Testing and Evaluation of a Technique to Estimate Moose Habitat Use in West-Central Alberta

By:

Jason R. Kerr

A Practicum
Submitted to the Faculty of Graduate Studies in
Partial Fulfilment of the Requirements
for the Degree

MASTER OF NATURAL RESOURCES MANAGEMENT

Natural Resources Institute
The University of Manitoba
Winnipeg, Manitoba

0-612-45070-8

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FACULTY OF GRADUATE STUDIES
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ABSTRACT: This project was designed to test and evaluate a technique to estimate moose (*Alces alces*) habitat use in west-central Alberta, Canada. Home range size and habitat use of adult female moose were estimated for portions of a Wildlife Management Unit in west-central Alberta. Nineteen radio collared adult female moose were relocated from January through March 1997. Mean distance travelled between daily relocations was 1.51 $\pm$ 0.04 SE km, and the mean home range size was 68.77 $\pm$ 5.38 SE km^2. Moose were found to prefer areas classified as browse, wet areas and 25 - 29.99 m tall forest stands. Statistical and trended analysis indicated that moose preferred areas classified as browse, wet areas, low to medium % canopy closure, and tall trees when selecting winter habitat.

ACKNOWLEDGEMENTS

A project of this nature involves the co-operation of numerous individuals and organisations. From a financial standpoint, this project would not have been feasible were it not for the support of several sources. The Government of Alberta provided the initial project funding. The Natural Sciences and Engineering Research Council of Canada (NSERC), Weldwood of Canada Limited - Hinton Division, Sundance Forest Industries - Edson, and Weyerhaeuser Canada Limited - Edson, deserve high marks for participating in the NSERC industrial fellowship. The Alberta Sport, Parks, Recreation and Wildlife Foundation and NOVA Gas Transmission Limited also independently provided significant financial contributions to this project. In addition to furnishing lodging at their ranch west of Edson, Howard and Judy Bugg provided stimulating conversation on integrated resource management from the private landowners perspective. A special debt of gratitude goes to my father Gordon and mother Marilyn for lending the assistance of KERR & Associates for work force resources and for providing moral and financial support.

I am grateful to the Alberta Natural Resources Service and Weldwood of Canada Limited, Hinton Division, for contributing the necessary survey equipment to conduct this study.

I am indebted to Dr. R. Baydack, Dr. R. Stiehl, Dr. N. Kenkel, Mr. R. Bonar, and Mr. K. Smith for their assistance in planning this investigation.

Mr. S. Barry of the Canadian Wildlife Service, Edmonton, and Dr. N. Kenkel of the university of Manitoba, Botany Department assisted with statistical queries. Mr. M. Gartrell of the Canadian Forest Service, Edmonton, provided invaluable GIS assistance.

I would like to thank Dr. Richard Baydack of the Natural Resources Institute for reviewing manuscript drafts, and having both faith in my abilities and patience.

My wife Shauna, and children Daniel and Madison deserve a special thank you for being patient, supportive, and a driving force behind the completion of this project.

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1.0 ORGANIZATION OF STUDY

This Practicum is presented in 4 chapters. Chapter 1 provides an introduction, states study objectives, and outlines how resource selection analysis, statistical analysis, spatial analysis, and habitat modelling can be used to assist managers in problem resolution. Chapter 2 is a literature review of information regarding moose (*Alces alces*) habitat use, and a summary of moose management principles and prescriptions employed in the study area over the past 8 years. Chapter 3 is prepared as a journal article analysing moose habitat preference in the style of the Journal of Wildlife Management. Chapter 4 provides conclusions and management implications.

1.1 INTRODUCTION

The forests of Alberta provide many benefits to society. These benefits are often compounded by competing economic and social values (Gray 1994). Co-operative planning and management provides for accommodation of competing values and possible provision of sustainable management (Berkes 1989). Integrated well defined planning between forest and wildlife managers offers a viable approach for maintaining or enhancing wildlife habitat quality and quantity within managed forest ecosystems (Eastman and Ritcey 1987, McNicol and Gilbert 1987). However, effective management of forest ecosystems for the purpose of improving wildlife habitat is often limited by incomplete data or by information not organised in ways to justify modification of silvicultural techniques (Ellis 1986). For managers to effectively accommodate moose (*Alces alces*) habitat requirements in managed forest areas, the quantification of optimal size, shape, and spatial arrangement of habitat is needed. Little empirical research has been undertaken to quantify these needs for moose (Allen et al. 1987, 1991).

In 1993, moose populations in portions of northern Alberta were below historic levels, causing First Nation and licensed hunters alike to experience decreased harvest success (Alberta Natural Resources Service 1998a, 1998b). It appeared there were insufficient moose to meet public demand, with the general opinion within the hunting community that the decreased harvest per unit effort was directly related to population decline (Alberta Natural Resources Service 1998a). The question before managers within the Natural Resources Service (NRS) was to determine if there was a population decline, and if so, why?

In an effort to determine moose population status, the Northern Moose Management Program (NMMP) was initiated in 1993 to investigate causal factors for perceived decline. The following factors were considered: disease, predation, over-winter mortality, over harvesting, loss of primary winter habitat, and land use practices. General information and experience of managers provided no indication of any prevalent disease and no notable increase in predator populations. Though bull to cow ratios were below desirable levels in many areas, over harvesting was not considered to be problematic. Severe weather had not been common or persistent. Affecting the quality and quantity of habitat available to moose during the critical winter months, land use was seen as a potential causal factor by many area biologists (H. Carr, Alberta Environmental Protection, personal communication). To effectively manage a wildlife population, resource managers should consider a mixture of population and habitat assessment data to support management decisions to offset all of the above influences on the moose population (Wildlife Working Group 1991).

Of the 2 phases of the NMMP, phase 1 was an extensive inventory of northern Alberta to enumerate moose population density with 90% confidence. In phase 2, cow moose were radio collared in 4 Wildlife Management Units (WMU), including WMU 346 north of Edson in west-central Alberta (Figure 1.1). This radio collared sample, in conjunction with the digitized geographic inventory (Alberta Vegetation Index (AVI)), provided the opportunity to collect habitat specific data. This data could then be used to create a habitat supply analysis using the principles of Habitat Suitability Index (HSI) modelling. When applied on a landscape level, this process facilitated the assessment of generalist species spatial habitat requirements (Clark et al. 1993, Donovan et al. 1987). Statistical models, being inductive and empirical, offer the potential to minimise validation problems when tested against real habitat use data (Schamberger and O'Neal 1986, Pereira and Itami 1991), and is the approach selected for this study.

For relatively large, mobile animals, radiotelemetry is a technique commonly used to monitor movements of individuals (White and Garrott 1990, Clark et al. 1993a, 1993b). Contemporary computer-based Geographic Information System (GIS) technology is a relatively new tool for the resource manager with promise for wildlife management (Donovan et al. 1987). When radiotelemetry is combined with GIS, the potential to determine habitat preferences of an animal may be greatly increased (Davis et al. 1990).

