).

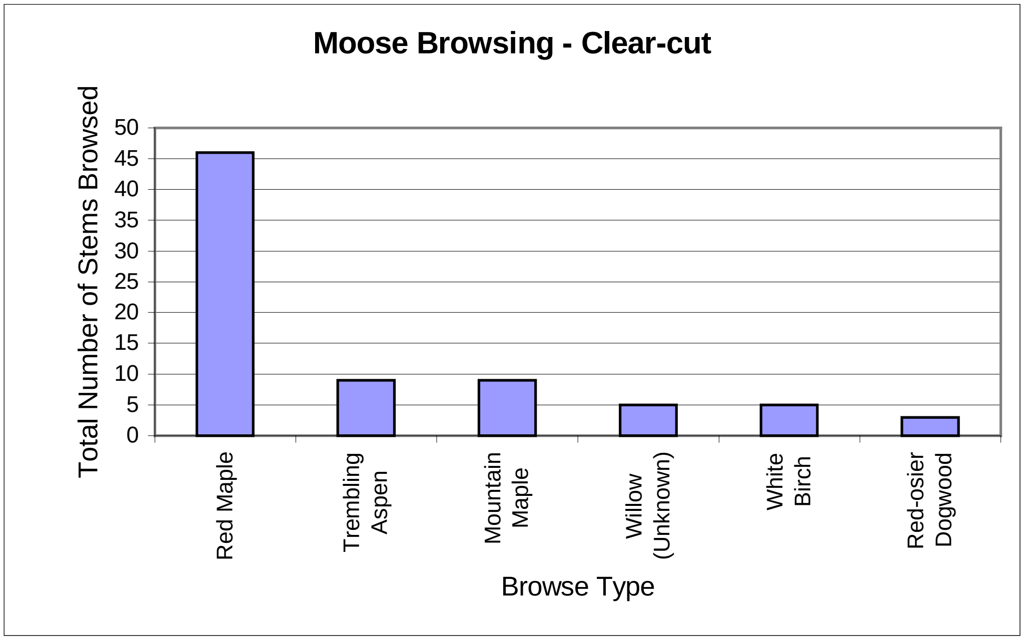
Appendix VII



The total number of stems browsed by moose along trails at all sites (n = 56) in the selection cut silvicultural system.

