IS THE IDENTIFICATION OF MOOSE EMPHASIS AREAS WELL MAINTAINED IN ONTARIO'S SUSTAINABLE FOREST LICENCES?

by

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Faculty of Natural Resources Management

Lakehead University

Thunder Bay, Ontario

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ABSTRACT

Ontario's Ministry of Mines, Northern Development, Natural Resources and Forestry is responsible for wildlife data collection to support forest management throughout the province. Moose aquatic feeding areas (MAFAs) are a seasonally important habitat feature for moose and are classified using a standardized ranking system to assess their quality. However, throughout the province, over 64% of MAFAs were surveyed more than 15 years ago and over 84% were surveyed more than 10 years ago, with some sites last surveyed as long ago as 36 years. Forest management polices relating to moose habitat have undergone relatively recent changes, such as the requirement for identifying Moose Emphasis Areas. However, MAFA data is still regularly used throughout the planning process. Due to natural macrophyte succession, the effects of beavers as ecosystem engineers, and the effects of ongoing moose herbivory, dated information on MAFAs may not accurately reflect their current state. To test the hypothesis that the quality of MAFAs may change over time, 32 sites in the Nipissing Forest were resurveyed for comparison. Over a third changed in quality since the last survey. Future management considerations may include updating information on MAFAs more frequently, such as on a 10-year basis, so that resource managers can make more informed decisions.

Keywords: *Alces alces,* moose aquatic feeding area, macrophyte, succession

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INTRODUCTION

The moose, *Alces alces* (L., 1758), is an iconic species and occurs throughout Ontario, being highly valued for its socioeconomic, cultural, and ecological benefits. The Ministry of Northern Development, Mines, Natural Resources, and Forestry (OMNR) is responsible for the management of this cervid species in Ontario, but the responsibility of managing habitat is largely delegated to 39 Sustainable Forest Licensees (Watkins, 2021). Moose habitat management policies have undergone major changes by replacing the previous provincially featured species approach used in the *Timber Management Guidelines for the Provision of Moose Habitat* (OMNR, 1988) with a coarse- and fine-filtered approach used in the *Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales* (OMNR, 2010). This "Stand and Site Guide" (SSG) provides management direction for stand-level habitat features.

Throughout spring and summer, moose are frequently found using what the *Timber Management Guidelines for the Provision of Moose Habitat* (OMNR, 1988) identified as Moose Aquatic Feeding Areas (MAFAs). Presumably, moose use of MAFAs is due to the substantially higher levels of sodium and other important nutrients in aquatic vegetation that are inadequately found in terrestrial browse (Fraser et al., 1984). The sodium content is 500 times greater in submergent and floating-leaved macrophytes, and about 50 times greater in emergent macrophytes than in terrestrial vegetation (Jordan et al., 1973). Thus, MAFAs provide seasonal but nutritionally significant habitat and could possibly act as a primary limiting factor on moose populations if an adequate supply of suitable sites is not maintained. Due to a shift in policy, there are now no Areas of Concern (AOCs, or designated areas of protection) associated explicitly with MAFAs, but lakes and ponds are given 30-to-90-meter AOCs that retain at least

50% of the area around a waterbody as residual shoreline forest during logging operations. Additionally, Moose Emphasis Areas (MEAs) are identified as locations with moderate to high moose carrying capacity with an intention to enhance habitat. Each MEA must be at least 2,000 hectares with a composition of 5-10% wetlands, 5-30% browse, 15-35% mature conifer, and 20-55% hardwood/mixedwood (OMNR, 2010).

The OMNR conducts Wildlife Value Area surveys using the standardized methodology from *Selected Wildlife and Habitat Features Inventory Manual* (Ranta, 1998), of which MAFAs comprise over 77% of the total database. This data was accessed from the Land Information Ontario website, Ontario GeoHub, which is actively updated by the OMNR and currently used by planning foresters in the selection process for MEAs. However, over 64% of MAFAs were surveyed more than 15 years ago and over 84% were surveyed more than 10 years ago, with some dating back 36 years ago, leaving many areas with management decisions to be made based on aged information (Land Information Ontario, 2021). This thesis describes an attempt to resurvey 32 wetlands in the Nipissing Forest to assess whether MAFA data is adequate for the identification of MAFAs and in the selection of MEAs. The study area is a managed forest, the Nipissing Forest, with a dominance of White Pine, *Pinus strobus* (L.) and a tolerant hardwood mix, located in the southern portion of northeastern Ontario.

First, current Ontario policy and forest management planning related to MAFAs is explored to determine if all forest tenure holders take the same approach and use the same data sources when addressing moose habitat. Although it is well accepted that moose use aquatic feeding areas, their importance will be reiterated in a literature review that includes detail on preferred macrophyte species and the processes that may alter the suitability of moose aquatic feeding areas over time. Second, the results from the contemporary survey of wetlands in the

Nipissing Forest are compared to older MAFA survey data. Third, given wetland succession and the role of beavers as ecosystem engineers, the Nipissing Forest resurvey results are compared to the previously identified MAFAs to determine if the habitat conditions differ since the date of their original designation. This data will provide information on how well habitat planning in forest management is meeting the physiological needs of moose during spring and summer. If the recently resurveyed sites from the study area are not similar to the newer MNRF database, a recommendation should be that MAFA surveys be updated more frequently in order to make better informed management decisions.

LITERATURE REVIEW

Controversy exists over the taxonomy of moose; some recognize Eurasian elk, *Alces alces* (Linnaeus, 1758), and moose, *Alces americanus* (Clinton, 1822), as two distinct species (Wilson and Reeder, 2005), while others consider moose, *Alces alces*, to be a true species that should be divided at the subspecies level (Hundertmark et al., 2002). Based on morphological differences such as palate size (Peterson, 1955) and the spatial distribution of haplotype diversity (Hundertmark, 2002), there are four distinct subspecies of moose recognized in North America, of which the Western moose, *Alces alces* L. *andersoni (*Peterson 1952) and the Eastern moose, *Alces alces* L. *americana (*Clinton 1822) are found in Ontario. *A. a. andersoni* ranges from western Canada to the Great Lakes and *A. a. americana* ranges from the Great Lakes to the east coast (Peterson 1955); moose in the Nipissing Forest case study are assumed to be *Alces alces americana*.

