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The effects of landscape disturbance on the population dynamics and behaviour of moose (*Alces alces*) in the Greater Pukaskwa Ecosystem, Ontario

by

Frank G. M. Burrows ©

A graduate thesis submitted in partial fulfillment of the requirements
for the Degree of Master of Science in Forestry

Faculty of Forestry and the Forest Environment
Lakehead University

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ABSTRACT

Burrows, F.G.M. 2001. The effects of landscape disturbance on the population dynamics and behaviour of moose (*Alces alces*) in the Greater Pukaskwa Ecosystem, Ontario. 87pp. Advisor: Dr. Arthur R. Rodgers, Centre for Northern Forest Ecosystem Research and Faculty of Forestry and the Forest Environment, Lakehead University, Thunder Bay, ON.

Key words: home range, kriging, landscape disturbance, moose (*Alces alces*), population surveys, Pukaskwa National Park.

I studied the population dynamics, movements and home range of moose (*Alces alces*) in the Greater Pukaskwa Ecosystem, Ontario, during 1995-1999. My study compared two landscapes experiencing different management regimes: Pukaskwa National Park (PNP), a wilderness park, and the adjacent Wildlife Management Unit #33 (WMU33), a multi-use forest with commercial timber harvest (part of the White River Forest). I hypothesized that because PNP was not disturbed (i.e., by fire or timber harvest) and WMU33 was, the condition of moose and moose habitat carrying capacity would be better in WMU33 than PNP. I used 5 triennial aerial moose surveys to assess population dynamics and distribution, and 35 radio-collared adult female moose to assess productivity, survival, marrow condition, blood condition, morphometrics, movements and home range. I found the mean moose density per plot in the most recent aerial surveys to be slightly higher but not statistically different in WMU33 than PNP (0.332 and 0.273 moose/km^2, respectively), and kriging demonstrated that most of the high moose densities occurred in WMU33 and were increasing more than in PNP. Survival rates were not significantly different between landscapes (93% in PNP and 89% in WMU33), and were similar to findings of other studies. Marrow fat showed differences among seasons, being highest in summer and lowest in late winter, but was not significantly different between landscapes. Movements in PNP were greater than in WMU33, and PNP moose showed distinct movements between summer and winter ranges, which was not seen in WMU33. Seasonal movements were significant, with summer being the greatest (22.0 m/hr in PNP and 20.1 m/hr in WMU33) and winter the smallest (6.9 m/hr in PNP and 5.5 m/hr in WMU33). Annual MCP home range sizes were significantly larger in PNP than WMU33 (70 and 43 km^2, respectively). Home ranges also showed significant season effects, being largest in summer and smallest in winter. In my study, I found that moose occupying the WMU33 landscape have shown a slight positive response to forest disturbance, caused by timber harvest, through increased population density. I did not find statistically important differences in physical condition of moose between the two landscapes, but moose in WMU33 made smaller movements and had smaller home ranges than moose living in the undisturbed landscape of PNP.

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CHAPTER 1: INTRODUCTION

The Province of Ontario has an interesting history of ungulate populations and management. One of the most intriguing and debated issues has been the apparent decline in woodland caribou (*Rangifer tarandus caribou*) densities correlative with European colonization and increases in moose (*Alces alces*) densities (Darby et al. 1988, Fritz et al. 1993). Woodland caribou are believed to have occupied a continuous range throughout the Boreal forest and into the Great Lakes - St. Lawrence forest at relatively low densities ($< 0.1/km^2$) (Darby et al. 1988). In Ontario this includes the entire province south to Lake Nipissing. In the late 1800s and early 1900s caribou are believed to have experienced dramatic declines (Fritz et al. 1993). However, there is some disagreement as to the pre-moose caribou abundance. Coleman (1899 in Bergerud 1989) reported caribou abundant at Tip Top Mountain and the Pukaskwa River, within present day Pukaskwa National Park (PNP) at the northeast corner of Lake Superior.

Today, caribou are generally found north of the main CNR railway line (50° N) through northern Ontario, which also coincides with the present limit of commercial timber harvest. Several small relict caribou populations are found along the north shore of Lake Superior on the Slate Islands, Pic Island and in PNP. Moose were believed to be absent from north-central Ontario prior to the late 1800s. However, since the early 1900s moose have steadily colonized north central Ontario, arriving in PNP in about 1907 (Peterson 1955).

The expansion of moose into northern Ontario is generally believed to be coincident with the decline of caribou. One hypothesis is that increased development of the north in the early 1900s (brought about by new railway and road construction, logging, and mining) accelerated the colonization of moose and increased the pressure on caribou through hunting and increased predation by wolves (*Canis lupus*) (Bergerud 1988). Corroborating evidence shows that wolf populations generally increased in Ontario and the Lake Superior States following range expansions of deer and/or moose (Cringhan 1956 cited in Bergerud et al. 1984). There is also general agreement that the abundance of wolves is ultimately determined by biomass per unit area of ungulate prey (Keith 1983). Thus, the expanded moose populations apparently supported higher wolf densities. Because caribou are easier to kill (Holleman and Stephenson 1981), wolves may have killed caribou when opportunities arose. The net result was that with increased moose densities, wolf densities were higher and predation on caribou increased. This drove the caribou to localized extinction in many areas. This hypothesis is often called the "predation decline hypothesis" (Bergerud 1988).

Prior to the official establishment of PNP in 1983, preliminary studies of the fauna of the region identified a small population (approximately n=25) of woodland caribou within the park (Bergerud 1974). Caribou were identified as a valued ecosystem component in Pukaskwa's first two management Plans (Parks Canada 1982, Parks Canada 1996) and have been given considerable attention within the resource management program over the last 25 years (Bergerud 1989). By 1995, the caribou population in PNP was still very small and possibly decreasing (Wade 1995).

Why are so few caribou left in Pukaskwa and how have they managed to persist? Bergerud (1985, 1988), Bergerud et al. (1984) provided some evidence for his hypothesis that viable populations of caribou cannot survive on ranges frequented by high numbers of wolves (maintained mainly by moose prey) unless there are special habitat features providing escape for cows with young calves. In PNP, the Lake Superior shoreline and islands seem to provide this special habitat feature that allows caribou to persist in the park. There are at least two possible explanations for their small population size. One hypothesis is that an increase in densities of moose caused by landscape disturbance adjacent to the park has increased wolf densities, which has subsequently increased predation on caribou (Bergerud 1988). An alternative, and possibly related hypothesis, is that logging and development of the forest adjacent to the park has decreased older mature habitat which is preferred by caribou, while fire suppression and lack of disturbance inside the park has been to their benefit (Bergerud 1988, Darby et al. 1988).

Although moose are apparently at historically high densities within PNP (Bergerud 1989), they are still relatively low when compared to other regions of the province (McKenney et al. 1998). Bergerud et al. (1983) proposed 4 significant limiting factors to explain these low moose densities: reproduction, starvation, egress and/or predation. He concluded that predation was a significant factor in limiting the growth of the moose population in PNP. If Bergerud's (1988, 1989) overall hypothesis is supported (landscape disturbance - moose increase - wolves increase - caribou decrease), then:

- Moose should respond positively (increased density and/or improved condition) to habitat disturbance, since it will provide ample forage in early successional stands.
- Wolves should show a positive numerical and/or functional response to increasing moose prey.
- Predation on caribou should increase with increasing wolf numbers.

In the mid-1970s, questions regarding the status of the provincial moose population prompted an analysis of moose population survey data. The results indicated a sharp decline of 35% over 15 years (Euler 1983). The population decline was attributed to poaching, predation, habitat loss and hunting. In 1980, the Wildlife Branch of the Ontario Ministry of Natural Resources (OMNR) developed a provincial Moose Management Policy (OMNR 1980). The document outlined objectives of moose management strategies in Ontario and focused on use of hunting controls and habitat management as management tools. Poaching and predation were felt to be less significant than hunting or habitat loss. In 1983, increased regulation of hunters was introduced through a selective harvest system. Regulating the harvest by strict control of the cow and bull harvest using a quota system was believed to be an important factor in improving the subsequent productivity of the moose herd (Timmerman and Whitlaw 1992).

To complement the selective harvest system, the OMNR developed Guidelines for Moose Habitat Management in Ontario (OMNR 1984). This was the first attempt at aligning forest management activities with moose habitat requirements. The goal was to produce good moose habitat with a minimal loss of wood fibre. The guidelines were furthered in 1988 with the publication of "Timber Management Guidelines for the Provision of Moose Habitat " (OMNR 1988; hereafter referred to as the "Timber Management Guidelines"). These latter guidelines recognized timber harvest operations as the major habitat-altering process which, if managed properly, could be used to change forest structure for the benefit of moose populations. The primary objective of the guidelines is to maintain or improve moose habitat carrying capacity.

The Timber Management Guidelines (OMNR 1988) provide for moose habitat in a number of ways. They address life history requisites of moose by ensuring that seasonal moose habitat requirements are identified and maintained. Specific areas of concern and associated buffers (e.g., aquatic feeding areas, moose calving sites, and mineral licks) are withdrawn from timber harvest eligibility. The guidelines also ensure that sufficient summer, early-winter and late-winter habitats are available. Summer habitat includes early successional plant communities that follow major disturbance such as fire or logging, as well as aquatic feeding sites. Early-winter concentration areas may be typified by mature or over-mature, open-canopy, mixed-wood stands of relatively low stocking (<60%). These areas provide considerable browse (open canopy) and provide protection from winds as well as predators. Late-winter concentration areas are usually fairly large areas of well-stocked stands of mature conifer (>70% stocking) with a high degree of crown closure which provides overhead protection from snow accumulation and severe cold. These areas are most functional when near early-winter or other feeding habitat so that travel distance between food and shelter is low. In summary, the best habitat for moose contains food (early successional plant communities) and cover (semi-mature and mature conifer) in close proximity (OMNR 1988).

The area around PNP is managed as the provincial Wildlife Management Unit #33 (WMU33). This area includes part of the White River Forest (WRF), where timber has been intensively harvested according to the Timber Management Guidelines (OMNR 1988) since the early-1980s. As a result, the park has become an island of "protected area". The park's recent Ecosystem Conservation Plan (Geomatics International 1996) identified the “insularization” of the park as a significant threat to its long-term integrity. Increased human access and use, the park's isolation from its “greater ecosystem”, and alteration of important ecosystem processes such as fire and predator-prey relations are some of the transboundary concerns identified in the plan. Moreover, successful application of the Timber Management Guidelines (OMNR 1988) in the adjacent WRF presents a potential threat to the ecological integrity of the park. Parks Canada defines “ecological integrity” with respect to a park as “a condition that is determined to be characteristic of its' natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes” (Parks Canada 2000). If Bergerud's (1988, 1989) overall hypothesis is correct, and moose respond positively to the application of the Timber Management Guidelines by increasing their productivity and population density as expected, then caribou may ultimately be lost from the Pukaskwa ecosystem.

This study compares the population dynamics and behaviour of moose in PNP and the adjacent WMU33 (this includes part of the WRF) to determine whether moose have responded positively to habitat disturbance brought about by timber harvesting in WMU33. Absence of habitat disturbance and/or poor overall habitat within PNP may limit the availability of necessary habitat components (early succession forage, winter browse, and dense conifer cover) for moose. As a result, the habitat-defined carrying capacity (K) for moose within PNP may be lower than in the adjacent WMU33 where it has been enhanced through the creation of disturbed habitat caused by timber harvesting. Thus, productivity and density of moose in WMU33 should be greater than in PNP. It is expected that moose in poor quality habitats within PNP will also demonstrate differing behaviour patterns, such as larger home range and greater movements in an effort to find sufficient resources of food and cover, than moose occupying better habitat in WMU33. As well, moose occupying the WMU33 landscape with higher habitat quality will show significantly better condition indices than moose in poorer quality habitats within PNP. Data from aerial moose surveys, information from mortality investigations (predation, hunting, road kills and rail kills), live captures and radio-collared adult cow moose are used to assess the population characteristics and behaviour of moose in the two landscapes.

CHAPTER 2: STUDY AREA

The study area is located approximately 350 km east of Thunder Bay, Ontario, Canada centred 85° 45' N, 45° 30' W on the north shore of Lake Superior (Fig. 2.1). It includes the Greater Pukaskwa Ecosystem. This area is approximately 800,000 ha, bounded by Highway 17 on the east and north, and Lake Superior on the west. PNP, a 187,800 ha protected wilderness, and north-western sections of the WRF (approximately 60,000 ha), which is part of Wildlife Management Unit #33 (WMU33), are the two landscapes compared in this study.

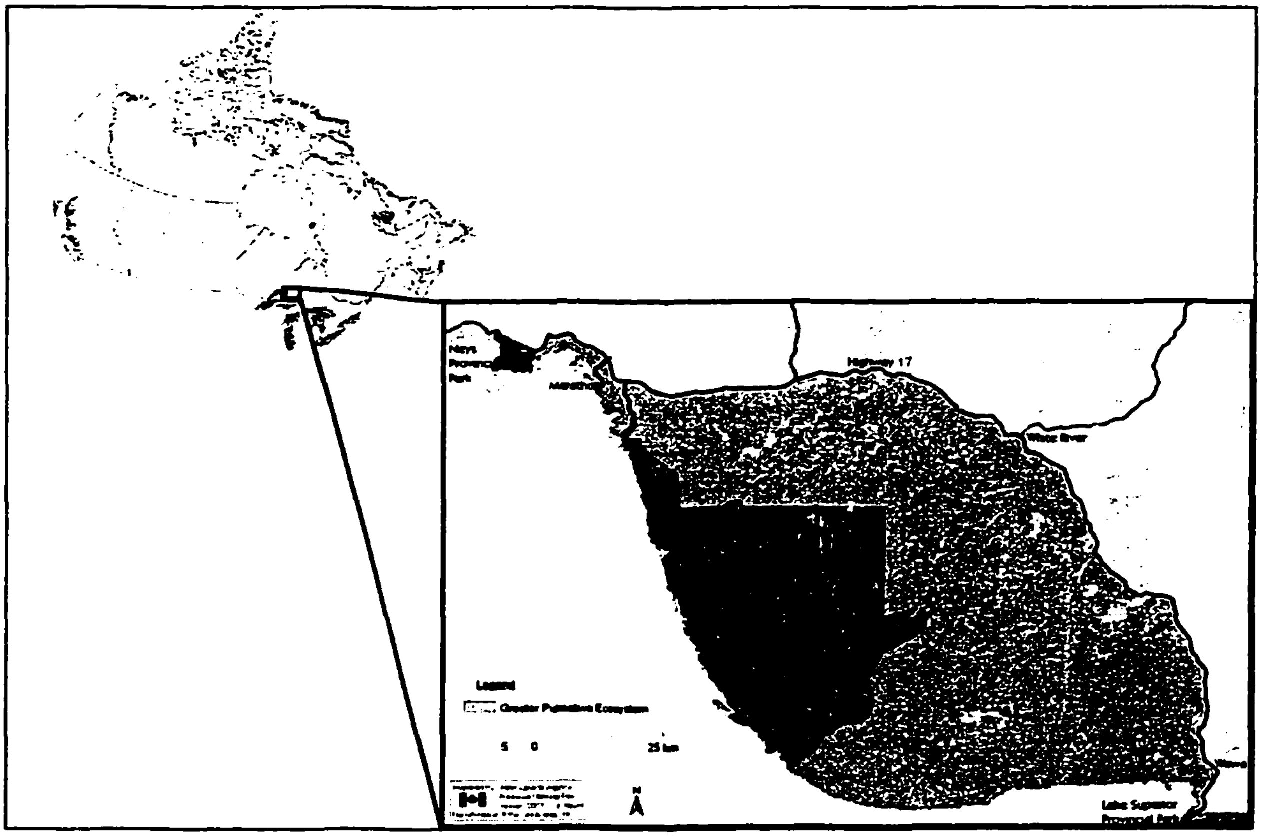

Figure 2.1: Location of the Greater Pukaskwa Ecosystem, Ontario, Canada.

PNP is representative of the Central Boreal Uplands natural region, one of the 39 terrestrial natural regions designated for representation by Parks Canada's systems plan (Parks Canada 1974). It is within the Boreal forest region with some influence of the Great Lakes - St. Lawrence forest region, especially to the south and east (Rowe 1972). This includes Site District 3E-4, Tip Top Mountain of Site Region 3E, Lake Abitibi (Hills 1961). The Park is situated where the Canadian Shield meets Lake Superior, and portrays a typical boreal forest dominated by mixed stands of black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*P. glauca* (Moench) Voss), jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* (L.) Mill.), paper birch (*Betula papyrifera* Marsh.) and trembling aspen (*Populus tremuloides* Michx.).

Approximately 25% of the park area was burned during large fires in 1931 and 1936. The topography varies significantly over the study area. Within PNP it is characterized by a heavily eroded mountain landscape, scoured by continental glaciers which left a drainage system into Lake Superior of swift-flowing rivers in steep-sided valleys. PNP's 128-km shoreline with Lake Superior is rugged, with rocky headlands, sheltered coves and sand and cobble beaches. The Coastal Hills ecodistrict of the park has rugged topography whereas most of the remaining areas, including the WRF, are rolling plateaus and river plains. The soils are shallow (often <10cm) with many rocky outcrops. Large-mammal populations represent the normal boreal complement, which includes a relict population of woodland caribou (15-40 animals). Moose densities are approximately 0.20 moose/km^2, which are considered in the lower range of the moose densities in the province of Ontario (McKenney et al. 1998). There has been no legal harvest of wildlife within the park since the early 1980s with the exception of First Nation's hunting and trapping which is considered negligible (D. Michano pers. comm.).

The area around the park is part of the Wawa District of the Ontario Ministry of Natural Resources and includes the White River Forest to the north and east of PNP and the Wawa Forest Management Unit to the south (Fig. 2.2).

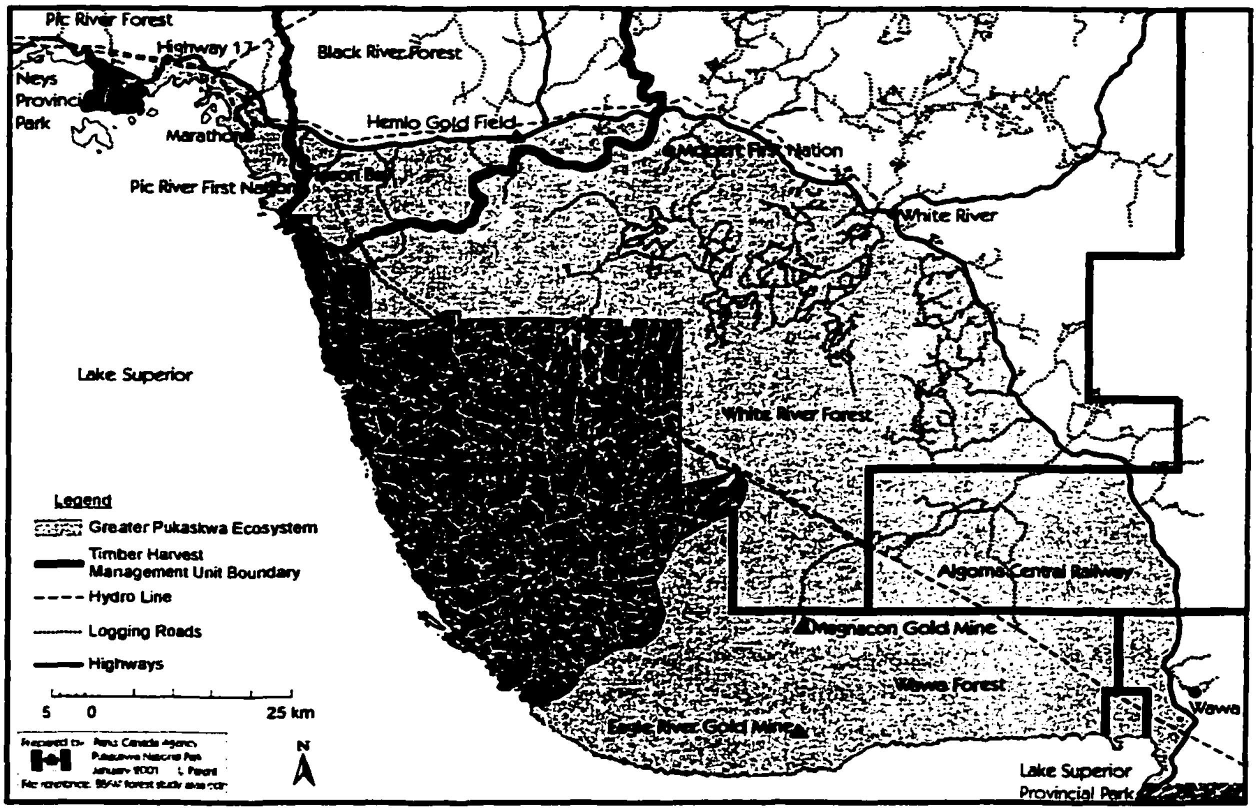

Figure 2.2: Forest Management Unit boundaries, logging roads and active mine locations in the Greater Pukaskwa Ecosystem, Ontario.

The White River Forest occupies a total area of 607,409 ha surrounding the community of White River and straddling Highway 17; of this area; Crown production forest consists of 471,935 ha. Large-scale timber harvest in this area began with the construction of the

White River sawmill in 1978 and greatly intensified in the mid-1980s. The production forest area is comprised largely of spruce (30%), poplar (24%), jack pine (23%) and white birch (20%) working groups. Age-class distributions for all the major working groups exhibit an imbalance favouring the mature to overmature classes. Domtar Inc. is responsible for managing the timber resources under the terms of a Sustainable Forest Licence. Over the period 1988-1993, Domtar harvested 24,294 ha (2,021,213 m^3) of timber (Domtar 1993). In the period 1993-1998, Domtar harvested approximately 2,013,315 m^3 softwood, 906,555 m^3 hardwood and constructed 53.7 km of primary roads and 112.1 km of secondary roads (Domtar 1998). Harvesting decreased to almost nil in the study area in the 1995-1997 period. Mean cut block size was 80-130 ha as recommended by the OMNR Timber Management Guidelines (OMNR 1988). As a result of these differing management regimes, the % cover of some vegetation classes is considerably different in each landscape. The cutover landscape has considerably more disturbed landscape and less mixed-wood vegetation classes than the park (Fig 2.3).