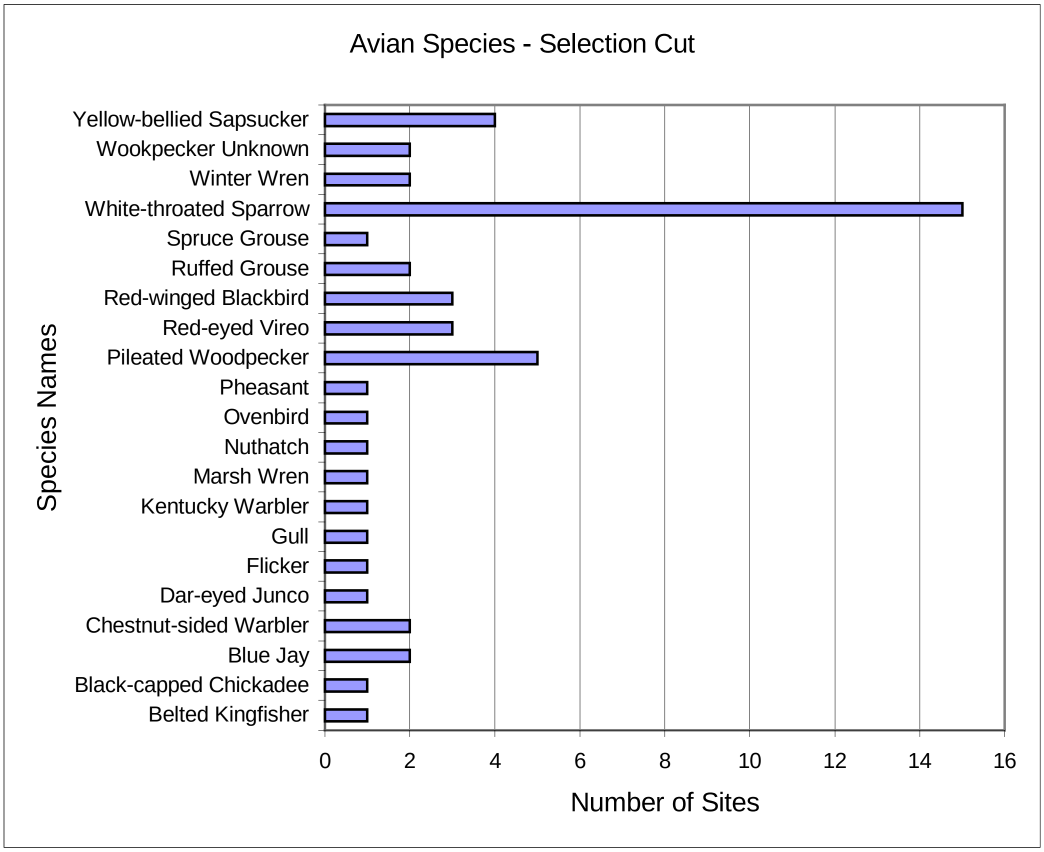


The total number of stems browsed by moose along trails at all sites (n = 55) in the shelterwood cut silvicultural system.