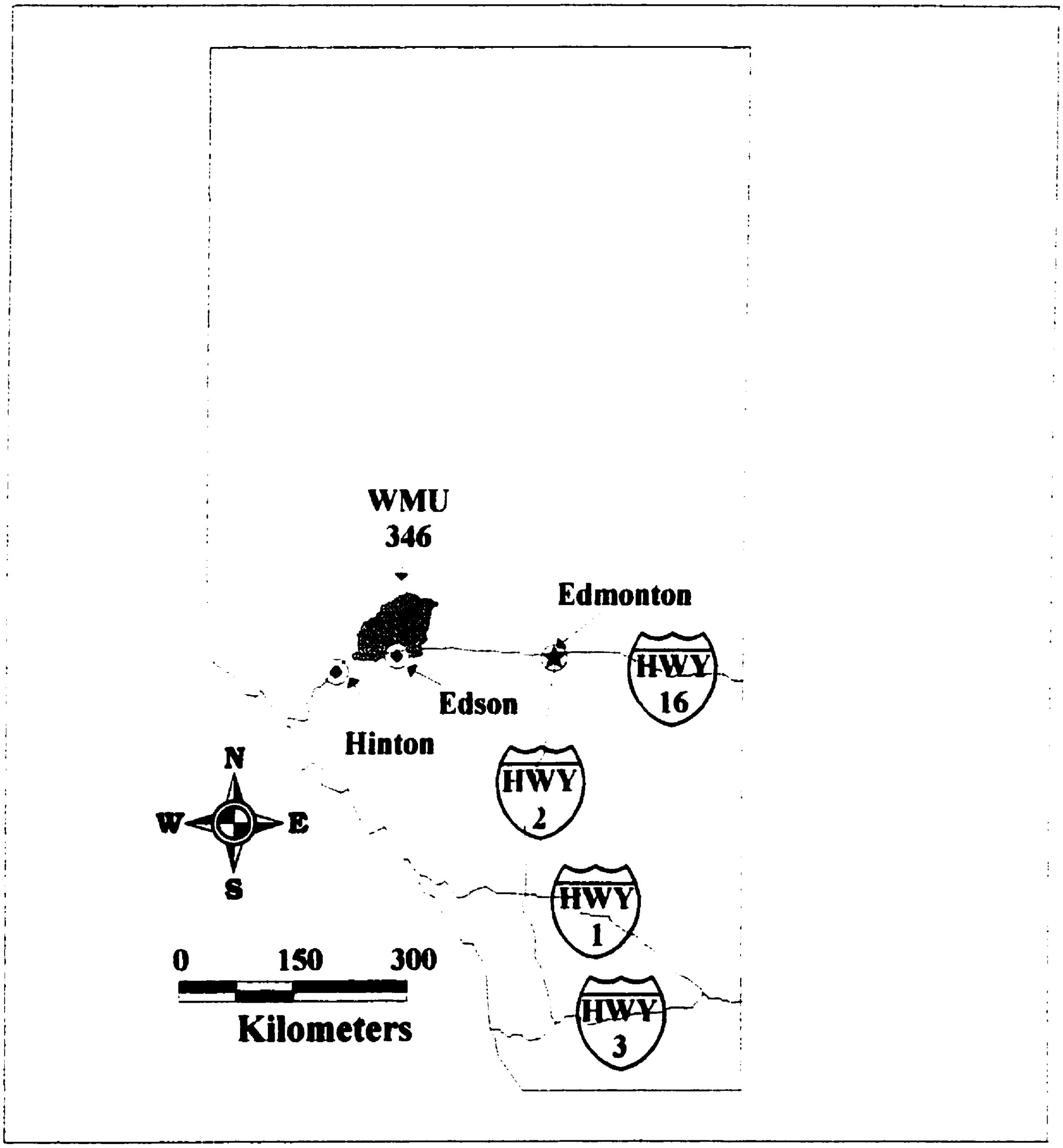

Figure 1.1: Location of WMU 346 north of Edson in west-central Alberta.

To conduct a radiotelemetry study, animals are captured and fitted with a radio transmitter tuned to a specific frequency. When the animal is released, it can then be relocated with use of a radio receiver and directional antennae. Triangulation of the animal's position may be obtained if each relocation occurs from a minimum of 3 different geographical positions to create a relocation site. For the purpose of determining an animal's habitat preference, each capture site can be visited and habitat characteristics measured. This, however, can be an extremely expensive undertaking in terms of both time and financial burden, especially if the animal is wide ranging and/or a large number of relocation sites were recorded. With the advent of GIS technology, it is possible to conduct habitat analyses of an animal's relocation sites using existing digitised data sets (Clark et al. 1993a, 1993b), including the Alberta Vegetation Inventory (AVI).

A GIS can be used to perform simple cartographic procedures. However, the true power of GIS lies in the ability to perform complex spatial queries through analysis of digital landscape information. Digital data used in a habitat preference study may be created by the research team or obtained from external sources. Digital data may include basic geo-referenced information on the location of roads, railways, transmission and seismic lines, as well as the location of lakes, streams and rivers. Other data available may include landform information such as vegetative composition (and various attributes therein) and elevation. From the elevation information, data can be manipulated to create other useful information.

Contemporary forest use both consumptive and non-consumptive, has the potential to either increase or decrease habitat quality and/or quantity for moose. In Alberta, hunters were concerned that the increased effort required to harvest moose was an indicator of population decline. As a result, there was a call for information identifying the status of the population. The requirement for this information occurred at a time when advanced technology could be used to more accurately census the population and determine life requisites. The following document is a report of information collected on radio relocated cow moose in west-central Alberta during the winter of 1997. Using a sample of previously radio collared moose, relocation sites and AVI data were used to determine winter habitat preference, and provide the basis for the creation of a habitat supply analysis. Given specific population goals, habitat modelling may ultimately be used by resource managers to predict moose population potential under differing land management scenarios.

1.2 PROBLEM STATEMENT

The moose population in west-central Alberta has not responded to management prescription. Moose habitat selection has not been empirically determined for this area. A tested and verified HSI model has not been defined for the region. The AVI data has not been tested to determine its utility for estimating moose habitat preference. Given the absence of data, resource managers are unable to develop a comprehensive moose management plan to consider habitat change resulting from land use practice and natural change.

1.3 RESEARCH OBJECTIVES

1. To identify and quantify moose habitat use during winter by comparing telemetry data with AVI data.
2. To assess the utility of using AVI data for determination of moose habitat use.
3. To recommend management options to improve moose habitat assessments and management.

1.4 RESOURCE SELECTION & ANALYSIS

1.4.1 Resource Selection

When attempting to measure the extent to which animal populations are selective in their choice of habitat, wildlife managers are presented with a number of options for analysis, particularly in relation to habitat availability (Johnson 1980, 1981, White and Garrott 1990, Manly et al. 1993). One approach is based on the concept of a resource selection function; a function of habitat characteristics measured on resource units such that the value for a unit is proportional to the probability of that unit being used. Manly et al. (1993) suggest this approach can be used when resources can be categorized as either used or unused by an animal, and where every unit can be characterized by the values that it possesses for certain variables. Digital data within a GIS can be used to identify spatial habitat variables required for resource selection studies (Clark et al. 1993, Donovan et al. 1987). Manly et al. (1993) argue that this concept leads to a unified theory for the analysis of resource selection, and can replace many ad hoc statistical methods that have been used in the past.

It is often assumed that a species will select resources that are best able to satisfy its life requirements, and that high quality resources will be selected more than low quality ones. When resources are used disproportionately to their availability, use is said to be selective (Johnson 1980). Manly et al. (1993) follow Johnson (1980) in providing the following definitions:

Resource Use-- is that quantity of the resource utilized by the animal (or population of animals) in a fixed period of time.

Resource Availability-- is the quantity of resource accessible to the animal (or the population of animals) during the same period of time.

Additionally, they distinguish between availability and abundance by defining the latter as the quantity of the resource in the environment. They also suggest that selection and preference are often used as synonyms in the literature, and define them as follows:

Selection-- is the process in which an animal chooses a resource,

Preference-- is the likelihood that a resource will be selected if offered on an equal basis with others.

Resource selection occurs in a hierarchical fashion based on scale: from the geographic range of the species, to individual home ranges, to the use of general features or habitats within a home range, down to the selection of particular elements or features within (Johnson 1980).

When the decision is made to estimate an animal's resource selection, the next 2 steps are to determine the appropriate scale and scope of the study. The scale and scope of the study must reflect animal biology, but may be influenced by other factors including management needs or data and resource availability. These decisions may be subjective, can have significant impacts on the project outcome, and may be difficult for the research team (Manly et *al.* 1993, Stiehl, 1995). Thomas and Taylor (1990) provide three designs for evaluating selection:

1. *Design I*– Protocol is such that measurements are made at the population level and used, unused, and available resources are censused or sampled for the entire study area as well as for all the study animals within that area. Individual animals are not identified under this protocol.
2. *Design II*– Availability is measured at the population level and the use of resources is measured for each identified animal.
3. *Design III*– Individuals are identified and at least two of either used, unused, or available resource units are censused or sampled for each animal.

Both Designs II and III identify individual animals, which in turn permits reference to the population and estimates of variability of these estimates as long as the animals identified are a random sample from that population (Manly et al. 1993). This approach, called first and second stage analysis by Cox and Hinkley (1974), has been recommended for analysis of resource selection data by White and Garrott (1990). Manly et al. (1993) further suggest that the advantages of this approach are 3 fold:

1. The observations on any one animal may be time-dependent. For example, the independence of several radio locations depends on the time between these relocations and the animal's behavioural pattern. Therefore, as a general rule it is better to estimate sampling variances and test hypotheses using variation between animals rather than the variation between observations on one animal.
2. It allows estimation techniques that are applicable at the population level.
3. The variation among individuals may be examined to determine, for example, whether sex or age differences in habitat use between animals occur, and to identify animals that are unusual with respect to their selectivity.

As with the differing designs available to the researcher, there are also differing sampling protocols to be followed depending on the design selected. Manly et al. (1993) provide the following sampling protocols:

Sampling Protocol A– Available resource units are either randomly sampled or censused, and a random sample of used resource units taken.

Sampling Protocol B-- Available resource units are randomly sampled or censused and a random sample of unused resource units taken.

Sampling Protocol C-- Unused resource units and used resource units are both independently sampled.

In addition to the various levels of study, habitat selection may be among various discrete habitat categories (i.e. open field, forest, muskeg) or among a continuous array of habitat attributes such as shrub density, percentage cover, distance to water, canopy height, etc.

Resource selection studies involve comparison between samples or censuses of used, unused, and available resource units. Therefore, at an early stage, the analysis of data should involve the comparison of the distributions of x variables for the samples being compared. This will provide an indication of the differences, if any, and highlight any unusual aspects of the distributions. Table 1.1 identifies a number of tests that may be performed on either categorical or continuous data to determine if resources are selectively used and to compare the strength of selectivity. Aldredge and Ratti (1986, 1992) compared the Neu et al. (1974), Johnson (1980), Friedman (1937), and Quade (1979) tests, and concluded that no test was better than the other for both type I and type II error rates. Univariate tests can be carried out on several variables simultaneously, including X^2 tests to compare samples in terms of the proportions of units in different categories (Neu et al 1974, Manly et al. 1993).

1.4.2 Statistical Analysis

When considering resource selection, the question of interest is whether the differing habitat types in an area are used proportionally to availability. The 1974 study by Neu et al. demonstrated the utility of X^2 for testing the hypothesis that animals randomly select habitat in proportion to its availability and for comparing proportions of used and unused habitat categories (Manly et al. 1993, White and Garrott 1990). If the test is significant, simultaneous Bonferroni confidence intervals may be computed by comparing proportions of used resources of different types to corresponding availability (Neu et al 1974, Byers et al. 1984, White & Garrott 1990, Manly et al. 1993).