MOOSE HABITAT IN ONTARIO'S FOREST MANAGEMENT POLICIES

Ontario has over 70 million ha of forests, of which 46.4 million ha are in the Managed Forest Zone or "Area of the Undertaking" (Watkins, 2021). The forest cover accounts for 66% of the province's total land area, 20% of Canada's forests, and is equivalent to approximately 2% of the world's forests (Watkins, 2021). Over 15% of the Managed Forest consists of water or wetland land classes, leaving a large and heterogenous landscape to be maintained by forest management (Watkins, 2021). Previously, moose habitat management direction in Ontario was laid out in the *Timber Management Guidelines for the Provision of Moose Habitat* (OMNR, 1988). The guide recommended applying 120-m Areas of Concern around identified moose aquatic feeding areas (MAFAs) and restricting or modifying adjacent operations to enhance moose habitat. Cut blocks were to be irregularly shaped, reduced to 80 to 130 ha in size, and consist of scattered shelter patches if cover-to-cover distance was greater than 400 m. The guide recommended giving 30- to 150-m-wide shoreline reserves around lakes and streams in proximity to active operations to be used as corridors that permitted moose sufficient cover and continued access to these waterbodies. This guide was a part of the provincially featured species approach, but forest management policies shifted in 2010 to managing wildlife habitat across the landscape using coarse- and fine-filtered approaches.

First, the Cervid Ecological Framework broadly delineates Ontario's Area of the Undertaking into Cervid Ecological Zones (CEZ) with management objectives of desired density ranges for each cervid species found in Ontario: moose, white-tailed deer (*Odocoileus virginianus* Zimmermann, 1780), elk or wapiti (*Cervus elaphus* L. *canadensis* Erxleben, 1777), and caribou (*Rangifer tarandus* L. *caribou* Gmelin, 1788). Forests managed for low densities of these ungulates can be harvested more intensively, while areas managed for high densities are required to take habitat into consideration. Further management direction for wildlife habitat is found in the *Forest Management Guide for Boreal Forest Landscapes* (OMNR 2014) or the *Forest Management Guide for Great Lakes-St. Lawrence Forest Landscapes* (OMNR 2014), depending on the location of Sustainable Forest Licence (SFL) area. These guides are considered coarse-filter methods that emulate natural disturbances and produce variation in amount and arrangement of habitat across the landscape to provide for the majority of wildlife species' needs. Areas known as Large Landscape Patches (LLPs) are used to maintain a diversity of ecosystem conditions by meeting the targets for specific Landscape Guide pattern indicators. The fine-filter methods are found in the *Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales* (OMNR, 2010), which prescribes a series of science-based standards, guidelines and best management practices for stand-level habitat features that are not adequately addressed in the landscape guides.

Moose Emphasis Areas (MEAs) are a type of LLP with an objective for moose habitat. Selected MEAs must be greater than 2,000 hectares, but preferably 10,000 hectares; they must have population density modelling results indicating a moderate to high carrying capacity for moose, and they must meet a number of other criteria (OMNR, 2010). MEAs should occur on productive, nutrient rich sites and be comprised of 5-10% wetlands, including previously identified MAFAs. Forest composition also needs to meet ranges of 5-30% browse, 15-35% mature conifer, and 20-55% hardwood or mixedwood forest, as well as specific criteria to meet summer and winter cover requirements. There are no longer AOCs explicitly for MAFAs, but their indirect protection still occurs with prescriptions for retention of shoreline forest around waterbodies and the provision of summer cover for moose. All MEAs are required to maintain a minimum of 15 ha of summer cover in any 500-ha area, which is recommended to be retained next to MAFAs most likely used by moose. Sections 4.1.1 and 4.1.2 of the standards (OMNR, 2010) address water quality by giving the area around all lakes and ponds 30- to 90-meter AOCs that retain at least 50% residual shoreline forest, preferentially adjacent to MAFAs, to provide access routes and cover for moose.

CHARACTERISTICS OF IDEAL MOOSE AQUATIC FEEDING AREAS

Moose are large, semi-aquatic herbivores that are commonly seen feeding in the littoral regions of lakes, ponds, streams and wetlands, known as MAFAs. Aquatic habitat use by moose is not fully understood, but is likely related to meeting sodium requirements (Fraser et al., 1980) and maximizing foraging efficiency (MacCracken et al., 1993). An average moose, weighing around 425 kilograms, should consume 11,000 calories per day and will eat 3 to 4 times more in volume throughout the spring and summer (Timmerman and McNicol, 1988). These seasons are nutritionally significant due to the abundance of vegetation, and the MAFAs are especially important during spring and summer months, since around 90% of mineral intake is acquired from aquatic plants (Peek et al., 1976).

It is well documented that macrophytes are a seasonally important browse source for moose and can be further divided into three categories; submerged, emergent, and floating-leaved plants (Newmaster et al., 1997). Emergent macrophytes average 50 times more sodium, and submerged and floating macrophytes average 500 times more sodium concentration than found in terrestrial vegetation (Jordan et al., 1973). Despite being a generalist herbivore, moose will travel up to 30 km to reach a preferred feeding area based on the relative availability of desired aquatic plants, generally selecting those with the highest sodium content (Fraser et al., 1980). A recent isotopic analysis has estimated the summer diet of moose inhabiting Isle Royale, Michigan, as 13 to 27% aquatic in origin (Tischler et al., 2019), and 88% of their annual sodium intake is obtained solely from aquatic vegetation (Jordan et al., 1973).

Some moose populations do not seem to consume aquatic plants at all, while others seem to use them year-round (MacCracken et al., 1993), and large variations exist in the extent to which aquatic species are selected by moose. Moose occupying the Great Lakes-St. Lawrence region consume aquatic vegetation higher in sodium, but nutritional factors and the importance of this habitat feature to moose may vary geographically (Morris, 2014). In Algonquin Park, Floating Bur-reed (*Sparganium angustifolium* Michx.) and Yellow Pond-lily (*Nuphar variegatum* Durand) are two of the most preferred species during early spring, while Water-shield (*Brasenia schreberi* Gmel.) is a more important browse species during late summer due to local abundance (Peterson, 1955). White Waterlily (*Nymphaea odorata* Aiton), Northern Watermilfoil (*Myriophyllum verticillatum* L.), and various Pondweeds (*Potamogeton* spp.) are also preferred (Newmaster et al., 1997). Generally, favored vegetation occurs in lakes with floating-leaved plants, and light-green, submergent vegetation is less preferred over dark-green, emergent vegetation (Ranta, 1998). The table below lists the aquatic plants species found in the 32 lakes throughout the study area, supported by evidence of moose consumption in geographically similar regions and based on literature.