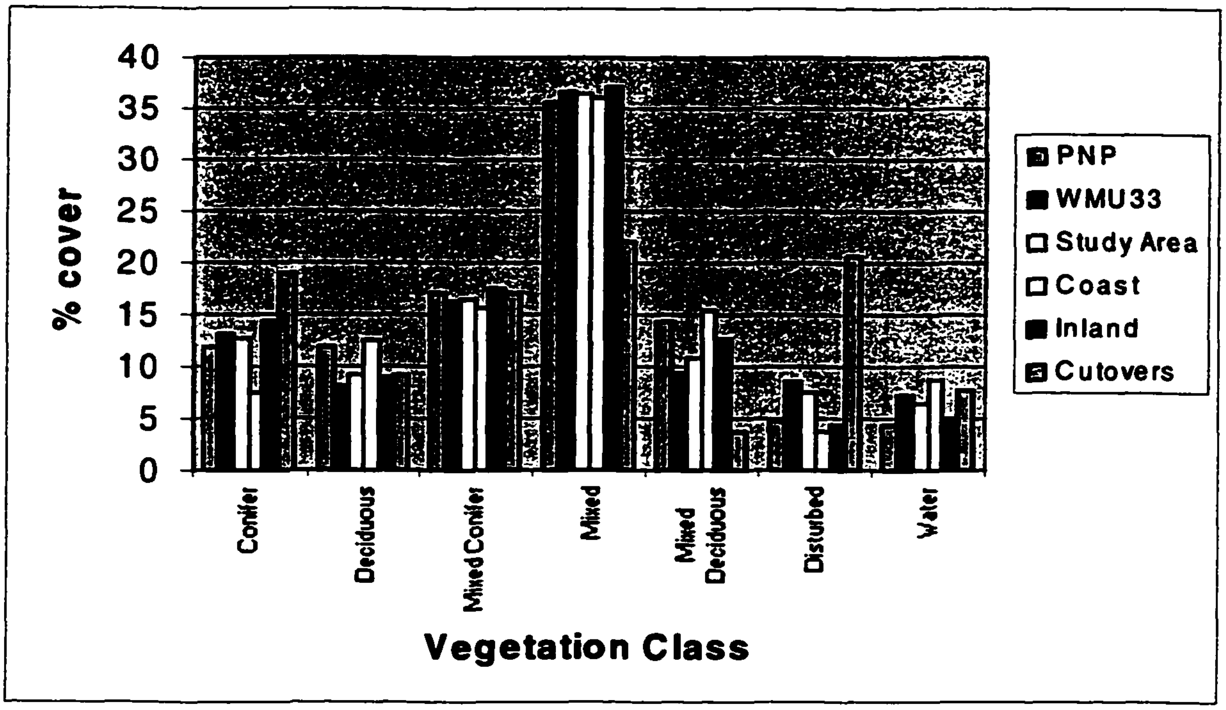

Figure 2.3: Percent vegetation cover classes of 6 different landscapes in 1999 within the Greater Pukaskwa Ecosystem, Ontario.

One of the key objectives of the recent Forest Management Plan (Domtar, 1993) was to ensure that timber management activities closely mimicked natural disturbance patterns and processes. This modified management approach led to the design of a cutting pattern that varies from the traditional application of Timber Management Guidelines. The result of this application has increased the range of cut block sizes up to approximately 200 ha (G. Eason pers. comm.). Furthermore, with the recent construction of the Oriented Strandboard (OSB) mill near Wawa, the demand for hardwoods (primarily poplar) is changing from almost nil to 200,000 m^3 per year (approximately 2000 ha) in the White River Forest.

Extensive activity has also occurred within the mining sector. However, a majority of this activity is outside the core of the study area. In 1985, the Hemlo gold field was developed, resulting in one of the largest gold mines in North America. The area south of the park is also being developed around Mishibishu Lake, where two small mines have been operating sporadically since 1987.

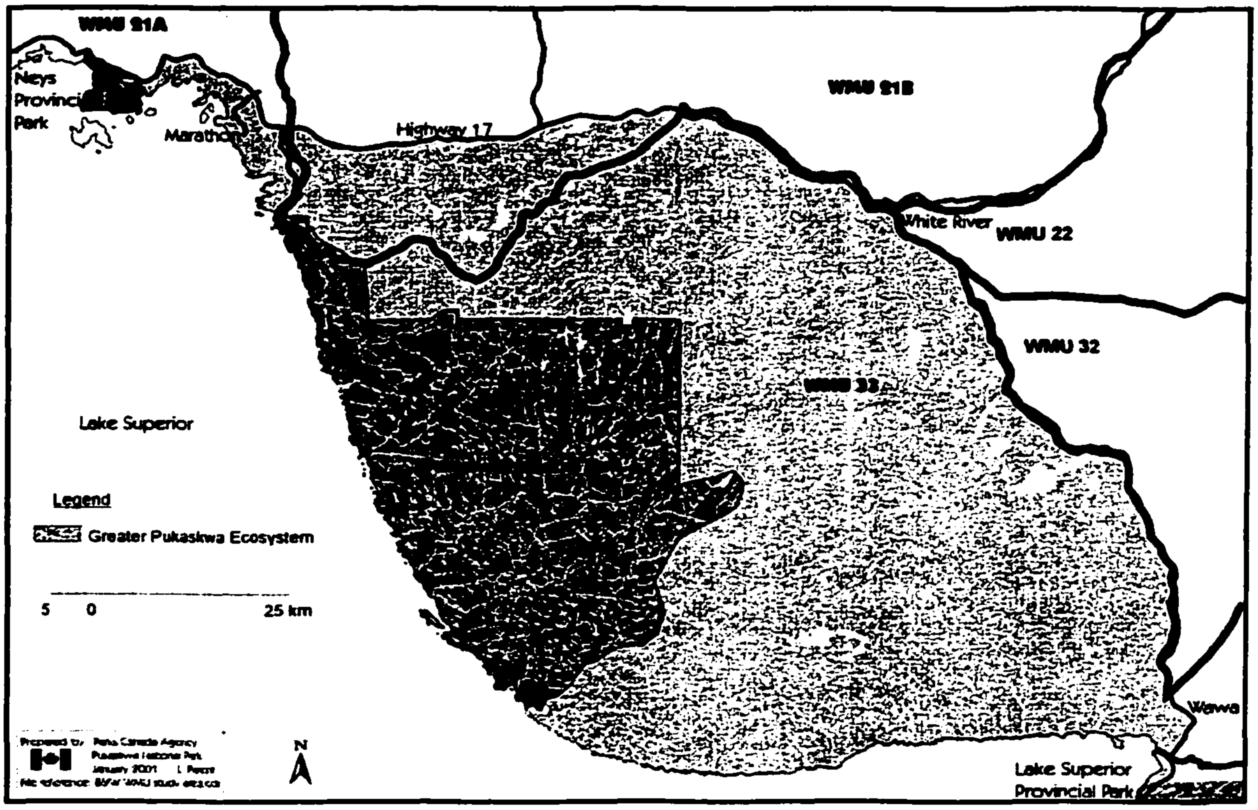

Figure 2.4: Provincial Wildlife Management Unit boundary locations in the Greater Pukaskwa Ecosystem, Ontario.

The area around the park is designated as Wildlife Management Unit #33 (WMU33) (Fig.2.4), which produced moose densities in the 0.15-0.20 moose/km^2 range during the 1970's (G. Eason pers. comm.). Similar to the park, this is considered at the lower end of the range of moose densities in Ontario. Hunting is minimal; only 40 bull tags (plus 5 remote tourist outfitter's tags) and 5 cow tags were issued in 1995, and the calf harvest is estimated at approximately 20 per year (G. Eason, pers. comm.).

CHAPTER 3: METHODS

Capture

Twenty-five adult female moose were captured in March 1995 and an additional 10 adult female moose were captured in February 1996 for a total of 35. Captures were conducted using a Hughes 500 helicopter and a net gun (5X5 m mesh net discharged from a net gun). Captured animals were hobbled with straps around their lower legs, blind-folded, processed and released. Animal handling protocols were approved by the Ontario Ministry of Natural Resources Animal Care Committee (protocols #95-25 and #96-25).

In 1995, the capture goals were to place 13 collars on moose in the cutover areas of the WRF north of the park and 12 collars on moose inside PNP, preferably south of the electricity transmission line (Fig. 3.1). A total of 16 animals were captured in the park and 9 outside the park. Most of the moose collared within the park were from the Rein and Louie Lakes areas whereas in the cutovers most were in the Triplet Lakes area. In 1995, captures ranged from 3-8 animals per day with a total flying time of 18.1 hours over the 5 days it took to capture 25 moose. In 1996, we captured 10 moose in the southern coastal area of the park. All of these were captured within 10 km of the coast, south of Tip Top Mountain and east of Otter Cove.

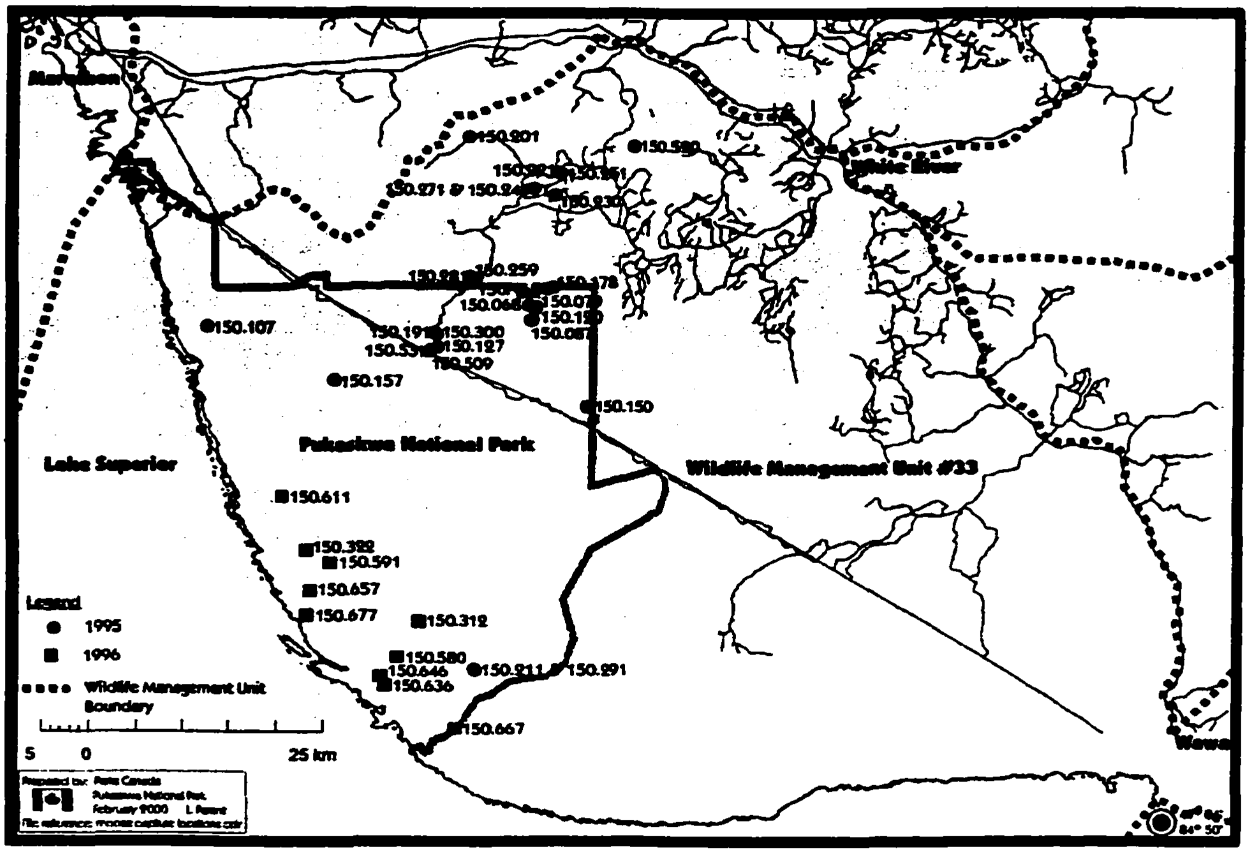

Figure 3.1 Locations of moose captures (n=35) in 1995 and 1996 in the Greater Pukaskwa Ecosystem, Ontario.

Chase length during capture was of interest and was a key element of the animal care requirements since considerable stress can be placed on an animal. The protocol stipulated a 5-min. maximum time for "hard chase" duration. "Hard chase" is defined as the animal running continuously at top speed. In 1995, mean chase time was 6.65 minutes (SE=1.07, range 2-17, n=17). Chase characteristics varied considerably. Some animals walked and stood still for significant portions of the "chase" period. In these cases the chase period was extended since the stress on the animal appeared minimal. Other animals appeared much more stressed as depicted by the fast trots and canters while being driven to a netting area. In these cases times were watched carefully. Two chases were stopped because of the 5-min. hard-chase duration being exceeded.

During handling, most of the moose seemed rather agitated in the early stages of restraint, especially as they were being belted and the net removed. However, once the blindfold was placed, most moose calmed down and were quiet for the processing period.

All moose captured were females. One was a calf, two were suspected to be yearlings (22 months) and the remaining were judged to be adults. Ear tags were placed on each ear and they were fitted with very-high-frequency (VHF) radio collars with a battery life of at least 4 years (model LMRT 4 ™ Lotek Engineering Inc., Newmarket, ON). Collars were secured with spacing of approximately 10 cm (the width of a fist) between the collar and the neck. Ten collars did not have mortality sensors; the remaining 25 had a 12-hr. mortality sensor. Blood was successfully taken from most animals, a majority of the time from the jugular vein, but on occasion from the cephalic vein. Sufficient blood (20 cc) for analysis was taken from the jugular in less than 20 sec. on average. Preliminary processing of the blood was done at the Marathon hospital (centrifuge, placed into tubes) then shipped to the Ontario Veterinary College (Guelph, ON) for analyses. Blood was distributed into red-top tubes (no additives) and was spun in a centrifuge to separate whole blood from serum (cell-free blood). Serum was used for biochemistry profiles, cortisol (an indicator of short-term stress) and "T4", a thyroid hormone that is an indicator of longer-term stress (e.g., nutritional stress in winter). Red-top residues were used for genetics tests. Blue-top tubes (with anti-coagulant additive) were spun and plasma (cell free) with fibrinogen was used to assess long-term chronic inflammatory condition. Lavender-top tubes (with anticoagulant EDTA additive) were used to make a qualitative (smear) and quantitative complete blood count (CBC). CBCs provide a red/white cell ratio, packed cell volume, and hemoglobin (Hb). These measures are good indicators of overall moose condition (Franzmann et al. 1987). Grey-top tubes (fluoride additive) were used to estimate glucose concentrations, which are influenced by stress.

Hair was removed from the shoulder of all animals. On occasion, several ticks were also removed. However, ticks were rare in the moose population in general. Urine sampling was not attempted on any animals. Faeces were collected using a plastic glove and removing several pellets from the anus. A 35 cc intramuscular injection of an antibiotic - *Liquimycin LA* ™ was given to all moose in the hind quarter in 3-6 separate locations (dosage =1cc/10kg). To help minimize effects of capture stress, a 3-6 cc intramuscular injection of MU-SE ™ (selenium/vitamin E) was injected at the base of the neck (dosage =1cc/90kg). Body measurements of neck circumference, ear length, head length, shoulder height, foreleg length, 1/2 chest girth, hind leg length, hind foot length, tail length and total length were taken. Chest girth was calculated by doubling the 1/2 chest girth measurement.

Upon completion of the sampling, the nets, blind fold and belts were removed. A majority of the moose quickly stood up and trotted away. In 1995, total chase and processing time averaged 29.8 minutes (SE=1.39, range 17-43, n=22). Complete details of capture information can be found in Appendix 1.

Relocations were obtained by radio-telemetry from a STOL-equipped Cessna 185 fixed-winged aircraft (Air Superior, Wawa, ON). Animals were located using a Lotek SRX-400™ receiver (150.000 - 152.000 Mhz), left/right switch box and strut-mounted, paired 4-element Yagi ™ antennas. The locations were fixed using an on-board Garman 75™ Aviation GPS receiver (non-differential correction). Location fixes were also supplemented by ground telemetry using a Lotek SRX-400™ receiver and hand-held 3-element Yagi™ antenna. I attempted to locate each moose at least weekly year round and more frequently in May/June to assess calving, and in December/January to assess calf recruitment. Each time a radio-collared moose was located from the aircraft, a visual confirmation was attempted, but due to vegetation, visuals were not always possible. Habitat type (topography, overstorey and crown closure), activity, aggregation size, confidence of the location co-ordinates and number of calves were recorded. Locations were recorded in degree decimal minutes of latitude/longitude and transformed to UTM co-ordinates, NAD 27 using Geocalc™ computer program (Blue Marble Geographics, Bangor, ME).

To assess location accuracy of the telemetry fixes, a radio "test collar" was placed by an independent observer and geo-referenced by differentially corrected GPS. The test collar was then located by the aerial observer normally one fix per flight, and was moved throughout the study area until approximately 30 fixes were obtained and an accuracy estimate of location fixes was known for each observer.

Population Density

Triennial aerial surveys were used to produce estimates of population size, density and distribution in the two landscapes. Aerial surveys conducted between 1984 and 1999 were standard OMNR stratified-random surveys (Bisset and Rempel 1991) which are based upon Gasaway et al. (1986) and are recognized as the North American standard for conducting moose population surveys (Timmermann 1993). These surveys are stratified proportional to expected moose density, with approximately 20% of the land area surveyed. Within strata, (usually high, medium and low), sample design is sampling with replacement, where survey plots are randomly selected and each plot has an equal chance of being selected.

Surveys were conducted in early to mid-winter (January) prior to moose entering late winter cover. This allows for maximum sightability as well as the use of shallow and often fresh snow for improved tracking conditions. Plot size was 25 km^2 (2.5 X 10 km), (except PNP in 1986 and 1990 when they were 4 km^2 -2 X 2 km) usually oriented north-south on Universal Transverse Mercator (UTM) projection grid lines. Systematic flight lines were flown with rotary-wing aircraft on the long axis with a spacing of 500 m and travelling at speeds of approximately 60 knots. Surveys were conducted 12-72 hours after a fresh snowfall greater than 10 cm, to ensure accurate definition of recent tracks. The pilot, one navigator and two rear-seat observers scanned the ground for visuals on moose or moose tracks. Every moose observed was sexed and aged (at least to calf or adult), and fresh moose tracks were followed until they left the plot or the moose was identified. The sightability correction factor was not used in my analysis since its application varied among years, landscapes and individual biologist, and I wished to mimimize the manipulation of the raw data. The results therefore constitute a total moose census of the 25 km^2 area with age and sex statistics.

Similar to Rempel et al. (1997), I tested the hypothesis that population density did not vary over time (5 surveys) or between landscapes (PNP and WMU33). Regression residuals from analysis of trends in year-to-year data are not independent so I tested changes over time using autoregression analysis. Regression co-efficients and probability B=0 were estimated with exact maximum-likelihood methods (SPSS Inc. 1993). The autoregression model allows estimation of regression models reliably when the error from the regression is correlated between one time and the next. This is common in time-series analyses (SPSS Inc. 1993). Furthermore, preliminary analyses comparing simple linear regression to autoregression showed autoregression detected significant outcomes that were not detected by simple linear regression. I used a t-test to compare mean moose densities per plot between landscapes using the most recent aerial surveys (1997 for WMU33, 1999 for PNP).

Population Distribution (Kriging)

Using the 1988-1999 surveys, I determined the geographic centre of each survey plot and recorded it as a UTM co-ordinate to allow the mapping of data in a GIS. The total number of observed moose on each survey plot was tabulated. The survey data were divided into two time periods (1988-1993 and 1994-1999) to ensure that there were sufficient plots to adequately cover the spatial extent of the study area. This resulted in two sets of survey data in each landscape in each time period, for a total of eight surveys. The 1984 and 1986 surveys were excluded to allow for even pairing of the most recent data sets.

Spatial modelling of the survey data was performed using the ordinary kriging technique (Tydac 1997). Kriging is used to estimate the unknown value at a point using weighted linear combinations of samples available in the neighbourhood of the point (Ussaks and Srivastava 1989, McKenney et al. 1998). It is linear since the estimated values are weighted linear combinations of the available data and it is unbiased because the mean error approaches zero (Tydac 1997). I used the SPANS (Tydac 1997) kriging function, which is an interpolation method that uses point data to generate a continuous surface with the assumption that adjacent point values are correlated with each other spatially. It is a distance-weighted estimation technique which means that data points further away from the point being estimated will exert a smaller influence on the estimated value than do closer points. Kriging produces surfaces that are markedly smooth as compared to other interpolation methods and is believed to be the best linear unbiased estimator because it minimizes the estimator variance (Tydac 1997).

Semivariance is used to describe the spatial correlation between point values in a data set and its calculation is the first step in kriging (Ussaks and Srivastava 1989). A semivariogram is similar to a scatterplot on which the results of the semivariance calculations are plotted. Once the plot values are determined, a variogram type or model is selected (basically a best fit line). I used a spherical variogram since it is the most commonly used variogram type and because the variogram parameters are easiest to estimate from it. Variogram parameters were the default values; i.e., nuggut (0.0), sill (1.0) and range, which is automatically calculated.

The models were resolved to a continuous, spatially explicit surface across the study area and then reclassified into five density ranges where they provided a spatial prediction of moose density/km^2.

To visualize spatially the change in population estimates over time, I compared the two time periods by creating a density–change surface from the differences in density in the two periods. A map was generated showing these differences.

Productivity

Triennial aerial population surveys and 35 radio-collared adult female moose were used to determine productivity parameters at both the population and individual animal levels. Data from the aerial surveys used standardized reporting ratios expressed as number of bulls/100 cows, number of calves/100 cows and calves as a percentage of the total moose classified. These ratios are calculated only on the moose observed and not the estimated population. This information provides valuable indicators such as herd productivity (recruitment) as well as other indicators of herd demographics which are particularly important in hunted populations in which harvest allocations are set based on sex and age criteria.

Productivity estimates were also calculated using a radio-tagged sample of the population. Weekly telemetry flights using fixed-wing aircraft to locate and observe radio-collared moose were conducted throughout the study. Flights provided an opportunity to observe the collared cows when conditions permitted. Once cows were located, attempts were made to observe directly the collared moose and search for any associated calf. Number of calves, including "no calves", were recorded. At times the search was terminated prior to a good visual or confirmation of a calf present due to search time restrictions (i.e., limited aircraft time). Extra efforts were made during June to estimate parturition rates and in December/January to estimate 8-9-month recruitment rates, and in April to estimate 12-month recruitment. The December/January period was an excellent time of year for sightability since the moose were often in mixed-wood habitat with good snow conditions for tracking. This period also corresponded with the aerial population surveys. Due to sightability limitations and variability of obtaining good cow/calf visuals, repeated observations were collected and tabulated over the year to improve confidence and accuracy. Often a cow would need to be observed at least 3 times to confirm accuracy and confidence of calf presence or absence.

Recruitment was calculated in January as it is the 9th month in the biological year (births occur in May) and it is believed that animals of that age are subject to the same mortality rate as older animals (Timmermann and Buss 1998). As well, January is the most common aerial survey month and allows comparisons between population survey and telemetry data.

