# AN EXAMINATION OF THE ABSENCE OF ESTABLISHED MOOSE (*ALCES ALCES*) POPULATIONS IN SOUTHEASTERN CAPE BRETON ISLAND, NOVA SCOTIA, CANADA

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ABSTRACT: An analysis was performed on habitat-related factors for the southeastern side of Cape Breton Island, Nova Scotia to investigate the continued absence of moose (*Alces alces*) from the region. Temperature and snow depth, at times, reach levels that could cause thermal stress or impede movement of moose; however, it is unlikely that these factors dictate the absence of moose. No clear relationships were established between environmental concentration levels of the heavy metals molybdenum, cadmium, copper, and lead and moose distribution; however, high concentration levels of molybdenum in the Cape Breton study area warrant further investigation. Road density assessments showed that the study area has a higher level of road density compared to 2 mainland control sites; however, higher road density occurs in other areas in which moose persist. Anthropogenic factors such as poaching were not considered influential enough to exclude moose. A forest habitat comparison analysis was performed to identify habitat features that were statistically correlated with moose presence, and then were applied in a probability model to predict moose presence in the study area. The logistic regression model used to predict the probability of moose presence was composed of positively associated forest inventory variables (softwood average maturity, hardwood average maturity, % mixed hardwood, % non-forested area, total wetland area) that best fit the data. The model identified 43% of the Cape Breton study area as having a high-probability weighting for moose presence. Overall, this study did not reveal a clearly identifiable cause for the continued absence of moose in southeastern Cape Breton Island.

ALCES VOL. 44: 81-100 (2008)

**Key words:** *Alces alces*, exclusion factors, geochemistry assessment, geographical features, habitat analysis, moose, Nova Scotia, probability model, road density.

Two subspecies of moose are found in Nova Scotia; indigenous moose (*Alces alces americana*) exist in localized groups in mainland Nova Scotia, and moose (*A. a. andersoni*) introduced from Alberta, after the extirpation or near-extirpation of the endemic species, exist in northern Cape Breton Island. On the mainland, we use the term localized groups as there is currently insufficient data to determine whether they qualify as distinct subpopulations. Genetically, a subpopulation is defined as individuals within a given larger population that are further defined by some recognizable level of relatedness. Since this is not determined throughout mainland Nova Scotia, we use the general term, localized groups (Beazley et al. 2006).

In 2003, the indigenous mainland moose was listed as 'endangered' under the *Nova Scotia Endangered Species Act,* with 1000-1200 animals existing in localized groups (Parker 2003). The reasons behind the decline of the mainland moose are not entirely understood (Beazley et al. 2006). In contrast with their decline, the moose population in northern Cape Breton reached high densities while subject to the only open moose hunting season in the province, and is currently estimated as 5000 ± 1000 animals (Parks Canada, unpublished data) (Fig. 1).

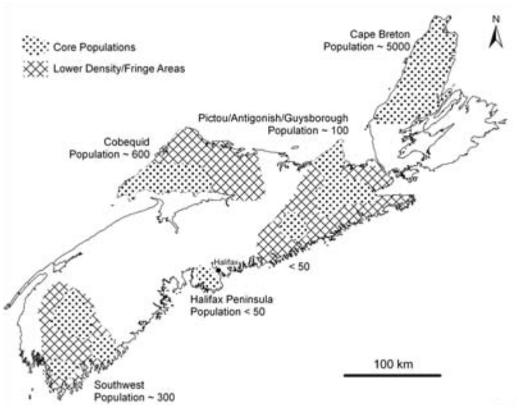



Fig. 1. Current moose distribution in mainland Nova Scotia and Cape Breton Island, showing core populations and lower-density/fringe-areas. Remnants of the indigenous moose population (*A. a. americana*) exist in small, localized groups in mainland Nova Scotia. In contrast to the high abundance of moose (*A. a. andersoni*) in northern Cape Breton, there is a notable absence of established populations in southeastern Cape Breton.

The high abundance of moose in the Highlands area of Cape Breton is such that animals are dispersing throughout most of northern Cape Breton. Further, hunting is not permitted in Cape Breton Highlands National Park that encompasses approximately 40% of the Highlands. There is, however, a notable and unexplained absence of established moose populations in southeastern Cape Breton, with only occasional sightings. Interestingly, black bears (*Ursus americanus*), the only significant natural predator of moose in the province, are also absent from this same area, yet white-tailed deer (*Odocoileus virginianus*) inhabit the area (unpublished data, NSDNR; see MacMichael 2007). The absence of two wide-ranging mammals from the same geographical region suggests that there may be issues with habitat suitability, and/or with human activities such as past and current hunting and poaching. This paper examines factors that may help explain the exclusion of moose from southeastern Cape Breton, as well as the limited distribution and apparent continued decline of surviving remnant localized groups on mainland Nova Scotia. The 3 objectives of this research were to 1) determine the historical distribution of moose in Nova Scotia, 2) compare habitat characteristics in the Cape Breton study area with control sites in coastal mainland habitat to identify potential exclusion factors, and 3) identify any non-habitat associated, anthropogenic exclusion factors.

## METHODS

The Cape Breton study area included part of Richmond County and all of Cape Breton County, comprising 318,193 ha (Fig. 2). We examined existing archival records and documented the historical distribution of moose across the province, particularly Cape Breton County, to determine whether moose had inhabited the study area at some time in the past. We then examined moose presence/absence data, geographical characteristics including geology and climate, geochemistry, road density, biogeographic factors, interspecific interactions, and overall forest habitat suitability in the study area, and made comparisons with the control sites in ecologically similar moose habitat on mainland Nova Scotia. Non-habitat factors that could potentially exclude moose from the area, such as poaching and human development,were also identified. With the exception of interviews with key informants, the research was limited to analysis of existing information. For a full description of the

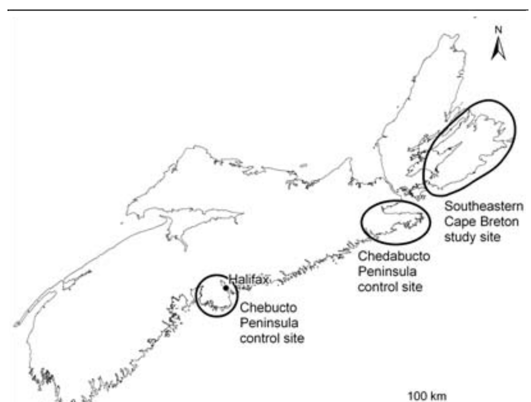



Fig. 2. Cape Breton study area and mainland control sites on Chebucto and Chedabucto Peninsulas.

study design refer to Kwan (2005).