Table 1. Aquatic vegetation found in the study area and reported to be consumed by moose.

Scientific Name	Common Name	References
Alisma triviale Pursh	Northern Water Plantain	1
Brasenia schreberi Gmel.	Water Shield	1, 2, 7
Calla palustris L.	Wild Calla	5, 6
Equisetum fluviatile L.	Water Horsetail	1, 2, 3, 4, 5, 6
Myriophyllum spp.	Water Milfoils	5
M. sibiricum Kom.	- Northern	1
M. alterniflorum D.C.	- Alternate-leaved	3
Nuphar variegatum Durand	Yellow Pond Lily	1, 2, 4, 5, 6, 7
Nymphaea ordorata Aiton	White Water Lily	1, 2
Pontederia cordata L.	Pickerelweed	2
Potamogeton spp. L.	Pondweeds	1, 2, 5, 7
P. amplifolius Tuckerm.	- Large-leaved	3, 4
P. epihydrus Raf.	- Ribbon-leaved	3, 4
P. gramineus L.	- Grass-leaved	3, 6, 4
P. natans L.	- Floating-leaved	3, 4
Ranunculus longirostris	Water Crowfoot	1, 5
Sagittaria latifolia Willd.	Broad-leaved Arrowhead	1, 2, 3
Sparganium spp. L.	Burreeds	5
S. fluctuans (Morong) Robins.	- Floating	2
S. americanum Nutt.	- Lesser	4, 7
Schoenoplectus subterminalis Sojak	Water Bulrush	2, 3, 4
Typha latifolia L.	Broad-leaved Cattail	4
Ultricularia vulgaris L.	Common Bladderwort	1, 2, 4, 6

Location references are: 1 Ontario in general (Newmaster et al. 1997), 2 Algonquin Provincial Park (Peterson, 1955), 3 Chapleau Crown Game Preserve (Vos 1958), 4 Sibley Provincial Park (Fraser et al. 1984), 5 Superior National Forest in northeastern Minnesota (Peek et al. 1976), 6 Isle Royale National Park in Michigan (Jordan et al. 1973), and 7 western Quebec (Joyal and Scherrer, 1976).

MACROPHYTE SUCCESSION IN FRESHWATER ECOSYSTEMS

All lakes, ponds, and wetlands undergo a continuous process of aging and eutrophication from the accumulation of nutrients. Water bodies naturally become shallower and more nutrient rich due to the cumulative effects of processes such as sedimentation, but they can oscillate between alternative states, especially when influenced by beaver disturbance cycles (Nummi et al. 2019). Fluctuations in water depth and turbidity influences light availability in the water column, which can govern littoral macrophyte assemblages (Vermaire et al., 2012). Total phosphorus (TP) concentrations are used to infer nutrient levels because phosphorus is a limiting factor in macrophyte growth. There are three main trophic states: oligotrophic, mesotrophic, and eutrophic. In Ontario, lakes with less than 10 micrograms per liter (µg/L) of TP are classified as oligotrophic, lakes with between 10-20µg/L are classified as mesotrophic, and lakes with over 20 µg/L are considered eutrophic (MECP, 2019). Macrophytes, especially submerged species that stabilize lake ecosystems and act as phosphorus sinks, are an important component of aquatic ecosystems and can be used as bioindicators for trends in lake trophic status or evidence of disturbance regimes (Vermaire et al., 2012).

Plant communities vary on a temporal and spatial scale, and there are many variables that could impact which species are present. Phosphorus is a primary nutrient, so TP can be a good indicator of macrophyte growth. Out of the 32 water bodies in this study, four of them were a part of Ontario's Lake Partner Program in 2003 and water quality was measured (MECP, 2021). Looking at the TP concentration from this program, there were readings ranging from oligotrophic to near eutrophic levels (5.4, 9.8, 12.4, & 17.2 µg/L). The lakes with higher TP were also MAFAs that ranked high in quality, while the lake with a low TP level was ranked lower in quality due to fewer aquatic plants present. Changes in nutrient availability such as TP concentrations can result in variation of macrophyte assemblage and total richness, thus changing habitat suitability for wildlife.

Signs of eutrophication in temperate, freshwater wetlands also include turbid conditions with accelerated phytoplankton growth, resulting in macrophyte loss, as highly diverse aquatic plant communities become replaced with highly productive monocultures (Vermaire et al., 2012). A shift towards algal-dominated lakes is detrimental to suitable moose aquatic habitat because emergent macrophytes, which are less nutritionally valuable, become prevalent. MAFAs could also decrease in quality if the water body shifted back towards an oligotrophic state that has little to no aquatic vegetation due to low nutrient concentrations (MECP, 2019). Other stressors to inland lakes on the Precambrian Shield region of Canada may include acidification, shoreline modification, invasive species, and watershed disturbances that are exacerbated by climate-induced changes that include warmer water temperatures and longer ice-free periods (Winter et al. 2011).

Not all wetlands are equivalent in terms of producing aquatic forage for moose. Productivity is higher in large (> 1 ha), young- to medium-aged (6 to 38 years) ponds, and species richness and biomass are generally lower in smaller ponds older than 50 years (Morris, 2014). Early successional ponds, aged 1 to 10 years, are first colonized by floating aquatic plants, followed by submerged species at intermediate ages between 11 and 40 years (Ray et al., 2001). Old ponds have a more developed emergent plant zone (Windels, 2017), suggesting that late successional ponds are lower quality MAFAs, because moose mainly eat submerged and floating-leaved aquatic plants such as pondweeds and lilies (Morris, 2014). Selective grazing by moose has also been known to significantly reduce aquatic plant biomass, species richness, and diversity (Quarnemark & Sheldon, 2004). Prolonged herbivory effects could lead to a shift in the composition of the macrophyte community (Fraser et al. 1984) such as favoring the growth of shade-intolerant species that are competitively inferior under natural conditions (Quarnemark & Sheldon, 2004). Some species may be able to withstand adverse impacts of herbivory by growing in deeper water because moose only feed in areas where they are able to stand on the lake bottom. However, the lack of long-term water quality and aquatic vegetation monitoring data for inland waterbodies makes it difficult to assess whether spring and summer moose habitat fluctuate on a spatial or temporal scale.

