RECOVERY PLAN FOR THE MOOSE *(ALCES ALCES AMERICANA)* IN MAINLAND NOVA SCOTIA

A report prepared for the Nova Scotia Department of Natural Resources and Renewables

2021

Recommended citation:

Nova Scotia Department of Natural Resources and Renewables. 2021. Recovery Plan for the Moose (*Alces alces Americana*) in Mainland Nova Scotia. *Nova Scotia Endangered Species Act Recovery Plan Series*. 96pp.

Additional copies:

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Cover illustration: Mainland moose in a protected area on the Eastern shore of Nova Scotia. Photographer: Len Wagg.

PREFACE

This Recovery Plan has been prepared by the responsible jurisdiction, the Nova Scotia Department of Natural Resources and Renewables in cooperation with the Nova Scotia Mainland moose Recovery Team and built upon the work of two previous documents: The 2007 *Recovery Plan for the Moose (Alces alces americana) in Mainland Nova Scotia*, and the 2013 *Action Plan for the Recovery of Eastern Moose (Alces alces americana) in Mainland Nova Scotia.*

Recovery plans are not designed to provide a comprehensive summary of the biology and status of moose on mainland Nova Scotia. For more information regarding Mainland moose, refer to the Status Report on the Eastern Moose (*Alces alces americana*) in Mainland Nova Scotia (Parker 2003).

Under the *Nova Scotia Endangered Species Act (2007)*, a Recovery Plan must be developed for species listed as Endangered or Threatened under the Act and include the following:

- Identification of the needs and threats to recovery of the species;
- The viable status needed for recovery;
- The options for recovery as well as the costs and benefits of these options;
- The recommended course of action or combination of actions to achieve recovery of the species;
- A schedule for implementation of the recovery plan including a prioritized listing of recommended actions;
- Identification of habitat; and,
- Identification of areas to be designated as core habitat for the species.

The goals, objectives, and actions identified in this Recovery Plan are based upon the best available information on the species and are subject to modifications and/or revisions as new information becomes available. Recovery of species at risk is a shared responsibility and the collaborative approach emphasized in this document is reflective of this. Implementation of the actions and approaches identified in this plan is subject to budget constraints, appropriations, and changing priorities.

ACKNOWLEDGEMENTS

The province contracted Crystal Doggett and Jeffie MacNeil of the Mersey Tobeatic Research Institute (MTRI) to draft the Recovery Plan (2007) and Action Plan (2013), respectively, in consultation with the previous Recovery Team. In 2019, the Department of Lands and Forestry (now Natural Resources and Renewables) appointed a new Recovery Team of experts which led the development of a new direction for recovery and a new Recovery Plan.

The Department would like to thank those individuals and/or organizations who have contributed to the recovery of Mainland moose in Nova Scotia. In particular, the following members of the Nova Scotia Mainland moose Recovery Team are recognized for their significant contributions to the development of this Recovery Plan:

- Dr. Karen Beazley
- Dr. Scott McBurney
- Randy Milton
- Dr. Joe Nocera
- Jason Power

The Department would also like to thank the following staff who supported the Recovery Team in the development of this Recovery Plan: Mark McGarrigle, Claire Wilson-O’Driscoll, Dr. Donna Hurlburt, Frances MacKinnon, Jamie Ring, and Rob O’Keefe.

EXECUTIVE SUMMARY

Eastern Moose (*Alces alces americana*) are the largest member of the cervid family and can weigh up to 450 kg (1,000 lb). They are characterized by long legs, high shoulders, a coarse brown coat, large ears, and a short neck. Adult males produce large palmate antlers which are shed and regrown each year. Females give birth to 1-2 calves in late spring which stay with their mother a full year. Moose are associated with mature coniferous and deciduous forests. At all times of the year, moose require large tracts of forest for shelter, thermoregulation, and foraging, although the amount and successional stage may vary. Once considered abundant and widely distributed throughout Nova Scotia, the population has been reduced to a remnant of pre-colonial numbers in three localized groups (Tobeatic, Cumberland/Colchester, and Pictou/Antigonish/Guysborough).

Although considered relatively secure throughout the rest of its range, on mainland Nova Scotia Eastern Moose (referred to in this document as Mainland moose) were listed as “Endangered” under the Nova Scotia Endangered Species Act (NSESA) in 2003.

Threats to the Mainland Moose are well known but complex, and may be interrelated and/or cumulative, which makes addressing them challenging. Generally, threats can be categorized as habitat loss, fragmentation, poaching, and disease. Residential and commercial developments, and industrial activities such as mining and quarrying, result in a permanent conversion of habitat to that which is unsuitable for the use of Mainland Moose. Habitat fragmentation and loss of habitat connectivity is a major concern primarily the result of road placement and road density. Forest management can be both advantageous and disadvantageous to moose, and when disadvantageous contributes to habitat degradation and fragmentation. Parasites such as *Parelaphostrongylus tenuis*, or brainworm, and *Dermacentor albipictus*, or winter tick, are considered major threats to Mainland moose, and are drivers regulating population abundance and distribution. Although the impacts of climate change are not well understood for this species, it is recognized that increasing temperatures will exacerbate known threats such as parasites as well lead to increased thermal stress on moose.

The viable status for recovery of the species, intended as a long-term goal of removing the Mainland moose from the NSESA, is:

- A minimum of 5000 individuals throughout mainland Nova Scotia, at least 500 of which are breeding individuals, distributed throughout 3 localized groups (Cumberland/Colchester, Pictou/Antigonish/Guysborough, and Tobeatic). These localized groups should function as a connected population, with additional connections for genetic exchange via immigration and emigration into and from New Brunswick, through habitat corridors, for long-term viability.

The 20 year population and distribution objectives for recovery of the Mainland moose in Nova Scotia are:

1. To increase the census populations, numbers of breeding individuals, and calf survivorship, by at least 10% respectively, in each of the 3 localized groups;
2. To enhance connectivity to improve genetic health and demographic parameters and to support symmetrical exchange of migrants between each pair of localized groups within the Eastern mainland (Cumberland/Colchester, Pictou/Antigonish/Guysborough) and the Tobeatic; and,
3. Given the lack of currently available information, assess the status of the Tobeatic localized group and increase connectivity, if feasible, with the larger localized groups in the Eastern mainland.

Broad recovery measures and actions are identified within Section 6 of the Recovery Plan to address threats, protect and enhance habitat (including Core Habitat), improve connectivity, advance policy and guidance to support recovery, and provide a basis for surveys and assessment.

Core Habitat has been identified which addresses the habitat requirements for the three localized subgroups (Cumberland/Colchester, Pictou/Antigonish/Guysborough, and Tobeatic) that is necessary to support population and distribution objectives for viable population size, as well as improving connectivity throughout the mainland. Modelling suggests there is insufficient suitable habitat available over the next 30 years to support the populations necessary to achieve recovery objectives for the two eastern mainland localized groups. Therefore, the focus of management in these regions is twofold: to maintain existing identified high-quality habitat as well as enhancing habitat suitability in the remainder of the Core Habitat with the goal of improving future habitat suitability.

The Recovery Team is of the opinion that Mainland moose are at a critical juncture of species recovery, and that most of the actions identified in the Recovery Plan should be considered a High priority. In some cases, actions were identified as Very High priority, and are considered critical requirements necessary to support or form the basis for other important actions for recovery. Baseline surveys of the current distribution and abundance of Mainland moose are required to provide important information to support monitoring, habitat assessments, and direct where specific actions should occur on the landscape.

RECOVERY FEASIBILITY

The recovery of Mainland moose in Nova Scotia is considered technically and biologically feasible if the following four criteria can be met:

1. Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.

   Yes. Breeding individuals are present in Nova Scotia. In addition to this, recent work suggests low genetic differentiation between New Brunswick and mainland Nova Scotia, as well as some evidence of gene flow (B. Scott, pers. comm.); efforts to improve connectivity along the Chignecto Isthmus may allow for movement of genetically compatible individuals from New Brunswick.

2. Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration.

   Unknown. Although Parker (2003) indicated that suitable habitat may be a factor limiting population growth, at the present time the Recovery Team considers it unlikely that sufficient suitable habitat is currently available to support the species. Actions proposed in this Recovery Plan to protect Core Habitat, improve landscape connectivity, and create additional suitable habitat through Best Management Practices (BMPs) and changes to forest management will augment and/or enhance currently available habitat and potentially support a larger population now and in the future.

3. The primary threats to the species or its habitat (including threats outside Canada) can be avoided or mitigated.

   Unknown. Threats to Mainland Moose (habitat loss and fragmentation, poaching, disease, and climate change) are interrelated and possibly cumulative, making their assessment and mitigation complex. A significant challenge to species recovery in Nova Scotia will be to reduce transmission of brainworm through management or removal of the reservoir host, white-tailed deer. Climate change is expected to exacerbate other threats, but the long-term impacts are not well understood.

4. Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.

   Unknown. Recovery techniques have been identified which can maintain or enhance the population and distribution of Mainland moose in Nova Scotia, which includes protection of Core Habitat, road management, forest management guidance for Crown and private lands, policy changes, and enhancement to existing policies and guidance. Given that population and distribution objectives are beyond the lifespan of this Recovery Plan, there will be opportunities to revise and adapt actions as necessary based upon new information concerning the recovery of the species and its habitat requirements, as well as evaluation of the success (or lack thereof) of previous actions.

Basing their decision upon the precautionary principle, the appointed members of the Recovery Team for Mainland moose believe that recovery of the species in Nova Scotia is feasible. However, the Team recognizes that significant challenges exist and that recovery will require changes to forest management practices in Nova Scotia, addressing road density disturbance and other developmental pressures, the designation, protection, and management of Core Habitat, and significant financial resources to address threats and implement actions for recovery.

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1. NSSARWG ASSESSMENT SUMMARY*

* The following definitions are applicable in this section and elsewhere: NSSARWG (Nova Scotia Species at Risk Working Group); NSESA (Nova Scotia Endangered Species Act.

Assessment Summary:

Common Name: Eastern Moose (Mainland Nova Scotia)

Scientific Name: *Alces alces americana* (Clinton 1822)

Status: Endangered (2003)

Reason for Designation: The native population of moose in Nova Scotia is limited to approximately 1000 individuals in isolated herds/groups across the mainland. The population has declined by at least 20% over the past 30 years with much greater reductions in distribution and population size over more than 200 years, despite extensive hunting closures since the 1930's. The decline is not well understood but may involve a complex of threats including: historic excessive hunting, poaching, climate change, parasitic brainworm, increased road access to moose habitat, spread of white-tailed deer, possible high levels of cadmium and dietary deficiencies (e.g., cobalt), unknown viral disease, and disturbance.

Moose on Cape Breton Island are not at risk as they are abundant and the result of a re-introduction of a different subspecies of moose (*Alces alces andersoni*) from Alberta in the 1940's.

Occurrence: Widely distributed; found in every province and territory in Canada except for Prince Edward Island. In Nova Scotia, observations of moose are recorded throughout the province, there are five main concentration areas for moose: the Tobeatic Region, Chebucto Peninsula, Cobequid Mountains, Pictou-Antigonish highlands, and the interior of the eastern shore area from Tangier Grand through Guysborough.

Status History: Designated Endangered in 2003.

2. SPECIES STATUS INFORMATION

Moose (*Alces alces*) is considered nationally and provincially/territorially secure throughout Canada except for Nova Scotia, where it is critically imperiled. In the United States, it is considered nationally secure (N5), with state rankings varying between secure (Alaska, Maine, New Hampshire, Vermont) to vulnerable (Idaho, Minnesota). NOTE: NatureServe does not differentiate between the subpopulations for their status ranking.

Table 1. NatureServe conservation status ranks for Eastern Moose in Canada (NatureServe 2020)*

Global (G) Rank[a]	National (N) Rank[b]	Subnational (S) Rank[c]
G5	N5	AB(S5), BC(S5), NF(SNA), Labrador(S4S5), Manitoba (S5), NB (S5), NWT (S4S5), NS (S1), NU (SU), ON (S5), QC (S5), SK (S5), YU (S5)

[a] G-Rank – Global Conservation Status Rank, G1 = Critically Imperiled; G2 = Imperiled; G3 = Vulnerable; G4 = Apparently Secure; G5 = Secure

[b] N-Rank – Provide ranking for each province the species is found in. National Conservation Status Rank, N1 = Critically Imperiled; N2 = Imperiled; N3 = Vulnerable; N4 = Apparently Secure; N5 = Secure

[c] S-Rank – Sub-national (provincial or territorial) ranks, S1 = Critically Imperiled; S2 = Imperiled; S3 = Vulnerable; S4 = Apparently Secure; and S5 = Secure. SNA = Not Applicable. B = breeding; and U = Unrankable.

*A full list of definitions can be found in Definitions of NatureServe Conservation Status Rankings at http://help.natureserve.org/biotics/Content/Record_Management/Element_Files/Element_Tracking/ETRACK_Definitions_of_Heritage_Conservation_Status_Ranks.htm

3. SPECIES INFORMATION

3.1. Species Description

The largest member of the deer (Cervidae) family, moose have a solid torso and short tail, with long legs and broad, tall shoulders. They have a short neck, broad overhanging muzzle, and long ears. Their coat has a coarse, brittle texture and varies in colour from brown, to brown-black, to gray. Adult males are known for their large, palmate (broad and flattened) antlers that are shed and regrown annually, and the “bell” or dewlap that hangs on the upper throat region. Moose usually weigh less than 450 kilograms. Calving occurs in late May, resulting in one to two calves weighing about 12 kilograms each. Calves have short bodies, long legs and ears and light reddish-brown fur with a dark, dorsal stripe. They quickly grow to resemble the colour of adults. The cow and calf (or calves) will remain together for a year (Parker 2003).

3.2. Population and Distribution

With the exception of Prince Edward Island, moose occur in all provinces and territories in Canada. Four subspecies of moose are recognized in North America by Peterson (1955). Eastern Moose (*Alces alces americana*) occupy Eastern Canada and Northeastern United States-New York north through New England, and from eastern Ontario east to the Atlantic provinces. The current population of moose on Cape Breton Island is the result of an introduction of moose from Elk Island National Park in Alberta in 1947-1948 and is considered part of the northwestern Moose subspecies (*Alces alces andersoni*). Only the Eastern Moose in Nova Scotia are considered at risk. For the purposes of this Recovery Plan, Mainland moose will be referred to throughout the document in place of Eastern Moose.

It is estimated that prior to European settlement there may have been approximately 15,000 moose in Nova Scotia (Parker 2003). Rapid European colonization of the New England states in the 1700s-1800s led to habitat loss and over-hunting, resulting in the moose population declining to several thousand and a reduction in distributional range. This declining trend continued into New Brunswick and Nova Scotia, such that by 1875 game laws to restrict hunting were initiated to address tremendous declines in both provinces. Subsequently, moose began to recover and were once again plentiful in mainland Nova Scotia, potentially approaching a number possibly close to that present prior to European colonization. However, moose had already been extirpated from Cape Breton and did not become established again until the introduction of 18 moose from Alberta in 1947 and 1948 (Dodds 1974, Corbett 1995).

Following continued declines in the Mainland moose population, hunting closures were enacted in Nova Scotia in 1937. Aerial surveys were first used to count Mainland moose in the 1960s and results indicated that the population at that time was between 2500 and 4000 animals. Based on these findings, the two areas with the highest densities (in eastern mainland) were opened for a restricted hunting season in 1964. By the mid-1970s, the population was estimated to have declined to 1600 - 1700 moose (Parker 2003). Moose hunting seasons on mainland Nova Scotia have been closed since the season of 1981. Despite hunting closures, aerial and pellet group surveys indicated a significant and continuous decline over the next three decades; by the mid-1990s there was estimated to be only 357 moose in the northeastern mainland of Nova Scotia (Parker 2003).

A population curve based on historical trends was generated for the 2003 Status Report on Mainland moose (Figure 1). Modest increases in population counts in the northwest and northeastern areas occurred during the same time as provincial declines, suggesting a shift in spatial dynamics of the population, as these two areas (Cobequid Hills and Pictou-Antigonish) currently support two of three known localized groups (Parker 2003). At the time of the Status report, Parker (2003) estimated the population of Mainland moose to be in the range of 1000-1200 individuals; however, this was likely an over-estimate of the population at that time. An analysis by Brannen (2004) of limitations of the approach used by Hall (2001) to estimate moose densities, as well as an additional review of the data and calculations by R. Milton (pers. comm.), estimates the population of Mainland moose in Nova Scotia at fewer than 700 individuals at the time of the Status Report, not 1000-1200 as reported by Parker (2003). Surveys have been conducted since 2003 in various areas of the province, as well as a thermal imaging survey in 2017 and 2018; however, methods have been inconsistent, and coverage has been insufficient to provide statistically valid estimates likely due to very low densities of animals. No updated province-wide population estimates are available since the time of the Status Report.

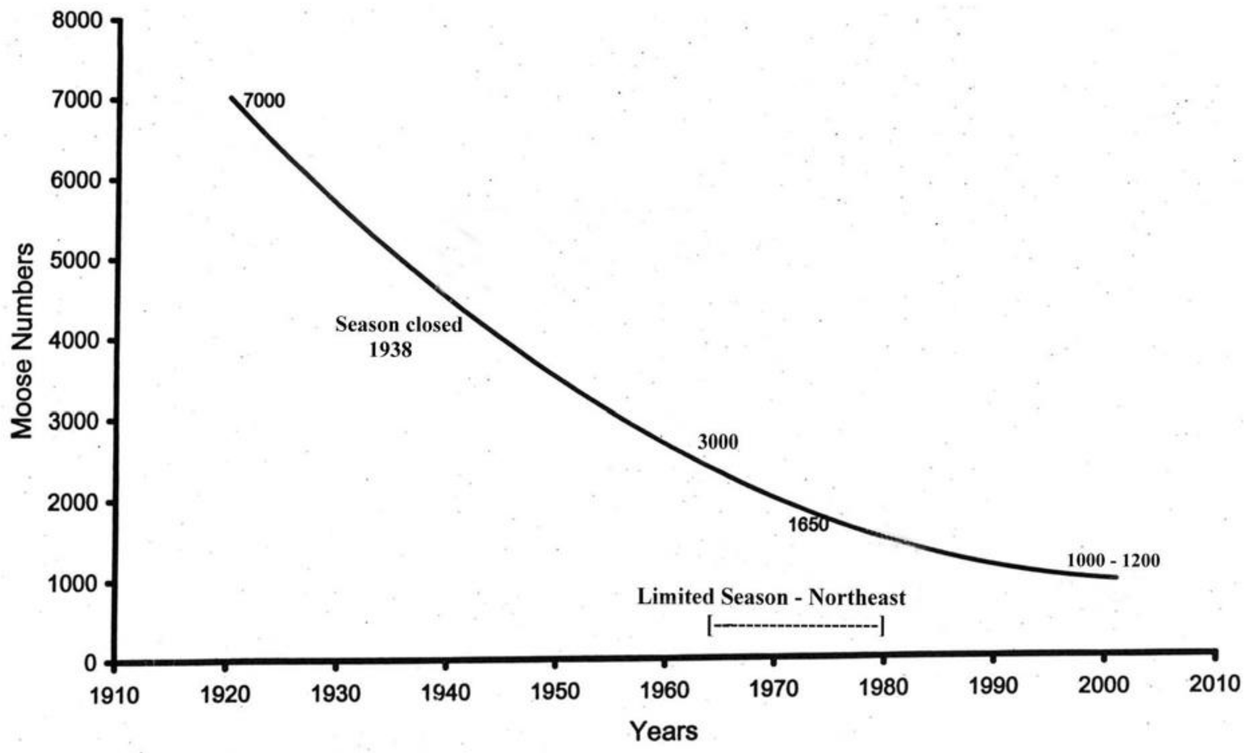

Figure 1. Projected slope of decline in numbers of moose on mainland Nova Scotia based upon early estimates and subsequent aerial and ground surveys (1920 – 2003) (Parker 2003).

Mainland moose have retained a similar distribution since the 1960s, with localized groups occupying the northern Cobequid Hills and Pictou-Antigonish Highlands, the southwestern interior in and around the Tobeatic Wildlife Management Area, and scattered pockets along the eastern shores of Guysborough, Halifax, Shelburne, Queens and Yarmouth Counties. Moose population concentration areas were mapped using a model based upon observation records from 1999-2011 and have been used to manage habitat on Crown land but is not considered Core Habitat (Figure 2). The majority of the Mainland moose population is thought to exist in the Colchester/Cumberland region of Nova Scotia.

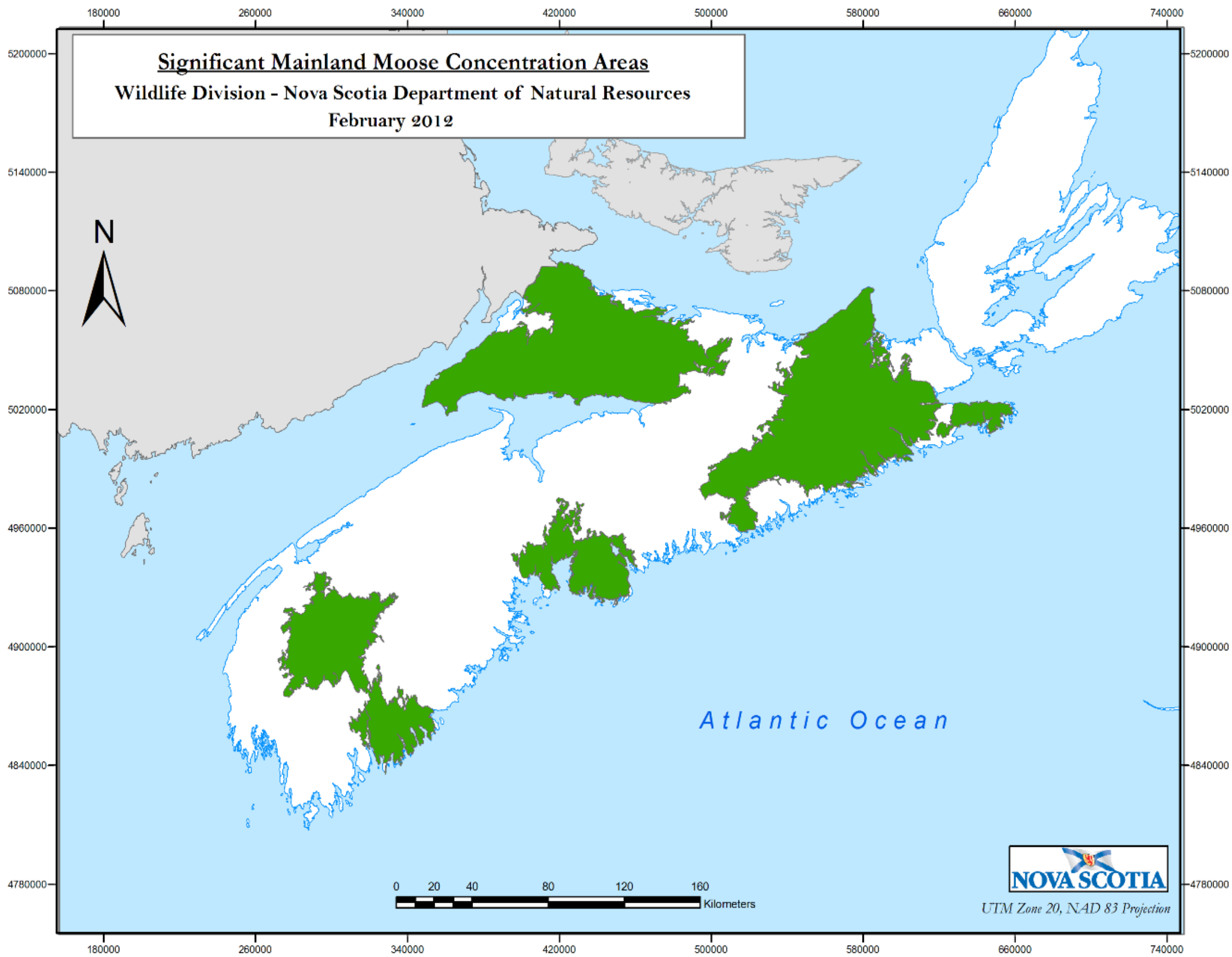

Figure 2. Mainland moose concentration areas within Nova Scotia.