In summary, I used 5 aerial surveys from WMU33 - 1984, 1988, 1991, 1994 and 1997, and 5 surveys from PNP - 1986, 1990, 1993, 1996 and 1999. I used actual (observed) calf, bull and cow counts to provide ratios and % calves in each population as a measure of herd demographics. However, caution must be used in interpreting these measures, especially in hunted populations where there may be a high harvest of adults, particularly bulls. For example, simple % calves after the hunt may artificially elevate the % calves and thus herd growth as it ignores this significant mortality factor. Therefore, a measure of number of calves/100 cows is often a better indicator of herd productivity since it considers the number of cows in the herd at the same time. A third important measure is the number of bulls/100 cows as there may be concerns that low bull/cow ratios could influence conception dates and newborn sex ratios (Bishop and Rausch 1974, Crete et al. 1981). A balanced sex ratio is also believed to ensure breeding and genetic diversity, and provides a balanced social structure (Timmermann and Buss 1998).

Using the telemetry data, I calculated the latest month in the biological year that calves appeared alive with each of the 35 collared moose and considered it recruited if it was alive on January 1 of each of the four years 1995-1998. This provided specific recruitment data for each moose. These data were summarized as number of calves/100 cows in each of the treatment landscapes.

Similar to the approach with population density, I tested the hypothesis that productivity indices did not vary over time using autoregression, and I used a t-test to compare mean productivity per survey plot between landscapes using the most recent aerial survey data (1997 for WMU33, 1999 for PNP).

Survival

I used the Kaplan-Meier survival estimator (Pollock et al. 1989) to calculate survival rates of radio-collared female adults each year and throughout the study, with the log-rank test to compare survival between landscapes. The year or "annual" was based on the biological year beginning May 1st and ending April 30th. The number of animals alive each year and the number of days they stayed alive each year were used to calculate annual mortality rates. The absolute number of days the collared animals were alive was used to calculate survival rates over the entire study. The Kaplan-Meier method allows for entry of animals into the study at any time, makes no assumptions about the shape of the survival curve, and accounts for individuals with radio collars that failed or those with unknown fates (censoring). Censored animals were eliminated from analysis the last date they were located alive. Censoring resulted from animals disappearing because of failure to obtain radio signals or animals surviving past the end of the study period.

I ascertained the fate of radio-collared animals that died by examining remains shortly after receiving a mortality signal from the collar. I determined the identity of predators through tracks, scats and nearby sightings. If evidence of a struggle was found, such as broken branches or excessive chase tracks, I concluded the animal was killed by a predator and not merely scavenged. All mortalities were classified as predation, hunted, or natural (e.g., drowning, old age).

Marrow

Between September 1996 and July 1998, 92 dead moose were investigated throughout the study area to assess bone marrow fat content. Moose were located during regular telemetry flights when collared wolves were observed on kill sites or when collared moose themselves were found deceased. Moose were also obtained from road-killed and hunter-killed sources. I tried to obtain equal numbers of “naturally” killed moose (i.e., predation, disease) and “unnaturally” killed moose (i.e., hunted, road accidents). Both sources of dead moose were necessary to provide a representative sample of the population and increase sample size.

At each carcass investigation, a 1st incisor and a femur bone were collected. When a femur was unavailable, a mandible or another long bone (tibia or metatarsal) was collected. The bones were collected throughout the year and all animals were aged by counting annuli in tooth cementum layers of the 1st incisor, assuming an average birth month of May (Matson's Lab, Milltown, MT). Date of death was estimated and was usually less than seven days prior to sampling. Probable cause of death, sex, habitat type, and morphometric measurements were recorded when possible. Bones were collected fully intact, double-bagged in heavy-duty plastic to reduce desiccation, and frozen until analysis. The water loss prior to analysis was considered to be negligible (Kie 1978). Bone marrow fat was estimated using Neiland's (1970) dry-weight method. Each bone was slit and a 10-40 g section of the marrow was removed and weighed. The marrow was dried in an oven at approximately 60°C until a constant weight was obtained (48-72 hr). The small amount of non-fat residue was ignored (Snider 1980, Ballard et al. 1981). Percent fat was calculated as dry weight/wet weight X 100.

Femur bones were preferred and were obtained a majority of the time. When femur bones were not available, mandible bones were the preferred bone. The fat values of mandible bones were converted to femur equivalent values using the relationship published by Cederlund et al. (1986) (femur = mandible - 27.34/0.54). Since the values were percentages, they were transformed using the arcsin square root transformation to ensure a distribution that was nearly normal. The primary question in this component of the study was measuring the effects of different landscapes (PNP vs. WMU33) on marrow fat content. However, since other factors such as season, age and cause of death are known to affect fat content (Cederlund et al. 1986), the effect of these other factors were first investigated, and if there was no significant effect ($P>0.05$), the data were pooled. The data were partitioned into 3 seasons (early winter October 1st - January 15th, late winter January 16th – April 30th and summer May 1st - September 30th), age (<2 and equal to or > 2 yr) and cause of death (natural vs. unnatural). Data sets were tested for homogeneity using Levene's test for equality of variances, and if normally distributed, an independent-samples t-test and single-factor ANOVA were used to test for differences in these factors.

Movements

I calculated movements by measuring the straight-line distance between successive locations of each collared moose. Since time between successive locations was not always uniform, I described movement as speed (m/hr). My main question was "do moose move differently in each landscape?". However, I expected there may be effects caused by year and season so before pooling the data I tested for the three main effects of landscape, year and season using ANOVA.

To ensure the monitoring periods were balanced, to include even numbers of seasons and years, and to ensure sample sizes were similar, I used two full biological years of relocation data for the detailed analysis. Therefore, year 1 was defined using data from May 1, 1995 until April 30, 1996, and Year 2 was defined as May 1, 1996 to April 30,

1997. I used only locations with confidence classes of 1 and 2 (<250 m error). Since the animal, not the location, is the sampling unit, I calculated the mean movement of each moose based on landscape, year and season. If no effects of year or season were evident, then I pooled the data.

Home Range

I calculated individual home range sizes for collared moose with the MCP method (Mohr 1947) and adaptive kernel method (Worton 1989) using Ranges V software (Kenward and Hodder 1996). I used the MCP method to enable comparison between previous studies and the adaptive kernel method as it allows better determination of core activity areas. Hundertmark (1998) reported that adaptive kernel is less biased to the chosen scale or grid density, and could produce more reliable results than the more widely used harmonic mean method (Dixon and Chapman 1980).

I used 95% of locations for MCP and 90% of locations for adaptive kernel calculations. Similar to the movement analysis, I only used the locations of accuracy class 1 and 2 from two full biological years of data and partitioned the data by landscape, year and season. If the years were similar, then the two years of data were pooled and I compared the two landscapes and three seasons using 2-way ANOVA. I also calculated the annual home ranges sizes and sizes for the duration of the study (two-year data set). I used the default values in Ranges V of 1.0 m for fix resolution and 1.0 m for the scaling parameter, which means that each co-ordinate was 1.0 unit from the next.

CHAPTER 4: RESULTS

Relocations

Thirty-five moose were relocated a total of 3606 times between March 1995 and June 1999. Moose were intensively monitored from time of collaring until September 1997 (29 months for 1995 captures, 18 months for 1996 captures). After that time, monitoring decreased to one location every 3-8 weeks to record only gross movements and survival. During the intensive monitoring period, 3123 locations were obtained that were high quality (confidence class 1 or 2). The confidence accuracy for the 3606 locations was: class 1 (within 100 m) 86.5%, class 2 (100-250 m) 7.8%, class 3 (250-450 m) 2.2%, class 4 (>450 m) 1.6%, and class 5 (mortality check only) 1.9%. On average I located each moose every 8.51 days (SE=0.69, n=3123). Aerial telemetry locations accounted for 93.3% of the total locations with the remainder (6.7%) from ground telemetry and captures. The number of locations per moose ranged from 3 to 141 with a mean number of 103.0 (SE=5.65). Seventy-five percent of the locations were obtained midday, between 1100 hrs and 1600 hrs. Eight observers collected portions of the data as follows: Frank Burrows 38%, Barry Desmoulin 18%, Graham Neale 18%, Peter Krizan 11%, Keith Wade 9%, Anne Forshner 4%, Cam McTavish and Louis Nabigon less than 2% each. Visual observations of the collared moose were confirmed in 34.9% of the locations. Season of year, however, greatly influenced visuals; in early winter 62.3%, in late winter 49.9% and in summer 10.6 % of locations were visually confirmed.

Five observers located a total of 102 test-collar positions (Fig. 4.1). Mean error was estimated to be 218.9 m (+/- 95% CI=71.9). Numbers of locations per observer varied from 10 to 33 and mean error varied from a low of 106.2 m (+/- 95% CI=15.2) to a high of 563.9 (+/- 95% CI=548.1). The high error was obtained from an observer who obtained only a small percentage (9%) of locations.

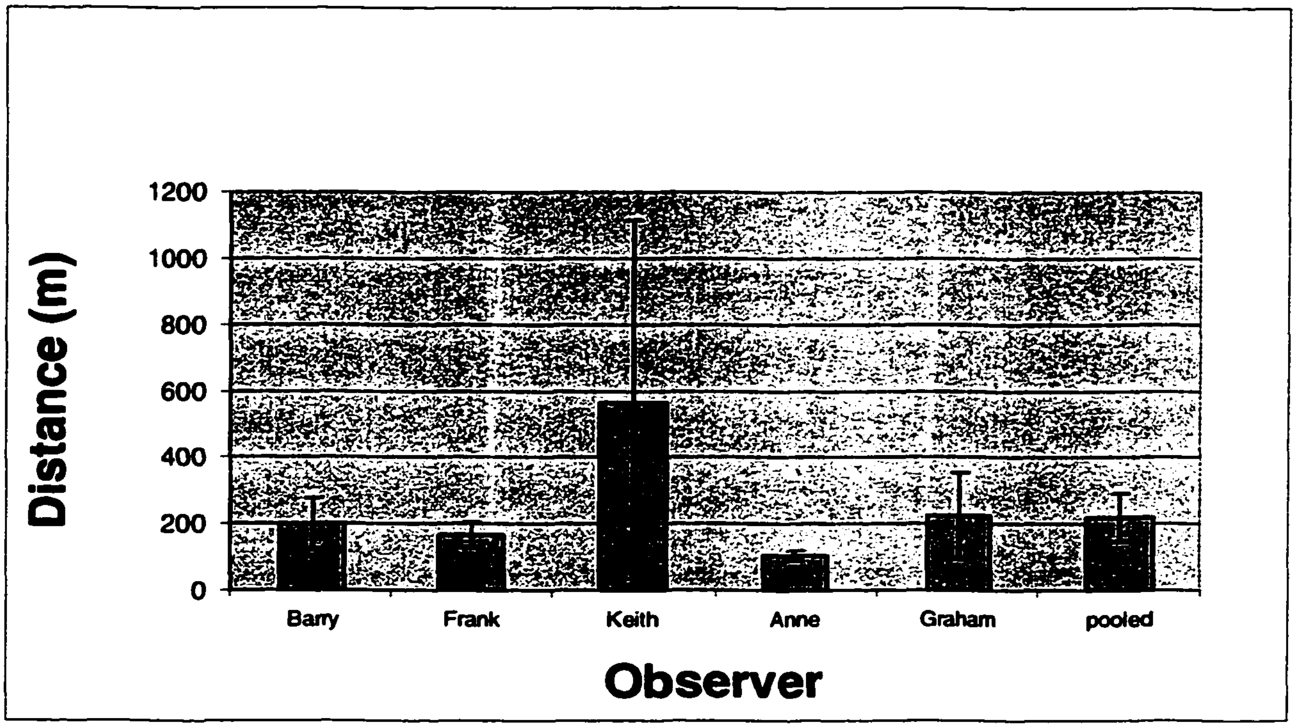

Figure 4.1: Mean distance in metres (+/- 95% CI) between estimated location from aerial telemetry and true locations of test collars (n=102) by each observer and pooled observers in the Greater Pukaskwa Ecosystem, Ontario. The "true" location was obtained from differentially corrected GPS data collected at the collar location.

Population Density

Five surveys were completed in each landscape over the time period (Fig 4.2). The densities in PNP were relatively stable over time with the exception of one year (1996) when the population exhibited its lowest value. Autoregression analysis revealed no significant trend over time (B=-0.0033, P=0.526) indicating that the population density trend was stable. In WMU33 the trend seemed to be more pronounced; it increased over time but again was found to be statistically insignificant (B=0.0027, P=0.666). Using a t-test, I tried to reject the null hypothesis that both landscapes were the same in terms of moose density per survey plot for the most recent aerial surveys. The mean density per plot (number of moose/km^2) in WMU33 in 1997 was 0.332 while in PNP in 1999 it was 0.273. These were not significantly different (t=-0.764, P=0.449).

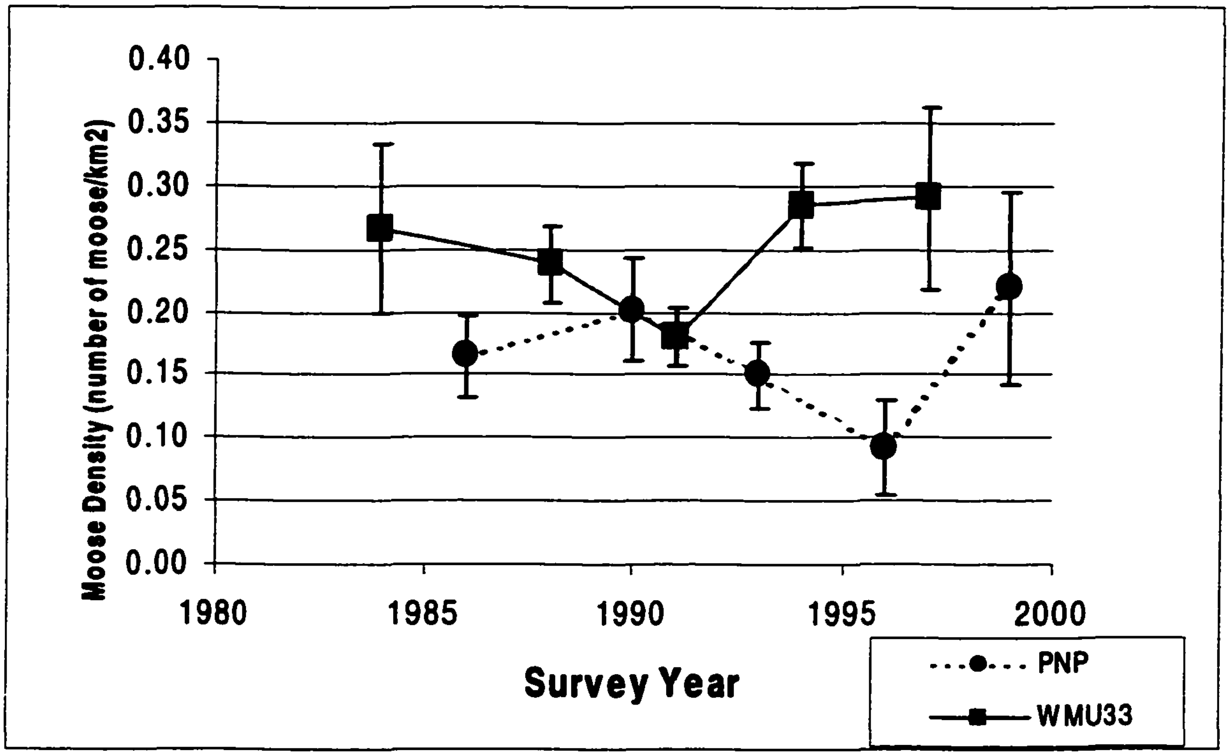

Figure 4.2: Moose density in moose/km^2 from 1984 to 1999 in 2 landscapes of the Greater Pukaskwa Ecosystem, Ontario. Bars indicate +/- 90% CI. Data were collected during triennial aerial surveys.

Population Distribution (Kriging)

For both time periods, kriging clearly shows higher densities of moose concentrated in the disturbed forest of WMU33 (Figs. 4.3 and 4.4).

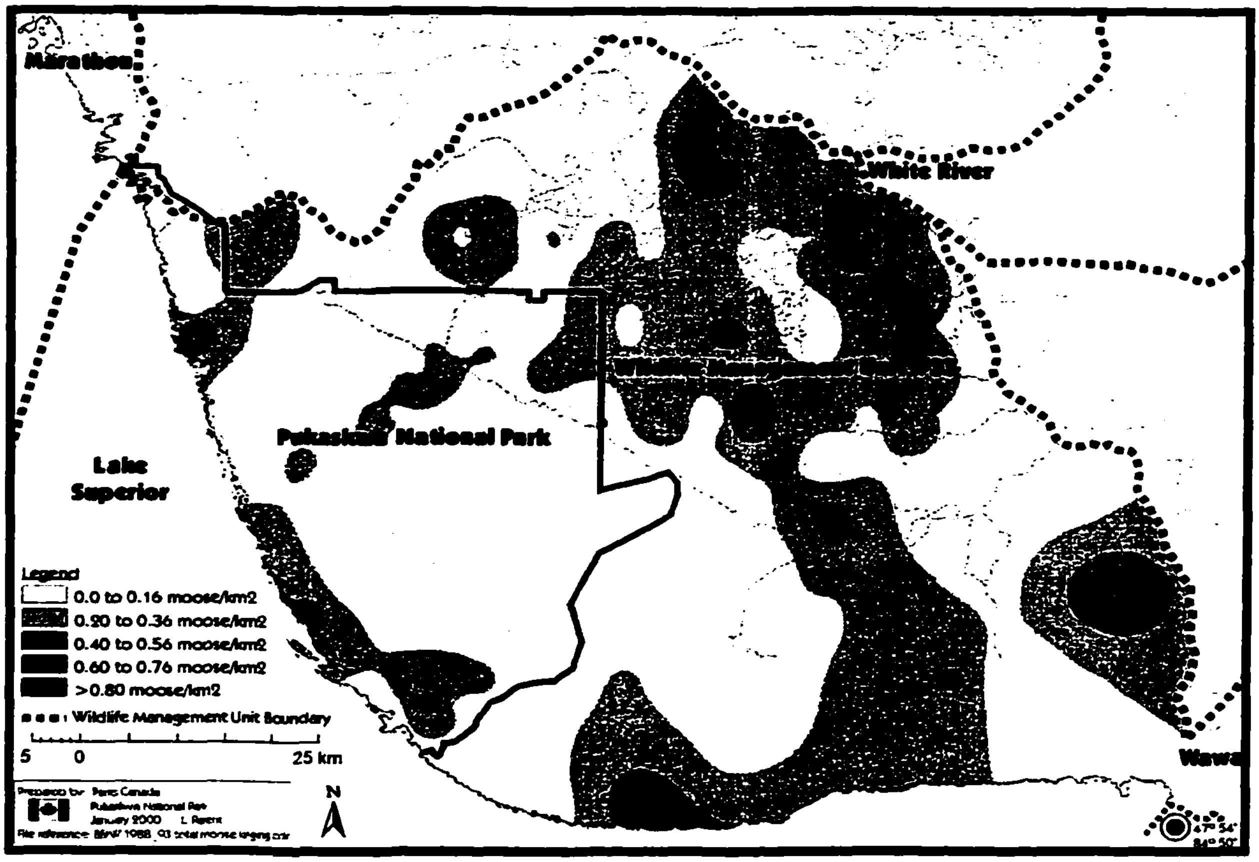

Figure 4.3: 1988-1993 spatially explicit moose densities determined using kriging in the Greater Pukaskwa Ecosystem, Ontario. Densities were grouped into classes (moose/km^2) for presentation. Data were collected during triennial aerial surveys in PNP and WMU33.

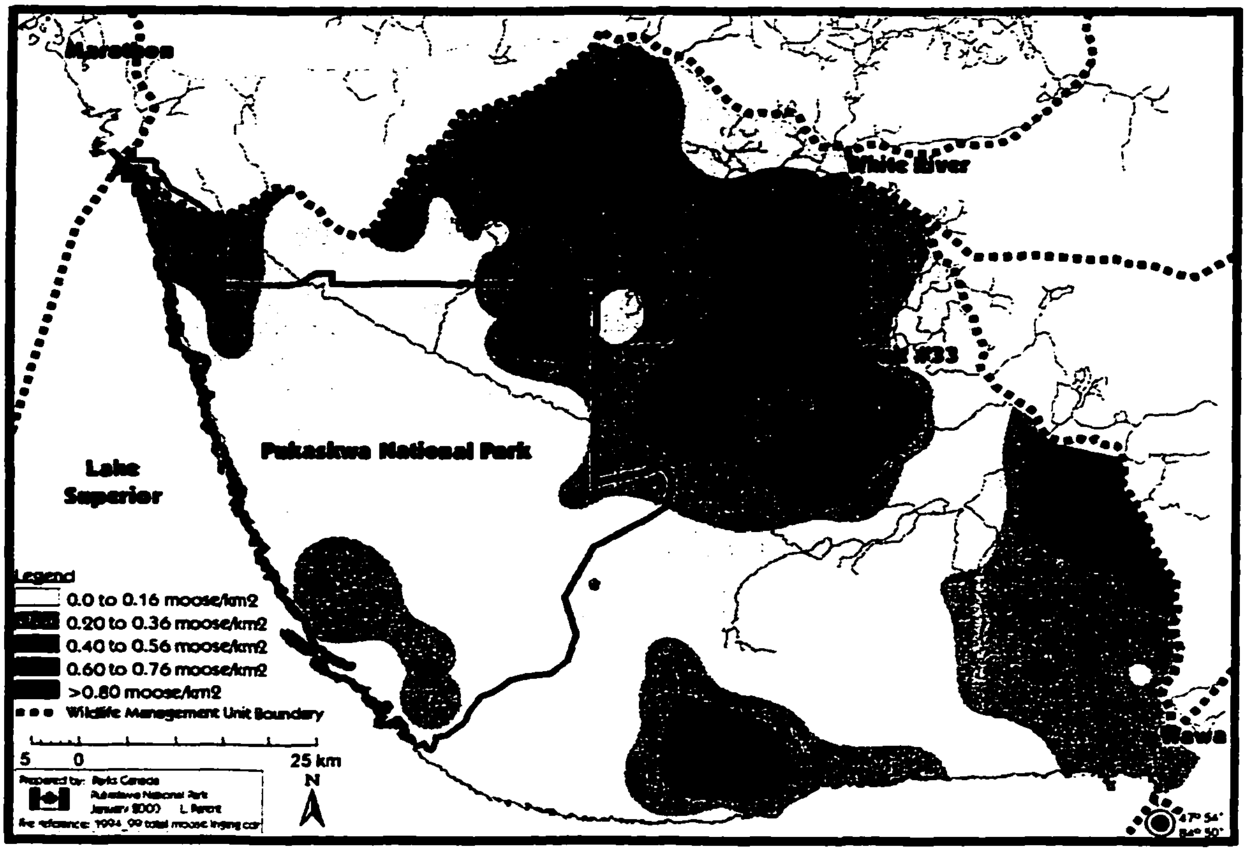

Figure 4.4: 1994-1999 spatially explicit moose densities determined using kriging in the Greater Pukaskwa Ecosystem, Ontario. Densities were grouped into classes (moose/km^2) for presentation. Data were collected during triennial aerial surveys in PNP and WMU33.