HERBIVORY EFFECTS & BEAVERS AS ECOSYSTEM ENGINEERS

The North American Beaver (*Castor canadensis* L.) is a well-known keystone species and another generalist mammalian herbivore that consumes both aquatic and terrestrial vegetation. Aquatic macrophytes are important to beavers, as their annual diets are estimated to consist of 55% (Severud et al., 2013) to 80% (Milligan & Humphries, 2010) of this vegetation type. Equal amounts of terrestrial and aquatic vegetation are consumed during the critical winter months for survival. In winter, because water lilies grow in deeper water, their rhizomes are still accessible by beavers (Severud et al., 2013). The amount of food per unit effort consumed by beavers is 2.5 times greater when they forage on aquatic vegetation, leading to improved efficiency and reduced risk of predation when compared to foraging on land (Belovsky, 1984). However, beavers may also seek aquatic vegetation for the same reasons that moose do (Tischler, 2004); there is a nutritional advantage in consuming aquatic macrophytes for their higher sodium content and better digestibility.

Beavers control the dynamics of many aquatic ecosystems, creating a mosaic of habitat in different stages of succession across the landscape. Dams can transform streams into beaver ponds, which mature into marshes, and eventually drain to form beaver meadows following abandonment in as little as 10 to 20 years or over a much longer time period (Newmaster et al. 1997). Beavers are often referred to as ecosystem engineers due to their ability to modify their environment and enhance habitat conditions for other wildlife species (Jones et al., 1994). Dam construction and nutrient rich sediment build-up around beaver lodges promotes the growth and dispersal of aquatic plants (Ray et al., 2001). Other beaver activities, such as food caching, tree-felling, and selective foraging on palatable aquatic plants, result in substantial successional changes to wetlands.

Moose are positively associated with beaver ponds due to the early successional deciduous trees and increased aquatic productivity (Nummi et al. 2019). Species richness and biomass of moose forage are two to four times greater in small beaver-created wetlands than lakes formed by other agents (Morris, 2014), while larger lakes offer more long-term stability in aquatic vegetation due to their size and greater diversity of habitats (Ray et al., 2001). The use of beavers as a keystone species to restore degraded or late successional wetlands can help to mitigate the effects of climate change on hydrological regimes and increase heterogeneity across the landscape (Hood and Bailey, 2009), such as more aquatic vegetation for moose.

The cumulative effects of moose and beaver foraging have the potential to significantly lower the biomass and species richness of aquatic plant communities (Quarnemark & Sheldon, 2004), but the temporal pattern of their effects is not well known. The percent cover of rhizomatous, floating-leaved macrophytes, such as water lilies (*Nymphaea* spp., *Nuphar* spp.), can be used as a leading indicator of beaver colony density (Bergman et al., 2018). *Brasenia schreberi* is a key species in supporting long-term beaver colony occupancy in smaller lakes, but is susceptible to biomass declines during periods of high moose and beaver density (Tischler et al., 2019). This depletion is mainly the result of moose browsing, while depletion of

Potamogeton spp. is associated more with beaver foraging (Bergman and Bump, 2015). Influences of moose browsing on macrophyte abundance and species composition have also been recorded at a lake in Sleeping Giant Provincial Park, Ontario, where *Nuphar variegatum* once dominated in the 1960s, but became absent or scarce by 1980 in areas heavily used by moose (Fraser et al., 1980). Due to disturbance vulnerability, *Potamogeton filiformis* largely disappeared as well, resulting in a shift to a plant community dominated by annuals such as *Potemogeton foliosus*. This example indicates the temporal scale of which macrophyte communities can change. If this lake underwent these drastic changes in fewer than 20 years, then MAFAs surveyed by the OMNR 36 years ago may look very different now. An understanding of the long-term changes in plant community composition and species richness over time would have important implications for moose habitat management.

METHODOLOGY

STUDY AREA

The study area is located in the Papineau-Cameron township of Central Ontario, just north of the Algonquin Provincial Park boundary and just south of the Ottawa River. The area is within Cervid Ecological Zone (CEZ) D2, Wildlife Management Unit (WMU) 48, Ecoregion 5E/Georgian Bay, and the Nipissing Forest Management Unit. There is an abundance of moose aquatic feeding areas (MAFAs) and an extensive forest access road network in the area, and it is within the transitional zone between the Great Lakes-St. Lawrence and Boreal Forest regions. The objectives for CEZ D2 are to maintain a moderate to high density moose population, to maintain a moderate density of white-tailed deer, and to manage elk at the local level when needed. The MNRF has calculated the overall carrying capacity of WMU 48 at 33 to 40 moose per 100 square kilometers (OMNR 2013).

APPROACH TO MAFA SURVEYS

The standardized methodology outlined in the *Selected Wildlife and Habitat Features: Inventory Manual* (Ranta, 1998) is still used today by the MNRF in identifying and delineating MAFAs. There is a ranking system of (0) nil potential, (1) low potential, (2) moderate potential, (3) high potential, and (4) very high potential based on varying degrees of aquatic vegetation abundance, waterbody sizes, and accessibility. There are also some general rules such as, if vegetation appears sparse, reduce the rank by 1, and if the stand composition along the shoreline is Black Spruce, *Picea mariana* (Mill.) or Jack Pine, *Pinus banksiana* (Lamb.), the area cannot be ranked higher than 2, because these tree species usually indicate nutrient poor sites (Ranta, 1998). If any limiting factors are present or if the MAFA is a beaver pond, the area cannot be ranked higher than 3. Limiting factors include mine waste sites, human development such as cottages, and steep cliffs or other terrain features that hinder the accessibility of an area. Beaver ponds also affect the ranking due to their temporary nature that only provides short-term benefits to moose, even though many MAFAs are associated with beaver ponds. The following table summarizes the characteristics for each rank.

Table 2. Summary of the ranking system used in MAFA surveys.

Rank	Potential	Characteristics
0	Nil	Lakes, creeks, & rivers with no aquatic vegetation.
1	Low	Bog lakes or areas difficult to access. Sparse vegetation.
2	Moderate	< 1 ha in size. Some preferred aquatic species but dominated by graminoids. Shoreline stand composition is primarily Sb & Pj.
3	High	> 1 ha in size. Less than 50% preferred aquatic species. More than 50% graminoids. Few limiting factors.
4	Very High	Large area. No limiting factors. More than 50% preferred aquatic species. Less than 25% graminoids.