Table 1.1: Statistical tests to determine resource selection. From Manly et al. (1993).

Statistical Test	**Example References**
Categorical Data	
Chi-square goodness-of-fit test*	Neu et al. (1974), Byers et al. (1984)
Johnson's prefer method*	Johnson (1980)
Friedman's test*	Pietz and tester (1982, 1983)
Chi-square test of homogeneity	Marcum and Loftsgaarden (1980)
Quade's test*	Alldredge and Ratti (1986, 1992)
Log-linear models	Heisey (1985)
Wilcoxon's signed rank test	Kohler and Ney (1982), Talent et al. (1982)
Continuous Data	
Kolmogorov-Smirnov two-sample test	Raley and Anderson (1990), Petersen (1990)
Multiple regression	Lagory et al. (1985), Grover and Thompson (1986)
Logistic regression	Hudgins et al. (1985), Thomasma et al. (1991)
Discriminant function analysis	Dunn and Braun (1986), Edge et al. (1987)
Multivariate analysis of variance	Stauffer and Peterson (1985)
Principal components	Edwards and Collopy (1988)
Multiple response permutation procedures	Aldredge et al. (1991)

* Represents tests compared by Aldredge and Ratti (1986, 1992)

Regardless of the animal of study, selection of a method for analysing habitat data is dependent on the type of data collected, its reliability, how observations are weighted, the assumptions required for the test, and the hypothesis to be tested. If habitat availability values are explicitly known, the univariate approach of Neu et al. (1974) may be suitable. On the other hand, multivariate methods are useful in analysing more general questions related to resource selection (Clark et al. 1993a).

1.4.3 Spatial Analysis

Geographic Information Systems are computer-based systems that are used to store and manipulate large volumes of geographic information (Aronoff 1993, Duncan et al. 1995), and have become commonplace in the study of wildlife/habitat interactions (Donovan et al. 1987, Lyon et al. 1987, Clark et al. 1993a, 1993b, Duncan et al. 1995). GIS databases are often generated from remotely sensed information which creates a coarseness in the database such that GIS-based habitat models are most effective for species with generalized habitat requirements. Given their limitations, GIS systems are capable of quantifying the spatial relationships between wildlife and their habitat at a level not economically practical using traditional mapping techniques (Aronoff 1993). Detailed ground sampling may be used to correct the low level of resolution provided by the GIS, but may come at a high economic cost in areas of decreased accessibility (Ormsby and Lunetta 1987).

1.4.4 Habitat Modelling

For many years, planners, foresters, managers, and biologists have recognised that there is a need to accurately evaluate wildlife habitat. In the past, the increasingly narrow and specialised approach toward resources, and especially wildlife and habitat management, has resulted in fragmented perceptions and understanding of the larger systems at work in the natural world (Stiehl 1995). Recognising the necessity for a more holistic approach to development planning, the Government of the United States passed the National Environmental Policy Act (NEPA) in 1969 which required all U.S. federal agencies to employ systematic and interdisciplinary techniques in planning and decision making. Further, NEPA required the installation of methods and procedures designed to ensure that environmental amenities and values (i.e. clean air and ecological integrity) traditionally not quantified be given appropriate consideration in decision making (Stiehl 1995). Resulting from NEPA was the development of the Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980); an evaluation procedure for use in project planning.

In 1991, Environment Canada, in co-operation with Wildlife Habitat Canada, released the Guidelines For The Integration Of Wildlife And Habitat Evaluations With Ecological Land Survey (ELS) (Wildlife Working Group (WWG) 1991). This publication identified and described the interrelating physical and biological components of the environment from a hierarchical perspective of ecologically functional and geographically recognisable entities or wholes. Ecological Land Survey is an interdisciplinary approach to landscape ecology involving the collection and interpretation of environmental data. Under this approach the environment is considered to be composed of natural or man-modified ecosystems that are land based. Within ELS, land is holistically referred to as being composed of a complex and interconnected web of abiotic and biotic ecological components, including bedrock, landforms, soils, water, climate, vegetation, and wildlife. As the ELS guidelines were developed in parallel with the US HEP approach, there are many similarities.

HEP/ELS permits the use of a number of habitat modeling techniques to describe wildlife/habitat relationships (Slauson 1988). With the advent of modern technology, along with its greater potential for data storage and manipulation, there is renewed interest by resource managers to use HEP/ELS techniques to enhance both biological systems understanding and management decision making. HEP/ELS provides information for 2 types of wildlife comparisons: 1) the relative value of different areas at the same point in time, and 2) the relative value of the same area pre- and post-development (Stiehl, 1995). As a result, HEP/ELS may be adapted to many different uses, including project planning and habitat management.

A similarity between HEP and ELS is the use of HSI models to evaluate habitat potential. Berry (1986) described HSI models as correlations between species and different habitat components. The methodology of HSI is centered on basic ecological principles and concepts, which include the assumption that at the species level the value of the habitat can be described by a set of measurable habitat variables (life requisites) that are important for the species (Stiehl 1995). Further, the value of an area may be influenced by changes in either habitat quantity or quality. The value of an area to a given species is a product of the size of the area and the quality of the area. This can be stated mathematically, as:

HABITAT (UNIT) VALUE = HABITAT QUANTITY X HABITAT QUALITY.

For HEP/ELS, the quantity part of the formula is any measure of area which is appropriately sized for the particular study. The quality measurement of the formula is expressed in the form of an HSI, which varies from 0.0 to 1.0. The HSI is a measure of how suitable the habitat is for the particular species when compared to optimum habitat, with 1.0 representing the optimum.

It is important to establish quantitative output goals for the model through the establishment of an area based performance related measure (Stiehl 1995). The Habitat Unit (HU) is the basic accounting unit for HEP/ELS, and is determined by multiplying HSI x Area (Stiehl 1995). A suitable quantifiable performance measure is, for example, the number of moose a forest stand will support per km^2. Ultimately, habitat units may be summed across the study area to determine habitat supply.

2.0. LITERATURE REVIEW

2.1 LIFE REQUISITE/HABITAT ASSOCIATIONS

Habitat represents the essential factor determining wildlife population fitness, with food and cover being the primary components (Crichton 1977, Stelfox 1988). Quinlan et al. (1990) provide a comprehensive literature review of moose habitat requirements across North America, with specific reference to the Edson Forest Region of Alberta. Moose are forest edge, generalist herbivores dependent upon early successional forest for browse, and mature to old coniferous forest for escape and winter cover (Cairns and Telfer 1980, Rolley and Keith 1980, Mytton and Keith 1981, Hauge and Keith 1981). Occupying a variety of forest biomes offering edge or disturbed areas (Crichton 1977, Telfer 1984), moose feed on a wide variety of shrub species and depend on mineral licks (Alberta) or aquatic vegetation (primarily eastern Canada) for essential minerals (Timmermann and McNicol 1988). Mixed-wood forests and shrublands in close association with lakes, ponds, streams, and bogs are considered prime moose habitat (Soper, 1964). Food and cover requirements vary seasonally, where moose exploit the shrub and ground strata of deciduous, mixed and coniferous forests and shrubland cover types (Cairns and Telfer 1980, Rolley and Keith 1980, Mytton and Keith 1981, Neitfeld et al. 1984, Risenhoover 1989). Cairns and Telfer (1980) state that although moose will utilize many forest stands of varying composition, shrubland appears to be the year-round habitat choice. Smith (1982) reported that during the dormant season, moose preferred deciduous forest. Moose habitat quality is a multidimensional function of temporal variation, the physical structure and spatial relationships of forest vegetation, land form, snow conditions, protection from thermal stress, and forage quality (Allen et al. 1987, Peek et al. 1976, Peek et al. 1992).

The temporal and spatial scale of resource exploration and extraction may have both positive and negative effects on moose habitat availability and utilization (Tomm et al. 1981, Timmermann and McNicol 1988). Positive effects of disturbance include production of early successional browse, while negative effects include loss of thermal and escape cover (Timmermann and McNicol 1988, Allen et al. 1987) and increased harassment in areas of uncontrolled access (Tomm et al. 1981).

To assist managers in decision making, the optimal interspersion and juxtaposition of moose habitat requirements need to be quantified on an area basis if resource interests are to be managed sustainably and holistically. Giles (1978) defined interspersion as the intermixing of units of different habitat types, where heterogeneous habitats possess a greater degree of interspersion than homogenous habitats. Juxtaposition may be defined as a measure of adjacency or proximity of one habitat type to another (Giles 1978). Telfer (1978, 1984) suggests that the dormant season is critical to moose survivorship where the adjacency of quality forage and cover are of importance. The identification of dormant season moose habitat use in west central Alberta will permit the quantification of habitat resource interspersion and juxtaposition. This information will assist resource managers in making informed decisions towards the integration of forest resource extraction and moose management. This will benefit both moose populations and related social and economic values.