PNP moose densities were stable over the two periods whereas WMU33 shows a shift to more area with higher moose densities (Fig. 4.5). A majority of the PNP area had densities below 0.16 moose/km^2 in both periods (79.1% and 74.6%) with the exception of some localized areas. These included the southern coastal area (Otter Cove), northern coastal area (White and Willow Rivers) and north-east corner around Rein Lake where moose densities were 0.20 to 0.36 moose/ km^2 and higher. However, quite the opposite occurred in most of WMU33. Only 49.6% and 37.6 % of the area had lower moose densities in the same periods. For both periods, large areas (49.9% and 55.1%)

experienced densities in the 0.20 to 0.56/moose km^2 range and several areas were at 0.60/moose km^2 and higher.

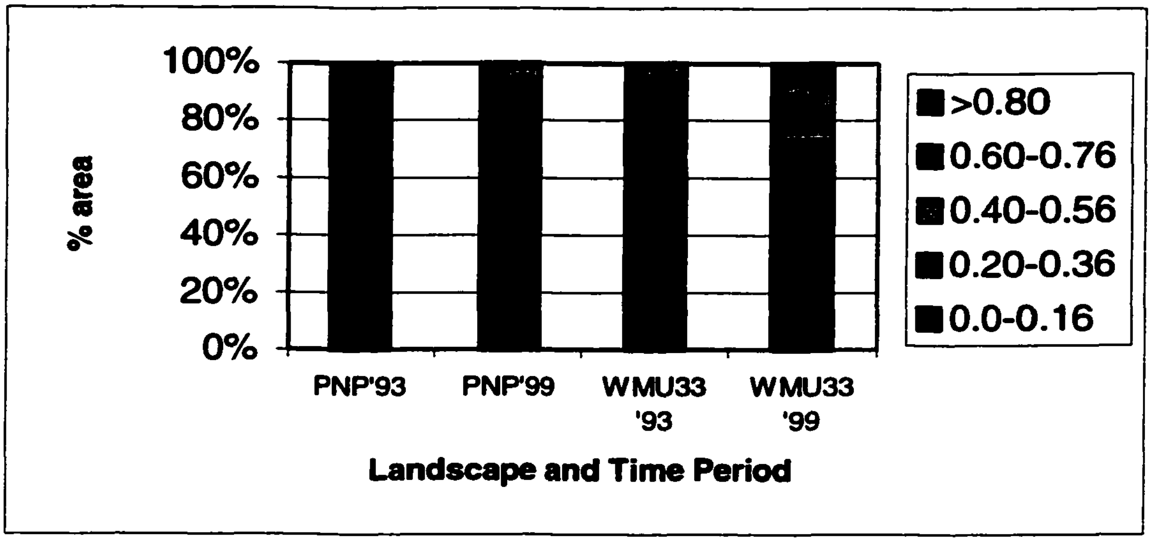

Figure 4.5: Moose densities in moose/km^2 as percent area of PNP and WMU33 in 2 time periods (1988-93 and 1994-99). Area analysis was from kriging maps; data were collected during triennial aerial surveys.

To better quantify and display the change occurring between the two time periods, I created a density change map by overlaying the 2 kriging maps to identify locations and degree of change in the moose densities. This map shows spatially what the comparison of the areas analysis showed (Fig. 4.5). Figure 4.6 demonstrates that most of the moose density changes were increases in moose densities within WMU33.

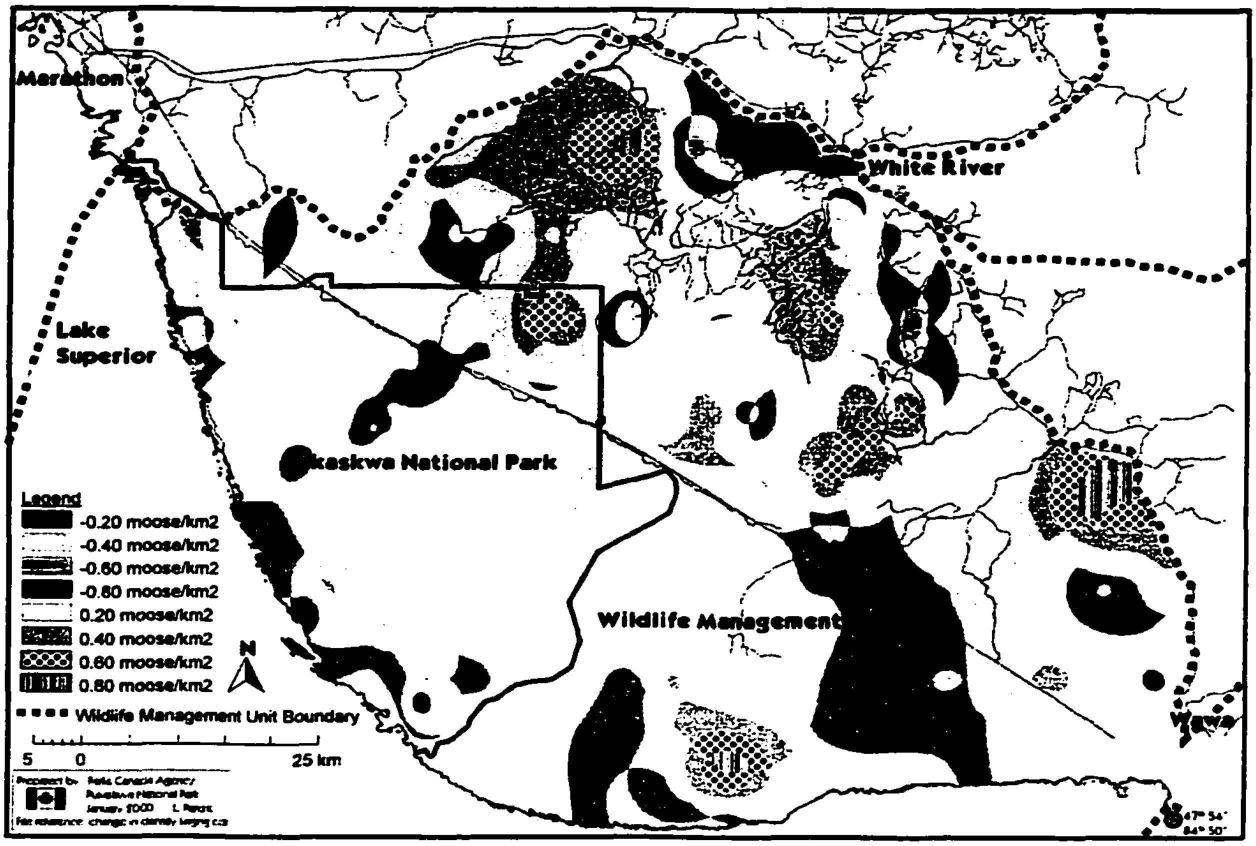

Figure 4.6: Rate of change in moose density in the Greater Pukaskwa Ecosystem, Ontario, between 1988-1993 and 1994-1999. Changes were estimated by comparing kriging maps between the two periods. Densities were grouped into classes (moose/km^2) for presentation. Data were collected during triennial aerial surveys in PNP and WMU33.

Productivity

Table 4.1 provides the results of the productivity estimates from the triennial aerial surveys from 1984 to 1999 for both WMU33 and PNP. Five surveys were completed in each landscape over the time period. Ratios and percentages were calculated from observed moose seen (not estimated) during surveys, which ranged from 59 observed in the 1988 PNP survey to a high of 559 in the 1994 WMU33 survey.

Table 4.1 Moose productivity indices from triennial aerial surveys in PNP and WMU33 of the Greater Pukaskwa Ecosystem, Ontario, 1984-1999.

Year	'84	'86	'88	'90	'91	'93	'94	'96	'97	'99	n	Mean	SE	*B*	*P*
calves/100cows															
PNP		41		14		28		16		25	5	24.7	4.9	-0.642	0.254
WMU 33	44		55		23		35		15		5	34.6	7.6	-2.580	0.015
%calves															
PNP		20		8		12		9		13	5	12.2	2.2	-0.241	0.402
WMU 33	15		19		11		16		7		5	13.6	2.1	-2.580	0.015
bulls/100 cows															
PNP		48		62		100		65		65	5	67.9	8.6	1.236	0.649
WMU 33	110		86		83		81		84		5	90.1	5.3	-1.749	0.182

Trends

Figure 4.7 shows that numbers calves/100 cows in both landscapes declined over time and was on average higher (34.6 SE =7.6 vs. 24.7 SE=4.9), but showed a steeper decline, over time in WMU33 compared to PNP. The decline in WMU33 was statistically significant (B=-2.580, P=0.015), but in PNP it was not (B=-0.642, P=0.254).

Figure 4.8 shows that % calves in both populations also declined over time. This decline was statistically significant in WMU33 (B=-2.580, P=0.015) but not in PNP (B=-0.241, P=0.402).

The number of bulls/100 cows showed differing trends over time in each landscape, (Fig. 4.9). In WMU33, bull ratios decreased over time while in PNP the bull ratio increased. However, neither trend was statistically significant (WMU33 B=-1.749, P=0.182 and PNP B=1.236, P=0.649).

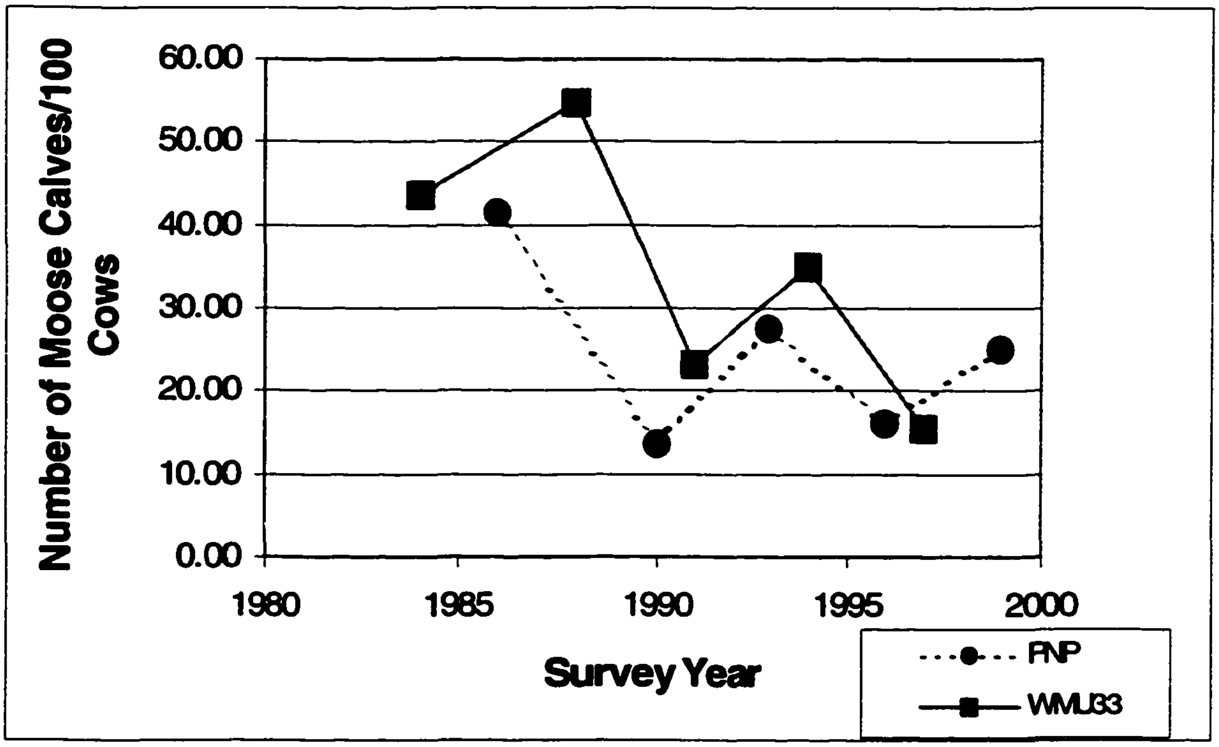

Figure 4.7: Number of moose calves/100 cows from 1984 to 1999 in WMU33 and PNP of the Greater Pukaskwa Ecosystem, Ontario. Data were collected during triennial aerial surveys.

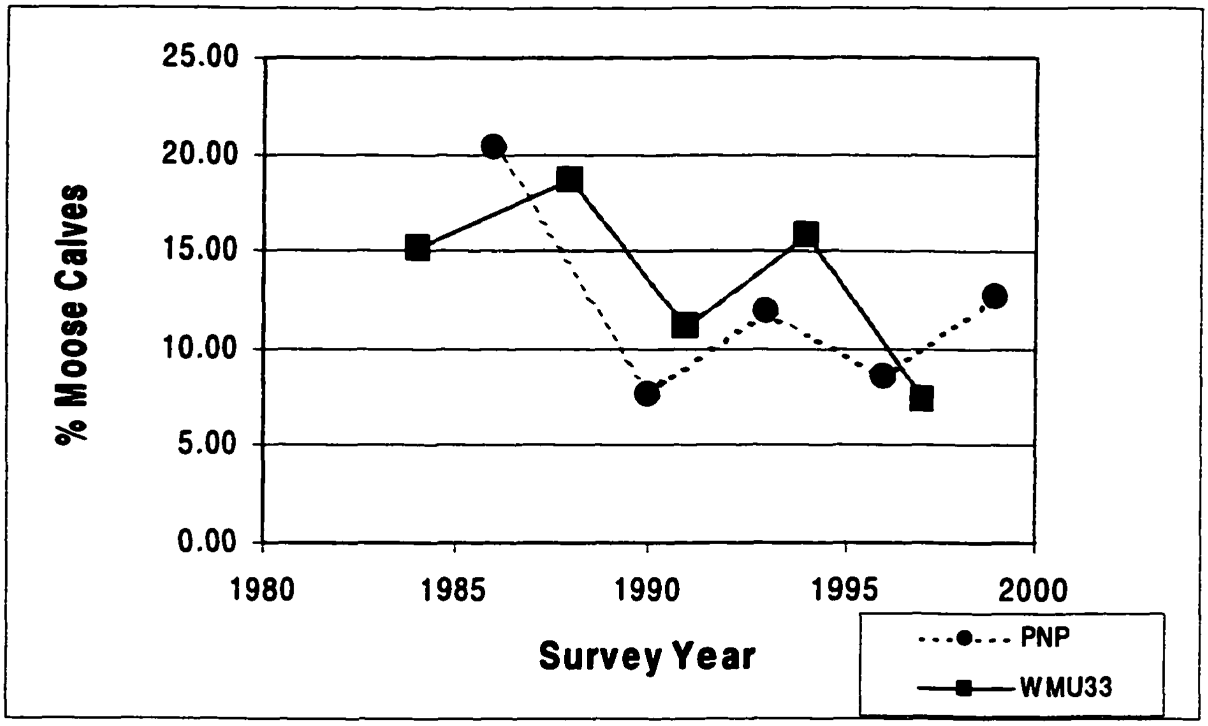

Figure 4.8: Percent moose calves in populations from 1984 to 1999 in WMU33 and PNP of the Greater Pukaskwa Ecosystem, Ontario. Data were collected during triennial aerial surveys.

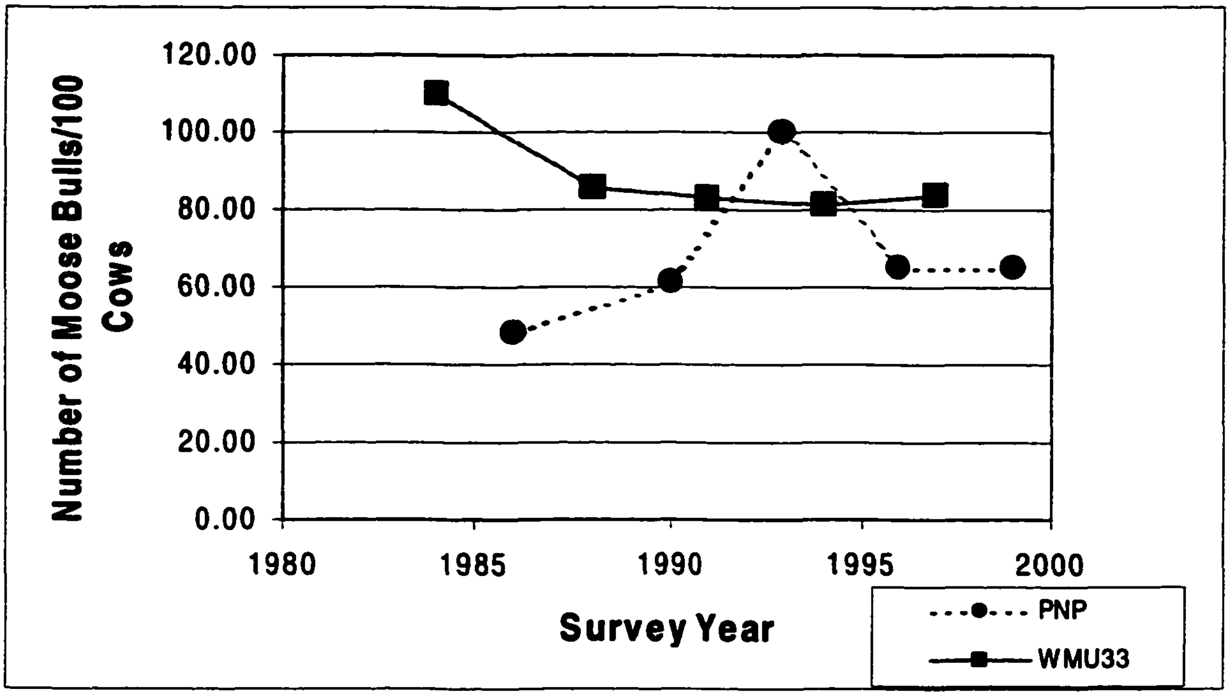

Figure 4.9: Number of moose bulls/100 cows from 1984 to 1999 in WMU33 and PNP of the Greater Pukaskwa Ecosystem, Ontario. Data were collected during triennial aerial surveys.

Differences between landscapes

Using a t-test, I tried to reject the null hypothesis that both landscapes were the same in terms of productivity indices in the most recent survey year. The mean number of calves/100 cows per plot was similar in WMU33 vs. PNP (19.5 vs. 18.8), and was not found to be statistically different (t=-0.088, P=0.930). The mean percent calves per plot in the most recent survey was also similar in both landscapes at 11.32% in PNP and 9.88% in WMU33 and these were not statistically different either (t=0.378, P=0.707). Finally, the mean number of bulls/100 cows per plot during the last survey in WMU33 was 67.2 and 75.5 in PNP. These again were not statistically different (t= 0.223, P=0.825).

In summary, the survey data show some interesting patterns. The slight decrease in calves in WMU33 may be expected since it is a hunted population, and the adult tag allocation can place strong hunting pressure on calves. The trend in bulls/100 cows is also interesting, as PNP is a non-hunted population. The pattern of these indices may indicate that PNP bulls are returning to a ratio typical of a non-hunted population (i.e., 50:50).

Table 4.2 shows the number calves/100 cows as measured from the 35 radio-collared female moose. A total of 438 observations (12.1% of total possible) were made on collared moose in the 4 years of the study. Overall the data collection was at times difficult due to highly variable sightability of collared moose and difficulty confirming the presence of a calf with the collared moose. As a result, the confidence in these data is limited.

Table 4.2: Moose calves/100 cows based on observations (n=438) of 35 radio-collared female moose in PNP and WMU33 of the Greater Pukaskwa Ecosystem, 1995-1998.

Landscape/ Year	1995	1996	1997	1998	n	Mean	SE	B	P
PNP	64	22	24	17	4	31.8	10.9	-7.263	0.281
WMU33	71	75	20	100	4	66.5	16.8	0.975	0.940

Number calves/100 cows showed high variability over time and between landscapes (Fig. 4.10). The trends showed decreasing calves/100 cows over time in PNP and increasing in

WMU33, but autoregression analysis revealed no statistically significant trends over time in either landscape (PNP B=-7.263, P=0.281 and WMU33 B=0.975, P=0.94).

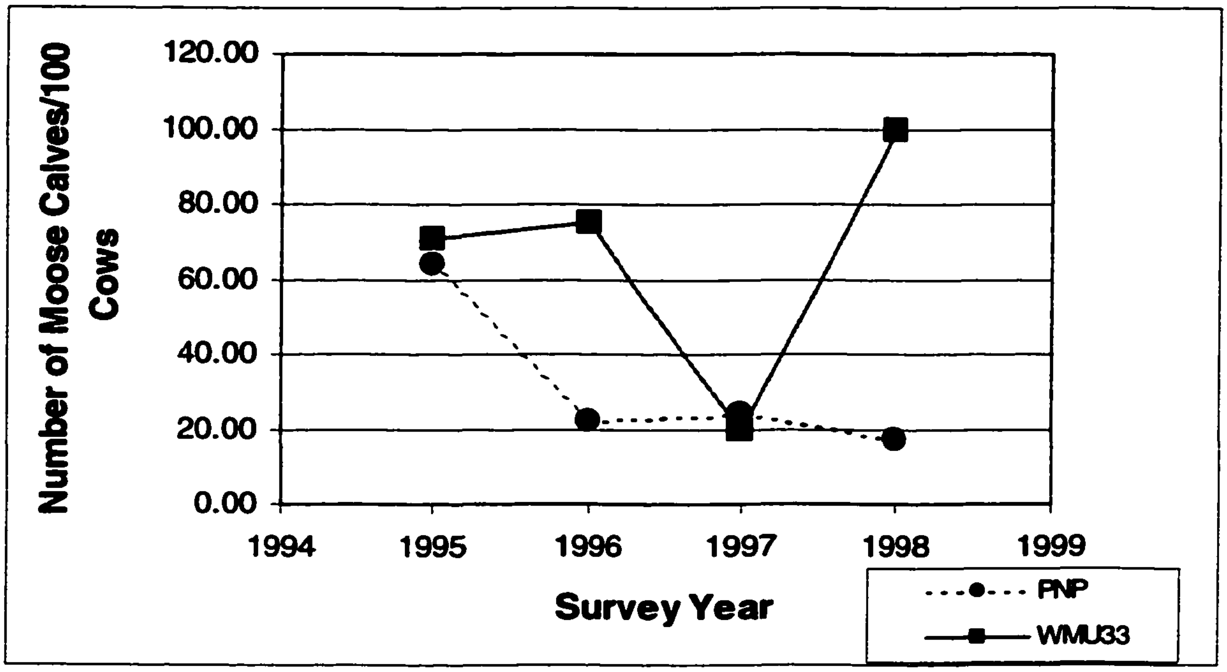

Figure 4.10: Number of moose calves/100 cows from 1995 to 1998 in WMU33 and PNP of the Greater Pukaskwa Ecosystem, Ontario. Data were collected during aerial telemetry of 35 radio-collared adult cow moose (n=438 observations).

I did not test for differences in landscapes because of the limited data set.

Survival

Moose were monitored for 40,783 radio-days (range=43-1544 days/moose). Nine of the 35 radio-collared adult moose died during the study.