3.3. Species Needs

Moose are associated with varying ages and types of boreal and temperate coniferous and mixedwood forest habitats with an abundance of mature forest that they use for security and thermal cover and interspersed young deciduous trees and shrubs that they use for food. These habitat types can be achieved through both natural disturbances (e.g., fire, wind, disease) and human induced disturbances (e.g., timber harvesting) though too much cumulative disturbance can result in insufficient mature forest cover.

Habitat use and importance of differing habitat types varies according to season, sex, and biological needs. Moose across their range show a high cold tolerance but are easily stressed by heat (Renecker and Hudson 1986, Street et al. 2015). Cool, moist habitats assist in temperature regulation during summer months, so wetlands and access to submerged and emergent aquatic vegetation is important where available (Timmerman 1988). Moose often seek out streams, ponds, and shorelines of lakes in summer to escape heat and insects (Franzmann and Schwartz 1998). Cows utilize secluded areas such as islands, peninsulas, or shorelines as calving sites (Peterson 1955), although the relative importance of such habitat may vary with respect to wetland availability and predator influences (Scarpitti et al. 2007, McClaren et al. 2017). Vegetative cover is an important component of their habitat needs and provides basic functions such as shelter, protection from predation, and protection from the adverse effects of extreme heat, cold, wind, and deep snow (Timmerman 1988, Snaith and Beazley 2004). Closed-canopy conifer forests are important to moose in summer for thermoregulation (Schwab and Pitt 1991); a study by Broders et al. (2012) found that moose in Nova Scotia altered their behaviour during periods of high temperatures, using softwood forest types at a higher proportion than other forest types during the summer months. During late winter moose increasingly utilize closed conifer and mixedwood cover, vegetation types which provide shelter from deep snow conditions and extreme cold (Snaith and Beazley 2004). At the home range scale, snow depth and forage are limiting factors influencing movement and use (Dussault et al. 2005). Stands with closed canopy conditions and patches of high browse production of sufficient quality and quantity interspersed within this area provide ideal winter habitat (Timmerman 1988).

A review by Timmerman (1988) showed moose browsing requirements across the species' range to be fairly restrictive during the summer months, focusing primarily on trembling aspen (*Populous tremuloides*) and white birch (*Betula papyrifera*). Aquatic and semi-aquatic plants, when available, supplement the summer diet. Preferred species include pondweed (*Potamogeton* spp.), common yellow pond lily (*Nuphar lutea)*, water shield (*Brasenia schreberi)* and bur-reed (*Sparganium fluctuans*) (Parker 2003). During the winter months, moose tend to be more generalist, foraging on deciduous and coniferous species. The winter diet of moose in Nova Scotia is comprised of the terminal twigs and branches of coniferous and deciduous woody plants, such as mountain maple (*Acer spicatum*), yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharum*) and balsam fir (*Abies balsamea*) (Prescott 1968, Snaith and Beazley 2004). Regardless of the season, deciduous woody plants make up the bulk of the moose diet. Diversity of foods in spring increases as new leaves and growth appear. Balsam fir appears to be avoided in the summer but is utilized again after October frosts (Peterson 1955).

4. THREATS

4.1. Threat Assessment

The Mainland moose threat assessment is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threat classification system (IUCN 2012). Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (in this case, the province of Nova Scotia). Limiting factors are not considered during this assessment process. For purposes of the threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of the threats are presented in Section 4.2 *Description of Threats*

Table 2**.** Threat calculator assessment.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
1	**Residential & commercial development**	High	Large	Serious	High	
1.1	Housing & urban areas	High	Large	Serious	High	Habitat loss, fragmentation and incursion from infrastructure and stress from human presence, including noise, lighting (e.g., buildings, parking lots, lodges, land cover change, fencing, roads, and indirect activities (e.g., access provided by associated roads).
1.2	Commercial & industrial areas	Medium	Restricted	Extreme	High	Habitat loss, fragmentation and incursion from infrastructure and stress from human presence, including noise, lighting (e.g.,

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						buildings, parking lots, lodges, land cover change, fencing, roads, and indirect activities (e.g., access provided by associated roads).
1.3	Tourism & recreation areas	Low	Restricted	Moderate	High	Habitat loss, fragmentation and incursion from infrastructure and stress from human presence, including noise, lighting (e.g., buildings, parking lots, lodges, land cover change, fencing, roads, and indirect activities (e.g., access provided by associated roads).
2	**Agriculture & aquaculture**	High	Large	Serious	High	
2.1	Annual & perennial non-timber crops	High	Large	Serious	High	Habitat loss, fragmentation and incursion from crops and related human structures (e.g., fencing, roads, trellising), noises (crop-protecting ‘canons’, whistles) and direct and indirect activities (e.g., recreational, hunting and other access provided by associated roads) and associated stresses.
2.2	Wood & pulp plantations	Medium	Large	Moderate	High	Plantations for pulp wood and fuel wood result in younger-aged land cover, with less diversity in forage and less mature forest canopy for shelter, security, and thermal cover; roads and other harvesting activities result in habitat fragmentation and

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						increased access for humans, deer, and other predators, competitors, disease/pathogens.
2.3	Livestock farming & ranching	Medium	Large	Moderate	High	Both small-holder and agro-industry grazing and farming by pasturing and 'factory'/ method could result in fragmentation, habitat conversion, and behavioural disruption.
2.4	Marine & freshwater aquaculture	Negligible	Negligible	Slight	High	
3	**Energy production & mining**	High	Pervasive	Serious	High	
3.1	Oil & gas drilling	Low	Small	Slight	High	Exploration and testing for hydraulic fracturing create noise, dust, land clearing, and roads, opening up areas to human access, potentially leading to incursions of predators, competitors, poachers and other human activities and developments.
3.2	Mining & quarrying	High	Pervasive	Serious	High	Incursion into habitat, causing loss, fragmentation, conversion, degradation from the mine, construction, extraction, spoil, tailings, tail ponds, lighting, noise, dust, human presence and access, roads, increased road traffic/hauling, indirect effects related to opened up access (recreation, poaching,

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						new developments, invasion by deer); hazards due to dramatic changes in terrain (deep pits; steep cut faces).
3.3	Renewable energy	Medium	Large	Moderate	High	Habitat loss, conversion, degradation, fragmentation caused by clearing for windfarm turbines and associated fencing, roads, lighting. Stress from light disturbance (flicker effect).
4	**Transportation & service corridors**	Very High	Pervasive	Extreme	High	
4.1	Roads & railroads	Very High	Pervasive	Extreme	High	Habitat loss, fragmentation, degradation; population fragmentation/isolation from roads, rails and associated fencing, rock cuts and fills, bridging, ditching, etc. Direct mortality from collisions. Indirect mortality and stress associated with incursion of species/diseases (*P. tenuis*) and human access (opportunities for poaching; recreational access); noise, lighting, and dust; increasing access for additional road building and associated land developments and resource extractions, etc.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
4.2	Utility & service lines	High	Large	Serious	High	Habitat fragmentation, population fragmentation/isolation
4.3	Shipping lanes					Not applicable
4.4	Flight paths					Not applicable
5	**Biological resource use**	High	Pervasive	Serious	High	
5.1	Hunting & collecting terrestrial animals	High	Pervasive	Serious	High	Primarily poaching. With small, localized groups, increased human activities and presence/ incursion into habitat causes stress.
5.2	Gathering terrestrial plants	Negligible	Negligible	Negligible	Insignificant/Negligible	
5.3	Logging & wood harvesting	High	Pervasive	Serious	High	Fragmentation, changes in quality or quantity of thermal cover; reduced opportunity for immigration/emigration; increased human interaction and access.
5.4	Fishing & harvesting aquatic resources	Low	Small	Slight	High	
6	**Human intrusions & disturbance**	High	Pervasive	Serious	High	
6.1	Recreational activities	High	Pervasive	Serious	High	Off road vehicle use (ATVs and snowmobiles). Noise, light, and dust; human activities, presence and incursions into habitat cause stress to moose and open up

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						access to predators, competitors, disease, and poachers.
6.2	War, civil unrest, & military exercises	Negligible	Negligible	Negligible	High	
6.3	Work & other activities	Negligible	Negligible	Negligible	High	
7	**Natural system modifications**	Medium	Large	Moderate	High	
7.1	Fire & fire suppression	Medium	Large	Moderate	High	Direct effects of forest fire (mortality). Direct and indirect changes in habitat quality, quantity and distribution. Increased fuel loads from historic fire suppression increasing fire frequency and severity. Alteration of natural disturbance regime impacts forest resilience. Changes in disturbance regime result in changes in pattern and distribution of forest age classes and species diversity through direct impact and indirect changes such as to soil quality and distribution of other species such as deer. Changes in distribution of moose habitat features (forage, cover) and suitability.
7.2	Dams & water management/use	Negligible	Negligible	Negligible	High	

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
7.3	Other ecosystem modifications	Negligible	Negligible	Negligible	Insignificant/Negligible	Over-management; reclamation; abandonment; coastal hardening.
8	**Invasive & other problematic species & genes**	Very High	Pervasive	Extreme	High	
8.1	Invasive non-native/alien species	High	Pervasive	Serious	High	Impact on cover and forage from Hemlock wooly adelgid, Emerald ash borer, invasive aquatic plants.
8.2	Problematic native species	Very High	Pervasive	Extreme	High	White-tailed deer are reservoir hosts for brainworm (*P. tenuis)* and winter tick (*D. albipictus*) both of which cause physical debilitation and mortality in moose.
8.3	Introduced genetic material	Negligible	Negligible	Negligible	Moderate	
8.4	Problematic species/diseases of unknown origin					Not applicable.
8.5	Viral/prion-induced diseases	Negligible	Negligible	Negligible	Low	Chronic wasting disease is present in white-tailed deer populations in more southerly areas of eastern Canada and is moving north-eastward; may pose potential future threat for local deer populations and subsequently be transmitted to moose.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
8.6	Diseases of unknown cause	High	Pervasive	Serious	High	Antler abnormalities as well as low reproductive rates and calf recruitment. These factors are associated with copper deficiency in other populations, but also could be related to stress, poor nutrition and predation.
9	**Pollution**	Medium	Large	Moderate	High	
9.1	Domestic & urban waste water					Not applicable.
9.2	Industrial & military effluents	Low	Restricted	Moderate	High	Seepage from mining acid rock drainage, arsenic from gold mining and mine tailings/ponds may affect aquatic vegetation important as forage for moose
9.3	Agricultural & forestry effluents	Medium	Large	Moderate	High	Herbicide applications limit tree and shrub species richness with impacts on species important as summer and winter forage and cover for moose.
9.4	Garbage & solid waste	Negligible	Negligible	Negligible	Low	
9.5	Air-borne pollutants	Unknown	Pervasive	Unknown	High	Acid rain altering water chemistry and chemically induced release of heavy metals (e.g., cadmium) in soils and uptake by vegetation.
9.6	Excess energy	Low	Small	Slight	High	Light from pulp and paper plants, airports and along highways, especially at interchanges.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
10	**Geological events**					
10.1	Volcanoes					Not applicable
10.2	Earthquakes/tsunamis					Not applicable
10.3	Avalanches/landslides					Not applicable
11	**Climate change & severe weather**	High	Pervasive	Serious	High	
11.1	Habitat shifting & alteration	Unknown	Pervasive	Unknown	Moderate	Climatic events may be a threat because moose and their habitat are compromised/degraded from other threats and have lost resilience and are thus vulnerable to the disturbance.
11.2	Droughts	Unknown	Pervasive	Unknown	High	Winter snowfall and summer rain fall below the normal range of variation. Decreased snow depth results in decreased competitive advantage for moose and incursion of deer into habitat; decreased rainfall reduces water levels and access to water and aquatic forage, along with causing stress to tree species/forest habitat.
11.3	Temperature extremes	High	Pervasive	Serious	High	Heat waves; increased summer and winter temperatures and resulting range reduction; critical energy deficits (e.g., thermoregulation).

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
11.4	Storms & flooding	Medium	Pervasive	Moderate	High	Ice storms may reduce access to winter forage and impede daily travel to important habitat components (cover, forage).
11.5	Other impacts	Unknown	Pervasive	Unknown	Moderate	Climate changes may enhance conditions for disease and parasites (e.g., brainworm and winter ticks) and problematic native species such as deer.
12	**Other options**					
12.1	Other threats					Not applicable

[a] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g.,, if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment timeframe (e.g.,, timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[b] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted; Small; Negligible).

[c] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate; Slight; Negligible; Neutral or Potential Benefit ≥ 0%).

[d] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2. Description of Threats

Threats to Mainland moose in Nova Scotia are fairly well known and understood, with the exception of climate change. However, the interrelated nature of threats and their interactions makes their collective impact on populations are more challenging to address. Major threats which are thought to have driven population declines in Mainland moose are discussed here, in order as they appear in Table 2 Threat calculator assessment.

Residential and Commercial Development – Housing and Urban Areas (H)

Habitat loss and habitat fragmentation is one of the most serious challenges to recovery of Mainland moose. Development (residential or commercial) represents a permanent conversion of habitat to another use that is typically unfavourable to moose. Residential development is likely more of a concern than commercial/industrial development (such as quarries) or development relating to tourism (such as golf courses and campgrounds), primarily due to the larger scope or distribution of the former. Behavourial changes and avoidance of developed areas are common (Faison et al. 2010, Wattles et al. 2013). These types of land conversion are cumulative and complex as additional fragmentation results from the services-power line corridors and roads- are required to support these developments as well as increased pollution from noise, light, and effluents.

Human population increases and consumption will drive demand and need for additional housing and development, and the demand for services and industries to support this increasing population will add additional stress to habitat needs for species. There is less risk of development pressure due to the geographic isolation of currently recognized subgroups of Mainland moose in Nova Scotia, however, it likely that development has led to declines in the Chebucto Peninsula region. Additionally, this development creates a loss of connectivity across the landscape, and geographic isolation may result in reduced health, loss of productivity, and potential genetic deterioration. For an already heavily fragmented region such developments may create challenges for recovery, especially with respect to smaller groups such as those in the Tobeatic and Chebucto Peninsula regions, and for connectivity among Mainland moose groups and with New Brunswick.

Agriculture and Aquaculture - Annual and Perennial Non-Timber Crops (H)

Multiple activities that convert forest habitat to agricultural crop production occurs throughout the province. In the Annapolis Valley of Nova Scotia, forests are converted to corn fields for cattle feed. Blueberry fields and the potential for blueberry crop expansion is present in the Cobequid Highlands, where it is believed the largest localized group of Mainland moose occurs. Maple syrup production is also an important industry in that region of the province, with year-round placement of piping as an entanglement concern. Associated fencing, roads, lights, and noise makers also add to the stressors.

A review of the current Nova Scotia Interpreted Forest Inventory (available at https://novascotia.ca/natr/forestry/gis/forest-inventory.asp) identified less than 10,500 ha (1.7% of the total land area) currently in maple syrup or blueberry production in Cumberland County. There has been no increase in requests for Crown land use for these activities over the past 5 years, and it is not anticipated to increase in the future. However, applications for agriculture use continue to be received and reviewed annually, depending on demand at the time (P. Lynch, pers. comm.).

Energy Production and Mining – Mining and Quarrying (H)

Mineral exploration, exploitation of areas (such as tailings ponds), pollution, and increases in services (roads and transmission lines) have resulted in habitat loss, degradation, and fragmentation across the Mainland moose range. According to the Nova Scotia Environment Environmental Assessment website (https://novascotia.ca/nse/ea/projects.asp), 61 projects associated with mining operations or quarry development and expansion have been approved or under review since 2000. This would not include applications made to the province for mining exploration, which occur on Crown land and are reviewed by the Regional Services Integrated Resource Management Teams. A total of 137 prospecting permits were issued from 2017-2019, with the number of permits increasing each year (27 in 2017; 45 in 2018; 67 in 2019). Similarly, a total of 97 new mining exploration permits on Crown land were issued over the same time period (15 in 2017; 43 in 2018; 39 in 2019) (Tizzard 2019). Exploration may advance from “grass roots” prospecting of single or multiple drill holes in an area, to advanced-stage exploration with grids of bore holes to assess the extent of an ore body. Mining exploration impacts are difficult to quantify for multiple reasons: number of drill holes associated with each permit; distribution of drill holes; requirements for new extraction trails; or, use of pre-existing trails or forest roads which likely lessens their impact. Cumulatively, prospecting and exploration permits have been increasing considerably over the past 3 years.

Although quarry operations (both new quarries and quarry expansions) are smaller in scale, the sheer number of them on the landscape, their cumulative impacts, and additional service requirements would be extensive. Although there are requirements for reclamation at the end of the quarry’s lifespan, quarries are typically on the scale of 25-30 year project timelines, and reclamation does not return the area to pre-quarry habitat conditions.

Transportation and Service Corridors – Roads and Railroads (VH)

Human access to habitat constitutes one of the most significant threats to Mainland moose. Road density can be considered an indicator of biodiversity loss and a key driver of anthropogenic threats such as fragmentation, degradation habitat loss, and the introduction of invasive species (Beazley et al. 2004). Direct consequences of roads include habitat loss, degradation, and fragmentation, as well traffic-induced mortality. Indirectly, road access creates opportunities for poaching, facilitates white-tailed deer movement (and consequently, *P. tenuis* and *D. albipictus*), and increases access for recreational use into traditional moose habitat (such as OHVs). Rempel et al. (1997) found that access to habitat increased as a consequence of increased road density. There are also individual disruptions (e.g., habitat avoidance) that may result in long-term population level impacts which must be considered as a result of the disturbance, and which are more prominent for wide-ranging species such as Moose (Jalkotzy et al. 1997).

Studies show that road density negatively impacts behavior, habitat selection, and habitat use. The effects of roads are scale-dependent; at the landscape level, there appears to be a positive correlation to roads as these are strongly associated with transitions from conifer dominant to mixedwood forests and better foraging opportunities, while at the finer scale, moose avoid roads (Beyer et al. 2013). Snaith et al. (2002) found that road density had a greater effect on habitat selection by moose than the composition of habitat itself. Road density is negatively correlated with moose presence; deleterious effects are found to be present up to 1,000 m from a road, and densities exceeding 0.6 km of road per km^2 had negative effects on populations (Beazley et al. 2004). Although road density is much lower in the Tobeatic region of Nova Scotia, road density in the central area of the province has created connectivity issues between this localized group and the one found in Cobequid Hills, thus limiting movement of individuals, decreasing gene flow, and potentially affecting viability of the Tobeatic group. Highway 103 is a barrier to moose movement between the Chebucto Peninsula group and the rest of mainland Nova Scotia. It is important to note that types of road (e.g., highway versus forestry road) and their use has a bearing on the magnitude and type of impact it will have on a population (Beazley et al. 2004). Road density in excess of 0.6 km per km^2 is not uncommon in the Colchester-Cumberland region of Nova Scotia, which also has the highest concentration of Mainland moose in the province (Beazley et al. 2004). Higher density of roads correlates with an increase in home range size, which could be either compensatory for loss of habitat or movement-specific for sodium (Laurian et al. 2008). Yet these roads result in indirect effects such as facilitating incursions of humans and deer into moose habitat—thereby increasing potential for further development, timber harvesting, poaching and transmission of *P. tenuis*, as addressed in other threat categories—with negative impacts on moose. Such direct and indirect effects may explain recent declines in moose numbers even in areas of relatively higher concentrations such as the Colchester-Cumberland region.

Road mortality is a direct impact on the Mainland moose population and is directly tied to both presence of roads and road density. Seasonally, sodium may be a limiting factor resulting in movement of moose towards roads (Laurian et al. 2008). Fudge et al. (2007) reported 14 moose-vehicular deaths over a 5 year period in Nova Scotia, while Beazley et al. (2004) in their study found 6 of 16 (37.5%) moose carcasses sent to the Atlantic Veterinary College for necropsy were the result of vehicular trauma. The Biodiversity

Incident Report (BIR) database which supports provincial government data management for species incidents and observations recorded 34 moose-vehicle interactions (injury or mortality) for mainland Nova Scotia during the most recent 10 year period (2010-2020). Although it is difficult to assess the impact that road mortality has on Mainland moose in the absence of annual population estimates, the loss of any breeding individuals from a depressed population is significant. Vegetation management along roads can play a key role in reducing this mortality risk, with recent cutting providing less suitable moose browse (Tanner and LeRoux 2015). Road avoidance habituation of moose through aversion tactics employed during winter highway patrols by Guardian groups has also been shown to be successful in driving moose away from the roadway; the Misipawistik Cree Nation kanawenihcikew Guardians conducted highway patrols in winter months, which was successful in driving moose away from the roadway and identified high traffic areas for future signage and interventions (Cook, in press).

The cumulative impacts of roads and road usage on the Nova Scotia Mainland moose population and their habitat cannot be understated in terms of severity.

Transportation and Service Corridors - Utility and Service Corridors (H)

Studies of ungulate species shows that generally there is no behavioural disturbance associated with power lines and that species may benefit from increased browse availability and travel routes. However, Right of Ways (ROWs) fragment habitat and increase access for recreational activities and poaching. Moose use adjacent forest habitat cover more frequently than ROWs, which appears to be a function of scale of use where Moose avoid ROWs at a landscape level (Bartzke et al. 2014). There is also the concern of vegetation management of ROWs and how this activity alters browse composition and the usefulness of the ROW for moose.

Biological Resource Use - Hunting and Collecting Terrestrial Animals (H)

A regulated harvest for moose in mainland Nova Scotia has been banned since 1936 in the western part of the province and across the entire mainland since 1981. Due to the nature of the activity, it is impossible to quantify the impact poaching has on the Mainland moose population; however, the removal of any breeding individuals from a depressed population should be considered significant. Anecdotal reports indicate that poaching is a threat to the species in the Chignecto Isthmus region and occurs with some frequency (Needham et al. 2020). Department of Natural Resources and Renewables staff respond to possible incidents of poaching (e.g., discovery of carcasses), but it is difficult to prosecute perpetrators, with no charges having been placed in the past 5 years (O. Fraser, pers. comm.).

Biological Resource Use - Logging and Wood Harvesting (H)

Forest management can degrade or enhance moose habitat on the landscape. Harvesting that removes the overstorey and creates large openings in the canopy make habitat unsuitable due to loss of shelter from the elements and inability to meet thermoregulatory needs. Removal of cover increases exposure to threats such as poaching, and access into moose habitat for recreational activities increases with density of forest roads and extraction trails. These changes also tend to favour deer, increasing risk of exposure to brainworm and winter tick for moose. Harvesting, however, can increase the amount of available browse for moose, if deciduous species are allowed to regenerate naturally and there is adequate cover for thermal and security needs in close proximity (typically less than 200m away) (Snaith and Beazley 2004).

Moose require mature conifer stands for thermoregulation, shelter, protection from wind, calving needs, and travel when snow depth is a factor (Timmerman 1988). Coincidentally, these stands have also traditionally been the most valuable in terms of merchantable timber from a harvesting perspective. Large-scale forest harvesting reduces the amount of mature forest and favours homogeneity on the landscape-increasing number of stands of similar species composition and age. Silviculture practices such as precommercial thinning, and glyphosate spray programs reduce amount of available browse through promotion of even-aged coniferous forests (Snaith and Beazley 2004). Overall, these practices create a more homogenous forest composition unsuitable for moose, resulting in habitat being less available and more fragmented on the landscape. A review by Snaith and Beazley (2004) suggested that forest harvest methods such as partial or selective cuts could meet moose habitat needs promote deciduous browse growth and maintain forest cover, provided 55-70% of the landscape is retained in mature cover within patches greater than 8ha in size, including some larger (100ha) patches, designed in such a manner that browse areas are not greater than 200m from suitable forest cover.