2.1.1 Moose Winter Cover

Moose behaviour is dependant on environmental conditions (Renecker et al. 1978). Moose will use their surrounding habitat to mitigate the effects of extreme weather conditions, and have been shown to demonstrate a characteristic pattern of habitat use during the dormant season (Peek et al. 1976, Telfer 1978, Rolley and Keith 1980, Hauge and Keith 1981, Allen et al. 1987). In Rochester, Alberta, moose avoided lowland vegetation types and moved into uplands of mature aspen between early and late winter (Rolley and Keith, 1980). Use of pine, aspen-pine and aspen-spruce stands in winter was limited (Rolley and Keith 1980). In west-central Alberta, moose over winter in areas of high browse production (Telfer 1978). As winter severity increased, moose preferences changed from high forage producing areas to areas of higher cover, lower forage abundance (Telfer 1984, Timmerman and McNichol 1988) and where snow cover was reduced (Hauge and Keith, 1981). Also within west-central Alberta, cover, both security and thermal, was a greater determinant of habitat use than forage availability (Stelfox 1984). Other studies in Alberta (Tomm et al. 1981, Holroyd and Van Tighem 1983, Westworth et al. 1984) reported the importance of cover and forage for moose during winter. In Ontario, good early winter habitat consisted of several small residual stands of mixed or coniferous trees with an average coniferous basal area of 9.5 m^2/ha and mean stand height of greater that 6 m situated proximally to dense aspen stands containing suitable browse (Ontario Ministry of Natural Resources 1984). In the Lake Superior Region of Ontario, Allen et al. (1987) proposed that ideal late winter cover was comprised of coniferous canopy closure ≥ 75% and stand height > 6 m. Further, winter cover quality increased as the proportion of conifers in the stands increased, where stands composed of ≥ 60% coniferous species of sufficient height provided maximum thermal protection and lower snow depths (Allen et al. 1987).

2.1.2 Moose Winter Food

Moose are generalist herbivores which subsist on deciduous and shrubby browse during the dormant season (Telfer 1984). Willow was an important early winter food, but when snow accumulation impeded movement, shade tolerant species such as hazelnut and saskatoon were preferred (Soper 1964). Use of food by moose in winter was to a large degree determined by availability, where the primary limiting factor was winter range condition (Peek 1974) and the characteristics of accumulated snow (Bonar 1985).

In winter, moose eat a wide variety of plants including willow (*Salix spp.*), red-osier dogwood (*Cornus stolonifera*), saskatoon (*Amelanchier alnifolia*), trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), paper birch (*Betula papyrifera*), bog birch (*B. glandulosa*), pincherry (*Prunus pensylvanica*), chokecherry (*P. virginiana*), high-bush cranberry (*Viburnum opulus*), low bush cranberry (*V. edule*), mountain ash (*Sorbus scopulina*), beaked hazelnut (*Corylus cornuta*), balsam fir (*Abies balsamea*), rose (*Rosa spp.*), and green alder (*Alnus crispa*) (Stelfox 1974, Nowlin 1978, Trottier 1981, Nietfeld 1984 , Irwin 1985, Timmerman and McNicol 1988).

2.1.3 Moose Habitat Area Requirements

Moose exhibit both spatial (LeResche 1974, Hauge and Keith 1981) and temporal variation in home range size, with larger areas being utilized during winter conditions or when browse quality is low (Lynch and Morgantini 1984). Moose tend to be most aggregated during fall and winter, with variation between populations related to habitat quality and quantity, population density, and sex ratio (Peek et al. 1974). Alberta moose have also been found to exhibit sex and age specific differences in seasonal home range size (Rolley and Keith 1980, Lynch and Morgantini 1984). In an area representing the Upper and Lower Foothills Natural Subregions of

Alberta, winter home ranges were recorded to be as large as 51.6 km^2 for bulls and 46.8 km^2 for cows (Lynch and Morgantini 1984).

2.2 MOOSE RESPONSE TO DISTURBANCE

The forested regions of Alberta, and specifically areas within wildlife management unit 346 in west-central Alberta, experience both natural and anthropomorphic disturbances. Through oil and gas exploration, forest harvest practices, agriculture, electrical power generation, as well as transportation to facilitate these industries, the forest habitat is fragmented by roadways, cut-lines, pipelines, cut-blocks and pasture. These man induced elements reflect management history and independently and cumulatively influence moose habitat availability and use. The following is a review of several factors which may impact the fitness of a moose population within a given area, and as a consequence, may affect land use or management decisions.

2.2.1 Oil, Gas & Transportation

The impacts of the oil and gas industry on the integrity of the forested ecosystem may be divided into three separate phases. Phase 1 occurs primarily during freeze-up, and includes seismic line construction. The act of seismic line construction produces noise disturbance and linear disturbance as transects are bulldozed to facilitate seismographic testing (Smith 1982). In a 1982 report, Smith studied the pre- and post-impacts of wellsite development in west-central Alberta from December 31, 1980 to March 20, 1981. Drilling activity negatively corresponded with moose presence (Smith 1982). Construction initially disturbs the soil and removes woody vegetation, which may be of importance to moose. Oriented in a grid pattern, linear seismic transects produce unnatural features in an environment where linearity does not exist. The resulting grid of linear disturbance creates travel corridors for moose, but also moose predators such as black bear (*Ursus americanus*), wolf (*Canis lupis*), cougar (*Felix concolor*), and man. Predators learn to use the matrix of corridors to their advantage (L. Morgantini, University of Alberta, personal communication). Depending on the substrate on which they are placed, seismic lines are typically non-permanent disturbances with the effects being area specific, or as exploration progresses, area wide (B. Stelfox, Forem Consultants, personal communication).

Phase 2 is exploration and includes drilling and construction of semi-permanent or permanent road networks for transportation. Similar to phase 1, road construction produces noise disturbance and unnatural linear disturbance. Noise disturbance is recurring dependent on traffic while linear disturbance is more significant due to the creation of wider right of ways and soil compaction. Increased traffic will increase the incidence of animal collisions. Road networks increase the accessibility for hunting. Romito et al. (1993) proposed that areas ≤ 100 m of roads was of lesser habitat quality for moose due to animal visibility and safety. Habitat quality increased linearly with distance from a road, with optimum habitat occurring at ≥ 400 m.

Phase 3 involves field development and includes installation of semi-permanent structures such as pumping stations as well as high grade roads. These structures remove portions of the habitat from availability, including a buffer area surrounding the disturbance site, with size dependent on the nature of the disturbance. These structures may become attractions to some animals in search of minerals (L. Morgantini, University of Alberta, personal communication).

2.2.2 Agriculture & Timber Harvesting

In Alberta and other regions, land management practices can be a significant factor contributing to the improvement of moose habitat through the creation of browse associated with early successional habitat (Prescott 1974, Telfer 1978, Stelfox 1988). Agriculture and forest management both create moose and degrade moose habitat. Crete (1976) indicated that stem abundance was the most important component of the habitat to influence moose habitat use. In west-central Alberta, Stelfox (1974, 1988) found that moose used logged areas significantly more than mature forest during summer, but use decreased during winter. Decreased use during winter was suggested to be due to lack of cover.

In west-central Alberta, the influence of agriculture has been removal of tree vegetation in favour of grazing pasture. The removal of woody vegetation eliminates seasonal moose cover and forage, but can create significant winter forage attractions (i.e. alfalfa bails). The landscape of west-central Alberta limits the productivity of the land, and such, the impact of agriculture is highly varied across the landscape.

Timber harvesting fragments the forest through removal of wood fibre and road construction. Moose habitat can be destroyed if too much critical habitat (cover and forage) is lost, or if large areas are harvested for replanting to monoculture (Thompson and Euler 1987). Initially, forest harvesting changes the age structure of the forest. When harvested areas are replanted with commercial stock, natural succession that would occur after fire is disrupted. Silvicultural practice not only influences the dominant overstory composition, but also associated understory composition. To facilitate transport of fibre, roads are created which further fragment the habitat.

When studying the effects of forest harvesting on big game in west-central Alberta, Stelfox's (1988) 32 year study (1956 - 1988) indicated that during the first five years following harvest, shrubs and trees were too low to provide cover. By year 17, dense pine regeneration and rapid conifer and deciduous tree growth resulted in moderate thermal/security cover for moose. Stelfox (1988) further indicated that scarified clear-cuts were delayed five to ten years behind unscarified clear-cuts in providing adequate winter cover. Pine and unscarified mixedwood clear-cuts provided acceptable winter security cover at year 26. By year 32, all clear-cut cover values increased, but only pine clear-cuts provided adequate thermal cover (Stelfox 1988). This study found that moose seeking cover selected pine clear-cuts over those of spruce and mixedwood. Moose require a mixture of cover and forage to survive the sometimes harsh winter months, and Stelfox (1988) reported that a positive relationship existed between cover and forage availability during the dormant season, where deciduous browse was found to be used in great extent when coniferous cover was high. For the same area in 1984, Stelfox discovered that total browse consumption coincided more with cover quality than browse production. When comparing post harvest treatments, Stelfox (1988) determined that scarification increased browse production in mixedwood and spruce clear-cuts, but decreased production if pine clear-cuts. It was found that browse production peaks around year 17 for unscarified spruce and mixedwood clear-cuts, and about year 26 in scarified blocks.