**Historical Distribution**

Archival information was obtained from the Public Archives of Nova Scotia and the Fortress of Louisbourg National Historic Site in Cape Breton County. The historian at the Fortress (K. Donovan) provided additional information on moose presence, or the lack thereof, in the proximity of the historic site in the 1700s. Relevant sources were reviewed and any indication that moose were historically present in the study area and surrounding region was noted. Key sources included Denys (1672), Pichon (1760), Smith (1801), Dodd (1805), Holland (1935), Benson and Dodds (1980), Fortier (1983), Pulsifer and Nette (1995), and Landry (1997).

**Habitat Assessment**

Habitat assessment was performed in an attempt to determine whether suitable habitat was the limiting factor influencing moose distribution in the Cape Breton study area. The habitat assessment included examination and comparison of moose presence/absence, biogeographic factors, interspecific interactions, geographical features, road density, geochemical analyses, and forest composition. This coarse-scale habitat comparison used 2 mainland sites (Fig. 2) as controls, which required that these sites be as ecologically similar as possible. The Chebucto Peninsula and the Chedabucto Peninsula occur within the Atlantic Coastal Ecoregion (Neilly et al. 2003) as does a large portion of the Cape Breton study site, such that these areas share the same coastal influence and have similar climate effects and vegetation types. Both of the mainland control sites support localized groups of resident moose, indicating their suitability for comparison with the Cape Breton study area.

Moose presence in the study sites was determined by assessing the provincial Pellet Group Inventory (PGI; unpublished data, NSDNR 1983-2003), which is a system of randomly placed 1-km-long sampling transects used to inventory deer and moose pellet groups. The PGI system, originally developed in 1983 to monitor deer population density, includes information on moose pellet group presence. Pellet groups deposited after leaf-fall and throughout the winter are counted during the spring survey, and reliably indicate moose presence or absence during late fall-early spring only. The presence of moose pellets on a transect was considered indicative of moose presence, regardless of the number of pellet groups recorded.

Biogeographic factors were considered by visually assessing maps of the region in terms of physical distances, barriers (including human settlement), or bottlenecks in the landscape that may potentially exclude or restrict moose dispersal into the study area. Interspecific interactions between moose and predators, and competitors and pests, particularly white-tailed deer, were examined by qualitatively comparing the study area with sites elsewhere in Nova Scotia and information in the literature.

Potentially relevant geographical features of the Cape Breton and mainland sites including climate, bedrock geology, predominant tree species, soil pH, and elevation were compared qualitatively using data derived from existing sources (Table 1). Sources on local features include Environment Canada (2004), Ecological Land Classification for Nova Scotia (Neilly et al. 2003), and The Natural History of Nova Scotia, Volume 1: Topics and Habitats, and Volume 2: Theme Regions (Davis and Browne 2003a, b). Comparisons of these features were conducted to identify potential variations across sites, and to assess any variations against acceptable ranges or limiting values for moose identified in the literature.

Road densities for the Cape Breton and mainland sites were extracted from a pre-existing GIS-based road-density classification

Table 1. Comparison of selected geographical features across the mainland control sites at Chebucto Peninsula and Chedabucto Peninsula and the Cape Breton study area (compiled from Davis and Browne 2003a, b, Neilly et al. 2003, Environment Canada 2004).

| Feature | Chebucto Peninsula (Shearwater A weather station) | Chedabucto Peninsula (Stillwater Sherbrooke weather station) | Cape Breton Richmond (Sydney A weather station) |
|---|---|---|---|
| Mean elevation | 71 m | 115.5 m | 119 m |
| Mean aspect | South-facing | South-facing | South-facing |
| Bedrock | 95% granitic with 5% metasandstones of the Goldenville formation | 50% granitic intrusions with 25% metasandstone units and 25% Halifax formation slate | South: volcanic and associated plutonic rocks (granitic)<br>North: sandstone, presence of coalbeds |
| Predominant tree species | Red and black spruce | Red and black spruce with some balsam fir | Balsam fir with some black spruce and larch |
| pH | 5.0-6.5 | ≤6.0 | 6.5-7.5 |
| Total annual precipitation | 1400-1500 mm | 1400-1500 mm | 1400-1500 mm |
| Average total annual snowfall | 200-250 cm | 150-250 cm | 150-300 cm |
| Snow depth maximum (1971-2000) | Average <10 cm; highest recorded value 84 cm | Average <20 cm; highest recorded value 92 cm | Generally moderate; <25 cm; highest recorded value 123 cm |
| Average winter (Jan-Feb) mean maximum temperature (1971-2000) | -0.2°C; extreme high recorded 16.2°C, 1994 | -0.9°C; extreme high recorded 17.5°C, 1995 | -1.9°C; extreme high recorded 18°C, 2000 |
| Average winter (Jan-Feb) mean minimum temperature (1971-2000) | -9.2°C; extreme low recorded -26.5°C, 1994 | -11°C; extreme low recorded -39°C, 1985 | -11.1°C; extreme low recorded -27.3°C, 1994 |
| Average summer (Jul-Aug) mean maximum temperature (1944-2000) | 22.4°C; extreme high recorded 33.3°C, 1945 | 24°C; extreme high recorded 34°C, 1999 | 23°C; extreme high recorded 34.4°C, 1944 |
| Average summer (Jul-Aug) mean minimum temperature (1961-2000) | 13.5°C; extreme low recorded 5.6°C, 1965 | 12.7°C; extreme low recorded 1.7°C, 1968 | 12.3°C; extreme low recorded 2.2°C, 1961 |
| Fog days | 101 | 115 (Canso) | 80 |

(1-km square grid; 6 density classes) for Nova Scotia (Snaith 2001, Snaith et al. 2002, Beazley et al. 2004) and were compared visually. Since road density of 0.6 km/km$^2$ has been suggested as a threshold value above which populations of many large vertebrate species decline (Forman *et al*. 1997), road densities for primary and secondary roads were reclassified into 2 density classes (i.e., <0.6 km/km$^2$ and $\geq$0.6 km/km$^2$). The proportion of area with road densities in these 2 classes was compared in each study site. Moose sightings ($n$ = 11) from Wildlife Incidence Reports (WIR; unpublished data, NSDNR 1985-2004) in the Cape Breton study area were plotted against the road density values and assessed visually for spatial correlation.