Annual survival rates of radio-collared adult females were higher within PNP, ranging from 0.88 to 1.00 with a mean of 0.93 (SE=0.03), whereas they ranged from 0.83 to 1.00 with a mean of 0.89 (SE=0.04) within WMU33 over the four years of study (Table 4.3). There was, however, no significant difference in the survival rates between the two landscapes in any of the years (Table 4.4). When landscapes were pooled, the annual survival rates ranged from 0.90 to 0.96 with a mean of 0.93 (SE 0.01). When all years were pooled over the four-year study, survival rates were lower in WMU33 as compared to PNP (0.64 vs. 0.77), but were still not statistically different.

Table 4.3: Annual survival rates (SR) with SE of adult female moose in the Greater Pukaskwa Ecosystem, Ontario. Data partitioned by landscape, year and landscape pooled. Rates calculated using Kaplan-Meier survival estimator (Pollock et al. 1989).

	1995			**1996**			**1997**			**1998**			**Years pooled**		
	SR	**SE**	**n**	**SR**	**SE**	**n**	**SR**	**SE**	**n**	**SR**	**SE**	**n**	**SR**	**SE**	**n**
PNP	0.875	0.083	16	0.957	0.043	23	0.905	0.044	22	1.000	0	22	0.769	0.083	26
WMU33	1.000	0.000	9	0.889	0.105	9	0.857	0.132	8	0.833	0.152	6	0.635	0.169	9
Landscapes pooled	0.920	0.054	25	0.938	0.043	32	0.898	0.056	30	0.962	0.038	26	0.727	0.079	35

Table 4.4: Results of testing for differences in annual survival rates of adult female moose in two landscapes (WMU33 and PNP) of the Greater Pukaskwa Ecosystem, Ontario, 1995-1998.

Year	Log-rank Test Statistic	df	P
1995	0.07	1	0.80
1996	1.67	1	0.20
1997	1.45	1	0.23
1998	3.33	1	0.06
Landscapes pooled	0.18	1	0.67

Causes of mortality

Nine of the 35 radio-collared moose died during the study and one disappeared and was censored. Five died from predation, two naturally, one unknown and one from hunting. The two natural deaths were from drowning (breaking through the ice in late winter) and apparent collapse with no sign of trauma. The "unknown" cause of death was from a collar that was in mortality mode, but the location could not be easily reached and investigated, and the moose was assumed dead. One moose disappeared, and even after extensive searches was never located.

Patterns of mortalities were not apparent; mortalities occurred in both landscapes (Fig. 4.11) and survival rates were not different between landscapes. Mortalities occurred in all seasons and ages of moose at death varied greatly from 3 to 18 years. Sufficient marrow samples were only obtained from two radio-collared moose carcasses, but were both greater than 90% marrow fat and therefore in good condition.

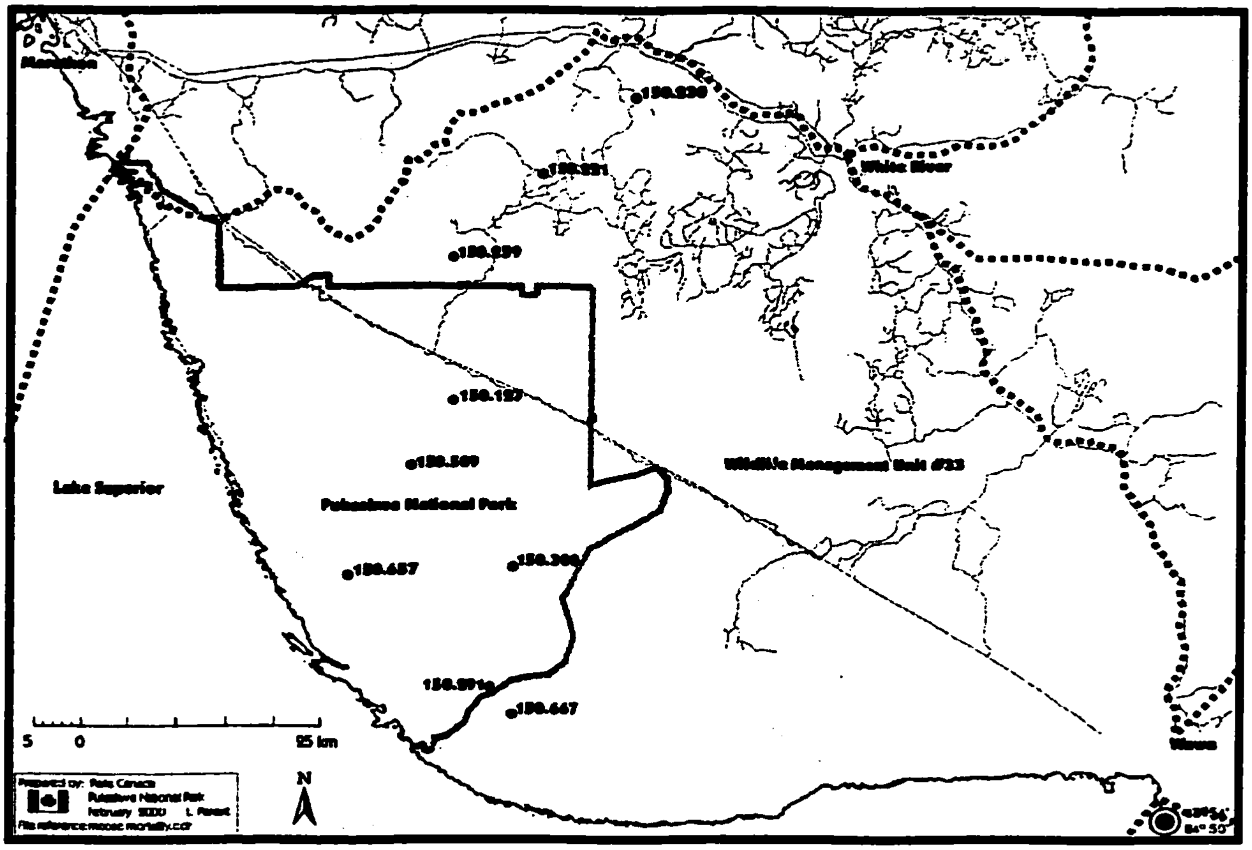

Figure 4.11: Locations of radio-collared moose mortalities (n=9) during the study in the Greater Pukaskwa Ecosystem, Ontario, 1995-1999.

Marrow

Of the 92 non-radio-collared moose carcasses investigated, marrow fat estimates were successfully obtained from 45 animals. Many of the samples were lost early in the study because a priority was not placed on collecting marrow or the marrow was not handled properly. Other samples were unavailable at kill sites because the carcass was dismembered and nearly totally consumed.

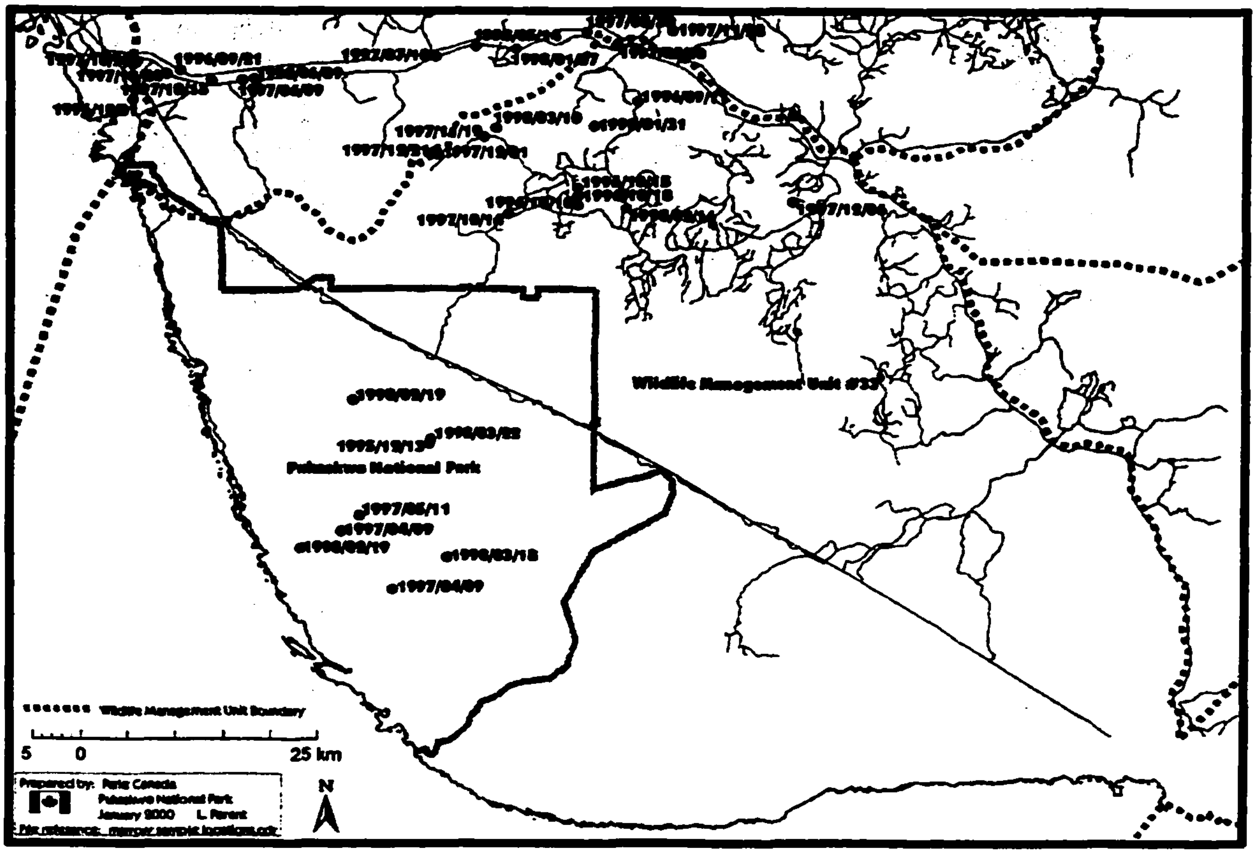

Figure 4.12: Locations and collection dates of bone marrow samples from non-radio-collared moose (n=45, some locations are outside map area) during the study throughout the Greater Pukaskwa Ecosystem, Ontario. Fine black lines indicate logging roads.

Mean marrow fat content in adult moose samples was greater than calves, but there was no statistically significant difference (t=-1.57, 43 df, P=0.12) between average percent (±SE) fat levels of the two moose age classes (>2 years, 63.4 ± 2.71%, n=29; <2 years, 56.0 ± 4.07%, n=16). Mean marrow fat content of moose killed by natural causes (predation) was less than moose killed by unnatural causes (primarily hunting and road accidents), but again there was no statistically significant difference (t=1.78, 43 df, P=0.08) between the groups (predation, 67.9 ± 5.50% n=22; other causes, 79.2 ± 3.61%, n=23).

Mean marrow fat content of moose located in different seasons showed that the lowest marrow fat content occurred in late winter, followed by early winter, with summer showing the highest fat content of any season. Significant differences were recorded between seasons (F=7.43, 44 df, P=0.002). Post hoc tests (Tukey HSD) revealed statistically significant differences between late winter and summer (P=0.001) but not between early and late winter (P=0.124) or early winter and summer (P=0.070).

Mean marrow fat content in moose was lower within the PNP landscape than the WMU33 landscape. However, there was no statistically significant difference (t=1.89, 43 df, P=0.07) between mean percent fat levels in the two landscapes (PNP, 63.5 ± 7.99%, n=12; WMU33, 77.4 ± 3.35%, n=33).

Morphometrics

During captures, all 35 moose were successfully measured for most of the 11 morphometric variables. During the 1996 captures, the hind leg and hind foot variables were incorrectly measured and therefore excluded from this summary. Most of the moose were similar in size and the extreme measurements are attributed to the capture of one calf and two yearlings (Fig.4.5). Otherwise all moose were adults.

Table 4.5: Descriptive statistics for morphometric measurements of moose captured (n=35) during the study in the Greater Pukaskwa Ecosystem, Ontario. (raw data can be found in Appendix 1).

	Neck Circum.		Ear L		Head L		Shoulder Ht		Foreleg L	
	WMU	PNP	WMU	PNP	WMU	PNP	WMU	PNP	WMU	PNP
Mean	78.9	77.2	27.6	29.1	78.4	78.6	186.9	184.2	59.2	59.8
SE	0.9	3.0	0.5	0.5	1.1	1.7	1.9	5.3	1.1	2.9
SD	4.5	9.0	2.5	1.5	5.3	5.2	9.6	15.8	5.3	8.7
Min.	68.6	57.2	22.9	26.7	60.0	66.0	162.6	148.6	54.6	53.3
Max.	88.9	88.9	30.5	30.5	88.9	83.8	205.7	195.6	81.3	82.6
Count	25.0	9.0	25.0	9.0	25.0	9.0	25.0	9.0	25.0	9.0
CI-95.0%	1.9	7.0	1.0	1.1	2.2	4.0	3.9	12.2	2.2	6.7

	1/2 Chest Girth		Chest Girth		Hind Leg		Hind Foot		Tail L		Total L	
	WMU	PNP	WMU	PNP	WMU	PNP	WMU	PNP	WMU	PNP	WMU	PNP
Mean	103.4	99.6	206.9	199.2	78.5	76.5	25.1	25.1	7.0	9.2	293.3	297.7
SE	1.2	2.5	2.4	5.0	0.5	1.3	0.4	0.6	0.5	0.6	3.2	7.4
SD	6.1	7.6	12.2	15.1	2.0	3.9	1.6	1.8	2.5	1.8	16.0	22.3
Min.	91.4	83.8	182.9	167.6	74.9	68.6	22.9	22.9	0.4	6.4	256.5	251.5
Max.	114.3		228.6	213.4	81.3	81.3	27.9	29.2	10.2	11.4	317.5	320.0
Count	25.0	9.0	25.0	9.0	16.0	9.0	16.0	9.0	25.0	9.0	25.0	9.0
CI-95.0%	2.5	5.8	5.1	11.6	1.1	3.0	0.9	1.4	1.0	1.4	6.6	17.1

I used an independent-samples t-test to determine whether moose in the different landscapes were different with respect to the morphometric variables measured. All variables, with the exception of ear length and tail length, were not statistically different. Both mean ear length and tail length were longer in WMU33 than in PNP (ear length; t=2.261, df 23.4, P=0.033: tail length; t=3.060, df 20.7, P=0.006).

Blood

During the 1995 capture, blood samples were successfully obtained from 24 moose, while the 1996 capture resulted in 10 samples. The blood was processed (smears and serum) at Wilson Memorial Hospital in Marathon and then shipped to the Clinical Pathology Lab at the University of Guelph for analysis (Ev Grift). See Appendix 2 for raw data.

Results obtained from the lab showed serum was successfully used in 33 biochemistry profiles including LDH and B-HBA as well as cortisol and T4. Using plasma, fibrinogen was successfully estimated from 28 samples. Smears were obtained from all 33 samples. In 1995, the hematology (CBC's etc.) analyses were unsuccessful because of the amount of time in transit which spoiled the samples, but in 1996 the haematology work was successful. Because of the complexity of analysis, blood assays were not a priority for this research project. It is expected that collaboration with the necessary expertise will be arranged to examine these data in the future.

In 1995, residue from 25 samples was shipped to Dr. Curtis Strobeck and the University of Calgary for archiving in the Parks Canada genetics archive. In 1995 and 1996, all 35 red top residues were provided to Paul Wilson, McMaster University (now Trent University, Peterborough, Ontario) as part of a moose genetics study.

Movements

From the total of 3606 locations, I removed all locations with a confidence class higher than 2 that did not fall within the defined 2-yr period, for a total of 2641 locations remaining. For each movement, the distance and time were calculated and converted to a speed in m/hr. The mean number of days between successive locations for the entire two-year data set was 8.5 days (range 1-45, SE=0.69). The maximum speed recorded in the data was 351.7 m/hr when one moose travelled 42 km in 5 days. This is actually straight-line translocation distance and the moose likely travelled much further. On approximately 15 occasions throughout the study, moose took 30-40 km excursions out of their home range for several days to weeks and then returned. On the other hand, I observed several moose that did not move more than 200 m over a 10-week time span in late winter.

The data were partitioned by landscape, year and season and the mean speed of each moose within each partition was calculated. The number of observations per sampling unit (individual moose) varied from 10.3 to 23.9 with a mean of 14.5 (+/-95% CI=2.96). A sample size of 176 resulted from the data partitions.

The movement data were not normally distributed (P=2.531, P=0.006) so the data were square-root transformed. The transformed data demonstrated normality (P=1.270 in PNP, P=0.246 in WMU33). Univariate ANOVA showed no significant main effects of year so the data were pooled among years. Mean movements were higher in PNP (14.2 m/hr) than WMU33 (13.0 m/hr), but not significantly different (F=2.733, P=0.100). Significant season effects were observed (Fig.4.13) and mean movements were highest in the summer (22.0 and 20.1 m/hr in PNP and WMU33, respectively), significantly lower in early winter (15.1 and 12.9 m/hr in PNP and WMU33, respectively) and the lowest in late winter (6.9 and 5.5 m/hr in PNP and WMU33, respectively) (F=44.88, P<0.001). There were no significant interaction effects of landscape and season (F=0.025, P=0.975).

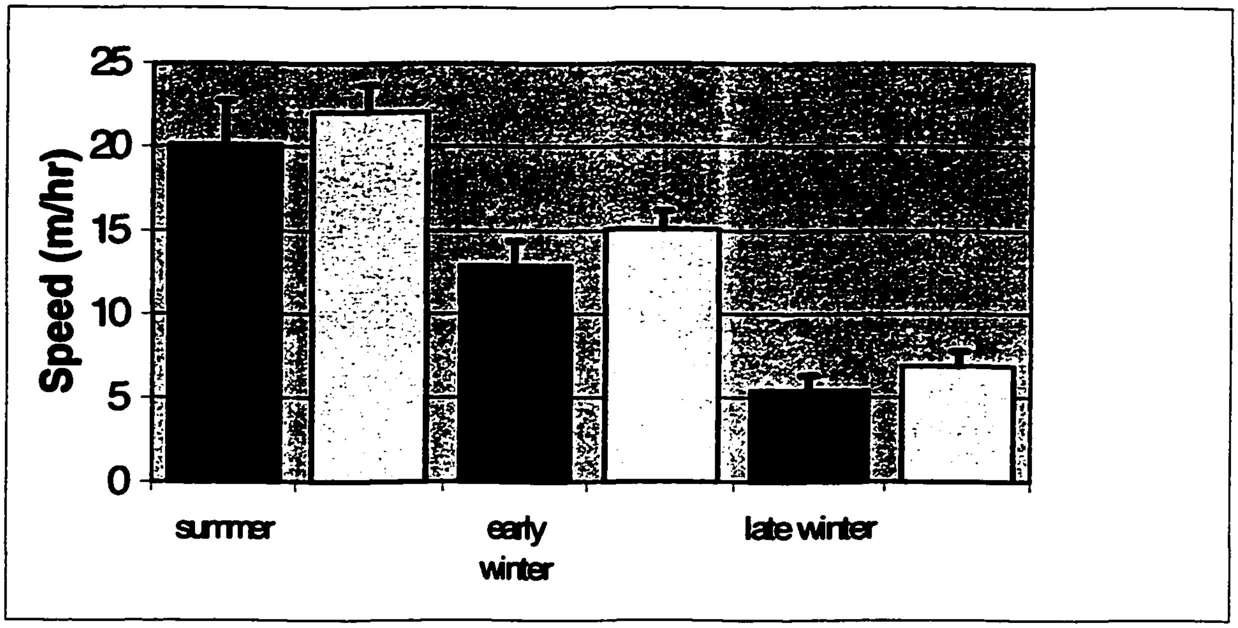

Figure 4.13: Mean speed (m/hr) with SE of moose movements (n=176, based on 2641 locations) in two landscapes: Pukaskwa National Park (PNP) (dark) and WMU33 (light) in the summer, early winter and late winter seasons. Differences among seasons are significant (P<0.05), while differences between landscapes in each season are not.

In summary, there was a pronounced season effect on moose movements. Moose showed the greatest movement in summer followed by early winter, and the least movement in late winter. The lack of movement in late winter was obvious during data collection, as moose were frequently observed selecting conifer stands and often only moving within a 10-15 ha area over the late winter months. The year effects were slightly more subtle but the data show that moose moved differently between years. The *a priori* hypothesis was not supported, as moose movements in the PNP and WMU33 landscapes were similar.

Home Range

The average home range varied considerably over the seasons and between the landscapes. Within the park, several individual moose exhibited distinctive seasonal shifts within their home ranges. Seven moose in the inland area of the park showed a north-south movement pattern of 10-14 km between summer and winter ranges. This seasonal migration was not noted in WMU33 (Figs. 4.14, 4.15 and 4.16).

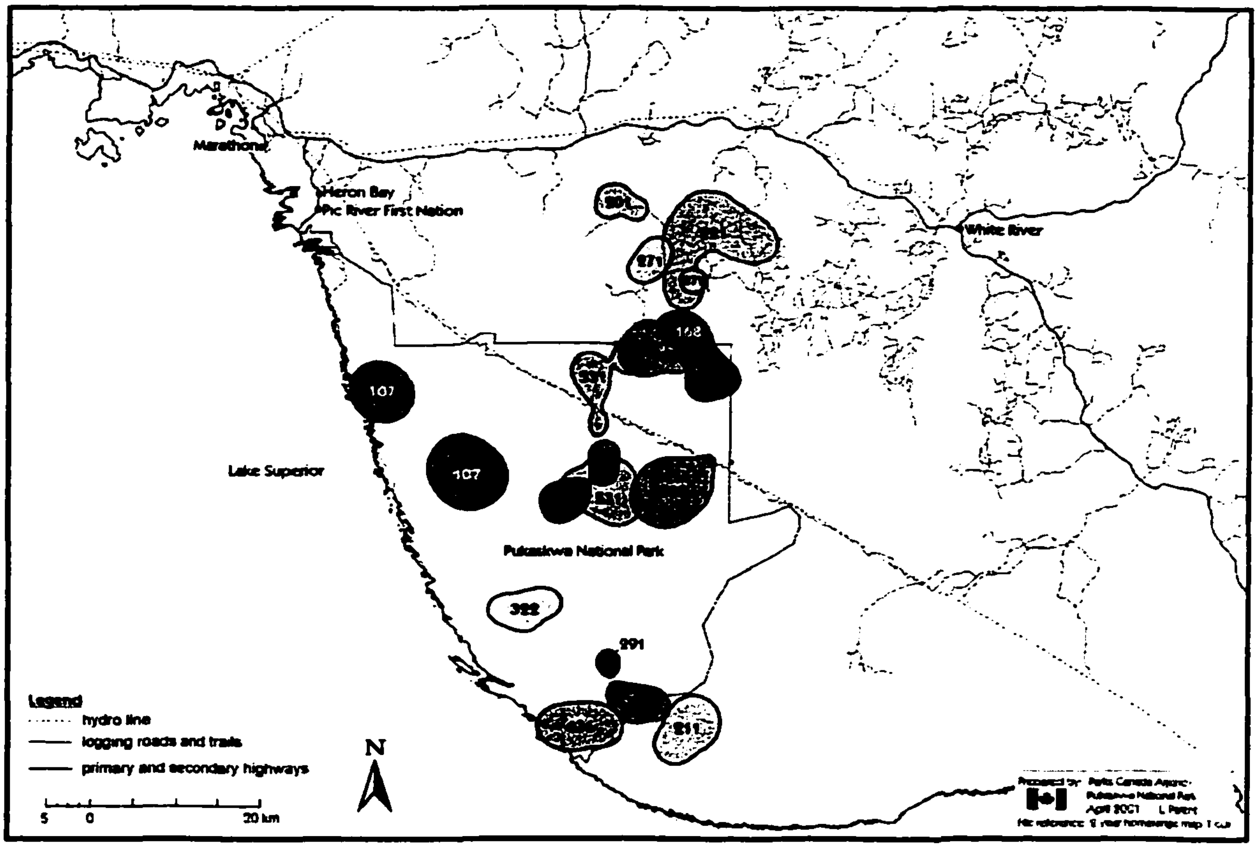

Figure 4.14: Study (2 full years) home range plots calculated by 90% adaptive kernel estimator for radio-collared adult female moose locations in the Greater Pukaskwa Ecosystem, Ontario, 1995-1998. Numbers depict moose identification. This figure shows 12 of the 35 collared moose.

