STATUS REPORT
on
The Eastern Moose
(*Alces alces americana* Clinton) in
Mainland Nova Scotia

by

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TECHNICAL SUMMARY

DISTRIBUTION

Extent of occurrence: Mainland Nova Scotia; ~ 55,000 km2

Area of Occupancy: Fragmented; ~ six foci of distribution of ~ 10,000 km2

POPULATION INFORMATION

Total number of individuals in the mainland Nova Scotia population: Uncertain, but approximately 1,000 to 1,200.

Number of mature individuals in the mainland Nova Scotia population (effective population size): Perhaps 85% of estimated population, or 850 to 1,000individuals.

Generation time: Average life expectancy of 8-10 years.

Population trend: __X____ declining _____increasing
_____ stable _____unknown

Rate of population decline: ~ 20% in 30 years

Number of sub-populations: Possibly 3: northeastern; southwestern; eastern shore.

Is the population fragmented? Yes.

number of individuals in each subpopulation: see map in Figure 1.

number of historic sites from which species has been extirpitated: All of mainland except where noted above.

Does the species undergo fluctuations? Irregular long-term trends.

THREATS

The moose of mainland Nova Scotia are fully protected from legal hunting but are subjected to poaching of an uncertain extent. Increased incursion into wilderness moose habitat by forestry roads raises the threat of disturbance from humans and illegal kill. Moose are also subject to mortality from the parasite *Parelaphostrongylus tenuis*, a brainworm common to white-tailed deer, and are often restricted to areas of deer absence or scarcity. Dead or dying moose have been necropsied with symptoms of an unidentified viral infection – the real threat of this possible pathogen is yet to be determined.

Moose carry high levels of the heavy metal cadmium - the health risk to the moose remains uncertain. Loss of older growth conifer habitat to forest harvesting may pose additional threat to local populations.

RESCUE POTENTIAL

Does species exist outside mainland Nova Scotia? Yes, on Cape Breton Island (separate subspecies), in New Brunswick, Maine and several other northeastern states and throughout much of the northern transitional and boreal forests of Canada and Alaska.

Is immigration known or possible? Moose may immigrate from New Brunswick or from Cape Breton Island, but impact on population levels in mainland Nova Scotia would be marginal.

Would individuals from the nearest foreign population be adapted to survive in mainland Nova Scotia? Yes.

Would sufficient suitable habitat be available for immigrants? Probably not, suitable habitat availability may be the factor currently restricting population growth.

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EXECUTIVE SUMMARY

Description

The eastern moose (*Alces alces americana*) is one of four recognized subspecies which occupy the northern mixed and boreal forest zones of North America. Three other subspecies, referred to as European elk, are found in similar biomes across Eurasia. The moose is the largest member of the deer (Cervidae) family, characterized by long legs, high shoulders, a short tail, broad overhanging muzzle, large ears and short neck. Adult males develop extremely large and palmate antlers. The hair is coarse and brittle, the colour assuming various shades of brown, brownish-black and gray. The average bull moose of mainland Nova Scotia weighs less than one thousand pounds, while a twelve hundred pound specimen would be an exception. Adult cows give birth to one or two calves in late May, often on islands or peninsulas. A young calf, which weighs about twenty-five pounds at birth, has a short body, long legs and ears and light reddish brown fur with a dark dorsal stripe. Growth is rapid and the young moose soon assumes the blackish-brown of adults with brown shading into yellowish-gray on the legs and belly (Merrill, 1916). Calves remain with their mothers throughout the full year.

The moose was important to the early Aboriginal First Nations as a source of food, clothing and shelter. Later, early European settlers also came to depend upon the moose for food while many were slaughtered in the early and mid-1800s for commercial trade with English merchants. In the late 1800s and early 1900s moose were hunted for sport. The season for hunting moose on mainland Nova Scotia was closed in 1938, opened again for the five northern counties from 1964 through 1974, closed in 1975 and 1976, and re-opened again from 1977 through 1981. It has remained closed since. The moose was assigned "red" rank by the province in 2000, identifying it as a species at risk of extirpation.

Distribution

Beginning in the late 1700s, and accelerating through the 1800s, the southern range limits of eastern moose retreated north from most New England states due to loss of habitat and excessive kill by humans. In New Brunswick and Nova Scotia moose met a similar although delayed fate and by 1875 there were few remaining in either province. But with the introduction of game laws in the 1880s which served to limit the human harvest, moose began to increase and once again became common throughout mainland Nova Scotia. Moose were extirpated on Cape Breton Island years earlier and did not return to that part of the province until they were reintroduced to Cape Breton Highlands National Park from Elk Island National Park, Alberta in 1948 and 1949. Following closure of hunting in Nova Scotia in 1938, moose continued to decline. From 1960 to the present, most moose on the mainland have been restricted to the northern Cobequid Hills and Pictou-Antigonish Highlands, the isolated 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.

Habitat

Moose are commonly associated with wilderness boreal and mixedwood habitats, although the species is most often found where its preferred food - the twigs, stems and foliage of young deciduous trees and shrubs - is most abundant. Such preferred habitats include forested landscapes recently disturbed by fire, wind, disease and timber harvesting. Preferred summer habitats, especially for female and young moose, include an interspersion of wetlands with access to submerged and emergent aquatic vegetation. In winter moose prefer a landscape supporting recently disturbed mixed forests for food and adjacent mature conifer cover for escape and shelter. The availability of suitable habitat is critical for maintenance of optimum individual physical and reproductive condition and population productivity.

Population Size and Trend

The productivity and total numbers of moose are often dependent upon the availability of deciduous shrubs, which are most abundant in recently disturbed forests. It is reasonable, then, that the historic abundance of moose in Nova Scotia has been closely associated with the occurrence of such events. Given the generally accepted range of moose densities in similar habitats and under comparable circumstances, an estimate for numbers of moose in a pre-European mainland Nova Scotia may have been in the range of 0.38 moose/km2 (1.0 moose/mi2), or approximately 15,000 animals. Following European settlement and excessive human harvest, moose had declined to a low of several thousand by 1825. Protective legislation allowed moose to increase again and by 1908 their numbers may have rivalled that of the pre-European era. Although the harvest remained fairly steady until the close of the season in 1938, that may have been an artifact of increased hunting pressure rather than population stability - the total population may well have declined. In the early 1960s the first aerial surveys showed that numbers of moose had declined to between 2,500 and 4,000 and 1,600 to 1,700 by the mid-1970s. The most recent surveys confirm that the decline, although somewhat abated, has continued and moose on mainland Nova Scotia probably number between 1,000 and 1,200 animals.

Limiting Factors and Threats

The most significant threat to many exploited moose populations is overhunting and predation by wolves (*Canis lupus*) and bears (*Ursus americanus*). On mainland Nova Scotia, where hunting is illegal and wolves are absent, the importance of those two threats, although not removed, is greatly lessened. Illegal hunting still exists, and may be critical to the survival of certain local populations, but the actual loss of moose to poaching is unknown. This source of mortality may be greatly enhanced through access from the profusion of roads associated with increased forest harvest operations. Although Aboriginals are allowed to harvest moose for their own use, once mainland moose were assigned “red” status in 2000, such activity has been restricted to the more healthy population on Cape Breton Island. Black bears kill some calves, but predation from bears should not pose a serious threat to a population protected from legal hunting. The moose is an animal which does best in a habitat supporting an abundance of young regenerating forests. With increased forest harvesting throughout the province such habitat should be readily available and accessible. However, the caveat lies in enhanced access to poaching from increased roads, a consequence which may nullify any benefit from habitat improvement. Restrictions on access in areas of known moose distribution might be considered as part of a provincial management plan. If not shot, moose can adapt to human presence and habitation. Another cause for concern is the accelerated loss of mature conifer stands to forestry and the potential importance of that habitat to moose for body heat regulation in the summer. The one source of mortality thoroughly identified and studied is the parasite *Parelaphostrongylus tenuis*. This threat is unlikely to disappear anytime soon due to the reservoir of white-tailed deer. There are few remedial options but more information on all facets of the disease in the province is recommended. There is limited evidence of moose dying from a neurological disorder unrelated to *P. tenuis*, possibly from an unidentified viral source. The potential threat to the health of moose from cadmium and other heavy metals should be monitored and remedial actions, if required, adopted.

Moose Management

In most parts of Canada, moose are managed as a renewable resource which can be hunted during specific seasons, usually from late September through November. The moose of mainland Nova Scotia have been protected from legal hunting since 1981, and since assigned a “RED”status - at risk of extirpation under the General Status of Nova Scotia Wildlife assessment process - in 2000, has received full protection including from Aboriginal harvest. (Note – A “RED” species is one that is known, or is thought to be at risk of extirpation or extinction. Currently, General Status designation affords no direct legal protection to a species, but rather, identifies relevent conservation concerns and the priority for formal, in-depth assessment that may be required). With no legal harvest to manipulate, management of moose has been one of protection from illegal kill (enforcement) and the introduction of cutting guidelines for forest companies to enhance habitat for moose, deer and provide for ecosystem biodiversity. Coordination of inventory and monitoring is done through the Wildlife Division and delivered across the province by Regional Biologists. In recent years those efforts have focused on spring-early summer counts of cervid pellet groups along established transects to obtain indices of temporal and spatial abundance (moose specific transects were established in 2000). In Cumberland and Colchester Counties, counts of pellet groups on transects in specific sample plots have been conducted periodically since 1979 in an effort to obtain population estimates. Snow cover optimizes observation of moose and moose sign from the air in winter. A lack, or unpredictable occurrence of such conditions has limited the value of aerial surveys to monitor distribution and numbers over most of the mainland.

Existing Protection

On mainland Nova Scotia moose have been protected from hunting since the season was closed in 1981. Moose may be hunted during a short autumn hunting season on Cape Breton Island. Although recent judicial rulings allow moose in Nova Scotia to be killed by Aboriginals, mortality from that source has been restricted to Cape Breton Island since the province assigned a "red" rank to mainland moose in 2000. Persons apprehended in the act of killing moose on mainland Nova Scotia may be charged under the provincial Wildlife Act.

SPECIES INFORMATION

Name, Classification and Taxonomy

Eastern Moose
Alces alces americana (Clinton 1822)

The distribution of *Alces alces,* known as the moose in North American and the European elk in Eurasia, is circumpolar in the boreal and mixedwood forests of the world (Peterson, 1955). The occurrence of moose across Canada, from Newfoundland/Labrador and Nova Scotia west and northwest through New Brunswick, Quebec, Ontario and the northern Prairie Provinces into the Yukon and Alaska, is generally considered continuous. Peterson (1955) recognizes seven subspecies, three of which are distributed in the Old World and four in North America. The eastern moose, *Alces alces americana* (Clinton), which is found on mainland Nova Scotia, occupies suitable range from Maine and Nova Scotia westward through Quebec and into northern Ontario where it intergrades with the northwestern moose, *Alces alces andersoni*.

In 1904 specimens of the eastern subspecies were captured near Newcastle, New Brunswick and introduced to the island of Newfoundland. In 1928 and 1929 seven moose were unsuccessfully reintroduced to Cape Breton Island from mainland Nova Scotia. That was followed by the successful translocation of eighteen moose to Cape Breton Highlands National Park from Elk Island National Park, Alberta by the federal government in 1947 and 1948 (Dodds, 1974; Corbett, 1995). The population of moose on Cape Breton Island, therefore, represents the subspecies *Alces alces andersoni*. Because of these and other relocations of moose within the past one hundred years, studies of the genetic structure of moose from eleven regions in Canada suggest there are now at least seven genetically distinct populations in North America (Broders, et al., 1999). However, muscle tissue samples for that study from Nova Scotia were collected only from moose on Cape Breton Island, analysis of which showed that moose there were most closely associated with moose from Alberta, i.e. their source, and, not unexpectedly, quite distinct from other eastern Canadian moose populations. To better understand the genetic relationship between mainland moose and those on Cape Breton Island and in New Brunswick, as well as among moose from isolated areas of distribution on the mainland itself, a collaborative study is currently in progress between Nova Scotia Department of Natural Resources and a PhD student at Trent University. The objective of that study is to identify the amount of genetic diversity within moose populations of the province and determine if they are at risk of inbreeding depression (Nette, 2002; MOU, 2001). As of May, 2001, twenty-five recent DNA samples had been collected from mainland moose and thirty samples of bone and antler from mounted specimens dating back to 1912 (Nette, 2001). Results of that study are not yet available.

Description

The moose is the largest member of the deer (Cervidae) family. It is about the size of a saddle horse with "heavy body, long legs, high shoulder region, short tail, broad overhanging muzzle, large ears and short neck. Adult males develop extremely large antlers with characteristically broad palmate blades and projecting tines" (Peterson, 1955). Males develop a unique "bell," or dewlap, on the upper throat region, its physiological purpose uncertain. The hair is coarse and brittle, the colour assuming various shades of brown, brownish-black and gray. A large moose is taller than the tallest horse but the largest horse is much heavier than the heaviest moose. The average bull moose of mainland Nova Scotia weighs less than one thousand pounds, while a twelve hundred pound specimen would be an exception. Adult cows give birth to one or two calves in late May, often on islands or peninsulas. A young calf, which weighs about twenty-five pounds at birth, has a short body, long legs and ears and light reddish brown fur with a dark dorsal stripe. Growth is rapid and the young moose soon assumes the blackish-brown of adults with brown shading into yellowish-gray on the legs and belly (Merrill, 1916). Calves remain with their mothers throughout the year.

DISTRIBUTION

Eastern North America

At the time of earliest European settlement, moose were common in the northeastern states of Maine (Morris and Elowe, 1993), New Hampshire (Bontaites and Gustafson, 1993), Vermont (Alexander, 1993), Massachusetts (Vacellio, et al., 1993), and as far south as northern Pennsylvania (Peterson, 1955). The early Aboriginals of the northeast depended upon the moose for food and clothing, and later, moose hides became an important article of trade and commerce among fur traders. Great quantities of hides were returned to England from colonial outposts in New England and l'Acadie to meet the demands of the fashion industry. Later, with the outbreak of the American Civil War, thousands more were slaughtered for their hides to supply uniforms for the union troops, especially in the manufacture of leather belts. Due to excessive mortality and habitat loss in northeastern United States, most of those moose came from Maine and New Brunswick. Moose were eliminated from Massachusetts as early as 1800 and approached extirpation in Vermont by 1850 and New Hampshire by 1898. But through season closures and protection from poaching, they managed to survive in small and isolated numbers. In Maine moose were reduced to several thousand animals by 1900 and the season, which had been quite restrictive since 1927, was closed entirely in 1936.

Through total protection, moose in Maine increased until a limited hunting season was introduced in 1980. Today, moose in Maine are restricted to the northern two-thirds of the state, and the population in 1993 was estimated to number between 20,000 and 25,000.

The story was similar in the Maritimes. Moose were all but extirpated in New Brunswick by the early 1880s (Merrill, 1916). But through protection of cow moose in 1890, reduced seasons for bulls and increased protection against poachers, the moose experienced a steady increase through the early 1900s. As in other states and provinces, however, moose began to decline again through the 1920s and the season was closed in 1937. A slow increase in the provincial population over the next several decades allowed a restricted season in 1960, the first in twenty-four years, and which has continued to this day.

Nova Scotia

Historic

When Europeans first settled in the land known as l'Acadie, the eastern moose was the most common and widespread of large game animals. The profusion of lakes, streams and meadows interspersed across a landscape of mixed Acadian forest provided ideal habitat for this large northern deer. Wetlands provided an abundance of aquatic plants while the adjacent mature conifer and mixed forests afforded the required shelter from the heat of summer. Those same forests provided a mix of shelter and deciduous browse during the winter months. Historian Marc Lescarbot of Paris spent some time with de Monts' colony in Port Royal, and on his 1609 map of la Nouvelle France he shows a drawing of a moose near a stream which he named Riviere de l'Orignac, a stream now bearing the name Moose River, at the mouth of which is the present day village of Clementsport (Lescarbot, 1609). This is believed to be the earliest picture of the North American moose. Lescarbot referred to the moose as "...the most abundant food which the savages have, except fish." The early explorers adopted the Basque word *orenac* when referring to the moose, and considered the animal identical to the elk of Europe. The Indians named this deer of the northern forests “*Mosse*”. Explorer Nicolas Denys wrote in 1672 that moose had been exterminated from Cape Breton Island by the Indians, who themselves were forced to leave the island because of lack of game (Denys, 1672).

As in most other areas of the northeast, the Mi'kmaq and Maliseet tribes of the First Nations were dependent upon the moose and caribou for survival during the winter months. Wolves, the natural predator of moose, were never abundant in Nova Scotia and were probably extirpated by 1847 (Dodds, 1993). Wolves were not responsible for the general decline in moose throughout northeastern North America during the 1800s. Describing the territory at the head of the Bay of Fundy, Denys wrote "The Sieur d'Aunay in his time [1645-1650] traded in moose skins there to the extent of 3,000 skins a year, besides beaver and otter, which was the reason why he dispossessed the Sieur de la Tour of it." Moose hides in particular produced a fine buff-leather used to make clothes and a wide array of other products. The demand in England for moose and beaver (*Castor canadensis*) skins soon brought both to the brink of extinction in the Maritime Provinces. The unrestricted slaughter of moose continued, both in Nova Scotia and New Brunswick, especially around 1825, until a closed season for three years was enacted for the province of Nova Scotia in 1874. Several years later, in 1879, snaring and hunting with dogs was prohibited, restrictions which some consider may have saved the moose from extirpation (NSDLF, 1933). Any benefits of the three year closure and the prohibition of snares and dogs was offset in 1877 when a five year season was introduced which allowed the killing of three moose and five caribou during the period October through January.