The geochemistry of the study area was examined for particular heavy metals known to have negative health effects in moose when they accumulate in the body or are at deficient levels, such as molybdenum, cadmium, and copper (Crichton and Paquet 2000, Frank et al. 2000 a, b, Selinus and Frank 2000, Pollock 2006). A biological imbalance of these metals may cause physiological abnormalities, aberrant behaviour, or have toxic effect on the reproductive and central nervous systems. Lead, while not reported to have negative effects on moose, has been known to cause anemia and neuropathy or encephalopathy in mammals (Underwood 1971). Four geochemical datasets from the NSDNR were screened for concentration levels of molybdenum, cadmium, copper, and lead. These sets included 1) a vegetation survey completed in 1991 (Dunn et al. 1992 a, b), 2) stream sediment surveys completed in 1982-83 (Rogers and Lombard 1990) and 1986-87 (Mills 1989), 3) lake sediment surveys completed in 1977-78 (Bingley and Richardson 1978, Richardson and Bingley 1980, Rogers and Lombard 1990) and 1983 (Rogers and MacDonald 1983 a-g, Rogers and Lombard 1990), and 4) glacial till surveys initiated in 1977 (Stea and Fowler 1979, 1981; Stea 1982, 1983; Stea and Grant 1982; Stea and Finck 1986; Turner and Stea 1987a, b, 1988a, b) and 1984-89 (Bonner et al. 1990). Concentrations of metals were "normalized" across sample media (lake sediment, stream sediment, glacial till, and vegetation (i.e., red and black spruce bark)) in an attempt to make meaningful comparisons across the different sample media. We identified the mean value of each element in each dataset, then divided the remainder of the data into standard deviations around the mean.

Habitat assessment was based on vegetative features associated with mainland sites currently used by moose. Habitat associations were created by linking provincial PGI data (unpublished data, NSDNR 1983-2003) that indicated moose presence/absence with Forest Resource Inventory data that identified vegetative features (NSDNR 1999), following methods developed by MacKinnon (2001) and Brannen (2004). To better ensure that habitat use by moose was identified in this analysis, the plot size for data extraction was set with a 1 km buffer around each transect because a pellet group could occur at any point along a transect; this resulted in 2x3 km plots. The aim was to discover habitat preferences by comparing and contrasting quantifiable forest variables from plots where moose were present against those where moose were absent. The PGI data were statistically analyzed using logistic regression (SPSS, v.11.5; $p<0.05$) to allow for direct comparison between PGI transects with moose presence and absence. The presence/absence information was used to extract 32 habitat variables (Table 2) from the Forest Resource Inventory following MacKinnon (2001) and Brannen (2004). Correlations between these 32 habitat variables and moose presence were then tested with a stepwise binary logistic regression analysis. The nature of the analysis forced the assumption that the PGI are spatially and temporally independent, which may not be true. The benefit of doing such an analysis is that no prior assumptions are made as to what comprises preferred habitat.

From the results of the stepwise binary logistic regression analysis, 3 models were created that should be able to predict the probability of moose presence (Table 3). One of these predictive models, Model 3, was shown to best fit the data using 2 data fitness tests (-2 Log Likelihood, and Nagelkerke R Square) and was also found to better predict moose presence. Model 3 appeared to make the most sense biologically to meet moose requirements based on the variables used to construct the model. The log (P/1-P) values produced by these equations were then converted into probability values, which fell within the range 0.0-1.0, by applying the equation,

Probability = $\exp(\text{Model}_x/1 + \exp(\text{Model}_x)$, where $\exp(\text{Model}_x)$ is equivalent to $e^{(\text{Modelx})} = 2.7183^{(\text{LogModelx})}$.

These values were then broken into 5 categories for habitat classification (Table 4).

The models were then applied to the mainland control sites and the Cape Breton study area using a moving-window technique

Table 2. At total of 32 habitat variables were extracted from the Forest Resource Inventory (NSDNR 1999) through statistical analysis (logistic regression (SPSS, v.11.5; $p<0.05$)) of forest variables from PGI-transect plots with moose presence and absence. Correlations between these 32 habitat variables and moose presence were then tested with a stepwise binary logistic regression analysis to create predictive models (see Table 3) of the probability of moose presence in the mainland control sites and the Cape Breton study area.

| Habitat variable | Description |
|---|---|
| P_SW | Percent softwood |
| SW_AVGHT | Softwood average height (m) |
| SW_AVGMT | Softwood average maturity value (class) |
| SW_SVGCR | Softwood average crown closure |
| P_HW | Percent hardwood stands |
| HW_AVGHT | Hardwood average height (m) |
| HW_AVGMT | Hardwood average maturity value (class) |
| HW_AVGCR | Hardwood average crown closure |
| P_MSWD | Percent mixed softwood dominant |
| MS_AVGHT | Mixed softwood average height (m) |
| MS_AVGMT | Mixed softwood average maturity value (class) |
| MS_AVGCR | Mixed softwood average crown closure |
| P_MHWD | Percent mixed hardwood dominant |
| MH_AVGHT | Mixed hardwood average height (m) |
| MH_AVGMT | Mixed hardwood average maturity value (class) |
| MH_AVGCR | Mixed hardwood average crown closure |
| P_UC | Percent unclassified forest |
| SP1_DOM | Dominant tree species in the plot |
| SP1_PROP | Proportion of habitat SP1 occupies |
| SP_RICH | Total number of tree species |
| SP_DIV | Species diversity (Shannon's Index of Diversity) |
| P_FOREST | Percent of forested area |
| P_NONFOREST | Percent of area that is brush, rock barren, urban, barrens, agriculture, alders, miscellaneous |
| P_CLEARCUT | Percent of area occupied by clearcuts |
| WTLND-AREA | Total wetland area (ha) |
| STREAM-LEN | Length of streams and rivers (m) |
| LAKE_AREA | Total area of lakes (ha) |
| PRIM_RDS | Length (m) of primary (paved) roads other than 100 series highways |
| SECON_RDS | Length (m) of unpaved roads |
| TRAILS_RDS | Length (m) of trails, wood roads, abandoned roads, abandoned railways |
| ELEV-MEAN | Average elevation (m) |
| HAB_DIV | Habitat diversity using % softwood, % hardwood, % mixed softwood, % mixed hardwood, wetlands, barrens, clearcuts, and agriculture (Shannon's Index of Diversity) |

developed by Duinker et al. (1991, 1993) and previously applied to mainland Nova Scotia by Snaith et al. (2002). This GIS technique calculates a value for each search window, in this case a 2x3 km plot to remain consistent with the data extraction. During the model run,