Between July 30 and August 2, 2021, the same ranking system was used to resurvey 32 sites previously identified by the MNRF. A GPS waypoint was taken at each site and a visual macrophyte survey was conducted by recording all observed plant taxa within an estimated fixed radius plot of 4 meters. At each MAFA site, aquatic plants occurred in four vegetation communities: floating, narrow-leaved emergent, broad-leaved emergent, and submergent. Visual examinations took place in the littoral zone with water depths of less than 30 cm to ensure consistency among the macrophyte species richness sampling sites. Moose habitat use near each MAFA was inferred by counting the number of pellet groups and the number of tracks or trails seen along a transect line 2-meter wide and 100 meter long. All MAFA site locations, macrophyte sampling plot locations, and azimuths for transect line directions were determined by randomized selection. The 32 MAFAs were found throughout a study area 140 km^2 in size (Figure 1). Each rank of MAFA quality will be compared to the ranking last assigned to the location by the MNRF during their provincial wildlife values inventory to determine if any changes have occurred over time.

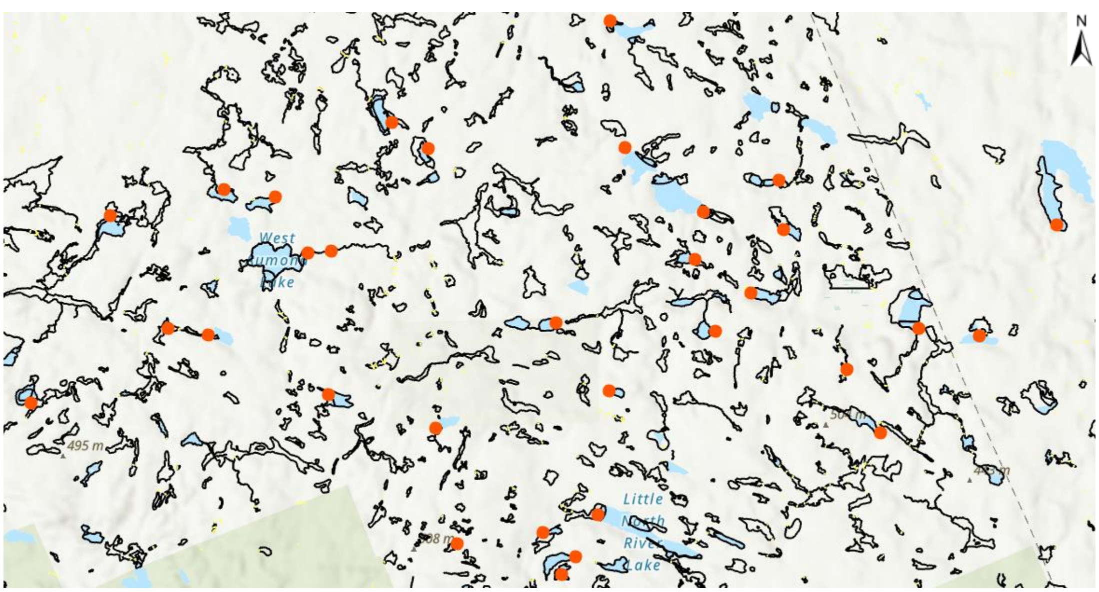

Figure 1. Map of study area showing individual survey locations and previously identified Moose Aquatic Feeding Areas (MAFAs).

FOREST MANAGEMENT PLAN REVIEW

All current plans and associated documents are available online through the provincial government’s Natural Resources Information Portal. The MEA implementation and selection process in 13 forest management plans were reviewed for comparison across multiple Sustainable Forest License Areas (SFLs) to determine how much of the landscape is managed specifically for moose. The majority of these SFL areas fall within the Cervid Ecological Zones of C2 and D2, which have the management objective of maintaining moderate to high density moose populations, requiring increased consideration for moose habitat. The map below shows all SFL areas in Ontario, and the ones chosen for forest management plan review (Figure 2) to summarize MEA implementation (Watkins 2021). The yellow dot indicates the study location where the MAFA surveys were conducted.

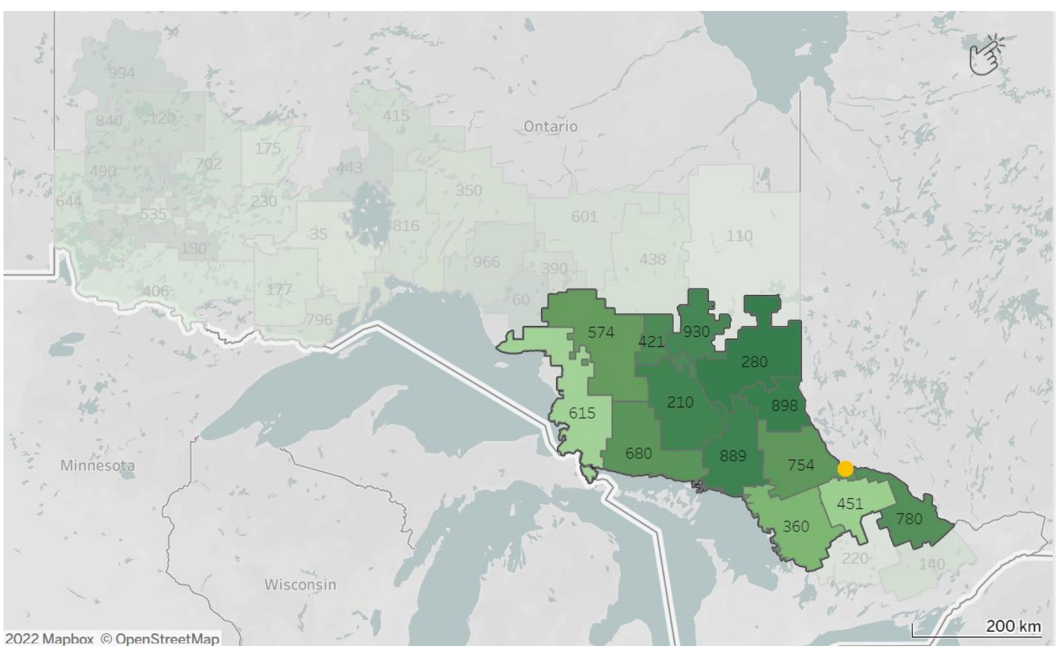

Figure 2. Map of Ontario's Managed Forests to summarize Moose Emphasis Area (MEA) implementation.