Figure 4.15: Study (2 full years) home range plots calculated by 90% adaptive kernel estimator for radio-collared adult female moose locations in the Greater Pukaskwa Ecosystem, Ontario, 1995-1998. Numbers depict moose identification. This figure shows 12 of the 35 collared moose.

Figure 4.16: Study (2 full years) home range plots calculated by 90% adaptive kernel estimator for radio-collared adult female moose locations in the Greater Pukaskwa Ecosystem, Ontario, 1995-1998. Numbers depict moose identification. This figure shows 11 of the 35 collared moose.

Mean home-range sizes of radio-collared moose were calculated by partitioning the data by landscape, season and year. The MCP and adaptive kernel data were not found to be normally distributed, and were normalized using a square-root transformation. The between-year effects were found not to be different, so the years were pooled. With both estimators, I found the home range size larger in the park than the cutovers, and sizes decreased through the summer to early winter to late winter seasons (Table 4.6).

Table 4.6: Comparison of mean seasonal and study home range sizes (km^2) by method of calculation for radio-collared adult cow moose studied in the Greater Pukaskwa Ecosystem, Ontario, 1995-1998.

	95% MCP				**90% Adaptive Kernel**			
	PNP (n=26)		**WMU33 (n=9)**		**PNP (n=26)**		**WMU33 (n=9)**	
Season	Mean Area	SE	Mean Area	SE	Mean Area	SE	Mean Area	SE
Entire Study	97.6	15.1	71.9	15.8	76.9	9.3	55.3	10.3
Annual	69.5	9.0	42.6	7.5	62.8	7.2	49.8	9.9
Summer	40.2	8.4	33.4	7.9	78.9	30.0	32.6	5.4
Early-Winter	34.5	5.9	16.6	5.3	48.2	8.2	33.8	8.9
Late-Winter	4.6	0.8	2.7	0.7	14.6	3.6	5.4	1.4

Two-way ANOVA uncovered significant main effects of landscape (F=4.532, P=0.034). The mean MCP home range areas were consistently larger in the PNP landscape than the WMU33 landscape (Fig. 4.17). Significant main effects of season were also found (F=31.410, P=0.000) using MCP. Home range size over the entire study period was larger than annual home range size, which was larger than summer home range size. Summer and early winter home range sizes were similar. Late winter home range size was significantly smaller than all other seasons. No interaction was measured between season and landscape (F=0.347, P=0.846).

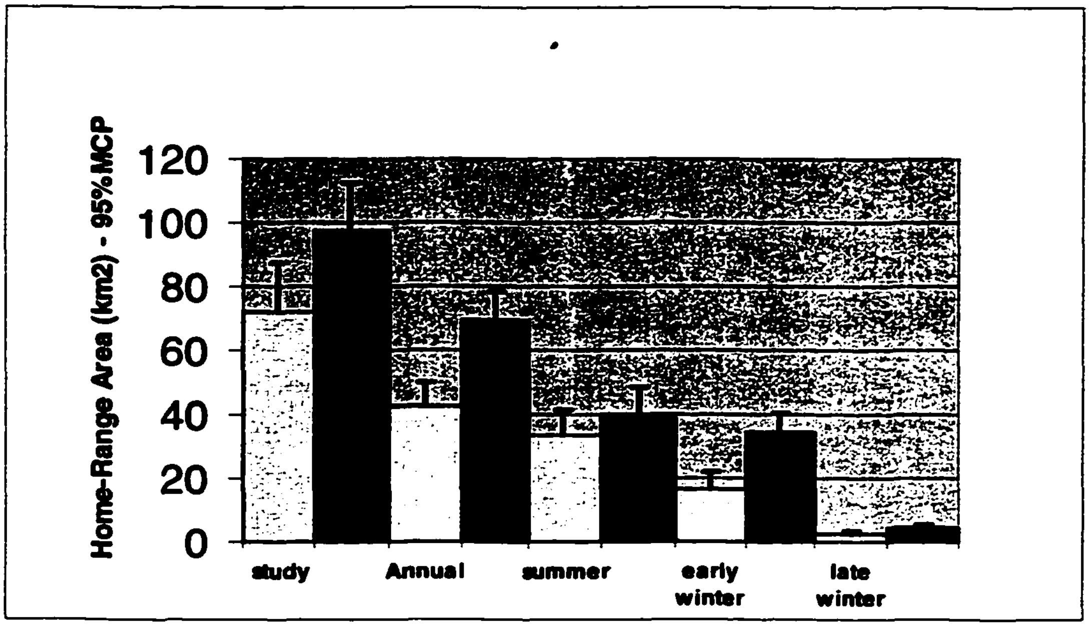

Figure 4.17: Mean home range area (km^2 with SE) estimated from 95% MCP for radio-collared adult female moose locations in two landscapes (light colour = WMU33, dark colour = PNP) and 5 different time periods in the Greater Pukaskwa Ecosystem, Ontario, 1995-1998.

Similar results were found using the adaptive kernel as the home-range estimator. Two-way ANOVA detected significant main effects of landscape (F=5.542, P=0.019). The mean adaptive kernel home range areas were consistently larger in the PNP landscape than the WMU33 landscape (Fig. 4.18). Significant main effects of season were also found (F=16.773, P=0.000) using adaptive kernel. Home range size over the entire study period was similar to annual and summer home range sizes. Annual, summer and early winter home range sizes were similar, but late winter home range size was smaller than all others. No interaction was measured between season and landscape (F=0.249, P=0.910).

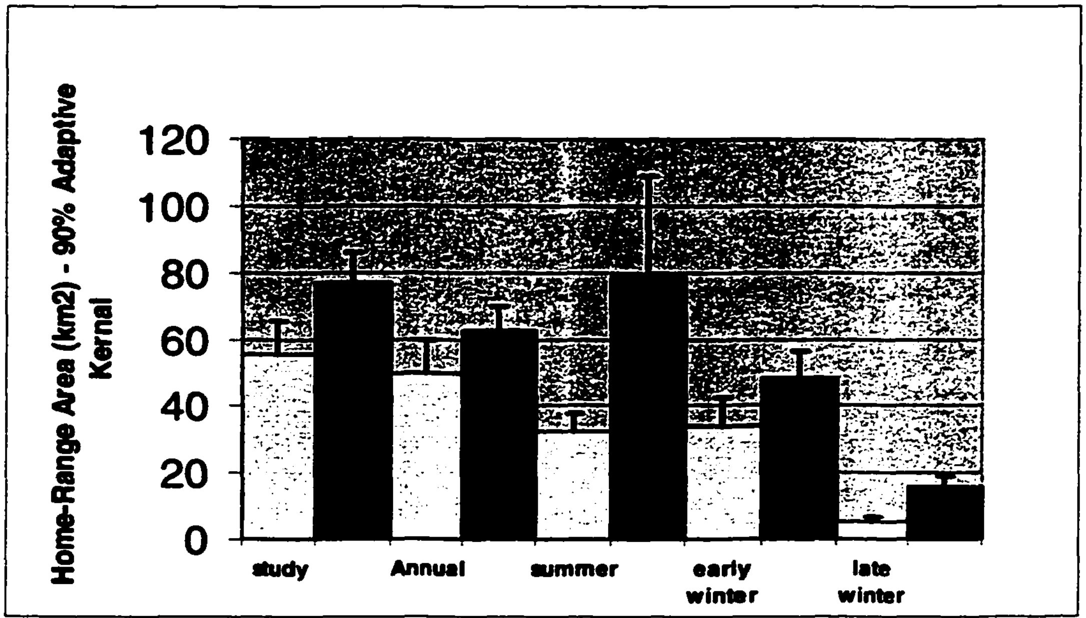

Figure 4.18: Mean home range area (km^2 with SE) estimated from 90% adaptive kernel for radio-collared adult female moose locations in two landscapes (light colour = WMU33, dark colour = PNP) and 5 different time periods in the Greater Pukaskwa Ecosystem, Ontario, 1995-1998.

CHAPTER 5: DISCUSSION

The PNP landscape has experienced few disturbances in recent decades, whereas WMU33 has experienced significant timber harvest over the last 15-20 years. Moose densities in the disturbed forest of WMU33 are slightly higher than those in PNP, thus lending some weak support to my general hypothesis that the habitat-defined carrying capacity (K) of moose within PNP may be lower than in the adjacent WMU33. Moose require a juxtaposition of early successional growth interspersed with cover habitat for predator avoidance and winter shelter (OMNR 1988). The landscape of PNP lacks significant amounts of early successional growth, thereby lowering habitat quality relative to WMU33, which has abundant availability of this necessary habitat component.

Density and Distribution

Although the trends over time in the moose population density were not statistically significant in either PNP or WMU33, direct examination of the data suggests important changes may have occurred in WMU33. Although not significant, the trend in WMU33 was toward slightly increasing moose densities. This should be expected if my general hypothesis is to be supported. The PNP population density is essentially stable. However, one data point (1996) is particularly lower than the others. This apparent aberration may be explained by the survey conditions during that year (K. Wade, pers. comm.). Midway through the survey, the region experienced a significant winter storm that created deep snow depths immediately and unusually early in the year. As a result, moose likely shifted to late winter behaviour (i.e., use of dense conifer habitat and small movements) before the survey was completed, thereby lowering sightability. With these conditions the population could have been underestimated in PNP. If so, moose density in PNP may be more stable than suggested by the data, while increasing in WMU33 at a greater rate than was recorded (Fig. 4.2). The disturbance in WMU33 caused by timber harvest is likely improving moose habitat, and moose densities responded positively.

I used a similar approach to that of McKenney et al. (1998) to calculate spatially explicit density maps and density change, but on a finer scale. Spatially, the kriging output clearly shows higher moose densities in WMU33 as compared to PNP (Fig. 4.3 and 4.4). Where timber harvest has occurred (i.e., cut blocks, roads), moose densities appear particularly high in remaining forest stands. When viewed as a change over time, increasing moose density in WMU33 is evident, but not in PNP (Fig. 4.6). McKenney et al. (1998) used data over a longer period (1975 – 1995) which showed the area of PNP appearing to have increased moose densities in the early 1980s and then decreased densities in the late 1980s and early 1990s. Their study, particularly in the early 1990s, shows results similar to my analysis, wherein the moose density of PNP is lower than WMU33. On a provincial scale, moose density in PNP is below the provincial mean of 0.209 moose/km^2, whereas the density in WMU33 is above the provincial mean. In terms of rate of change of moose density over 20 yrs., McKenney et al. (1998) found overall decreasing densities in PNP as well as WMU33, but not to the same degree in WMU33. My study suggests that moose may have responded positively to forest disturbance, particularly in the five years following the period examined by McKenney et al. (1998), and reversed the trend they observed previously in WMU33.

Rempel et al. (1997) looked at the effects of landscape disturbance and hunting on moose densities, and found that neither effects of landscape disturbance or hunter access alone could account for variation in moose densities among landscapes. However, the interaction between landscape disturbance and hunter access was crucial; moose density increased if disturbance occurred without increased hunter access. Examining this more closely, it was how the disturbance occurred. In areas that followed the Timber Management Guidelines (OMNR 1988) to create an extensive patchwork of cuts interspersed with leave blocks, an extensive network of roads was required. This extensive network of roads allowed for easy and widespread access by hunters, leading to an increase in hunter success and moose mortality. Within WMU33 the increase in hunter access, and thus moose mortality, that might have resulted from a similar application of the Timber Management Guidelines (OMNR 1988) may have been mitigated by the stringent allocation of hunter moose tags in WMU33 (G. Eason pers. comm., Eason 1985). Consequently, the impacts of hunters on moose density in WMU33 appear to have been minimal.

Productivity

Productivity is a term often used by wildlife managers to express the growth and condition of a population. There are several similar and related terms that require some clarification. *Fecundity* is the rate at which an average individual produces offspring; it equates to *birth rate* when referring to a population. In the Yukon, Larsen et al. (1989) found 84% of female moose (n=43) ≥ 24 months old were pregnant and the mean birth rate was 114 calves: 100 cows; twins were observed with 16 cows (28%). Simkin (1974) found similar numbers in Ontario: 87% of >30-month-old cows were pregnant. *Recruitment* is the addition of new individuals to a population. Many investigators assess recruitment at the yearling age during winter surveys, because post-natal mortality can be high in moose populations.

The rate of increase of a population, or gross productivity, is the number of calves that a population of 100 moose of given sex ratios and given pregnancy rates produce. This is also the percentage of the population that could be removed (i.e., harvested) if all the young that were conceived survived and the total population remained stable (i.e., similar sex and age/class distributions). Gross productivity in moose has been estimated to be approximately 24-26% (Simkin 1974). A more useful estimate is the net productivity at the yearling age, since this accounts for the increased vulnerability of calves in their first year due to predation, disease, accidents, etc. Net productivity is calculated as the number of calves expressed as a percentage of the total moose population. In Ontario, the provincial average for net productivity is 17%, with a range from 10-25% of the total observed population (Bisset 1995). In areas where predation is intense, the percentage of calves can be as low as 7% (VanBallenberghe 1987). Net productivity may be as high as 44% in populations where hunting is negligible (Rolley and Keith 1980).

In this study, the percentage of calves was decreasing in both landscapes over time, but it was not a statistically significant trend (Fig. 4.8). The mean percent calves per plot in the most recent surveys was about 10% in both landscapes. This net productivity is on the lower range of the provincial average. However, caution should be taken in interpreting the percentage of calves. In hunted populations, net productivity may be overestimated because there may be a proportionally higher harvest rate of adults, particularly bull moose in the Ontario situation, and the herd will appear more productive because the calves represent a larger proportion of the observed population. For this reason, using calves/100 cows may be a more accurate measure of recruitment and productivity. Using this measure, the calves/100 cows was decreasing at a significant rate in WMU33 but no trend was apparent in PNP (Fig. 4.7). This is an interesting statistic because it suggests the overall productivity in WMU33 is decreasing and density should be decreasing as well. However, density in WMU33 appears to be slightly increasing. This inconsistency may be the result of the limited allocation of adult tags in WMU33 that has caused hunters to place significant hunting pressure on calves, for which there are no set quotas.

Recruitment assessed from the radio-collared cow moose was highly variable and showed no statistically significant trends through time, or differences between landscapes (Fig. 4.10). Interpreting these results should be done with considerable caution due to the small sample size of only 35 radio-collared cows, as well as the highly variable sightability of individuals achieved at various times of the year. Confirmation of radio-collared cow moose accompanied by calves was at times difficult due to forest cover and ability to obtain good visuals from a moving aircraft. It is likely that many calves were missed. However, in PNP, other than the first year that had a high number of calves/100 cows, the ratios were similar to the results obtained from population surveys (around 20 calves/100 cows). Within WMU33, the ratios were extremely variable, most likely due to the small sample size of only nine radio-collared cows that were monitored outside PNP. The calculated number of calves/100 cows in WMU33 was generally above 60 calves/100 cows, which is quite unlikely since this is three times the estimate obtained from population surveys and well above any previously reported values.

The number of bulls/100 cows is important because low bull/cow ratios can influence conception rates and neonate sex ratios in ungulates (Bishop and Rausch 1974, Crete et al. 1981). These ratios were well above the lowest levels (20 bulls: 100 cows) recorded in other studies (Timmermann 1987). In Ontario, the allocation of adult hunting tags is planned to produce a bull/cow ratio of 66 bulls/100 cows in each Wildlife Management Unit (WMU) (Bisset 1995). The intent is to provide greater protection of cows and optimize productivity. Differential harvest of 2 - 3 bulls per cow is recommended to achieve and maintain this bull/cow ratio (Bisset 1995). In the non-hunted population of PNP, bull ratios were well below that target (high 40s) in the mid-1980s, but increased and achieved the target ratio (mid-60s) by the late 1990s. However, the increase in the number of bulls in PNP is the result of the shift from a hunted to non-hunted population and not planned moose harvests. All hunting, with the exception of some First Nation's harvest, was phased out in the early 1980s when the park was established. Eventually, the number of bulls may increase to produce a 50:50 ratio of bulls: cows that would be theoretically expected in a natural, unhunted population. The general trend in WMU33, although not statistically significant, appears opposite to that of PNP. The bull ratio in WMU33 (> 80) was well above the target ratio throughout the surveys but has declined since the mid-1980s. This decrease is a response to the differential harvest tag allocation, which favours cows and allows more bulls to be taken. The decline might have occurred at a greater rate if it weren't for the limited allocation of hunter moose tags in WMU33 (G. Eason pers. comm.). In the longer term, the bull ratio in WMU33 may approach the target of 66 bulls/100 cows if the trend continues.

Survival

Annual survival rates of the adult radio-collared cow moose were not different between the two landscapes, or over the four years of the study. The mean values for PNP were 93% while for WMU33 they were 89%. These rates are similar to what was found in Alaska, where the annual survival rates averaged 94.9% (Ballard et al. 1991). In two studies where hunting was not a significant mortality factor, Bangs et al. (1989) found a mean annual survival rate of 92% during a 6-yr study of 51 radio-collared moose. Larsen et al. (1989) found a mean annual survival rate of 91% during three years of tracking 41 adult females in the Yukon. In areas that have been hunted, mean annual survival rates have been reported from 75 to 94%, depending on the extent of hunting (Gasaway et al.

1992, Hauge and Keith 1981). In a hunted area of south-central Alaska, Modafferi and Becker (1997) found an annual survival rate of adult females of 90.8%.

Of the 35 moose that were radio-collared in my study, a total of nine died (3 in the WMU33 and 6 in PNP). Their cause of death was variable, with predation being the single largest cause (5). One of three deaths was caused by predation in WMU33 while four of six deaths were predation in PNP. Hunting caused only one death in WMU33, but only five adult cow tags were issued for that WMU and low mortality from hunting should be expected.

Marrow Condition

Marrow fat of longbones has been widely used as an index of the physical condition of ungulates at time of death (Neiland 1970, Franzmann and Arneson 1976, Peterson et al. 1982, Ballard 1995). Although this method has limitations, it is generally considered a valid indicator of relative condition. The important factor to consider is the seasonality of marrow fat. Typically marrow fat increases during summer and autumn and declines throughout winter (Ballard 1995). Cederlund et al. (1986) noted season (rut and late winter effects), age and sex differences in marrow fat, but felt they were a good relative measure of condition if these factors were taken into account. My results support these findings. I found significant differences in marrow fat content seasonally, particularly between summer and late winter, with late winter having the lowest marrow fat content. Cederlund et al. (1986) also found fat mobilization different for calves and adults and that males had decreased fat during and after the rut. Although not statistically significant, I also found marrow fat lower in calves than adults.

The marrow fat index may also vary with habitat and weather conditions. If this is true, what constitutes a "healthy" animal is relative to other members of the population at a given time. If the marrow fat index of animals dying of natural causes is compared to animals killed by unnatural causes (i.e., road kills, hunter killed), it may more accurately reflect the relative health of individuals at the time of death. These comparisons may indicate whether an individual animal was exhibiting abnormal stress caused by a specific problem (age, disease, injury, etc.) at the time of death, or the entire population is stressed because of a population-wide problem (i.e., weather and/or habitat). I compared moose killed by predation vs. other causes and found that moose killed by predation had lower mean marrow fat levels than moose killed by other means. This suggests that predators may have selected the more nutritionally stressed or poorer condition individuals.

I also compared marrow fat levels in WMU33 and PNP to determine whether moose in the different landscapes had different marrow fat content. I found lower marrow fat levels in PNP than in WMU33. Although they were not statistically different, the higher values of marrow fat obtained from samples collected in WMU33 suggests that moose occupying the WMU33 landscape may be responding positively to improved habitat quality brought about by timber harvests, which supports my general hypothesis. Further evidence of the positive response shown by moose condition in the WMU33 landscape may be available when the marrow fat data are used in combination with future results of blood sample analyses.

Movement and Home Range

The ways in which moose use their environment, both spatially and temporally, is key to understanding their ecology. I used movements and home range to assess how moose were using their environment within the Greater Pukaskwa Ecosystem. In the two landscapes compared, I predicted that due to lack of disturbance within PNP, the habitat would be poorer (lower carrying capacity) than that of WMU33. Based on McNab's (1963) hypothesis that energetics is the ultimate factor that determines home range size, it follows those animals living in relatively poorer habitat should have larger movements and home ranges than those in more productive habitat (Hundertmark 1998). Lynch and Morgantini (1984) and Miquelle et al. (1992) both demonstrated that distances moved by moose over a given time were directly related to forage biomass.

Although my results did not demonstrate statistical differences between landscapes, mean movements by moose in PNP were greater than those in WMU33 (Fig. 4.13). This suggests that habitat in PNP may be of lower quality than WMU33, requiring moose to move greater distances to obtain the necessary forage to meet energetic needs. On the other hand, there were strong seasonal differences in movements of radio-collared moose in both landscapes that appear to contradict the suggestion that individuals should adjust their movements to meet energetic demands. In both landscapes, the greatest movements occurred in summer and were least in winter; summer movements were about four times greater than in winter. These results are consistent with several previous studies (Phillips et al. 1973, Best et al. 1978, Joyal and Scherrer 1978, Garner and Porter 1990) and appear contrary to McNab's (1963) theory that home ranges should be larger in winter to address increased metabolic needs. However, Schwartz et al. (1988) demonstrated that moose actually have lower metabolic rates in winter because of behavioural and physiological changes. To conserve energy, moose often exhibit "yarding" behaviour (Peterson 1955), somewhat similar to white-tailed deer, particularly during late winter and in years with exceptionally deep snow. Moreover, the resting metabolic rate of moose in winter is only half the summer rate (Renecker and Hudson 1986). Consequently, seasonal differences in movements of moose reflect changes in metabolic requirements, whereas differences between landscapes within each season may be the result of differences in habitat quality.