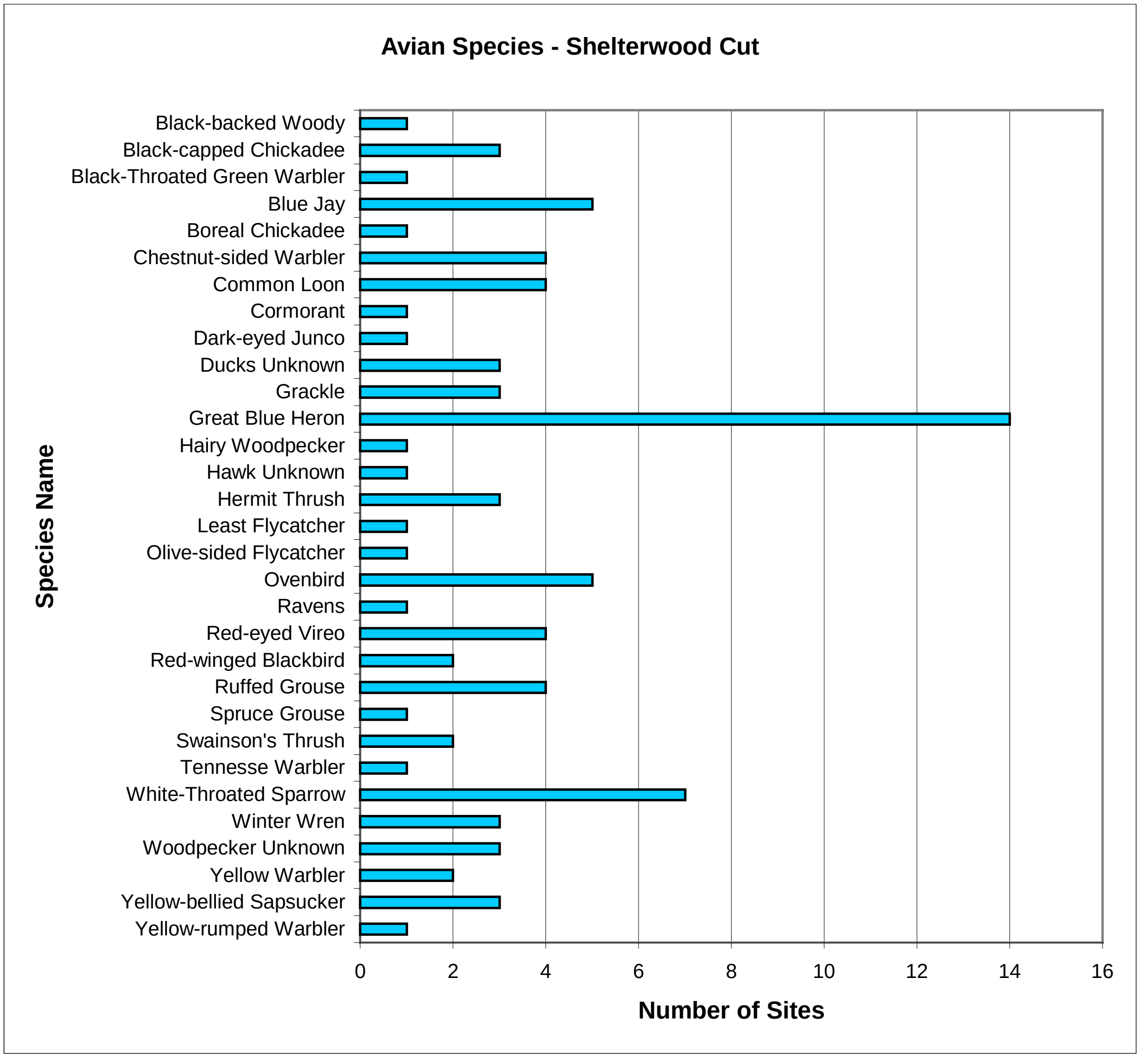


Total number of stems browsed by moose along trails at all sites (n = 48) in the clear-cut silvicultural system.