Parker (2003) in the Mainland moose Status Report suggested that "…*although the forested landscape of mainland Nova Scotia has experienced considerable changes through the past several hundred years, most of the food species preferred by moose, especially in northern districts, are common and widely available. If anything, food may be more available than ever given the intensity of forest harvesting and the proliferation of young regenerating deciduous and mixed forest stands*". Although harvesting may have resulted in increases to available browse, this statement ignores the impact that forest harvesting has on habitat alteration and fragmentation, especially forest cover for security and thermoregulation. Although forest cover losses accrue from land uses other than forestry, Global Forest Watch indicates a 13% decrease in tree cover in all of Nova Scotia since 2003 (2003-2019), the year Mainland moose were officially listed as Endangered.

Although moose will use regenerating cut blocks, this may vary depending on age and sex of moose, species composition, time since harvest, and distance from suitable cover. Natural regeneration after a harvest is dependent on overstorey species composition, harvest type, and environmental factors as determined through ecoregion classification (e.g., soil type, topography, climate) (Salmon et al. 2016), so not all sites may support appropriate browse species in necessary quantities at the appropriate time for moose. Studies have shown variability in cutover block age and their use by moose, typically in the range of 10-40 years post-harvest depending on age and sex of the animal (Hamilton et al. 1980, Thompson and Vukelich 1981, Snaith and Beazley 2004).

The application of provincial Acts, policy, and guidelines increases the complexity of the issue. Less than 34% of the land is under provincial ownership (including Crown land and Protected Natural Areas) (Nova Scotia Department of Lands and Forestry 2017). Policy and guidance which provide some measure of habitat protection, such as the Mainland moose Special Management Practices (SMP), apply only to Crown land. The province of Nova Scotia initiated an independent forest practices review, accepted the recommendations of the report, and is currently in the process of implementing the recommendations. If implemented into policy and practice, the recommendations have the potential to dramatically shift how forestry is conducted on Crown land, with a "biodiversity-first" application that has potential benefits to wildlife and their habitat, including Mainland moose.

Human Intrusions and Disturbance - Recreational Activities (H)

Recreational activities are a problematic issue for moose, and this type of disturbance can cause adverse reactions such as behavioural changes, avoidance, and range abandonment. Moose respond negatively to activities such as snowmobiles (Colescott and Gillingham 1998) and skiing (Ferguson and Keith 1982). Harris et al. (2014), in a summary of impacts of winter recreational activities on ungulate species (including moose), found that impacts ranged from habituation to the activity to increased movement and displacement.

This threat is closely linked to another threat (Transportation and Service Corridors – Roads and Railroads) as access allows for an increase in OHV traffic through Mainland moose habitat. Since the introduction of snowmobiles in the 1960s and All-Terrain Vehicles (ATVs) in the 1970s, there has been a steady increase in their use across the province. Although there are regulated trail systems associated with both activities, a mosaic of unregulated trail systems exists within the province and continues to be expanded upon.

Invasive and Other Problematic Species and Genes – Invasive Non-native/Alien Species (H)

Newly discovered forest pest species threaten to change the forest landscape with negative consequences to Mainland moose habitat. Hemlock Wooly Adelgid (*Adelges tsugae*) was first detected in southwestern Nova Scotia in 2017. The small aphid-like insects attack Eastern Hemlock (*Tsuga canadensis*) feeding off the nutrients and water storage at the base of the needles, and is transported by wind, livestock, wild animals, logs, and nursery stock. Its origins and how it arrived in Canada is unknown (Government of Canada, Canadian Food Inspection Agency 2020). Hemlock stands in Eastern Canada are primarily in the mature stage with few stands of young trees, and with lower mortality than other species found within its range (McWilliams and Schmidt 2000). Eastern Hemlock are important components of Mainland moose habitat and provide thermal cover and browse (Timmermann and McNicol 1988, Routledge and Roese 2004, Faison et al. 2010). Climate change may facilitate the spread of this non-native forest pest species, as low winter temperatures dictate the northern limit of its range (Taylor et al. 2020).

Emerald Ash Borer (*Agrilus planipennis)* was first detected in North America in 2002 (Haack et al. 2002), has since spread to a number of states and provinces, including Nova Scotia in 2019 (Government of Canada, Natural Resources Canada 2020). Adults are slender, metallic-green, and can fly, laying eggs in host *Fraxinus sp*.; larvae feed on the cambrium of the host tree (Haack et al. 2002). Ash is an important browse species for moose and comprises 2-3% of the Acadian forest landscape.

Other invasive species of concern to Mainland moose are ones that overtake native vegetation in wetlands or the forest understory, such as Purple Loosestrife (*Lythrum salicaria*), Japanese Knotweed (*Reynoutria japonica*), Glossy Buckthorn (*Rhamnus frangula*), and Dog-strangling Vine (*Vincetoxicum rossicum*), which impact available food sources.

Invasive and Other Problematic Species and Genes – Problematic Native Species (VH)

The native species which has the greatest impact to Mainland moose is *Parelaphostrongylus tenuis,* referred as "moose sickness" and "brainworm". Moose sickness has been present in North America for over 100 years, with the causal agent *P. tenuis* known since the 1960s. Terrestrial gastropods (e.g., snails) are the intermediate hosts, with white-tailed deer (*Odocoileus virginianus*) the final host and reservoir for the parasite in Nova Scotia. Climate is a determining factor in both the northern limits of the range of *P. tenuis* (tied to the northern range of deer) and precipitation and length of summer for survival of first-stage larvae as well as gastropod hosts (Lankester 2010). Affected animals show varying degrees of neurological and behavourial distress, which can include, but are not limited to, head tilting, limb weakness, stumbling, partial or complete blindness, travelling in circles, loss of fear of humans, and weight loss (Peterson 1955, Lankester 2010). Infection is dependent on the presence of deer, as the larvae rarely matures to complete its life cycle in moose (Lankester 2010).

Moose sickness has been reported as a serious threat to Mainland moose since the 1930s (Benson 1958). Infection rate of deer in Nova Scotia with *P. tenuis* is approximately 50-60%, and where moose and deer ranges overlap, brainworm is a significant mortality factor for moose (Parker 2003). Moose densities in other jurisdictions are inversely related to deer density, and even more so where larval content of *P. tenuis* in deer feces is highest (Whitlaw and Lankester 1994). There is evidence to suggest that brainworm is a regulating factor for Mainland moose, with subgroups mainly restricted to higher-elevation regions which receive greater snow depths (and hence lower deer densities) and act as a refugia (Telfer 1967, Beazley et al. 2006).

In addition to brainworm, another native species which affects the health of moose in Nova Scotia is the one host winter tick (*Dermacentor albipictus),* for which White-tailed deer are again the reservoir host. Eggs of ticks hatch in the ground, and then move into the vegetation where ungulates brush against them and they become attached to the host. Larvae further undergo two molt stages while attached, with the adult stage first present between January-February, persisting on the host until April; the adults then detach and females lay their eggs on the ground and the cycle is repeated (Leighton 2012). Winter tick infestations on moose cause severe irritation, resulting in increased grooming, hair loss, disruptions to behaviour and feeding, and, in high intensity infections, emaciation and death (Samuel and Welch 1991).

The severity of winter tick infestations can vary from year-to-year. Severely affected individuals can have over 30,000 ticks, and calves have a higher density overall (ticks/cm^2 of skin) (Leighton 2012). Winter tick has been associated with historical die-offs of central Albertan moose populations (Webb 1959; Samuel and Barker 1979) and the decline of moose on Isle Royale during 1988-1990 (DelGiudice et al. 1997). Anecdotal evidence suggested an epizootic outbreak of winter ticks, combined with deep snow in 2010-2011 caused significant calf and yearling mortality in New Hampshire, Vermont, and Maine (Bergeron et al. 2013). A recent study by Jones et al. (2019) in New Hampshire and Maine suggested winter tick as the primary cause of decline in the regional population, with 88% of calf mortality attributed to high winter tick infestation.

Weather, as well as density of moose and White-tailed deer, are key factors in tick abundance. Increases in survival of female ticks occur during warmer, shorter winters, with an increase in tick abundance occurring the following year (Samuel 2007). Although winter tick epizootic outbreaks are typically brief (1-2 years), an increase in mild winters due to climate change would create environmental conditions more favourable for winter tick reproduction (Jones et al. 2019). Dunfey-Ball (2017) associated warmer temperatures with suspected epizootic outbreaks in 5 of 10 years from 2007-2017 in studies of moose populations New Hampshire and Maine. Both Samuel (2007) and Dunfey-Ball (2017) correlated increased density of moose with increased tick abundance, with a density of less than 0.8 moose/km2 resulted in lower incidence of winter tick attachment in New England (Dunfey-Ball 2017).

Invasive and Other Problematic Species and Genes – Diseases of Unknown Cause (VH)

Antler abnormalities are commonly observed in male moose and reproductive rate and calf recruitment are low in the Mainland moose population. This has been associated with copper deficiency in other North American moose populations, but also could be related to stress, poor nutrition, and predation in Nova Scotia.

Trace element deficiencies (such as copper and selenium) are found in a number of regions (Murray et al. 2006) and can be linked to lower reproductive success and reduced calf survival (Flynn et al. 1977). Deficiencies are likely correlated with poor nutrient content of browse.

Studies in Nova Scotia population of moose and deer found lower concentrations of zinc and cobalt for provincial ungulates in comparison to other regions. Kidney cadmium levels are also high, which is consistent with studies in other regions (Pollock 2005). Continued monitoring of trace element concentrations and further studies are required to determine their potential involvement in these health problems that have been identified in Mainland moose.

Climate Change and Severe Weather – Temperature Extremes (H)

Although the impacts of climate change are difficult to predict or quantify, climate change is likely to alter Nova Scotia forests, increase parasite numbers, and impede the long-term viability of the Mainland moose population.

Weiskopf et al. (2019) provided a review of climate change impacts on moose and moose habitat which included: increased heat stress; behavioural changes; increased incidents of disease; altered forest composition; and, a northward shift of boreal biome. Although Mainland moose are not at the southern limit of the species range, there is an overall consensus that moose populations will likely decline in southern portions of its range. Warming temperatures and reduced snow depth will favour increased densities of deer on the landscape, resulting in increased exposure to brainworm (Murray et al. 2006, Weiskopf et al. 2019). Lankester (2010) suggests that shorter winters of reduced snowfall as well as longer and wetter spring seasons would favour increases in the populations of the gastropod intermediate hosts of *P. tenuis* and transmission of *P. tenuis* larvae to them. Increases in spring temperatures are linked to higher intensity winter tick infections and increased hair loss in moose the following winter, likely the result of more eggs surviving and hatching through the spring (Wilton and Gardner 1993). Climate change will likely increase the frequency of winter tick epizootics; however, low moose densities (such as those currently seen in Nova Scotia) are not favourable for winter tick outbreaks (Dunfey-Ball 2017). Additionally, illnesses in moose occurring at the same time (such as parelaphostrongylosis) will also exacerbate the effects of climate change, with health-compromised individuals showing less tolerance to higher temperatures (McCann et al. 2013).

Moose overall have low tolerance to temperature stress, with summer critical temperatures have a greater impact (Dussault et al. 2004, McCann et al. 2013). Mainland moose show signs of thermoregulatory stress, and reduced activity during high temperature periods (Broders et al. 2012, Ditmer et al. 2018). Anthony et al. (2017) predicts a shift in the composition of the Acadian forest by the mid-21st century, with fewer cold-adapted boreal species (such as trembling aspen, balsam fir, and red spruce) on the landscape. These species are key components of both foraging and thermal cover needs of moose. Increasing seasonal and daily temperatures, combined with a loss of traditional cover species which support thermoregulatory needs and loss of browse, would have a significant impact on moose.

Mammals with larger body mass such as moose are at increased risk of impacts from climate change due to loss of thermal cover, habitat alteration, and increases in parasite loads (Thompson et al. 1998). Teitelbaum et al. (2020) predicts "*…little change in use of cover types in 2080 under projected climate change*", suggesting that either a) other behavior factors could be constraining moose, or b) the small change in predicted habitat use could be sufficient to meet thermoregulatory needs. Distribution is likely to contract for moose at the southern limits of their range, where climate and habitat is considered marginal for the species and snow depth may no longer be sufficient to create separation in distribution between deer and moose (Murray et al. 2006). For Mainland moose, which are at the southern limits of their range and have a reduced population size, impacts of climate change may be cumulative, contributing to further population decline.

5. POPULATION AND DISTRIBUTION OBJECTIVES

Viable status for recovery

The viable status for recovery of the species, intended as a long-term goal of removing the Mainland moose from the NSESA, is:

> A minimum of 5000 individuals throughout mainland Nova Scotia, at least 500 of which are breeding individuals, and are distributed throughout 3 localized groups (Cumberland/Colchester, Pictou/Antigonish/Guysborough, and Tobeatic). These localized groups should function as a connected population, with additional connections for genetic exchange via immigration and emigration into and from NB, through habitat corridors, for long-term viability.

Population and distribution objective

> The 20-year population and distribution objectives for recovery of the Mainland moose in Nova Scotia are:

1. To increase the census populations, numbers of breeding individuals, and calf survivorship, by at least 10% respectively, in each of the 3 localized groups.
2. To enhance connectivity to improve genetic health and demographic parameters and to support symmetrical exchange of migrants between each pair of localized groups within the Eastern mainland (Cumberland/Colchester, Pictou/Antigonish/Guysborough) and the Tobeatic.
3. Given the lack of currently available information, assess the status of the Tobeatic localized group and increase connectivity, if feasible, with the larger localized groups in the Eastern mainland.

Rationale

The viable status for recovery of the species is intended to achieve the long-term goal of removing the Mainland moose from the NSESA. It is estimated that before European colonization, there may have been approximately 15,000 moose in mainland Nova Scotia (Parker 2003). With the first aerial surveys in the 1960s, the population was estimated to be between 2500 and 4000 animals. Based on these findings, a restricted hunting season was opened in 1964 in the two areas with the highest densities of moose (in eastern mainland, Nova Scotia). However, by the mid-1970s, the population was estimated to have declined to 1600 – 1700 individuals, prompting designation of six management zones in 1975, and in 1981, closure of moose hunting seasons on mainland Nova Scotia. Despite the absence of legal hunting, aerial and pellet group surveys indicated ongoing significant decline in moose densities by the mid-1990s. At the time of NSESA listing in 2003, the native population of moose on mainland Nova Scotia was estimated to be approximately 1000 individuals; however, a more recent analysis of the data and methodology provided a more conservative estimate of less than 700 individuals. Mainland moose are within isolated localized groups at various locations on the mainland, primarily including the Tobeatic in the western region of the province, and the Eastern mainland counties of Cumberland, Colchester, Pictou, Antigonish, and Guysborough.

Based on the historical moose numbers and trends, and significant changes in land use and cover since European colonization, a realistic long-term viable population for Mainland moose to permit delisting would be 5000 individuals in localized groups, functioning together as a connected metapopulation, with additional connectivity for genetic exchange via habitat corridors allowing immigration and emigration into and from New Brunswick respectively. Given the relatively large habitat ranges required to support moose in parts of mainland Nova Scotia, the small geographical size of mainland Nova Scotia, and anticipated climate changes, enhanced connectivity with New Brunswick is critical to long term viability (Snaith and Beazley 2004, Beazley et al. 2005, 2006).

Generation length[1] is the biological timeframe to achieve the population and distribution objectives and is thought to be 8-10 years for Mainland moose (Parker 2003). A 20-year benchmark (equal to a minimum of two generation lengths) for achieving the population and distribution objective is necessary in order to allow time for a response to recovery actions that can be measured.

The concept of the Mainland Nova Scotia moose population functioning as an interconnected population is supported by recent genetic research which demonstrates no evidence of genetic isolation in any of the localized groups and gene flow for the eastern mainland of Nova Scotia (B. Scott, pers. comm.). The exchange of individuals between subgroups to maintain or enhance viability has been studied extensively throughout taxonomic groups (Vandewoestijne et al. 2008, Lairke et al. 2016), but studies specific to moose and gene flow is limited (Murray et al. 2012). Symmetry of exchange (the equal exchange of migrants) has been noted as a requirement between localized groups and will be supported by developing strategies and actions to improve habitat connectivity across the landscape.

It is important to note that the Tobeatic localized group appears to be isolated from the Eastern mainland localized groups and is in more serious decline as evidenced by extensive winter aerial survey work by the Department of Natural Resources and Renewables from 2019-2020. Further study is required to determine if the Tobeatic localized group has the potential to be recovered from a biological/genetic perspective, even if improved connectivity to Eastern mainland localized groups can be re-established. If the Tobeatic group is deemed biologically or genetically unrecoverable, the primary focus of recovery efforts would shift to the Eastern mainland portion of the Nova Scotia Mainland moose population.

6. BROAD STRATEGIES AND GENERAL APPROACHES TO RECOVERY

6.1. Actions Completed or Underway

This list is not exhaustive but is meant to highlight important developments in Mainland moose recovery that have been undertaken since the Recovery Plan (2007) and Action

[1] Generation length as defined by COSEWIC is "…the average age of parents of a cohort (i.e. newborn individuals in the population). Generation length therefore reflects the turnover rate of breeding individuals in a population. Generation length is greater than the age at first breeding and less than the age of the oldest breeding individual, except in taxa that breed only once."

Plan (2013) and may provide context or assist in discussion of Section 6.2. *Options for Recovery*:

- Research examining Mainland moose occurrence records with stand and landscape structure is being undertaken by Thomas Millette at Holyoak College, Massachusetts.
- Researchers at Acadia University in Nova Scotia have examined genetic variability within and among moose populations in eastern mainland Nova Scotia as well as New Brunswick and Cape Breton Island. Preliminary results suggest evidence for gene flow occurring within eastern mainland areas, genetic connectivity between Nova Scotia and New Brunswick, and low genetic variability for the eastern Mainland as a whole.
- Through a partnership with Canadian Cooperative Wildlife Health Centre (CWHC) at the Atlantic Veterinary College, University of Prince Edward Island, post-mortem examination of moose continues to be undertaken for any mortality event.
- Department of Natural Resources and Renewables has undertaken several aerial surveys for Mainland moose under winter conditions to estimate abundance. With the exception of the Chebucto Peninsula, the surveys did not provide reliable population estimates. Surveys for the Tobeatic region were conducted in 2019 and 2020, but reliable population estimates are not available.
- In 2017 and 2018 a new technique to estimate Mainland moose abundance in Nova Scotia was employed using infrared aerial imagery linked to high resolution GIS capable cameras. Although successful in other jurisdictions (Millette et al. 2011), estimates could not be determined due to the low number of moose encountered during the survey.
- The Endangered Mainland Moose Special Management Practices continues to be implemented for all harvesting occurring on Crown Lands within identified Mainland moose concentration areas.
- Public observations of moose sightings and moose sign (scat and tracks) are submitted through the online reporting form on the Nova Scotia Natural Resources and Renewables website (https://www.gov.ns.ca/natr/wildlife/sustainable/msform.asp). This information is captured within the province's Biodiversity Investigation Reporting (BIR) system and is used to inform management decisions, such as the Special Management Practices.
- Enforcement operations to deter poaching occurs opportunistically in response to concerns or complaints about illegal activities, with the most recent occurring in Central region in the fall of 2020. No charges have been laid as a result of these operations over the past 5 years.

6.2. Options for Recovery

Table 3 summarizes recovery actions, the specific steps that need to be taken and their relative priority to affect recovery of Mainland moose. Key research priorities to address knowledge gaps are also provided.

Table 3. Recovery options planning table.

Recovery Measures	Threat(s) Addressed*	Actions	Priority*	Cost***	Benefit
Habitat Protection, Management, and Stewardship					
Improve habitat connectivity for Mainland moose.	1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 4.1, 4.2, 5.3, 6.1, 9.2, 9.3, 11.3	• Designate Core Habitat for Mainland moose localized groups and their movements that have been described using parameters such as habitat suitability and in the case of highways, to minimize collision data. • Protect Mainland moose Core Habitat through designation under provincial and municipal legislation (e.g., protected areas). • Conserve and restore key corridors and linkage areas for the three Mainland moose localized groups within Core Habitat through collaboration with NGOs and landowners, as well as municipal governments and Department of Public Works. • Mitigate barriers/threats related to highways through the use of wildlife underpasses, overpasses, and/or other methods to provide for safe passage in key crossing locations, with an immediate focus on Highway 104 from Amherst-Truro.	H H H H	$ $$$$ $$$ $$$$$	Potential rescue effect; increase in suitable habitat; augment existing habitat.

Identify and implement conservation mechanisms for buffer zones around Core Habitat.		• Identify buffer areas surrounding Core Habitat for application of land/forest management techniques consistent with supporting moose recovery and maintaining or restoring moose habitat. • Conserve and restore buffer zones.	H H	$ $$$	Habitat protection and enhancement.
Strengthen Special Management Practices for Mainland moose on Crown, public, and private lands.	2.2, 3.1, 3.2, 3.3, 4.1, 5.3, 9.3	• Evaluate and revise the current Mainland moose Special Management Practice towards strengthened/more effective measures in the context of the updated Recovery Plan.	H	$$-$$$	Habitat protection and enhancement.
Stewardship of Core Habitat and buffer zones on private land.	2.2, 3.1, 3.2, 3.3, 5.3, 9.3	• Develop an engagement process for stakeholders and Rights holders who may play a role in stewardship of Mainland moose habitat, i.e., population restoration project areas and engagement of stakeholder communities. • Tie management of Mainland moose habitat to incentives and disincentives such as silviculture payments.	H H	$ $	Habitat protection and enhancement; stakeholder investment in SAR recovery.
Adopt adaptive management principles and practices to better support Mainland moose population and habitat recovery.	2.2, 3.1, 3.2, 3.3, 4.1, 5.3, 8.2, 9.2, 9.3	• Initiate/revise landscape-level planning on a spatial and temporal scale to minimize direct and indirect impacts to Mainland moose and their habitat. • Incorporate results of monitoring and research activities into management of Mainland moose recovery actions. • Evaluate and revise forest management practices as part of Mainland moose habitat protection and/or enhancement and align with ecological forestry	H H H	$$$$ $ $	Habitat protection and enhancement; stakeholder investment in SAR recovery; forest management practices beneficial to habitat protection and enhancement; decrease in *P.*

		recommendations from the Lahey forest practices review. • Develop a road planning and access management system (including decommissioning) to limit habitat and population fragmentation and degradation/conversion in key Mainland moose concentration areas and to minimize/limit human access for non-approved and/or illegal activities. • Focus management of white-tailed deer within Mainland moose Core Habitat toward minimizing overlap with high deer densities. • Provide guidance and training to forestry professionals responsible for timber harvesting and silviculture planning on Mainland moose habitat requirements and objectives.	H H H	$$ $$ $	*tenuis* and winter tick transmission.
Ensure Mainland moose habitat is accommodated as part of Lahey forest practices review recommendations.	2.2, 4.1, 5.3, 9.3	• Incorporate identification of Mainland moose Core Habitat and buffer zones in delineating areas for the high production forestry and forest matrix/ecological forestry legs of triad and other relevant actions arising from implementing the Lahey recommendations.	VH	$	Habitat protection and enhancement; forest management practices beneficial to habitat protection and enhancement.
Surveys and Monitoring					
Health surveillance of Mainland moose.	8.2, 8.5, 8.6	• Continue Scanning Surveillance Program in collaboration with the Canadian Wildlife Health Centre (CWHC). Continue to deliver all known Mainland moose mortalities to the CWHC at the	H	$	Improved understanding of causes of mortality which inform actions to address threats.