The degree with which forest harvesting affects moose habitat use is a function of cutblock size, shape, interspersion and juxtaposition. Maintaining a mosaic of 15-30 year-old logged areas intermixed with mature, closed canopy timbered stands will provide productive moose habitat (Matchett 1985). In Alberta, Tomm et al. (1981) found that cutblocks from 16.6 - 32.4 ha that were buffered from adjoining forest openings by 221.2 - 402.2 m were preferred. Timber harvesting using selective cuts were recommended by Peek et al. (1987) to retain sufficient overstory cover for moose.

2.3 MOOSE MANAGEMENT

In Alberta, the moose resource is managed by the Government of Alberta and in the interest of the people of Alberta. In addition to the non-consumptive appeal of this majestic animal, moose are hunted by First Nations Peoples and licensed hunters for subsistence and sport. Following the 1992 hunting season, concern from the hunting population regarding declining moose numbers led to the Government of Alberta initiating the Northern Moose Management Program (NMMP) in 1993. Funded through the Fish and Wildlife Trust Fund, this five year program was established to answer questions about moose population dynamics and to identify the management actions required to stabilize or improve numbers of moose in the various Moose Management Areas (MMA) of the province (Alberta Natural Resources Service 1998a), including Wildlife Management Unit (WMU) 346 within MMA 5 (Figure 2.1). From NMMP inception, a number of initiatives have been made by the Government of Alberta to better manage the northern Alberta moose population. The following section documents why moose management is important, the moose management approaches taken by the Government of Alberta over the past decade, and identifies information gaps hindering the development of an effective and efficient moose management plan.

Moose management requires consideration of both the population and the people who value the resource. The following are six reasons for managing moose (Timmermann and Buss 1995) :

1. As creatures of our environment, moose deserve responsible attention and treatment.
2. Their presence adds beauty, diversity and interest to the environment.
3. They are an integral component of a complex ecosystem and our heritage.
4. They provide significant recreational and economic value.
5. They are a significant source of food.
6. Unmanaged, moose can inflict serious damage, both to humans and the environment.

In Alberta, 4 procedures associated with moose management at the WMU level can be recognised (H. Carr, Alberta Environmental Protection, personal communication):

1. Assessment of the status of the moose herd.
2. Assessment of harvest statistics.
3. Development of a set of objectives for population management.

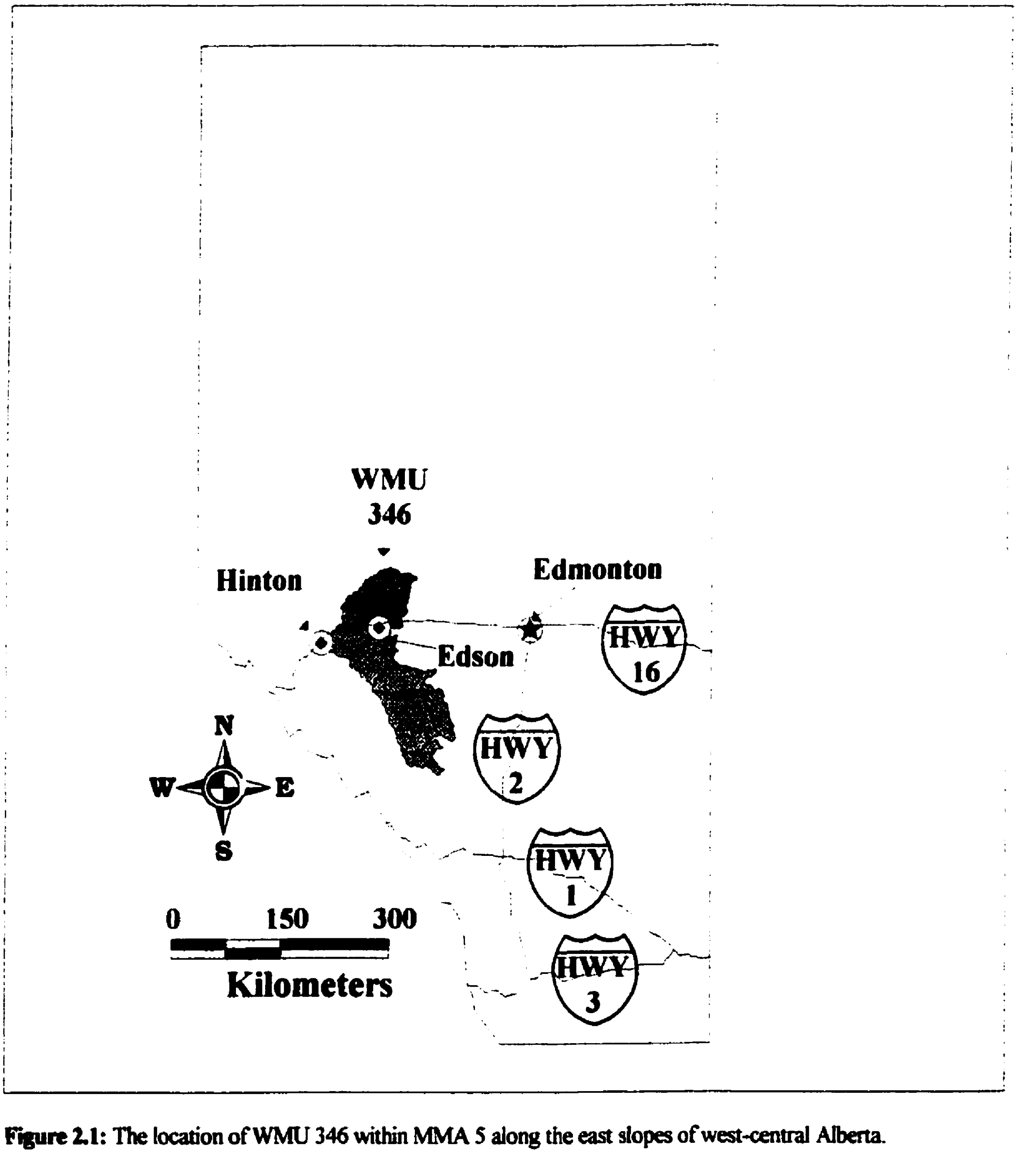

Figure 2.1: The location of WMU 346 within MMA 5 along the east slopes of west-central Alberta.

4. Development of a moose management strategy.

A the WMU level, objectives that may be identified for moose management in Alberta include:

1. Increase moose numbers.
2. Maintain existing moose populations.
3. Reduce the number of moose in an area.
4. Maintain a naturally balanced social structure in the moose population.
5. Increase the proportion of bulls in the population to a certain level - to increase harvest success and increase reproductive potential of the herd.
6. Expand non-consumptive use opportunities of the resource.
7. Maximise biomass production for consumptive use on a sustained basis.
8. Attain or maintain a certain moose density.
9. Achieve a certain level of recreational activity (hunter days/1,000 km^2).

In the 1980s moose numbers were declining. Factors contributing to the decline were high harvests of antlerless animals combined with increased unlicensed harvest, increased predation, and significant tick infestations (Alberta Natural Resources Service 1998a). The management approach was to control the harvest through season closures and reducing antlerless moose harvest by issuing a limited number of special permits available through lottery based draw (Alberta Fish and Wildlife Division 1992). For the 1990s, the goal of the Alberta Fish and Wildlife Division for moose management remained much the same, to increase the number of moose while maintaining hunting opportunity (Alberta Natural Resources Service 1998a).

In 1991, the moose season in a large portion of west-central Alberta, including WMU 346, was divided into two seasons (exact dates reflective of the 1992 season for WMU 346):

1. September 21 - October 10 - Antlered moose calling season special license draw (rut hunt).
2. October 12 - November 28 - General antlered moose license with the hunter limited to 1 license.

The intention of a split season was to reduce bull harvest, especially during the rut when bulls were most vulnerable (Alberta Fish and Wildlife Division 1992). Through this hunting regime, inadequate population data was collected (Alberta Natural Resources Service 1998a) to support management decisions.

Following the 1992 hunting season, the public expressed concern regarding moose populations of northern Alberta. In 1993, early data from the NMMP indicated that public concern was justified. The Government of Alberta used this information as the basis for asking the hunting public to participate in an incisor bar collection program for the 1993 season to estimate age structure of the population. Hunter effort and success was determined through telephone questionnaire. Incisor bar and questionnaire data was collated with ongoing NMMP efforts to determine management prescription for the following year (Alberta Fish and Wildlife Division 1993).

Review of harvest and NMMP data indicated that for the 1994 season, further hunting management was warranted for several WMU's, including WMU 346. In these units, bull:cow ratios were below acceptable levels and the percentage of bulls harvested was excessive (Alberta Fish and Wildlife Division 1994, Alberta Natural Resources Service 1998a). To correct the problem, the antlered moose calling season extended 1 week and the later general season opening similarly delayed. It was presumed that these alterations would enable the draw season to adequately control the bull harvest during the rut, thereby reducing the overall harvest (Alberta Fish and Wildlife Services 1994). Another change for the moose harvest for 1994 was the implementation of a cow moose special draw opening in WMU 346 and three other WMU's (360, 521, 522). From November 28 through December 10, this special season was closely regulated such that the reproductive tracts and incisor bars of each harvested female were collected for analysis. The uteri were examined and unborn fetuses were measured and weighed to determine the reproductive history and incidence of second estrus pregnancy. The harvest of the female cohort in these WMU's permitted the collection of age data in areas that had not been open to female harvest since 1989 (Alberta Natural Resources Service 1998a).

