IS HABITAT MANAGEMENT IN NORTHWESTERN ONTARIO MEETING THE PHYSIOLOGICAL NEEDS OF MOOSE IN THE FALL AND EARLY WINTER?

by

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(OMNR 2009c)

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A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific environmental management.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the Faculty or of Lakehead University.

MAJOR ADVISOR COMMENTS

In somewhat unusual circumstances, I took on the supervision of this thesis in late November after Mr. Buckler was well underway. Mr. Buckler had already begun work on a topic of interest that was outside my research focus. Fortunately, Mr. Gerry Racey, highly knowledgeable in the intersection of moose biology and forest management, agreed to assist and act as Second Reader. The product of this collaboration is a thesis that asks a solid research question, addresses that question from appropriate perspectives and, in the end, provides an answer. The process of writing a good literature review is demanding. Mr. Buckler has succeeded in navigating these sometimes tricky waters to produce a document of which he can be proud and that meets the requirements for an undergraduate thesis in the Faculty of Natural Resources Management.

ABSTRACT

Buckler, I.P. 2021. Is Habitat Management in northwestern Ontario Meeting the Physiological Needs of Moose in the Fall and Early Winter? 51pp.

Keywords: coarse filter, fine filter, Moose Emphasis Areas, nutritional carrying capacity

This thesis explores the question of whether the habitat management guidance provided by the Forest Management Planning Manual in Ontario is meeting the physiological needs of moose in the fall and early winter. Moose are found throughout Ontario and are managed for different densities in various areas. The focus of this thesis is on northwestern Ontario. Food, shelter and cover requirements of moose are summarized. How moose use habitats and balance energy are examined. Forest Management Units/Planning, the Cervid Ecological Framework and guidelines such as the Forest Management Guide for Boreal Landscapes and the Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales are reviewed in general and from this perspective. An approach to forest management planning that incorporates this information is described. The author concludes that the combination of the landscape framework provided by the Boreal Landscape Guide and the flexibility for influencing local conditions provided by the Stand and Site Guide make it possible for forest managers to design forest management plans that support goals associated with the physiological needs of moose.

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ACKNOWLEDGEMENTS

First and foremost, I am extremely grateful to my supervisors, Dr. Nancy Luckai and Mr. Gerry Racey for their invaluable advice, continuous support, and patience during my undergraduate thesis study. Their immense knowledge and plentiful experience have encouraged me throughout my academic research. Their combined insight and expertise has enlightened me in terms of research and habitat management knowledge. It is with their kind help and technical support that has made my study and thesis writing successful. Finally, I would like to express my gratitude to my parents, grandparents, and my girlfriend. Without their tremendous understanding and encouragement in the past couple years, it would have been very difficult for me to complete my study.

INTRODUCTION

The moose, (*Alces alces*), is common across North America and has four subspecies residing in Canada (Crichton et al. 2019), of which *Alces alces andersoni* (northwestern moose) and *A. alces Americana* (eastern moose) (Geist 2020) are found in Ontario. Eastern moose are found in Canada and the northeastern United States, while northwestern moose are found in Canada and North Dakota, Minnesota, and northern Michigan (Geist 2020). The two sub-species have overlapping ranges in Canada and share many similar characteristics. They are the largest of the deer family (Cervidae) and are found in every province except Prince Edward Island (Crichton et al. 2019). Moose have high Indigenous, economic and social value within Canada and are sometimes seen as Canada's national symbol (Crichton et al. 2019). They are hunted for sport and sustenance and viewed for pleasure and tourism.

Ontario has a total land base of 1,076,395 SQ KM (107,639,500 ha) (Wise 2020) 87% of which is Crown land managed by the Ontario Ministry of Natural Resources and Forestry (OMNRF) under the Public Lands Act (MNRF 2020b). Commercial forestry is permitted under the Crown Forest Sustainability Act (CFSA 1994) within forest management units and is guided by a set of four regulated manuals. The Forest Management Planning Manual, the Forest Information Manual, the Forest Operations and Silviculture Manual and the Scaling Manual are the regulated manuals under the CFSA (CFSA 1994). Figure 1 shows the extent of the area of forest subject to forest management under the Ontario Forest Management Planning Manual; the insert shows the Forest Management Units.

The commercial forest in Ontario consists of both Boreal and Great Lakes-St. Lawrence forest types, but northwestern Ontario is mainly boreal forest (Rowe 1972). Any forest modifications or operations completed are designated by the OMNRF through applicable policies, manuals and guidelines. Forest management encompasses four broad activities of access, harvest, renewal and tending. Habitat planning for moose occurs within this context.

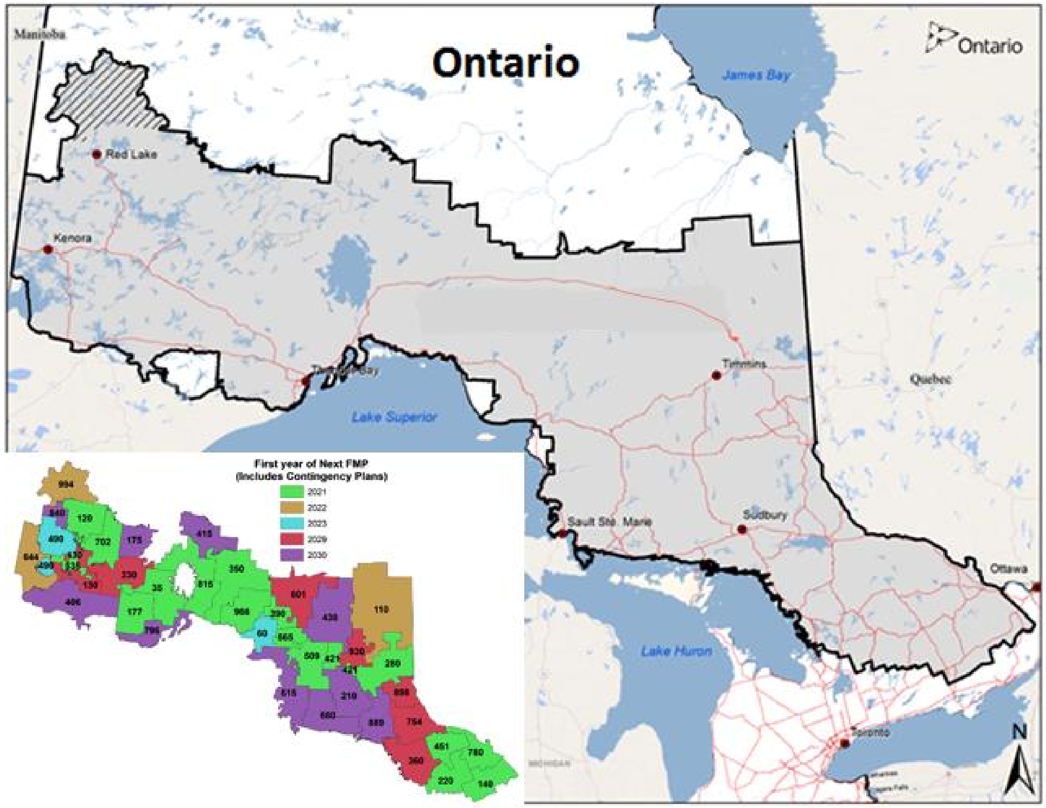

Figure 1 Ontario's Forest Management Units (MNRF 2021a, MNRF 2019).

Moose are one of four ungulates managed in Ontario within a provincial landscape of Wildlife Management Units (Figure 2). A comparison of Figures 1 and 2 confirms that the boundaries of Wildlife Management Units and Forest Management Units Management differ. Management priority is advised by the Cervid Ecological Framework (OMNR 2009a). Current moose habitat management operates under the Moose Management Policy (OMNR 2009c), the Forest Management Guide for Boreal Landscapes (MNRF 2014), the Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (MNRF 2010) and the regulated manuals under the CFSA (1994). Relevant habitat management direction for moose habitat provided by these guides is discussed in detail later in the paper.

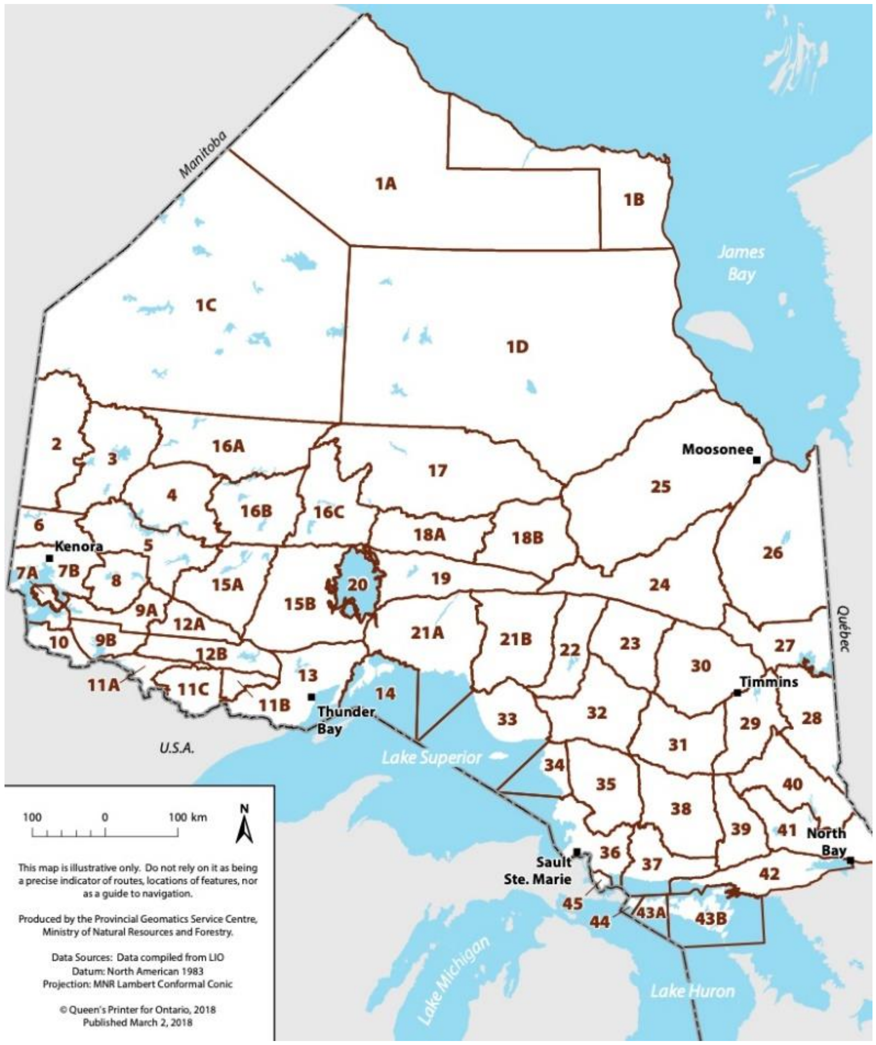

Figure 2 Northern Ontario Wildlife Management Units (MNRF 2020c).