		Atlantic Veterinary College for a complete post- mortem examination, an evaluation of known or suspected health threats and collection of tissue or other biological specimens for other health related projects. • Implement Targeted Surveillance Program in collaboration with the CWHC to assess current or future impacts of known health threats to the Mainland moose population such as Winter Tick (*Dermacentor albipictus*), parelaphostrongylosis, and secondary copper deficiency.	H	$$	
Augment existing knowledge of the distribution and abundance of Mainland moose.	All threats	• Develop and implement an intensive province-wide baseline survey to determine numbers of moose and where they are on the landscape (short-term, immediate action separate from subsequent standardized annual surveys) as a critical first step in recovery to guide and direct future activities. • Create and implement an annual, structured, systematic approach to monitor Mainland moose in Nova Scotia. • Develop regional/local stewardship through guardian groups, volunteers, and programs to conduct annual and other periodic surveys of sign of moose presence/absence (e.g., forest road-side surveys for prints, pellets, etc.). • Survey and assess wildlife-vehicle collision reports and wildlife incident reports to help	VH H H H	$$$$$ $$$$ $ $	Population and distribution knowledge to support recovery actions; increased awareness and public and industry engagement.

		identify Mainland moose presence and connectivity areas, moose road crossing points, and areas and amount of road mortality.			
Monitor population recovery.	All threats	• Develop monitoring strategies to evaluate effectiveness of recovery actions (e.g., monitoring threats).	H	$	Knowledge to inform recovery planning process.
Communication, Outreach, and Education					
Improved communication on poaching-citizen engagement, enforcement, and reporting.	5.1	• Explore opportunities to collaborate and share resources with the Mainland moose Guardians program, and to expand similar programs to other groups/communities across Mainland Nova Scotia. • Evaluate the current anti-poaching campaign in terms of applicability and efficacy and update/strengthen/expand for better protection of Mainland moose.	H H	$ $	Increased public awareness; increase in reporting and consistency in reporting of poaching.
Improve means of reporting sightings.	All threats	• Foster and enhance messaging around the critical importance of reporting sightings of Mainland moose or moose sign. Clearly define, implement/support, and communicate steps for citizens to report sighting without putting Mainland moose at risk of harm.	H	$	Population and distribution knowledge to support recovery actions; increased public awareness.
Information sharing and collaboration with First Nations communities.	All threats	• Meaningfully engage with Mi'kmaq communities about collaboration and insights for Mainland moose monitoring, habitat protection, poaching, and priorities for improvement in culturally appropriate ways.	H	$	Population and distribution knowledge to support recovery actions; increased awareness; habitat protection and enhancement.

Develop and implement outreach materials and programs for private landowners.	4.1, 5.3, 6.1, 9.3, 11.3	• Develop and distribute/implement outreach materials and programs targeted to private landowners on tools and resources available to support the maintenance/restoration of Mainland moose Core Habitat as well as buffer zones on their land.	H	$$	Habitat protection and enhancement; increased awareness and stakeholder engagement.
Law, Policy, and Enforcement					
Core habitat requirements and considerations.	1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 4.1, 4.2, 5.3, 6.1, 9.2, 9.3, 11.3	• Designate Core Habitat under the NSESA. • Consider implications of implementation of policies resulting from Lahey recommendations for Mainland moose Core Habitat and buffer zones (for example, High Production Forestry zones).	VH VH	$ $	Habitat protection; threat reduction.
Develop policy and management practices for Core Habitat and buffer zones.	2.2, 4.1, 5.3, 9.3	• Immediately following release of Recovery Plan, develop management procedures that can be applied to identified Core Habitat on a landscape level.	H	$	Habitat protection; threat reduction.
Incorporate Mainland moose habitat protection and enhancement into the Environment Assessment process and proposed development activities.	1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 4.1, 4.2, 9.2	• Communicate moose enhancement objectives as government-wide policy and require all authorizing agencies to incorporate them into project review, assessment, and authorization processes.	H	$	Habitat protection; threat reduction.
Statements of provincial interest considerations (under the Municipal Government Act).	1.1, 1.2, 1.3, 4.1, 4.2	• Review and update applicable land use strategies (land use plans, zoning requirements) to enable habitat recruitment where needed – place a high priority on population restoration project areas and engagement of stakeholder communities and Rights holders where possible.	H	$	Habitat protection; threat reduction.

Interdepartmental policy on road and trail moose-vehicle interaction data collection.	4.1	• Create stronger linkages between RCMP, Department of Public Works, and Natural Resources and Renewables to support increased knowledge of mortality events, connectivity, and threats, and for siting of roads in planning for future road development.	VH	$	Habitat protection; threat reduction; improved/targeted recovery actions.
Anti-poaching enforcement.	5.1	• Expand/strengthen anti-poaching enforcement, fines, charges (education program for crown prosecutors and judges who determine priority of cases and fines/penalties).	VH	$	Reduction in poaching.
Develop/support collaborative arrangements with New Brunswick to address cross-boundary moose recovery initiatives in the broader Chignecto Isthmus region.	All threats	• Improve collaborative efforts (e.g., the Priority Places program) to conserve and enhance Mainland moose habitat within the Chignecto Isthmus.	VH	$$$	Habitat protection; habitat connectivity; rescue effect potential.
Increase documentation and enforcement of SMP compliance on Crown and private land.	4.1, 5.3, 9.3	• Implement auditing and enforcement to assess and ensure SMP compliance on Crown and private land harvest blocks.	H	$$	Habitat protection and enhancement; increased stakeholder awareness.
Research to Address Knowledge Gaps					
Investigate the role of climate change in Mainland moose recovery over the near and long term.	All threats	• As temperatures are predicted to climb and tree composition shifts, identify climate resilient sites where Mainland moose are expected to survive. • Research the impact of climate change on Mainland moose. browse composition and abundance. • Research impact of climate change on parasites and diseases transmission.	M M H	$ $$$ $$$	Habitat protection and enhancement; potential threat reduction; improved/targeted recovery actions.

Assess/determine factors influencing spatial distribution, population sizes and demographic characteristics of local remnant groups.	All threats	• Allocate resources to undertake on the ground research to help understand factors influencing population sizes and demographic parameters. • Design and implement a study on calf mortality to determine its causes and whether or not it is a limiting factor in the poor reproductive performance documented in the Mainland moose population. • Investigate the efficacy of changes in management of white-tailed deer within Mainland moose Core Habitat (e.g., increase in doe tags with the goal of reducing the deer population, and hence, *P. tenuis*).	H H H	$$$ $$$ $$	Improved distribution, abundance, and demographic knowledge; improved/targeted recovery actions.
Assess threats within Mainland moose Core Habitat.	All threats	• Evaluate direct and indirect effects of threats (e.g., roads (paved, unpaved, trails), incompatible silviculture prescriptions, glyphosate, mining) on Mainland moose distribution, movement and exposure to poaching and deer incursion.	H	$	Threat reduction; knowledge to support recovery actions.
Assess Mainland moose habitat quality to inform habitat protection, management, and enhancement.	1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 4.1, 4.2, 5.3, 6.1, 9.2, 9.3, 11.1, 11.3	• Develop parameters to assess habitat quality/effectiveness within Mainland moose Core Habitat. • Evaluate Mainland moose Core Habitat using previously developed habitat assessment parameters.	H H	$ $	Habitat protection and enhancement.

*Threat or Limitation should refer to the IUCN Threat Classification Table Rankings. Either the first level or second level threat ranking can be used depending on how the Broad Strategy affects the threat. Multiple threats can be addressed under a single Recovery Measure.

**Priority should be classified as High(H), Medium(M), or Low(L). “Priority” is a qualitative measure of the relative degree to which an approach will have a positive impact on the recovery objective. High priority conservation approaches are considered those most likely to have an immediate and/or direct influence on reaching the management objective for the species. Medium priority conservation approaches may have a less immediate or less direct influence on reaching the management objective but are still considered important measures to implement. Low priority conservation approaches will likely have an indirect or gradual influence on reaching the management objective and are more tied to increasing knowledge or public perception/education.
***Use the following to assign a cost estimate to proposed activities: Cost categories: $ = < 10 000; $$ = 10 000-50 000; $$$ = 50 000-100 000; $$$$=>100 000-1,000,000, $$$$$ >1,000,000.

6.3. Narrative to Support the Recovery Options Planning Table

The recovery of Mainland moose will require a significant commitment from the provincial government, in terms of both an investment of resources to support actions and a shift in policy and procedures across various government departments, in addition to collaboration and commitment of stakeholders, private landowners, and the Mi'kmaq First Nation.

Habitat conservation, management, and stewardship

Habitat suitability and connectivity are key components of recovery that are addressed through multiple actions associated with policy, forest management, stewardship, and research. At the landscape scale, improved habitat connectivity between provinces is necessary for long-term population viability and will allow for gene flow and potentially mitigate against threats to moose posed by climate change. The Colchester/Cumberland area of NS has been identified as having some of the highest road densities in the province, in addition to currently containing the highest concentration of Mainland moose in NS; as a result, actions directed towards connectivity have broad implications provincially, but in some cases are specifically targeted to this area of the province. Weak genetic differentiation and evidence of gene flow between NS and NB indicates that the Chignecto Isthmus is a priority area for recovery actions that improved habitat and connectivity, given the potential rescue effect associated with the New Brunswick moose population.

A road management system would integrate the aspects of road placement, road type, and eventual decommissioning of roads as part of Mainland moose habitat protection measures, with the goals of decreasing road density, reducing habitat fragmentation, and improving landscape connectivity. Actions are targeted to improve connectivity through assessments of wildlife-road interactions and wildlife crossing structures. Highway 104, the major four- lane highway from Amherst to Truro, is a barrier to Mainland moose movement; costs associated with rehabilitating major highways to improve wildlife crossing would be more expensive than incorporating crossing structures and roadside fencing into the planning phase.

Forest management should be reviewed in the context of its impact on Mainland moose habitat requirements, both positive and negative. Where possible and practical, forest management at the landscape scale should be used to maintain and improve habitat suitability, enhance connectivity, and augment existing identified Core Habitat. At the stand level, forest management techniques that provide moose habitat and enhance natural regeneration in harvested areas should be encouraged. A review of the Mainland moose Special Management Practices (SMP) should be conducted in the context of the Recovery Plan, and how SMP can be used to enhance and augment existing habitat suitability, on both public and private lands. In addition to this, programs such as silviculture payments could be used to incentivize Mainland moose habitat enhancement on private land. As part of a province-wide landscape approach to Mainland moose habitat protection, habitat requirements relating to Core Habitat, buffer areas, and connectivity needs should be considered and required as part of implementation of the Lahey forest practices review recommendations.

Habitat protection, restoration, and enhancement will be a significant challenge in that most of the provincial forested land is privately owned. Improvements in policy, guidance, Best Management Practices (BMPs), and commitments from private woodlot owners to steward their land in the best interest of Mainland moose habitat requirements will be key to achieving habitat conservation and connectivity necessary for recovery.

Surveys and monitoring

Accurate baseline information is required to guide decision-making processes, in addition to developing monitoring programs for population recovery, habitat protection, and threat mitigation. Assessment and determination of spatial distribution of Mainland moose is a critical knowledge gap to be addressed. Although not always reliable, aerial surveys still offer significant advantages over other survey methods such as Pellet Group Inventory (PGI) counts and will likely be the preferred technique for Natural Resources and Renewables to survey for Mainland moose. However, options should be explored to determine how best to conduct surveys for moose in both summer and winter, in order to determine seasonal distribution and habitat associations.

Opportunities exist for collaborative arrangements with partner organizations for conducting surveys and collecting and recording observations of moose and moose sign. Opportunities for public engagement also exist through the development of a citizen-science survey program to increase awareness as well as augment existing sources of information. Protocols are required to ensure data is collected in a consistent, systematic and standardized manner, while acknowledging that Mainland moose are considered a data sensitive species.

Survey and monitoring programs should address not just species abundance and distribution, but also threats. Existing programs with the Canadian Wildlife Health Centre (CWHC) at the Atlantic Veterinary College in PEI should continue to be supported and enhanced as needed. A targeted surveillance program to assess current and future impacts of winter tick, brainworm, and secondary copper deficiency is also necessary. A review of mortality vehicle-wildlife incident reports will provide important knowledge on road usage and crossing areas to support changes to road placement, design, and crossing structure design/siting.

Communication, outreach, and education

Current outreach programs such as the anti-poaching campaign should be evaluated in terms of their approach, scope, and effectiveness in order to strengthen and expand them as required. Improving collaboration with Mi'kmaq communities to request their knowledge, insights, and work on habitat protection, poaching, and stewardship is fundamental to advancing actions on moose and protection of their habitat. Evaluation and enhancement of mechanisms of reporting observations is required to ensure data is captured accurately as this observational data from the public will help inform recovery efforts. Public communication and education are needed to build broad awareness and support for Mainland moose recovery efforts.

<u>Law, policy, and enforcement</u>

Law, policy, and enforcement augments or reinforces many of the actions identified in other sections and can be achieved through the creation of new policy, improvements to pre-existing policies, and guidance to support Mainland moose recovery.

Improvements to anti-poaching messaging and communication should translate to increased enforcement, charges, and fines. A component of this would be the education of provincial court system staff (and others who determine court case priorities and fines/penalties) on the NSESA, species at risk recovery, and the Recovery Plan.

As part of land use planning, an interdepartmental policy is needed that integrates efforts of RCMP, Department of Public Works, and Natural Resources and Renewables to improve reporting and assessment of moose-vehicle collision information to support better planning, siting of roads, infrastructure requirements, and improved habitat connectivity. Mainland moose is considered as part of the review for commercial and industrial activities under the Environmental Assessment process; requirements for review should be expanded to include those under the provincial Municipal Act (such as housing developments) which requires municipalities to consider provincial interests within their planning process.

Although Core Habitat will be defined and identified as part of this Recovery Plan, it is the designation of Core Habitat for Mainland moose under the NSESA that will provide the legislative protection necessary for conserving habitat across the province.

<u>Research to address knowledge gaps</u>

Research activities are primarily designed to provide insight into effectiveness of programs and policies designed to address threats and augment habitat. For example, surveys of Mainland moose Core Habitat are required to confirm moose presence, determine population demographics, and assess quality of habitat, which then feeds back into the review process for refinement of Core Habitat identification and designation, and long-term protection of that habitat.

The Recovery Team is of the opinion that, given the critical nature of the Mainland moose population and ineffectiveness of previous recovery/action plans, almost all of the actions identified in Table 3 should be consider High in terms of their priority. Although a number of actions relating to monitoring and habitat protection have been identified as Very High, province-wide baseline surveys of the current population and distribution of Mainland moose have been identified as an immediate priority by the Recovery Team within the next 2-3 years. This action is among the first steps necessary to support the suite of recovery actions proposed in this plan, inform decisions, and target actions to specific locations and stakeholder groups.

7. RECOMMENDED COURSE OF ACTION(S) FOR RECOVERY

Table 4 provides the recommended course of actions for recovery of the Mainland moose and the timeframe for completing these actions. Note that recovery actions identified in bold are those recommended by the Recovery Team as immediate priorities for recovery of the species, and in some cases are necessary prior to implementation of other actions.

Table 4. Recovery actions and implementation schedule of activities in support of recovery.

Recovery Actions	Implementation Schedule
Habitat Protection, Monitoring, and Stewardship	
Recovery Measure 1.1 Improve habitat connectivity for Mainland moose.	
Action 1.1.1 Designate Core Habitat for Mainland moose localized groups and their movements that have been described using parameters such as habitat suitability and in the case of highways, to minimize collision data.	2021-2023
Action 1.1.2 Protect Mainland moose Core Habitat through designation under provincial and municipal legislation (e.g., protected areas).	2021-2026
Action 1.1.3 Conserve and restore key corridors and linkage areas for the three Mainland moose localized groups within Core Habitat through collaboration with NGOs and landowners, as well as municipal governments and Department of Public Works.	2021-2031
Action 1.1.4 Mitigate barriers/threats related to highways through the use of wildlife underpasses, overpasses, and/or other methods to provide for safe passage in key crossing locations, with an immediate focus on Highway 104 from Amherst-Truro.	2021-2031
Recovery Measure 1.2 Identify and implement conservation mechanisms for buffer zones around Core Habitat.	
Action 1.2.1 Identify buffer areas surrounding Core Habitat for application of land/forest management techniques consistent with supporting moose recovery and maintaining or restoring moose habitat.	2021-2026
Action 1.2.2 Conserve and restore buffer zones.	
Recovery Measure 1.3 Strengthen Special Management Practices for Mainland moose on Crown, public, and private lands.	
Action 1.3.1 Evaluate and revise the current Mainland moose Special Management Practice towards strengthened/more effective measures in the context of the updated Recovery Plan.	2021-2022
Recovery Measure 1.4 Stewardship of Core Habitat and buffer zones on private land.	
Action 1.4.1 Develop an engagement process for stakeholders and Rights holders who may play a role in stewardship of Mainland moose habitat, i.e.,	2021-2026

population restoration project areas and engagement of stakeholder communities.	
Action 1.4.2 Tie management of Mainland moose habitat to incentives and disincentives such as silviculture payments (e.g., defund silvicultural payments for glyphosate spray programs in support of Forest Practices Review recommendation 61 near Mainland moose Core Habitat areas to preserve/enhance browse).	2021-2031
Recovery Measure 1.5 Adopt adaptive management principles and practices to better support Mainland moose population and habitat recovery.	
Action 1.5.1 Initiate/revise landscape-level planning on a spatial and temporal scale to minimize direct and indirect impacts to Mainland moose and their habitat.	2021-2026
Action 1.5.2 Incorporate results of monitoring and research activities into management of Mainland moose recovery actions.	2023-2031
Action 1.5.3 Evaluate and revise forest management practices as part of Mainland moose habitat protection and/or enhancement and align with ecological forestry recommendations from the Lahey forest practices review (i.e., evaluate how forest management guidelines may support, enhance, or hinder habitat protection and enhancement; review and update silviculture strategies for habitat maintenance and restoration/enhancement as appropriate).	2021-2026
Action 1.5.4 Develop a road planning and access management system (including decommissioning) to limit habitat and population fragmentation and degradation/conversion in key Mainland moose concentration areas and to minimize/limit human access for non-approved and/or illegal activities.	2021-2026
Action 1.5.5 Focus management of White-tailed deer within Mainland moose Core Habitat toward minimizing overlap with high deer densities (e.g., increase number of doe tags in Mainland moose Core Habitat in order to reduce parasite and disease transmission).	2021-2031
Action 1.5.6 Provide guidance and training to forestry professionals responsible for timber harvesting and silviculture planning on Mainland moose habitat requirements and objectives.	2021-2031
Recovery Measure 1.6 Ensure Mainland moose habitat is accommodated as part of Lahey forest practices review recommendations.	
Action 1.6.1 Incorporate identification of Mainland moose Core Habitat and buffer zones in delineating areas for the three legs of the triad (Lahey report), as well as management practices associated with each leg (e.g., high production forestry, forest matrix/ecological forestry) and other relevant actions arising from implementing the Lahey recommendations.	**2021-2023**
Surveys and Monitoring	
Recovery Measure 2.1 Health surveillance of Mainland moose.	
Action 2.1.1 Continue Scanning Surveillance Program in collaboration with the Canadian Wildlife Health Centre (CWHC). Continue to deliver all known Mainland moose mortalities to the CWHC at the Atlantic Veterinary College for a complete post mortem examination, an evaluation of known or suspected health threats and collection of tissue or other biological specimens for other health related projects.	2021-2031
Action 2.1.2 Implement Targeted Surveillance Program in collaboration with the CWHC. Develop a plan to assess the current or future impacts of known health threats to the Mainland moose population such as Winter Tick (*Dermacentor albipictus*), parelaphostrongylosis and secondary copper deficiency (i.e. excess dietary molybdenum, iron, zinc and/or sulfur as a contributing cause of antler deformities and the poor reproductive success already documented in the Mainland moose population).	2021-2031

Recovery Measure 2.2 Augment existing knowledge of the distribution and abundance of Mainland moose.	
Action 2.2.1 Develop and implement an intensive province-wide baseline survey to determine numbers of moose and where they are on the landscape (short-term, immediate action separate from subsequent standardized annual surveys) as a critical first step in recovery to guide and direct future activities.	**2021-2024**
Action 2.2.2 Create and implement an annual, structured, systematic approach to monitor Mainland moose in Nova Scotia.	2021-2031
Action 2.2.3 Develop regional/local stewardship through guardian groups, volunteers, and programs to conduct annual and other periodic surveys of sign of moose presence/absence (e.g., forest road-side surveys for prints, pellets, etc.).	2021-2031
Action 2.2.4 Survey and assess wildlife-vehicle collision reports and wildlife incident reports to help identify Mainland moose presence and connectivity areas, moose road crossing points, and areas and amount of road mortality.	2021-2026
Recovery Measure 2.3 Monitor population recovery.	
Action 2.3.1 Develop monitoring strategies to evaluate effectiveness of recovery actions (e.g., monitoring threats).	2021-2023
Communication, Outreach, and Education	
Recovery Measure 3.1 Improved communication on poaching-citizen engagement, enforcement, and reporting.	
Action 3.1.1 Explore opportunities to collaborate and share resources with the Mainland moose Guardians program, and to expand similar programs to other groups/communities across Mainland Nova Scotia.	2021-2026
Action 3.1.2 Evaluate the current anti-poaching campaign in terms of applicability and efficacy and update/strengthen/expand for better protection of Mainland moose.	2021-2026
Recovery Measure 3.2 Improve means of reporting sightings.	
Action 3.3.1 Foster and enhance messaging around the critical importance of reporting sightings of Mainland moose or moose sign. Clearly define, implement/support, and communicate steps for citizens to report sighting without putting Mainland moose at risk of harm.	2021-2031
Recovery Measure 3.3 Information sharing and collaboration with First Nations communities.	
Action 3.3.1 Meaningfully engage with Mi'kmaq communities about collaboration and insights for Mainland moose monitoring, habitat protection, poaching, and priorities for improvement in culturally appropriate ways.	2021-2023
Recovery Measure 3.4 Develop and implement outreach materials and programs for private landowners.	
Action 3.4.1 Develop and distribute/implement outreach materials and programs targeted to private landowners on tools and resources available to support the maintenance/restoration of Mainland moose Core Habitat as well as buffer zones on their land.	2021-2031
Law, Policy, and Enforcement	
Recovery Measure 4.1 Core habitat requirements and considerations.	
Action 4.1.1 Designate Core Habitat under the NSESA.	2021-2023
Action 4.1.2 Consider implications of implementation of policies resulting from Lahey recommendations for Mainland moose Core Habitat and buffer zones (for example, High Production Forestry zones).	2021-2026
Recovery Measure 4.2 Develop policy and management practices for Core Habitat and buffer zones.	
Action 4.2.1 Immediately following release of Recovery Plan, develop management procedures that can be applied to identified Core Habitat on a landscape level.	2021-2023
Recovery Measure 4.3 Incorporate Mainland moose habitat protection and enhancement into the Environment Assessment process and proposed development activities.	