Table 3. Three predictive models (Models 1-3) were created from correlations revealed through a stepwise binary logistic regression analysis of 32 habitat variables (see Table 2 for habitat variable descriptions) and moose presence on PGI-transect plots. Using 2 data fitness tests (-2 Log Likelihood, and Nagelkerke R Square), Model 3 was shown to best fit the data and predict moose presence.

| Model 1 |
|---|
| Mixed softwood stand average maturity, % mixed hardwood, % non-forested area, total wetland area |
| Model 1 = log (P/1-P) = MS_AVGMT + P_MHWD + P_NONFOR + WTLND_AREA |
| -16.993 + 1.669(MixedSW_Maturity) + 0.621(%MixedHW) + 0.078(%Nonforested) + 0.059(Wetland area) |
| **Model 2** |
| Softwood stand average maturity, mixed softwood stand average maturity, % mixed hardwood, % non-forested area, total wetland area |
| Model 2 = log (P/1-P) = SW_AVGMT + MS_AVGMT + P_MHWD + P_NONFOR + WTLND_AREA |
| -28.843 + 2.315(SW_Maturity) + 1.234(MixedSW_Maturity) + 0.718(%MixedHW) + 0.105(%Nonforested) + 0.101(Wetland area) |
| **Model 3** |
| Softwood stand average maturity, hardwood stand average maturity, % mixed hardwood, % non-forested area, total wetland area |
| Model 3 = log (P/1-P) = SW_AVGMT + HW_AVGMT + P_MHWD + P_NONFOR + WTLND_AREA |
| -53.289 + 6.555(SW_Maturity) + 1.340(HW_Maturity) + 0.844(%MixedHW) + 0.158(%Nonforested) + 0.161(Wetland area) |

the assessment units, or "windows", overlap with neighboring units by 50% to permit each forest stand to contribute to the calculation several times. This is meant to reflect the possibility that moose ranges overlap the boundaries of these arbitrary windows, and an attribute of a forest stand occurring just outside 1 window may affect the value of the adjacent window. This mechanism, following Snaith et al. (2002), is used to account for moose home ranges that encompass many forest stands, and the fact that moose range freely between these stands in spatial patterns difficult to predict. The roving window technique assesses a greater number of possibilities for home range composition based on the forest data. Once the units are amalgamated, they show a spatial pattern of how the different classifications of habitat are distributed across the landscape. The models were applied to the Cape Breton and mainland sites to identify and compare the extent to which suitable habitat exists at each site.

Table 4. Probability values for moose presence were derived from log (P/1-P) values produced by Models 1-3, then reclassified for rating habitat. The models were then applied to the Cape Breton study area and the mainland control sites to determine the percentage of land area in each probability class for moose presence (see Table 5).

| Probability value | Class | Rating |
|---|---|---|
| 0.0 – 0.199 | 1 | Very low probability |
| 0.2 - 0.399 | 2 | Low probability |
| 0.4 – 0.599 | 3 | Medium probability |
| 0.6 - 0.799 | 4 | Good probability |
| 0.8 – 1.0 | 5 | High probability |

## Non-habitat exclusion factors

Informal, semi-structured interviews with key informants (*n* = 11) were conducted to identify potential non-habitat exclusion factors. Participants included NSDNR staff, university professors, forest industry employees, and staff from museums and educational centres local to Richmond and Cape Breton counties. Common questions were asked of participants about the historical and current presence of moose in the area, whether they believe that sufficient quality and quantity of habitat exists in the area to support moose, why they think moose may be excluded from the area, and current local societal attitudes towards moose. Their responses were recorded and qualitatively assessed to identify the range of factors indicated and areas of agreement and disagreement.

## RESULTS

### Historical Distribution

European settlement of Nova Scotia took place in the early 1600s, and by all accounts moose and caribou (*Rangifer tarandus*) were abundant and hunted heavily for subsistence (Lescarbot 1609, DuCreux 1664, Denys 1672). Wide-scale alteration of the landscape and unrestricted hunting of these species caused the eventual extirpation of caribou and the decline of moose (Denys 1672, Benson and Dodds 1980). Historical memoirs from the Fortress of Louisbourg, a large French settlement established on the Cape Breton coast in 1713, mention a lack of fresh meat in the area by the mid-1700s (Pichon 1760), suggesting that moose were absent from that area of Cape Breton Island. White-tailed deer, while gradually expanding their range into the province, were purposefully introduced on mainland Nova Scotia in 1894, and spread across the province within 17 years (Benson and Dodds 1980). Moose were eventually extirpated or nearly extirpated from Cape Breton, while localized groups on the mainland were fragmented and declining. This led to harvest restrictions in the mid-1800s and eventual hunting closures that continued on Cape Breton until 1980 when it became apparent that a reintroduction of moose had been highly successful. On the mainland, moose numbers fluctuated with intermittent periods of hunting until the last legal hunt in 1981 (Benson and Dodds 1980, Pulsifer and Nette 1995). While these and other accounts indicate that moose existed on Cape Breton Island and mainland Nova Scotia, specific references to the study area do not exist.