The Cervid Ecological Framework (CEF) divides the province into areas of low to high densities of animals and provides a structure for managing habitat (OMNR 2009a). All cervids are not prioritized in every zone; the yellow area in Figure 3 represents medium to high moose densities while the green/ red zones are considered low moose density areas. Explanation behind the density differences throughout Ontario include other cervid species; white-tailed deer, caribou and elk are distributed differently than moose so management has adapted to focus higher population densities in specific areas. Another explanation is human populations/ accessibility. The red zone in southern Ontario has the highest human population numbers, so managing for low densities is the goal. The green zone is so far north and with few human populations, low densities of cervid are possible.

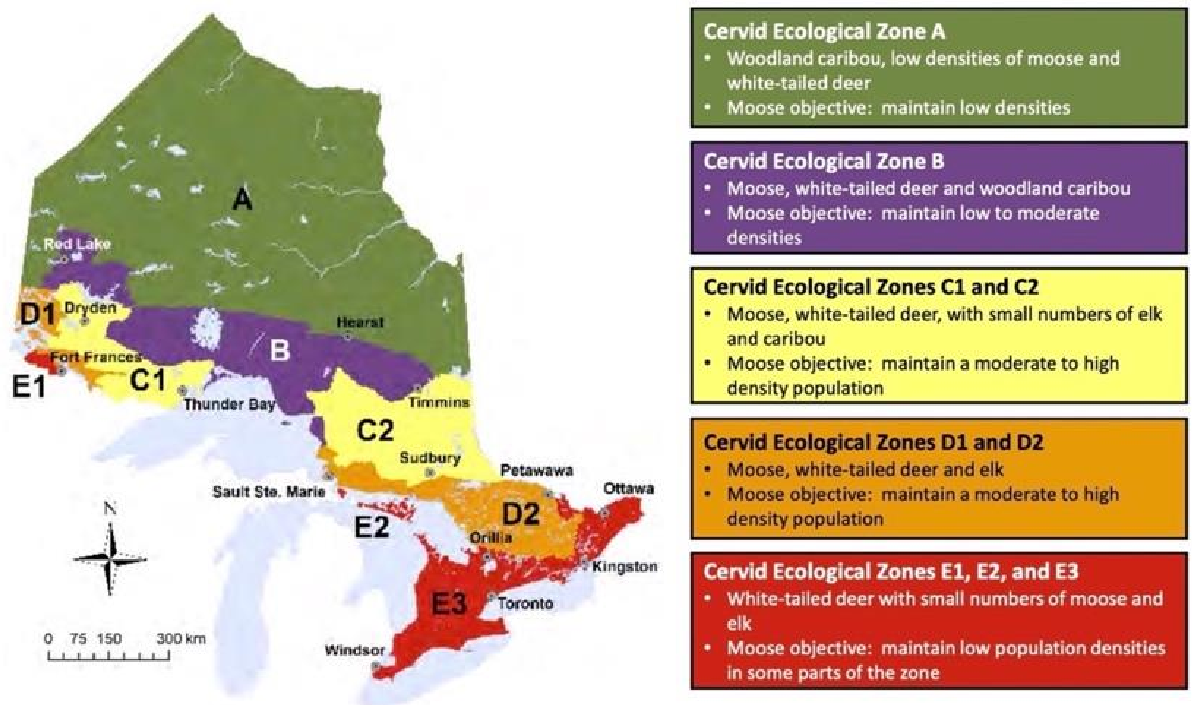

Figure 3 Cervid Ecological Framework Map (OMNR 2009a).

A multi-scale approach is used to define the borders of these zones; the approach begins at the ecological (landscape) level, followed by the ecoregional level and finally the localized level (coarse to fine level planning). Annual reporting between population and habitat management planning is completed to create appropriate objectives (OMNR 2009a). The zones are combined with Wildlife Management Unit (WMU) areas/ forest blocks to form broad/ dual management objectives (harvest/ habitat management goals). Moose populations have fluctuated over the years. The trend line since 2004 is downwards (Figure 4). Although only six years are listed, the numbers for northwestern Ontario (Table 1) equate to nearly half (41-50%) of the total moose population in Ontario. These population estimates indicate that a major percentage of the moose population use the habitat, cover and forage that is available in NWO.

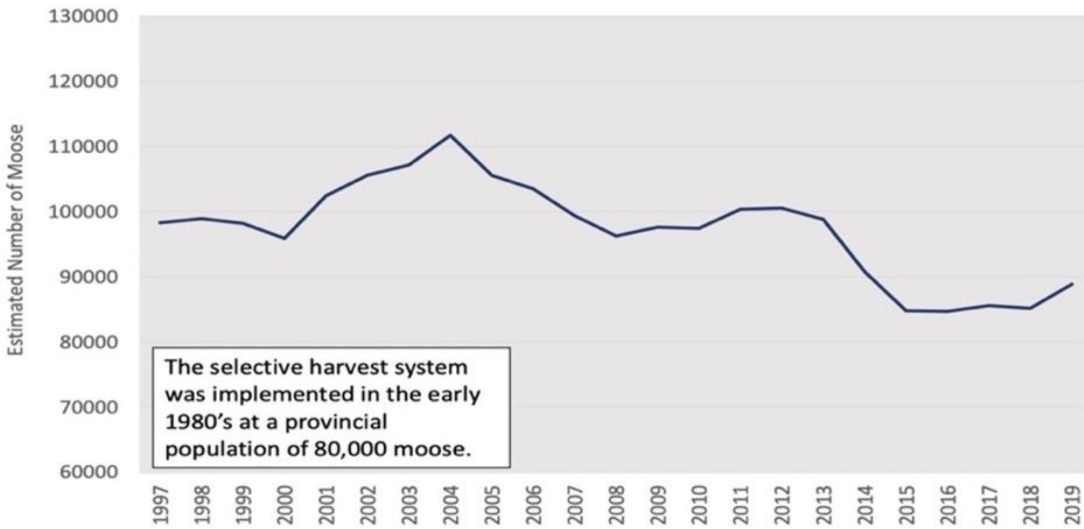

Figure 4 Provincial Moose Population Trend (BGMAC 2019a).

Moose management is complex, having to address factors affecting population and habitat and the interaction between the two. Wildlife species and their habitat tend to exhibit natural fluctuations in population size, ecosystem function, structure and composition conditions at multiple spatial and temporal scales; this is termed the "natural range of variation" (NRV) (Andison et al. 2016). This variability is thought to be driven by natural disturbance patterns which create different ecosystem conditions thereby affecting the biological responses of wildlife (i.e. the variability). (Andison et al. 2016). Commercial forest management, along with many other anthropogenic alterations to the landscape, operate on top of natural disturbance, adding to the complexity of understanding and explaining the relationship between moose and their habitat and the demonstrated patterns of population fluctuations and habitat use.

Further complexity is created by the practice and tradition of moose hunting which is significant in Ontario. Over 54,000 hunters participated in moose hunting in 2020 (MNRF 2021b) with 3,293 moose of all ages and sexes harvested; a 6% success rate (MNRF 2021b). Hunting advocacy groups in Ontario, including the Northwestern Ontario Sportsmen's Alliance (NOSA) (NOSA 2021) and the Ontario Federation of Anglers and Hunters (OFAH) (OFAH 2021) are keen observers, participants and, often, critics of moose management efforts by the OMNRF.

Table 1 Chronology of Ontario Moose Population Estimates and Moose Densities (Timmerman et al. 2002).

Year	Ontario Moose Population Estimates (#)	Ontario Moose Density (# per km^2) (Wise 2020)[3]	Northwestern Ontario Population Estimates (#)	Northwestern Ontario Moose Density (# per km^2) (Wise 2020)[3]
1953	42,000	0.039	-	-
1956-1957	70,548	0.066	-	-
1957-1958	80,325	0.075	-	-
1958	125,000	0.116	-	-
1960	78,000[1]	0.072	-	-
1965	80,000[1]	0.074	-	-
1970	82,000[1]	0.076	-	-
1975	91,000[1]	0.085	49,806	0.055
1978	75,000	0.070	-	-
1980	83,000[1]	0.077	41,530	0.046
1982	80,000	0.074	-	-
1985	99,000[1]	0.092	43,160	0.048
1990-1991	120,000	0.111	-	-
1990	92,883	0.086	43,661	0.049
1991	91,100	0.085	-	-
1992	104,500	0.097	-	-
1993	120,000	0.111	-	-
1994	120,000	0.111	-	-
1995	-	-	49,096	0.055
1997	100,000-120,000	0.093-0.111	-	-
1999	120,000	0.111	51,047	0.057
2001	100,000-110,000[2]	0.093-0.102	-	-
2014	92,300[2]	0.086	-	-

[1]Karns 1997.

[2]Timmermann and Rodgers 2017.

[3]Density calculated using Population Estimates divided by Ontario's/ NWO's total area.

It is important to recognize that moose management includes both population and habitat management. Population management is closely linked to hunting (e.g. tag allocations and limits) and is very complex. As such, it is not addressed in this thesis. Forest management impacts moose habitat directly though alteration of the age, species composition and density of stands, which has implications for how moose meet their life requirements. These life requirements change throughout the year (Renecker and Schwartz 1997) and moose adjust their habitat use to meet their changing needs. Most of this behaviour is expressed in how moose balance their needs for forage or shelter.

Of particular interest to the avid moose hunter, are the animal's habitat preferences and use patterns up to, through and following the hunting season, which occurs in the months of October up to mid-December. Knowledge of the biology of moose and moose habitat selection at that time of year could be valuable in cultivating more knowledgeable hunters. Evaluation of how forest management influences the suitability and availability of habitats could be valuable in adjusting habitat management guidance to improve moose physiological condition and well-being. As moose habitat management is guided by policy and largely implemented through commercial forest management, there remains the question of how well habitat management guidance addresses moose needs in the fall and early winter. The key research question of this literature review was whether or not current moose habitat management in northwestern Ontario aligns with the physiological needs of moose in the fall and early winter. The fall season not only reflects a crucial time in the life cycle of moose, but also a time where relevant and important knowledge of habitat selection behaviour can improve the experience of moose hunters.