RESULTS

There are currently 126,406 records of spatial data collected by the MNRF for various wildlife habitat features throughout Ontario, and moose aquatic feeding areas (MAFAs) account for over 77% of the locations identified. However, over 64% of MAFAs were surveyed more than 15 years ago and over 84% were surveyed more than 10 years ago, with some sites last surveyed as long ago as 36 years (Figure 3).

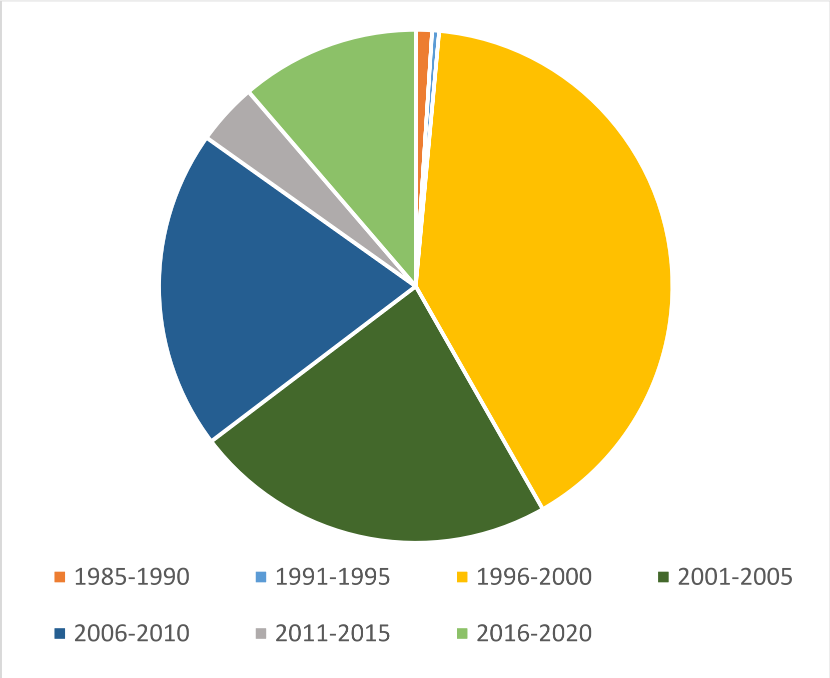

Figure 3. Summary of the dates when 126,406 moose aquatic feeding areas (MAFAs) in Ontario were last surveyed by the Ontario Ministry of Mines, Northern Development, Natural Resources and Forestry (OMNR).

On average, over 12% of the area of every Forest Management Unit reviewed is managed as a moose emphasis area (MEA; Table 3). However, over 34% of MAFAs in this study had changed in rank from previous survey dates, over a period that ranged from 24 to 11 years ago (Figure 4). Out of 32 MAFAs assessed, 3 were found to have lowered in quality, 21 remained the same, and 8 had improved in quality. A full dataset of all results can be found in Table 1 of the Appendix. One of the MAFAs increased in area by default, as it was never surveyed before, and three MAFAs were previously classified as Nil, meaning there was no aquatic vegetation, while low to moderate areas of preferred vegetation were observed during the most recent survey. A discontinued beaver dam inventory dataset that was completed by the MNRF's provincial mapping unit was accessed using Ontario GeoHub to see if beavers historically influenced the MAFAs. According to the dataset, 14 of the surveyed sites were found to have beaver constructed features in 2004, while 20 of the sites surveyed in 2021 had recorded beaver dams. This trend of increased beaver presence also reflects the increased quality changes found in the MAFAs, suggesting there may be a positive effect of beavers on MAFA rank.

Table 3. Quantity and size of moose emphasis areas (MEAs) in fourteen of Ontario's forest management plans.

Sustainable Forest License (SFL) area	Current FMP term	Total SFL area (ha)	MEA count	Total MEA area (ha)	Percent of SFL area
Algoma	2020-2030	1 565 141	8	112 889	7.2
Algonquin Park	2021-2031	763 009	5	190 906	25.0
French-Severn	2019-2029	1 279 383	5	152 327	11.9
Martel-Magpie	2021-2031	1 631 921	12	199 673	*12.2
Mazinaw-Lanark	2021-2031	324 631	1	17 029	5.2
Nipissing	2019-2029	1 146 900	5	91 463	*8.0
Northshore	2020-2030	1 251 461	7	127 434	10.2
Ottawa Valley	2011-2022	806 219	2	184 666	*22.9
Pineland	2021-2031	391 271	5	50 504	12.9
Romeo Malette	2019-2029	629 977	9	53 526	8.5
Spanish	2020-2030	1 226 452	12	148 403	12.1
Sudbury	2020-2030	1 098 356	8	81 885	7.5
Temagami	2019-2029	582 999	4	56 798	9.7
Timiskaming	2021-2031	1 528 996	11	160 590	10.5

(*) The area of MEAs includes the total land area, except for those marked with an asterisk, which only includes the area of productive forest.

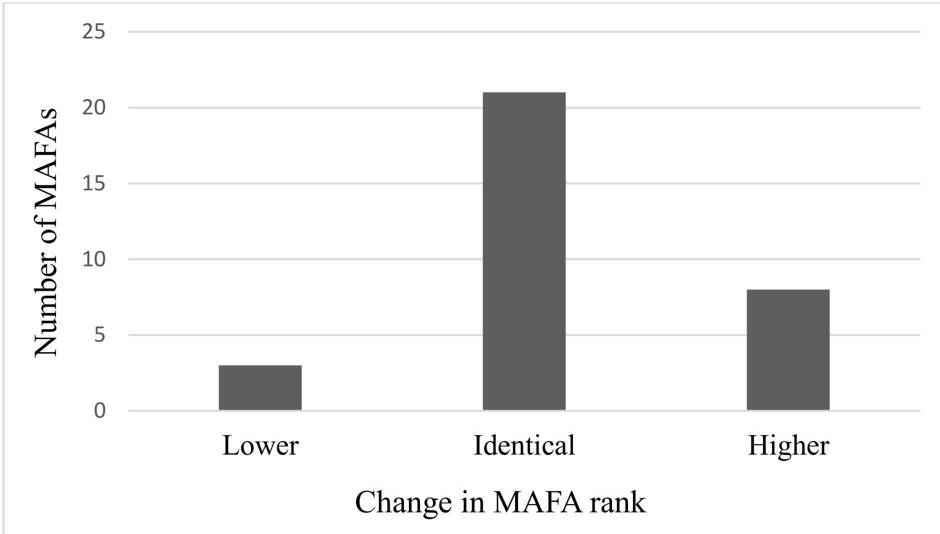

Figure 4. Number of MAFAs that have changed in quality over time.