Prior to European colonization and subsequent widespread cutting of timber, first for the British navy and later to help fuel American industrial expansion, moose were most common in and near areas of abundant food, a condition often created from natural disasters, such as fire, wind storms and outbreaks of insects, e.g. spruce budworm. Later, as the forests fell before the lumbermen's saw and axe, the structure of the forests changed, a process still in progress. Through stand conversion, the subsequent younger and deciduous-dominated forests provided more forage for moose than before European influence. Early forest harvest technology (axe and saw) and product selection (old mature pine and spruce) left a "messy" landscape but one which provided a heterogenous mosaic of food and cover - ideal habitat for moose. And the moose responded.

Annual kill records by county show that during the thirty year period 1908 through 1937, at which time the season was closed, moose were distributed throughout most of the province (Dodds, 1963). The counties of Halifax, Guysborough, Annapolis, Shelburne, Queens, Colchester and Cumberland were the most consistant contributors to the overall provincial kill. The largest contributor to the annual kill was the southwest region, followed by the northeast. It is also apparent that those two regions, beginning in the early 1920s, accounted for the greatest declines. What is most relevent to our understanding of the past and current spatial dynamics of the provincial moose population are thirty year trend lines for the northwest and northcentral regions. Both show a modest increase during a general provincial decline, and both regions now support two of the three core areas of moose occupation.

Recent (1960s - 1970s)

Don Dodds, the new big game biologist for Nova Scotia in 1960, began a concerted effort to determine the numbers and distribution of moose in the province. An aerial survey in 1961 was followed by ground surveys in 1962 and the submission of monthly forms by all Forest Rangers containing information on sightings of moose and their sign (Dodds, 1963). From all of these data sources the apparent decline in moose over the previous twenty-five years was disturbing. Warden reports from the four provincial sanctuaries were especially alarming. The spring, 1962 aerial surveys of the eastern mainland counties, although of questionable value, did suggest that moose were most common within the limited ranges of the Cobequid Hills, while reports from provincial wildlife field staff suggested highest densities in the eastern mainland counties. In 1963 Dodds provided the following summary on the status of moose in the province: 1- In western Nova Scotia there were no moose left on the North Mountain or in the Annapolis Valley Basin; 2- The highest density in the western region was in the "five county area" on and near the Tobeatic Game Sanctuary; 3- The highest density of moose in the province was in the eastern mainland along the Cobequid Hills and adjacent uplands; and, 4- The remainder of the mainland supported a low and scattered population with several pockets of moderate density in Halifax and Guysborough Counties.

Dodds correctly noted that the elevated areas of moose occupation in northeastern Nova Scotia also represented areas where moose and deer were least likely to share winter range, an observation which has proven helpful in explaining spatially-specific distributions for infection rates of *P. tenuis* in moose. Dodds searched for reasons to explain the decline following cessation of hunting. Records of the annual harvests suggested that the population was not in a significant decline at the time of the 1938 closure. Even though hunter kill trend lines showed a general decline in most parts of the province beginning in the early 1920s, in 1937 hunters enjoyed their highest kill per unit of effort since statistics were collected in 1908. Moose had also declined within provincial sanctuaries where hunting was prohibited. Dodds believed that hunting, legal or illegal, was not the main source of mortality contributing to the decline, and concluded his 1963 paper by stating that "It is my opinion that the decrease in numbers of moose in Nova Scotia is a direct result of interspecific competition with white-tailed deer...I feel that the correlation of our highest moose densities existing in sections where the overlap into winter deer range areas is lowest is not an accident." Dodds speculated the correlation between high deer-low moose was habitat related, with the more abundant deer out-competing moose for preferred foods. Of course, subsequent studies have proven him correct and confirmed the incompatability of high deer and high moose densities on sympatric ranges, although the reason was not interspecific competition for food. It would be another year before experimental studies in Ontario would provide causative linkage between deer, the parasite *P. tenuis*, terrestrial gastropods and clinical signs of moose sickness which had long been observed in the province (Anderson, 1964a).

An aerial survey of the province in the late winter of 1963-1964 found that the areas of highest density included southern Cumberland and Colchester Counties and restricted portions of Antigonish and Pictou Counties. This 14 percent of total occupied range supported 76 percent of the estimated population. Lower densities were found in adjacent ranges in the northeast as well as the Tobeatic district of southwestern Nova Scotia, while much of the mainland was classified as "scattered low density" (Telfer, 1968a). Aerial surveys of Cumberland, Colchester, Antigonish and Pictou Counties continued in the late 1960s (Prescott, 1968) and mid-1970s (Scott, 1976) and although the surveys confirmed earlier limits of distribution for moose they also suggested a significant decline in numbers from 1964 through 1975 (Table 1).

Current (1980s - Present)

With closure of the moose season on mainland Nova Scotia following the 1981 hunting season, management interest shifted to the growing population on the highlands of Cape Breton Island. But monitoring of moose continued in the northern moose management zones on the mainland, with aerial surveys flown through the late 1970s, 1980s and early 1990s (Pulsifer and Nette, 1995). More recently, winter aerial surveys were combined with regional specific spring pellet counts for a 2001 estimate of distribution and numbers of moose in Cumberland and Colchester Counties (Hall, 2001). Also, a 2003 winter aerial survey of moose in Antigonish and Guysborough Counties provides a current estimate of numbers of moose and their distributions there (Pullsifer, pers. comm.). Results of those surveys confirmed that although distribution has changed little over the previous several decades, total numbers have declined markedly. Because of the threat of road construction and associated urban development south of the Halifax metropolitan area, surveys have been flown over the small and isolated population on the Chebucto Peninsula, where there may be 25 -30 moose (Archibald, 2003).

Since the early 1960s, the main concentration of moose in southwestern Nova Scotia has been in or adjacent to the southwestern section of the Tobeatic Wildlife Management Area, especially the small "five county area" which had been described earlier by Dodds as containing portions of Yarmouth, Shelburne, Queens, Annapolis and Digby Counties. In the early 1960s, Dodds (1963) estimated the population of western Nova Scotia at between 300 and 600 moose. Aerial surveys by Telfer in 1964 suggested somewhat fewer, perhaps 200 to 300 moose. Because the moose season remained closed in western Nova Scotia since 1937, there were few attempts to obtain population estimates from aerial surveys. Exacerbating the difficulty of conducting meaningful aerial surveys in that region was, and remains, the absence or scarcity of winter snow to facilitate observations of moose and moose sign. A winter survey flown in 1993 (Nette, pers. comm.) counted 96 moose from which an estimate of 168 moose was calculated later by Brannen (pers. comm.). Brannen flew a survey over his Tobeatic study area in January, 2001 and, using the same statistics as applied to the 1993 survey, estimated a total of 109 moose. The current consensus among provincial wildlife authorities is that the population in the Tobeatic "core" area numbers between 115 and 150 moose, and is probably declining (Nette; Brannen; MacDonald; pers. comm.). Four small pockets of moose are found outside the Tobeatic core area. They are (1) ~ 20 northwest of Great Pubnico Lake, Yarmouth Co., (2) ~ 100 in the MacKenzie Barren – Canada Hill area north to North Division Bog (Shelburne Co.), east to Tidney River area, south to Port Mouton (Queens Co.), (4) ~ 15 east of Upper Woods Harbour, and (4) ~ 15 in the Lower Stave Lake area (Shelburne Co.) (Peter MacDonald, pers. comm.). Moose continue to be most abundant in the northeastern counties of Cumberland and Colchester. There are a few scattered moose, perhaps another 100-200, in the eastern counties of Halifax and Guysborough. Moose are virtually absent elsewhere. The current limits of core distribution and estimated numbers of moose on mainland Nova Scotia are shown in Figure 1.

Distributions of moose sightings from the Wildlife Investigation Report program suggest that moose do wander on occasion from the widely separated and often isolated core areas (Figure 2a,b,c). The paucity of such reports in the past several years might be due to a decline in the rate of public reporting, a lag time for reports to reach provincial staff or an actual decline in moose.

HABITAT

General

"The basis of a favourable habitat for moose is continual forest succession or regeneration. Moose populations apparently reach their maximum in the early stages of succession and decrease as the forest reaches maturity" (Peterson, 1955). Little has changed in conventional thought over the past fifty years to alter that basic definition of prime moose habitat. The moose is a large herbivore of obvious flexibility in its life's needs, capable of survival in the balsam fir-birch boreal forest zone of central Newfoundland, the mixed Acadian forests of New Brunswick and Nova Scotia, the aspen parklands of the northern prairies, the valleys and mountains of the interior Rockies and the taiga scrubland of the Yukon Territory. Moose have been seen as far north as Chesterfield Inlet on the west coast of Hudson Bay, hundreds of kilometers from the treeline. The adaptability of this deer of the northern forests is remarkable. And in most sectors of its range the moose is a game animal highly sought after by the hunter for its meat, antlers and the sporting challenge.

Wherever it is found, however, moose are largely dependent on successional forest stages for suitable habitat, especially in winter. Riparian areas which support willow and shrubs, burned areas and logged over sites are preferred habitats rich in early successional trees and shrubs. Over fifty years ago, researchers concluded that "...the declining carrying capacity noted in a forest approaching its climax stage results from decreases in both the quantity and quality of food produced. It is further concluded that the most desirable winter range for moose is one upon where there is a variety of palatable species, predominantly in an early stage of growth, but with an intermixture of older forest stands bearing palatable coniferous [particularly cedar (*Thuja occidentalis*) and balsam fir (*Abies balsamea*)] trees" (Cowan, et al., 1950). But moose can also have an impact upon the habitat. Over-browsing is common in wintering yards, and in summer aquatic vegetation can be destroyed in heavily frequented ponds and streams.

The three natural disturbances to the mature forest system most beneficial to moose are fire, wind and disease, the most important of which is fire. All three are closely affiliated with the northern forests used by moose across North America. In eastern Canada the spruce budworm (*Chloristoneura fumiferana*) has been the forest pest most important to moose, periodically ravaging expansive amounts of balsam fir-dominanted forested landscape. In its wake a profusion of shade-intolerant trees and shrubs regenerate, among which, and important to moose, are raspberry (*Rubus* spp.), balsam fir, red maple (*Acer rubrum*) and birch (*Betula* spp.). Fire often cleans up the dead and tinder dry fir and spruce (*Picea* spp.) following disease which further enhances range as prime moose habitat. The 1825 Miramichi fire was an example of such a cataclysm, and many suggest that it was that disaster which allowed the moose of New Brunswick to experience a population increase in the late 1800s (Wright, 1956).

In summer, moose seek out streams, ponds and the shorelines of lakes to escape the heat and the torment of insects and feed upon submerged and emergent vegetation, such as pond lilies (*Nymphaea advena*) and water shield (*Brasenia Schreberi*). The sequence of forest regeneration following fire often produces a proliferation of aspen (*Populus* spp.) which enhances the landscape for beaver. In turn, beaver create more wetlands which provide more aquatic habitat for moose and the cycle continues. The importance of closed conifer forest to moose in summer as a means of body thermoregulation is becoming increasingly evident (Schwab and Pit, 1991). In winter moose move to the forests and seek out regenerating mixed woods with abundant deciduous and balsam fir browse and adjacent conifer-mixed forest with closed canopy for cover. In regions with deep winter snow, moose, like deer, often congregate in suitable habitats in groups of two to six and stay in "yards" during the months of January through March.

Selection and Use

Although moose show a wide selection of preferred plant species, it has been suggested that failure of populations to increase may be correlated with low rates of reproduction (in contrast to population suppression from disease, parasites or predators) which is often influenced by quality, and to a lesser extent quantity, of prevailing food supplies (Peterson, 1955; Pimlott, 1961). In Nova Scotia, Dodds (1963) suggested that the decline of moose might have been due to competition for food supply with increasing white-tailed deer, although that suggestion was speculative and generally dismissed in later years.

In Maine, female moose in summer preferred lowland forests, wetlands and recent cutovers while males preferred upland hardwood and mixed wood habitats. Cut-overs were more important to females than males (Leptich and Gilbert, 1989; Dunn, 1976; Crossley and Gilbert, 1983). The importance of cutovers to moose in Maine is consistant with moose habitat preferences in Alaska (Doerr, 1983), Idaho (Pierce and Peek, 1984), Ontario (Pimlott, 1953) and the Maritime Provinces (Telfer, 1972). But in New Brunswick, Telfer (1972) showed that moose may not fully use cutovers larger than 130 hectares until new stands have grown sufficiently to provide shelter (~15 years or more after logging).

Moose increased five-fold on a large burn in northern Minnesota within two growing seasons after the fire with most of the increase due to immigration by yearlings (Peek, 1974). Moose densities were estimated at 1.0 moose/ km2 and still increasing through improved calf production and high rates of twinning (Irwin, 1974). Selection of burned communities was related to the quantity of food (Irwin, 1975). Deer did not respond as positively to the burn. Moose may be better adapted for rapidly colonizing large burned areas because of their social behaviour in which both sexes of yearlings disperse (Geist, 1971). Peak deer response may occur later in successional sequences. Deer and moose move to the periphery of a burn in winter with deer preferring the closed conifer more so than moose. Habitat characteristics capable of insuring low associations during critical periods may have an influence upon the impact of the nematode *P. tenuis* on moose, similar to the altitudinal separation in Nova Scotia in winter (Telfer, 1967). The fire in Minnesota may have also reduced the numbers of terrestrial gastropods, the intermediate host for *P. tenuis*. It may be assumed, then, that moose evolved mechanisms for rapidly colonizing recently burned forests and capitalizing on the generous quantities of available browse in deep snow areas characteristic of the mid-continental moose range. In contrast, white-tailed deer are less capable of utilizing such areas under similar conditions and require greater amounts of cover within their wintering habitats than moose (Christensen, 1959; Verme, 1965).

In 1967 and 1968, Prescott (1968) studied the moose of northern Nova Scotia and sampled vegetation in forty-three winter yards for availability and use. Earlier, Telfer (1965; 1968a) and Parker (1966) suggested that moose in northern Nova Scotia had become restricted to the uplands as a successful survival alternative to being exposed to deer wintering areas on the lowlands which harbored high densities of snails infected with *P. tenuis*. Subsequent late-winter aerial surveys confirmed that most moose were on the uplands while most deer were on the lower slopes and in river valleys. This presented an interesting situation for Prescott to study.

As mixedwood predominated in most of the yards, Prescott concluded that in northeastern Nova Scotia, where most moose on the mainland were distributed, a habitat of widely diversified vegetation types was the critical factor influencing the use of areas for winter concentration. He identified such typical areas as a belt of open mixed wood along the upper one-third of a slope, usually above 150 m asl (500 ft asl), and lying between the predominantly hardwood dominated tops of the hills and the softwood dominated lower slopes. He found that shelter in the absence of food was not attractive to moose and concluded that moose wintering habitat could be improved through forestry practices designed to provide a good stand mixture of hardwood regeneration for food and mature conifer or conifer/hardwood for shelter. The use of "edge" in the winter was also reported by Telfer (1968b) in New Brunswick, confirming results of earlier studies of wintering moose in Ontario (Peterson, 1955). The amount of mature conifer "shelter" required in this mosaic of forest stand types selected by moose as wintering habitat is dependent upon the depth and duration of snow on the ground.

Less attention has been given the moose of southwestern Nova Scotia, perhaps due to closure of the moose season there since 1938. But that may be the population of moose most threatened. Habitat there lacks the availability of preferred deciduous browse common to the wintering areas on the uplands of northern Nova Scotia, while the absence of altitudinal separation of deer and moose in spring and winter exposes moose to infection by *P. tenuis*. The largest concentration of moose there is towards the southwestern edge of the Tobeatic Wildlife Management Area. Tufts (1981) suggested that the “Tobeatic” moose favour use of the semi-barren or brush barren habitat type. This habitat is restricted to infertile, shallow and coarse granitic soil with large surface boulders and an indurated iron pan which restricts downward movement of water and roots. A more recent study using radio telemetry shows that moose do use the brush barren habitat but only in proportion to its availability, and show marginal preference for mixed hardwood and softwood stands. There are few commercial stands of timber and the better drained sites support only a scrubby sparse growth of white pine (*Pinus strobus*), black spruce (*Picea mariana*) and a heavy cover of tall ericaceous shrubs (Mailman, 1975). Much of land in the TobeaticWildlife Management Area was repeatedly burned through the 1800s and the shallow acidic soils which overlay granitic bedrock have been slow to recover.

The interior "barrens" provide little food for moose in winter, and the more recent effects of acidification on aquatic vegetation, which is little understood, may have further decreased the ability of the landscape to support moose in the summer. In the absence of food habit studies, we can only assume that the quality of the diet of moose there is considerably below that found on moose range in northern Nova Scotia. A recent study of deer and coyotes (*Canis latrans*) a few kilometers to the northeast of the Tobeatic Wildlife Management Area found deer densities there lower than in a twinned study area on Cape Breton Island, even though they were not exposed to mortality from hunting (Lock, 1997; Patterson, et.al., 2002). The authors attributed low densities of deer in southwestern Nova Scotia to less favourable habitat i.e. reduced browse production and proliferation of mature stands of softwood and hardwood dominated mixed wood. Given the tree and shrub species common to the brush barren habitat favoured by moose in the nearby Tobeatic country, it is reasonable to assume that moose there are are also in less favourable habitat than those in other regions of the province such as the hills of Cumberland, Colchester and Antigonish counties. Moose in and around the Tobeatic probably make use of balsam fir, white (*Betula papyrifera*) and gray birch (*Betula populifolia*), red maple and possibly alder (*Alnus* spp.) and ericaceous shrubs.