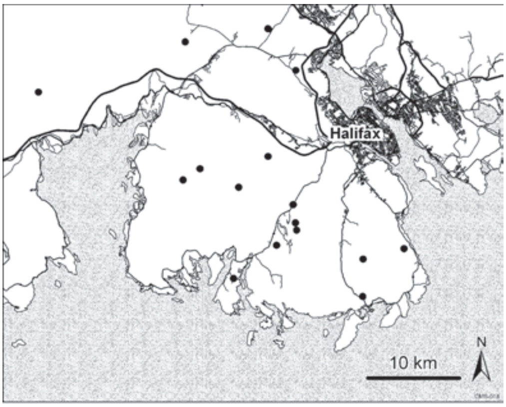
### Habitat Assessment

**Moose Presence --** Moose have occupied the Chebucto Peninsula since establishment of the PGI in 1983 (8 of 12 PGI transects with pellet groups; 25-30 resident moose; density 1:21-25km$^2$) (Fig. 3). The Chedabucto Peninsula has a sparser and perhaps more recently established moose population, as pellet groups were recorded only since 1995 (2 of 17 PGI transects with pellet groups; 8-12 resident moose; density 1:218-272 km$^2$). In contrast, no pellet groups were found on 28 PGI transects at the Cape Breton study area, although moose are seen occasionally.

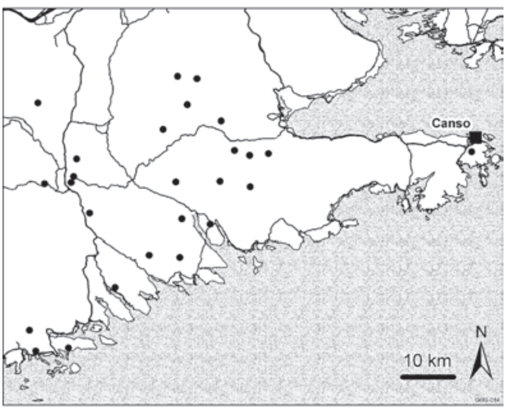
**Biogeographic factors --** In 1947-48, 18 moose were introduced to Cape Breton Island from Alberta. These moose, and any native moose surviving in the region at that time, form the basis of the current population (Broders et al. 1999). Moose have thus had >50 years to re-establish in the southeastern side of Cape Breton, yet continue to be absent. Moose expand into new territory at rates ranging from 8-24 km/year (Pimlot 1953, Mercer and Kitchen 1968), and moose in some populations seasonally migrate 40-80 km/year (Edwards and Ritcey 1956, Gillingham and Klein 1992, Van Ballenberghe 1992). Some moose have dispersed 100-200 km beyond their normal range (Kelsall 1987). Given these behaviors and distances, it seems unusual that moose have not expanded into southeastern Cape Breton since the introduction.

Bras d'Or Lake essentially divides Cape Breton into 2 parts (Fig. 4). Land bridges that provide the major connectivity for highways and human activity are narrow. To the south, Bras d'Or Lake is separated from the Atlantic Ocean by a very slender land bridge at St. Peter's Inlet, which is narrow and dotted with small islands. Movement across St. Peter's Inlet is not physically inhibited, but may be influenced by lack of security, disturbance, or poaching associated with the local human population.

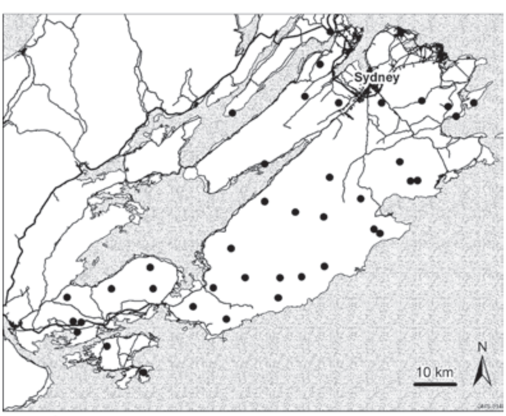
The north contains a more densely human populated and developed area, including the communities of Sydney, Sydney Mines, and North Sydney, and several major highways that might cause an avoidance response. Moose would be much more visible and vulnerable




3a. Chebucto control site




3b. Chedabucto control site




3c. Cape Breton study area

Fig. 3. Locations of Pellet Group Inventory (PGI) transects at the two mainland control sites and the Cape Breton study area. The Chebucto control site (3a) had 8 of 12 PGI transects with moose pellet groups, the Chedabucto control site (3b) had 2 of 17 PGI transects with pellet groups, and 0 of 28 PGI transects in the Cape Breton study area (3c) had pellet groups.

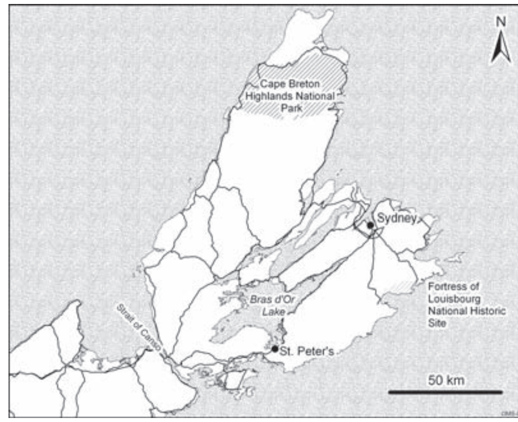



Fig. 4. Configuration of the Cape Breton study area, showing narrow land bridge at St. Peter's and separation of the study area from the remainder of Cape Breton by Bras d'Or Lake.

to the greater traffic in this region. In contrast, there are a number of narrow channels and bays that moose could easily cross to avoid many of these situations. Moose are strong swimmers (Benson 1957) and have been documented swimming to offshore islands and across large bodies of salt water such as the Strait of Canso (Benson and Dodds 1980). Access to the southeastern side of Cape Breton should not influence moose dispersing from the north. As evidence, moose have been observed in southeastern Cape Breton in the past, but sighting reports typically cease abruptly (A. McLain, Manager of Heritage Protection, Halifax Parks Canada, ret.). These disappearances were attributed to poaching in the absence of any other reasonable explanation or indication that moose dispersed from the area (L. McDonald, Supervisor of Forest Services, NSDNR, pers. comm.; M. Pulsifer, Regional Biologist, NSDNR pers. comm.; L. Reeves, Senior Park Warden, Fortress of Louisberg, pers. comm.).