Only 20 macrophyte species were observed in the Nipissing Forest study area (Table 4), although this list is not complete and there is no comparison from the past surveys as the MNRF do not include macrophytes in their data collection process. During the recent surveys, some submergent species may have been missed or were growing in deeper water. The most common vegetation community found in the study area was the floating-plants community, which is predominantly comprised of water lilies, watershield, and some species of floating-leaved pondweeds. Submergent vegetation communities consisted of watermilfoil, bladderwort, crowfoot, and submergent pondweeds. These two plant communities contain strongly preferred browse species for moose and indicate deeper water conditions. Shallow water species that are less preferred by moose were found in either a narrow-leaved emergent community containing horsetails, bulrushes, cattails, bur-reeds, and various graminoids (sedges, grasses, & rushes), or a broad-leaved emergent community containing arrowhead, pickerelweed, water arum, and water plantain.

Table 4. Plant communities in MAFAs in the Nipissing Forest.

Narrow-leaved emergent	Broad-leaved emergent	Submergent	Floating plants
Equisetum fluviatile	*Alisma triviale*	*Myriophyllum sibiricum*	*Brasenia schreberi*
Sparganium fluctuans	*Calla palustris*	*Myriophyllum alterniflorum*	*Nuphar variegatum*
S. americanum	*Pontederia cordata*	*Potamogeton amplifolius*	*Nymphaea ordorata*
Schoenoplectus subterminalis	*Sagittaria latifolia*	*Ranunculus longirostris*	*Potamogeton epihydrus*
Typha latifolia		*Ultricularia vulgaris*	*P. gramineus*
			P. natans

DISCUSSION

Stressors to inland wetlands include eutrophication, acidification, shoreline modification, invasive species, and watershed disturbances, all of which can be exacerbated by climate change (Winter et al., 2011). The three moose aquatic feeding areas (MAFAs) that lowered in quality in the Nipissing Forest study area may have been subject to an increase in shallow water conditions that resulted in a successional shift towards emergent plant communities. The change to a lower quality MAFA indicates that macrophytes are less abundant or there is an increase in less preferred macrophytes. Lakes gradually become shallower and more nutrient rich over time from erosion and sedimentation. The response of aquatic vegetation to natural eutrophication is increased primary productivity of excessive algal growth and increased dominance of emergent macrophytes and graminoids in the littoral area (Vermaire et al. 2012). Sodium contents are 500 times greater in submergent and floating-leaved aquatic plants and only about 50 times greater in emergent plants compared to terrestrial vegetation (Jordan et al., 1973). Plants in these emergent communities are less preferred by moose, presumably due to their lower sodium concentrations (Fraser et al., 1984).

MAFAs could also decrease in quality if the water body shifted back towards an oligotrophic state that has little to no aquatic vegetation due to low nutrient concentrations (MECP, 2019). Additionally, changes could be explained by herbivore-macrophyte interactions including selective grazing, which has been known to alter the composition of aquatic plant communities and reduce the diversity and biomass of preferred browse species (Quarnemark & Sheldon, 2004). Beaver abandonment that leads to the formation of beaver meadows following dam collapse can also increase the presence of emergent plants and graminoids (Hood and Bailey, 2009), which are not characteristic of high-quality MAFAs. This situation was not encountered in the Nipissing Forest study area.

The eight MAFAs previously identified in the Nipissing Forest study area that improved in quality at the time of this study may reflect shifting lake conditions from a clear, oligotrophic state with little vegetation to a more productive, mesotrophic state with higher levels of nutrients that support the occurrence of floating-leaved and submerged macrophytes (MECP, 2019). The sites with the highest recorded moose presence and quality of feeding area were positively correlated with the three most frequently encountered taxa: Watershield, Yellow Pond Lily, and White-Water lily, which tended to dominate the open water and had high cover values. The presence of these three floating-leaved perennial macrophytes may be explained by invasion from adjacent waterbodies, due to the degree of hydrological connectivity that permits the dispersal of rhizomes (Ray et al., 2001). Beaver activity may have also altered the aquatic plant communities by flooding areas and creating more open water habitat for plant colonization (Morris, 2014). Beaver disturbance cycles can reverse successional change upon return to areas and re-create ideal moose habitat, such as adjacent young, deciduous forests, slower moving streams, and wetlands with aquatic vegetation. Species richness and biomass of moose forage is two to four times greater in beaver-created wetlands (Morris, 2014), where moose are significantly more likely to be found than in wetlands that are not altered by beaver activity (Nummi et al. 2019). A dynamic landscape with an active beaver population typifies the Nipissing Forest study area.

From the results of this study, over 84% of MAFAs were surveyed more than 10 years ago and some MAFAs were last identified and ranked in 1985. Considering the successional patterns observed in this study, the MAFAs in the Nipissing Forest may have been influenced by changes in beaver activity or transitioned into a different trophic state within the time frame since the last survey. Moose habitat selection is known to be primarily driven by their foraging ecology, but there is temporal variation in MAFA conditions. Various processes and disturbances can trigger changes to the biomass and distribution of macrophytes over time, which would directly affect the quality of MAFAs. Accurate rankings are important because low quality feeding areas become less significant to operational planning or the selection of MEAs, while higher quality sites receive more priority in future management decisions. Ontario's MAFA data may need to be updated more frequently by resurveying sites every 10 or so years, resulting in informed current and future management decisions on MEA selection, maintenance of summer cover for moose habitat, and retention of residual shoreline.