Management

An assessment of Ontario's Moose Habitat Guidelines concluded that a landscape managed by modifying disturbance patterns by restricting size and configuration of clearcuts supported lower densities of moose than under a management plan with an unmodified progressive clearcut landscape. Much of the problem was the proliferation of access roads to service the smaller cuts and subsequent increased mortality from hunting (Rempel et al., 1997). The authors concluded, however, that landscapes managed to emulate the structure of natural burns concurrent with restrictions on hunter access would lead to increased densities of moose. Habitat manipulation which creates large cutting units or allows fires to burn naturally, especially in areas dominated by northern hardwoods, could favour moose populations. If burns were simulated by logging areas of similar size and shape, moose would be favoured over the more recently resident white-tailed deer.

On mainland Nova Scotia, where approximately 50% of forested land consists of small private woodlots, such a “landscape” management strategy for moose is not possible. On larger contiguous tracts of Crown Land and private ownerships, such as the Highlands of Cape Breton Island, size of clearcuts might be increased to more closely simulate the pattern of disturbance following outbreaks of spruce budworm and wild fire. The Nova Scotia forest management guidelines set operational standards such as maximum cut size and stream buffer widths, among others, designed to enhance ecosystem integrity and biodiversity objectives and not necessarily to improve habitat for moose. They do, however, serve to improve habitat diversity and thereby benefit herbivores, such as deer and moose that require a variety of accessible forest age classes for food and shelter. It is interesting that on Anticosti Island, where there is intensive forest harvesting and where deer densities approach 15-20/km2 (6-8/mi2), there are also approximately 1,000 moose. Deer are heavily infected with *P. tenuis* (~75% of the herd) and the topography is relatively flat (J. Huot, Laval University, pers. comm.). But moose there are restricted to the 20% of the island which was burned a number of years ago and where deer are few. This spatial separation of the two species appears sufficient to allow moose to avoid significant rates of infection with *P. tenuis.* It is also a situation from which more might be learned for maintaining viable moose numbers within a landscape supporting moderate to high densities of white-tailed deer.

BIOLOGY

General

Although the North American moose is a herbivore with a broad distribution across the northern forests, it is also one dependent upon the abundant forage produced within habitats recently (ten to twenty years) disturbed by natural or man-induced disturbances. Home ranges are not large and densities in favourable habitats can reach several per square kilometer. Under such conditions productivity is high and rates of twinning common. However, due to their sedentary nature, high densities often lead to over-browsing and reduced carrying capacity, weakened physical and physiological condition and consequent population declines. Where wolves, the natural predator of moose, are common, a balance is maintained between predator and prey which avoids extreme deterioration of moose habitat from overuse. On mainland Nova Scotia, where wolves are absent, moose have on occasion exceeded the carrying capacity of available range (Dodds, 1963). Recently, however, with no serious predators and full protection from legal harvest, moose have not responded as expected. Ranges for the several recognized local populations have continued to contract and productivity, as a measure of calves to cows, has remained low. Concern has been expressed for the long-term viability of mainland moose (Snaith, 2001). Research is needed to further document population parameters of regional populations and to develop practical management strategies to ensure the long-term survival of this endemic species.

Sex and Age Structure

In Alberta, the pooled male:female sex ratio of yearling and adult moose was 21:50 and survival of moose calves through the summer was variable. Calves comprised 30% of the winter population in 1975-76, 18% in 1976-77 and 20% in 1977-78. Spring calf:cow ratios for females ≥ 3 years old averaged 44:50 (Hauge and Keith, 1981). The sex ratio of the calf harvest in northern Nova Scotia from 1964 through 1974 was 50:50 (Vukelich, 1977). Since hunters favoured adult males over females, it is not surprising that the adult male:female sex ratio in the Nova Scotia harvest was 62:38 as hunters were selecting for trophy bulls. Vukelich (1977) suggested that the adult sex ratio of the population was closer to 45:55 in favour of females. He then proceeded to calculate the gross productivity and rate of increase for the Nova Scotia population and compared those numbers to other studies (Table 2). Those comparisons showed the moose of northern mainland Nova Scotia at that time to be healthy with a moderate to above average reproductive capacity.

More recently, aerial surveys were used to collect information on the sex and age structure of moose in the Tobeatic core area as part of a broader study of the population dynamics and habitat use of moose in southwestern Nova Scotia. Adult male:female sex ratios from surveys in 1993 and 2001 (Brannen, pers. comm.) were 45:50 and 30:50, respectively, not unlike the adult ratio reported for moose killed by hunters in northern Nova Scotia from 1964 through 1974 (Vukelich, 1977).

Reproduction and Productivity

Peterson (1955) reported the length of gestation in moose in Ontario to be 240-246 days while Stewart et.al. (1987) reported 216 days in Saskatchewan, Markgren (1969) 234 days in Sweden and Schwartz and Hundertmark (1993) 231 days in Alaska. In Alaska, Lent (1974) reported estrus to last only 20-23 days, Edwards and Ritcey (1958) cited 30 days and Schwartz and Hundertmark (1993) found it to be 22-28 days. Severe undernutrition may lengthen the period of gestation. Bulls began digging rutting pits in early September in Alaska and remained interested in cows well into November. The rut there began well before and continued well after the majority of conception occurred (Schwartz and Hundertmark, 1993). The age of cows did not influence estrous timing and there was often a second estrous. Age at first reproduction and rates of twinning are related to climate and nutrition (Pimlott, 1959; Markgren, 1969). Gasaway et. al. (1992) found twinning was positively related to habitat carrying capacity, from a high of 90% to a low of 23%. Body condition alone does not control twinning, at least not for cows on a high plane of nutrition. Sex of fetus does not influence the size of calves but single calves are larger regardless of sex (Schwartz and Hundertmark, 1993). The adult pregnancy rate of moose in Alaska was 84% with a birth rate of 114 calves:100 females and a frequency of twinning of 28% (Larsen and Gauthier, 1989).

An analysis of 3,159 moose shot on northern mainland Nova Scotia during the public hunting seasons of 1964 through 1974, found that female moose in the province were as productive as any other population of North American moose (Vukelich, 1977). Of the 135 ovaries examined in that study, the ovulation rate was 90 per 100 adult cows and 20.8% of the adult cows showed double ovulations. There were no triple ovulations in the sample. Six of 13 (46.2%) yearlings showed evidence of approaching estrus. Eighty-five percent of adult females had conceived the previous year with 21.4% having twins. As twinning is often considered an indicator of range condition, the rate in Nova Scotia suggested that moose there were on a satisfactory nutritional plane. Fifty percent of the yearlings from the previous year had conceived as yearlings. Pregnancy rates were 50 calves per 100 yearling cows and 107 calves per 100 adult cows. Net productivity of Nova Scotia moose, as a percent remaining after mortality from causes other than hunting were deducted, was approximately 27%. Pimlott (1959) estimated net productivity of 25% to be expected on good range and that rates of ovulation are influenced by winter and summer nutritional factors. Reproductive parameters of moose on northern mainland Nova Scotia suggested high quality winter and summer ranges (Table 3).

Productivity data from winter aerial surveys flown over moose in the Tobeatic core showed the ratio of calves to adult females to be a healthy 50:100 in 1993 (Nette, pers. comm.) but only 18:100 in 2001 even though calves produced per adult collared female was a healthy 1.26. Aerial observations of collared and uncollared moose during the Tobeatic study showed autumn calf: cow ratios to be 16:100 and 44:100 in 1999 and 2000, respectively, and winter ratios to be 30:100 and 18:100 in 1999 and 2000, respectively (Brannen, pers. comm.). Of nine collared female moose in the Tobeatic, six gave birth but only one of those calves survived the first year. The proportion of collared females with calves that had twins was 26.6%, and although not high, comparable to other North American populations (Brannen, pers. comm.). Although the herd composition data from the Tobeatic surveys show considerable variation, there is reason for concern over the apparent low rates of calf survival.

Mortality and Survival

In a study in Alberta, the annual survival rate of calves was 0.27 with 29% of the calf crop lost to wolves. The pooled survival rate of yearlings and adults was 0.75 (Hauge and Keith, 1981). Moose in areas with few natural predators, such as Nova Scotia, commonly show lower rates of adult mortality, ranging from 4-11% per year (Mytton and Keith, 1981; Gasaway et al., 1983; Messier and Crête, 1985). Similar to Nova Scotia, the only important natural predator of moose in

Newfoundland is the black bear, which primarily attacks calves. By six months of age, however, moose in Newfoundland experience an estimated 5% rate of mortality from bears, similar to that of adult moose. (Fryxell et al., 1988). Young moose are probably free of high mortality from bears much earlier, possibly by six weeks of age (Nette, pers. comm.)

Annual survival of adult females in Alaska was 91% with most deaths occurring between May and October (Larsen and Gauthier, 1989). Grizzly bears (*Ursus arctos*), wolves and humans accounted for 50, 26 and 9% of all mortalities of moose >1 year of age. The authors concluded that bears and wolves were limiting northern moose populations in their study area. Mean annual survival of collared female moose in Kenai National Refuge in Alaska, from 1980 to 1986 was 0.92. Causes of death, in order of importance, were automobile, natural accidents, old age related disease, grizzly bear and hunting. There was no mortality from wolves. Survival of moose 1-5 years of age is often near 1.0 and for moose ≥11 years old ≤0.60 (Mech, 1970; Peterson, 1977; Gasaway et al., 1983). Habitat quality, winter severity, predation, legal hunting, poaching and parasites influence moose survival. In a high moose density area of Quebec, hunters harvested 20% of the population over 10 years old with no measureable decline in moose (Crête and Bédard, 1975). In general, survival rates for adult moose range from 0.75 to 0.94.

In New Brunswick a 4-year study of the dynamics of moose subjected to a three-day and 6,000 licence season in September found the annual mortality rates for adult males and females to be 47% and 25%, respectively, although hunting accounted for only 20% and 7%, respectively. Natural mortality was responsible for most of the loss of adults, specifically from *P. tenuis*, poaching and vehicle collisions (Boer, 1988). Total loss of New Brunswick moose to hunting was 11% compared to 24% in Quebec (Messier and Crête, 1984).

A study of the reproduction and productivity of the moose in northern mainland Nova Scotia during the hunting seasons of 1964 to 1974 found that the major sources of non-hunting mortality were *P. tenuis*, illegal hunting and collisions with vehicles and trains (Vukelich, 1977). Other than the black bear, there are no major predators of moose in Nova Scotia and no evidence that the newly established eastern coyote is a predator of any significance. On the mainland there is no legal hunting. In other systems, particularly in the northwest, both wolves and bears have been found to be major predators of adult and calf moose (Fuller and Keith, 1980; Hauge and Keith, 1981; Bergerud et al., 1983; Messier and Crete, 1985; Ballard and Larsen, 1987; Gasaway et al., 1983). Removal of predators often increases adult and calf survival and population growth (Gasaway et al., 1983; Ballard and Miller, 1990). Wolves limited the increase of moose in Pukaskwa National Park in Ontario (Bergerud et al., 1983). Those authors considered mortality from predation, especially bears, to be negligible and could find no reason to suggest that mortality of calves differed from that of adults. The illegal kill was unknown but believed to have been significant in certain accessible areas. They expressed concern for the proliferation of access roads associated with the forest industry and the subsequent increased rates of poaching. Vukelich (1977) considered loss of moose to predation from black bears in northeastern Nova Scotia to be negligible. He summarized reported losses of moose (n=141) to causes other than legal hunting for the five northern counties of mainland Nova Scotia, 1962 through 1975 (no data for 1970-73): to *P. tenuis* – 15.7% (all ages), illegal kill – 14.8% (all ages), unaccounted accidents to calves 10.0% and adults and yearlings 59.5%. Vukelich quoted Hansen (1975) as suggesting that a 6% mortality from *P. tenuis* in moose of Nova Scotia to be reasonable.

In southwestern Nova Scotia the apparent high loss of calves in early summer (80% of calves with collared females) may be due to predation by bears (Brannen, pers. comm.). Bears there are abundant, and most loss of calves appears to occur in spring-early summer when calves are most vulnerable to predation. But other factors of unknown origin may be responsible as well, such as recently detected elevated levels of heavy metals in tissue samples of moose from the Tobeatic area (Nette, pers. comm.).

Food Habits

The moose has been the subject of much study across its range and its choice of habitats and feeding habits have been described at great length. The general rule seems to be that the choice of plants eaten is more closely related to availability than palatability. Species selected by moose in winter include the terminal twigs and branches of both coniferous and deciduous woody plants, such as willow (*Salix* spp.), dogwood (*Cornus stolonifera*; *C. alternifolia*), elder (*Sambucus pubens*), pin cherry (*Prunus pennsylvanicus*), mountain ash (*Sorbus* spp.), maple, white birch, aspen and balsam fir, among others. Most are shade intolerant species common to early and mid-successional forest stands found on mainland Nova Scotia. Moose seek out habitats which support those food sources. Although duration and depth of winter snow may restrict movement and survival of white-tailed deer, moose, with longer legs and higher reach, are seldom hindered by winter weather conditions in the Maritimes, especially on mainland Nova Scotia. In times of food scarcity, moose may "ride down" small saplings to reach browse otherwise unavailable. Under specific conditions in Nova Scotia, such as in budworm ravaged stands where balsam fir is often the dominant regenerating plant species, that food source can be important to moose. Moose in Newfoundland, with some of the highest densities on the continent, survive the winter quite nicely on a diet rich in balsam fir (Pimlott, 1953). Dodds (1955) found that the four species of browse preferred by moose on selected burns in Newfoundland to be pin cherry, white birch, balsam fir and trembling aspen (*Populus tremuloides*). In most of the Maritimes, fir is replaced by maple, and in Labrador and much of the mainland taiga, by willow. In parts of Ontario birch, balsam fir and alder are readily consumed and in the northwest aspen, willow and birch.

In spring, with the appearance of leaves and new growth of deciduous twigs, the diet of moose expands to include many of the available plant species. But the general palatability preferences for deciduous woody plants during summer is similar to those during winter (Krefting, 1946; Krefting and Lee, 1948). Four species of browse - paper birch, willow, mountain ash and pin cherry - were used by moose in cutovers in Ontario and accounted for 76% of browsed twigs (Pimlott, 1953). The author suggested that a low density of moose is often thought to be responsible for low use of balsam fir, i.e. more deciduous browse available. Balsam fir is avoided in the summer and is not readily eaten until after the frosts of October (Peterson, 1955). Spruce and pine, common in southwestern Nova Scotia, are seldom eaten and are considered a starvation diet. Ground hemlock (*Taxus canadensis*), where available, is a preferred species at all seasons (Murie, 1934). It is generally accepted, especially in the eastern part of its range, that aquatic and semi-aquatic plants comprise the bulk of the diet of the moose in summer. Pondweed (*Potamogeton* spp.), common yellow pond lily, water shield, and bur-reed (*Sparganium fluctuans*) are supplemented with upland plant species such as honeysuckle (*Diervilla Lonicera*). In New Brunswick extensive feeding by moose on aquatic vegetation, such as pond lilies, can cause the reduction or disappearance of those species from specific wetlands (Wright, 1956). With the arrival of autumn frosts and reduced palatability of aquatic plants, moose leave the wetlands and move back into the forests, preferring open habitats until January at which time they move into closed conifer and mixed wood cover (Nette, pers. comm.). Seepage areas with high concentrations of calcium, or salt licks, are often heavily trampled and used by moose, especially in eastern Canada (Wright, 1952).

Assessments of browsing in winter yards in northern Nova Scotia (Prescott, 1968) indicated that the "most browsed" species were, in order of preference, red maple, balsam fir, yellow birch (*Betula lutea*) and mountain maple (*Acer spicatum*). A separate browse analysis found that 65.5% of available twigs consisted of the following six species, in order of importance - mountain maple, yellow birch, sugar maple (*Acer saccharum*), balsam fir, red maple and hazel (*Hamamelis virginiana*). Those six species accounted for 90.1% per cent of food eaten. An earlier study of moose range in southcentral New Brunswick showed that preferred winter food by moose included gray birch, yellow birch, white birch, red maple, striped maple, willow, aspen, white cedar, among others (Wright, 1956). Only moderate use was made of balsam fir. Prescott (1968) found that balsam fir was used as an alternative food in the absence or scarcity of the preferred deciduous browse species in northern Nova Scotia. In high density moose wintering yards in Quebec, the four most commonly used browse species were mountain maple, balsam fir, beaked hazelnut (*Corylus cornuta*) and paper birch (Crête and Bédard, 1975). In Minnesota, fifty percent of the terrestrial diet of moose consisted of willow, red maple, aspen and white birch (Irwin, 1975).

Moose are large ruminants that require substantial quantities of plant biomass intake to sustain growth, health and successful reproduction. Calculated daily comsumption rates for moose in Quebec vary from 2.5 kg. dry wt. per day (Crête and Bedard, 1975) to 10.0 kg dry wt. for cows and 6.7 kg for calves (DesMeules, 1965). In Newfoundland moose consumed 7.7 to 9.9 kg dry wt. of balsam fir per day (Bergerud and Manuel, 1968), during summer on Isle Royale in Michigan 4.5 kg dry wt. per day (Belovsky et al., 1973) and in Alaska 1.3 to 5.4 kg dry wt. per day in winter (Gasaway and Coady, 1974). In the Alaska study the authors further calculated daily energy needs and estimated an adult moose required 4.5 to 5.5 kg dry wt. per day to sustain body condition. Moose have evolved with body condition and photoperiod as mechanisms which control the level of food intake. These mechanisms operate regardless of availability of high quality food and moose voluntarily reduce intake in winter. In spring, the process is reversed. There is increased intake with environmental changes in food quality and availability (Schwartz et al., 1984). Rather than conventional thought for improving winter range by habitat enhancement through forest harvest operations it may be more beneficial (for moose) to increase value of both summer and winter range (Schwartz et al., 1988).

In summary, 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. The opposite may be true in the southwest, where fire suppression, in particular, has allowed the interior scrub barrens to regress into habitat supporting low food resources for moose or deer. Home ranges of moose there are large compared to studies elsewhere (Brennan, pers. comm.), suggesting lower quality of habitat. Possible reduced availability of aquatic food species should be given special attention considering the recent changes in water chemistry from anthropogenic acid deposition over much of the province, especially the southwestern sector where a granite substrate provides little buffering capacity.