In 1995, the Alberta Fish and Wildlife Services became the Alberta Natural Resources Service. At the same time the approach to moose management was altered. Results of the 1994 moose harvest and NMMP surveys indicated that despite best efforts, moose still appeared to be over-harvested (Alberta Natural Resources Service 1998a). To gain greater control of bull harvest during the entire rutting period, the antlered moose calling season for all northern WMU's was extended (Alberta Natural resources Service 1995). The general moose season was deferred to an October 30 opening. In addition, to more effectively monitor the female cohort of the population, female moose were radio collared in WMU's 346 (n = 34) , 350 (n = 36), and 358, (n = 44). This collared sample was regularly relocated to determine both cow and calf survival rates as well as the amount and causes of mortality.

From 1993 to 1995, the trend in moose management in Alberta had been the institution of a restricted harvest special license draw for the rut season, and delaying the general season. For 1996, this trend continued in all areas except Moose Management Area (MMA) 5, including WMU 346. Results from the 1995 harvest and the NMMP survey indicated that bull harvest rates for MMA 5 were 45 percent higher than projected, effectively skewing the population sex ratio in favour of females (Alberta Natural resources Service 1998a). To counter, the open general season was replaced with a second late season draw from November 1 - 30 (Alberta Natural Resources Service 1996).

Hunting regulations for moose remained largely unchanged from 1996 to 1997, the beginning of field work for this research. Using a sample of previously radio collared female moose in WMU 346, a winter (January - March) habitat use and availability assessment was conducted.

1998 marked the end of the 5 year NMMP including the intensive moose incisor bar collection program. No significant changes occurred to moose hunting regulations from 1997.

Public concern and scientific information led the Government of Alberta, Fish and Wildlife Services/ Alberta Natural Resources Service to alter moose harvest regulations. Using harvest and population data, the moose management approach that the government of Alberta followed during the period of the NMMP was one focused on controlling the bull harvest. Justification for this approach was a two fold assumption: 1) reducing the bull harvest would, through time, increase the number of bulls in the various populations available for harvest. 2) with a greater number of bulls in the population, the number of females successfully bred would increase, thereby allowing the population to grow (Alberta Natural Resources Service 1998a).

There seems, however, to be a component of the moose population management equation which is missing. The Wildlife Working Group (1991) of the Canadian Committee on Ecological Land Classification suggest that wildlife managers seek an appropriate mix of population and habitat assessments to support management decisions. When wildlife habitat is classified, population surveys can be employed to establish or validate land unit ratings, monitor population status, and provide benchmark carrying capacities. Without an accurate assessment of available habitat, it is premature to set population goals or objectives if it is unknown whether the habitat is available to support desired population numbers.

As of the end of August 1999, Alberta Environment, Natural Resources Service did not have a documented moose management plan for any region of Alberta. Pending a solidified management plan, Natural Resources Service have not developed population density goals for the province. The formulation of a management plan and subsequent population goals are, however, a priority (H. Carr, Alberta Environmental Protection, personal communication). Population estimates for portions of Alberta resulting from a 5 year contracted study are available to the Natural Resources Service, but not available outside that Service. The population information, coupled with an assessment of habitat quality and quantity, will provide management with the essential tools required to develop the much needed moose management plan, including the establishment of population goals.

3.0 MOOSE HABITAT SELECTION IN WEST-CENTRAL ALBERTA

3.1 INTRODUCTION

In 1993, moose (*Alces alces*) populations in west-central Alberta were below historic levels (Alberta Natural Resources Service 1998a). In an attempt to determine causal factors for the decline, the Northern Moose Management Program (NMMP) was initiated by the Alberta Fish and Wildlife Division/Natural Resources Service (NRS). Through this initiative, 34 female moose were radio collared in Wildlife management Unit (WMU) 346 to monitor the segment of the population critical to survivorship (Lynch 1997). The intention of this research was to: 1) use the radio collared sample of female moose and Alberta Vegetation Index (AVI) digital data estimate winter habitat preferences; 2) determine the utility of using AVI data for estimation of moose habitat preference; and 3) suggest management recommendations.

The relationship with which an animal selects 1 available resource over another is of prime importance to a resource manager as it assists in the identification of the life requirements of that organism. When this information is collected, it provides baseline information that may then be utilized to effectively manage or regulate the animal population of interest independently or from a community perspective.

3.2 STUDY AREA

The study area includes portions of Wildlife Management Unit WMU 346 within MMA 5. Highway (Hwy. 16) defines the southern border of the WMU. From the north-east to south-west, the border is defined by the Athabasca River, with the eastern border being the McLeod River (Figure 3.1). The area has a continental sub-humid climate with long, cold winters modified by short periods of Chinook (fohn wind) conditions, and short, cool summers. The study area is generally snow covered from early November until mid/late April (Powell and McIver 1976, Powell 1977, Hillman et al. 1978). During survey, January 13 - March 21, 1997, cumulative precipitation for Shiningbank was 81.6 mm at an elevation of 829 m, with snowfall accounting for 77 mm. For Entrance, snowfall accounted for 80.2 mm precipitation at an elevation of 1003 m. Snow depth for Shiningbank varied during the survey, with minimum and maximum values of 20 mm and 49 mm respectively. At Entrance, minimum and maximum snow depths were respectfully 19 and 50 cm. Mean temperature at Shiningbank was -9.5 °C, while Entrance was -6.8 °C. Appendix I contains Environment Canada weather records for both Shining bank and Entrance monitoring stations during the period of study.

The study area is heterogeneous in vegetative composition with 3 major forest types identified through dominant overstory species composition; white spruce (*Picea glauca*), mixed wood and lodgepole pine (*Pinus contorta*). The area has been identified as the Upper and Lower Foothills Subregions (Beckingham et al. 1996). Old (125-140yr) white spruce and mature (80-100yr) mixedwood forests fall within the Upper Foothills subregion. The young-mature (60-70yr) lodgepole pine forest lies within the Lower Foothills subregion (Beckingham et al. 1996).

Understory browse vegetation of mature white spruce forests resemble the shrub-herb faciation described by Moss (1953). The overstory consists of tall, dense stands of white spruce, with a scattered distribution of mature balsam poplar (*Populus balsamifera*) in mesic sites. Sparse deciduous tree and shrub strata include willow (*Salix* spp.), dogwood (*Cornus stolonifera*), honeysuckle (*Lonicera dioica* and *L. involucrata*), low bush cranberry (*Vibernum edule*), buffalo-berry (*Shepherdia canadensis*), shrubby cinquefoil (*Potentilla fruticosa*), birch (*Betula spp.*), prickly rose (*Rosa acicularis*), ground and creeping juniper (*Juniperous communis* and *J. horizontalis*) and saskatoon (*Amelanchier alnifolia*).

Overstory vegetation of the mature mixedwood forest is dominated by spruce, but balsam poplar and lodgepole pine are common. Characteristic lesser tree and shrub species are aspen (*P. tremuloides*), honeysuckle, buffalo-berry, prickly rose, snowberry (*Symphoricarpos occidentalis*), willow, common bearberry (*Arctostaphylos uva-ursi*) and saskatoon.

The lodgepole pine association consists of dense stands of young to mature pine with a sparse deciduous tree and shrub strata of a few clones of balsam and aspen poplar plus small amounts of green alder (*Alnus crispa*), prickly rose, low-bush cranberry, willow, mountain ash (*Sorbus scopulina*), wild red raspberry (*Rubus idaeus*), wild goose-berry (*Ribes oxyacanthoides*) blueberries and bilberries (*Vaccinium spp.*), honeysuckle and elderberry (*Sambucus racemosa*).

The three forest types can be further characterised through Government of Alberta Vegetation Index data, with 13 dominant species defined for overstory stand composition, five moisture regimes, and