I hypothesize that current moose habitat management in boreal Ontario aligns with the physiological needs of adult moose in the fall and early winter. In order to address this hypothesis, I document how moose physiological and habitat needs change through the year with an emphasis on fall and early winter. I will compare those against habitat management direction and look for evidence of alignment or identify challenges in applying forest management guidance to meet the physiological needs of moose.

Moose are found around the world. The information presented focuses on North American literature, particularly that most relevant to the forest habitats of boreal Canada and northwestern Ontario.

LITERATURE REVIEW

MOOSE

General Information

Moose are the largest species in the deer family (Crichton et al. 2019) with the eastern (Taiga) and northwestern moose sharing the same body size, coat colouration, antlers and breeding behaviour traits (Bubenik 1997). Average weights range from 360 – 600 kilograms (kg) (Bubenik 1997) and their shoulder height can reach up to 1.98 metres (6.5 feet). The bull's life span is up to 15 years while a cow may live until 19 years old (Ballenberghe and Ballard 1997). Individual home-range sizes are based primarily on food availability and habitat productivity (Dussault et al. 2005a). The eastern North American moose average home-range is 20-40 km^2 (Timmermann and McNicol 1988). Females with calves used similar home-range sizes as males in Quebec (Dussault et al. 2005a).The Algonquin word for moose is "twig eater" (Timmermann 1998). Moose are herbivores.

Moose habitat requirements and forest planning procedures vary among Canadian jurisdictions. For the purposes of this paper, bull and cow moose will generally be considered to have similar habitat requirements and the geographical context will be northwestern Ontario. Situations such as calving, areas of defence, and season will lead to different preferences in terms of cover and stand composition and these are discussed in more detail below.

Antlers on bull moose begin growth in April and start to be shed in November but may persist later in some animals (Crichton et al. 2019). The antlers are used for defense and competition for mates, with the bull showing off the tine/ palm size to impress the female (Crichton et al. 2019). Other special features include the dewlap, or bell, that is located below the throat (Crichton et al. 2019). Main identification details when observing a cow compared to a bull include a white vulva patch just below the anus and the lack of antlers during the summer and autumn (bulls have no antlers during the winter season) (Crichton et al. 2019).

Starting in mid-August, the moose breeding season begins with behavioural changes, also called the "rut" (Crichton et al. 2019). This breeding period goes from mid-September to mid-October (Crichton et al. 2019) and is one of the most active times of year, where bulls will travel more during the rut than cows (Jackson et al. 1991). Calves are born in the spring and become “yearlings” after a year of growth (Schwartz 1997).

An average 425kg moose consumes 11,000 calories per day (Kcal) (Timmerman and McNicol 1988). Moose eat 3-4 times the volume of food in the summer than in the winter (Timmermann and McNicol 1988). Several hundred plant species are eaten, but only 25-30 species in one locality (Timmermann and McNicol 1988). Cow moose’ heaviest weight occurs in early winter, making the weight gain at the most ideal time before the winter (Schwartz 1997). Females lose 15-19% of their body mass throughout the winter and gain 25-43% body mass throughout the summer (growing) season (Schwartz 1997). Overwinter weight loss in bulls ranges from 7-23% of their pre-rut body mass, whereas the summer weight gain is 33-41% of the post-winter lows (Schwartz 1997).

Moose have a range of physiological needs that vary throughout the year. Antler growth, bone development, hair replacement and bodily functions (Timmermann and McNicol 1988) place a high demand for sodium and other minerals. Sodium is necessary for osmotic homeostasis, buffering of body fluids, nerve transmission, reproduction, hair production, lactation, growth, and the maintenance of body weight and appetite (Timmermann and McNicol 1988). Cow moose also have to meet demands for fetal development, milk production and infant growth (Timmermann and McNicol 1988). Rut-behaviour differs from post-rut behaviour; hormones shift the animal from a “mating” condition to a “replenish fat reserve” state (Schwartz 1997). High fat reserves are required to help the moose survive the winter (Timmermann and McNicol 1988).

Moose Physiology

All terrestrial animals share general requirements for food, water, shelter, warmth and opportunities to reproduce. Moose seek these habitat components to support their physiological functions and activities and their changing physical and chemical demands though the seasons. Moose respond to environmental stresses by changing how they meet their physiological needs through increasing energy intake (e.g. finding better forage) or reducing energy loss (e.g. seeking appropriate shelter) or both. Figure 5 illustrates the relationship between behavioural decisions and factors affecting the energy balance of moose.

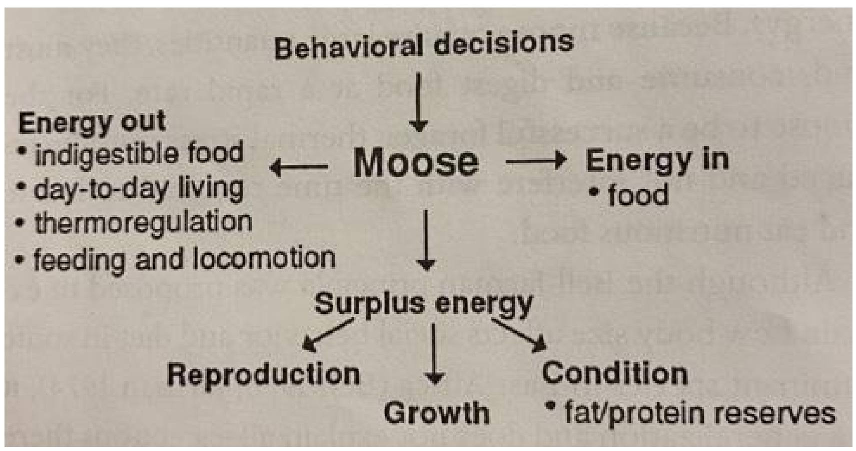

Figure 5 Energy Balance of Moose (Schwartz 1997).

Moose meet these competing demands by developing patterns of seasonal habitat selection and foraging behaviours such that they improve their chances of survival and minimize energy loss. Growth, as an outcome of Surplus Energy, is not discussed in detail in this paper because the focus is on activities that are critical to the fall/ early winter season (i.e. Reproduction and Condition). Table 2 shows how energy intake (forage consumption) supports the daily life requirements of moose and the surplus used to support health and well-being.

Table 2 Selected Behaviours of Moose in Fall/ Early Winter that illustrate Connections to their Physiological Requirements.

Energy In

- Food/ Water
    - Consume fallen leaves until such time as the leaves are degraded and/or under snow cover (Timmermann and McNicol 1988).
    - Select highest calorie food available at this time of winter which includes twigs from deciduous shrubs, broad-leaved and conifer trees. (Timmermann and McNicol 1988).
    - Although 90% of mineral intake is acquired through browsing on aquatic plants, this behaviour no longer applies as of mid-September (depending on forage palatability between areas) (Peek 1997).
    - Little nutrient value in woody browse, therefore continually eating to meet body function requirements (Schwartz and Renecker 1997).
    - Although cows continue to eat during the rut, bulls do not (Schwartz 1997).
    - Immediately following the rut, bulls shift their priority to replenishing fat reserves for best survival (Schwartz 1997).

Energy Out

- Thermoregulation
    - Habitats chosen where the least amount of body temperature regulation occurs (heavy tree/ shrub cover during harsh winter conditions) (Schwartz and Renecker 1997).
    - Vegetative cover is used throughout the year as shelter from predation and elements (e.g. solar radiation, precipitation, wind) (Timmermann 1998, Schwartz and Renecker 1997).
    - In early Winter, switch to more conifer dominated-habitat due to less snow and reduced wind (Timmermann and McNicol 1988).
    - Severe winter temperatures (ie.-30°C and below)will force moose to adopt activities that either retain energy (ie. seeking more sheltered bedding areas) or expend energy to increase internal body temperature (eg. shivering, finding additional browse) (Schwartz and Renecker 1997).
- Feeding and Locomotion
    - Forest edges facilitate access to both open areas (preferred for browse) and more heavily vegetated areas (preferred for protection) (OMNR 1988).
    - Waterbodies used for feeding, travel and predation avoidance until frozen (Peek 1997).

- Bulls travel farther distances to find a cow during the rut than cows (testosterone increase causes less safety concerns) (Jackson et al. 1991, Schwartz 1997).
- In Quebec, snow depths >60 cm impede movement therefore increasing risk of predation (Dussault et al. 2005a).
- Diet of twigs causes longer rumination (rechew food eaten earlier) (Schwartz and Renecker 1997).
- Bite size, bite rate, browse diameter, abundance of suitable biomass, standing/ walking and activity patterns all affect moose feeding and movement rates (Renecker and Schwartz 1997).

Surplus Energy

- Growth (not applicable)
- Reproduction
    - Rut occurs mid-September to mid-October (Crichton et al. 2019).
    - Testosterone in bulls peaks causing behaviours such as;
        - Following the cows (Bubenik 1997).
        - Fighting with other bulls; attracts others (Bubenik 1997).
        - Avoid eating during rut (Schwartz 1997).
        - Searching for cows takes priority over safe travel (e.g. attraction of predators) (Schwartz 1997).
    - Estrogen peaks in cows causing behaviours such as
        - Close to waterbodies as a resource (Peek 1997).
        - Allowing bulls to mount during the rut (Schwartz 1997).
        - Sporadic feeding during attracting phase of rut (Bubenik 1997).
        - Avoids bulls until sexually receptive (Bubenik 1997).
- Condition
    - Bulls reach peak body condition just before the rut (during velvet shedding) (Schwartz 1997).
    - Due to lack of eating, bulls gorge on browse post-rut (replenish fat reserves) (Schwartz 1997). This makes adequate conditioning before winter difficult.
    - Cows reach peak body condition by early winter; do not sustain weight losses like bulls during rut (Schwartz 1997).
    - Cows reach maximum body weight earlier and weigh less than bulls (Schwartz 1997).
    - Cows require a certain level of body condition to grow calves throughout the winter (Schwartz 1997).