Harvest

In 1902 the number of moose shot on mainland Nova Scotia was estimated at 350; in 1907, the first year hunters were required to report their kill, it was 486. In 1908 cow moose were protected, and the population responded, with a harvest of 1,480 by 1921 (Peterson, 1955). The kill declined to 890 in 1924, increased to 1,567 in 1931 only to fall back to 809 in 1935. The season was closed in 1938 (Figure 3). The trend line suggests that the population peaked in the mid-1920s and declined thereafter (Figure 4). The decline in harvest of moose shows an inverse trend with the increase in harvest of deer (Figure 5). Following the first aerial moose survey in winter 1963-64, a ten day trial season was opened in 1964 for the four northern counties of Cumberland, Colchester, Pictou and Antigonish. Four hundred licences were issued by lottery. Results were assessed in 1965 and the season reopened in 1966 with 800 licences issued. One thousand licences were issued in 1967 and the season continued unchanged though 1974.

Prescott (1968) compared the average kill of moose for specific counties in northern mainland Nova Scotia for the years 1964, 1966 and 1967 to averages from 1908 to 1937 (Table 4). In most instances the kill of moose per square kilometer in the mid-1960s was greater than that from 1908 to 1937. Lack of reliable license sales by county for the earlier period discourages a less bias assessment of change in moose abundance through kill estimates. But distribution of moose throughout the mainland was more restricted in the 1960s, suggesting that although the overall range and numbers of moose had declined, densities had remained stable in those areas which still supported moderate numbers of moose. There was little change in the annual kill from 1967 through 1974. Following a two year closure, the season was reopened in 1977 in the northeastern counties - 650 licences from random draw were distributed among six moose management zones. The season was closed following the 1981 hunt due to concern over declining hunter success and numbers of moose (Table 5).

Although several hundred moose were left in the population each year following closure of the season in 1981, the population failed to grow. In fact, it appears that numbers of moose in northern mainland Nova Scotia declined, from an estimated 1200 in the mid-1970s (Vukelich, 1977) to 600-800 by 2001 (Hall, 2001). The question to be asked is what prevented the northern mainland population from increasing, given the absence of legal harvest, minimal predation from black bears, low rates of accidental death, good rates of reproduction and high rates of twinning and calf survival reported by Vukelich in the 1970s? Possibilities include poaching, mortality from *P. tenuis* and reduced availability and quality of habitat from increased forest harvesting through the 1980s and 1990s.

Disease

The disease of greatest concern to the health of moose in eastern North America is the internal nematode parasite *Parelaphostrongyly tenuis*, commonly referred to as "moose sickness," or "brainworm." Although the moose, similar to most ungulates, can be host to a variety of parasites and insect pests, few, other than *P. tenuis*, have proven to be of serious consequence to the overall health of most populations. East of the St. Lawrence River, where wolves have been rare to absent for many years, moose are generally considered to be free of tapeworm hydatid cysts (*Echinococcus* spp.*; Taenia* spp) common to populations where the two species cohabit (Sweatman, 1952). It is uncertain how the recent colonization of eastern North America by the coyote may influence the transmission of such diseases. It is reasonable to expect low incidences of such endemic internal parasites as liver fluke (*Fascioloides magna*), bladderworm (*Cysticercus* sp.) and assorted intestinal nematodes.

Historically, the most important external parasite of moose was the winter or moose tick, *Dermacentor albictus*. Nymphal and adult ticks engorge on blood during the critical March-April period of progressive nutritional and energetic stress, then drop off (Glines and Samuel, 1989). Winter tick epizootics have been associated with major die-offs of moose in central Alberta (Webb, 1959; Samuel and Barker, 1979). Low precipation and warm temperatures during April appear to be conducive to maximum survival and subsequent reproduction of ticks, thus potentially resulting in increased numbers the following autumn and winter. Snow cover adversely affects survival of disengaging females and survival of winter ticks decreases at mean April temperatures ≤3-4° C. Severe nutritional restriction associated with tick infestation may have contributed to the decline of moose on Isle Royale during 1988-90 (DelGiudice et al., 1997). The winter tick infestation rate on moose appears to be weather dependent and density independent (DelGiudice et al,, 1997). It was reported as common when populations were larger, such as in the early 1930s (NSDLF, 1932; 1936), but with the current low densities it is uncertain how important the winter tick is to the general health of the provincial population. Moose live-captured during a radio-telemetry study in the Tobeatic region (1998-2001) were quite heavily infested with winter ticks, and had lost significant amounts of fur from rubbing (Peter MacDonald, pers. comm.). The wood tick, *Dermacentor variabilis,* common only in southwestern Nova Scotia, is believed to have been brought to Yarmouth on hunting dogs transported by ferry from New England in the early 1900s (Benson, 1964). Although this external parasite may be an “irritant” to moose in the summer, it does not remain on hosts in winter and should not pose a health risk to the moose in that part of the province.

Although the source of the disease known as "moose sickness" was uncertain at the time, Peterson (1955) provided the following accurate description of the clinical symptoms almost fifty years ago. "Moose are subject to a 'moose disease' which seems to be manifested by a large variety of symptoms, including loss of fear of man, weakened and emaciated condition, aimless wandering or refusal to leave a certain place, partial or complete blindness, travelling in circles, dropping of one ear, holding of the head to one side, partial paralysis of the limbs, and finally inability to rise or stand, followed by death." Thomas and Cahn (1932) made the first attempt to isolate the cause of this sickness when they attributed it to a "virulent organism" transmitted to moose by the winter tick. Unable to repeat their experimental transmissions of a single pathogen, Fenstermacher (1934a, 1934b) suggested the cause of moose sickness might be from a combination of factors, including diet. In Maine, Lamson (1941) supplemented the diet of several sick captive moose with foods high in vitamins with some success and concurred that the cause might be from nutritional deficiencies. In Nova Scotia, Cameron (1947) was the first to report a yearling moose with visual impairment. In the early 1950s, Benson (1952) successfully treated a captive sick moose in Nova Scotia with cobaltus chloride and concluded that the disease might be caused by cobalt deficiency but was unable to repeat those results. He later reported on forty-seven cases of moose showing behavioural symptoms suggestive of neurologic disorder which, he suggested, was most likely a product of environmental changes and subsequent nutritional problems (Benson, 1958a; 1958b). By the early 1960s, Dodds (1963) confirmed the surprisingly high "natural" mortality of moose in Nova Scotia and agreed with Pimlott (1961) who suggested that the nutritional concerns expressed by Benson might be related to competition for food with the newly established and expanding population of white-tailed deer.

It was not until the experimental transmission of *P. tenuis* larvae from terrestrial gastropods to captive moose in Ontario that the real cause of "moose disease" was demonstrated (Anderson, 1964a, 1964b, 1965). The ground-breaking studies by Anderson spawned a profusion of field research projects in the northeast. Sick moose from Nova Scotia and New Brunswick were brought to Agriculture Canada's Animal Pathology Laboratory in Sackville, New Brunswick where four of nine were found to harbour *P. tenuis* (Smith et al., 1964). In Nova Scotia, Telfer (1965) conducted aerial surveys, doccumented the concentration of moose on the uplands in the northeast and attributed that distribution to their separation from deer in the winter and early spring when the deer move to the lowlands because of the deep snow and subsequent lower exposure of moose to gastropods carrying infective *P. tenuis* larvae. Parker (1966) documented frequencies of infection of deer feces and gastropod species with *P. tenuis* larvae throughout the province and agreed with Telfer that winter deer yards represented areas of high concentration of feces and infective larvae. A recent study in Ontario (Lankester and Peterson, 1996) confirmed the higher incidence of *P. tenuis* infective larvae in gastropods collected in deer yards (0.16%) to gastropods collected at random (0.04%). Upshall et al. (1986) collected gastropods in various forest types in New Brunswick and confirmed that most were restricted to deciduous dominated habitats. He also found that *P. tenuis* larvae were restricted to three species of gastropods and the infection rate for all gastropods collected at random was a surprisingly high 2.4% (compared to 0.7% in Nova Scotia - Parker, 1966).

Other studies followed. Hanson (1975) further clarified the rates of infection of deer (~66%) in the province and found low rates in apparently healthy moose shot by hunters (6%). Brown (1983) confirmed those rates of infection in both deer (50-60%) and moose (6-12%) in Nova Scotia. Thomas and Dodds (1988) examined hundreds of fecal and brain samples from Nova Scotia and found infection rates of 50-60% in deer and 7-12% in apparently healthy moose. A province-wide collection of deer feces in 1992 found the mean incidence of infection by *P. tenuis* larvae to be only 29% (Meade, 1993), a time when deer densities throughout the province had dropped significantly from the highs of the 1980s. Lower densities of deer may have decreased opportunities for transmission of the disease within the provincial deer herd. In contrast, more recent analyses (2000-2001) of 127 deer fecal samples collected throughout the province showed an infection rate of 54.3% (Brannen, pers. comm.). It appears that spatial rates of infection may show considerable variation, but that the average rate in the provincial deer herd is in the range of 50-60%. By the early 1970s, the occurrence of neurologic disease in moose of northeastern North America was well doccumented. Examination of 1450 white-tailed deer pellet groups collected from Nova Scotia to eastern and central Saskatchewan confirmed the wide distribution of the disease (Bindernagel and Anderson, 1972).

Most authors have assumed that the incidence of *P. tenuis* in moose, and subsequent rates of moose mortality, are correlated with numbers of white-tailed deer which share a common range (Karns, 1967; Anderson, 1972; Gilbert, 1974; Kearney and Gilbert, 1976; Lankester, 1987; Morner, 1987). Others have suggested differently. Both moose and deer numbers increased in Maine through the 1970s and 1980s (Dunn and Morris, 1981; Lavigne, 1986) and during the 1970s in Minnesota (Irwin, 1975). Moose in Maine increased from the late 1960s through the 1980s even though the prevalence (~80% rate of infection) and geographic distribution of *P. tenuis* in adult deer remained constant (Bogaczyk et al., 1993). Moose in New Brunswick increased concurrent with peaks in harvests of white-tailed deer in the mid-1980s, prompting Boer (1992) to conclude that "If *P. tenuis* is an ultimate factor which determines the potential density of moose below K carrying capacity, then the relationship does not appear to be strictly a function of deer density."

Garner and Porter (1991) further questioned conventional thought and pointed out the expanding populations of both deer and moose throughout northeastern United States (late-1980s), a fact suggesting that, under certain circumstances deer and moose were able to co-exist. Rather than a direct correlation with deer density, moose might be equally impacted by regional factors which influence rates of infection of both gastropods and moose, such as precipitation, habitat type, soil type, abundance of suitable gastropod hosts, and the degree of ecological separation between moose and deer. Gilbert (1974) hypothesized that although moose might appear to cohabit range with deer they were actually restricted to "refugia," which for whatever reason, allowed little contact between deer and moose. Subsequent research by Kearney and Gilbert (1976) in Ontario confirmed that such a situation existed on the Himsworth Game Preserve and strengthened their hypothesis in support of the importance of ecological isolation in protecting moose from the parasite. Nudds (1990) chose to challenge the untested hypothesis of the effects of *P. tenuis* on moose populations. He suggested such reasoning had been accepted uncritically and that there was little evidence to suggest that mortality of moose from *P. tenuis* had necessarily resulted in the effects on moose populations and habitat use ascribed to it. He chose, rather, to postulate that the importance of habitat alteration, food competition and other sources of mortality might be of equal or greater importance than disease on moose demographics. Gilbert (1992) in turn challenged the critical analysis by Nudds but did agree that the data were correlative and suggestive only while supporting the possibility of alternative hypotheses. Nudds (1992), having the final say, agreed to disagree but called for studies to test the validity of the deer-moose correlations.

Whitlaw and Lankester (1994a) accepted the challenge and examined long-term historical data for associations between moose population declines, white-tailed deer densities and reports of *P. tenuis* as a test of the hypothesis that a direct correlation does exist. Although they did find that moose declines were associated with deer densities greater than 5/km2, the existing data failed to discount other factors which may have influenced those declines, and the authors concluded that the ways and extent to which the disease limits moose populations cohabiting with infected deer required further research. In a related paper (Whitlaw and Lankester, 1994b) the authors continued that theme and concluded that "the documented persistence of moose in numerous areas with infected deer, and case studies of recent moose declines, suggest that the effect of this parasite on moose populations is more subtle than was previously believed, and further study is required to separate and measure its importance relative to other mortality factors known to act on moose populations."

In Nova Scotia there currently exist several spatially separated populations of moose at alarmingly low densities. One is restricted to the hardwood-dominated uplands of Cumberland and Colchester counties, with lower numbers further to the east in the Pictou-Antigonish Highlands, both of which are believed to be confined there due to altitudinal separation from deer during the winter and early spring seasons when deer retreat from the highlands due to the deep snows. This seasonal demarcation of range, the hypothesis suggests, decreases opportunities for infection of moose with infective stage larvae common in areas of winter and early spring deer concentration. But moose in Pictou County, in particular, have experienced a marked decline in the past twenty years, perhaps due to an increase in clear-cutting of the highlands and proliferation of forestry roads (Ross Hall, pers. comm.). These changes have allowed greater access by deer and humans into moose range and increased potential for both disease and poaching. As in other areas of the northeast, however, deer and moose do successfully cohabit certain ranges, but the exact mechanism (s) which allow this apparent anomaly to conventional thought remain unknown. Irwin (1975) has suggested such situations might be explained by low diversity and densities of terrestrial gastropods exacerbated by recent soil acidification from anthropogenic sources. Densities of deer in Nova Scotia and New Brunswick declined significantly in the late 1980s due to severe winters and predation by the newly established eastern coyote. Deer numbers have remained low in spite of moderating winter weather, giving support to the hypothesis that the coyote has replaced the wolf as the major predator of deer in the northeast and mortality from coyotes, especially fawns in the summer, may be additive and contribute to sustained suppressed deer populations (Ballard et al., 1999; Whitlaw et al., 1998). Deer densities may be sufficiently low in areas occupied by moose in southwestern Nova Scotia that opportunities for infection by moose, and perhaps deer, are such that the two species can successfully cohabit common range, as has been suggested elsewhere, albeit with moose remaining at dangerously low densities.

Based upon *P. tenuis* larvae in moose droppings, some researchers have suggested a gradual tolerance by moose to the parasite (Clark and Bowyer, 1987; Thomas and Dodds, 1988), but others have questioned the credibility of those analyses, both in the identification of the larvae themselves (Ballantyne and Samuel, 1984) and in the possibility of contamination of equipment during the analyses (McCollough and Pollard, 1993; Forrester and Lankester, 1997). But the identification of *P. tenuis* eggs in the lungs from a moose near Baddeck, Victoria County in 2000, and from the meninges of the brain from a moose found dead in surprisingly good condition in Colchester County in 2003, further demonstrates that the nematode is able to complete its life cycle in moose before dying from the disease (McBurney, pers. comm.).

Even with the profusion of studies that followed the initial identification of *P. tenuis* as the causative agent for what is known as "moose sickness" almost 40 years ago, there remains much confusion and debate on what dictates current moose and deer densities on sympatric ranges in eastern North America. That *P. tenuis* causes "moose sickness" is without question. That the disease was responsible for declines in moose populations concurrent with increases in white-tailed deer is generally acknowledged. What has allowed moose to increase, or remain stable, in the past several decades on ranges apparently cohabited by white-tailed deer remains the subject of debate. Gibbs (1994) provides the following appropriate conclusion to this discussion. "It seems that unequivocal evidence for a direct inverse relationship between meningeal worm prevalence in deer and numbers of moose is lacking. The epidemiology of meningeal worm infection in moose is complex. Because of different behavioral patterns, some sort of ecological separation between sympatric populations of deer and moose may exist. Possibly because of differences in feeding behavior, opportunities for acquisition of larvae by moose even in heavily contaminated areas may be absent or reduced."

An interesting example of an apparent successful sympatric range occupation by moose and deer is on Anticosti Island. The island is approximately 8,000 km2 in size and supports approximately 120,000 white-tailed deer (~15-20/km2) and 1,000 moose. Although moose are protected, sport hunting of deer is a major industry and contributes more to the economy than an active forest industry. A study in the mid-1970s showed that approximately 70% of the deer carried *P. tenuis* (Jean Huot, Laval University, pers. comm.) but there have been no known mortalities of moose by the disease. The calcareous soils support high populations of terrestrial gastropods. Most moose are restricted to the 20% of the island that was subjected to a recent wildfire. This may be the reason that moose have avoided infection by *P. tenuis,* i.e. disparate habitat selection by moose and deer.

One other concern for the health of moose in Nova Scotia is both recent and disturbing, with possibility of significant consequences. Many contaminants may bioaccumulate in the organs of wild animals, and some, such as the metal cadmium (Cd) tend to accumulate at higher levels in herbivores than carnivores (Frank, 1986). Consequences of cadmium toxicity include kidney and liver dysfunction, brittle bones and reproductive failure (Scheuhammer, 1991). Cadmium occurs in the environment from both natural and anthropogenic sources, yet another product of industrial pollution. Similar to other air borne contaminants, cadmium may travel great distances from point sources before entering the soil and water through the medium commonly referred to as "acid rain." Surficial geology is important in the process of acidification of soils and waters from the long-range transport of these air-borne contaminants. Carbonate bearing bedrock such as gypsum, limestone, marble and calcite are considered to be non-sensitive to acid loading. Sensitive bedrock to acid loading include sandstone, granite and gneiss. Conifer forests are conducive to producing acidic environments while deciduous forests contribute to a high buffering environment (Roger, 2002). In areas where the buffering capacity of the soil is low, such as much of southwestern and northeastern mainland Nova Scotia and on the Highlands of Cape Breton Island, the effects of acid rain are most damaging to the environment (Roger, 2002). Approximately 85% of Nova Scotia has terrain characteristics that have minimal buffering capacity to neutralize acid precipation (Hirvonen, 1984).