CONCLUSION

Given limnological factors, natural aquatic succession, selective herbivory by moose, and extensive effects of ecosystem engineers such as beavers, I suspect that lakes, ponds, and wetlands in Ontario's managed forest have the capacity to move to an altered state within the time since the area was last surveyed if this time exceeds 10 years. These changes may result in either an increase in quality due to more preferred aquatic browse species, or conversely become less suitable and decrease in quality due to the presence of more emergent macrophytes and graminoids. Both outcomes would require differing management considerations. The majority of MAFAs in Ontario have not been assessed for the past 10 to 15 years and the results of this study have shown that over 34% of MAFAs changed in rank from previous survey dates. Since data collection should be an active part of forest management planning, it would be beneficial to resurvey MAFAs, possibly at a frequency of every 10 years, to ensure the accuracy of mapping of Moose Emphasis Areas and their ability to reflect the current state of moose habitat. Decisions on the maintenance of summer habitat for moose, and on the selection of which residual forest to retain, are integral to conservation of moose on the landscape. Thus, providing moose with the best available aquatic feeding areas that are adequately enhanced with the provision of adjacent summer cover and residual shoreline forest is paramount. Also, beavers create heterogenous landscapes and newly flooded wetlands which moose regularly use, so promoting facilitative ecosystem engineering by beavers may be a feasible practice in habitat conservation. Future management considerations should include using paleolimnology, aerial surveys or remote imagery to monitor macrophyte variation.

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APPENDIX

Table 1. Compiled field data collected in 2021 (left) along with OMNR data collected from 1998-2011 (right).

Site Number	UTM (17 T)	Waterbody Name	2021 MAFA Rank	# of Pellet Groups	# of Tracks/Trails	Beaver Presence	Date Verified	Habitat Rank	Species Evid.	General Comments	Beaver Presence (2004)	Total P µg/L (2003)
MAFA01	0691927 5111038	UNK Marsh	2 +	-	2	Y	2011-01-17	Low	No		N	
MAFA02	0695725 5114862	Tallspruce Lake	0 -	-	-	N	2011-01-17	Low	No		Y - within 100 m	
MAFA03	0694395 5116566	Second Twin Pond	2	-	-	N	2010-06-15	Moderate	No	Pre-1991 Survey	N	
MAFA04	0691390 5113942	Little Burnt Lake	3 +	-	-	Y	1998-04-28	Moderate	No	Pre-1991 Survey	N	
MAFA05	0694079 5111321	UNK Marsh	4	3	2	Y	2010-06-15	Very High	No	Pre-1991 Survey	N	
MAFA06	0695450 5111761	Little North River	4 +	2	-	Y	2011-01-17	High	No	1991 Methodology	N	12.4
MAFA07	0694892 5110706	Rinne Lake	2 +	-	-	Y	2011-01-17	Low	Yes		Y	9.8
MAFA08	0694538 5110269	Maki Lake	2	-	1	N	2010-06-15	Moderate	No		Y	
MAFA09	0690300 5121583	East Thompson Lake	4 +	-	-	Y	2007-03-08	High	No	Pre-1991 Survey	Y	
MAFA10	0691199 5120925	Bastien Creek - Pond	4	1	3	Y	2010-06-17	Very High	Yes		N	17.2
MAFA11	0688196 5118308	West Aumond Lake	3	-	1	Y	2010-06-15	High	No		N	
MAFA12	0688791 5118353	West Aumond Creek	2	-	-	N	2010-06-15	Moderate	No	Pre-1991 Survey	N	
MAFA13	0687388 5119724	Red Pine Lake	0	-	-	Y	2011-01-11	Nil	No		Y	
MAFA14	0686111 5119895	Pieurot Lake	2 -	-	-	N	1998-04-28	High	N/A	Pre-1991 Survey	N	
MAFA15	0688710 5114778	Rainy Lake	2 +	-	-	Y	2011-01-10	Nil	No		N	
MAFA16	0685708 5116261	Upper Boom Lake	3	2	2	Y	1998-04-28	High	N/A	1991 Methodology	N	
MAFA17	0684694 5116421	Boom Creek	3	-	-	Y	2010-06-15	High	No	1991 Methodology	Y	
MAFA18	0683250 5119244	Perch Lake	2	-	-	Y	2010-06-15	Moderate	No		Y	
MAFA19	0681276 5114560	Richard Lake	3	2	-	Y	2007-04-02	High	N/A		Y - within 400 m	5.4
MAFA20	0696134 5120942	Big Poplar Lake	2 +	-	-	Y	N/A	N/A	N/A		N	
MAFA21	0695759 5124115	Deposit Lake	3	-	-	N	2010-06-17	High	No		N	
MAFA22	0698093 5119343	Aumond Lake	3	-	2	Y	2010-06-17	High	No	Pre-1991 Survey	N	
MAFA23	0699966 5120130	Carpenter Lake	3	1	2	N	2010-06-17	High	No		Y - within 150 m	
MAFA24	0700082 5118899	Mart Lake	1 +	-	-	N	2010-06-17	Nil	No	Pre-1991 Survey	N	
MAFA25	0701575 5115395	UNK Pond	2	-	-	Y	2010-06-15	Moderate	No		Y	
MAFA26	0697880 5118159	Houghton Lake	0	-	-	N	2010-06-17	Nil	No	Pre-1991 Survey	N	
MAFA27	0698389 5116366	Crystalline Lake	2	-	-	N	2010-06-15	Moderate	No		N	
MAFA28	0699277 5117325	Span Lake	3	1	-	Y	2010-06-15	High	No	Pre-1991 Survey	Y - within 200 m	
MAFA29	0703479 5116426	Rit Lake	2	-	-	N	2010-06-15	Moderate	No		N	
MAFA30	0704987 5116248	Paddy Lake	3	-	-	Y	2000-07-17	High	Yes	Location Class: Upland I	Y - within 50 m	
MAFA31	0706916 5119016	Greenbough Lake	3 -	-	-	N	2000-07-14	Very High	Yes	Location Class: Upland I	N	
MAFA32	0702513 5113807	Mums Lake	2	-	1	Y	2010-06-15	Moderate	No		Y	
							Nil = 0, Low = 1, Moderate = 2, High = 3, Very High =4					

Table 2. List and meaning of abbreviations used.

ABBREVIATION	MEANING
CEZ	Cervid Ecological Zone
FMP	Forest Management Plan
FMU	Forest Management Unit
MAFA	Moose Aquatic Feeding Area
MEA	Moose Emphasis Area
OMNR	Ministry of Natural Resources and Forestry or Ontario Ministry of Natural Resources Current: Ministry of Northern Development, Mines, Natural Resource, and Forestry (MNDMNRF)
SFL	Sustainable Forest License
SSG	Stand and Site Guide – Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales
WMU	Wildlife Management Unit