Action 4.3.1 Communicate moose enhancement objectives as government-wide policy and require all authorizing agencies to incorporate them into project review, assessment, and authorization processes.	2021-2031
Recovery Measure 4.4 Statements of provincial interest considerations (under the Municipal Government Act).	
Action 4.4.1 Review and update applicable land use strategies (land use plans, zoning requirements) to enable habitat recruitment where needed – place a high priority on population restoration project areas and engagement of stakeholder communities and Rights holders where possible.	2021-2031
Recovery Measure 4.5 Interdepartmental policy on road and trail moose-vehicle interaction data collection.	
Action 4.5.1 Create stronger linkages between RCMP, Department of Public Works, and Natural Resources and Renewables to support increased knowledge of mortality events, connectivity, and threats, and for siting of roads in planning for future road development.	**2021-2026**
Recovery Measure 4.6 Anti-poaching enforcement.	
Action 4.6.1 Expand/strengthen anti-poaching enforcement, fines, charges (education program for crown prosecutors and judges who determine priority of cases and fines/penalties).	**2021-2026**
Recovery Measure 4.7 Develop/support collaborative arrangements with New Brunswick to address cross-boundary moose recovery initiatives in the broader Chignecto Isthmus region.	
Action 4.7.1 Improve collaborative efforts (e.g., the Priority Places program) to conserve and enhance Mainland moose habitat within the Chignecto Isthmus.	**2021-2031**
Recovery Measure 4.8 Increase documentation and enforcement of SMP compliance on Crown and private land.	
Action 4.8.1 Implement auditing and enforcement to assess and ensure SMP compliance on Crown and private land harvest blocks.	2021-2031
Research to Address Knowledge Gaps	
Recovery Measure 5.1 Investigate the role of climate change in Mainland moose recovery over the near and long term.	
Action 5.1.1 Research impact of climate change on parasites and diseases transmission.	2021-2031
Recovery Measure 5.2 Assess/determine factors influencing spatial distribution, population sizes and demographic characteristics of local remnant groups.	
Action 5.2.1 Allocate resources to undertake on the ground research to help understand factors influencing population sizes and demographic parameters. Distribution/locations and population sizes of remnant groups of moose represent critical knowledge gaps for recovery planning which is a data requirement for recovery planning metrics.	2021-2031
Action 5.2.2 Design and implement a study on calf mortality to determine its causes and whether or not it is a limiting factor in the poor reproductive performance documented in the Mainland moose population.	2021-2031
Action 5.2.3 Investigate the efficacy of changes in management of white-tailed deer within Mainland moose Core Habitat (e.g., increase in doe tags with the goal of reducing the deer population, and hence, *P. tenuis*).	2021-2031
Recovery Measure 5.3 Assess threats within Mainland moose Core Habitat.	
Action 5.3.1 Evaluate direct and indirect effects of threats (e.g., roads (paved, unpaved, trails), incompatible silviculture prescriptions, glyphosate, mining) on Mainland moose distribution, movement and exposure to poaching and deer incursion.	2021-2031
Recovery Measure 5.4 Assess Mainland moose habitat quality to inform habitat protection, management, and enhancement.	
Action 5.4.1 Develop parameters to assess habitat quality/effectiveness within Mainland moose Core Habitat. This may include, for example,	2023-2026

composition of thermal refugia, browse species amount and composition, density of road networks, and abundance of deer.	
Action 5.4.2 Evaluate Mainland moose Core Habitat using previously developed habitat assessment parameters.	2026-2031

8. IDENTIFICATION OF CORE HABITAT

Under the Nova Scotia Endangered Species Act, Core Habitat means specific areas of habitat essential for the long-term survival and recovery of endangered or threatened species and that are designated as core habitat pursuant to Section 16 or identified in an order made pursuant to Section 18.

8.1. Core Habitat Identification

Mainland moose have complex spatial and temporal habitat requirements that include a mosaic of woodland and wetland habitat types that provide food, shelter, and appropriate thermal regulatory conditions. Specific spatial and temporal habitat preferences and limiting factors are poorly documented for Mainland moose. However, the literature review by Snaith and Beazley (2004) on spatial and site use by moose with a focus on Nova Scotia can be referred to for background information.

The intent is to not define Core Habitat based only upon the current distribution of Mainland moose, but rather upon those conditions most likely to secure habitat and connectivity requirements that are spatially appropriate to recover a viable population from one that is currently small, declining, and fragmented. Core Habitat was identified using a Habitat Suitability Index (HSI) model developed by Allen et al. (1987) and modified for use in Nova Scotia by Snaith et al. (2002), with further refinement to incorporate current knowledge and expertise of Recovery Team members. The HSI model employed a 10 km by 10 km analytical roving window approach to assess relative suitability of habitat which is then converted to 5 km by 5 km display units. The choice of a 10 km by 10 km hexagon was based upon assumptions of the home range size for moose and what was an appropriate scale for assessment of habitat requirements using previous work by Allen et al. 1987, Snaith et al. 2002, and additional studies referenced by these papers. HSI values were combined with road density to develop a ranking system for habitat suitability for Mainland moose (Figure 3). A more detailed description of the equations, parameters, and inputs used to identify Core Habitat is provided in Appendix A.

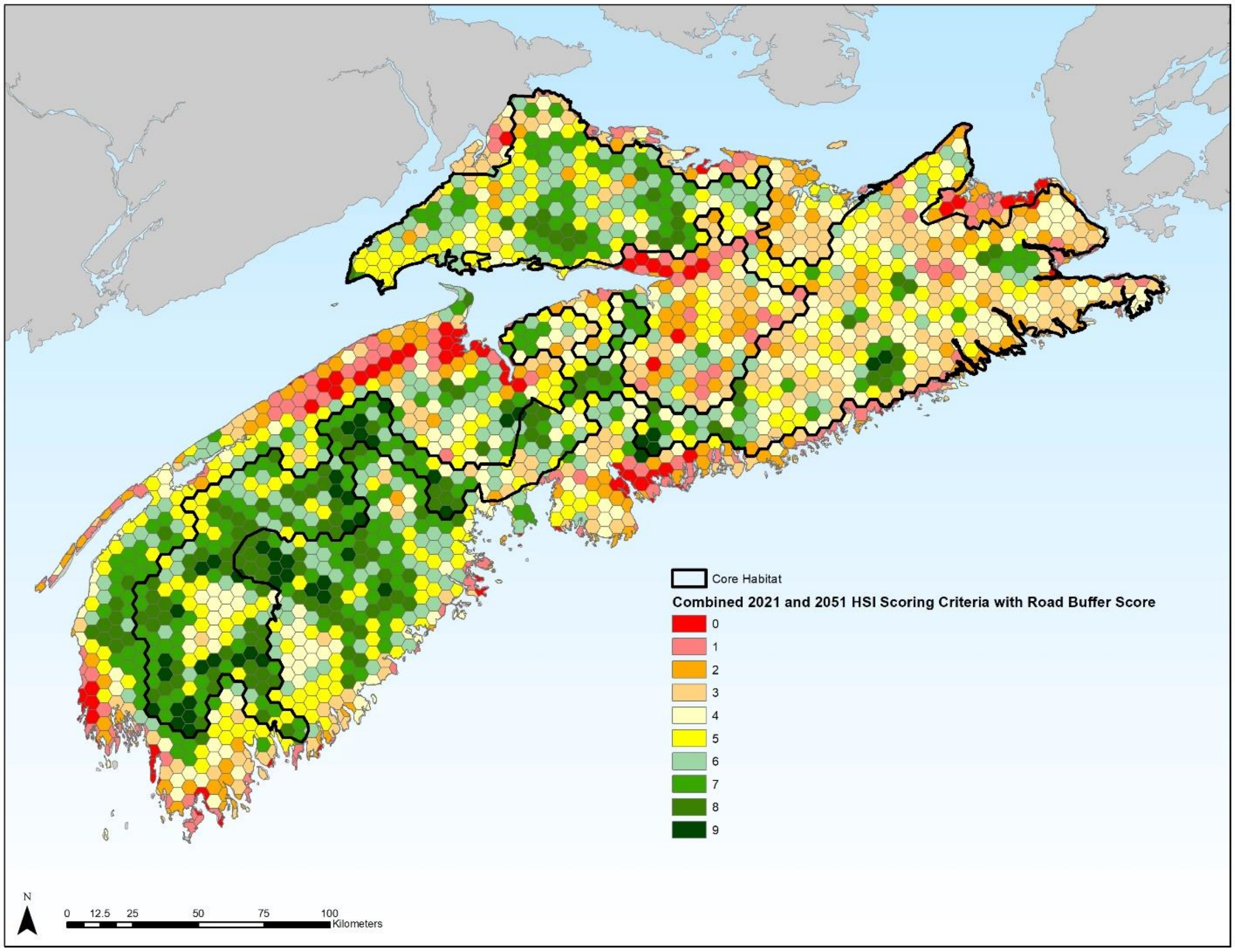

Figure 3. HSI model and road density scores (ranked least suitable (0) to most suitable (9)).

For recovery of Mainland moose, Core Habitat has been identified as those areas within the mapped region (Figure 4) that:

- Currently contain biophysical attributes that provide for life cycle requirements of Mainland moose.
- Are expected or likely to contain biophysical attributes that provide for life cycle requirements of Mainland moose over the next 30 years (to 2051).

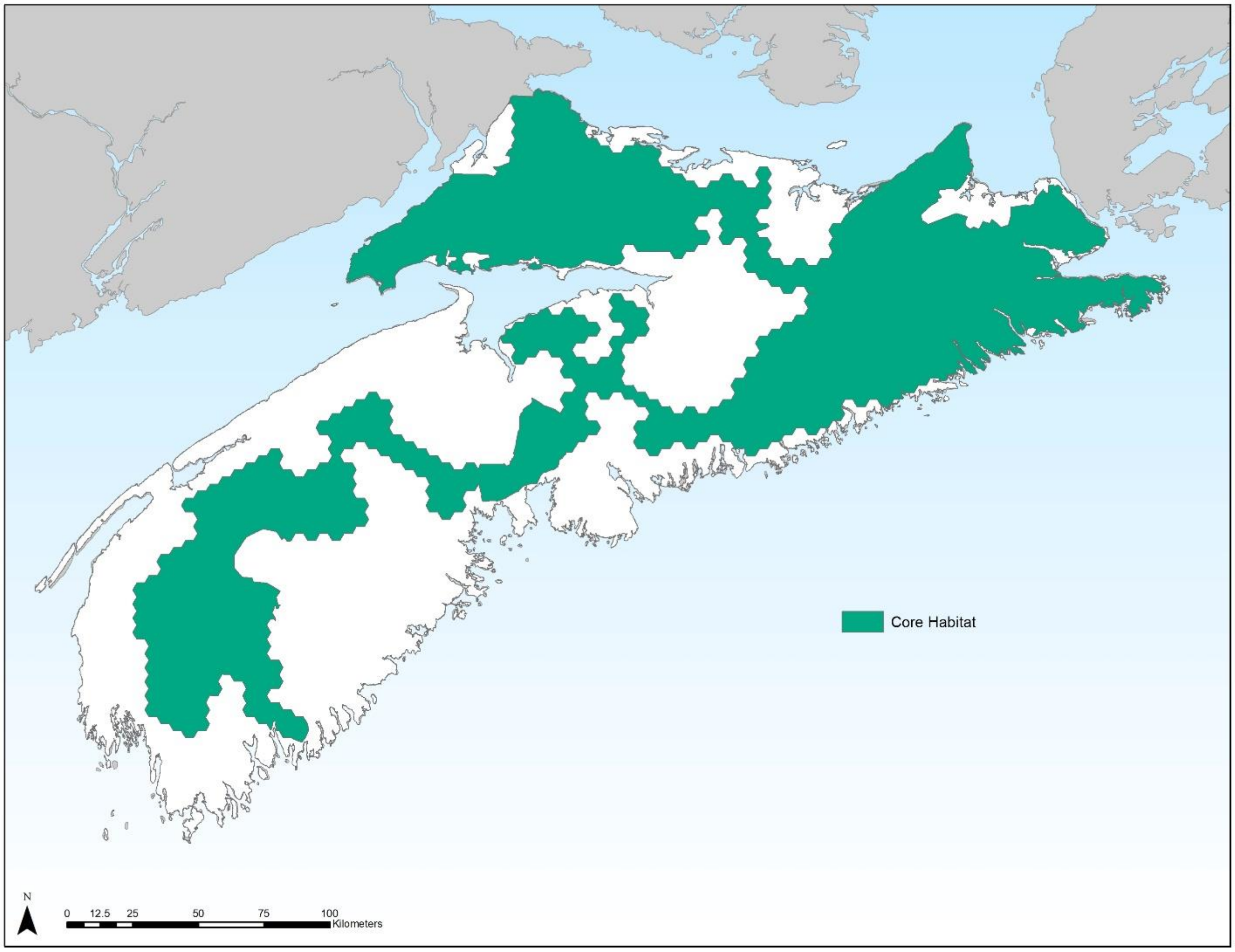

Figure 4. Core Habitat for Mainland moose in Nova Scotia.

Core Habitat has been identified for each of the three localized subgroups (Cumberland/Colchester, Pictou/Antigonish/Guysborough, and Tobeatic) that is necessary to support population and distribution objectives for viable population size (Table 5). Corridors are also required between these areas to support the movement of migrants and to reduce or prevent inbreeding depression. Within Core Habitat, areas of high HSI scores combined with low road density have been identified as important areas for priority focus of protection and management (combined HSI and road density scores of 4-9, Figure 5).

Table 5. Amount of Core Habitat with respect to localized group and connectivity.

Localized Group or Area of Province	**Amount of Core Habitat (km^2)**	**Priority Area Within Core Habitat* (km^2)**	**Amount Required to Meet Recovery Objectives (km^2)**
Cumberland/Colchester	5,130.09	1,938.51	0.3-0.35 moose/km^2; breeding population 250 animals; total population ~1850-2000 animals; Area = ~ 5300 km^2.
Pictou/Antigonish/Guysborough	6,348.77	2,280.76	0.20-0.25 moose/km^2; breeding population 200 animals; total population ~1400-1500 animals; Area = ~ 6300 km^2.
Tobeatic	1,913.66	1,382.87	0.15-0.20 moose/km^2; breeding population 50 animals; total population ~300- 500 animals; Area = ~ 2000 km^2.
Remainder of Mainland Nova Scotia (including connectivity needs)**	8,934.22	4,901.28	0.05-0.10 moose/km^2; total population ~500-1000 animals.
Total	22,326.77	10,503.42	

* Refers to the areas of importance for connectivity within and between localized groups that meet minimum threshold HSI scores and road density criteria for 2021-2051.

** Area required throughout Mainland Nova Scotia provides for both animals that reside outside of the localized groups as well connectivity necessary for travel between localized groups.

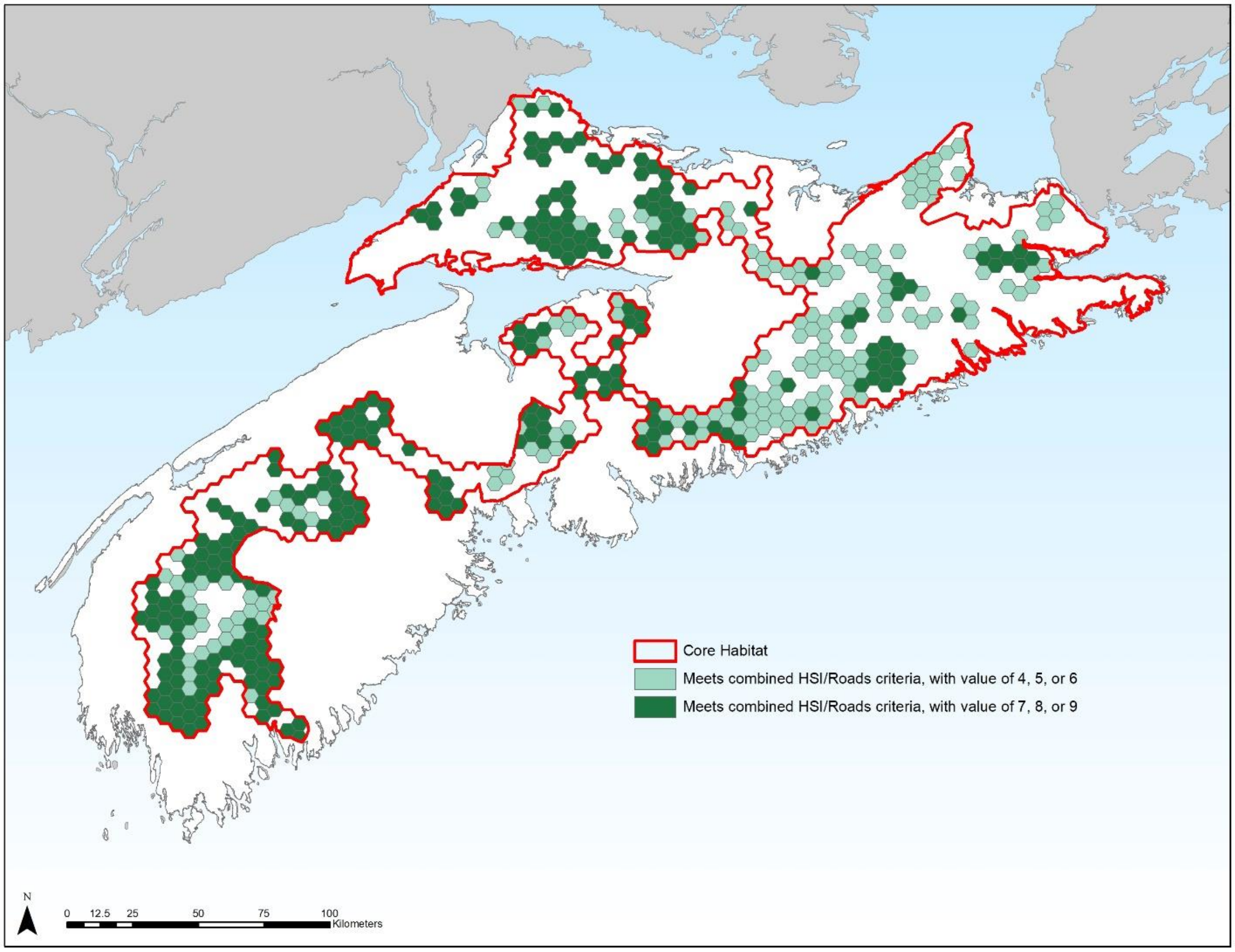

Figure 5. Areas with combined HSI and road density scores of 4-9 (least to most suitable) within Core Habitat.

Core Habitat as identified in this plan is considered essential for the long-term survival and recovery of Mainland moose. Each area of Core Habitat must meet the seasonal needs of Mainland moose, particularly for summer, winter, and calving requirements. Based upon the current year forest inventory and the projected 30-year inventory, there is insufficient suitable habitat available to support the populations necessary to achieve recovery objectives for the two eastern mainland localized groups. Therefore, the focus of management in these regions is twofold: to maintain existing identified high-quality habitat as well as enhancing habitat suitability in the remainder of the Core Habitat with the goal of improving future HSI rankings.

Core Habitat was mapped against Crown land and parks and protected areas (both current as well as pending or proposed) (Figure 6). Roughly 66% of the area identified as Core Habitat is Crown land or parks and protected area (14,708.85 km^2).

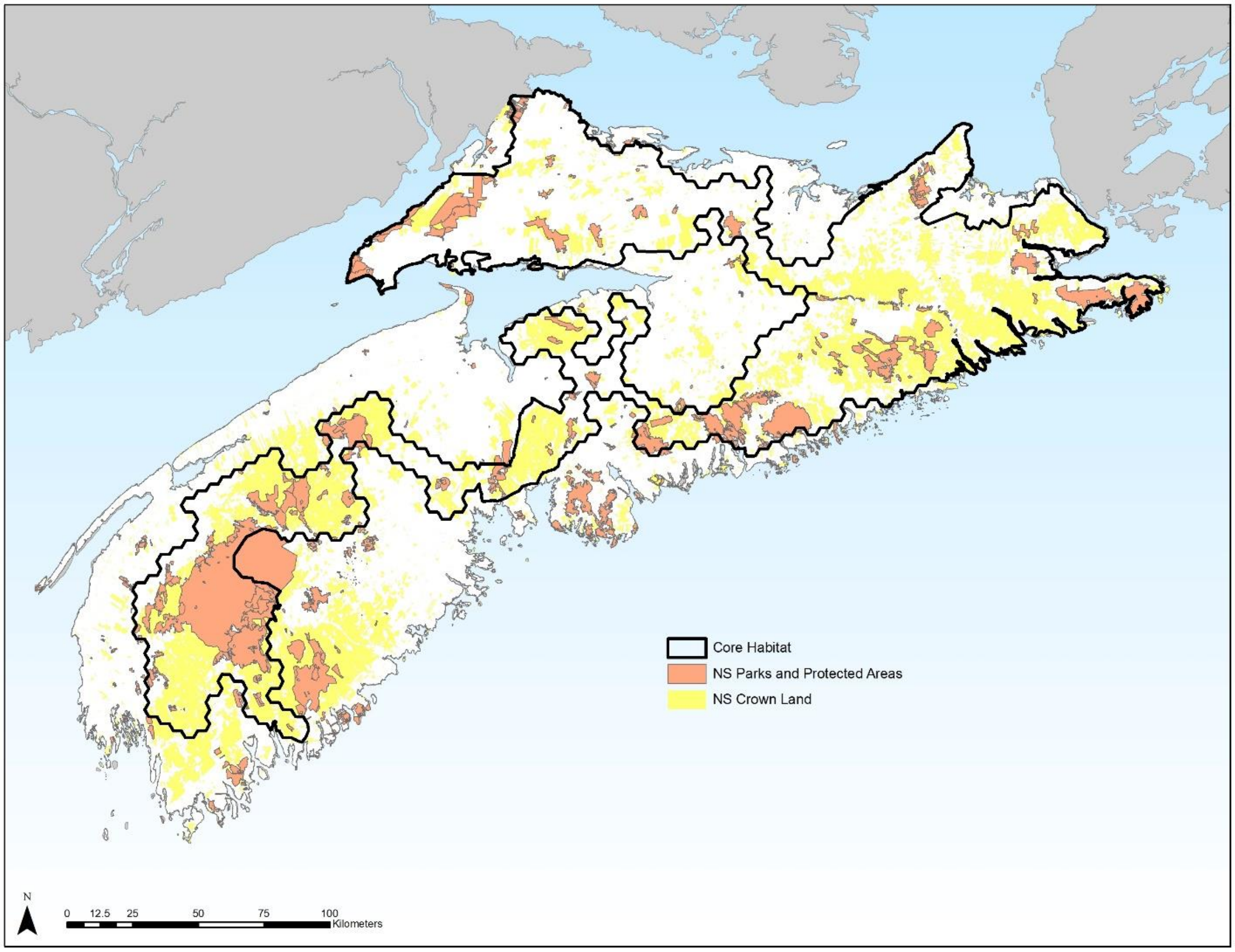

Figure 6. Crown land and parks and protected areas in Nova Scotia within Core Habitat.

A 100 m buffer surrounding Core Habitat has been identified as a transition zone which will be used to support and maintain the continued function of Core Habitat. The approach to management and allowable activities within the buffer zone will be not as restrictive as those within Core Habitat but will be designed to support the functionality of Core Habitat. A width of 100 m was chosen as there is no consensus within peer-reviewed science to support what would be considered an appropriate buffer width to maintain the integrity and function of Core Habitat. Further research to refine buffer width requirements is required.

Core Habitat has been identified using the best available knowledge of the species and its habitat requirements. However, as with any exercise of this nature, limitations exist with respect to knowledge gaps, available data, and available habitat suitability models. It is recognized that identification of Core Habitat is an iterative process and will be refined when new information becomes available.

8.2. Attributes of Core Habitat

Recognizing that habitat requirements and habitat quality for Mainland moose in Nova Scotia have not been well documented, it was necessary to draw from studies elsewhere in the Acadian forest (i.e., New Brunswick and northern Maine). At all times of the year, adequate cover adjacent to available browse (with browse being less than 200m from cover) accommodates daily movement patterns balancing nutritional needs with resting and cover requirements. Anthropogenic areas are not considered part of Core Habitat as they would not meet biophysical requirements. Examples of areas which would be considered unsuitable habitat include: urban areas (e.g., towns or cities); housing and associated managed areas; agricultural fields; industrial infrastructure; and, transportation corridors.

The biophysical parameters for Mainland moose Core Habitat that were used in the HSI equation, and how they differed from previous equations, are described in Table 6. Full details on stand definition criteria for winter and summer cover are provided in Appendix A.

Table 6. Habitat parameters as provided by Allen et al. (1987), Snaith et al. (2002), and those used for the identification of Core Habitat.

Habitat Component	Allen et al. 1987	Snaith et al. 2002	Nova Scotia Core Habitat Parameters
Summer Forage Area (S1A)	40% to 50% of area is composed of shrub or forested cover type less than 20 years old.	40% to 50% of area in any forested type less than 20 years old.	20% to 40% of area in any regenerating forested type within 200 m of cover (summer or winter), or mature mixedwood or tolerant/intolerant hardwood.
Winter Forage Area (S1B)			15% to 20% of area in any regenerating forested type, or mixedwood or tolerant/intolerant hardwood within 200 m of winter cover, or softwood dominated mixedwood.
Winter Cover (S2)	5% to 15% of area composed of spruce/fir greater than 20 years old.	5% to 15% of area in softwood greater than 20 years old.	10% to 20% of area in softwood or softwood dominated mixedwood stands that meet mature cover requirements.
Summer cover (S3)	35% to 55% of the area is composed of upland deciduous or mixed forest greater than 20 years old.	35% to 55% of area in deciduous or mixedwood greater than 20 years old.	35% to 55% of area in deciduous or mixedwood or conifer stands that meet mature cover requirements.
Calving Area (S4)	5% to 10% of the areas in wetlands not dominated by woody vegetation.	5% to 10% of area in wetlands not dominated by woody vegetation.	5% to 10% of area in open water or wetlands that meet adjacency requirements for cover and forage.