The natural metals of the bedrock may also be released through the process of acidification allowing certain toxic materials, such as cadmium, to be absorbed into the natural environment through plant intake and subsequently into herbivorous animals, such as deer and moose. On intake by herbivores, cadmium becomes concentrated in certain organs, especially the liver and kidneys, much more so than in muscle tissue. Through the process of biomagnification, cadmium accummulates in those organs over the life of the animal. Unacceptably high levels of cadmium in the kidneys and livers of deer and moose is not new and has led to health advisories on the consumption of these organs from wild cervids from a number of northeastern states and provinces (Stansley and Roscoe, 1991).

The recent isolation of high concentrations of cadmium in the livers and kidneys of moose and deer in Nova Scotia represent some of the highest ever reported in free ranging herbivores in the northeastern states and eastern provinces (Roger, 2002; Tables 6 and 7). Even more disturbing is the increase in cadmium levels of deer liver tissue over the past few years (Table 8). Experimental evidence suggests that cadmium may function in, or may be an etiological factor for, various pathological processes including testicular tumours, renal dysfunction, hypertension, arteriosclerosis, growth inhibition, chronic diseases of old age, and cancer (Roger, 2002). One of the main physiological consequences of high-level cadmium dosage has been changes in bone. A study linked chronic zinc-cadmium exposure to lameness, swollen joints and nephrocalcinosis in horses. Although there is reason for concern of high levels of cadmium in Nova Scotia moose and deer, no evidence for associated illness or disease has yet been isolated in provincial wildlife.

Recently, moose have been found incapacited with symptons similar to those associated with *P. tenuis* but, on autopsy, show diffuse inflammation and legions of the brain more typical of viral infection and an absence of adult *P. tenuis* worms (Scott McBurney, pers. comm.). Most sick animals do not show the emaciation often associated with advanced symptons of *P. tenuis*. Possible sources of viral disease include rabies, distemper and West Nile virus. These investigations continue by Dr. Scott McBurney of the Canadian Cooperative Wildlife Health Centre at the Atlantic Veterinary College diagnostic laboratory in Charlottetown, Prince Edward Island. Prior to these recent investigations, many sick moose from Nova Scotia were "assumed" to have harboured *P. tenuis*, when they may have suffered from other causes, such as the recent cases of suspected viral infection.

Movements/Home Ranges/Dispersal

In winter, when low-quality forage limits energy intake, cervids living in northern latitudes decrease metabolic rates and reduce forage intake (Ozoga and Verme, 1970; Moen, 1978). Summer may be a critical season for moose because fat and protein stores are replenished and the size of those stores determines how long animals survive in a negative balance during winter (Belovsky, 1978; Schwartz et al., 1988). Moose in Denali National Park, Alaska showed daily activity patterns that increased in May, peaked in early June and decreased thereafter (VanBallenberghe and Miquelle, 1990). The mean number of activity bouts per day did not vary but moose varied the duration of activity and resting. In June, moose may spend 75% of active time feeding and food intake can increase by two to three fold from winter to summer (Schwartz et al., 1984); Renecker and Hudson, 1985). "Large body size, high energy requirements and the need to store fat and protein for long winters of negative energy balance result in feeding being a dominant summer activity of moose even when forage is superabundant" (Van Ballengerghe and Mirquelle, 1990).

Dispersal has been defined as any movement of an individual or its offspring that brings the animal out of its home range and results in the establishment of a new home range. Dispersal is most frequently observed in juveniles of a species - the sedentary nature of adult moose limits their contribution to colonization. In Quebec, dispersal is most common in yearlings (72% of incidences) and individuals can disperse up to 50 km (Labonté et al., 1998) creating potential for ingression into declining populations and the maintenance of metapopulations (McCullough, 1996). The ranges of many moose populations are not contiguous, and the persistence of such metapopulations is dependent on dispersal. Moose from high density areas may disperse into areas of low density (or from unhunted to hunted areas). Population density is generally considered the most important factor influencing dispersal of young moose (from high to low) (Gasaway et al., 1980; Ballard et al., 1991).

Home range is an area normally traversed by an organism for food collecting, breeding and rearing of young (Burt, 1943). In Alberta moose displayed seasonal shifts between winter and summer home ranges, many of which exceeded 20 km., and there were no differences in size of home ranges between males and females (Hauge and Keith, 1981). Moose home ranges in summer were reduced to 2.5 km2 in Minnesota (Van Ballenberghe and Peek, 1971) and 3.0 km2 in Alaska (Houston, 1968) and Ontario (de Vos, 1956). In northwestern Minnesota home ranges of collared moose, in summer and fall, were 17.9 km2 for cows and 14.5 km2 for bulls. Winter home ranges averaged 3.6 km2 for cows and 3.1 km2 for bulls. About 20% of moose were migratory, distances ranging from 14.4 to 33.6 kms. Rates of travel were greatest in the summer months (average 0.9 km.) per 24 hour period). Bulls traveled widely during the rutting period while cows remained sedentary (Phillips et al., 1973). These home ranges were similar in size to those found in other studies (Peterson, 1955; Knowlton, 1960; McMillan, 1954; Houston, 1968).

A study of the population dynamics and habitat modeling of moose in the Tobeatic district of southwestern Nova Scotia was conducted from 1998 through 2001, the results of which will be submitted to Acadia University in spring, 2003 as partial requirements for a M.Sc. degree (Brannen, pers. comm.). Radio telemetry of moose showed that individual home ranges often overlapped, varied little in size with season and significant movement between seasons was rare. The mean sizes of winter, summer and autumn home ranges for nine collared females were 20.3, 23.9 and 22.7 km2, respectively. The overall home range was 41.9 km2, much larger than those reported for moose elsewhere. Only one collared moose, a female with calf, showed extensive annual movement, ranging approximately 32 km. (20 mi.) between winter and summer home range for two consecutive years.

In Maine, where moose are mainly sedentary, winter home ranges are within or adjacent to summer home ranges (Dunn, 1976; Crossley and Gilbert, 1983). Radio tracking of moose in Maine in 1984 and 1985 found mean home ranges of 27.9 km2 (Leptich and Gilbert, 1989). There was no difference in home ranges between males and females although individual home ranges varied from 2 - 60 km2. The variation was due to configuration i.e. females often moved in elongated ranges between aquatic habitats and the forest. Other home ranges for moose are: Minnesota - 15.9 km2 (Phillips et al., 1973); Alberta - 20 km2 (summer) (Hauge and Keith, 1981); Maine - 18.1 km2 (cow and calf in summer) (Dunn, 1976); and Maine - 25.8 km2 (cows and calves in summer) (Crossely and Gilbert, 1983). Most studies have confirmed similar home range size between sexes and a great degree of home range fidelity by both sexes (Leptich and Gilbert, 1989; Crossley and Gilbert, 1983). In Sweden, mean home range of adult female moose was 12.6 km2 (Cederlund and Okarma, 1988). Females often use several core areas within a home range containing a mean of 85% of telemetry locations but only 50.4% of the total area. Moose made greater use of core areas in winter while summer home ranges were twice as large as home ranges in winter. The increase in moose in Fennoscandia in the 1970s and 1980s was related to an increase in the amount and distribution of food resources caused by changes in forest management and controlled, selective hunting.

POPULATION SIZE AND TRENDS

It remains uncertain how many moose may have been on mainland Nova Scotia at the time of first European colonization in the early 17th century. Moose were certainly abundant and widespread and the Mi'kmaq relied extensively on the meat and hide for sustenance, especially during the winter months (Denys, 1672). In the absence of significant human population growth and landscape change during the next one hundred years or so, the numbers of moose remained relatively uninfluenced by residents of the few settlements scattered along the coast. Most settlers relied upon the soil and sea for their livlihood and few ventured far into the encroaching forests in search of wild game. With the arrival of the New England Planters following deportation of the Acadians in 1755, and the influx of Loyalists in the early 1780s during the American Revolution, the impact of humans on wildlife took a turn for the worse. The subsequent growth in commerce with Britain brought growing demand for the wildlife and timber from the remaining American colonies. The hunting of moose in winter for their hides to supply the British fashion industry created a great drain upon the moose of the Maritimes. Benson and Dodds (1977) provide a good review of references to moose and caribou in records from the province during the late 1700s. And wild game meat became a valued commodity at the city and country markets of Nova Scotia - thousands fell to the market hunters and poachers each year. Repeated fires, most caused by humans, became rampant, especially in the southwest, and much of the interior was converted to scrub barrens, a condition which remains today.

Based upon a summer survey, Smith (1801) expressed concern over the dwindling supplies of moose and caribou. "The moose appear to be almost destroyed in most parts of the Province...," and, "Upon the great influx of inhabitants into the Province after the American War many new settlements being formed and great numbers of moose killed by white hunters, the Indians in general seem to have resolved to destroy the game rather than share them with the whites. In many places they killed ten times as many as they could make use of, and in the course of three or four winters almost entirely destroyed the Moose and greatly diminished the Caribou." It appears likely that this period of moose scarcity around 1800 continued to at least 1825, and perhaps longer (Benson and Dodds, 1977). We do know that British legislation was introduced in the early 1840s which empowered the province to take measures to protect moose through closed seasons, but whether such actions were implemented in a meaningful manner is uncertain.

The first hunting season for moose in Nova Scotia was established from September 1 through January 31, 1856, with no mention of bag limits, methods of hunting or restrictions on the sale of meat (Benson and Dodds, 1977). Around that time Captain Campbell Hardy, an officer in the Royal Artillary of the Halifax garrison and an ardent sportsman wrote extensively on his hunting and fishing exploits in the Maritimes. He estimated that moose in Nova Scotia numbered no more than "several thousand head" (Hardy, 1869). Hardy's estimate was just that - an estimate by one person with limited ability, or intent, to survey the entire mainland. It was a comment by a sportsman and how close it was to actual numbers will never be known. It certainly seems low but does correspond to the first closed seasons for hunting moose. Perhaps those restrictions were a direct response to moose scarcity at the time. Earlier reports of several thousand moose being killed per year confirms that moose had formerly been far more abundant. By 1870 Gilpin (1871) remarked that the moose were then generally distributed and quite abundant.

By the mid-1800s moose had recovered throughout much of the mainland perhaps in part from declining British demand for the hides, although settlers with the aid of dogs continued to hunt moose in late winter for the meat to sell on the open market. But the mechanism for protection had been established, probably through pressure placed on elected members by city sportsmen and officers of the British military. "Game laws may have been the expression of the disgust of officers and gentlemen at the idea of settlers dogging and snaring moose and selling meat in the market at Halifax. In spite of such nefarious activities, moose were again plentiful at the mid-century mark" (Benson and Dodds, 1977). But this increase appears to have been short-lived, and the population of moose declined again until about 1890 (Dodds, 1974) following which their numbers increased until at least 1920.

In 1908, the first year that moose harvest estimates were recorded and the last year for some time that female moose could be shot, hunters legally killed 688 moose. The kill remained unchanged until 1914 when it began a noticeable although inconsistent increase, reaching a maximum of 1,677 in 1927, the only year since 1908 that the season was open on cow moose. Closure of the season on cow moose the following year saw the kill drop to 984, a decline of 41%. It is generally believed that the moose of mainland Nova Scotia reached a peak some time in the early 1920s, although kill estimates over the next fifteen years suggest that densities remained fairly stable until the closure of the season in 1938. Peterson (1955), referring to early kill records, commented on early abundance of moose in Nova Scotia. "During the period from 1929 to 1934, the province of Nova Scotia would have had to have almost one moose for each square mile (2.6 moose/km2) to support a ten per cent kill. The highest kill recorded from that province was 259 in Annapolis County (1,285 mi2; 3,341 km2) in 1926. This represented one moose killed for every five square miles (1 moose/13 km2) of the county. Assuming a ten per cent kill, the population density would have been roughly two moose per square mile (2 moose/2.6 km2). Since this high rate of kill was not maintained, it appears that it probably exceeded an assumed ten per cent. The highest average rate maintained from 1908 to 1937 was in Halifax County (2,063 mi2; 5,363 km2) where an average of 222 moose were killed each year at the average rate of one moose for each 9.3 square miles (1 moose/24.9 km2). At this rate one might assume that about one moose per square mile (1 moose/2.6 km2) was an average normal maximum density for habitat conditions found in Nova Scotia."If we assume that the harvest represented approximately 20% of the population, and an average of around 1200 moose were harvested from 1914 through 1937, the population would have been in the range of 5,000 to 7,000 animals.

In the early 1960s, Dodds (1963) estimated the total mainland population at 2,400 to 3,900 moose, broken down as follows: Western Counties 300 - 600 and Eastern Counties 2,100 - 3,300. Dodds continued with his assessment by estimating that, based upon the final harvest of moose in 1937, the provincial population in 1962 represented a 60 - 75 % decline from that in 1937. It was late winter of 1964 when the first systematic aerial survey of moose was conducted on mainland Nova Scotia using "modern survey techniques" and which represented "the first objective, quantitative estimate of Nova Scotia's mainland moose herd"(Telfer, 1968). Random survey plots were distributed among four "previously delineated" moose population density strata. The total population of moose on mainland Nova Scotia was estimated to be 3,265 (95% probability range: 2,605 to 4,079), and the distribution and densities confirmed the previously delineated density classification strata. Moose in high density strata of northern Nova Scotia reached a "satisfactory" 1.2 per square mile (3.1 moose/km2). Overall, moose density in the total occupied range of the province was slightly less than 0.2 moose per square mile (0.52/km2), one-fifth the estimate for the province in 1955 (Peterson, 1955) but well within the 2,400 to 3,900 estimate submitted by Dodds a year earlier. Results of the survey led to the opening of a restricted hunting season in 1964 within the two areas of highest density. Prescott (1968) confirmed the earlier estimates supplied by Telfer (1968) for northern Nova Scotia. Moose in the areas defined as containing high densities were estimated at 1.2 and 1.3 moose per square mile (3.1 and 3.3 km2) in 1964 and 1968, respectively. Based upon results of 1975 aerial surveys and subsequent moose management recommendations (Scott, 1976), the province introduced six management zones for the four northern mainland counties which would allow zone-specific management actions. The population of the four northeastern counties in the mid-1970s was estimated to be approximately 1,200 moose (Vukelich, 1977) and for all moose management zones in northern mainland Nova Scotia approximately 1,400 moose (Dodds and Patton, 1978). These estimates, of course, did not include moose in the central or southwestern districts of the province.

By the mid-1990s aerial surveys suggested a further 43 % decline in overall moose densities, reaching an alarming estimate of only 357 moose (range: 276-506) in northern Nova Scotia, or approximately 0.08 moose per square kilometer. A recent aerial survey during the winter of 2000-2001, which sampled moose management zones 1 and 7, confirmed continued losses (Hall, 2001). In the very limited Zone 7 (599 km2), density of moose was estimated at a surprisingly high 0.49 per km2 - 293 moose, while in adjacent Zone 1 (1,211 sq km) only 0.09 per km2 - 73 moose. Hall concluded that moose there were in continued decline. He further combined results of the aerial survey of Zones 1 and 7 with results of moose pellet count surveys conducted in Zones 2 and 3 from 1979 through 2000 to obtain a total estimate of 600 moose in all of Cumberland and Colchester Counties, half of which were found in Zone 7. The estimate of moose densities in Strata I – III based upon pellet group counts from 1979 through 2000 show a disturbing trend lower (Table 9; Hall, 2001).

A simulated and somewhat hypothetical population curve, based upon the past trend, is not encouraging (Figure 6). But the intensity of the decline appears to have moderated and the provincial population may have stabilized at 1,000 – 1,200 animals. Most moose, approximately 600, or 50% of the estimated mainland population, are distributed on the uplands of the Cobequid Hills in Cumberland and Colchester Counties. But more alarming is the concentration of as many as 275 of those moose (~ 25% of the mainland population) in the small (559 km2) and restricted Moose Zone V11 at the extreme southwestern tip of Cumberland County. The next largest concentration is in southwestern Nova Scotia where there may be 250-275 moose distributed among five recognized areas of distribution. These moose are isolated and although calf production is good, survival of calves appears to be low, possibly a result of predation by bears in spring and early summer. The only other area with moderate numbers is in Antigonish County and the northern part of Guysborough County. Two small and vulnerable concentrations of approximately 20-30 moose each are found on the Chebucto or Halifax Peninsula and in northeastern Halifax County near Ship Harbour (Figure 1).

There is unanimous agreement among Nova Scotia Wildlife Managers and Biologists that the mainland moose population has experienced a significant and continuous decline over the past thirty years.

LIMITING FACTORS AND THREATS

Moose, which were once common and widespread throughout most of mainland Nova Scotia, are now fewer and restricted in distribution. The situation appears to have worsened over the past twenty-five years. Why is that so and what are the factors now limiting or threatening their continued viability.

Disease- The most studied suppressant to demographic growth is the nematode *P. tenuis*, the causative agent of moose sickness and which is harboured as an endemic parasite of white-tailed deer. Even so, examples of co-occurrence of moose and white-tailed deer suggest the effect of *P. tenuis* on moose populations may be more subtle than previously believed suggesting that further study is warranted (Whitlaw and Lankester, 1994b). Specific patterns of seasonal behaviour and habitat selection by moose and deer may be responsible for allowing moose to avoid contact with the disease in those areas of current moose occupation. Practical management options available to alter that situation appear limited. The recent colonization of Nova Scotia by the eastern coyote has introduced a new predator of white-tailed deer and contributed to a general population decline of that species. This situation is also unlikely to change and the consequent suppressed densities of deer may allow a moderate increase in numbers of moose, as has happened in parts of New Brunswick. Investigation continues to search for verification and identification of an apparent viral-related disease which may be causing mortality of moose, especially in southwestern Nova Scotia. Clinical symptoms are very similar to those of *P. tenuis*, further confusing the issue. The other potential, although little understood threat is the recent isolation of high levels of heavy toxic metals in the liver and kidneys of moose and deer. Sampling needs to continue to better assess the severity of the situation in moose throughout the province. There appear to be no provincial management options for correcting such a threat from long-range sources of environmental pollution.