**Inter-species interactions** -- There are no natural predators of moose in the Cape Breton study area given the absence of black bears, and gray wolves (*Canis lupus*) are extirpated from the province (Whitaker 2006). As elsewhere, however, there is overlap between winter browse use by moose and white-tailed deer

(Telfer 1972). Studies of moose and white-tailed deer in eastern North America have often demonstrated that when one species increases in numbers, the other declines (Dodds 1963, Telfer 1970, Benson and Dodds 1980, Pulsifer and Nette 1995). This is usually related to "moose sickness" or parelaphostrongylosis as a result of the transmission of the nematode parasite, *Parelaphostrongylus tenuis*, normally carried by white-tailed deer (Telfer 1967a,b; Peterson et al. 1996, Lankester and Samuel 1998), not as direct competition for resources. While it is unclear the extent to which the presence of white-tailed deer can depress moose populations through the transmission of *P. tenuis*, the potential mortality of moose is well documented (Thomas and Dodds 1988, Schmitz and Nudds 1994, Lankester and Samuel 1998, Beazely et al. 2006). Nonetheless, moose and deer persist together in other regions in Nova Scotia including the two mainland control sites, as well as other eastern Canadian provinces and the northeastern United States. Further, there is no evidence of moose in the area prior to establishment of deer in the region. Thus, it would seem that this interaction, taken alone, cannot explain the absence of moose from the Cape Breton study area.

In combination with climatic and geological factors, however, *P. tenuis* may play a role in limiting or excluding moose from the Cape Breton study area. Beazley et al. (2006) suggest that parelaphostrongylosis may regulate moose populations on mainland Nova Scotia, with localized groups surviving in refugia in elevated regions of the province where white-tailed deer are absent or in low density (T. Nette, NSDNR, unpublished data), or in areas with granitic soil that is not compatible with the intermediate molluscan hosts of *P. tenuis* (R. Cameron, NSDNR, unpublished data). Similar geographic and interspecific factors may be influencing the distribution of moose in Cape Breton; moose at high densities exist in the elevated, granitic regions of the Cape Breton highlands where white-tailed deer densities are low, and moose are limited in southeastern Cape Breton where elevations are lower and deer densities are higher. This possibility is explored in the following section with reference to relevant geographical differences.

**Geographical comparison --** The Cape Breton study area and the two mainland control sites fall primarily within the Atlantic Coastal Ecoregion. However, the mainland control sites lie within the Granite Barrens Ecodistrict, dominated by granite bedrock, much of it exposed and with acidic soils, whereas the Cape Breton study area lies primarily within the Till Plain, a low-lying area with poorly drained surface and neutral pH levels (Davis and Browne 2003b) (Table 1). Both moose and deer exist in the granitic mainland control sites, whereas in the Cape Breton study site deer exist in higher densities and moose are infrequent. Moose exist in higher densities in other areas of the Atlantic provinces with similar geology to southeastern Cape Breton. Localized groups of moose in the Cobequid Mountains, Antigonish-Pictou Highland, and Cape Breton Highlands all fall within the Avalon Terrane in which the Cape Breton study area is also situated.

The volcanic, sedimentary, and minor Precambrian plutonic rocks of the Cape Breton study area extend into the Avalon Peninsula in eastern Newfoundland and the Caledonia Highlands in New Brunswick. These areas are at higher elevations and latitudes and may limit deer or geographically separate them from moose in these areas. Conversely, both moose and deer occur in the more granitic and lower altitudes of the Meguma Terrain in which mainland moose at the control sites and in southwest Nova Scotia occur. While geographic and interspecific interactions do not separately explain absence of moose in the Cape Breton study area, in combination, soil types that favor presence of white-tailed deer and the intermediate molluscan hosts of *P. tenuis*, and climatic factors related to elevation and/or coastal influences that support or favour deer, may relate to the absence of moose in the Cape Breton study area. While these interactions may serve to limit moose at present, and thus warrant further research, it is unlikely that these factors alone could have excluded moose historically, prior to the arrival of deer.

Thermoregulatory influence on moose presence is possible because Nova Scotia is in the southernmost range of moose with regard to heat tolerance (Telfer 1984, Karns 1998). Moose are at risk of thermoregulatory stress while in winter coat at temperatures >5.1 °C and at ≥14 °C when in summer coat (Karns 1998). The average maximum winter temperature does not approach 5.1 °C at any study site; however, extreme high winter temperatures, mean maximum summer temperatures, and extreme seasonally high temperatures at all sites exceed the critical temperatures. These temperature values are, however, similar at all the study sites. It is possible that both summer and extreme seasonally high temperatures could cause thermoregulatory stress at all 3 sites; however, since moose occupy the mainland control sites, it seems unlikely that a site-specific effect occurs only in southeastern Cape Breton.

Snow depth plays a critical, influencing role on moose movement during winter. Snow depth >60 cm can severely impede mobility and add to seasonal energetic demands (Prescott 1968, Telfer 1970, Kelsall and Prescott 1971). The 'highest recorded value' for snow depth was at the Cape Breton study area, but it is also well above 60 cm at both mainland control sites. Because average snow depth at all sites is well below 60 cm, it is unlikely that snow depth limits moose presence in the Cape Breton study area.

**Road Density --** As road density increases, the likelihood of species extirpation also increases from the provision of access for competitors, predators, hunters, and vehicular collisions (Noss 1995, Forman et al. 1997, Nasserden et al. 1997). Moose are vulnerable to increased hunting near roads, particularly illegal hunting (Lyon 1984, Boer 1990), and the increased human activity associated with roads can also disrupt normal moose behavior (Jalkotzky et al. 1997, Gucinski et al. 2001, Beazley et al. 2004, Laurian et al. 2008). Moose-vehicular mortality is 2-6 annually on mainland Nova Scotia (Beazley et al. 2006). A comparison of the study and control sites demonstrated that while road density appears higher in the Cape Breton area than either mainland site, substantial areas with low-no road density exist within the Cape Breton study area, and other areas of Nova Scotia have higher road density with persistent localized groups of moose (Snaith 2001, Snaith et al. 2002, Beazley et al. 2004). The Cape Breton study area appears to have a larger area of road density above the threshold (0.6 km/km$^2$) than do the 2 mainland sites (Fig. 5), although 11 moose were sighted on roads in 1985-2004. While it is likely that the open road corridors and higher traffic density increased the likelihood of sightings, it would not appear that the presence of roads interferes with moose movement, as only 1 sighting in the study area resulted from a vehicular mortality.

Moose on Chebucto Peninsula live in close proximity to Halifax and persist to date; however, the question remains as to whether moose are able to persist in areas with relatively high road density given the direct and indirect mortality and disturbance effects. Although roads do not explain the historical absence of moose in the Cape Breton study area, this area has higher road density than both mainland control sites, thus road density could relate to the continued absence of moose and warrants further study.