The following provides descriptions used for defining Mainland moose Core Habitat biophysical parameters:

Summer forage (S1A):

1) Mature: same stand definition criteria as mature summer cover (S3), but no minimum size
2) Or regenerating forest of any type adjacent to summer (S3) winter cover (S2) with a regenerating forest age of 3 to 15 years
3) Only area within 200 m of mature forest cover
4) No minimum size for the summer forage stands
5) Mature stands for forage do not have a minimum distance requirement from cover

Winter forage (S1B):

1) Same stand definition criteria as mature winter cover, but no minimum size

Forage must be immediately adjacent to mature softwood cover: only the area of the stand within 200 m of cover.

2) Or regenerating hardwood, mixedwood, and conifer stands adjacent to mature conifer cover with a regenerating forest age of 3 to 15 years.
3) Only area within 200 m of mature forest cover.

Winter cover (S2):

Mature softwood and softwood dominated mixedwood with the following attributes:

- Crown closure >= 60%
- Height >= 12 m or >= 8 m with a depth to water table <= 50 cm
- Minimum stand size = 5 ha

Summer cover (S3):

Mature softwood, mixedwood, or hardwood with the following attributes:

- Crown closure >= 60%
- Height >= 12 m or >= 8 m with a depth to water table <= 50 cm
- Minimum stand size = 5 ha

Calving area (S4):

- Open water immediately adjacent to mature cover (S2 or S3) or open water immediately adjacent to regen forage that is within 200 m of mature cover (S2 or S3) or open water immediately adjacent to mature forage.

8.3. Activities Likely to Result in the Destruction of Core Habitat

The destruction of Core Habitat refers to any activity that degrades habitat, either temporarily or permanently, to an extent that it becomes unsuitable for a species needs. What constitutes destruction of Core Habitat may be complex or not readily understandable, such as the cumulative effects of multiple activities over time. It should be noted that not all activities may have been captured in Table 6, and that the list of activities may evolve over time with increased understanding of both Mainland moose and Core Habitat requirements.

Table 7. Activities which may result in the destruction of Core Habitat.

Description of Activity	Rationale
Silviculture practices that do not provide the spatial and temporal habitat requirements of winter and summer cover, access to forage, and protection from disturbance. This is dependent on scale of activity; localized harvesting may benefit by increasing available browse in conjunction with maintaining cover, while large-scale overstorey removal would be detrimental to habitat needs of the species.	Loss of mature vegetative cover and canopy closure increases thermal stress in the winter and summer months. Habitat conversion increases risk of brainworm and winter tick through creation of favourable habitat conditions for White-tailed deer. Disturbance from light, noise, and vehicle pollution as well as forestry effluents increases stress and habitat avoidance. Secondary effects from forest roads and extraction trails include habitat fragmentation, degradation, recreational activities, and poaching.
Vegetation management (glyphosate spraying).	Loss of naturally regenerated and deciduous browse near forest cover will make an area unsuitable as forage and reduce overall suitability of habitat to meet species' needs.
Mineral and aggregate extraction and removal.	Habitat conversion resulting in permanent loss of vegetative cover and loss of area used by moose. Habitat conversion increases risk of brainworm and winter tick through creation of favourable habitat conditions for White-tailed deer. Disturbance from light, noise, and vehicle pollution. Risk of industrial effluent pollution. Secondary effects from use of roads and clearing activities for exploration include habitat fragmentation, degradation, recreational activities, and poaching.
Road construction, which includes any classification or type of road or trail. This would not include existing roads or road maintenance unless maintenance has an impact on the biophysical parameters. Road upgrades could be considered an activity that results in destruction of Core Habitat if there is an increase in the footprint of the road or an increase in traffic.	Linear access results in habitat loss and fragmentation. Behavourial changes vary with the type of road or trail but include increases in range size and differences in movement patterns. Direct mortality events occur due to moose-vehicle interactions. Light, noise, and vehicle pollution increase stress. Increased opportunities for recreational activities and poaching lead to losses. Incursion into previously inaccessible areas increases potential for development (residential, commercial, and industrial).
Commercial and/or residential development.	Habitat conversion resulting in permanent loss of vegetative cover and loss of area used by moose. Increased habitat fragmentation. Secondary effects include mortality from increased traffic, pollution

	(commercial, residential, and vehicle), as well as disturbance from light, noise, and human activity.

9. MEASURING PROGRESS

9.1. Performance Indicators

The performance indicators identified below are a means by which progress towards population and distribution objectives can be measured. Progress will be monitored and reported on during the 5-year review process of the Recovery Plan. Performance will be assessed through the completion of actions identified under Table 5 of Section 7, *Recommended Course of Action(s) for Recovery*.

Short-term (5 years):

- Threats to Mainland moose have been reduced;
- Policies and guidance identified within the recovery actions have been developed and implemented;
- Core Habitat has been designated and measures to protect Core Habitat have been applied;
- Baseline surveys to establish current levels of distribution and abundance have been completed;
- Mainland moose abundance is stable or increasing (within the three localized groups).

Long-term (20+ years):

- Census populations, numbers of breeding individuals, and calf survivorship has increased by at least 10% in each of the 3 localized groups;
- Connectivity between subgroups has increased on the landscape, supporting an exchange of individuals and gene flow;
- Three localized groups are increasing in abundance and distribution higher than the short-term population and distribution objective, towards achieving the viable status for recovery (5000 individuals with a minimum 500 breeding individuals distributed through the three localized groups);

9.2. Monitoring

Three monitoring approaches are required: demographics (population and distribution); threats; and, habitat assessment.

Demographics:

Monitoring will be required to assess whether population and distribution objectives are met and should be designed towards achieving this goal. Systematic, standardized surveys to monitor the population of Mainland moose will be established following analysis of baseline surveys to provide up-to-date estimates of abundance and distribution, and should include, at a minimum, the following:

- GPS locations (to georeferenced distribution and correlate with GIS mapping layers for habitat);
- Habitat conditions relating to key factors such as forage and cover;
- Proximity to threats (such as road networks or abundance of White-tailed deer);
- Weather, temperature, cloud cover, and other environmental conditions at the time of survey;
- Age and sex;
- General condition (weight, signs of brainworm, presence of ticks).

It is likely not a necessity to resurvey regions in consecutive years; rather, a rotational schedule of different regions every 2-3 years is likely sufficient to capture trends in abundance.

Threats:

Threats monitoring focuses on those threats where it is possible to quantify the impact of threat reduction. For example, where white-tailed deer management is determined to be required in areas of Core Habitat, a measure of success of the action would be to: conduct surveys to evaluate if there is a reduction of the white-tailed deer populations in the identified areas over time; review harvest reports and hunter success rates in management zones and determine if quotas have been met; or demonstrate declines in mortality of moose related to brainworm and/or winter tick. Surveys may be opportunistically conducted at the same time as other surveys. For other threats, monitoring may be a desktop exercise; for example, the review of Environmental Assessments over several years to determine how projects incorporated Mainland Moose recovery planning requirements into their applications.

Habitat changes may be monitored through desktop assessments of land cover and land use, linking both negative and positive impacts on habitat suitability, amount, and connectivity. In this way, changes to land cover and land use that benefit moose may be better understood, along with those that convert, degrade or fragment habitat.

Two actions currently support assessment of threats to health of moose: Scanning Surveillance Program and the Targeted Surveillance Program, both delivered in collaboration with the Canadian Wildlife Health Centre (CWHC). Results from these programs can be used in monitoring and evaluation of threats relating to brainworm, winter tick, and secondary copper deficiency.

Habitat:

Assessment of habitat components will be developed to confirm and refine the parameters used in the identification of Core Habitat. Field assessments of these components will be used in an iterative process to evaluate and refine parameters for Core Habitat identification, delineation, and designation. Field survey requirements should capture, at a minimum:

- Tree species composition;
- Height, crown closure, stem density;
- Composition and density of understorey browse species (foraging);
- Mainland moose sign (observations, tracks, pellets);
- Deer activity and sign (observations, tracks, pellets);
- Proximity to threats (such as roads, trails, development, or forest harvests);
- Condition of the parcel surveyed (health of trees, threat incursions);
- Location, size, and shape (georeferenced) of the surveyed parcel.

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APPENDICES

APPENDIX A. MAINLAND MOOSE CORE HABITAT PROCESS

Under the Nova Scotia Endangered Species Act, Core Habitat means specific areas of habitat essential for the long-term survival and recovery of endangered or threatened species and that are designated as core habitat pursuant to Section 16 or identified in an order made pursuant to Section 18.

Habitat Suitability Index (HSI) Equation and Parameters

It was decided by the Mainland moose Recovery Team to use the Habitat Suitability Index (HSI) model and a roving window technique developed by Allen et al. (1987) as the first step of defining Core Habitat. The model developed by Allen et al. (1987) was designed in the context of integrated resource planning and could be used as a tool to identify impacts to habitat or measures to enhance habitat quality. The model assumes that in the absence of factors affecting mortality (such as *P. tenuis*), populations that have an abundant food source of sufficient quality interspersed with a suitable quality and quantity of thermal cover have the potential to stabilize or increase at a high density. Although originally applicable only to moose populations of the Great Lakes region, Snaith et al. (2002) modified the model parameters to assess habitat suitability for Mainland Nova Scotia. A member of the Recovery Team, Dr. Karen Beazley, was a co-author of this study. The HSI model is a means of ranking suitability of habitat using required biophysical components necessary for optimal habitat; however, it is limited in that it cannot account for special features such as mineral licks, or mortality issues such as land use practices or poaching (Snaith et al. 2002).

HSI Equation, Values, and Roving Window Technique

<u>HSI equation and suitability index values:</u>

Snaith et al. (2002) proposed six different equations to calculate HSI values for moose in Nova Scotia. Results of their models suggested that the most reliable index of habitat quality were those equations which excluded wetlands while also addressing road density. The Recovery Team evaluated the suitability of the equation parameters against biological requirements of Mainland moose and concluded that wetlands fulfill an important calving need for the species. Based upon expert knowledge and best available science, the Team decided on the following equation and parameters:

$$HSI = (S1A*S1B*S2*S3*S4)^{1/5}$$

Where:

- S1A = percent of summer forage area
- S1B = percent of winter forage area
- S2 = percent of winter cover
- S3 = percent of summer cover
- S4 = percent of calving area

Table 1. Habitat parameters as provided by Allen et al. (1987), Snaith et al. (2002), and those used for the identification of Core Habitat.

Habitat Component	Allen et al. 1987	Snaith et al. 2002	Nova Scotia Core Habitat Parameters
Summer Forage Area (S1A)	40% to 50% of area is composed of shrub or forested cover type less than 20 years old.	40% to 50% of area in any forested type less than 20 years old.	20% to 40% of area in any regenerating forested type within 200 m of cover (summer or winter), or mature mixedwood or tolerant/intolerant hardwood.
Winter Forage Area (S1B)			15% to 20% of area in any regenerating forested type or mixedwood or tolerant/intolerant hardwood within 200 m of winter cover, or softwood dominated mixedwood.
Winter Cover (S2)	5% to 15% of area composed of spruce/fir greater than 20 years old.	5% to 15% of area in softwood greater than 20 years old.	10% to 20% of area in softwood or softwood dominated mixedwood stands that meet mature cover requirements.
Summer cover (S3)	35% to 55% of the area is composed of upland deciduous or mixed forest greater than 20 years old.	35% to 55% of area in deciduous or mixedwood greater than 20 years old.	35% to 55% of area in deciduous or mixedwood or conifer stands that meet mature cover requirements.
Calving Area (S4)	5% to 10% of the areas in wetlands not dominated by woody vegetation.	5% to 10% of area in wetlands not dominated by woody vegetation.	5% to 10% of area in open water or wetlands that meet adjacency requirements for cover and forage.

The following provides descriptions used for defining Mainland moose Core Habitat biophysical parameters:

Summer forage (S1A):

6) Mature: same criteria as mature cover, but no minimum size

HIHw	A hardwood stand dominated by intolerant hardwood tree species.
HITHw	A hardwood stand containing a mix of tolerant and intolerant hardwood tree species.
HTHw	A hardwood stand dominated by tolerant hardwood tree species.
MIHwHS	A mixedwood stand where the hardwood component is dominated by intolerant hardwood tree species and the hardwood component is greater than the softwood.
MIHwSH	A mixedwood stand where the hardwood component is dominated by intolerant hardwood tree species and the softwood component is greater than the hardwood.
MTHw	A mixedwood stand where the hardwood component is dominated by tolerant hardwood tree species.

7) Or regenerating forest of any type adjacent to summer or winter cover:
    - Curr_Age = 3 to 15 (This is the grown age based on airphoto date)
    - Only area within 200 m of Mature Forest cover (has to be within 40 m of stand, but only including outer 200 m of stand)

8) No minimum size for the summer forage stands

9) Mature stands for forage do not have a minimum distance requirement from cover

Winter forage (S1B):

4) Mature: same criteria as mature cover, but no minimum size

HIHw	A hardwood stand dominated by intolerant hardwood tree species.
HITHw	A hardwood stand containing a mix of tolerant and intolerant hardwood tree species.
HTHw	A hardwood stand dominated by tolerant hardwood tree species.
MIHwHS	A mixedwood stand where the hardwood component is dominated by intolerant hardwood tree species and the hardwood component is greater than the softwood.
MTHw	A mixedwood stand where the hardwood component is dominated by tolerant hardwood tree species.

Forage must be immediately adjacent to mature softwood cover: only the area of the stand within 200 m of cover. Immediately adjacent was interpreted to mean ≤ 40 m (minimum width of streamside Special Management Zone - 20 m each side of stream).

5) Or regenerating hardwood, mixedwood, and conifer stands adjacent to mature conifer cover:
    - Curr_Age = 3 to 15 (This is the grown age based on airphoto date)
    - Only area within 200 m of mature forest cover (has to be within 40 m of stand, but only including outer 200 m of stand).

6) Or mature: same criteria as mature cover, but no minimum size

MIHwSH	A mixedwood stand where the hardwood component is dominated by intolerant hardwood tree species and the softwood component is greater than the hardwood.

Winter cover (S2):

Mature softwood and softwood dominated mixedwood:

SbFDom	A softwood stand dominated by balsam fir.
SbSPL	Softwood - planted black spruce.
SExPL	Softwood - planted exotic species.
SMHePiSp	A softwood stand dominated by a combination of hemlock, pine and spruce tree species.
SPiDom	A softwood stand dominated by pine tree species.

SrSbSDom	A softwood stand dominated by either red spruce, black spruce or a combination of the two tree species.
SrSPL	Softwood – planted red spruce.
SSpbFDom	A softwood stand dominated by a combination of the balsam fir and spruce tree species.
SwPPL	Softwood - planted white pine.
SwSDom	A softwood stand dominated by either white spruce, or other non-native softwood tree species.
SwSPL	Softwood - planted white spruce.
MIHwSH	A mixedwood stand where the hardwood component is dominated by intolerant hardwood tree species and the softwood component is greater than the hardwood.

Mature winter cover requirements:

- Crown closure >= 60%
- Height >= 12 m **or** >= 8 m with a depth to water table <= 50 cm
- Minimum stand size = 5 ha

Summer cover (S3):

Mature hardwood and mixedwood:

HIHw	A hardwood stand dominated by intolerant hardwood tree species.
HITHw	A hardwood stand containing a mix of tolerant and intolerant hardwood tree species.
HTHw	A hardwood stand dominated by tolerant hardwood tree species.
MIHwHS	A mixedwood stand where the hardwood component is dominated by intolerant hardwood tree species and the hardwood component is greater than the softwood.
MIHwSH	A mixedwood stand where the hardwood component is dominated by intolerant hardwood tree species and the softwood component is greater than the hardwood.
MTHw	A mixedwood stand where the hardwood component is dominated by tolerant hardwood tree species.

Mature softwood:

SbFDom	A softwood stand dominated by balsam fir.
SbSPL	Softwood - planted black spruce.
SExPL	Softwood - planted exotic species.
SMHePiSp	A softwood stand dominated by a combination of hemlock, pine and spruce tree species.
SPiDom	A softwood stand dominated by pine tree species.
SrSbSDom	A softwood stand dominated by either red spruce, black spruce or a combination of the two tree species.
SrSPL	Softwood – planted red spruce.
SSpbFDom	A softwood stand dominated by a combination of the balsam fir and spruce tree species.
SwPPL	Softwood - planted white pine.
SwSDom	A softwood stand dominated by either white spruce, or other non-native softwood tree species.
SwSPL	Softwood - planted white spruce.

Mature requirements:

- Crown closure >= 60%
- Height >= 12 m **or** >= 8 m with a depth to water table <= 50 cm
- Minimum stand size = 5 ha

Calving area (S4):

- Open water immediately adjacent to mature cover (S2 or S3) **or** open water immediately adjacent to regen forage that is within 200 m of mature cover (S2 or S3) **or** open water immediately adjacent to mature forage.
- Open water is fornon = 75 or 25 m of lake edge (fornon = 77)

Immediately adjacent = within 40 m

Suitability Index values were derived for each habitat component using information in Table 1 and based on previously developed predicted habitat suitability curves provided in Snaith et al. (2002). The HSI was calculated for each analytical unit as follows:

0 - 0.199 = 1 = Not Suitable
0.2 - 0.399 = 2 = Poor Suitability
0.4 - 0.599 = 3 = Fair Suitability
0.6 - 0.799 = 4 = Good Suitability
0.8 – 1.0 = 5 = Very Good Suitability

Roving window:

HSI models were developed at the following scales:

- 10 km by 10 km square
- 5 km by 5 km square
- 10 km by 10 km hexagon
- 10 km by 10 km hexagon

The Recovery Team ultimately selected 10 km by 10 km hexagons for the HSI roving window analysis for identifying Core Habitat, based upon assumptions of the home range size for moose and what was an appropriate scale for assessment of habitat requirements using previous work by Allen et al. 1987, Snaith et al. 2002, and additional studies referenced by these papers.

It should be noted that the hexagons do not have exact dimensions of 10 km by 10 km, but the area contained within them is the same as the roving window using 10 km by 10 km squares – 10,000 ha.

The roving window technique was developed by Duinker et al. (1991, 1993) and was employed by Snaith et al. (2002) in their Habitat Suitability Analysis for moose. Each 10 km x 10 km window overlaps the next by half, in both directions (north-south and east-west). The values generated are for the window/analytical unit (5 x 5 or 10 x 10) in that location. The HSI values for each of these windows/analytical units are displayed in mapped results; and because they overlap by half, the display units are ¼ of the size of the analytical units (i.e. 5 km x 5 km display unit for 10 km x 10 km analytical unit/window). Although the values are displayed at a finer resolution, they are based on the value of the larger analytical unit. According to Snaith et al. (2002), the roving window technique ”allows each stand to contribute to the HSI calculation several times, provides a more realistic representation of habitat heterogeneity, and accounts for the possibility that moose ranges overlap the boundaries of evaluation units.”

The 10 km by 10 km hexagon roving window using the HSI equation and suitability index values was applied to both the current (2021) and 30 year projected (2051) forest inventory. It should be noted that the 2051 forest inventory was developed in the absence of either natural disturbance or harvest.

Identified Core Habitat

<u>Inputs into Core Habitat Decision Process:</u>

Combining 2021 HSI and 2051 HSI:

A scoring system of 0-5 was developed by the Recovery Team for combined 2021 and 2051 HSI scores, with 0 being considered the least suitable habitat over the next 30 years and 5 being the best suitable habitat over the next 30 years (Table 2).

Table 2. Point scoring for combined 2021and 2051 HSI values for 10 km by 10 km hexagons.

HSI Value	Point Score
HSI_2021 = 4 and HSI_2051 = 4 (constant)	4
HSI_2021 = 5 and HSI_2051 = 5 (constant)	5
HSI_2021 = 4 and HSI_2051 = 5 (improving)	4
HSI_2021 = 5 and HSI_2051 = 4 (deteriorating)	3
HSI_2021 = 4 and HSI_2051 = 3 (deteriorating)	1
HSI_2021 = 5 and HSI_2051 = 3 (deteriorating)	1
HSI_2021 = 3 and HSI_2051 = 3 (constant)	2
HSI_2021 = 3 and HSI_2051 = 4 (improving)	2
HSI_2021 = 3 and HSI_2051 = 5 (improving)	3
HSI_2021 = 1 or 2 and HSI_2051 = 1 or 2 (constant)	0

Road Influence:

Roads were buffered for disturbance according to road type (Table 3). Each 10 km by 10 km hexagon cell was provided a point score based upon percentage of the cell occupied by roads and associated buffers (Table 4).

Table 3. Disturbance buffers by road type.