Illegal kill - Because of its illegal nature there are few data to measure the seriousness of this threat. But the illicit act of poaching becomes of greater concern as access roads for the expanding forest industry penetrate most remaining areas of moose occupation. Limiting public use of such roads combined with increased patrols of enforcement staff in areas of known moose distribution and human activity are obvious management options – education and greater public awareness is another.

Predation - Black bears can and occasionally do kill young moose although the seriousness of this potential mortality factor in Nova Scotia, which is probably greatest in the southwest (Nette; Brannen; pers. comm.), is unknown. As moose and bears have historically shared the forests of Nova Scotia with mutual success, predation by bears alone should not represent a limiting or threatening factor to moose. However, predation by bears combined with other sources of mortality, e.g. disease, illegal kill, may be sufficient to hinder or suppress population growth.

Habitat alteration/loss - The moose occupies a great diversity of habitat throughout its range in North America. Given an abundance of young deciduous trees and shrubs, and protection from poaching, moose show a remarkable flexability in preferred habitats and range occupancy. The amount of forested landscape in Nova Scotia has changed little in the past fifty years but the state of the forest has. Increased forest harvesting has shifted the pattern to a younger and more mixed structure with greater diversity and abundance of immature deciduous trees and shrubs, more regeneration of balsam fir and a proliferatiuon of edge habitat. Those changes by themselves should not be a deterrent to a productive moose population. But those changes have also enhanced summer habitat for deer and increased access to moose by poachers, two factors identified as deterrents to population stability and growth. Suppression of deciduous trees and shrubs by application of herbicide to recently harvested sites on Crown lands, which was once a common silviculture practice, is now seldom used and is not considered a threat to moose habitat (Duke, pers. comm.).

The large number of small private woodlots serves to create a complex pattern of forest stands within the larger landscape perspective, a condition which serves to increase moose-human interaction, expose moose to poaching and increase contact with deer. Habitat fragmentation also serves to increasingly isolate the several pockets of current moose occupation. The danger of isolation increases concern of progressive genetic deterioration, reduced individual health and population productivity, eventually leading to possible extirpation (Snaith, 2001). Remedial actions are few, although restoration/preservation of interconnecting forest corridors and moose translocations have been suggested (Snaith, 2001). Such suggestions may be more theoretical than practical – remedial actions should await the results of current DNA studies which will help measure the degree of genetic isolation of certain moose concentrations.

Closely aligned with concerns over mobilization of toxic metals in the organs of moose is the increased acidification of the terrestrial and aquatic environments - a threat of unclear dimension. Concerns of changes in water chemistry and consequent impact on availability and palatability of aquatic plants to moose remains unclear. The acceleration of heavy metal mobilization in plants growing on acidified soils is equally confounding. Remedial actions appear limited.

Global warming - The state of the forests are not only changing from the hand of man but also from changes to our climate. The impact of global warming on the forests of Nova Scotia remains unclear. But the trend of warming temperatures itself may have an adverse impact upon moose. Thermoregulation may become of greater concern to the health of moose in summer than in winter (Schwab, 1985; Schwab and Pitt, 1991). The trend of decreasing age structure of our forests limits access by moose to cool microclimates required in the heat of summer. The seriousness of this threat is entirely speculative but should be considered when evaluating real and potential limiting factors to mainland moose. There appear to be few practical remedial actions.

SPECIAL SIGNIFICANCE OF SPECIES

The eastern moose is the only true endemic wild cervid currently found in Nova Scotia. The woodland caribou was extirpated from the province around 1930. The white-tailed deer, now common throughout the province, was absent in recent historical times, and arrived through translocations and natural ingression from New Brunswick in the late 1800s. There is archaelogical evidence that deer occupied the province in one or more earlier eras, perhaps becoming extirpated from a cooling climate around 1100. But given the transitory history of deer in the Acadian forests, its status might be considered "transitory resident” rather than a true endemic to this northern biome. The historical uniqueness of the eastern moose to the Nova Scotia landscape emphasizes its special significance, a recognition which justifies special efforts to ensure its continued occurrence as a viable endemic to the provincial fauna. The moose represents a unique natural resource attractive to the growing business of eco-tourism and, if and when population levels permit, the source of fresh meat to the Aboriginal First Nations. On Cape Breton Island, where moose are hunted for sport, as many as 16,000 residents have applied for 200 licenses – the same potential exists for mainland populations.

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Gerry Parker (BS-1964; MS-1966, Acadia University) retired in October, 1997 after a 31 year career as research biologist/scientist with Canadian Wildlife Service. His career focused on wildlife research and included the study of barren-ground caribou, muskoxen, Peary caribou and Arctic hare in northern Canada (1966-1975), muskrat (New Brunswick) and moose (Newfoundland) (1976-77), Canada lynx on Cape Breton Island (1978-80), coyotes and impacts of forest silviculture on wildlife in New Brunswick (1981-84), black ducks and waterfowl ecology (1985-90) and forest ecosystems and sustainable forestry in the Maritime Provinces (1991-97). Through his career Mr. Parker published results of his research in scientific journals (~45 peer-reviewed papers), gave presentations at scientific conferences and was on editorial review committees for a number of scientific journals. He also published two books - *Eastern coyote, the Story of its Success* and *The Eastern Panther, Mystery Cat of the Appalachians*. Mr. Parker is currently Research Scientist Emeritus with Canadian Wildlife Service in Sackville, New Brunswick.

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TABLES

Table 1: Estimated numbers of moose in the four northern counties of Cumberland, Colchester, Pictou and Antigonish, 1964 - 1975 (Scott, 1976).

Survey Year	Estimated Population	Confidence Interval	Range

Telfer	1964	2886	95%	2605 to 4079
Prescott	1968	3072	not reported	
Scott	1974	1097	80%	399 to 1795
Scott	1975	832	80%	643 to 1177

Table 2: Gross productivity and rates of increase for six moose populations (from Vukelich, 1977).

Region	Adult Sex Ratio*	Reproductive Rates Yrlg	Reproductive Rates Adults	% Rate of Increase	% Reproduction by Yearlings
1- Ontario	50:50	0.20	1.13	34	5
2- Nfld					
Eastern	53:47	0.70	1.20	37	19
Sandy	51:49	0.30	0.80	27	9
Island-Wide	52:48	0.50	1.00	33	13
3- B.C.	50:50	-----	1.20	36	----
4- Sweden	44:56	-----	1.30	37	----
5- Montana	50:50	0.32	1.00	34	7
6- Nova Scotia	45:50	0.50	1.07	34	15

1 - Simkin, 1963; 2 - Pimlott, 1959; 3 - Edwards and Ritcey, 1958; 4 - Markgren, 1969;
5 - Schladweiler and Stevens, 1973; 6 - Vukelich, 1977; * Male:Female

Table 3: Comparison of pregnancy rates of moose from Nova Scotia with other studies in North America (from Vukelich, 1977).

Region	Age	Percent Pregnant	Percent Twins	Pregnancies/100 Cows
1- Montana	Yrlg.	31.8	------	31.8
	Adult	86.3	13.7	100.0
2- British	Yrlg	----	-----	-----
Columbia	Adult	76.3	16.6	92.9

3- Newfoundland	Yrlg	46.0	3.0	48.7
	Adult	81.0	14.0	100.0
4- Ontario	Yrlg	16.7	-----	16.7
	Adult	87.3	25.3	112.6
5- Nova Scotia	Yrlg	50.0	-----	50.0
	Adult	85.7	21.4	107.1

1 - Schladweiler and Stevens, 1973; 2 - Edwards and Ritcey, 1958; 3 - Pimlott, 1959
4 - Simkin, 1963

Table 4: A comparison of moose killed in the five northern counties of mainland Nova Scotia between 1908-37 and 1964 -67 (from Prescott, 1968).

County	Square Kilometers	Average Kill	
		1908-37	1964-67
Guysborough	4,188	104	21
Colchester	3,772	65	107
Pictou	2,922	48	58
Antigonish	1,406	19	35
Cumberland	4,375	49	70
Totals	16,663	285	291

Table 5: Moose harvest on mainland Nova Scotia - 1964 through 1981 (from Nova Scotia Natural Resources files).

Year	Licences	Moose Killed	Season	Comments
1964	400	183	Sept. 28-Oct.3	Cumberland, Colchester, Antigonish, Pictou; Limit 1 moose either sex.
1965			SEASON CLOSED	
1966	800	361	Sept.17-Sept.28	" + Guysborough
1967	1,000	316	"	"
1968	"	282	"	"
1969	"	318	Oct.1-Oct.11	"
1970	"	310	"	"
1971	"	340	"	"

1972	"	409	"	"	Record harvest
1973	"	321	"	"	
1974	"	319	"	"	
1975			SEASON CLOSED		
1976			SEASON CLOSED		
1977	650	229	Oct.1-Oct.11	6 Zones	
1978	605	226	"	"	
1979	600	182	"	7 Zones	
1980	660	209	"	8 Zones	
1981	440	161	"	8 Zones; 28 of the 161 moose killed on Cape Breton Island from 50 licences	

Table 6: Cadmium concentrations in moose livers and kidneys from across North America (from Roger, 2002).

Source	Location	Year	Mean cadmium concentrations (dry weight- ug/g)	
			Liver	Kidney
Roger , 2002	Nova Scotia	2002	8.64	77.35
Paré et al., 1999	Quebec	1999	11.22	72.43
Scanlon, et al., 1986	Maine	1986	5.64	26.76
Crichton, 2002	Manitoba	2000	1.19	6.84
Gustafson, et al., 2000	New Hamp.	1989	0.70	2.39
Brazil, 1989	Nfld/Lab	1989	0.26	1.10

Table 7: Cadmium concentrations in deer livers from across North America (from Roger, 2002)

Source	Location.	Year	Mean cadmium concentration (dry weight- ug/g)
Roger, 2002	Nova Scotia	2002	2.75
Stansley, 1990	New Jersey	1991	2.40
Sileo, 1985	Pennsylvania	1985	1.90
Crichton, 2002	Manitoba	2000	0.56
Woolf, 1982	Illinois	1982	0.37

Table 8: Summary of cadmium levels (dry weight- ug/g) in deer liver tissues collected from Nova Scotia in 1987 and 2002 (Roger, 2002).

Year	Sample	Mean	SD	Range
1987	22	1.09	1.43	0.06 - 5.60
2002	57	2.41	4.26	0.05 - 28.12

Table 9: Changes in densities of moose (km2) in parts of Cumberland and Colchester Counties based upon counts of moose pellets along fixed transects within sample blocks on Moose Zones I, II and VII (from Hall, 2001).

Years Sampled	Zone II	Zone III	Zone VII
1979		0.29	

1980	0.28		
1981			0.42
1982		0.22	
1983	0.17		
1984			0.48
1985		0.17	
1989	0.11		
2000	0.10	0.08	0.48

APPENDICES

Appendix A: A summary of methods used for estimating the numbers of moose in Colchester and Cumberland Counties, 1979 through 2000.

Estimations of moose in the northwestern counties of Cumberland and Colchester have relied, in part, upon the results of spring counts of winter pellet groups along pre-established linear transects (Hall, 1979; 1980; 1981; 1982; 1986; 1989; 2000) combined with winter aerial surveys. Regional biologist Ross Hall initiated the design and application of the pellet group surveys for this district, beginning in the spring of 1979. Hall recognized the limitations of aerial surveys over a landscape where unpredictable winter snowfall often limits the practicality, and credability of moose observations and subsequent population estimates. Results of pellet group counts in spring, 1979 were compared to results from an aerial survey of the same area in spring, 1978. Hall has continued the pellet group surveys using similar methodologies as those first described in 1979.

This status report on moose of mainland Nova Scotia has relied upon numerical estimates provided by the regional biologists, many of those estimates based upon "best guesstimates" rather than from application of accepted ungulate survey methodologies. Recognizing the shortcomings of many of these estimates, there is concern among some personnel within the Nova Scotia Department of Natural Resources that the pellet group surveys are especially biased and tend to over-estimate actual moose densities and subsequent population estimates. This is of special concern when as many as 50% of the estimated mainland population may be found within those two counties. For that reason the following summaries are extracted from Hall's original reports and are here appended for reference by the reader to the methodologies and analytical applications used in the subsequent population estimates for those counties.

In his first report, Hall (1979) stated that the initial application of the pellet group count survey was a preliminary appraisal of that procedure to inventory moose and deer populations in Nova Scotia. Although an aerial census for moose in Nova Scotia had been developed by Scott (1976), winters with little snow often prevented or limited its use. Hall listed other variables associated with the aerial count method which served to lessen confidence in results and limit its use to the manager. He suggested that counts of pellet groups combined with observations of moose and moose tracks in winter from aerial surveys, and other population indicators, might provide a more accurate picture of population levels.

Moose Zone III was chosen as the area to test the pellet group count method. Partial aerial counts for moose were made in this Zone in March and December, 1978. (Note - see accompanying map for Moose Zones, survey blocks and years of pellet group count surveys). Following years of heavy hunting pressure and over-harvest in Zone III, hunting was closed in 1975 and 1976 and a reduced number of 50 and 35 licenses issued in 1977 and 1978 - only 24 and 9 moose were harvested in those years, respectively. After four years of reduced hunting pressure, Hall suggested that moose numbers in Zone III should have increased.

Each sample plot was a strip transect measuring 5,280 ft (80 chains) long and 5.28 ft wide. Transects were walked in a rectangular pattern. A compass person travelled 30 chains in a magnetic north direction, then 10 chains west, then 30 chains south, and 10 chains east to the point of beginning. A tally person followed and within each two chain interval recorded the numbers of moose and deer pellet groups and surrounding forest type. The tally person carried a measure stick 2.64 feet long. On encountering a pellet group the stick was held at a right angle to the chain. If the centre of the pellet group was within 2.64 feet distance from either side of the chain it was recorded. Each strip transect sampled a 1/1000 square mile area. Moose and deer pellet groups considered to have been deposited prior to leaf fall in October, 1978 were not counted (i.e. scattered leaves laying on top of pellet group).

Plot locations were chosen on the basis of forest inventory Temporary Sampling Plots (TSP), randomly located in 1968 (Nova Scotia Department of Lands and Forests, 1968). A forest inventory is conducted annually over one-seventh of the total area of the province. TSPs are established at the rate of eight per provincial forest inventory mapsheet and their locations are recorded on mapsheets at the Forest Inventory office in Truro. Each TSP is a linear mile - transect plots to sample moose and deer pellet groups in 1979 were rectangular to conserve walking distance. Time and manpower limitations limited sampling to a 238 mi^2 block of the 573 mi^2 Moose Zone III. Past aerial surveys indicated that the area of greatest moose concentration was sampled. Eight different persons were fully or intermittedly involved in gathering data. Tally persons discussed such things as pellet age to achieve consistent results. A two man crew usually completed two plots per day - the 39 plots required 39 man days to complete.

Population estimates were made on the following assumptions: (1) the daily defecation rate for both moose and deer was 13, and (2) pellet groups were deposited in a 206 day period from October 15 (leaf fall) to May 9 (time of 50% completion of plots). Moose and deer pellet groups per square mile were 2,500 ± 28% and 12,800 ± 28%. The number of moose per square mile was estimated at 0.93 ±0.26 at 90% confidence, for an estimate 221 ± 62 moose within the 238 mi^2 sample area. Number of deer per square mile was 4.78 ± 1.3 at 90% confidence, or 1,138 ± 319 deer in the 238 mi^2 sample area.

Most of the 39 plots were positioned within the Cobequid Mountain range where moose were most common - aerial surveys had found only a few moose on the lowlands north of the Cobequids. Hall added 10% more moose for the unsampled area, for a total estimate of 243 moose in Moose Zone III. Conversely, deer numbers in winter on the higher elevations of the Cobequids were low, many deer moving to the lower elevations to avoid deep snow. The winter of 1978-79 was an exceptional snow-free winter and many deer remained on their summer range in the Cobequids. A large number of deer pellet groups observed on the plots were deposited in late fall.

Using the Scott (1976) aerial count technique in March, 1978, Hall (1978) calculated 138-210 moose in Zone III . Twenty-three definite and twelve possible moose winter concentration sites were sighted. As no helicopter was available to determine the number of moose per aggregation, a moose per aggregation value of 2 was used, similar to that proposed by Scott (1976), who also calculated that during winter surveys one-third of all aggregations were sighted. Considering an approximate 25% increment from the 1978 winter moose herd to the 1979 winter herd, Hall considered the results of the aerial and pellet group count survey methods surprisingly similar.

Hall recognized the greatest bias with the use of pellet group counts to be the determination of a daily rate of pellet group deposition. At that time, the most widely used estimate for the daily defecation rate of moose was 13.0 (Timmerman, 1974). Overton and Davies (1969) reviewed studies by various authors who also suggested a defecation rate for deer of 13.0. Timmerman (1974) concluded that pellet group counts provided a good basis to compare relative densities among areas, and from year to year, on specific areas. Hall concluded that because information on defecation rates remained somewhat inconclusive, estimates of populations should be treated with caution. He suggested that in Nova Scotia the pellet group count technique, even with cautious interpretation, appeared to have a great potential - comparisons of ungulate densities among different zones, sanctuaries, years, and to levels of annual harvest could provide information useful for the management of the resource.