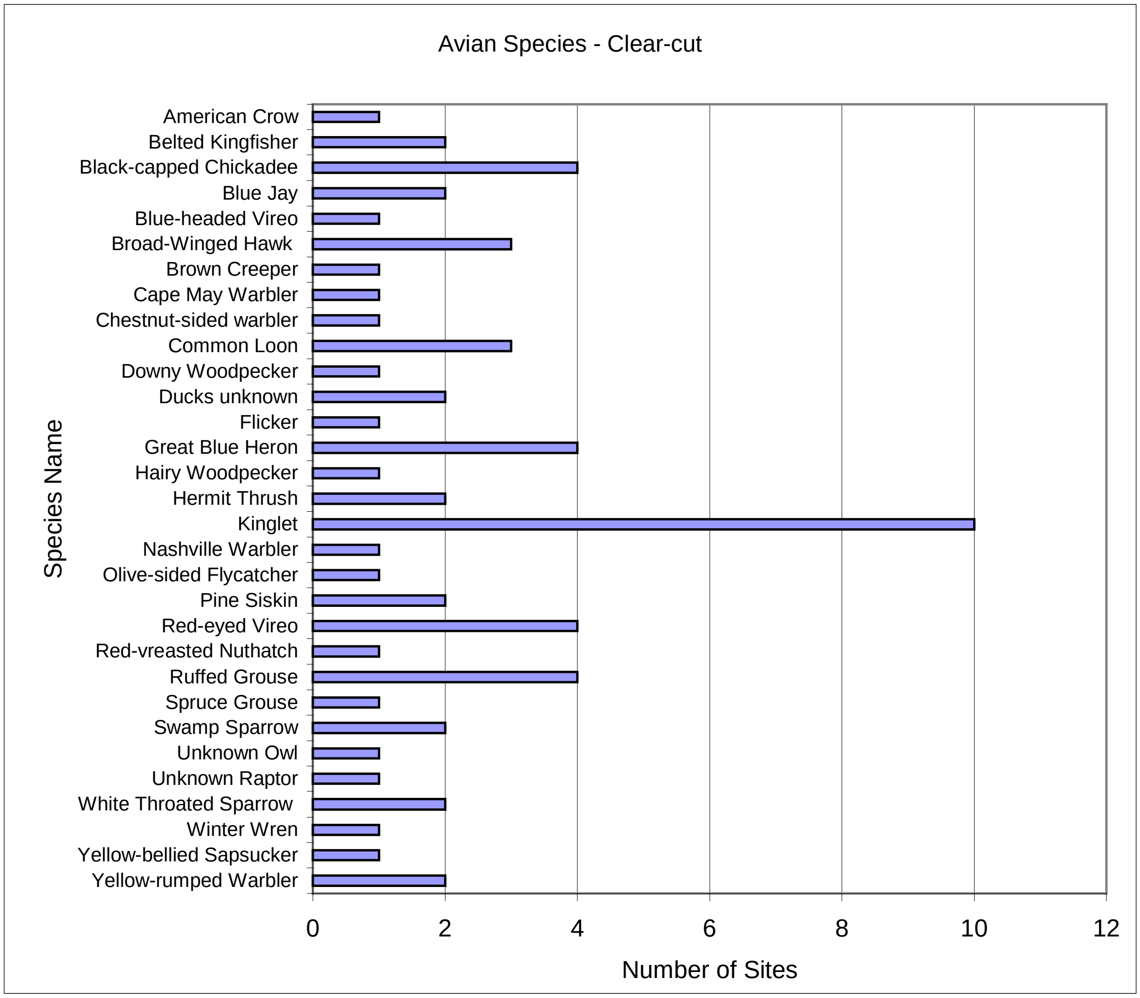
Appendix VIII



Birds observed at all sites (n=56) in the selection cut silvicultural system.

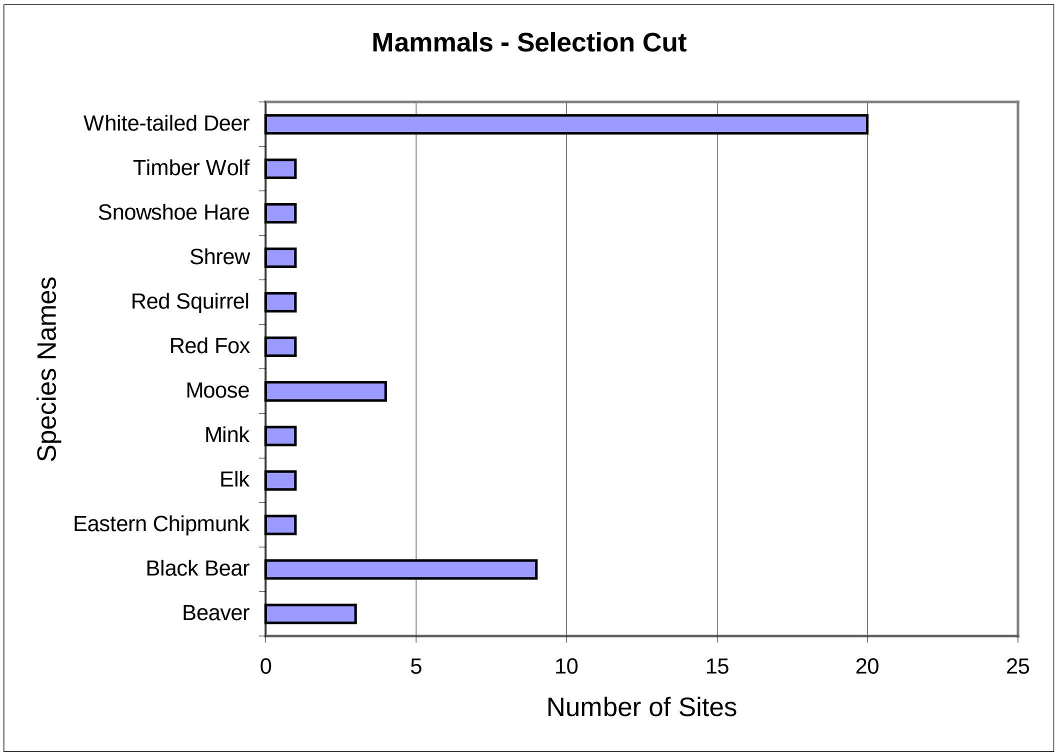


Birds observed at all sites (n=55) in the shelterwood cut silvicultural system.