Description	Class	Estimated Vehicles/Day	Buffer (m)
TRACK	1	0	0
TRACK - Indefinite/Approximate	1	0	0
TRACK - Addressed Feature - No Vehicular Traffic	1	0	0
TRACK - Addressed Feature - Indefinite/Approximate - No Vehicular Traffic	1	0	0
TRAIL - No Vehicular Traffic - No Vehicular Traffic	1	0	0
TRAIL - Indefinite/Approximate - No Vehicular Traffic	1	0	0
TRAIL - Addressed Feature - No Vehicular Traffic	1	0	0
TRAIL - Addressed Feature - Indefinite/Approximate - No Vehicular Traffic	1	0	0
RAILROAD ruin/inactive/abandoned	1	0	0
ROAD - Abandoned - Dry Weather - 1 Lane - Unpaved	1	0	0
ROAD - Abandoned - Local - 1 Lane - Unpaved	1	0	0
ROAD - Abandoned - TRACK	1	0	0
ROAD - Abandoned - 1 Lane - Unpaved	1	0	0
RAILROAD line	1	0	0
RAILROAD under construction	1	0	0
RAILROAD overhead	1	0	0
RAILROAD TURNTABLE point	1	0	0
ROAD - Resource Access - Dry Weather - 2 Lanes - Unpaved	2	<10	250
ROAD - Resource Access - Dry Weather - 1 Lane - Unpaved	2	<10	250
ROAD - Resource Access - 2 Lanes – Paved	2	<10	250
ROAD - Resource Access - 2 Lanes - Unpaved	2	<10	250
ROAD - Resource Access -1 Lane – Paved	2	<10	250
ROAD - Resource Access - 1 Lane - Unpaved	2	<10	250
ROAD - Local - Driveway - 1 Lane - Unpaved	2	<10	250
ROAD - Local - Divided - 1 Lane - Paved - Low speed thoroughfare - access to properties	3	10-100	250

ROAD - Local - Dry Weather - 1 Lane - Unpaved - Low speed thoroughfare - access to properties	3	10-100	250
ROAD - Local - 2 Lanes - Unpaved - Low speed thoroughfare - access to properties	3	10-100	250
ROAD - Local - 1 Lane - Paved - Low speed thoroughfare - access to properties	3	10-100	250
ROAD - Local - 1 Lane - Unpaved - Low speed thoroughfare - access to properties	3	10-100	250
ROAD - Local Highway - 1 Lane - Unpaved - Low speed thorogthfare to ROW	3	10-100	250
ROAD - Local Highway - 2 Lanes - Unpaved - Low speed thorouthfare to ROW	3	10-100	250
ROAD - Local Collector - 2 Lanes - Unpaved - Low speed thoroughfare to ROW	3	10-100	250
ROAD - Local Collector - 1 Lane - Unpaved - Low speed thoroughfare to ROW	3	10-100	250
ROAD - Local - Divided - 3 Lanes - Paved	4	100-200	500
ROAD - Local - Divided - 2 Lanes - Paved	4	100-200	500
ROAD - Local - 4 Lanes - Paved	4	100-200	500
ROAD - Local - 3 Lanes - Paved	4	100-200	500
ROAD - Local - 2 Lanes - Paved	4	100-200	500
ROAD - Local Collector - 1 Lane - Paved	4	100-200	500
ROAD - Collector - 1 Lane - Paved	4	100-200	500
ROAD - Local Collector - 2 Lanes - Paved	5	200-500	500
ROAD - Local Collector - Divided - 3 Lanes - Paved	5	200-500	500
ROAD - Local Collector - Divided - 2 Lanes - Paved	5	200-500	500
ROAD - Local Collector - Divided - 1 Lane - Paved	5	200-500	500
ROAD - Local Collector - 4 Lanes - Paved	5	200-500	500
ROAD - Local Collector - 3 Lanes - Paved	5	200-500	500
ROAD - Collector - 4 Lanes - Paved	5	200-500	500
ROAD - Collector - 3 Lanes - Paved	5	200-500	500
ROAD - Collector - 2 Lanes - Paved	5	200-500	500
ROAD - Local Highway - 1 Lane - Paved	6	<1000	1000
ROAD - Local Highway - 2 Lanes - Paved	6	<1000	1000
ROAD - Local Highway - Divided - 3 Lanes - Paved	6	<1000	1000

ROAD - Local Highway - Divided - 2 Lanes - Paved	6	<1000	1000
ROAD - Local Highway - Divided - 1 Lane - Paved	6	<1000	1000
ROAD - Local Highway - 4 Lanes - Paved	6	<1000	1000
ROAD - Local Highway - 3 Lanes - Paved	6	<1000	1000
ROAD - Highway - Divided - 3 Lanes - Paved	7	>1000	1000
ROAD - Highway - Divided - 2 Lanes - Paved	7	>1000	1000
ROAD - Highway - Divided - 1 Lane - Paved	7	>1000	1000
ROAD - Highway - 4 Lanes - Paved	7	>1000	1000
ROAD - Highway - 3 Lanes - Paved	7	>1000	1000
ROAD - Highway - 2 Lanes - Paved	7	>1000	1000
ROAD - Arterial - 2 Lanes - Paved	7	>1000	1000
ROAD - Arterial - 1 Lane - Paved	7	>1000	1000
ROAD - Local Arterial - 2 Lanes - Paved	7	>1000	1000
ROAD - Local Arterial - 2 Lanes - Unpaved	7	>1000	1000
ROAD - Local Arterial - 1 Lane - Paved	7	>1000	1000
ROAD - Local Arterial - 1 Lane - Unpaved	7	>1000	1000
ROAD - Arterial - Divided - 2 Lanes - Paved	7	>1000	1000
ROAD - Arterial - 4 Lanes - Paved	7	>1000	1000
ROAD - Arterial - 3 Lanes - Paved	7	>1000	1000
ROAD - Local Arterial - Divided - 3 Lanes - Paved	7	>1000	1000
ROAD - Local Arterial - Divided - 2 Lanes - Paved	7	>1000	1000
ROAD - Local Arterial - Divided - 1 Lane - Paved	7	>1000	1000
ROAD - Local Arterial - 4 Lanes - Paved	7	>1000	1000
ROAD - Local Arterial - 3 Lanes - Paved	7	>1000	1000
ROAD - Trans-Canada - Divided - 2 Lanes - Paved	7	>1000	1000
ROAD - Trans-Canada - 3 Lanes - Paved	7	>1000	1000
ROAD - Trans-Canada - 2 Lanes - Paved	7	>1000	1000
ROAD - Trans-Canada - 1 Lane - Paved	7	>1000	1000
SERVICE LANE - 2 Lanes - Paved	7	>1000	1000

Table 4. Point scoring of road influence for 10 km by 10 km hexagon cells.

Amount of Cell Occupied by Road Buffer	Point Score
0% to 19.99%	4
20% to 39.99%	3
40% to 59.99%	2
60% to 79.99%	1

80% to 100%	0

Values from combined HSI (Table 2) and road influence values (Table 4) provided a point score value of 0-9. Highest value cells were those with highest HSI values (5 pts) and lowest road influence (4 pts) for a combined value of 9; lowest value cells were those with lowest HSI values (0 pts) and highest road influence (0 pts) for a combined value of 0.

The combined road-buffer density and HSI maps (resistance layer) were determined to be the best way using currently available information to identify those areas that are both high suitability and low road influence and vice versa, along with gradations in between. These are the two primary factors thought to be influencing Mainland moose presence/persistence, and the spatial distribution of these considered together would be useful in delineating Core habitat for the three localized groups (Cumberland/Colchester, Pictou/Antigonish/Guysborough, and Tobeatic) as well as the connecting areas between.

Mainland moose concentration areas:

Mainland moose concentration areas were identified using a scientifically-based geographic model that included an estimate of total occupied range, relative population density, and significant population concentration areas. It was developed using 3272 moose observational records compiled between 1999 and 2011. Although moose can be encountered throughout the mainland, there are a number of areas of concentration that the species is typically found. This analysis was the basic geographic boundaries for application of the provincial Endangered Mainland Moose Special Management Practices on Crown land.

Although the concentration areas provided information on distribution and occupancy, the Recovery Team acknowledged that for future iterations of the Core Habitat the model will need updating to reflect current observational records (2012-present).

It should be noted that concentration areas may not be reflective of the most suitable habitat available for Mainland moose; other factors (such as lower deer densities, and hence, reduced prevalence of *P.tenuis*) may be driving current Mainland moose distribution patterns.

Protected areas and crown land:

Protected Natural Areas (PNAs) and National Parks are protected from activities that may result in habitat loss, conversion, or degradation, which make them suitable for inclusion in Core Habitat. Likewise, Crown lands are under the direct control of the province, and management of these lands are more easily influenced than private land holdings.

Population and distribution objectives:

Based on surveys in the 1960s by Telfer and Prescott (Parker, 2003) when a conservative estimate of the Mainland moose population was in the range of 4000-5000 individuals, estimates were calculated of the required population density and breeding population for the three localized groups (Cumberland/Colchester, Pictou/Antigonish/Guysborough, and Tobeatic) and area requirements to support these populations.

Localized Group or Area of Province	**Amount Required to Meet Recovery Objectives (km^2)**
Cumberland/Colchester	0.3-0.35 moose/km^2; breeding population 250 animals; total population ~1850-2000 animals; Area = ~ 5300 km^2 .
Pictou/Antigonish/Guysborough	0.20-0.25 moose/km^2; breeding population 200 animals; total population ~1400-1500 animals; Area = ~ 6300 km^2 .
Tobeatic	0.15-0.20 moose/km^2; breeding population 50 animals; total population ~300- 500 animals; Area = ~ 2000 km^2 .
Remainder of Mainland Nova Scotia (including connectivity needs)**	0.05-0.10 moose/km^2; total population ~500-1000 animals.

Other:

Hexagon cells were selected for inclusion in Core Habitat that did not meet suitability requirements (determined by the Recovery Team to be a combined HSI scores/Road network scores of 4-9 and road buffered density of less than 40%). There were multiple factors involved in this decision: The need to provide connectivity between the eastern mainland and western localized groups; lack of high-quality suitable habitat in the eastern localized groups (in particular Pictou/Antigonish/Guysborough); and a requirement to identify enough habitat to meet the stated population and distribution objectives. This will require management approaches that will improve quality of habitat for these areas.

Maps:

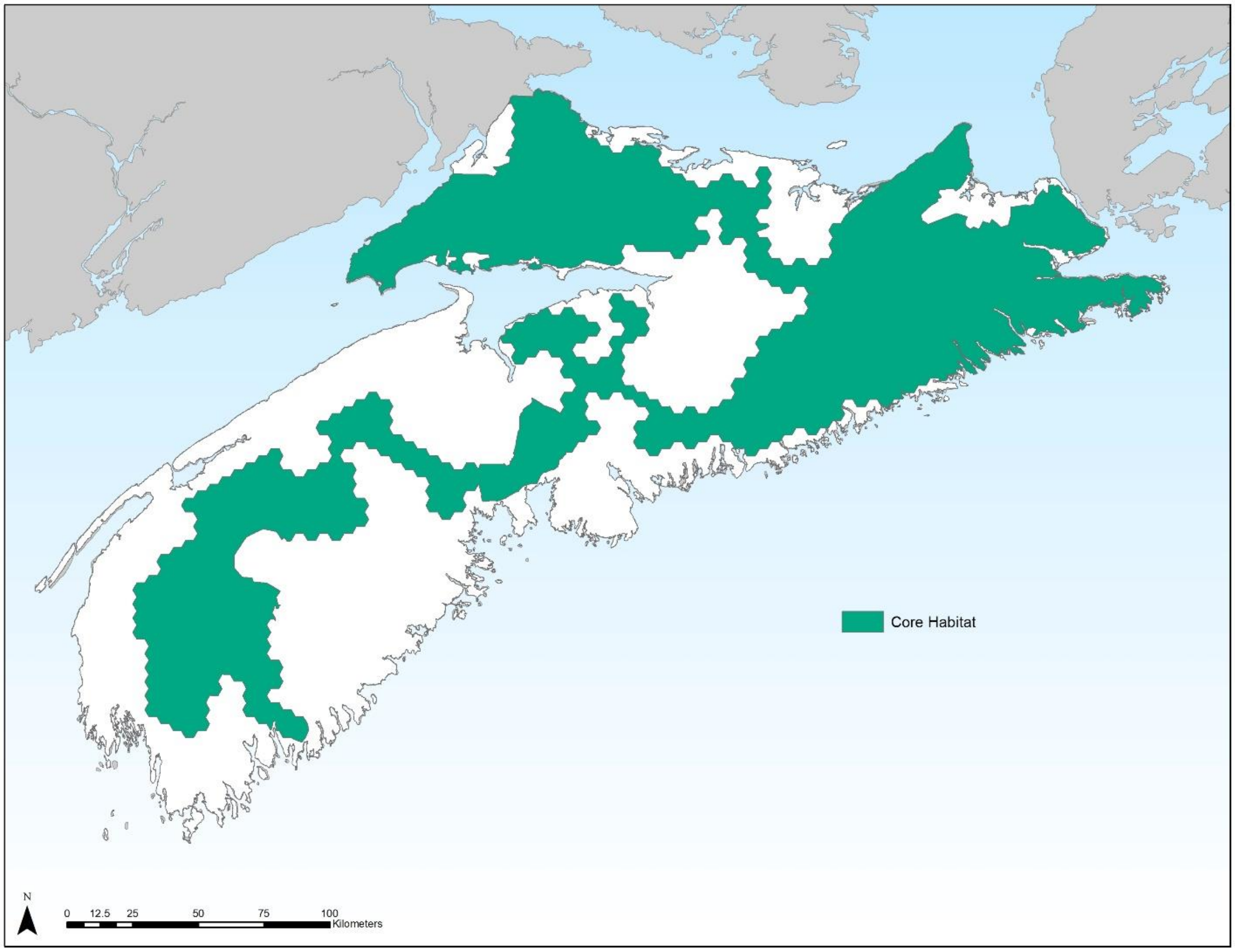

Figure 1. Core Habitat for Mainland moose in Nova Scotia.

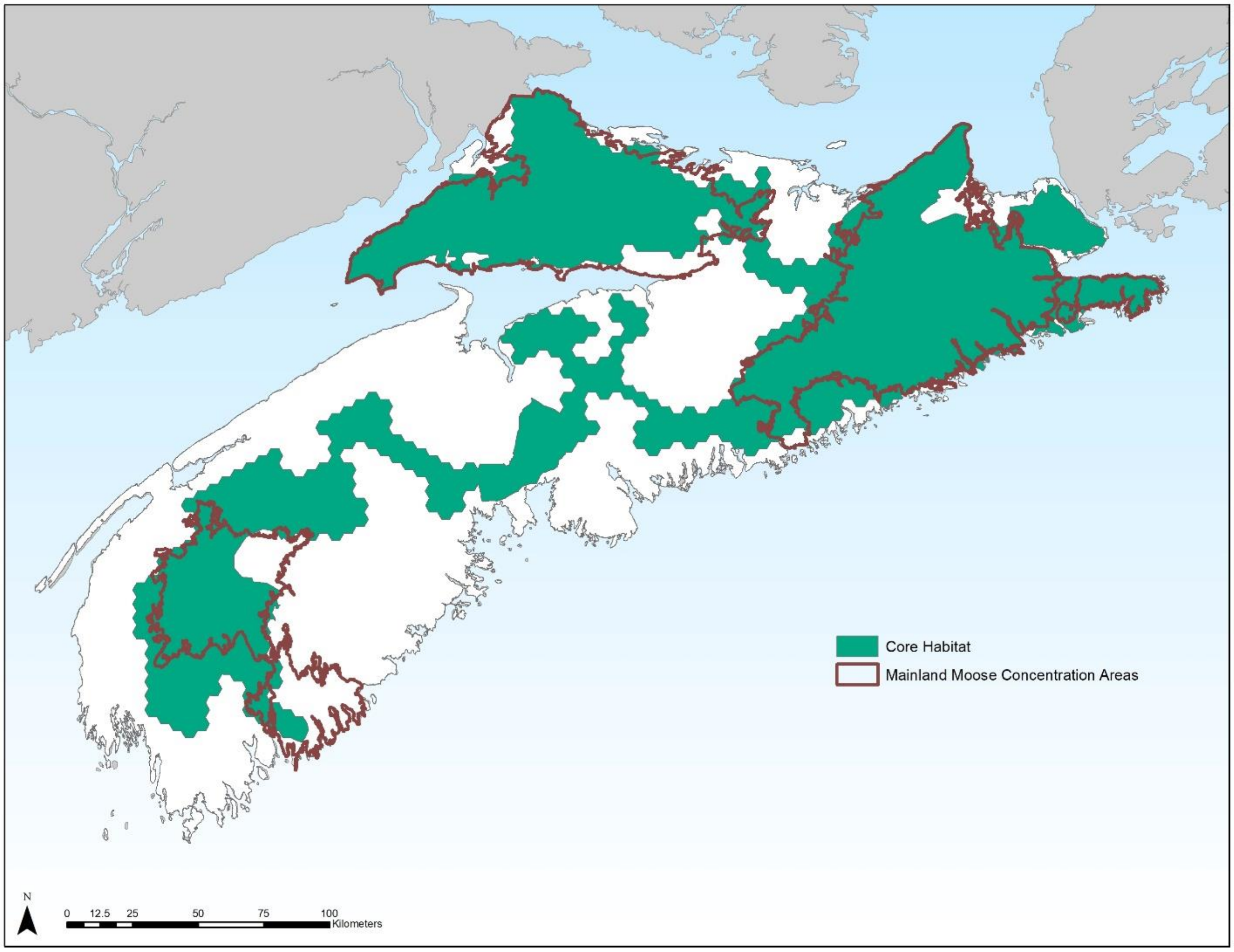

Figure 2. Core Habitat for Mainland moose in Nova Scotia and modelled Mainland moose concentration areas.

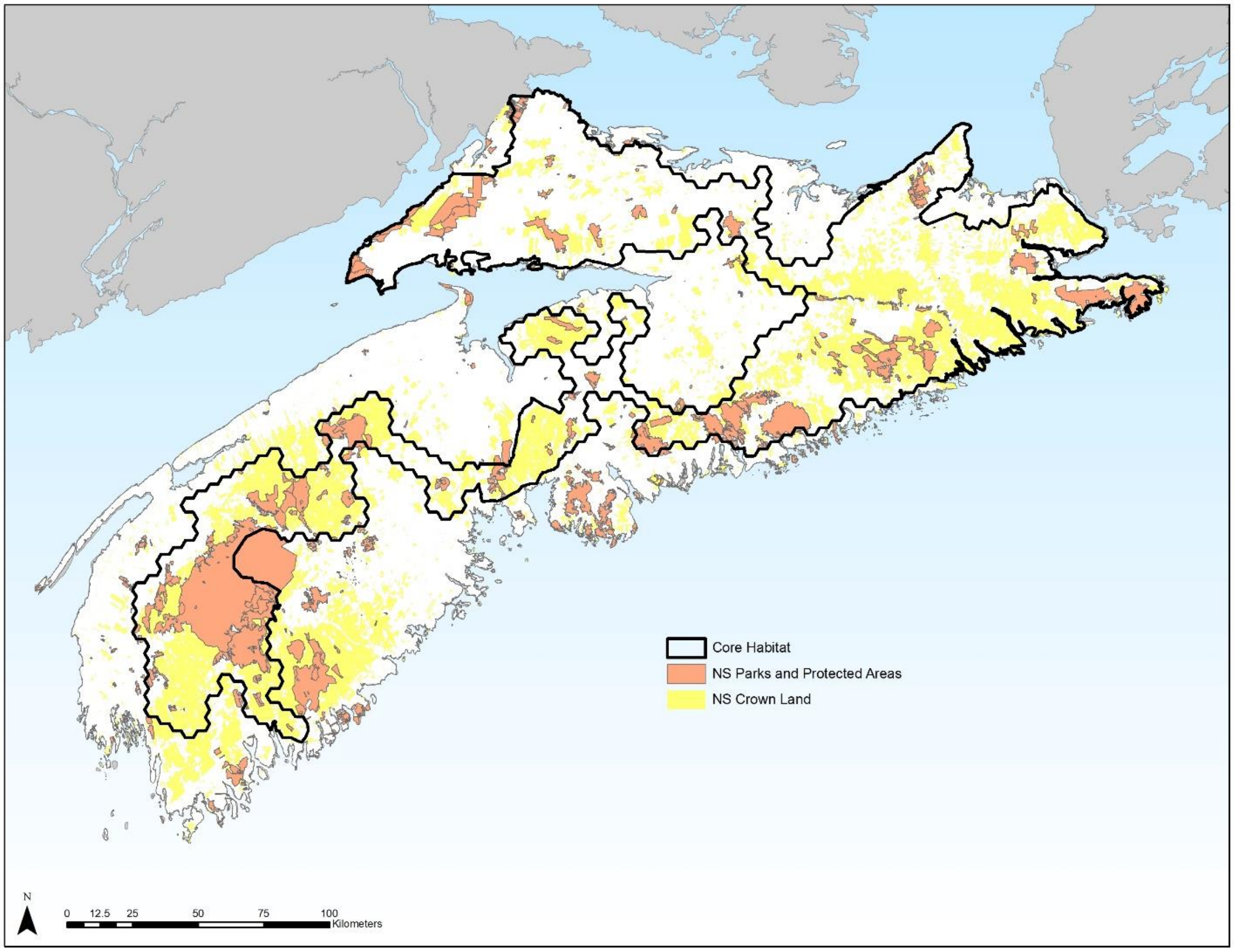

Figure 3. Core Habitat for Mainland moose in NS showing overlap with protected areas and Crown land.

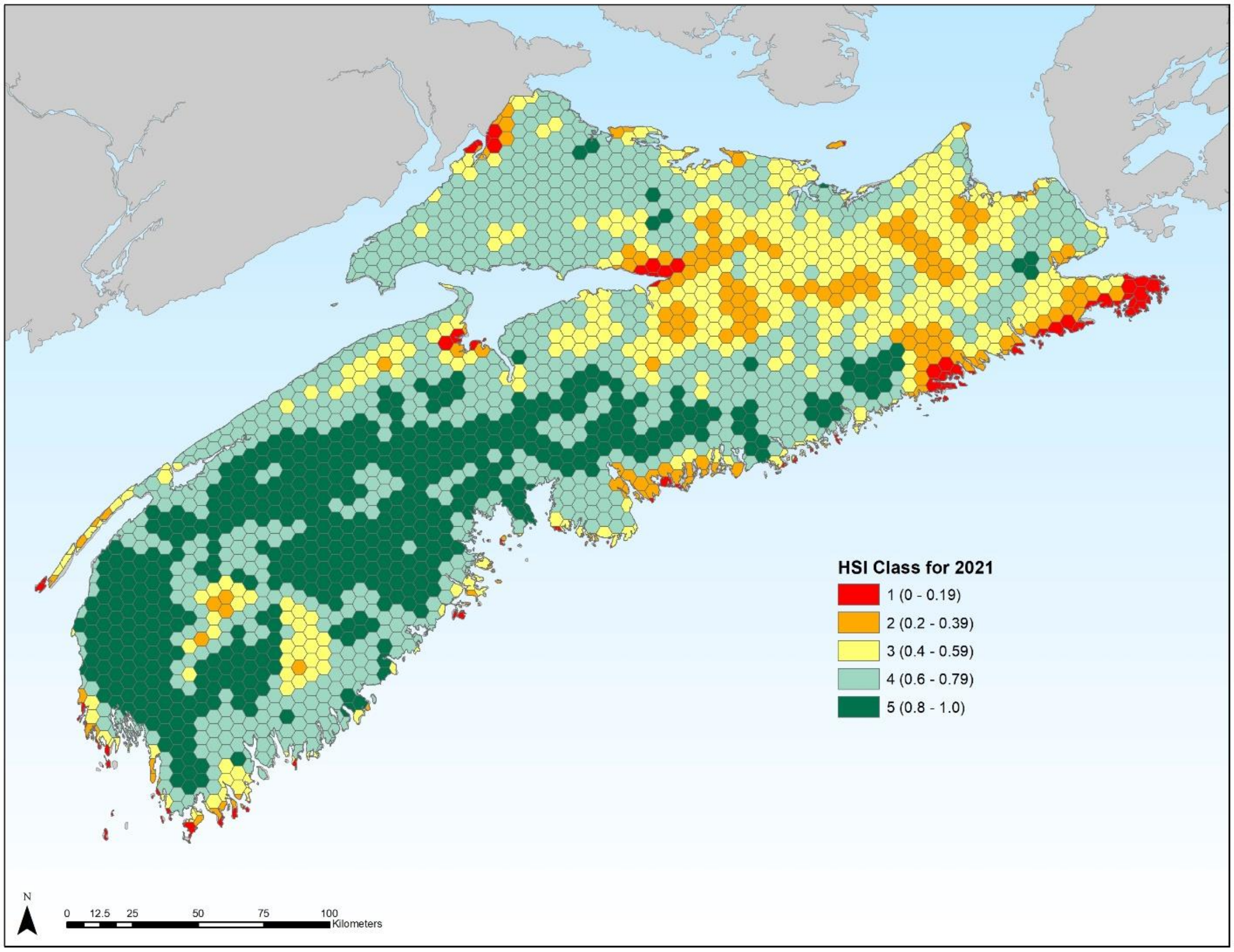

Figure 4. Habitat Suitability Index (HSI) scoring based on the 2021 forest inventory.