The 1979 survey of Zone III was followed by a similar pellet group survey of Zone II in spring, 1980. Two survey blocks, each 100 mi^2, sampled 17% of the 1,200 mi^2 zone. In contrast to the rectangular sample plots used in 1979, transects in 1980 remained linear. Reason given for the change was "…to better sample different habitat types and to lessen any effect of moose clumping on the results." As in 1979, forest types were recorded as transects were surveyed. Forty liner plots were completed, 20 in each of the 100 mi^2 blocks. Similar to 1979, sample transects (plots) were one mile in length and all pellet groups were counted within a belt of 5.28 feet in width.

Calculations of moose densities were based upon three assumptions: (1) moose, and deer, deposited 13 pellet groups per day; (2) pellets were deposited over a 207 day period (from leaf fall to date of tally); (3) there was no bias in the sampling method. Calculations assumed that one moose in a square mile would deposit 2,700 pellet groups over the 207 period. The survey provided estimates of 0.9 moose and 5.7 deer mi^2 for the two study blocks combined, or numerical estimates of 1,080 moose and 6,840 deer for Zone II. The author cautioned that the 0.9 moose/mi^2 appeared high compared to previous estimates and that sources of bias might have included surveyors avoiding impenetrable thickets and accepting an average deposition rate of 13.0 pellet groups per day.

In spring, 1981, Hall again expanded the pellet group survey to Zone VII. The objective was to compare the results of that survey to those from an aerial survey of Zone VII flown in late winter of 1981. Sixty random points were selected within the 215 mi^2 (559 km^2) zone, from which 1,000 metre sample transect plots were positioned in a northery direction. Forest types were recorded and all pellet groups counted within a two metre belt along each transect.

Recognizing the uncertainty of pellet group deposition rates, Hall referred to a recent study in Alaska which increased average rate of deposition by moose to 17 groups per day (Oldemyer and Franzman, 1981) and chose to use that figure in future calculations for his surveys in Nova Scotia (from 13 per day). Using calculations similar to earlier pellet group surveys, Hall provided population estimates of 223 moose and 775 deer in Zone VII. If he had chosen a deposition rate of 13 groups per day, population estimates for that zone would have increased to 290 moose and 1,015 deer. Hall points out the deficiencies of aerial surveys to estimate moose in Nova Scotia, especially the lack of suitable snow cover and inability to detect moose when in closed conifer habitats. Advantages of pellet group surveys include independence from winter snow conditions, ability to estimate moose and deer, and measureable confidence intervals which facilitate temporal and spatial comparisons. He stated that, in his opinion, pellet group counts provided a much more accurate measure of actual moose and deer populations than winter aerial surveys. The estimate of moose in Zone VII from the 1981 winter aerial survey was 91, compared to 223 ± 64 from the spring, 1981 pellet group survey.

In spring, 1982, Hall re-surveyed Zone III, the zone where he first applied the pellet group survey three years earlier in 1979. There were several adjustments in survey methodology between the two surveys. In 1979 transect sample plots were rectangular, 1,600 m in length with an effective belt width of 1.6 m within which pellets were counted, and conducted by 2 persons – a chain person and a tally person. In 1982 transect sample plots were straight, 1,000 m in length with a belt width of 2 m. and conducted by one person using a hip chain. Starting points for transects were not exactly the same between years, although within the approximate same area and similar habitat. Each transect in 1979 surveyed 2,560 m^2; in 1982 each surveyed 2,000 m^2.

Results were quite surprising. Over the three years, estimated number of deer increased by 109% while number of moose declined by 24%. The author had expected, given the good habitat and reduced legal kill over the previous several years, that moose numbers would have increased. He attributed the decline in moose to illegal kill and increased mortality from *P. tenuis*, the latter due to the doubling in numbers of deer and increased opportunities for infection by moose.

Hall continued pellet group surveys in the springs of 1983 (repeat of Zone II), 1984 (repeat of Zone VII and first for Chignecto Sanctuary in Zone I), and 1985 (repeat of Zone III). In 1986, he summarized the results of all pellet group surveys from 1979 through 1985, and acknowledged the several modifications to the survey design following the initial years. Densities were calculated by dividing the number of pellet groups/km^2 by the expected number from one animal based upon a deposition rate of 17 pellet groups per day over a 200 day period of potential deposition (November 1 to survey day in May).

Hall presented some interesting trends for numbers of moose and deer within Moose Management Zones of his Cumberland and Colchester District. In Zone III, for instance, while numbers of deer tripled from 1979 through 1985, the estimated density of moose declined from 0.29/km^2 to 0.17/km^2 (-41%). The trend in Zone II was similar while in Zone VII deer increased while moose remained relatively stable. Cause of death for 26 of 81 (32%) dead moose reported in his district from 1982 through 1985 was attributed to *P. tenuis*; another 24% from illegal kill. Hall considered those two factors the most important contributors (50% of known mortalities) to declining moose numbers in his district.

In 1989 Hall resurveyed pellet group transects in the two 100 mi^2 blocks positioned in Moose Zone II. Earlier surveys within those blocks had been conducted in 1980 and 1983. Results showed continued declines in moose densities, especially in that block located on the lowlands near Oxford. Although moose densities continued to decline on the upland Cobequid block, that decline was marginal between 1983 (0.18/km^2) and 1989 (0.13 km^2). Provincial estimates of deer from pellet surveys suggested a peak in 1986 followed by general declines through 1989, at which time estimates were comparable to those in 1982.

In the spring of 2000, Hall conducted an extensive re-survey of all pellet group sample plots in an effort to obtain a uniform and current trend of moose and deer densities in the Moose Zones previously surveyed – methodologies remained similar to those used earlier. Results suggested the following numbers of moose by Moose Management Zone: Zone I – 210; Zone II – 310; Zone III – 45; Zone VII – 266; Total estimate – 832 moose. Declines were most noticeable in Zones II and III, from 1979-80 estimates of 0.26 – 0.29 km^2 to the 2000 estimate of 0.08 to 0.10 km^2, a decline of approximately 65%. Moose remained stable in Zone VII, and Hall estimated a decline of 25-35% in Zone I (from extrapolating a density of 0.24/km^2, or one-half that found in the Chicnecto Sanctuary, to the total 1,211 km^2 - aerial surveys the following winter (2001) found that the overall density in Zone I was only 0.09/km^2 and suggested that the 2000 extrapolation by Hall was unwarranted).

Finally, in the late winter of 2001, Hall conducted an aerial search for moose on thirty 25 km^2 survey blocks (2.5 km X 10 km) using a Hughes 500 helicopter and following a standardized format from the Moose Population Aerial Survey Manual (1994. New Brunswick Department of Natural Resources and Energy, Fredericton). Sample plots were positioned, when possible, to fall within areas sampled earlier by the spring ground pellet group surveys. In contrast to the 2000 estimate of 832 moose in his district based upon pellet group surveys, the aerial surveys provided an estimate of 600 moose - 28% fewer. But some of the comparisons of results between survey types are interesting. In Zone II, for instance, the 2000 pellet survey provided an estimate of 0.16 moose/km^2; the 2001 aerial survey 0.15 moose/km^2. The density of moose in Zone VII, from the 2000 pellet survey, was 0.48/km2; the 2001 aerial survey 0.49/km^2. The greatest difference in results between survey types was in Zone I which had been sampled by pellet plots positioned only within the Chignecto Game Sanctuary. Hall had “subjectively” extrapolated an estimate of 0.24 moose/km^2 to the total Zone and had, apparently over-estimated the moose population by a considerable margin (~ 65%, or 137 moose). The average density for Zone I from the 2001 aerial survey was only 0.09/km^2. That difference for Zone I accounts for 60% of the discrepancy between the two surveys (137 of the 232 moose).

It is the opinion of this author that results of the pellet group survey designed and conducted by Hall in Cumberland and Colchester Counties from 1979 through 2000 deserve further study. In several of the Zones, estimates of moose densities between the pellet group and aerial helicopter surveys are quite similar. Hall acknowledged the inherent weaknesses of both types of survey, and for those reasons chose to begin monitoring deer and moose by the pellet group count method. Not only is the pellet group count method more economical but it also allows comparable estimates of deer densities and, by recording habitat type along transect routes, ungulate-habitat associations are possible. It might prove useful to examine the latter in greater detail. Neither survey method is free of bias and error – a combination of both, similar to that applied by Hall, and which he advocated as early as 1979, would appear to be the best approach. Combined aerial and ground pellet group surveys may be most practical in districts where moose densities are moderate to high, such as the Cumberland/Colchester District, and the Tobeatic region in the southwest.

References to Appendix A

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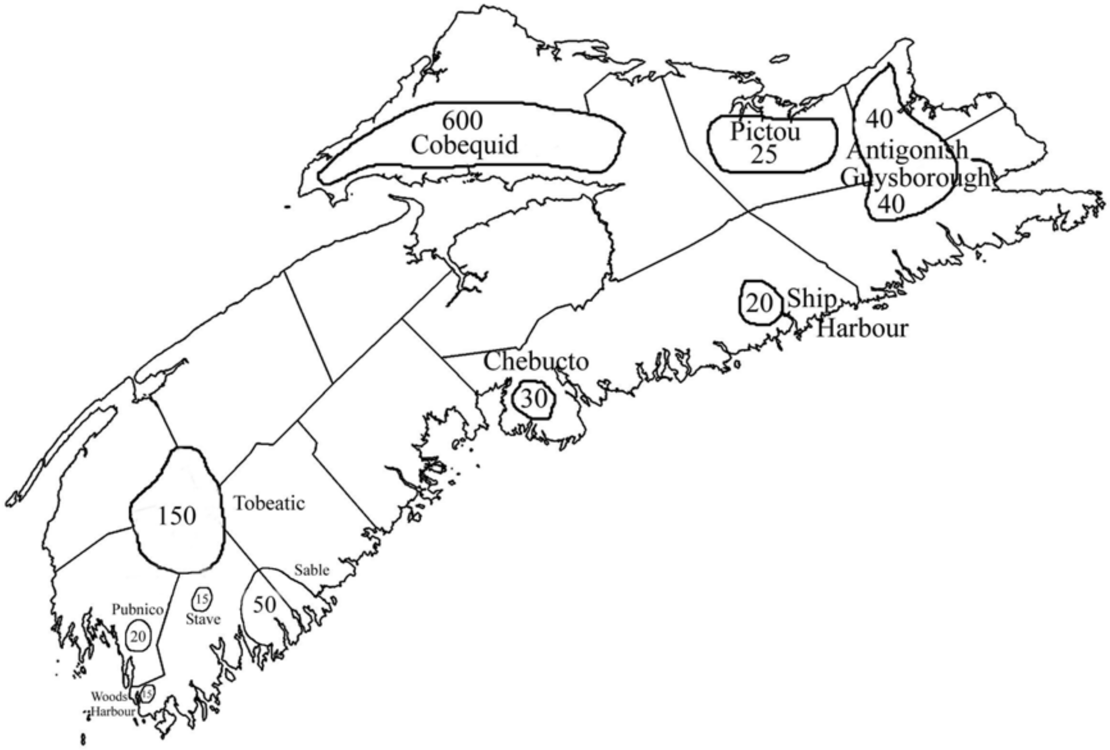

Figure 1: Core areas of moose distribution on mainland Nova Scotia and approximate numbers based upon personal interviews with regional biologists - numerical estimates are frequently based upon data collected using different methodologies. Another 150 moose scattered throughout Halifax, Guysborough and Pictou Counties provides a total estimate for for mainland Nova Scotia of approximately 1,200 moose.

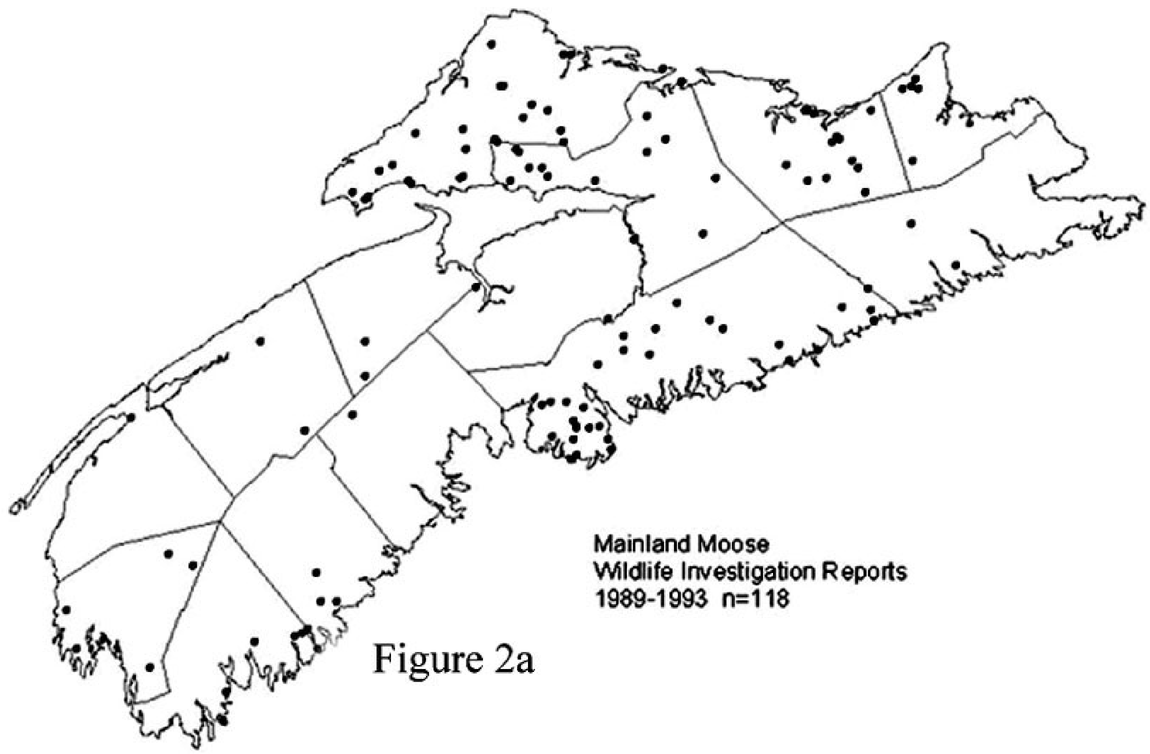

Figure 2a

Figure 2: Distributions of moose in Nova Scotia from Wildlife Investigation Reports for 5 year intervals, 1989 through 2002 - (a) 1989-1993; (b) 1994-1998; (c) 1999-2002.

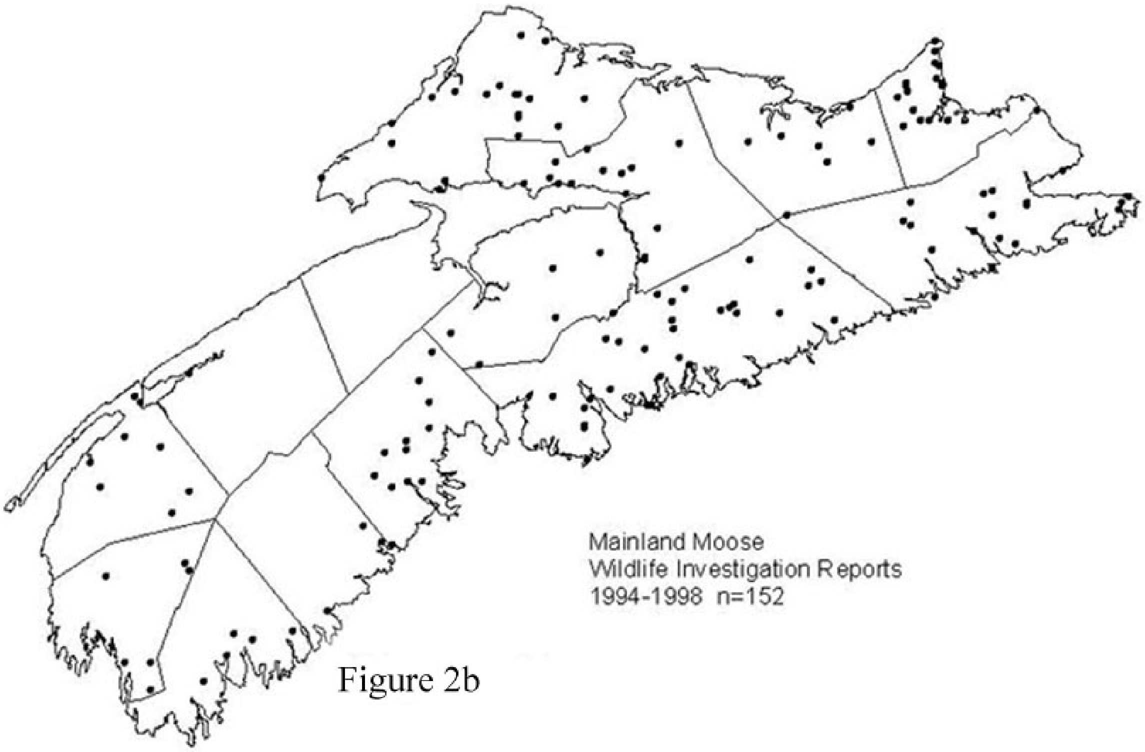
Mainland Moose
Wildlife Investigation Reports
1994-1998 n=152