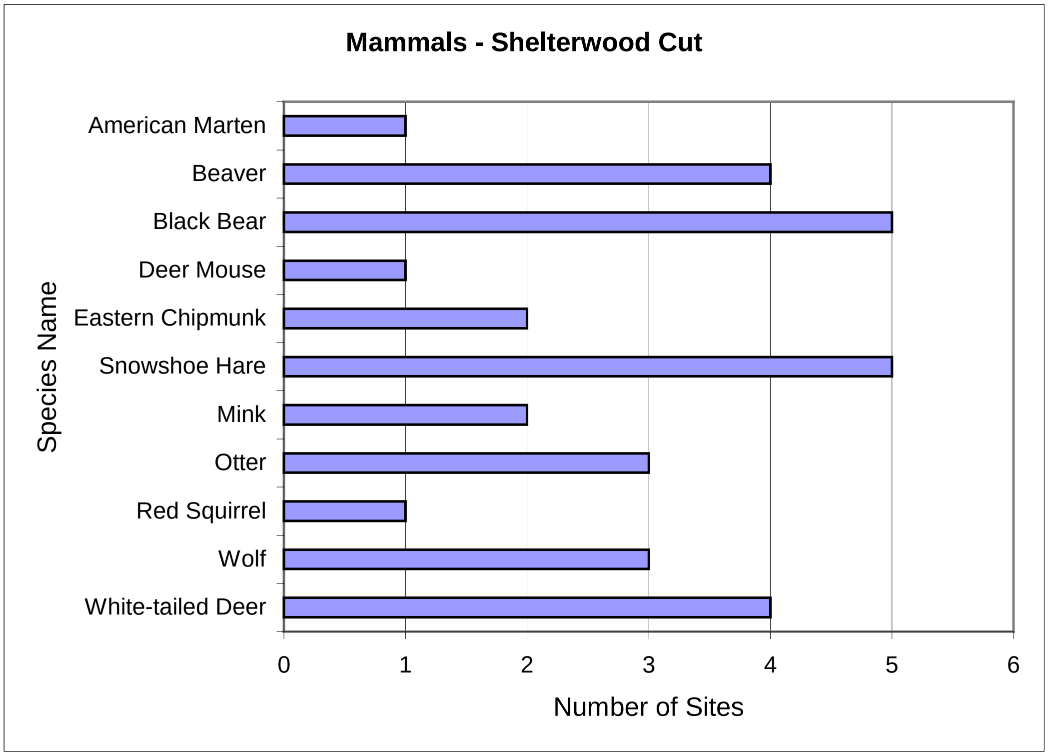


Birds observed at all sites (n=48) in the clear-cut silvicultural system.