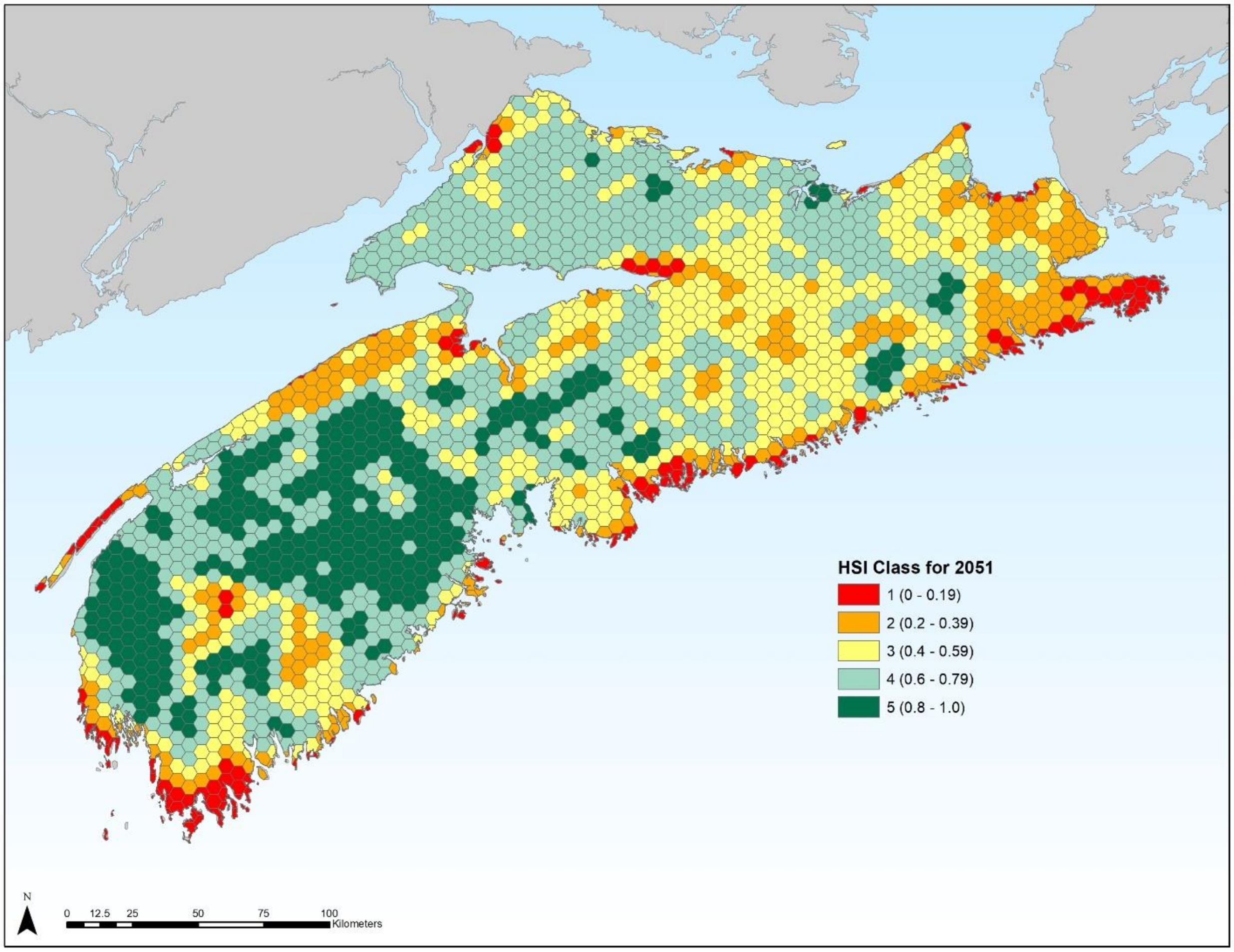

Figure 5. Habitat Suitability Index (HSI) scoring based on the 2051 forest inventory.

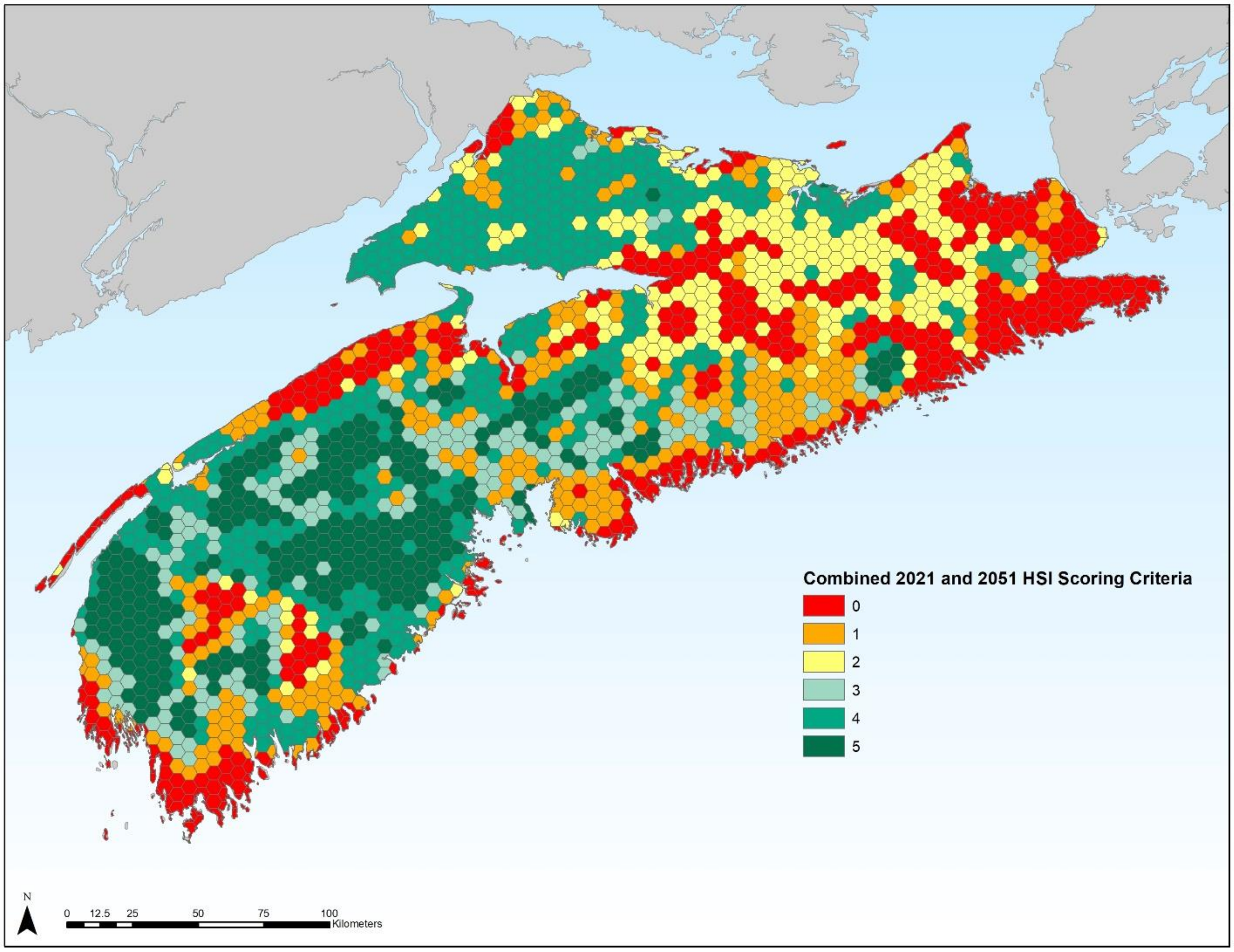

Figure 6. Point scores for combined 2021 and 2051 HSI values using criteria from Table 2.

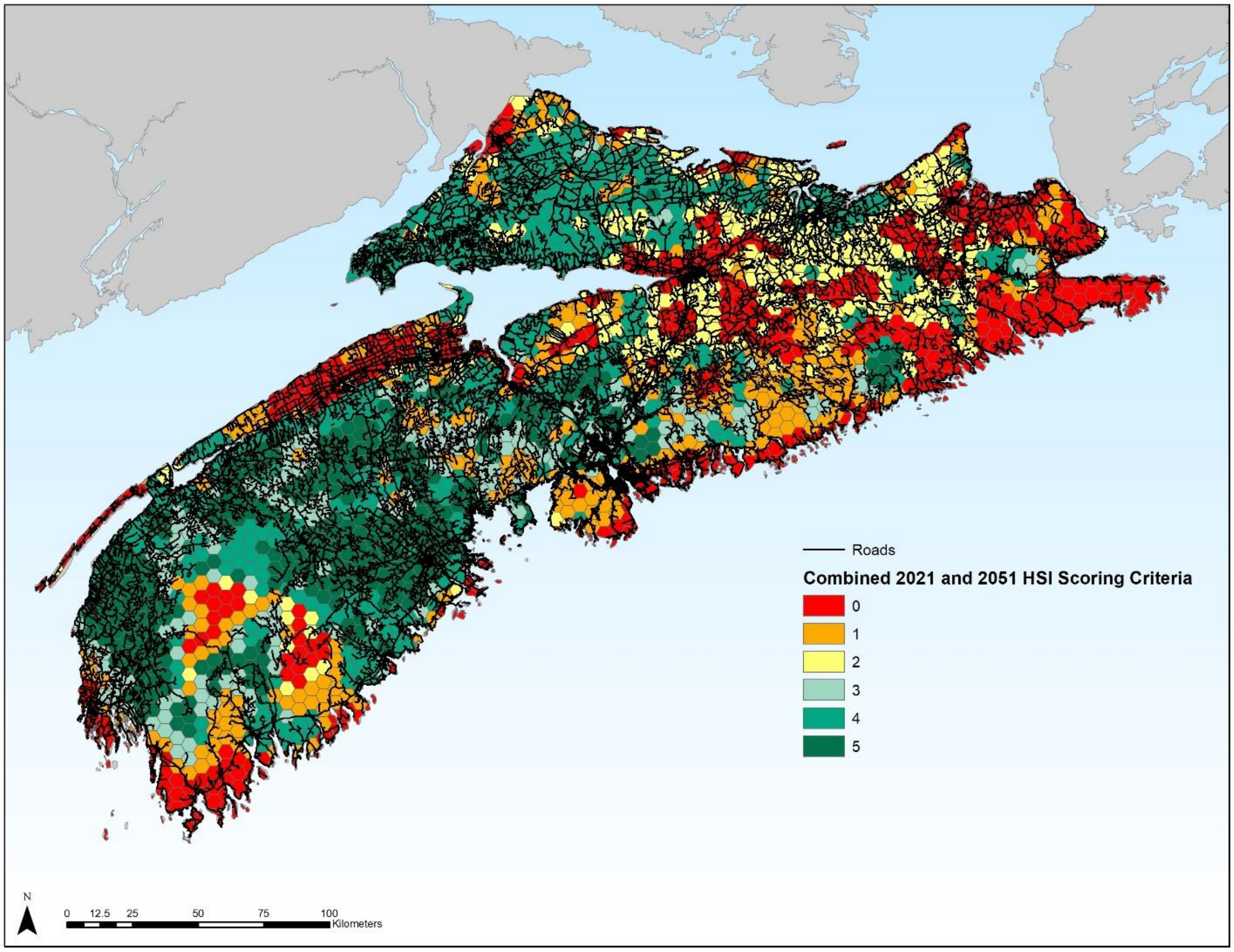

Figure 7. Point scores for combined 2021 and 2051 HSI values using criteria from Table 2 with provincial road network.

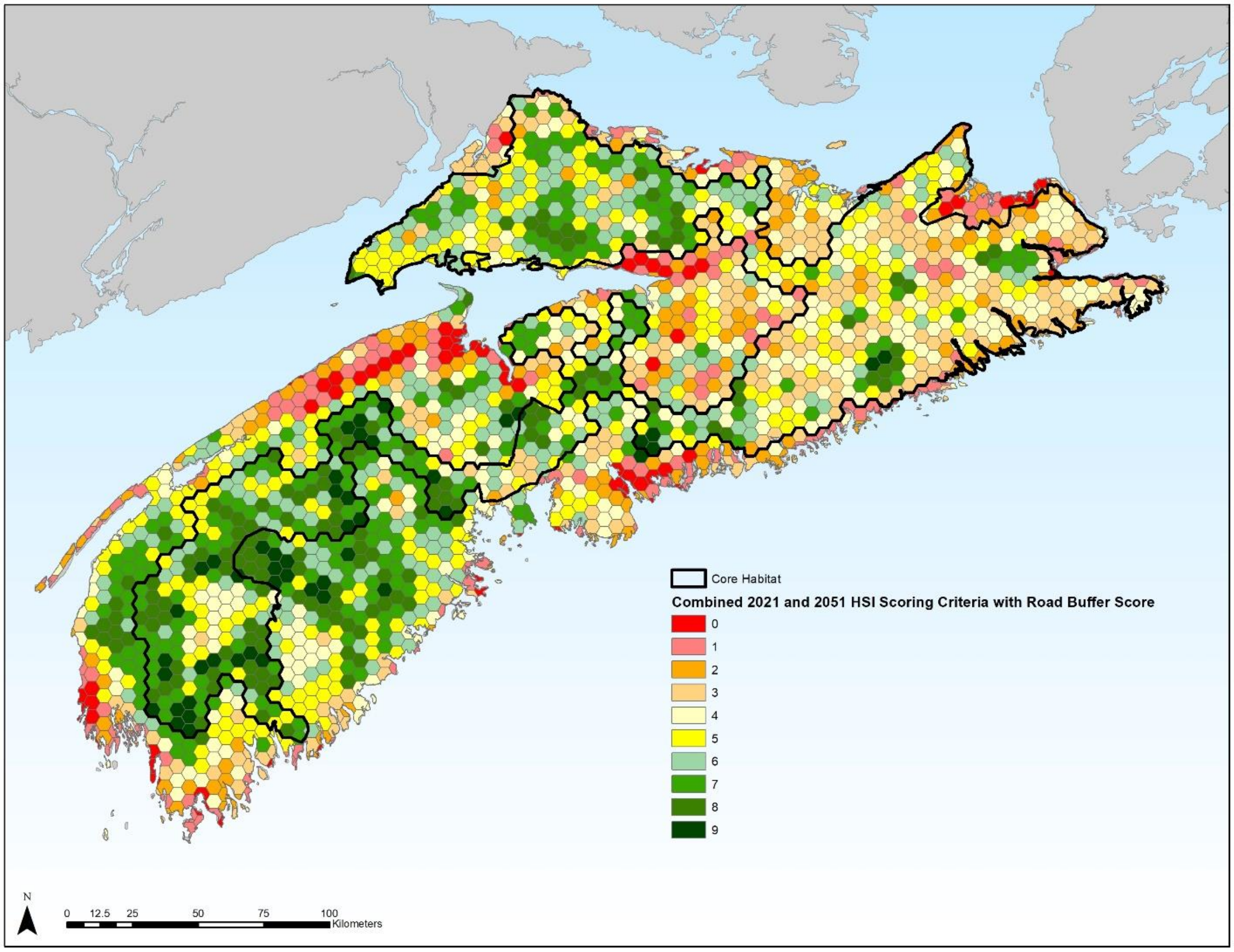

Figure 8. Point scores for combined 2021 and 2051 HSI values (Table 2) and road buffer density scores (Table 4).

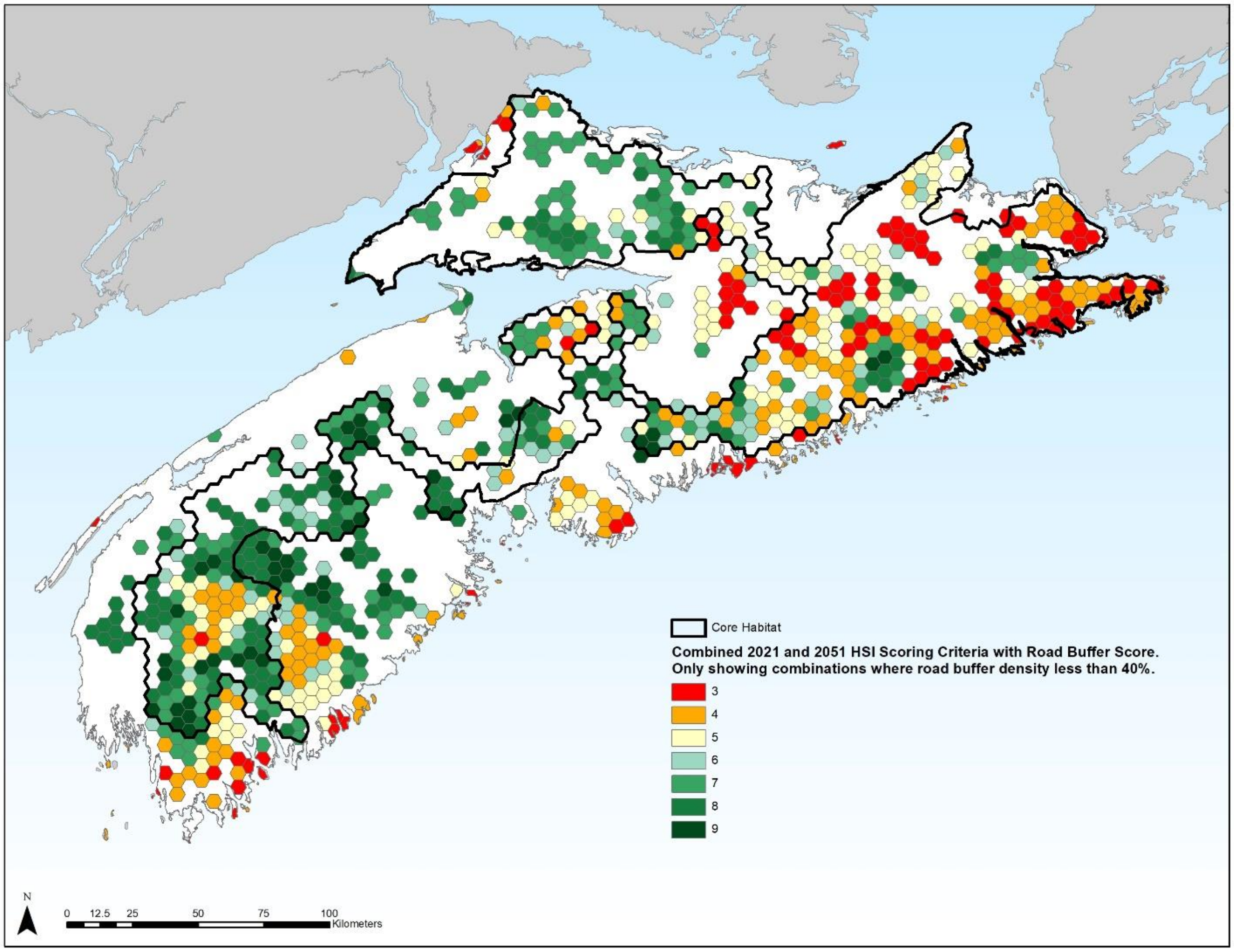

Figure 9. Point scores for combined 2021 and 2051 HSI values (Table 2) and road buffer density scores (Table 4) where road density is less than 40% of the hexagon cell total area.

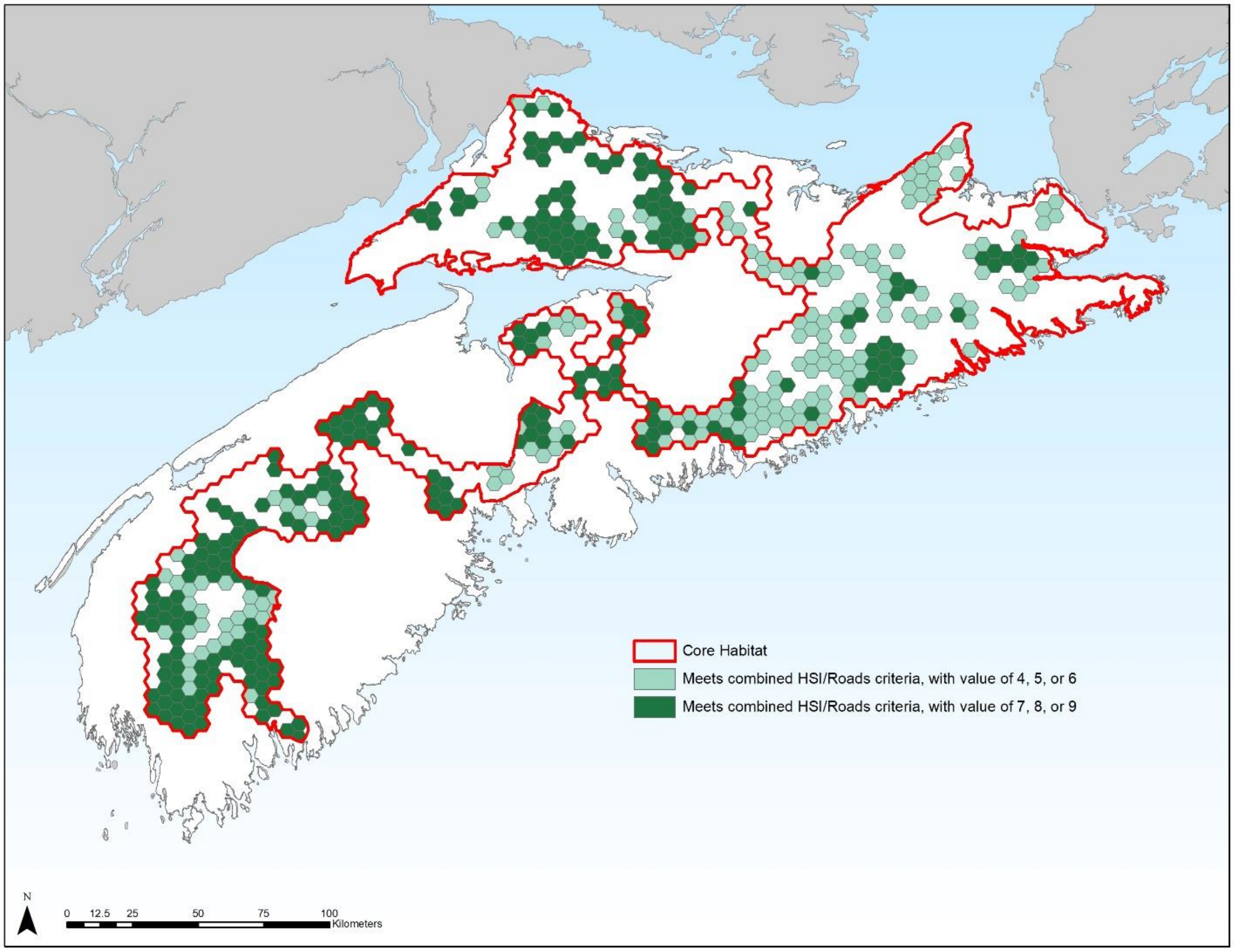

Figure 10. Areas with combined HSI and road density scores of 4-9 within Core Habitat.

Next Steps

Knowledge gaps:

- Update Mainland moose concentration area analysis to include current (2012-present) moose occurrence records and compare with previous concentration area analysis to determine how Core Habitat may be affected.
- Assess connectivity requirements between the three localized groups. For example, is it necessary to have a corridor of suitable habitat connecting the localized groups, or would the use of "stepping stones"-large patches of suitable habitat- between localized groups provide the connectivity requirements necessary for movement of animals and gene flow.
- Monitoring of threats and collection of data within Core Habitat to support review and update of Core Habitat as needed.

Management:

- Through research and consultation with forestry experts, identify the type of management needed to be undertaken in Core Habitat to ensure conditions for HSI 4 and 5 are maintained, and important lower-quality areas are enhanced.
- Develop White-tailed deer density maps from provincial Pellet Group Inventory (PGI) counts in conjunction with Core Habitat and identify management approaches for high deer density regions.

Data Sources

Crown Lands Forest Modelling Layer:

The Crown Lands Forest Modelling (CLFM) from Forestry Division was used as the Forestry Layer. In this dataset, the Forestry Division modellers grew the forest attributes to present day (2021) and some added columns were grown specifically to 2051 for this project.

Title: Crown Lands Forest Modelling Landbase
Source: Nova Scotia Department of Natural Resources and Renewables (Forestry Division)
Date of Data:

- Version 2020_v1 released in August
- Updated in October 2020 with volumes added
- sent another version March 2021 with the added data for 2051

Forest Layer – for Wetlands and Open Water:

Title: Nova Scotia Forest Inventory

Source: Nova Scotia Department of Natural Resources and Renewables (Forestry Division)
Download from: https://nsgi.novascotia.ca/gdd/
Date of Data: 2020-07-14
Downloaded: 2020-08-20

Roads:

Title: Nova Scotia Topographic Database - Roads, Trails and Rails
Source: Province of Nova Scotia
Download from: https://nsgi.novascotia.ca/gdd/
Date of Data: 2020-02-20
Downloaded: 2020-11-26

Water:

Title: Nova Scotia Topographic Database – Water Features
Source: Province of Nova Scotia
Download from: https://nsgi.novascotia.ca/gdd/
Date of Data: 2019-04-10
Downloaded: 2020-01-07

Crown land:

Title: CrownLand Property Database
Source: Nova Scotia Department of Natural Resources and Renewables (Land Services)
Date of Data: 2020-11-03
Downloaded: 2020-11-03
Note: Downloaded from Lands Service Branch (controlled access to this data). The public can download similar version, same polygons, but less attributes from https://nsgi.novascotia.ca/gdd/.

Parks and Protected Areas:

Title: Parks and Protected Areas
Source: Nova Scotia Department of Environment and Climate Change
Date of data: 2020-10-29
Note: Data received directly from the Nova Scotia Department of Environment and Climate Change.

Moose Concentration Areas:

Title: Endangered Mainland Moose Concentration Areas
Source: Nova Scotia Department of Natural Resources and Renewables (Wildlife Division)
Date of Data: February 2012