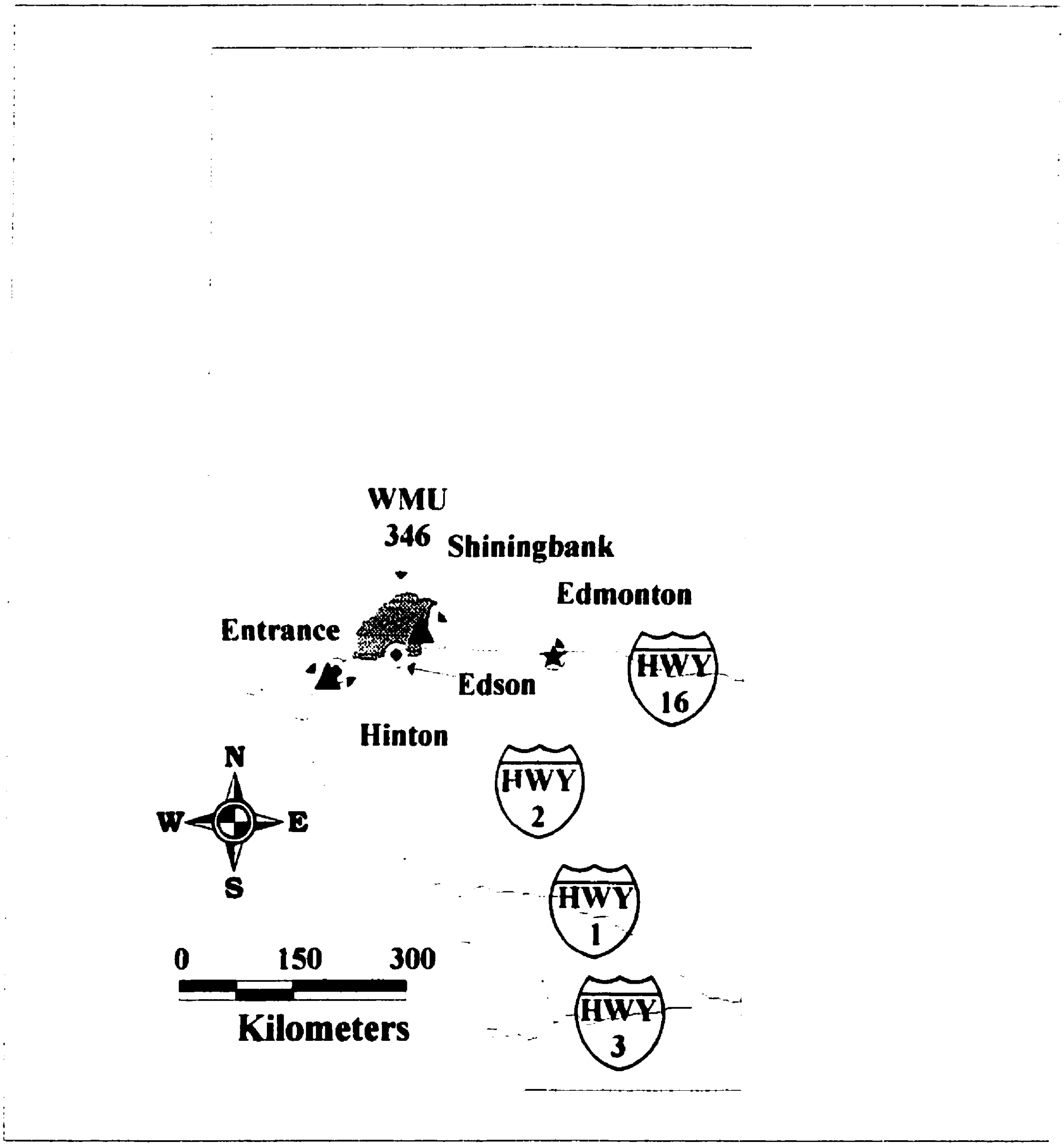

Figure 3.1: Location of the study area in west-central Alberta.

five crown closure classes. Height and stand origin are also identified for each forest stand. Appendix II contains a listing of the AVI variables used for analysis of moose habitat selection within the study area.

3.3 METHODS

Between June 1994 and June 1996, the Government of Alberta captured and radio-collared 34 female moose within WMU 346 to monitor that segment of the population most critical to survivorship and productivity (Lynch 1997). Nineteen radio-collared cows resided within the study area and provided the basis for the collection of habitat availability and preference information. Relocation of this radio collared sample and GIS based habitat data was used to test the hypothesis that moose use habitat in proportion to its occurrence within the study area.

The approach used follows Manly et al. (1993) and is based on the concept of a resource selection function; a function of habitat characteristics measured on resource units such that the value for a unit is proportional to the probability of that unit being used. Radio telemetry and digital AVI data within a GIS was used to determine habitat use and availability. To determine whether observations of moose habitat use follow the same pattern of occurrence found for habitat availability, the Neu et al. (1974) X^2 technique was employed (Byers et al. 1984, White and Garrott 1990, Clark et al. 1993a, Manly et al. 1993). To assist the NRS integrated management planning, a habitat supply analysis was conducted.

3.3.1 Telemetry

Telemetry materials and methods follow that of Lynch (1997). The telemetry receiver was a Telonics TR-2 unit equipped with TS-1 scanner. The receiving antenna consisted of 2 Cushcraft 4-element yagi antenna elements fastened to a 3 m antenna tower section. To accommodate the horizontal orientation of the transmitter antenna and the presence of forest vegetation, horizontal polarization was used (Cochran 1980). The entire system was mounted to a hinged platform which fit within the box of a 4 wheel drive pick-up truck.

Differing from Lynch (1997), a matrix of survey points were established along roadways and trails within the study area such that each moose could be relocated several times during 50 minutes of survey; a period of time suggested to provide a suitable level of accuracy given animal movement and triangulation error (G. Lynch Alberta Environmental Protection, personal communication). To increase reception strength and accuracy, the location of survey sites were strategically placed on heights of land devoid of tall vegetation (especially hardwoods) and distant from metal objects and power lines (Cochran 1980). Survey tracking station locations were established using a differentially corrected Trimble GeoExplorer GPS unit (DGPS). The Trimble Pathfinder software program (Trimble Navigation V 2.0) was used to correct survey tracking station reference positions with downloaded Base-Station correction files. Survey tracking station locations were saved as a map layer in MapInfo and as a look up table within Microsoft Excel.

To calculate the error distribution associated with moose capture sites, 5 test collars were placed at 15 random locations within the study area with their positions recorded using DGPS. To mimic the conductivity of the animal's body, test collars were attached to a plastic bottle containing a saline solution (White and Garrott 1990). Using triangulation techniques, the percentage of error-generated locations classified differently from the original set of locations were utilized to assess the relative effect of triangulation error on the analysis (White and Garrott 1986). Mean triangulation error was applied to all relocations originating at all location survey sites. MapInfo was used to determine the area of the relocation polygon, a value indicative of the accuracy of the triangulation (Lynch 1997).

The protocol for relocating collared moose followed that of Lynch and Schumaker (1995). Moose were relocated once daily From January 13 - March 24 1997. The survey starting point was rotated to ensure variation in time of animal relocation. The antenna was used to find the true azimuth to a moose. The intersection of bearings from 3 or more locations were used to geometrically determine an animal's position relative to these locations (White and Garrott 1990). When 3 or more tracking stations were used to locate a signal, a polygon was formed through the intersection of triangulation lines. Calculating to account for triangulation error, MapInfo was used to generate lines of triangulation and to determine the areas of polygons produced when lines of triangulation cross. Lines of triangulation were repeated until the capture site polygon was ≤ 0.15 km^2, signifying an area which balances the limits of the technology as well as time and finances. Capture sites were recorded between 0630-1930 hours each day of survey, with the tracking station starting point rotating daily to randomise relocation time/individual.

3.3.2 Calculating Available Habitat

MapInfo was used to determine available habitat for each moose (Figure 3.2). The distance between the estimated geographic centroid[1] of each successive relocation site was measured and the mean distance travelled was recorded for each moose. The outlying nodes of each moose relocation polygon cluster were then connected to create a perimeter polygon, where the distance between each node could not exceed the mean distance travelled for that animal during the survey period. If the nodes were further apart than the mean distance travelled, the perimeter polygon was collapsed inward until another polygon node was contacted at a distance $\leq$ the mean distance traveled per day. The inflection of the perimeter polygon followed this protocol unless the result would be a long sliver of home range. In the event that this occurred, the perimeter polygon connected to the next node on the next polygon such that the resulting polygon for home range represented an area that the moose could have traveled to reach the next point. For determination of available habitat for the population, the footprint of all individual moose available habitats was traced within MapInfo. This technique eliminated double counting of habitat typed resulting from overlap of individual available habitat areas.

3.3.3 Digital Data Manipulation

Digital landscape information in the form of ArcInfo E00 files were received from two sources, each of which maintained different data management practices. Data files were translated into MapInfo format and attributes were then separated into individual map layers for ease of analysis. Weldwood of Canada Ltd. Hinton Division (WC), provided digital Alberta Vegetative Inventory (AVI) classification data for portions of the study area falling within their Forest Management Agreement Area; a resource representing approximately 50% of the overall study area. Additional AVI data was obtained from the

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[1] MapInfo calculates the centroid of a polygon to be the centre of the rectangular selection area surrounding the polygon when selected. Thus, the MapInfo derived centroid will not represent the geographic centre unless the polygon is geometrically perfect.