Reproduction

Cow moose are sexually active at 1.5-2.5 years old and breeding occurs in autumn when hormones shift animal behaviour from foraging to mating (Schwartz 1997). Yearling moose ovulation and pregnancy levels are related to habitat and food quality (Schwartz 1997). Nearly all yearlings ovulate when in ranges with high quality forage and up to 62% can become pregnant (Schwartz 1997). When dealing with ranges of poor quality, yearlings may not have the chance to give birth (Schwartz 1997). Fat reserves and range conditions indirectly affect fetal growth, weight, lactation, calf growth and future reproductive success (Timmermann and McNicol 1988). The timing of breeding (early/ late) and whether single or twin calves are produced affects the chances of survival of the calves during the winter (Schwartz 1997). Fetal development occurs for 216-240 days from the time of breeding; calving happens in late May (Schwartz 1997). The cows will nurse their calf or calves until early autumn when the annual process restarts (Schwartz 1997).

There are three basic periods of growth for calves: prenatal, suckling and maturity (Schwartz 1997). The prenatal phase starts at conception until birth, when the calf and cow are considered a “single unit” (Schwartz 1997). The suckling phase is post-birth to weaning of milk, when the calf becomes more independent (Schwartz 1997). The last phase is maturity, post-weaning until death, when the animal is independent (Schwartz 1997). The calf experiences accelerated growth from May to September with solid foods eaten at 1.5-2 months of age (Schwartz 1997). The process of maturity in calves is described to show the additional stress/ requirements a cow is under when selecting optimal habitats.

The reproductive cycle for bull moose begins in spring/early summer with the increase in testosterone and concurrent development of the antlers (Figure 6). The antlers are fully grown by the late summer with the velvet encasing the antlers shed before breeding (Schwartz 1997). Males reach peak body condition just before breeding but experience weight loss during the rut due to a hormone shift/ imbalance (i.e. they are more concerned with mating than eating) (Schwartz 1997). Bulls may not eat for up to 18 days during the rut (Schwartz 1997). After the rut, testosterone levels decline which enables antler shedding (Schwartz 1997). Depletion of energy reserves also occurs, and a shift in hormone balance stimulates feeding and the build up of fat reserves for the winter, eating anything it can (Timmermann and McNicol 1988). During the winter, both bulls and cows change to energy conservation and seeking forage. (Schwartz 1997). Bulls want to sustain fat reserves while cows are growing their young throughout the winter. The cycle repeats when spring begins again.

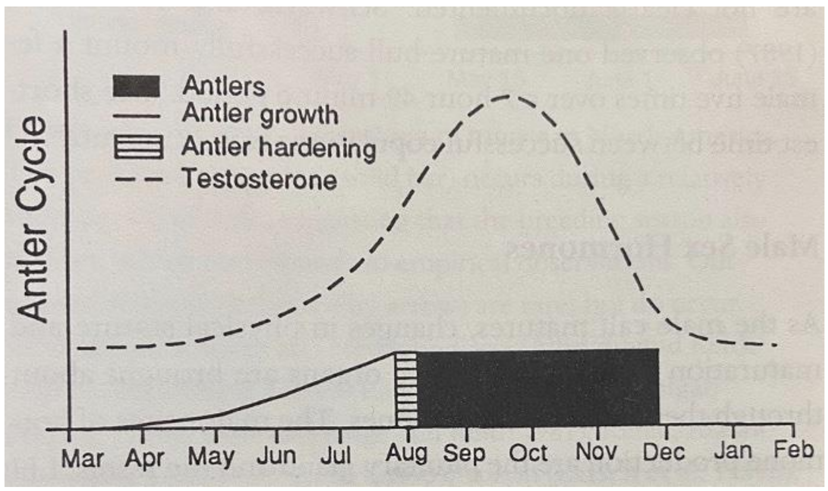

Figure 6 Bull Moose Annual Growth Cycle (Schwartz 1997).

MOOSE HABITAT NEEDS

Food

Moose are drawn to coniferous and mixed cover in the early winter where preferential browse and shelter exist (Jackson et al. 1991). Areas recently disturbed by fire, blowdown, insect damage or logging provide the winter diet of deciduous, conifer and broad-leaved twigs (Timmermann 1998). Disturbances can create shrub communities of varying composition and age providing abundant forage, especially in mixed conifer-deciduous forests (Timmermann 1998). Suitable food and cover provided by mixedwood stands of up to 30 years of age are best for moose (Timmermann 1998). Moose consume large quantities of plant matter with low nutritional value (Timmermann and McNicol 1988). Females with calves searched for high-quality forage, but accepted forage of lower quality in a trade-off with space usage for predator-avoidance (Dussault et al. 2005a). In the early winter season, moose selected food over habitat (Dussault et al. 2005a). Balsam fir and spruce combine to form a food and shelter haven for moose (McNicol and Timmermann 1988).

Moose early winter diet includes the twigs from deciduous shrubs, broad-leaved and conifer trees (Timmermann and McNicol 1988). Preferred woody species include dogwood, willow, aspen, birch, hazel, red maple, mountain ash, and several species of viburnums (OMNR 2010b). Quality of moose browse is determined by plant species, age of browse, size of browse, and nutritional content, often related to rate of growth or soil conditions (Rempel et al. 1997). Larger and coarser woody browse requires more chewing and takes longer to digest (Timmermann and McNicol 1988). Longer rumination periods (the process of digesting/ rechewing foods with high levels of structural carbohydrates) require more energy expenditure by moose (Schwartz and Renecker 1997). Fallen leaves from various deciduous species (aspen, birch and willow) are consumed before the concealment of snow for their higher nutrient content (Renecker and Schwartz 1997). Leaves are higher quality than woody browse due to more crude protein, higher dry matter digestibility and their ease of access on the forest floor (Renecker and Schwartz 1997). Woody browse has a highly lignified cortex where the most digestible parts are located on the outer bark/ buds (Schwartz and Renecker 1997). The outer material of twigs is digested effectively while the indigestible cortex is passed rapidly (Schwartz and Renecker 1997).

Timmermann and McNicol (1988) found that aspen leaf litter was heavily consumed in some areas, due to its easy digestibility and increased nutrient levels as opposed to woody browse. Needles from balsam fir are a favourite for moose during the winter (Timmermann 1998). High density browse with preferred species at various ages and twig diameters allow moose to feed while expending little energy in movement. When paired with conifer stands of varying ages, it presents the perfect pairing of nutrition and cover (Timmermann and McNicol 1988).

Table 3 shows various stand types in Quebec in relation to the amount of browse available, concealment cover and winter cover in that study area. This table illustrates interesting relationships between food availability, concealment and winter cover. Concealment cover was defined as the portion of a stand providing visual protection with the appropriate age and species of vegetation; lateral visual obstructions were measured between 0 and 2.5 m in height in 4 cardinal directions for a distance of 15 m with a cover board (Dussault et al. 2005b). The highest food availability (i.e. deciduous stems per hectare) is found in Stand Type A (deciduous and mixed with tolerant hardwoods) but this type of stand has the least concealment cover and relatively low winter cover. In Stand Types B, C and D (mixed and deciduous with intolerant hardwoods), food availability decreases with stand age while winter cover increases. Concealment cover drops from approximately 85% to approximately 69%; which is still better than Stand Type A. Stand Type E (conifer) has the lowest food availability but the highest winter cover and second highest concealment cover. These patterns illustrate the trade offs considered when managing for moose habitat. Having multiple habitat types with different compositions and ages ensures moose are not limited by their habitat components.

Table 3 Stand Type Characteristics (Mean +/- Standard Error) (Dussault et al. 2005b).

Stand Type	Food Availability (deciduous stems/ ha)	Concealment cover (%)	Winter Cover (conifer basal area, m^2/ ha)
A. Deciduous and mixed with tolerant hardwoods >= 50 yr	11,728 +/- 1,161	50.1 +/- 2.9	6.0 +/- 0.7
B. Mixed and deciduous with intolerant hardwoods 10 yr	10,097 +/- 824	84.8 +/- 1.5	2.4 +/- 0.6
C. Mixed and deciduous with intolerant hardwoods 30 yr	5,026 +/- 920	72.3 +/- 3.3	8.6 +/- 1.1
D. Mixed and deciduous with intolerant hardwoods >= 50 yr	3,803 +/- 649	68.7 +/- 3.1	13.2 +/- 1.4
E. Coniferous >= 30 yr	1,378 +/- 248	79.6 +/- 1.7	17.1 +/- 0.8

Schwartz and Renecker (1997) refer to the Energy In (Nutrient supply) versus Energy Out (Nutrient demands) ratio of moose as the Nutritional Carrying Capacity. The energy consumed through plant matter and other food depends on the moose's energy demands (Schwartz and Renecker 1997). Moose have a high metabolic rate in the summer, which is caused by their need to grow rapidly and fatten while the highest food quality is available (Schwartz and Renecker 1997). Figure 5 shows the trade offs made between energy intake/ demands, which directly relates to the nutritional carrying capacity. If the forage supply can be promoted then the nutrient demands of an individual moose can slowly decrease. Bigger animals do not necessarily experience a higher metabolic rate; a bull could have the same metabolic conditions as a cow with two calves (Dussault et al. 2005a).

Cover

Security

Moose use three different types of vegetative cover; security, winter and thermal (Timmermann 1998). Security cover is primarily used by cows during the calving period when secluded habitats are preferred (Timmermann 1998). Small islands, areas near water and isolated woody patches are desired habitats to defend against predation (Timmermann 1998). As the early winter season approaches, deciduous trees and shrubs decrease in their ability to provide cover, making forest edges more important for forage and escape purposes (Timmermann 1998). When timber harvesting removes forest cover, moose are more vulnerable due to hunting, forcing moose to select habitats near mixedwood edges (Timmermann 1998). Even small uncut residual patches left between cuts provides sufficient security cover for moose to travel (Timmermann 1998). Smaller-sized clear-cuts would provide a higher proportion of security cover that moose are desiring as opposed to larger clear-cuts (Timmermann and McNicol 1988).

Winter

Winter cover is chosen by moose using a strategy to minimize energy loss and maximize energy gain (Timmermann 1998). Moose in Quebec were shown to select habitats that avoided predation risk and deep snow as opposed to a nearby food source (Dussault et al. 2005b). Moose that travelled alone required less-protective habitats than a cow and calf seeking refuge (Dussault et al. 2005b). Snow depths greater than 60cm impede moose movement; this causes higher predation and lower survival (Dussault et al. 2005b, Timmermann 1998). Conifer-dominated stands are required entering the fall/ early winter to protect from wind and minimize energy loss during extreme cold (Timmermann 1998). The more coniferous composition in a stand, the higher the quality of winter cover available (Timmermann 1998). Stand composition of 60% or more conifer plus tree height's of over ten metres provide maximum thermal and snowfall protection (Timmermann 1998).