**Geochemistry --** Geochemical imbalances may cause a deficiency or excess of trace elements in associated vegetation as the material is naturally liberated from the soil and bedrock through erosion and acid deposition

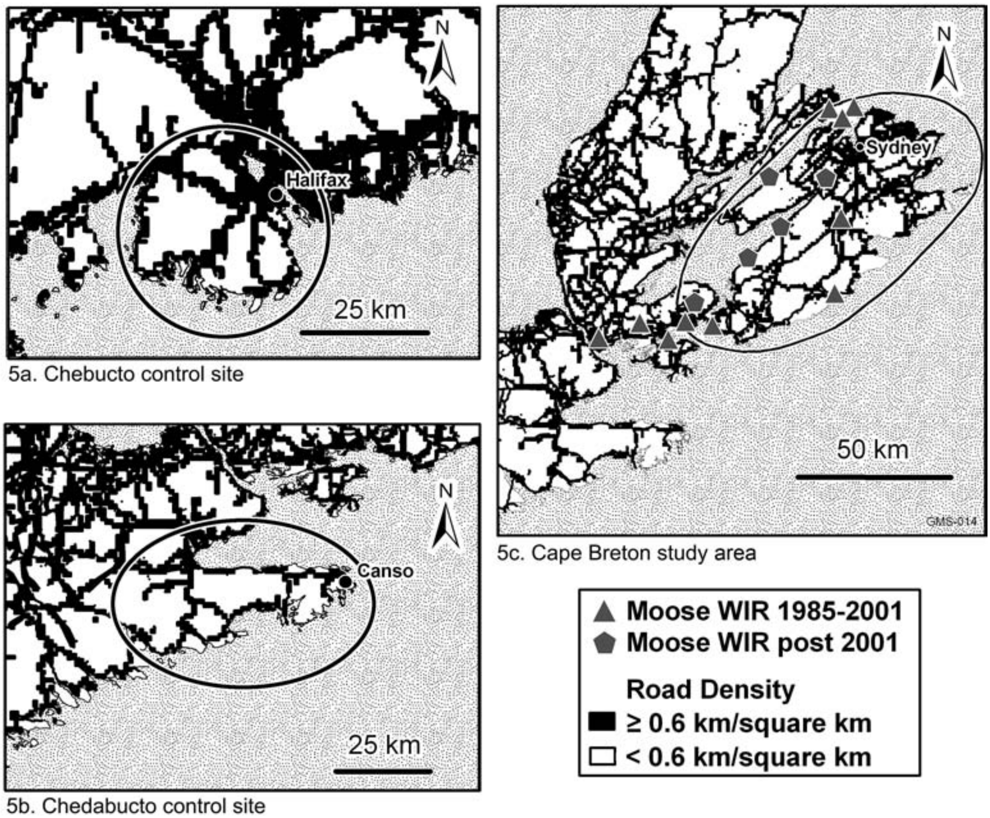



Fig. 5. Road densities in the mainland control sites (5a. Chebucto; 5b. Chedabucto) and the Cape Breton study area (5c). Road densities ≥0.6 km/km$^2$ are indicated in black tone, whereas intervening areas of <0.6 km/km$^2$ remain white. In figure 5c, grey-tone triangles represent moose sightings reported in Wildlife Incidence Reports (WIR) (1985-2001), and hexagons indicate moose WIR post-2001.

(Frank 1998, Environment Canada 2003). Heavy metals are highly mobile in acidic conditions (e.g., as associated with acid precipitation) particularly when the parent material has a low pH-buffering capacity (Environment Canada 2002). These free, naturally-occurring elements can bio-accumulate in herbivores and lead to disease (Scanlon et al. 1986, Frank 1998, Frank et al. 2000 a, b).

Spatial concentrations of heavy metals (Kwan 2005) suggest that there is a high occurrence of molybdenum in the Cape Breton study area that may warrant further investigation. Lead is high at a localized site, a former economically viable mine. However, the lead formation is not likely to have wide-spread effects across the entire region. No discernable pattern of copper and moose presence was found, and cadmium data were available only for northern Nova Scotia. Cadmium levels should be mapped for the rest of the province before conclusions are drawn as to its potential effect on moose habitat suitability; however, cadmium concentration appears high in the Cape Breton study area. High environmental concentration of a heavy metal does not necessarily translate into a high biological concentration, but may indicate relative availability for uptake.

The trace element status of moose and white-tailed deer from various locations across Nova Scotia was analyzed subsequent to our review (Pollock 2006, Pollock and Roger 2007). No moose from the specific Cape Breton study area were collected and measured, although deer were. In northern Cape Breton, concentration of cobalt in moose kidneys, and concentration of zinc and copper in deer were at levels considered marginal (marginally deficient or deficient with reference to values for domestic cattle (*Bos taurus*); Puls 1994) (Pollock 2006). The concentration of manganese, selenium, and lead in moose livers from Cape Breton, and of selenium in moose from the western mainland region were also considered marginal. While concentrations of these trace elements are considered marginal in Cape Breton, the samples were from areas where moose populations are high. There is little evidence that clinical deficiencies of trace elements occur in moose populations in Nova Scotia (Pollock 2006, Pollock and Roger 2007). However, it is possible that the health of individual animals may be impacted by marginal, deficient, or high levels of trace elements either directly or through interactions with other factors; thus, further monitoring and analyses are warranted. Necropsies of 22 mainland and Cape Breton moose since 1998 found no gross or microscopic lesions compatible with cadmium toxicity, or cobalt, copper magnesium, selenium, and zinc deficiencies, suggesting that clinical disease associated with these trace elements has not occurred in Nova Scotia (Beazley et al. 2006). We conclude that no evidence exists that trace element deficiencies or toxicities act to exclude moose from the Cape Breton study area.