Figure 2b

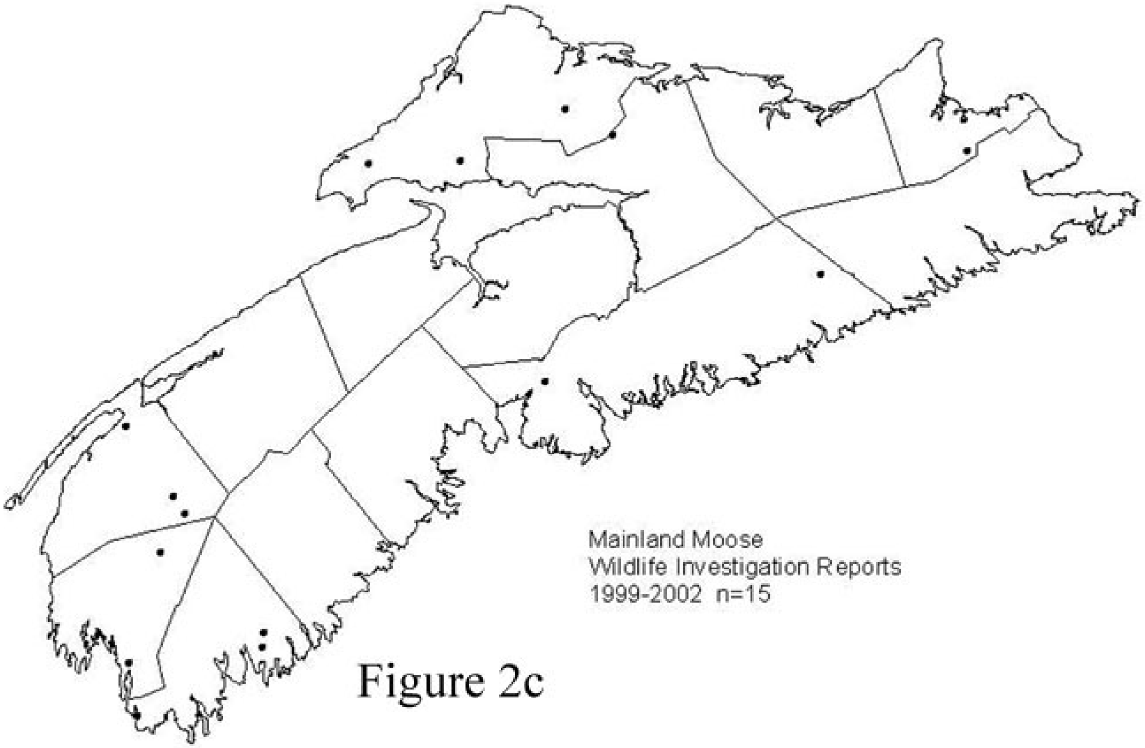
Mainland Moose
Wildlife Investigation Reports
1999-2002 n=15

Figure 2c

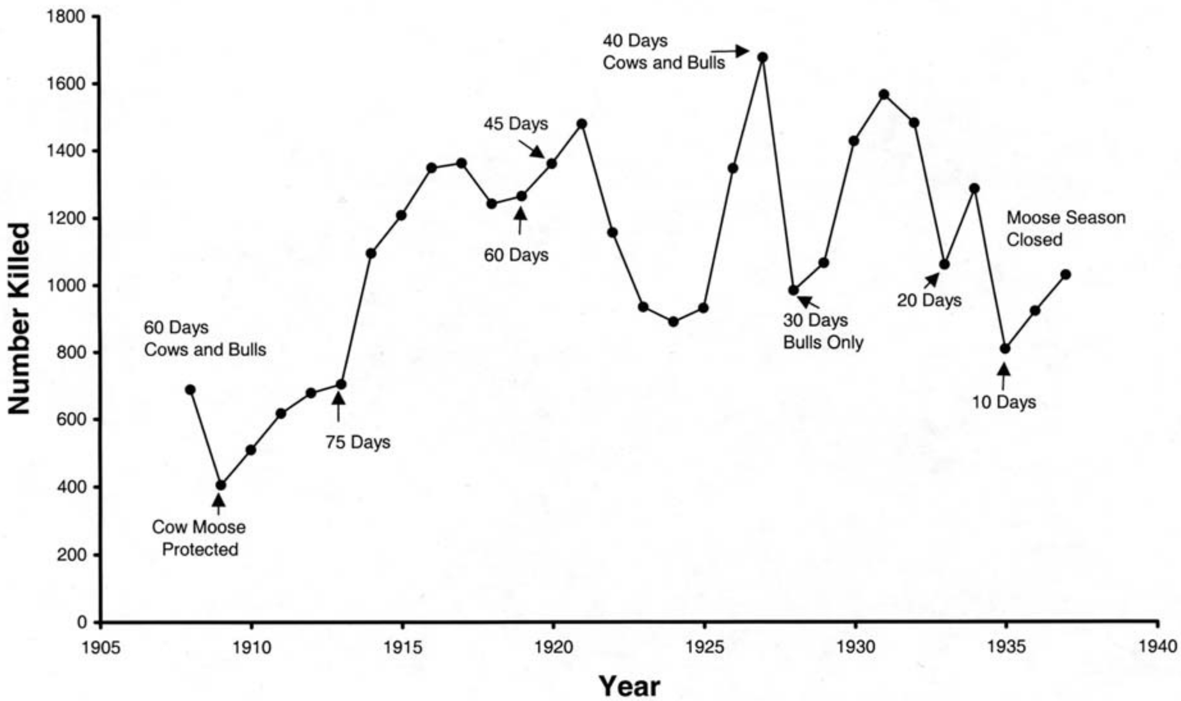

Figure 3: Estimates of the number of moose killed by hunters in Nova Scotia were first collected in 1908 and continued annually until the season closed in 1938. Season length and bag limit varied - both influenced changes in the kill through the years. A limited season in northern mainland Nova Scotia was reopened from 1964 to 1974, closed for two years and reopened again from 1976 through 1981.

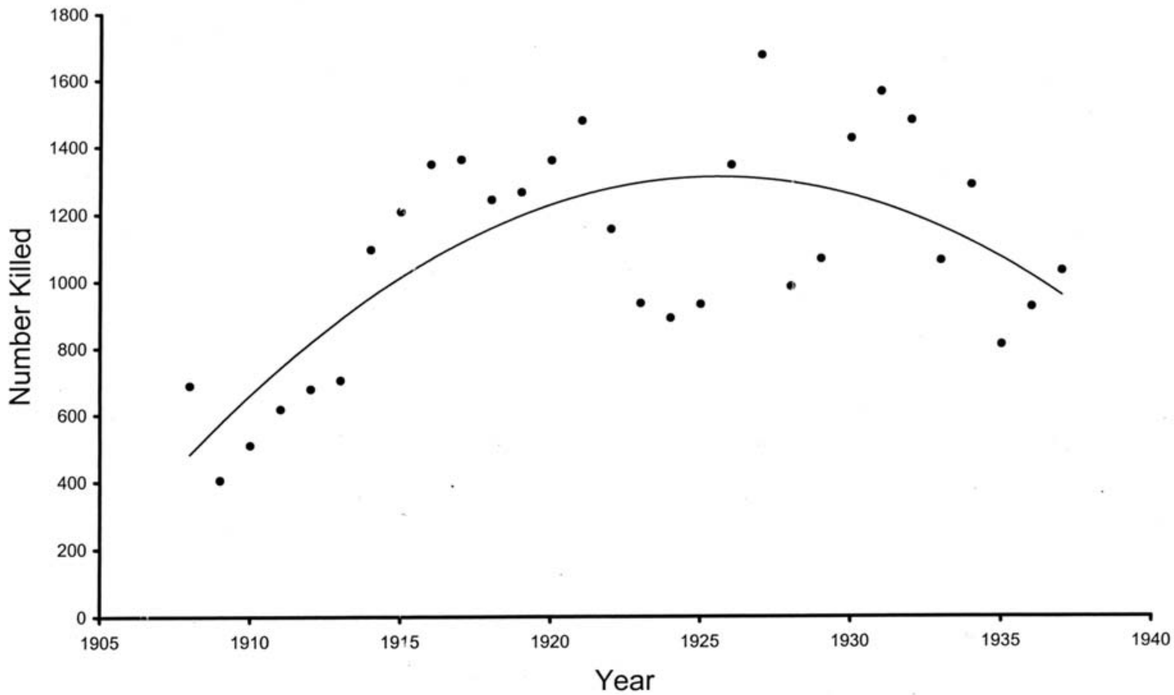

Figure 4: Kill statistics for moose suggest that the population peaked around 1925 and began a slow decline until the season was closed in 1938.

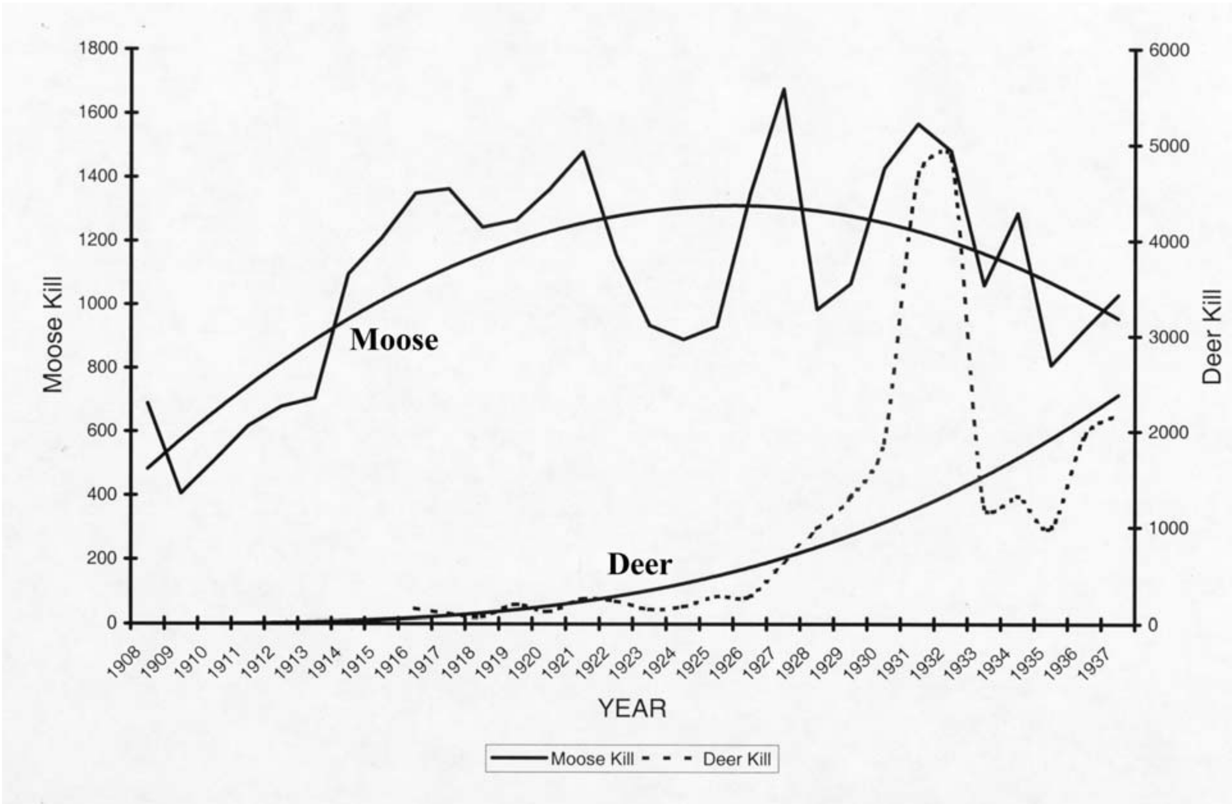

Figure 5: Moose appeared to decline at the time that white-tailed deer were increasing rapidly throughout the province. Deer brought with them the disease known as moose sickness, an illness caused by a nematode worm often fatal in moose. Many believe that it was that disease which caused the near decimation of moose thoughout the mainland.

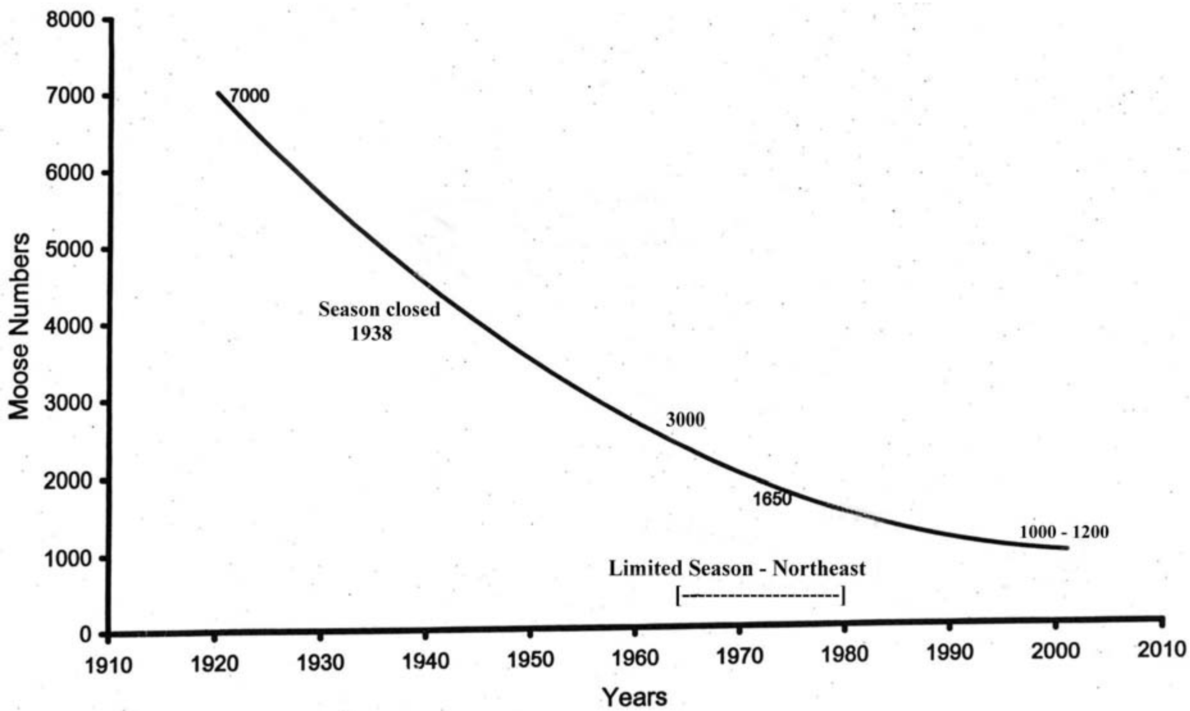

Figure 6: Projected slope of decline in numbers of moose on mainland Nova Scotia based upon early "estimate" and subsequent aerial and ground surveys - 1920-2003.

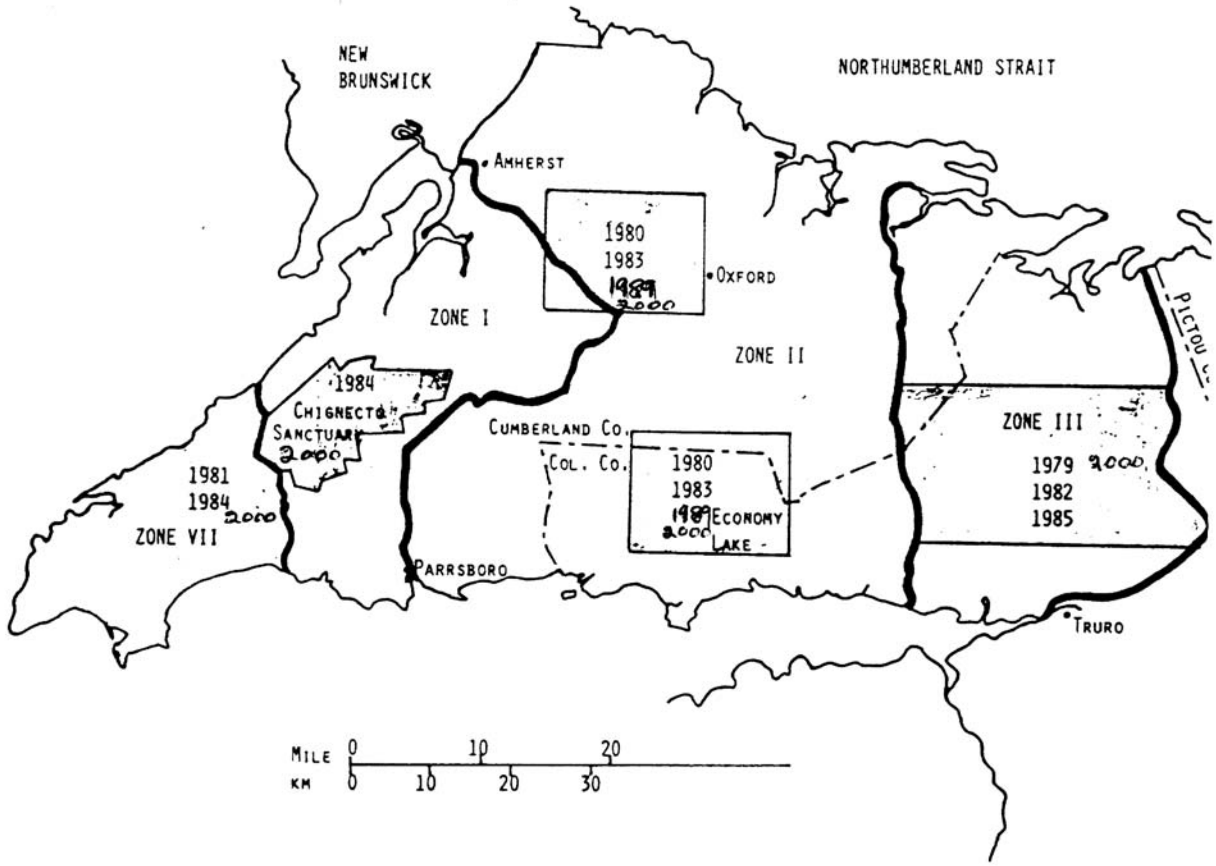

Figure 1: Locations of Moose Zones I, II, III, and VII in Cumberland and Colchester Counties, also showing moose pellet group survey blocks and years of survey.