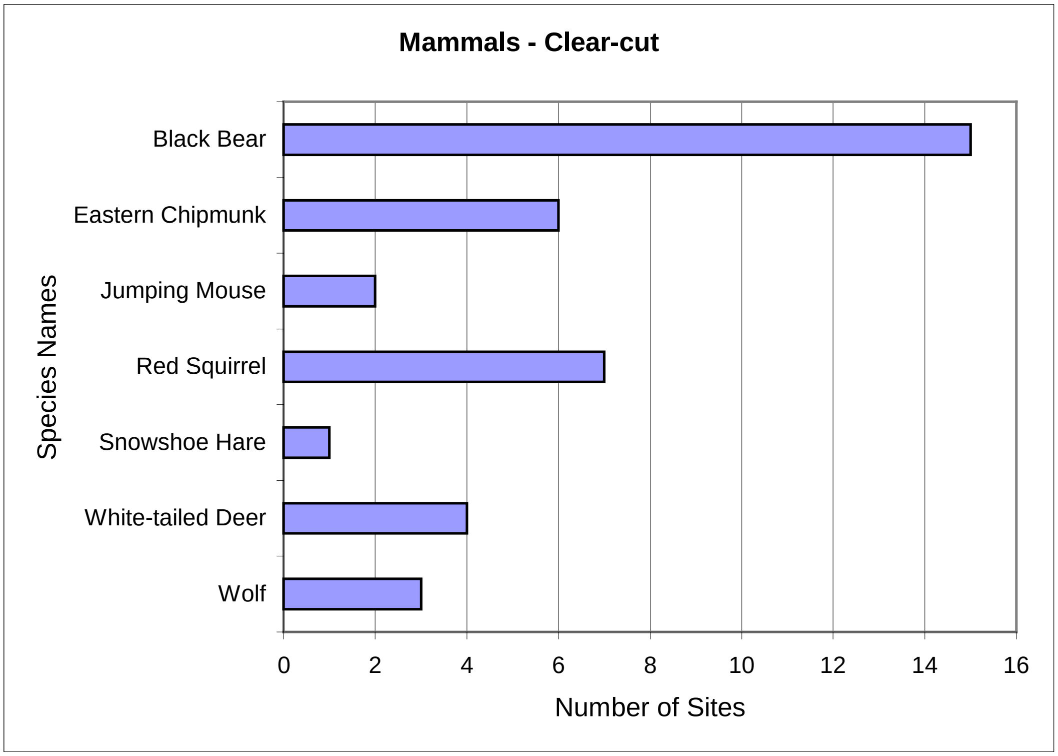
Appendix IX



Mammals observed at all sites (n=56) in the selection cut silvicultural system.

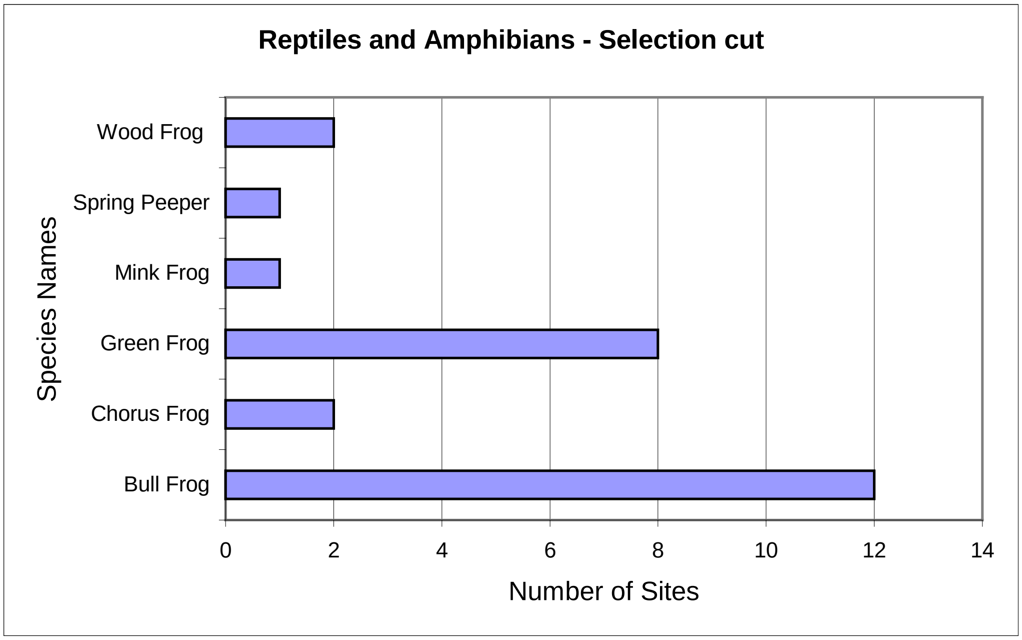


Mammals observed at all sites (n=55) in the shelterwood cut silvicultural system.