In this study, seasonal migrations were observed in some of the moose occupying the inland landscape of PNP. Migrations have been noted in numerous studies (Van Ballenberghe 1987, Ballard et al. 1991) and appear to be triggered by snow accumulation (Coady 1974). Ten moose in PNP showed shifts between summer and winter ranges. These shifts generally involved a pronounced north-south movement of 10-20 km (Fig. 4.14, 4.15, and 4.16) and occurred every year in May and October/November. Shifts between summer and winter ranges were primarily observed in the inland landscape of PNP where the moose selected dense conifer forest in the Rein Lake area, then shifted southward to mixed-wood and deciduous forest for the summer. Often these shifts were rapid and occurred over a period of 1-2 weeks. I did not observe any seasonal migrations of moose from inland areas to the coast of Lake Superior, as Bergerud (1985) suggested might occur in winters of heavy snow accumulation.

Home range sizes of moose in this study fall within the wide variation of home ranges published throughout North America (Table 5.1). Studies in Alaska have observed rather large home range areas on the order of several hundred square kilometres. In southern areas of moose range, several studies have reported home range sizes but only for very small sample sizes. Studies in Alberta generally found moose to have smaller home ranges than in Alaska; winter ranges varied from 18 to 47 km^2 and summer ranges from 9 to 37 km^2. The only published study in Ontario was by Addison et al. (1980), who found similar home range sizes to my study, although their sample size (n=3) was small.

Table 5.1. Selected moose home range studies using radio telemetry. These studies used adult females only and the MCP estimator. Results of this study calculated both early and late winter home ranges sizes where other studies did not differentiate.

Study Area	n	Total	Winter	Summer	Reference
Alaska	30	128	63	36	Bangs and Bailey 1980
Alaska	20	606	199	210	Grauvogel 1984
Alaska	19-43	290	113	103	Ballard et al. 1991
Alberta	29-66		18	9	Lynch and Morgantini 1984
Alberta	23-52		47	27	Lynch and Morgantini 1984
Alberta	7-12		30	37	Hauge and Keith 1981
NWT	29	174	57	68	Stenhouse et al. 1994
Ontario	3		6	43	Addison et al. 1980
Sweden	31	13.7	6	4	Cerderlund and Sand 1994
Ontario WMU33	9	43	17/3	33	This Study
Ontario PNP	26	70	35/5	40	This Study

In this study, I found significant differences in seasonal home range sizes of cow moose, with late winter being small and summer the largest. As discussed above, moose shift to dense conifer habitats and move very little in late winter to conserve energy. Some studies in Alberta, Alaska and Northwest Territories have found home range areas similar to my study (Table 5.1), but the seasonal patterns were reversed (i.e., larger in winter than summer) or absent (i.e., the same size in summer and winter). Hundertmark (1998) plotted mean home range size reported in North American studies against degrees north latitude. He found that below 60 degrees north latitude, summer home ranges remained relatively stable whereas winter ranges seemed to increase northward. In the more southern areas of North America, winter ranges were much smaller than summer, similar to what I found in my study. Hundertmark (1998) also determined that north of 60 degrees north latitude, sizes of both summer and winter home ranges increased dramatically. The variance of seasonal home ranges increased with increasing latitude as well. Partial explanation for this pattern may be the quality and availability of suitable moose habitat in the north.

Caution should be used in comparisons of seasonal home range sizes of moose because the definition of seasons may vary among studies. Annual home range is obvious but the definition of season varies. Most studies have divided the season into winter and summer, whereas I divided the winter season into early and late winter periods. I did this because wildlife managers in Ontario use that separation of the winter season to assist them in defining moose habitat needs. In any case, if these values were averaged for the winter period, the general comparisons made above would not be altered.

Additional factors that might affect comparisons of home range sizes of moose are age, sex and parental care. Cederlund and Sand (1994) found significant effects on moose home range size depending on season, age, sex and presence of a calf with cows. Because I only collared adult cows, I eliminated a majority of these confounding factors and comparisons among seasons or between landscapes are unlikely to have been affected.

Numerous methods to estimate home range size have been developed. The longest and most commonly used technique is the minimum convex polygon (Harris et al. 1990). One of the major disadvantages of this technique, as alluded to by Ballard et al. (1991), is that it often includes areas that may not be used by the animal. Ballard et al. (1991) reported some of the largest moose home ranges in a mountainous region of Alaska, but they also found that 31% of the area was actually unsuitable for moose because of steep slopes. These unsuitable areas were included in home ranges because of the MCP estimation technique, which clearly exaggerated the actual areas of home ranges. I used MCP to compare my results to previous studies simply because it is the most commonly used estimator, which necessitates its calculation for comparative purposes.

To address the limitations of MCPs, other estimators have been developed (White and Garrott 1990). Two alternative techniques are the harmonic mean (Dixon and Chapman 1980) and kernel (Worton 1989) estimates of home range size. These estimators do not have *a priori* assumptions about the shape of the home range, are non-parametric, and allow the identification of core areas. In my study, the adaptive kernel method gave different estimates of home range size than MCP (Table 4.6). The overall sizes of home ranges were not always different but the shapes of the polygons enclosing animal locations were. The delineation of home ranges using the adaptive kernel method was helpful in more precisely identifying areas being used by radio-collared moose. This was particularly true for migratory moose that shifted core areas (i.e., concentrations of locations) by season; the kernel method clearly distinguished two cores. The areas between seasonal cores that were not used by moose were excluded by the kernel technique thereby overcoming one of the major disadvantages of the MCP estimator.

Within my study area I found significant effects of landscape on the size of moose home ranges. Home range sizes in PNP were consistently larger than those in WMU33. This may support my hypothesis that the less disturbed landscape of PNP is less productive for moose. PNP has had little habitat disturbance and therefore limited availability of early successional stages of vegetation growth, which are believed to be a key food source for moose (OMNR 1988). McNab's (1963) theory that home range size is determined by energetics suggests that moose living in more productive habitats will use smaller home ranges, or at least have smaller core areas, while those living in less productive habitats will show the opposite characteristics. Following the energetics theory, moose in PNP were apparently required to move around more and use larger areas to find their necessary habitat prerequisites.

The seasonal or migratory shifts observed only in PNP moose suggests further that the juxtaposition of habitats was also less than ideal. For example, very little of the inland park area has dense conifer habitat which is believed to be a key component of winter requirements, and this is where I observed moose shifting to northern conifer areas in winter and then back southward to mixed-wood and deciduous forest in summer. In these examples, two core areas were often well defined. In WMU33, on the other hand, there is more conifer forest and more disturbed area from timber harvesting. Moose movements in WMU33 were shorter and home ranges sizes were much lower than in PNP. None of the WMU33 moose showed any seasonal movements and seemed to be able to meet all of their habitat requirements in a small, defined area. All of these observations suggest that moose occupying the WMU33 landscape may be responding positively to improved habitat quality brought about by timber harvesting while moose in PNP are limited by the availability of productive habitat to meet their requirements, which supports my general hypothesis.

Summary

The original intent of this study was to investigate the effects of landscape disturbance on the demographics and behaviour of moose through comparisons with an undisturbed landscape. My results weakly suggest that an absence of habitat disturbance and/or poor overall habitat quality may limit the availability of necessary habitat components and lower the productivity and density of moose. Moose in poor habitats also demonstrate differing behaviour patterns, exhibiting greater movements and occupying larger home ranges than those in good habitats, in an effort to find sufficient resources to meet their needs. As well, moose living in good habitats are generally in better physical condition than those in poorer habitats. In the specific context of my study, moose occupying the WMU33 landscape may have shown a slight positive response to habitat features, as seen by their somewhat higher population density. They have smaller home ranges and have more areas of higher densities than moose living in the undisturbed landscape of PNP. Whether this is caused by the application of the Timber Management Guidelines (OMNR 1988) or some other enduring feature of the habitat such as forest stand composition or climate is not conclusive in this study. This study shows clear differences in moose demographics and behaviour in the two landscapes. However, concluding these differences are only attributable to specific timber harvest guidelines is not entirely possible. Future research is required to ascertain the habitat differences, and understand in a more refined way exactly what are the habitat features that are significant to the moose populations. In this study, the habitat characteristics were only examined in a relatively simple fashion. Future research needs to quantify the habitat features using habitat modelling, such as habitat suitability index methods (Allen et al. 1987, Bender et al. 1996) or the more sophisticated models such as logistic regression (North and Reynolds. 1996). Habitat modelling and comparison of habitats in the different landscapes can then more confidently conclude exactly how and what habitat features are driving the patterns of moose demographics and populations.

The implications of this research on management of the WMU33 suggest that past management practices have been effective at maintaining and enhancing the moose population. The goals of timber harvest and moose production seem to be compatible. However, with the requirement to meet the more broad and diverse ecosystem management goals expected by the stakeholders of the resources, some consideration will be required to assess the impacts on the biodiversity and ecosystem processes of these landscapes.

If Bergerud's (1988, 1989) hypothesis is correct, these findings may have important implications for the persistence of caribou in PNP. If wolves show a positive numerical and/or functional response to the increasing availability of moose adjacent to PNP, predation on caribou might also increase. However, since the moose population within PNP appears to be stable, the reverse effect could actually benefit the remaining caribou herd; i.e., wolves may be drawn out of PNP and away from the remaining caribou in response to greater moose density in WMU33. The response of wolves to increasing moose density in WMU33 and any collateral effects on caribou in PNP remain to be seen.

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APPENDICES

Appendix 1: Data results of moose and caribou captures in 1995 and 1996 in the Greater Pukaskwa Ecosystem, Ontario.

appendix 1_capture

Collar Frequency	Capture Sequence	Capture date	Time of 1st Obs.	Time of Chase Start	Time of Chase End	Chase Length (min.)	Release Time	Total Handling Time (min.)	Chase Notes	Latitude	Longitude	General Location	In Park ?
150.291	95-1	13-Mar-95	11.58	12.00	12.05	5.0	12.30	32	pushed out of trees onto small marsh, 1 net, somersault, 40cm+ snow	48.04.81	85.47.85	west of Perry L	Y
150.211	95-2	13-Mar-95	13.52	13.54	13.57	3.0	14.22	32	pushed out of trees, across creek, 1 net, 20cm snow	48.04.81	85.47.85	west of Perry L	Y
150.201	95-3	13-Mar-95	17.02	17.03	17.06	3.0			in C/O, 1 net, almost escaped prior to belts, 20cm snow	48.04.62	85.47.74	near 730 rd	N
150.241	95-4	14-Mar-95		10.08	10.17	9.0			in C/O	48.34.08	85.42.55	south of Triplet Lakes	N
150.271	95-5	14-Mar-95	10.35	10.35	10.43	8.0	11.01	26	in C/O	48.34.08	85.42.55	south of Triplet Lakes	N
150.230	95-6	14-Mar-95	11.15	11.18	11.35	17.0			in C/O, lots of standing during "chase", 3 nets, one caught skid	48.33.88	85.41.35	south of Triplet Lakes	N
150.281	95-7	14-Mar-95	12.46	12.46			13.10	24	driven off ridge onto marsh, one net, 50cm+snow, very smooth	48.28.76	85.47.84	north of Cabin L	N
150.251	95-8	14-Mar-95	13.26				14.03	37	with calf, slow drive out of bush, netted in C/O, nasty roll over log	48.35.18	85.40.22	east of Oskabukuta L	N
150.221	95-9	14-Mar-95	13.26				14.04	39	calf of #8, 1 net, in C/O adjacent 719 rd	48.35.18	85.40.22	east of Oskabukuta L	N
150.300	95-10	14-Mar-95	16.55	16.55	17.10	15.0	17.22	27	with #11, driven along Louie L to north end marsh, 2 nets, long chase	48.24.51	85.50.84	north of Louie L	Y
150.191	95-11	14-Mar-95	17.32	17.34	17.45	11.0	18.15	43	with #10, nasty chase, 3 nets, "2 wedding veils", final net tangled in bush	48.25.24	85.50.97	north of Louie L	Y
150.127	95-12	15-Mar-95	10.53				11.15	22	driven onto marsh, 2 nets, somersaulted out of 1st net	48.24.00	85.49.30	south-east of Louie L	Y
150.531	95-13	15-Mar-95	11.35				12.10	35	driven off ridge to s. Louie marsh, with #14, one net on marsh	48.24.04	85.51.40	south Louie L	Y
150.509	95-14	15-Mar-95	11.35				12.05	30	with #13, 3 nets, two wedding veils ran into bush, see video	48.24.09	85.51.50	south Louie L	Y
150.150	95-15	15-Mar-95	14.14	14.18			14.40	26	in marsh, 2 nets, tangled in tree	48.20.73	85.38.50	NE of Gornupkagama L	Y
150.157	95-16	15-Mar-95	15.39	15.41	15.47	6.0	16.04	25	with 1 M,1 F, driven off ridge onto reverse creek, 2 nets, into trees	48.22.59	85.59.47	upper Reverse Creek	Y
150.259	95-17	15-Mar-95	16.55	16.56	16.58	2.0	17.13	17	1 net, excellent net in marsh, 50cm+ snow	48.28.73	85.47.67	north of Cabin L	N
150.107	95-18	16-Mar-95	9.21	9.21	9.28	7.0	9.44	23	driven out of blowdown onto peninsula of marsh, 2 nets, almost escaped, videoed	48.25.10	86.10.30	NE of Oiseau Bay	Y
150.520	95-19	16-Mar-95	12.56				13.30	34	driven out of leave block onto marsh, 2 nets	48.36.62	85.33.90	S of Animone L (Mobert)	N
150.168	95-20	16-Mar-95	15.48	15.48	15.54	6.0	16.15	27	on open slope south-east of Rein L, 2 nets, 40cm+ snow	48.28.08	85.41.13	east of Rein L	Y
150.178	95-21	16-Mar-95	16.25	16.25	16.31	6.0	16.59	34	with 4 others, 2 driven of ridge (same as #20) onto marsh, 2 nets, smooth	48.28.08	85.41.13	east of Rein L	Y
150.068	95-22	19-Mar-95	11.40	11.41	11.49	8.0	12.10	30	with group of 7, driven up hill, one net, tricky belts due to rock and trees	48.26.01	85.42.95	south of Rein L	Y
150.120	95-23	19-Mar-95	12.35	12.35	12.37	2.0	13.10	35	with #24, driven onto lake, 1 net on ice, very smooth	48.26.60	85.43.01	south of Rein L	Y
150.079	95-24	19-Mar-95	12.35	12.35	12.37	2.0	13.11	36	with #23, driven on lake, netted on lakeshore, 1 net, very smooth	48.26.60	85.43.01	south of Rein L	Y
150.087	95-25	19-Mar-95	13.40	13.41	13.44	3.0	14.01	21	1 net, on marsh edge (ice), frisky animal	48.26.95	85.41.93	south-east of Rein L	Y
150.657	96-1	15-Feb-96								48.07.89	86.01.30	Scapula Lake	Y
150.677	96-2	15-Feb-96								48.06.39	86.01.65	mainland E of Otter Island	Y
150.667	96-3	15-Feb-96								48.01.19	85.49.81	Pukaskwa River	Y
150.611	96-4	16-Feb-96								48.13.70	86.03.56	North Swallow	Y
150.322	96-5	16-Feb-96								48.10.39	86.01.24	Swallow River	Y
150.591	96-6	16-Feb-96								48.09.60	85.05.96	small lake, Cascade River	Y
150.646	96-7	16-Feb-96								48.02.62	85.55.55	Bonamie Cove	Y
150.636	96-8	17-Feb-96								48.02.06	85.55.05	Bonamine Cove	Y
150.312	96-9	17-Feb-96								48.05.91	85.52.21	Tagouche Creek, inland	Y
150.580	96-10	17-Feb-96								48.03.78	85.54.14	inland of Bonamine Cove	Y
150.627	c96-1	17-Feb-96								48.06.00	86.03.00	Otter Island (on lake)	Y
150.619	c96-2	17-Feb-96								48.06.00	86.03.00	Otter island	Y
150.329	c96-3	18-Feb-96								48.06.00	86.03.00	Otter island	Y
150.319	c96-4	18-Feb-96								48.06.00	86.06.00	Otter island	Y
150.685	c96-5	18-Feb-96								48.06.00	86.03.00	Otter island	Y

appendix 1_capture

Collar Frequency	Sex	Age	Ear Tag # Left	Ear Tag # Right	Collar Frequency	BPM normal	BPM Mortality (12hr)	Date of Collar Purchase	Total cc	Red Top	Serum	Lavender Top (EDTA)	Smear	Blue Top	Plasma	Hair	Urine	Faeces	Laquamycin cc	MU-SE cc
150.291	F	A	9535	9535	150.291	71	130	Jan 95	25	Y	N	Y	Y	Y	Y	Y	N	Y	35	6
150.211	F	Y	9527	9527	150.211	71	129	Jan95	25	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.201	F	A	9532	9532	150.201	71	129	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	6
150.241	F	A	9529	9529	150.241	71	129	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.271	F	A	9534	9534	150.271	71	130	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.230	F	A	9531	9531	150.230	72	129	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.281	F	A	9533	9533	150.281	71	131	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.251	F	A	9528	9528	150.251	71	131	Jan95	15	Y	Y	N	N	Y	Y	Y	N	Y	35	5
150.221	F	C	9530	9530	150.221	71	129	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.300	F	A	9537	9537	150.300	71	129	Jan95	15	N	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.191	F	A	9536	9536	150.191	71	130	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	20	5
150.127	F	A	9543	9543	150.127	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.531	F	A	9539	9539	150.531	71	131	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.509	F	A	9538	9538	150.509	76	138	Oct92	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	4
150.150	F	Y	9536	9536	150.150	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	3
150.157	F	A	9547	9547	150.157	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	4
150.259	F	A	9526	9526	150.259	71	131	Jan95	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.107	F	A	9545	9545	150.107	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	4
150.520	F	A	9540	9540	150.520	76	138	Oct92	30	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.168	F	A	9549	9549	150.168	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.178	F	A	9550	9550	150.178	76	n/a	Mar93	0	N	N	N	N	N	N	Y	N	Y	35	5
150.068	F	A	9541	9541	150.068	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	N	35	5
150.120	F	A	9548	9548	150.120	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.079	F	A	9542	9542	150.079	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.087	F	A	9544	9544	150.087	76	n/a	Mar93	35	Y	Y	Y	Y	Y	Y	Y	N	Y	35	5
150.657	F	A	9517	9516	150.657	71	142	Dec-95									N	Y	35	
150.677	F	A	9523	9522	150.677	70	140	Dec-95		Y				Y		Y	N	Y	35	
150.667	F	A	9519	9518	150.667	70	140	Dec-95		Y				Y		Y	N	Y	35	
150.611	F	A	9504	9505	150.611	70	140	Dec-95		Y				Y		Y	N	Y	35	
150.322	F	A	9509	9508	150.322	70	140	Dec-95		Y				Y		Y	N	Y	35	
150.591	F	A	9507	9506	150.591	71	141	Dec-95		Y				Y		Y	N	Y	35	
150.646	F	A	9520	9521	150.646	70	140	Dec-95		Y				Y		Y	N	Y	35	
150.636	F	A	9513	9512	150.636	70	140	Dec-95		Y				Y		Y	N	Y	35	
150.312	F	A	9510	9511	150.312	70	140	Dec-95		Y				Y		Y	N	Y	35	
150.580	F	A	9515	9514	150.580	71	141	Dec-95		Y				Y		Y	N	Y	35	
150.627	F	A	9501	9502	150.627	62	124	Oct-92		Y				Y		Y	N	Y	12	
150.619	M	A		9503	150.619	61	125	Oct-92		Y				Y		Y	N	Y	12	
150.329	M	A	9522	9523	150.329	60	120	Mar-93		Y				Y		Y	N	Y	12	
150.319	F	A	9502	9501	150.319	60	n/a	Mar-93		Y				Y		Y	N	Y	12	
150.685	M	A	9521	9520	150.685	61	n/a	Mar-93		Y				Y		Y	N	Y	12	