Thermal

Thermal cover is used to reduce heat stress and provide cooler areas of foraging and resting (Timmermann 1998). Feeding is maximized at night due to cooler temperatures, otherwise dense/ moist conifer/ mixed wood stands are utilized during hotter periods (Timmermann 1998). Residual patches aid in the winter when moose are bedding, pointing towards thermal cover being a year-round necessity (Timmermann 1998). Thermal cover is critical when temperatures are 14 to 20ºC or higher in summer and between -5 and 0ºC in winter (Timmermann 1998). The upper critical temperature is reached when moose become too hot causing panting/ sweating (Schwartz and Renecker 1997). The lower critical temperature is reached when moose become too cold causing increased movement and metabolic rate (Schwartz and Renecker 1997).The thermoneutral zone is between the upper/ lower critical temperatures and does not need additional metabolic requirements. (Schwartz and Renecker 1997).

Optimal Early Winter Habitat

Moose fall/ early winter habitat is composed of mature mixedwood stands with roughly 60% stocking (Jackson et al. 1991, McNicol and Timmermann 1988). Moose switch to more dense conifer cover throughout the winter to avoid deep snow (McNicol and Timmermann 1988). Vegetative diversity and winter/ escape cover are provided by the coniferous regeneration (McNicol and Timmermann 1988). Optimal early winter habitat features accessible high energy and easily digestible browse of suitable quantity so that energy usage and their metabolic demands are reduced while increasing the chances of winter survival (Timmermann and McNicol 1988). Different stand types and age-classes provide browse in disturbed areas and the necessary mature coniferous cover (Timmermann and McNicol 1988). Small patches of suitable habitat and/ or habitats with abundant edges are preferred for quality early winter habitat (OMNR 2014). A variety of habitat compositions is important to prevent the limitation of habitat selection for moose; homogenous habitats do not provide the array of nutrients required (Timmermann and McNicol 1988).

HABITAT MANAGEMENT

"Habitat" refers to the combination of vegetation, land type and climate variables that creates ideal conditions for successful reproduction, food and shelter (MNRF 2020a). Habitat management in Ontario for moose is largely effected through the Forest Management Planning process following the Forest Management Planning Manual (OMNRF 2020b).

Evolution of Policy Drivers

Moose management policy has evolved through time (Table 4). Moose management, especially habitat management was not a concern in the 1800s – early 1900s. Few regulations were in place, making subsistence and unregulated hunting the norm (BGMAC 2019a). Over-harvesting and low moose populations were recognized in the 1940s but increasing public concern prompted more awareness of moose management in the 1950s (BGMAC 2019a). Outcomes of this period included creation of Wildlife Management Units (WMUs) in the 1960's and instituting post-rut seasons in the 1970's.

The Moose Management Policy in the 1980's (BGMAC 2019a) led to implementation of a selective harvest system (Timmermann et al. 2002) and creation of Timber Management Guidelines for the Provision of Moose Habitat (OMNR 1988) in the late 1980's.

A Class Environmental Assessment for Forest Management on Crown Lands in Ontario concluded in 1994 and included several recommendations for the management of moose habitat during Forest Management Planning (EAB 1994). Recommendations included the identification of moose habitat values such as moose concentration areas (early & late winter), moose aquatic feeding areas (MAFAs), mineral licks and moose calving sites on a values map (EAB 1994). From 1994 (OMNR 1998) until today moose are considered a Provincially Featured Species (BGMAC 2019b). A moose program review in 2008 addressed habitat, population and game tag distribution objectives (BGMAC 2019a). This review triggered other new guidelines and in the following year the Cervid Ecological Framework (OMNR 2009a), Moose Management Policy (OMNR 2009c), Moose Population Objective Setting Guidelines (OMNR 2009d) and the Moose Harvest Management Guidelines (OMNR 2009b) were brought into effect.

The Ontario Moose Project was finished in 2017 and addressed issues of harvesting, predation, parasite and climate change (MNRF 2015). A Moose Management Review was conducted in 2019 by the Big Game Management Advisory Committee (BGMAC) and several recommendations were issued in July 2019 (BGMAC 2019b). The recommendations included the inclusion of moose habitat needs in forest management with monitoring the effectiveness of implementation (BGMAC 2019b). They also recommended improving quota setting, hunting rules involving adult moose, and simplifying the tag allocation system (BGMAC 2019b).

Moose habitat management is designed to produce a landscape consistent with meeting physiological needs of moose at desired population densities while considering and addressing other values and wildlife species, where appropriate. Forest management for moose ideally provides both the necessary shrubs and trees of varying ages and in a desirable amount and arrangement to provide food and shelter, while facilitating the timber harvest of the maximum sustainable volume (OMNR 2014).

A major effort to consolidate various forest management guides culminated in the Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (FMGCBSSS) (2010) and the Forest Management Guide for Boreal Landscapes (FMGBL) (2014). The FMGBL (2014) uses natural landscape variability as an underlying concept in habitat management and acts as a coarse filter to address the habitat needs of a wide range of wildlife species. The FMGCBSSS (2010) incorporates site specific guidance to address the needs of other wildlife or habitat guidance that enhances certain types of habitat components such as those prescribed for Moose Emphasis Areas (MEAs), moose aquatic feeding areas and mineral licks. The FMGCBSSS acts as a fine filter. The coarse filter and fine filter approaches address landscape and local elements respectively.

Table 4 Chronology of moose management in Ontario (1800-2019) (BGMAC 2019a)

Year	Moose Management	Outcome/ Strategy
Late 1800s	No “moose” management.	Subsistence/ unregulated harvesting, land clearing/ logging, few regulations.
1888–1895	-	Over harvesting shutdown moose seasons.
1940s	-	Decreasing moose populations raise concerns.
1949	-	Ontario’s moose season closed.
1950s	Slow re-establishment of moose hunting.	Restrictions slowly lifted.
1960s	Moose management goals including maximum sustainable harvest volume and increasing moose populations.	Timber/ forest management and moose management combine.
1970–1980	Moose population crisis; WMU establishment.	Post-rut seasons/ reduced seasons to address moose harvest.
1980	First official provincial review of moose program.	Moose Management Policy (MMP) created.
1980–1982	Shorter seasons/ two hunters for every moose.	Over harvesting still occurred.
1983	Selective harvest system implemented in Ontario from parameters established from the MMP (Timmermann et al. 2002).	Calf tag purchase/ adult lottery (draw) system in place to increase population; habitat management integrated (Timmermann et al. 2002).
1988	Timber Management Guidelines for the Provision of Moose Habitat (TMGPMH) enacted; stemmed from MMP (OMNR 1988).	Party hunting allowed; guidelines established regarding forest access, harvest operations, site preparation, regeneration, and maintenance in regards to moose habitat (Timmermann et al. 2002).
1994	Declaration Order MNR-71: Class EA for Forest Management on Crown Lands in Ontario; moose included in recommendations (EAB 1994).	Moose modified into Featured Species Policy; designated as “provincially featured” (OMNR 1998).
2004	Controlled calf harvest in WMU’s 48, 55A, 55B, and 57.	Calf validation tag requirement; addressed declining moose population in eastern Ontario. Calf tag

		allocation and mandatory hunter reporting (MNRF 2014).
2008	Moose Program Review.	New policies addressing framework, population objectives/ management and tag distribution enacted in 2009.
2009	Cervid Ecological Framework (2009a), Moose Management Policy (2009c), Moose Population Objective Setting Guidelines (2009d), Moose Harvest Management Guidelines (2009b).	Moose-cervid management, sustainable population management, population objective management and harvesting guidelines created.
2010	Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (OMNR 2010a).	Forest management on Crown land combined with biodiversity conservation objectives (MNR 2010).
2014	Forest Management Guide for Boreal Landscapes to replace TMGPMH (1988) (OMNR 2014).	Forest management activities that coincide with natural landscape structures "emulation" (MNR 2014).
2014-2017	Ontario Moose Project conducted to address harvest/predation/parasite/climate pressures (MNRF 2015).	Limited calf season (2015)/ delay start of season (2016) to assist new population objectives (MNRF 2015).
2019	Moose Management Review; recommendations on moose management.	Improve quota setting, increase hunting opportunities for adult moose, simplify tag allocation system and improve public transparency (BGMAC 2019b).

<u>CFSA Regulated Manuals</u>

The Moose Management Policy (MMP) (2009) includes goals and objectives pertaining to harvesting, habitat management, legislation, activities and population management regarding moose (OMNR 2009c). The MMP uses the Cervid Ecological Framework (CEF) to identify geographic priority for cervid management and guiding principles. The legal framework applied in the MMP falls under various acts, including the Fish and Wildlife Conservation Act (1997) (FWCA), the Public Lands Act (1990) (PLA), the Constitution Act (1982), the Provincial Parks and Conservation Reserves Act (2007), the Planning Act (1990) and the Crown Forest Sustainability Act, 1994 (CFSA).

Moose habitat management actions are largely implemented through the application of two of the four regulated manuals under the CFSA.

The Forest Management Planning Manual (FMPM) (2020) prescribes a process to be followed for all Forest Management Units. The FMPM incorporates conditions from the Declaration Order MNR-75 regulated under the Environmental Assessment Requirements for Forest Management on Crown Lands in Ontario (2015) (MECP 2020). Section 1.2.5.1 of the FMPM, Management Zones, describes a process under which specific strategic management objectives may be set for moose (OMNRF 2020b). Moose Emphasis Areas and enhanced silviculture areas are to be considered as applicable concepts (OMNRF 2020b). Integration of moose habitat needs into regulated manuals makes implementation easier and becomes a part of the “normal” forest management planning process.

The Forest Information Manual (FIM) (2020) ensures key information required for management meets the standards required for effective use. It identifies the standards, requirements, responsibilities, timelines and conditions for Crown forest information (OMNRF 2020a). Section 3.0 in the FIM, Values Information, describes standards involved in identifying and documenting moose calving sites and aquatic feeding areas (OMNRF 2020a).