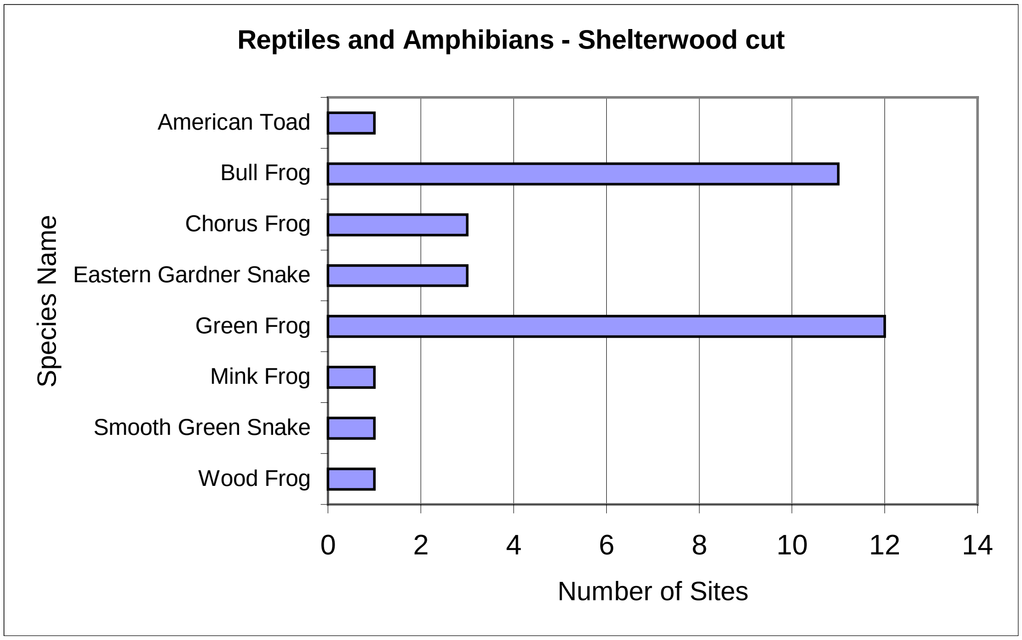


Mammals observed at all sites (n=48) in the clear-cut silvicultural system.

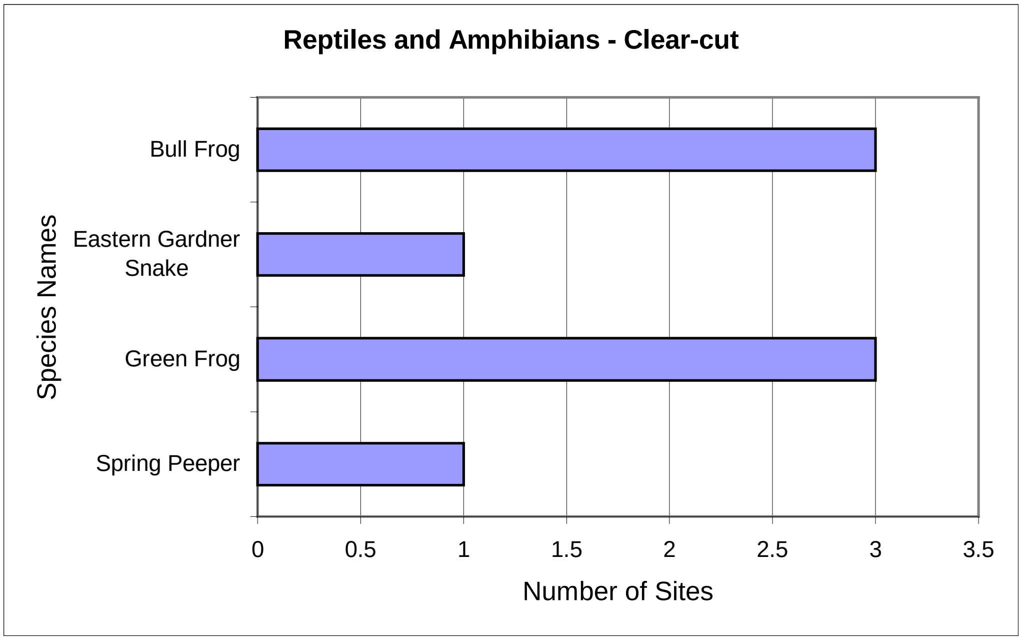
Appendix X



Reptiles and amphibians observed at all sites (n=56) in the selection cut silvicultural system.



Reptiles and amphibians observed at all sites (n=55) in the shelterwood cut silvicultural system.



Reptiles and amphibians observed at all sites (n=48) in the clear-cut silvicultural system.