Collar Frequency	Neck Circum. (cm)	Ear L	Head L	Shoulder Ht	Foreleg L	1/2 Chest Girth	Chest Girth	Hind Leg	Hind Foot	Tail L	Total L	Comments
150.291	77.5	26.7	81.3	200.7	81.3	102.9	205.7	78.7	27.9	7.6	307.3	agitated, trotted after release
150.211	77.5	29.2	78.7	193.0	61.0	94.0	188.0	78.7	27.9	10.2	262.9	quiet, trotted after release
150.201	73.7	29.2	77.5	188.0	55.9	106.7	213.4	77.5	24.1	8.9	306.1	quiet, trotted after release
150.241	81.3	30.5	80.0	167.6	57.2	91.4	182.9	81.3	25.4	7.0	309.9	
150.271	83.8	30.5	83.8	195.6	58.4	104.1	208.3	80.0	29.2	11.4	320.0	
150.230	73.7	30.5	80.0	195.6	55.9	101.6	203.2	76.2	25.4	10.2	315.0	quiet, trotted after release
150.281	76.2	26.7	78.7	193.0	58.4	105.4	210.8	77.5	25.4	10.2	284.5	very healthy appearance, quiet, hesitated getting up, trotted after release
150.251	88.9	27.9	78.7	188.0	58.4	99.1	198.1	72.4	24.1	8.9	276.9	calf captured at same time(#9), agitated, trotted after release
150.221	57.2	27.9	66.0	148.6	53.3	83.8	167.6	68.6	22.9	11.4	251.5	some ticks, good condition, handled by Jeff
150.300	81.3	27.9	83.8	186.7	55.9	100.3	200.7	78.7	25.4	8.9	313.7	no ticks
150.191	81.3	30.5	81.3	162.6	61.0	91.4	182.9	81.3	22.9	8.9	279.4	difficult handling due to tangle in trees, cut net off, seemed stressed, trotted away
150.127	78.7	30.5	81.3	195.6	54.6	100.3	200.7	78.7	24.1	6.4	289.6	agitated, slow after release, see video, Joe Hammer and Keith present
150.531	78.7	27.9	78.7	182.9	59.7	106.7	213.4	81.3	25.4	7.6	276.9	captured after #14, processed by Stewart, trotted after release
150.509	71.1	30.5	81.3	195.6	58.4	108.0	215.9	78.7	22.9	7.6	297.2	very warm, agitated, some blood from nostril, walked away slowly
150.150	68.6	29.2	73.7	179.1	55.9	97.8	195.6	74.9	25.4	8.9	256.5	smaller animal - 18 mos.?, frisky, smooth handling, trotted away immediately after release
150.157	81.3	30.5	81.3	190.5	57.2	106.7	213.4	78.7	24.1	10.2	315.0	through creek with net, smooth handling, trotted after release
150.259	82.6	30.5	83.8	188.0	82.6	99.1	198.1	76.2	25.4	6.4	307.3	with M calf, smooth handling, trotted after release
150.107	73.7	27.9	83.8	181.6	54.6	96.5	193.0	76.2	25.4	8.9	297.2	entire capture videoed, quiet, ticks present- (see photos)
150.520	77.5	27.9	78.7	193.0	58.4	105.4	210.8	78.7	24.1	8.9	308.6	bare patches, some ticks
150.168	81.3	30.5	81.3	188.0	58.4	101.6	203.2	78.7	26.7	7.6	302.3	healthy animal, good coat, agitated, walked after release
150.178	82.6	30.5	88.9	181.6	57.2	111.8	223.5	80.0	22.9	7.6	317.5	large healthy F, very fat, no blood, nice coat, trotted after release
150.068	83.8	30.5	81.3	200.7	57.2	114.3	228.6	81.3	25.4	7.6	297.2	difficult handling, agitated, walked after release
150.120	76.2	29.2	81.3	195.6	58.4	105.4	210.8	78.7	26.7	7.6	315.0	broke thur upper layer of ice, dragged out by helo, smooth handling by Stewart
150.079	76.2	26.7	77.5	179.1	55.9	106.7	213.4	74.9	24.1	7.6	284.5	smooth handling, quiet, light coat, slow getting up, trotted after up
150.087	71.1	27.9	74.9	181.6	57.2	95.3	190.5	76.2	24.8	7.6	289.6	smaller animal, very frisky, trotted after release
150.657	76.0	25.0	60.0	186.0	55.0	94.0	188.0	156.0	73.0	4.0	270.0	had calf, good condition
150.677	80.0	25.0	77.0	180.0	57.0	110.0	220.0	150.0	75.0	0.4	306.0	good, not ticks
150.667	83.0	24.0	75.0	196.0	66.0	105.0	210.0	160.0	78.0	5.0	282.0	
150.611	81.3	25.4	76.2	185.4	61.0	104.1	208.3	160.0	76.2	5.1	287.0	few ticks, good condition with 2 other cows
150.322	81.3	26.7	73.7	188.0	61.0	101.6	203.2	160.0	78.7	2.5	294.6	good condition, on very small lake
150.591	78.7	24.1	78.7	175.3	55.9	104.1	208.3	160.0	76.2	2.5	299.7	good condition, with female calf
150.646	88.9	22.9	76.2	177.8	58.4	106.7	213.4	154.9	76.2	7.6	289.6	very good - few ticks, with female calf
150.636	81.3	25.4	76.2	182.9	61.0	109.2	218.4	160.0	78.7	7.6	302.3	with six other moose-good condition
150.312	73.7	25.4	76.2	198.1	61.0	106.7	213.4	160.0	83.8	2.5	302.3	twin cow calves with cow
150.580	81.3	25.4	76.2	205.7	61.0	111.8	223.5	160.0	78.7	10.2	299.7	with cow and calf, good condition
150.627	55.9	14.0	40.6	124.5	43.2	66.0	132.1	106.7	58.4	15.2	203.2	
150.619	73.7	15.2	53.3	142.2	43.2	81.3	162.6	119.4	61.0	15.2	238.8	excellent condition
150.329	73.7	15.2	55.9	137.2	45.7	71.1	142.2	124.5	63.5	15.2	238.8	good condition, no tick, healthy fat
150.319	55.9	14.0	43.2	127.0	43.2	71.1	142.2	114.3	58.4	12.7	205.7	good condition, had calf with orange tags
150.685	76.2	15.2	53.3	134.6	45.7	69.9	139.7	121.9	63.5	14.0	236.2	healthy

Appendix 2: Raw data results of the blood analysis for the captured moose in 1995 and 1996 in the Greater Pukaskwa Ecosystem, Ontario.

appendix2_blood

	BioChemistry																																Hematology (with LKC & ERC)										Hematology - LKC Differential									
moose/caribou number	calcium mmol/L	phosphorus mmol/L	magnesium mmol/L	sodium mmol/L	potassium mmol/L	chloride mmol/L	carbon dioxide mmol/L	anion gap mmol/L	total protein g/L	albumin g/L	globulins g/L	A:G ratio	urea mmol/L	creatinine umol/L	glucose mmol/L	cholesterol mmol/L	total bilirubin umol/L	conj. Bilirubin umol/L	free bilirubin umol/L	alk phos U/L	ggt U/L	ast U/L	ck U/L	ld U/L	gdh U/L	b-hba UMOL/L	na/k ratio	calculated osmo mmol/L	fibrinogen	cortisol	T-4	P4	N-cells	Erco	Hgb	Hct	MCV	MCH	MCHC	RDW	PLTS	MPV	Segs-1	Segs-2	Lymphocytes-1	Lymphocytes-2	Monocytes-1	Monocytes-2	Eosinophile-1	Eosinophile-2	Basophile-1	Basophile-2
150 068	1.94	1.67	0.65	157	5 6	78	4	81	70	41	29	1.41	1.8	188	8.7	2.47	1	1	0	422	11	100	1875	233	3	729	28	313		66	42																					
150 079	2.38	1.72	1.02	145	7.0	97	10	45	78	46	32	1.44	2.2	230	9 0	2.42	1	0	1	104	34	157	307	349	12	498	21	294		139	61																					
150.087	2.65	2.47	1.19	149	7.5	103	5	49	89	48	41	1.17	2.5	228	10.2	2.97	0	0	0	792	22	119	261	327	5	647	20	304	3.4	92	49																					
150.107	2.26	2.82	0.88	125	21.2	98	10	38	72	41	31	1.32	1	207	8.1	2.32	8	2	6	527	24	114	492	293	8	1494	6	281	1.9	128	25																					
150.120	2.40	1.56	1.03	143	6.7	98	8	44	80	46	34	1.35	3.3	229	9.5	2.22	0	0	0	149	14	117	459	263	9	968	21	291	4.4	107	64																					
150.127	2.39	2.22	1.09	148	5.6	101	9	44	87	44	43	1.02	2.4	198	8.8	3.39	1	1	0	305	99	145	134	184	32	684	26	297	2.7	52	40																					
150.150	2.68	1.81	1.00	123	23.0	95	7	44	87	48	39	1.23	1.6	239	9.6	2.06	2	2	0	63	18	89	312	250	3	1265	5	283	2.2	114	50																					
150.157	2.42	2.75	1.07	138	14.2	98	11	43	82	35	47	0.74	1.8	230	7.3	2.74	1	1	0	596	15	94	329	245	6	709	10	292	4.7	89	24																					
150.168	2.02	1.36	1.01	154	7.8	79	6	77	71	39	32	1.22	1.6	173	7.7	2.82	1	1	0	88	15	74	194	165	5	502	20	310		83	43																					
150.178																																																				
150.191	2.08	2.22	0.88	131	18.9	95	3	52	78	45	33	1.36	3.2	231	8.0	2.13	1	1	0	1038	15	114	617	307	5	768	7	293	2.9	123	61																					
150.201	3.00	2.25	1.30	134	24.3	99	4	55	89	46	43	1.07	3.5	247	9.4	2.88	1	1	0	982	22	98	254	265	7	851	6	307	4.0	69	51																					
150.211	2.41	2.06	1.09	126	16.0	98	10	34	78	39	39	1.00	2.1	197	10.0	2.20	1	0	1	868	21	120	436	410	4	655	8	276	3.0	169	44																					
150.221	2.57	2.48	1.15	143	10.0	98	7	48	77	44	33	1.33	2.6	162	9.5	2.47	1	0	1	867	24	100	368	444	2	739	14	297	2.8	143	38																					
150.230	2.51	2.68	1.09	145	9.1	100	7	47	81	45	36	1.25	2.8	202	7.7	2.29	1	1	0	1302	19	95	257	272	3	769	16	297	2.9	97	45																					
150.241	2.64	2.13	1.29	147	9.7	100	6	51	85	48	37	1.30	2.5	212	7.9	2.25	1	1	0	116	17	112	182	258	6	951	15	302	4.1	70	74																					
150.251	2.42	1.71	1.11	139	8.3	97	5	45	81	46	35	1.31	4.2	178	7.9	2.82	2	2	0	567	17	114	330	308	8	1077	17	286		97	48																					
150.259	2.50	2.60	1.13	118	27.8	101	7	38	85	47	38	1.24	3.5	205	9.9	2.58	0	0	0	701	22	109	184	224	7	1027	4	285	3.7	67	49																					
150.271	2.86	2.05	1.41	152	9.1	103	5	53	100	52	48	1.08	1.8	264	9.0	3.07	1	1	0	1462	37	113	195	213	9	738	17	310	4 5	33	51																					
150.281	2.43	2.20	1.15	142	9.6	99	4	49	84	47	37	1.27	2.4	220	9.3	2.49	0	0	0	462	17	80	212	242	1	825	15	293	3.4	74	61																					
150 291																																																				
150.300	2.61	1.92	1.10	131	17.9	96	8	45	78	46	32	1.44	2.1	217	8.2	1.94	1	1	0	80	19	121	974	311	5	1168	7	287		92	53																					
150.509	2.53	2.35	1.08	157	5.6	112	5	46	98	39	59	0.66	1.6	206	6.7	2.93	1	1	0	729	18	104	597	222	1	813	28	311	4.9	68	31																					
150.520	2.16	2.19	0.85	133	16.9	96	7	47	84	47	37	1.27	2.5	193	11.7	2.05	0	0	0	781	11	85	273	273	5	774	8	293	4.7	168	58																					
150.531	2.63	1.86	1.08	147	4.9	98	5	49	85	47	38	1.24	1.7	226	9.1	3.06	1	1	0	761	32	110	224	198	9	692	30	293	3.5	57	51																					
150.312	2.68	1.82	1.82	147	5.7	94	11	48	88	40	48	0.83	0.8	179	8.1	1.88	5	3	2	274	17	78	218	279	3	884	26	293	3.6	52	32	<1.6	4.0	7.76	188	0.521	67.1	24.2	361	18.6			0.39	1.60	0.54	2.20	0.02	0.08	0.06	0.2		
150.322	2.79	2.39	1.48	152	4.7	98	8	53	73	42	31	1.35	3.6	224	7.9	2.45	4	0	4	142	22	109	204	213	3	540	32	303	4.2	63	34	26.0	4.4	8.29	203	0.580	70.0	24.5	350	16.4	73	7.9	0.36	1.60	0.63	2.80			0.01	0.04		
150.580	2.50	1.39	1.46	142	4.6	90	15	42	80	43	37	1.16	3.3	198	5.3	2.06	10	4	6	68	18	197	696	460	0	870	31	281	3.5	129	38	25.0	4.7	6.55	184	0.327	49.9	28.1	563	36.6			0.56	2.60	0.36	1.70	0.06	0.28	0.01	0.05	0.01	0.05
150.591	2.58	2.17	1.47	147	4.1	94	7	50	78	41	37	1.11	3.2	217	8.3	1.87	5	3	2	417	19	143	353	368	4	499	36	293	2.7	80	38	<1.6	4.3	7.63	181	0.523	68.8	23.1	346	18.2	84	7.4	0.37	1.60	0.61	2.60			0.02	0.09		
150 611	3.00	2.14	1.71	151	5.7	91	7	59	84	47	37	1.27	1.1	221	9.3	2.22	5	0	5	641	18	105	214	272	0	701	26	302	4 8	71	53	29.0	6.3	7.92	198	0.563	71.1	25.0	352	17.8	Big dump		0.24	1.50	0.71	4.50			0.03	0.19	0.02	0.13
150.636	2.62	1.93	1.48	147	5.7	91	6	56	81	42	39	1.08	2.2	203	8.5	2.41	2	0	2	558	19	139	419	248	0	703	26	295	5.5	88	32	25.0	6.8	7.91	197	0.552	69.8	24.9	357	17.8			0.31	2.10	0.61	4.20	0.03	0.2	0.05	0.34		
150.848	2.78	1.88	1.57	151	4.8	89	8	59	87	45	42	1.07	1.9	203	10.6	2.34	2	0	2	93	30	106	272	294	4	843	31	302	4.5	109	24	24.0	7.1	8.24	209	0.586	71.1	25.4	357	18.3	68	8.1	0.23	1.70	0.67	4.80	0.04	0.28	0.05	0.36	0.01	0.07
150.657	2.65	2.18	1.42	159	6.3	106	7	51	97	45	52	0.87	3.1	207	9.3	2.12	6	0	6	494	16	340	988	784	4	818	30	318	4.6	89	36	14.0	7.6	8.18	197	0.542	66.3	24.1	363	21.3			0.24	1.80	0.73	5.60	0.01	0.08	0.01	0.08		
150.667	2.91	1.77	1.46	162	5.2	105	10	52	85	44	41	1.07	2.8	235	9.1	2.22	4	0	4	727	24	114	270	370	4	581	31	323	4.9	106	57	19.3	7.8	7.98	200	0.544	68.3	25.1	368	18.9			0.3	2.48	0.55	4.30	0.06	0.47	0.09	0.7		
150.677	2 80	1.87	1.37	151	5.1	98	7	51	88	41	47	0.87	2.9	244	10.9	2 39	2	1	1	117	18	152	358	365	4	723	30	304	4.3	89	39	17.9	8.1	7.29	185	0.510	69.9	25.4	363	20.4	141	6.2	0.35	2.90	0.51	4.10	0.06	0.49	0.08	0.65		
Caribou																																																				
150 319	2 37	1.72	1.49	148	5.4	97	5	51	69	42	27	1.56	4.2	273	7.8	1.70	26	3	23	120	14	90	280	268	1	1432	27	297	4.5	140	168	12.0	3.6	11.56	198	0.544	47.3	17.2	363	15.3	190	6.5	0.49	1.80	0.41	1.50	0.02	0.07	0.06	0 22	0.02	0.07
150 329	2.33	1 43	1.34	148	5.9	97	9	48	72	37	35	1.06	4.7	275	7.1	1.51	19	4	15	132	27	89	720	331	3	1331	25	298	3.6	113	168	<1.6	4.6	13.82	212	0.576	42.9	15.3	368	14.8	282	4.9	0.4	1.90	0.49	2.30			0.09	0.41	0.02	0.09
150 619	2.12	1.45	1.28	143	4.7	96	8	44	73	32	41	0.78	5	267	6.2	1.52	26	5	21	190	24	75	822	268	2	1058	30	286	4 4	123	146	.1.6	4 3	11.46	200	0.530	44.0	17.5	377	15.1	121	6.3	0.4	1.70	0.49	2.10	0.06	0.26	0.04	0.17	0.01	0.04
150.627	2.31	1.53	1.37	148	3.9	97	7	48	67	42	25	1.68	5.6	273	8.1	1.46	39	9	30	142	22	89	495	301	4	1268	37	293	2.9	109	248	8.0	4 5	9.46	203	0.395	41.8	21.5	513	28.2			0.27	1.20	0.68	3.10	0.02	0.09	0.02	0.09	0.01	0.05
150.685	2.41	1.67	1.35	151	4.5	94	4	58	67	42	25	1.68	5 2	304	9 5	1.61	28	6	22	130	16	82	424	271	1	1259	34	304	2 3	181	212	<1.6	2.9	12 28	209	0.580	47.2	17.0	360	15.0	237	5 9	0.3	0.87	0.58	1.70	0.04	0.12	0.06	0.17	0.02	0.08

					Hematology - ERC Morphology			Hematology SI						Diluted Hematology SI						
moose/caribou number	Rubricytes-1	Rubricytes-2	Shift platelets	PLTS. EST	Anisocytosis	Crenation	Poikilocytosis	LKCS	ERCS	HB	Hct	MCV	PLT	Diluted LKCS	Diluted ERCS	Diluted HB	Diluted Hct	Diluted Hct 2	Diluted MCV	Diluted PLT
150.068																				
150.079																				
150.087																				
150.107																				
150.120																				
150.127																				
150.150																				
150.157																				
150.168																				
150.178																				
150.191																				
150.201																				
150.211																				
150.221																				
150.230																				
150.241																				
150.251																				
150.259																				
150.271																				
150.281																				
150.291																				
150.300																				
150.509																				
150.520																				
150.531																				
150.312			Neg			1+		5.5	7.82	190.0	0.534	68.3	245R3	2.5	3.72	90.0	0.253	0.506	68.1	103RM
150.322			Neg		1+	1+		6.6	8.40	204.0	0.579	68.9	173	2.8	4.03	97.0	0.276	0.552	68.5	74
150.580			Neg		2+		1+	8.6	7.56	185.0	0.522	69.0	49RM	3.8	3.67	88.0	0.250	0.500	68.1	49R3
150.591			Neg			2+		8.3	7.87	183.0	0.528	67.2	155R1	3.0	3.84	87.0	0.255	0.510	66.4	74RM
150.611			Neg					6.8	8.24	203.0	0.594	72.0	201R3	3.0	3.96	96.0	0.281		71.0	65
150.636					1+			10.7	7.91	201.0	0.555	70.1	45RM	6.0	3.77	92.0	0.261	0.522	69.4	20RM
150.646			Neg		1+			8.5	8.33	210.0	0.604	72.8	186	3.3	4.04	100.0	0.290	0.580	71.8	81
150.657	0.01	0.08	Neg	Normal	1+		1+	7.6	8.33	192.0	0.565	67.9	195	3.6	4.17	96.0	0.279	0.558	67.0	92RM
150.667			Neg		1+			7.1	8.14	198.0	0.565	69.5	174R3	3.1	4.06	97.0	0.280	0.560		86R1
150.677			Neg		1+			7.2	7.51	183.0	0.535	71.3	258R1	3.4	3.63	89.0	0.256	0.576	70.9	109R1
Caribou																				
150.319			Neg		2+			3.6	11.16	198.0	0.563	50.5	493RM	1.8	5.56	97.0	0.272	49.000	0.5	219RM
150.329			Neg			2+		4.5	12.24	211.0	0.575	4.0	1268	2.0	6.17	101.0	0.274	0.548	44.5	687RM
150.619			Neg		2+	1+		4.9	11.29	196.0	0.533	47.3	1011	2.3	5.86	96.0	0.266	0.532	45.4	511RM
150.627						3+		4.6	11.67	204.0	0.557	47.7	619RM	1.9	5.65	93.0	0.257	0.574	45.6	306RM
150.685			Neg		1+	2+		3.1	11.76	209.0	0.583	49.6	416	1.3	5.67	97.0	0.273	0.546	48.1	200RM

Appendix 3: Telemetry data sheet used in this study.

Bio-Telemetry Data Record
Pukaskwa National Park

Circle choice where appropriate, *areas **MUST** be recorded.

1. **Species:** wolf moose caribou	2. **Animal Name:** __________________	***3.Frequency**: 15___.________
***4. Observer** Frank Anne Keith Gray Other ________________	***5.Date** dd/mm/yy __________________	Affiliation pack name dispersing unk. coastal inland cutovers
6. Time of Search Start _____ : _____ hrs	***7. Time of Location** ____: ______hrs	**8.Total Time** (#7 minus#6) ________ minutes
9.Topography: 1.Flat 2.Rolling 3.Hilly 4.Rugged 5.Wetland/lake/river 6. On Lake/River Ice	**10.Vegetation Overstory:** 1.Conifer >75% 2. Decid >75% 3.Mixed 50/50 4.Cut over 5.Wetland/lake/river 6. Other_____________	**11.Crown Closure:** 1.>75% 2.51-75% 3.25-50% 4.<25% 5. Not Applicable
12.Proximity to cut over: 1.<200m 2.200-1000m 3.>1000m	***13. Obtained by:** 1.Aerial 2.Railkill 3.Ground 4.Trap/Hunt kill 5.Capture 6. Report 7.Roadkill 8.Other 9. tracking	**14.Activity** 1. Standing 5. Unknown 2. Bedded 6. Hunting 3. Moving 7. On kill –ungulate 4. Feeding 8. On kill – other (aquatics,cliff) 9. other________ 10. dead
15.Aggregation Size # or 99 for unk ________	**16.Photo:** 1. Yes 2. No	**17. Visual:** 1. Yes 2. No
***18.Lat** deg/dec min 48°__ __.__ __'	***19. Long** deg/dec min 8__°__ __.__ __'	***20. Confidence** 1.accurate <100m 2.reasonable <250m 3.questionable <450m 4. No Fix 5. mortality check
21. General Location (ie. lake/road name, major features - wetland, ridge)		
22. UTM E ie. 614000 __ __ __ __ __ __	**23. UTM N** ie. 5372000 __ __ __ __ __ __ __	**231. No. Of Calves Seen** 1.One 2. Two 3. Zero 4. Unkn.
24. Lat dec deg 48°.__ __ __ __	**25.Long** dec deg 85°.__ __ __ __	
26. Comments (if ground triangulation, record the following:) Time Station # Bearing Angle of Intersection Time from 1st to last bearing		
Databased By:	**Date:**	

Obs_card.doc Nov9/98

Appendix 4: Metadata information for data relating to this research and the P5 study.

P5 Metadata

Name	**Description**	**Status as September 1999**
p5_telem.mdb	telemetry - moose, wolf, caribou (also includes capture locs, mortality locs and non-collared wolves obs. Some duplication with wolf cap)	N=6226, last record June 4/99 Complete to date
p5_testcol.xls	test collar data - differentially corrected locations and estimated for Frank, Barry, Cam, Keith, Anne and Graham	N=102 complete
p5_wolf_cap.xls	all wolf capture, mortality and necropsy data (capture and mortalities have separate records therefore some wolves have >1 records)	N=75 complete to date, add necropsy results and new morts when available
p5_scat.xls	wolf scat data	N=393 (309 are Krizan's which are questionable quality) complete
p5_moose.xls	**capture** - collared moose (n=35) & caribou (n=5) capture data	Complete
	blood - collared moose/caribou blood analysis (from OVC, Guelph)	Complete
	carcass – all moose & caribou kill info (ID, location, marrow, morpho, jaw, age, chase etc)	N=92 complete to date, add new morts when available
	urine - spring 97 moose samples (no analysis)	Complete
	collars – deployed collar freq.	Complete
	msurvey - moose surveys (#per block, geo ref.) n=505 PNP: 99, 96,93,90,86 WMU 33: 97,94,91,88,84	Complete
p5_moohab.xls	moose browse from FRI/FEC plots n=130	Complete

p5_flights.xls	Fixed wing telemetry flights - dates and hours	n=350 (1219 hrs) complete
mooharvest.xls	from Al Bisset (MNR) hunter moose harvest 73-95 & 97 - #tags, age/sex etc.	need '96, confirm details of data format and quality
mnr_msurvey.xls	from Al Bisset (MNR) **survey data** – density/total # per WMU for entire province – 1975-1997/98	complete
p5_furharvest.xls	trapline harvests from OMNR by species and trapline trapline boundaries (polygons)	complete polygons being QC'ed by Lynn
human_use.xls	camis (backcountry) results 96,97,98 points of human features (n=647)	complete
Wolf	blood/disease data	blood sent to OVC 11/98
snow depth/transect	Graham's data snow station's at Hattie Cove	get digital copy
genetics	moose, caribou and wolf (still need to focus questions and collab.)	wolf sent to Wilson (12/98) will be forwarding summery to date
Slideindex.xls	Typical P5 photos High resolution scans (Kodak Pro CD)	Anne 18 slides Frank 40 slides Gray 28 slides
Caribou.xls	Historical caribou locations from OMNR, NE region	Not complete, should get Wawa's as well