**Forest Habitat Assessment** -- Model 3 consistently predicted the highest proportion of most suitable habitat (based on high probability of moose presence) at all 3 sites (Table 5). This model indicated that suitable habitat (based on mainland moose occupying ecologically similar terrain) exists in the Cape Breton study area, with 42.6% of the area classified as Class 5 (High Probability). Model 1 and Model 2 predicted less Class 5 habitat in the Cape Breton area, 31.6% and 39.8%, respectively. When combined with habitat in

Table 5. Models 1-3 were applied to the Cape Breton study area and mainland control sites to determine the percentage of land area in each probability class for moose presence at each site. The Cape Breton study area had the highest percentage of land area classified as high probability, and the lowest as very low probability in all 3 models.

| | | Chebucto Peninsula mainland control site | Chedabucto Peninsula mainland control site | Cape Breton study area |
|---|---|---|---|---|
| | Size of study area | 63,690 ha | 218,312 ha | 318,193 ha |
| Class 1 - | Model 1 | 57.3% | 85.5% | 46.0% |
| Very low probability | Model 2 | 52.3% | 86.4% | 45.0% |
| | Model 3 | 47.8% | 85.7% | 47.00% |
| Class 2 - | Model 1 | 11.3% | 5.2% | 8.8% |
| Low probability | Model 2 | 9.6% | 2.4% | 5.9% |
| | Model 3 | 4.7% | 1.5% | 4.4% |
| Class 3 - | Model 1 | 5.3% | 2.5% | 6.9% |
| Medium probability | Model 2 | 6.0 % | 2.1% | 4.3% |
| | Model 3 | 4.6% | 1.4% | 6.7% |
| Class 4 - | Model 1 | 7.3% | 1.9% | 6.7% |
| Good probability | Model 2 | 7.3% | 2.1% | 5.1% |
| | Model 3 | 7.0% | 1.7% | 2.9% |
| Class 5 - | Model 1 | 18.7% | 4.9% | 31.6% |
| High probability | Model 2 | 25% | 6.9% | 39.8% |
| | Model 3 | 36.2% | 9.5% | 42.6% |

the Class 3 (Medium Probability) and Class 4 (Good Probability) categories, the total amount of suitable habitat ranged from 45.2- 48.6% across the 3 models. Comparatively, Model 3 predicted 36.2% and 9.5% Class 5 habitat at the Chebucto and Chedabucto control sites.

We were not able to validate the models using statistical cross-validation due to the small sample size. Previous habitat suitability modeling based on optimal habitat conditions predicted little suitable habitat on the mainland (Snaith et al. 2002). Such results could suggest that moose occupy sub-optimal habitat. Given the lack of information concerning habitat preference of moose in Nova Scotia, the use of PGI offers an alternative predictive approach. Habitat suitability indices of Snaith et al. (2002) were unable to predict moose presence/absence, however road density alone and the combination of habitat suitability indices with road density predicted moose presence/absence; moose presence was negatively correlated with road density. The models created by this research did not contain a road component, since road occurrence was minimal in the PGI plots used to create the models, and thus could not be a variable. Our models were based on those created by Brannen (2004) who used a similar strategy to identify moose habitat preferences for the entire mainland with a road component. Given the reported effect of roads on moose and the equivocal results of this research, further analysis of the relationship between road presence, habitat use, and moose presence/absence is warranted in the study area and elsewhere in Nova Scotia.

### Non-habitat Exclusion Factors

Potential exclusionary factors identified by key informants included competition with white-tailed deer, *P. tenuis*, and poaching, though none of these were considered sufficient to explain exclusion. Because moose and deer coexist in other parts of their range, key informants believed that the presence of deer in the study area should not prevent an established moose population.

Poaching, and a high social tolerance for the practice, was suggested as a potential exclusion factor. The current social attitude towards moose is believed to be one of utilization based on the Acadian traditions of the region. Interviewees suggested that moose would be welcome in the area as an additional source for sport hunting, but that a high social tolerance towards illegal hunting prohibits a stable population. Conversely, northern Cape Breton has a legally and heavily hunted moose population that persists at high density. Consequently, opportunistic poaching, on its own, was not considered significant enough to exclude moose. These areas differ, however, in that much of the higher elevation areas of northern Cape Breton are inaccessible, and a substantial portion of the area contains protected areas where hunting is prohibited or restricted as in Cape Breton Highlands National Park and the Pollets Cove–Aspy Fault Wilderness Area.

## CONCLUSION

We were not able to identify any specific cause for the continued absence of moose from the southeastern side of Cape Breton. None of the examined habitat elements appear to exclude moose, and sufficient, suitable habitat appears to be available assuming the forest inventory data are accurate. Class 3, 4 and 5 habitat represented 154,641 ha (Model 3) in the Cape Breton study area, an area much larger than the Chebucto Peninsula that maintains a small, localized group of moose.

The geographical differences among the mainland control sites and the study area were not considered substantial enough to explain the lack of moose in the Cape Breton study area. It is possible that in combination, soil type (i.e., granitic), temperature and snow depth (i.e., that limit or exclude deer), and inter-specific interactions among white-tailed deer, *P. tenuis*, molluscan hosts, and moose serve to limit moose in the Cape Breton study area and other areas of Nova Scotia. Nonetheless, these factors seem insufficient to explain the historical absence of moose in the study area.

Future research could include further investigations of the geochemical composition of the area, the social tolerance of poaching behavior, and First Nations knowledge of historical and current moose distribution. A vegetative analysis in the Cape Breton study area could identify whether heavy metals accumulate in preferred browse that could affect forage palatability and moose health. A health assessment of white-tailed deer in the Cape Breton study area could potentially identify geochemically-related health issues that may also affect moose.

The habitat modeling relied heavily upon the provincial forest inventory database. This data is updated periodically, but is based primarily on the use of permanent sample plots located around the province and interpretation of aerial photographs. The information in the database should be field-verified before drawing definitive conclusions from the modeling exercise. A sampling of understory vegetation could improve the habitat model by improving its relevance to habitat suitability. As well, negatively correlated habitat features, such as road density and proximity to human population centers, should be incorporated into the modeling exercise as they often have negative impact on moose, habitat use, and habitat suitability.

## ACKNOWLEDGEMENTS

We acknowledge the support of the following, without whom this work could not have been completed: NSDNR's Wildlife Division and Graphic & Mapping Services, Martin Willison, Hugh Broders, Frances MacKinnon (GIS technical support), Dennis Brannen, Wade Blanchard, Terry Goodwin, Kenneth Donovan, and key informants Dave McCorquodale, Terry Power, LeeAnne Reeves, Lloyd McDonald, Trevor Wilkie, Bevan Lock, Don Dodds, Jenny Costelo, Doug Archibald, and Mark Pulsifer. Thanks to the editors of ALCES and anonymous reviewers.

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