Stand and Site Specific Information

The capability of forest stands to provide cover or forage is based on their soil and stand productivity. When managing for moose habitat, the Forest Ecosystem Classification Manuals can help categorize the site's soil and vegetation components. The Forest Ecosystem Classification for NWO (Sims et al. 1989) (FEC NWO) manual uses a two-step system of 38 vegetation types and 13 soil types to identify common northwestern Ontario forest plant community types and their associated tree and shrub components and vertical structure. The NWO Forest Ecosystem Interpretations (Racey et al. 1989) (NWO FEI) uses this plant community information to identify vegetation communities that have high potential to provide moose winter shelter, or forage even when in a mature state. Using the FEC NWO and the NWO FEI manuals can help forest planners predict the future vegetation based on common pre-harvest vegetation associations. Factors such as soil moisture, site drainage, texture, vegetation overstory, shrub, and herb composition aggregate to inform management predictions on the availability of moose browse/ response of browse species to forest management actions (Rempel et al. 1997).

Effects of Timber Management

There are four broad forest management activities; access, harvest, renewal and maintenance (OMNR 1988). Each has an impact on the amount and arrangement of forest types resulting from timber management. Access is not discussed in this paper but harvest, renewal and maintenance all affect the quality of moose habitat. Positive effects on moose habitat can be achieved by leaving standing timber within clear-cuts, creating various plant communities in and around the cut; increasing the amount of edge habitat produced and increasing the diversity of vegetation types present (OMNR 1988). As shown in Figure 7, the amount of edge is not directly related to the number of disturbance patches or to the amount of area harvested. Timber harvest operations that address edge and diversity, and mimic the original environment while emulating natural disturbance patterns (e.g. Item 6 in Figure 7) can be beneficial to promoting quality moose habitat. For example if one 100ha clear-cut was harvested, it should be done so that the cut's shape minimizes negative habitat effects while producing suitable edge and cover for various plant communities to thrive (OMNR 1988).

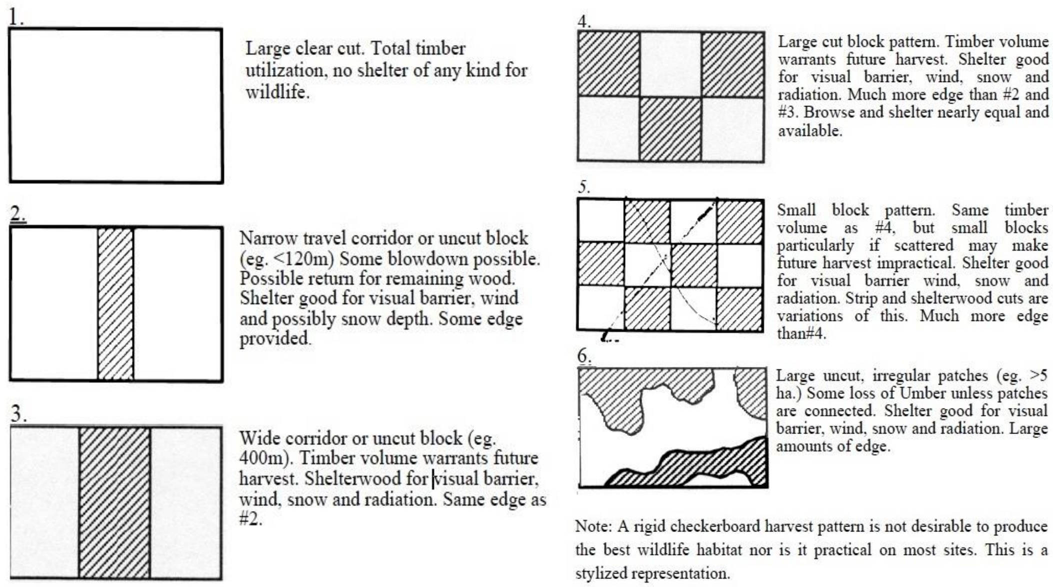

Figure 7 Stylized Illustration of Principles of Timber Harvesting Impacts on Wildlife and Timber Production (OMNR 1988).

Payne et al. (1988) shows the importance of maintaining edge using a “modified cut-block” approach to promote moose habitat in a case study near Thunder Bay, Ontario. Moose surveys were completed in 1976 and 1979 and moose densities were higher than average during the study (Payne et al. 1988). The study area had three blocks; A and C blocks had modified cutting while block B was clear-cut and served as a control element. Area C resulted in having double the moose activity in the cutover areas between January and March of 1987, compared to Areas A or B (Payne et al. 1988). The authors explained the increased moose activity in Area C as due to having 38% more edge and 65% more residual cover. Of that residual cover percentage, 28% had partially cut mixed-wood stands. This variability supported a diverse plant community with varying ages of deciduous and coniferous trees, which Payne et al. (1988) concluded is the perfect mixture for moose habitat. This study affirms the importance of optimizing edge for moose habitat, which eventually provides appropriate browse and cover (habitat). Figure 8 shows the pre-cut and post-cut areas and the observed moose utilization areas (habitat use areas).

Forest harvesting is one of the major sources of early successional regenerating stands preferred in early winter by moose (McNicol and Timmermann 1988, OMNR 1988). Shade-intolerant species, like white birch, trembling aspen, poplar and other browse-producing shrubs can be established and thrive once the canopy is removed. (McNicol and Timmermann 1988). Post-harvest residual deciduous and mixed forest stands help maintain age-class diversity and increase the amount of “edge” on the landscape (McNicol and Timmermann 1988).

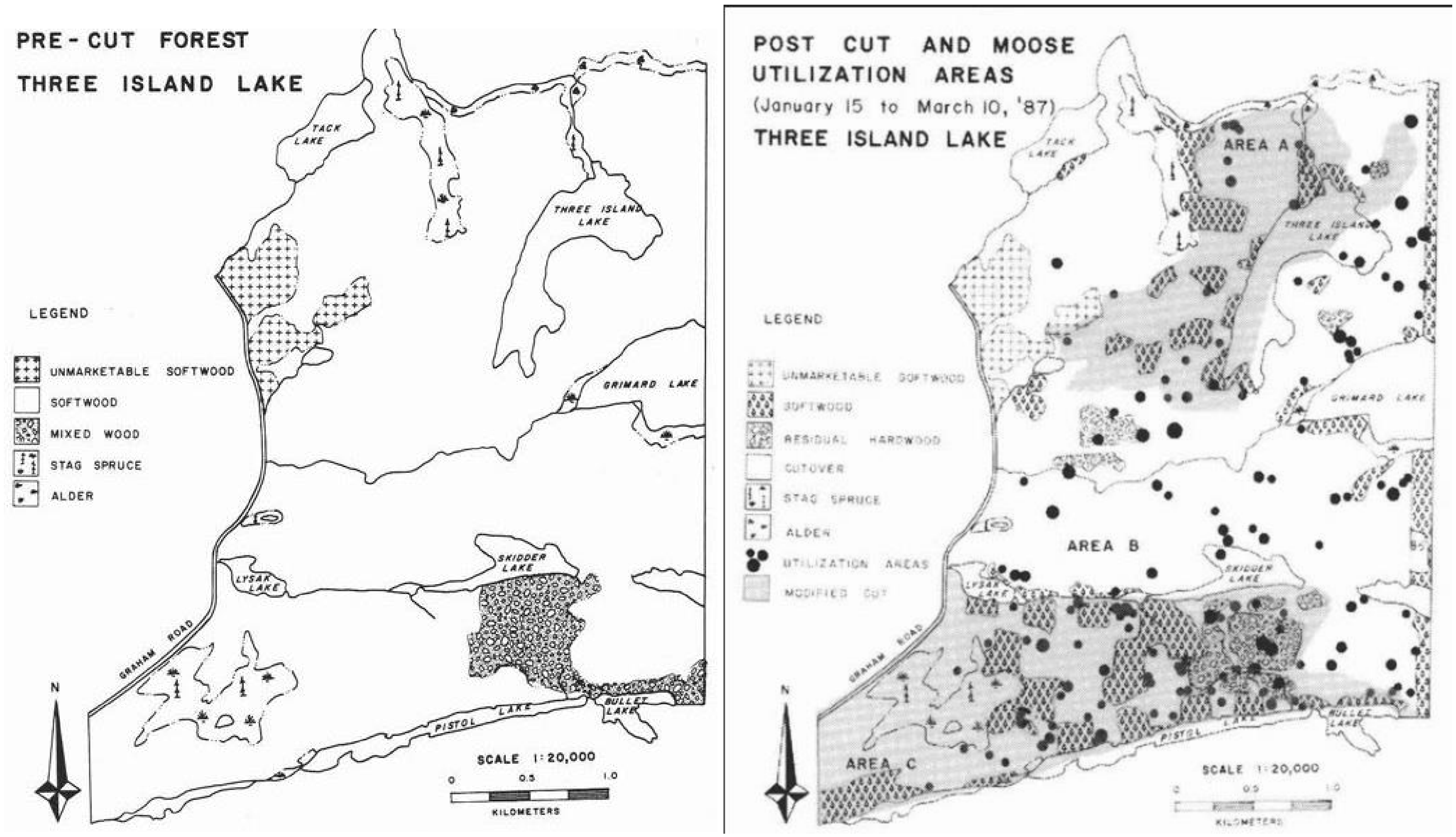

Figure 8 Patterns of moose habitat use in pre- and post-cut forest near Three Island Lake, Thunder Bay, Ontario (Payne et al. 1988) (the post-cut area show dots that represent moose utilization locations).

The Forest Management Guide for Boreal Landscapes (Coarse Filter)

Ontario adopted the Forest Management Guide for Boreal Landscapes (OMNR 2014) which attempts to emulate natural disturbance and landscape patterns based on a simulated range of natural variation (SRNV). Application of this guide acts as a coarse filter intended to achieve an environment which addresses the general needs of most biotic elements (OMNR 2014). Natural disturbances such as wildfires and insect outbreaks alter the terrain and promote biodiversity. The amount, pattern or arrangement of forest stands, categorized by species associations into forest units and broad successional stages make up the elements of the coarse filter approach (OMNR 2014). These indicators, when fulfilled, meet a range of different wildlife habitats while supporting ecosystem processes (OMNR 2014).

The Boreal Landscape Guide classes are identified by development stage ranging from Young to Old Growth Forest. The relative proportions of young and old forest in an area will influence the quality of moose habitat. Moose would not necessarily benefit from Old Growth Forest classes in the early winter, but could be desirable if they are located adjacent to Young Forest, meaning that good moose habitat could be achieved with the varying successional stages depending on the spatial arrangement or species present (OMNR 2014). If the CEF shows an area of managed primarily for moose, increasing the amounts of Old Growth or conifer forest would not necessarily benefit moose but increasing amounts of young forest and mixed forest might (OMNR 2014). Forest management strives to emulate natural disturbances using silviculture practices to produce the amount and arrangement for forest units and age classes consistent with the SRNV (OMNR 2014).

Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (Fine Filter)

Specific moose habitat enhancements are addressed through a fine-filter approach as described in the Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (FMGCBSSS) (OMNR 2010a). This fine-filter approach addresses local habitat requirements such as Areas of Concern around moose aquatic feeding areas (MAFAs), patch size, edge density and special consideration of cover and shelter requirements. Stand and Site Guide Background and Rationale for Direction (2010) is the research document behind the FMGCBSSS explaining the scientific basis for habitat requirements, browse and cover preferences for moose (OMNR 2010b).

The concept of Moose Emphasis Areas is described in the FMGCBSSS (2010). These areas are identified as being suitable to maximize the requirements of moose habitat and address their physiological needs (OMNR 2010a). Large Landscape Patches (LLPs) under the FMGCBSSS are deemed MEAs when certain criteria are achieved; 5-10% wetlands or MAFAs, nutrient-rich sites, 5-30% of the forest is browse-producing, 15-35% mature conifer-dominated and 20-55% mixed wood stands, and where modelling suggests high moose densities exist or are possible (OMNR 2010a). The main objectives is to have a young/ old mixed wood landscape of 50-500 ha with minimum 10 ha patches of young forest (OMNR 2010a). These areas range from 2,000 ha to 10,000 ha and above meeting the criteria for MEAs (OMNR 2010a). Candidate MEAs are assessed using criteria such as ecosite productivity, habitat amount/ arrangement and wetlands/ MAFAs/ access to the area (MNR 2018). These conditions create suitable forage for moose, which in turn ensures adequate habitat and shelter is provided and promotes their reproduction and survival chances. Guidance is provided for summer and winter cover, patch size and distribution, best management practices, and retaining features during forestry operations like MAFAs, residual forest beside water bodies and mineral licks (OMNR 2010a). Mineral licks and aquatic vegetation are sodium sources for moose; these licks contain spring water that has high mineral content (OMNR 2010a). Moose have a need for sodium and other minerals to maintain body condition (Timmermann and McNicol 1988). Moose store enough minerals from aquatic feeding and licks that they can maintain reserves throughout the winter (Timmermann and McNicol 1988). Ensuring that mineral sources are available and accessible is an important part of moose habitat management.

Moose Aquatic Feeding Areas (MAFAs) are important for moose to achieve their mineral requirements (OMNR 2010a). The feeding areas are located in shallow lakes, slow-moving rivers, shallow bays of deep lakes, and beaver ponds where submerged/ floating plants high in sodium are consumed (OMNR 2010a). Forest areas that are harvested must retain residual shoreline forest adjacent to MAFAs (OMNR 2010a). Criteria for MAFA identification include >4 ha areas (smaller areas considered) but >8 ha is preferred and having alder/ willow brush stands or open/ treed wetlands adjacent to MAFAs (OMNR 2010a).

Thermoregulation plays a role in moose habitat selection under temperature extremes (OMNR 2010b). Temperatures above -5°C in the winter will limit the movement of moose and cause them to pursue habitats with wind/ water cooling methods (OMNR 2010b). Conifer-cover in early winter creates cooler local conditions during warmer days and reduces snow depth/ hardness, which makes travelling less energy-consuming (OMNR 2010b). Winter cover in the FMGCBSSS (2010a) includes mature conifer/ mixed forest with a canopy of over 10 metres, suitable tree species (cedar, black/ white spruce) and canopy closure greater than 60% depending on the snow interception capability of the tree species. These winter cover requirements protect moose from snow while providing concealment from predators and food distribution where forest edges occur (OMNR 2010b).

DISCUSSION

As stated in the Introduction, the key research question of this literature review was to evaluate whether or not the current moose habitat management on Crown land in northwestern Ontario meets the physiological needs of moose in the fall and early winter. The Literature Review was structured to provide information about moose, moose habitat and the relevant guides and policies that provide forest management direction on Crown land. Moose physiological needs drive habitat selection. As noted above, the primary physiological need in the fall and early winter is to replenish energy reserves depleted during the rut. Forest managers can enhance the quality of habitat thereby influencing the ability of moose to meet those needs. The Discussion will consider the application of the information presented in the development of a hypothetical forest management plan (FMP).

The landscape or area being managed for moose habitat must be identified in its associated Forest Management Unit(s) (FMU), Wildlife Management Unit(s) (WMU) and location in Cervid Ecological Framework map. Each FMU has its own FMP that uses Indigenous input (concerns/ traditional ecological knowledge [TEK]) and stand/ site information to create a long-term plan incorporating suitable harvesting/ regeneration techniques specific to the area and moose habitat needs. Each WMU dictates the game that is hunted, the related open season dates and method of hunting (e.g. rifle, bow, etc.). The CEF displays areas where low to high moose densities are managed; this is important to identify for an area so harvesting practices/ the FMP can be modified. If an area is managed for low moose densities, a more intensive harvesting method can be chosen, therefore more timber can be harvested and few moose habitat management considerations (e.g. less edge, removal of more mature trees). High moose density areas are managed to provide suitable cover, browse, corridors and accessibility to resources so moose have the chance to thrive. All three structures combine to form broad management objectives for moose habitat. Moose habitat management in a FMP basically uses the coarse (FMGBL) to fine (FMGCBSSS) filter approach for addressing habitat requirements. The coarse filter method uses various forest stands that are categorized by species associations (forest units) and broad successional stages to meet a range of species' habitat requirements. The fine filter method details specific moose habitat requirements, browse and cover preferences that are not addressed in the coarse filter. Planners may include certain moose targets to support economic/ social objectives, which is completed under the existing FMPM.

The FMGBL is the broad-scale (landscape) technique of managing for moose habitat. The goal of the coarse filter direction is to meet the demands of moose physiological needs while meeting the habitat needs of other species. Landscape classes used from the FMGBL help a planner know what type of stand is present in a managed area. The amount and arrangement of habitat components (e.g. food, thermal and security cover) is driven by emulating how natural disturbances shape the landscape. Natural disturbance emulation does not necessarily favour moose (or any other critter) because the FMGBL is insensitive to the protection of local landscape components (e.g. calving sites, MAFAs, mineral licks, forest edges that support year round habitat). In this case, the manager has decided he wants to improve moose habitat that specifically supports moose health in the fall and early winter. The manager recognizes that - given this specific objective - more guidance at the local level is required to meet most/ all moose physiological needs. These physiological needs are not met to the highest degree using the coarse filter, so the application of the fine filter is necessary.

The FMGCBSSS is the fine-scale (local) technique of managing for moose habitat. The fine filter direction gives managers science-based standards, guidelines and best practices that can be used to enhance the quality and quantity of desirable habitat for a particular species. This flexibility of standards between species enables an emphasis on browse and cover production for moose. Emphasis from management can stem from utilizing the FEC and FEI manuals to help tell the planner the quality of the selected area (to use best management practice). The schedule of harvesting, the type of regeneration (e.g. natural, spray), the tree/ browse species managed for moose (mixedwood of varying ages) and any special moose habitat features would have a buffer/ riparian zone protection (calving sites, MAFAs, mineral licks) to promote moose habitat features. The harvesting pattern chosen should best suit the landscape to emulate, not mimic natural disturbances. Identification of specific features early in the planning process ensures proper protection is in place while keeping the feature "undisturbed." There is little value investing energy into low productivity/ low diversity landscapes because these areas will likely never provide a good return in terms of quality or quantity of moose habitat. The manager must therefore focus on areas with potential to support high densities of nutritional browse (e.g. mixed forest). This approach is particularly effective when these areas of high productivity-mixed forest are interspersed with other significant features such as MAFAs, corridors and mineral licks. MEAs can be decided depending on the moose density of the area and the level of habitat feature protection used during forestry practices.

Designing MEAs within the framework provided by the FMGBL and taking advantage of the flexibility provided by the FMGCBSSS makes it possible for a forest manager to develop a plan that meets most of the physiological requirements of moose in the fall and early winter. In general, heterogenous habitats of multiple landscape classes are more ideal than a homogenous habitat/ one or two landscape classes. This process does not directly increase moose populations, but through habitat management and appropriate forestry practices moose have the highest chance for reproduction, forage potential and winter survival.

CONCLUSION

This document has examined how well habitat management in Ontario meets the physiological needs of moose in the fall and early winter. Compared to management in the early 1900s, moose habitat management has come a long way. People and the federal/ provincial governments realized that cervids and especially moose are an important part of environmental/ wildlife maintenance. Moose habitat is characterized by food, shelter, cover and other landscape factors that help meet their physiological needs, such as reproduction and energy requirements. The type of forest management applied influences the age, quality, and abundance of browse depending on forest type and this, in turn, directly influences the quality of fall habitat for moose. Moose are not managed for high densities everywhere; habitat management efforts may be focused on priority areas called Moose Emphasis Areas, to provide high quality moose habitat and promote population health. Habitat management does not address population management directly, but production of abundant and high quality habitat is likely a requirement of supporting higher moose populations that the Province is trying to achieve.

There are many critical points that are conveyed in the Literature Review. Following the rut, moose have a strong need to replenish energy reserves and regain high levels of physiological health. Winter survival of adults is maximized with high energy reserves, while encouraging fetal development and calf survival. Maximizing the energy input of moose depends on their browsing behaviour and habitat selection. High energy, digestible (preferred) browse species are selected adjacent to thermal/ security cover. Moose habitat management aims to provide a landscape consisting of abundant/ well distributed forage and cover patches. Moose habitat is encouraged in areas of high productivity that will generate desirable browse species and mixed forest conditions. The Forest Management process following the Forest Management Planning Manual, the FMGBL and the FMGCBSSS provide habitat-related guidance for the creation of Moose Emphasis Areas where landscape conditions are conducive to a high return on management investment. Guidance from the FMGCBSSS provides specific recommendations on patch size, forest renewal and desirable habitat attributes that may be applied in these Moose Emphasis Areas to promote moose population health by meeting the physiological needs of adult moose.

Current guidelines are science-based, and habitat management recommendations appear to address the physiological requirements of moose as documented in the literature examined. The combination of the landscape framework provided by the FMGBL and the flexibility for influencing local conditions provided by the FMGCBSSS make it possible for forest managers to design forest management plans that support goals associated with the physiological needs of moose. Continuous monitoring and research of moose habitat management will benefit future landscape and local-level implementation measures. The analysis concludes that habitat management in northwestern Ontario does meet the physiological needs of moose in the fall and early winter.

LITERATURE CITED

Andison, D., L. Kremsater, A.C. Bélisle, Y. Bergeron and D. MacLean. 2016. Towards a Natural Range of Variation (NRV) Strategy for the Canadian Boreal Forest Agreement Summary Report. The Science Committee of The Canadian Boreal Forest Agreement. https://www.fpac.ca/wp-content/uploads/NRVSummary_2016FINAL_Englishcompressed.pdf. February 11, 2021.

Baldwin, K.A. and R.A. Sims. 1989. Field Guide to the Common Forest Plants in Northwestern Ontario. Canadian Forest Service, Thunder Bay, Ontario. 344pp.

Ballenberghe, V.V. and W.B. Ballard. 1997. Population Dynamics pp. 223-245 *in* Franzmann, A.W. and C.C. Schwartz (1st ed.) Ecology and Management of the North American Moose. Wildlife Management Institute, United States of America. 733pp.

[BGMAC] Big Game Management Advisory Committee. 2019a. Moose Management Review – Listening Sessions. Big Game Management Advisory Committee. https://www.ofah.org/wp-content/uploads/2019/05/MMR-engagement-presentation-May182019-compressed-002.pdf. February 20, 2021.

BGMAC. 2019b. Moose Management Review: Recommendations to the Minister of Natural Resources and Forestry on Moose Management. Big Game Management Advisory Committee. 37pp.

Bubenik, A.B. 1997. Evolution, Taxonomy and Morphophysiology pp. 77-123 *in* Franzmann, A.W. and C.C. Schwartz (1st ed.) Ecology and Management of the North American Moose. Wildlife Management Institute, United States of America. 733pp.

Crichton, V., A.T. Bergerud and E. James-Abra. 2019. Moose. The Canadian Encyclopedia. https://www.thecanadianencyclopedia.ca/en/article/moose. October 15, 2020.

Crown Forest Sustainability Act (CFSA). 1994. S.O. 1994, c. 25

Dussault, C., J.-P. Ouellet, R. Courtois, J. Huot, L. Breton and H. Jolicoeur. 2005b. Linking moose habitat selection to limiting factors. Ecography 28:619-628.

Dussault, C., R. Courtois, J.-P. Ouellet and I. Girard. 2005a. Space use of moose in relation to food availability. Can. J. Zool. 83:1431-1437.

[EAB] Environmental Assessment Board. 1994. Reasons for decision and decision: class environmental assessment by the Ministry of Natural Resources for timber management on Crown lands in Ontario. Environmental Assessment Board. Toronto, ON. 561 pp.

Geist, V. 2020. Moose. Encyclopædia Britannica. https://www.britannica.com/animal/moose-mammal. November 6, 2020.

Jackson, G.L., G.D. Racey, J.G. McNicol and L.A. Godwin. 1991. Moose Habitat Interpretation in Ontario. Ont. Min. Nat. Res., Northwestern Ontario Forest Technology Development Unit Technical Report 52, 74pp.

Karns, P.D. 1997. Population Distribution, Density and Trends pp. 125-139 *in* Franzmann, A.W. and C.C. Schwartz (1st ed.) Ecology and Management of the North American Moose. Wildlife Management Institute, United States of America. 733pp.

McNicol, J.G. and H.R. Timmermann. 1988. Effects of forestry practices on ungulate populations in the Boreal mixed wood forests. Appendix IV - Timber Management Guidelines for the Provision of Moose Habitat. Queen's Printer for Ontario. Ontario, Canada. 27-33 pp.

[MECP] Ministry of the Environment, Conservation and Parks. 2020. Environmental assessment requirements for forest management on Crown lands in Ontario. Government of Ontario. https://www.ontario.ca/page/environmental-assessment-requirements-forest-management-crown-lands-ontario. April 23, 2021.

[MNR] Ministry of Natural Resources. 2018. Lakehead Forest Moose Emphasis Areas for 2020-2030 Forest Management Plan. Lakehead Forest LCC Presentation. Government of Ontario. Lakehead_LCC_Moose Emphasis Areas Presentation_2018-06-12.

[MNRF] Ministry of Natural Resources and Forestry. 2014. Hunting Regulations – Moose – General - Moose Regulations. http://www.ofah.org/zonej/wp-content/uploads/2014/07/Moose-Regulations.pdf. January 29, 2021.

MNRF. 2015. Ontario's Moose Project – Phase 2 – Review of Factors Potentially Affecting Moose. Government of Ontario. https://ero.ontario.ca/archive/012-4587. April 15, 2021.

MNRF. 2019. How to get involved in forest management. Government of Ontario. https://www.ontario.ca/document/participate-forest-management-ontario/how-get-involved-forest-management. April 1, 2021.

MNRF. 2020a. Creating wildlife habitat. Government of Ontario. https://www.ontario.ca/page/creating-wildlife-habitat. April 10, 2021.

MNRF. 2020b. Crown land management. Government of Ontario. https://www.ontario.ca/page/crown-land-management. March 2, 2021.

MNRF. 2020c. Find a wildlife management unit (WMU) map. Government of Ontario. https://www.ontario.ca/page/find-wildlife-management-unit-wmu-map. April 4, 2021.

MNRF. 2021a. Management Units and Forest Management Plan Renewal Schedules. Government of Ontario. https://www.ontario.ca/page/management-units-and-forest-management-plan-renewal-schedules. April 1, 2021.

MNRF. 2021b. 2020 Mandatory Moose Hunter Report Summary. Government of Ontario. https://files.ontario.ca/mnrf-2020/mnrf-2020-moose-reporting-summary-en-2021-03-26.pdf. April 14, 2021.

[NOSA] North Western Ontario Sportsmen's Alliance. 2021. North Western Ontario Sportsmen's Alliance. North Western Ontario Sportsmen's Alliance. http://www.teamnosa.com. April 1, 2021.

[OFAH] Ontario Federation of Anglers and Hunters. 2021. Advocacy. Ontario Federation of Anglers and Hunters. https://www.ofah.org/about-us/advocacy/. April 9, 2021.

[OMNR] Ontario Ministry of Natural Resources. 1988. Timber Management Guidelines for the Provision of Moose Habitat. Queen's Printer for Ontario. Ontario, Canada. 40 pp.

OMNR [Ranta, B.W.]. 1998. Selected Wildlife and Habitat Features: Inventory Manual for use in Forest Management Planning. Peterborough: Queen's Printer for Ontario. 236 pp.

OMNR. 2009a. Cervid Ecological Framework. Ministry of Natural Resources. 19pp.

OMNR. 2009b. Moose Harvest Management Guidelines. Toronto: Queen's Printer for Ontario. 27 pp.

OMNR. 2009c. Moose Management Policy. Ministry of Natural Resources. 13pp.

OMNR. 2009d. Moose Population Objectives Setting Guidelines. Ministry of Natural Resources. 16 pp.

OMNR. 2010a. Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales. Toronto: Queen's Printer for Ontario. 211 pp.

OMNR. 2010b. Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales – Background and Rationale for Direction. Toronto: Queen's Printer for Ontario. 575 pp.

OMNR. 2014. Forest Management Guide for Boreal Landscapes. Toronto: Queen's Printer for Ontario. 104 pp.

OMNRF. 2020a. Forest Information Manual. Toronto: Queen's Printer for Ontario. 90pp.

OMNRF. 2020b. Forest Management Planning Manual. Queen's Printer for Ontario. 318pp.

Payne, D., J. McNicol, G. Eason and D. Abraham. 1988. Moose habitat management and timber management planning: three case studies. The Forestry Chronicle 64(3):270-276.

Peek, J.M. 1997. Habitat Relationships pp. 351-375 *in* Franzmann, A.W. and C.C. Schwartz (1st ed.) Ecology and Management of the North American Moose. Wildlife Management Institute, United States of America. 733pp.

Racey, G.D., T.S. Whitfield and R.A. Sims. 1989. Northwestern Ontario Forest Ecosystem Interpretations. Canadian Forestry Service, Thunder Bay, Ontario. 130pp.

Rempel, R.S., G.D. Racey and K.A. Cumming. 1997. Predicting moose browse production using the north-western Ontario forest ecosystem classification. Alces 33:19-31.

Renecker, L.A and C.C. Schwartz. 1997. Food Habits and Feeding Behavior pp. 403-439 in Franzmann, A.W. and C.C. Schwartz (1st ed.) Ecology and Management of the North American Moose. Wildlife Management Institute, United States of America. 733pp.

Rowe, J.S. 1972. Forest Regions of Canada. Canadian Forestry Service. Ottawa, Canada. 177pp.

Schwartz, C.C. 1997. Reproduction, Natality and Growth pp. 141-171 in Franzmann, A.W. and C.C. Schwartz (1st ed.) Ecology and Management of the North American Moose. Wildlife Management Institute, United States of America. 733pp.

Schwartz, C.C. and L.A. Renecker. 1997. Nutrition and Energetics pp. 441-478 *in* Franzmann, A.W. and C.C. Schwartz (1st ed.) Ecology and Management of the North American Moose. Wildlife Management Institute, United States of America. 733pp.

Sims, R.A., W.D. Towill, K.A. Baldwin and G.M. Wickware. 1989. Field Guide to the Forest Ecosystem Classification for Northwestern Ontario. Canadian Forestry Service, Thunder Bay, Ontario. 191pp.

Timmermann, H.R. 1998. Importance and use of mixedwood sites and forest cover by moose *(Alces alces)*. Bor. Mix. Notes (15):231-245.

Timmermann, H.R., R. Gollat and H.A. Whitlaw. 2002. Reviewing Ontario's Moose Management Policy – 1980-2000 – Targets Achieved, Lessons Learned. Alces 38: 11-45.

Timmermann, H.R. and J.G. McNicol. 1988. Moose habitat needs. The Forestry Chronicle 64(3):238-245.

Timmermann, H.R. and A.R. Rodgers. 2017. The status and management of moose in North America – Circa 2015. Alces 53:1-22.

Wise, S.F. 2020. Ontario. Encyclopædia Britannica. https://www.britannica.com/place/Ontario-province. January 16, 2021.