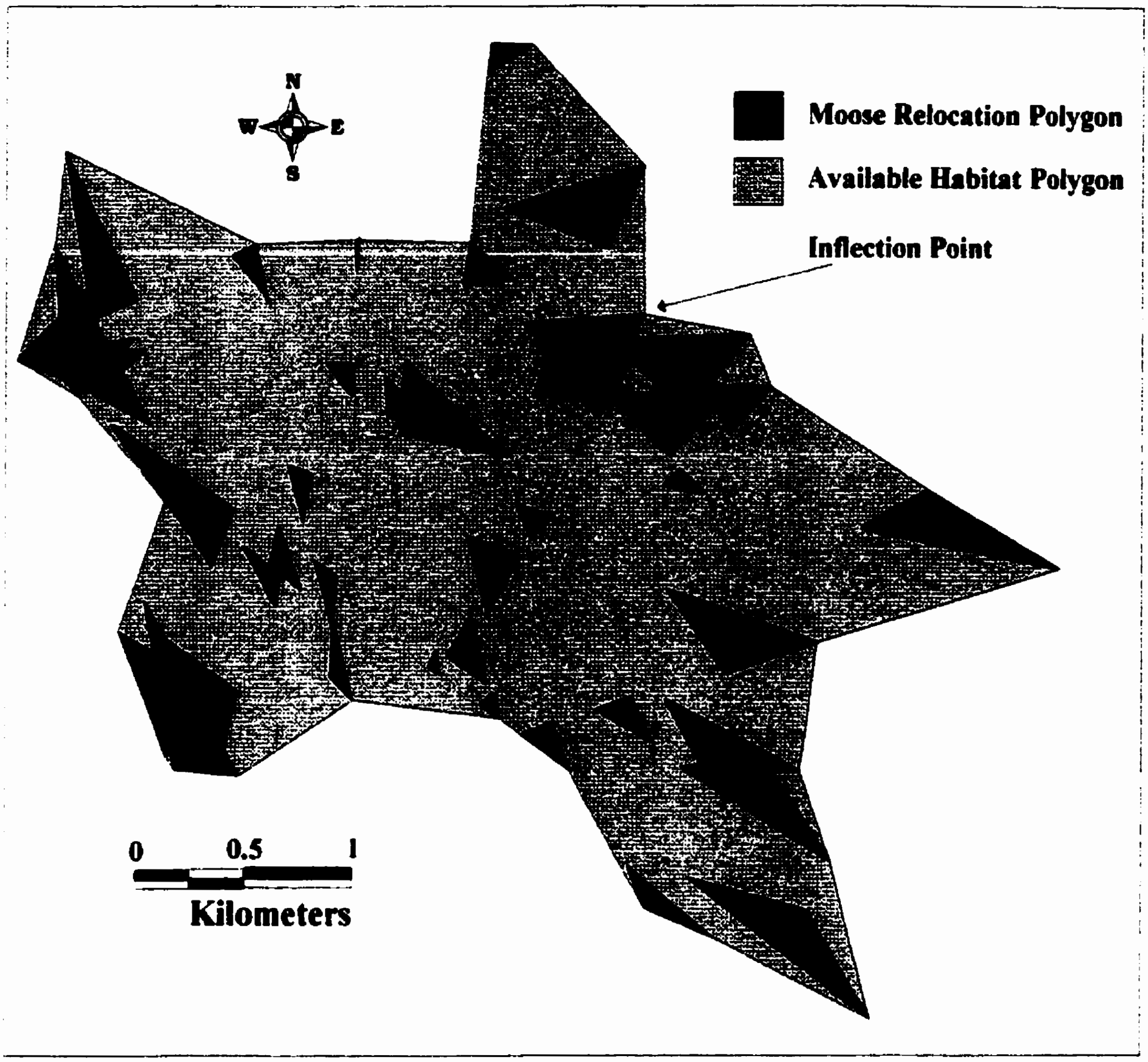

Figure 3.2: Example definition of available habitat for moose 835. Mean distance travelled/day for moose 835 = 0.84 $\pm$ 0.08 SE km. Perimeter polygons of relocation polygon cluster were connected to the next polygon if distance between nodes of polygon were $\leq$ mean distance travelled/day. Moose 835 available habitat = 9.26 km^2. Available habitat for population was created by tracing the footprint of all individual moose available habitat polygons. This process eliminated conflicts with habitat overlap between individuals.

Government of Alberta, Resource Data Division (RDD), which abutted the WC data and constituted the remaining study area. The WC forest inventory had a resolution of < 0.02 km^2 and RDD AVI files were created in 1996 and had a resolution of 0.02 km^2 minimum polygon area as determined through the Alberta Vegetation Inventory Standards Manual (Government of Alberta 1994).

The AVI files from both sources included many fields of records, some of which were of utility, others not. Each AVI file was edited within MapInfo such that only those records of utility remained; remaining attributes can be seen in Appendix II. Neither AVI data included the classification of understory species composition or related understory characteristics. Therefore, in some locations, no overstory designation existed. In these instances, mean stand height was used to further classify the data set. If stand height > 0 and dominant overstory species = "__". The dominant overstory species of the resulting table were reclassified into a new designation labeled "Br" representing potential Browse. The same procedure was used to select those stands where tree height = 0 and dominant overstory species = "__", which were reclassified to "Cl" for Clearing. An additional Field labeled HEIGHT5 was created which reclassified stand height in meters into five meter interval classes.

3.3.4 AVI Attribute Information

AVI attribute information was attached to the moose location site polygons in MapInfo, The proportions selector switch was chosen such that the area and perimeter of the newly created polygons were representative of the new polygon rather than that of the original AVI polygon proportions. Due to discrepancies in the RDD AVI data set, small slivers of forest stands occurred from this process. The query tool of MapInfo was used to select those slivers of habitat that were < 0.000001 km^2, each of which were subsequently deleted from the data file.

The following GIS map layers were generated from the AVI databases for integration into habitat analysis:

1. Stand dominant overstory species.
2. Stand overstory % Canopy Closure.
3. Stand moisture regime.

4. Stand height (5 m intervals; e.g. 0-4.99).

3.3.5 Habitat Availability and Use

Information from the previous section provided a census of all available habitat types and a random sample of female moose habitat use. Each moose relocation was considered as an independent observation in the sample of used points, and followed Design II as per Thomas and Taylor (1990) with SP A as described by Manly et al. (1993).

X^2 tests were completed to determine the significance of selection, and to test whether the different animals were using resources differently (Neu et al. 1974). As per White and Garrott (1990), X^2 test statistics from each animal were combined, rather than pooled over animals, and then analysed with the X^2 test. The form of test statistic used was

$$X_L^2 = 2\sum_{i=1}^{I} u_i \log_e(u_i/u_{.}\pi_i)$$

With I-1 df, where I represented the number of resource categories. The following notation applied: A_i = the # of available resource units in category i, for i = 1, 2, ..., I; $A_.$ = the size of the total population of available resource units; $\pi_i = A_i/A_.$, the proportion of available resource units that were in category i; U_i = the # of used resource units in category i in the population; $U_.$ = the total # used resource units in the population; u_i = the # of used resource units in category i in the sample of used units; $u_.$ = the total # of used resource units sampled; $o_i = u_i/u_.$, the proportion of the sample of used resource units that were in category i (Manly et al. 1993). This approach allowed a comparison of use versus availability for each habitat type across all animals.

Each relocation polygon representing used habitat contained several habitat types Habitat types were corrected to represent a proportion of relocation polygon area. As X^2 is sensitive to sample size, the # of used resources was standardised via the following equation:

$$(u_i/U_.)\ \#\ \text{relocations (population)}$$

The differences were investigated further through simultaneous Bonferroni confidence intervals between the difference in percent availability and percent use. If expected frequencies were outside the confidence interval, then that habitat was considered to be used greater or less than expected (Neu et al. 1974, Byers et al. 1984, White and Garrott 1990, Clark et al. 1993, Manly et al. 1993). This calculation took the following form:

$$o_i \pm z_{\alpha/2}\sqrt{\{o_i(1-o_i)/u_+\}},$$

where $z_{\alpha/2}$ was the percentage point of the standard normal distribution that was exceeded with probability $\alpha/2$. When α was set to 5%/I, then the probability that all i confidence intervals included their respective population ratios was about 0.95 (Manly et al. 1993).

As per Manly et al. (1993) resource selection functions were calculated and took the following form:

$$\hat{w}_i = o_i/\pi_i$$

To present selection ratios in a standardized form such that they add to 1.0, the following selection ratio equation was applied:

$$B_i = \hat{w}^*_i/(\Sigma\, w^*_i),$$

where $\hat{w}^*_i$ was an estimate of the resource selection probability function. The selection ratios could be interpreted as being the estimated probability that a category I resource unit would be the next selected if somehow it was possible to make each of the resource types equally available (Manly et al. 1993).

Standardised selection ratios were utilized to represent habitat suitability as per Slauson (1988) and took the following form:

$$(1.0_{(\text{optimal HSI value})}/B_{i(\text{maximum})}) \times B_{i(\text{attribute variable})}$$

To formulate a habitat supply analysis of the survey area on a per stand basis, each of the measured variables were aggregated through the following geometric mean formula:

$$\text{Forest Stand Suitability Index} = (V_{\text{dominant overstory spp.}} \times V_{\text{moisture}} \times V_{\text{\% canopy closure}} \times V_{\text{stand height}})^{1/4}.$$

3.3.6 Assumptions

To facilitate the analysis of resource selection and subsequent determination of habitat suitability of the forest stands for female moose, mobile tracking stations were established at selected locations within the study area. Survey of the mobile tracking station location was accomplished via GPS. When differentially corrected with base station files (DGPS), survey points possessed a location error ≤ 1 m, with the exact value of each point location error value being dependent on distance from the base station (Kremer et al. 1990). For this study, the error associated with mobile tracking station location error was assumed to be negligible in reference to the accuracy of subsequent recordings of moose capture sites. Referring to the radio collared sample of female moose, it was also assumed that the individuals selected for analysis was a random sample representative of the area.

In the estimation of resource selection functions, Manly et al. (1993) state that there are a number of assumptions involved; each of which were followed for this research and are listed below.

1. The distributions of all measured X variables for the available resource units and the resource selection probability function did not change during the study period.
2. The population of resource units available to the organisms were correctly identified.
3. The sub populations of used and unused resource units were correctly identified.
4. The X variables which actually influence the probability of selection were correctly identified, and
5. Organisms maintained free and equal access to all available resource units.

3.4 RESULTS

3.4.1 Moose Telemetry

From January 13 - March 21, 1997, 49 relocations were recorded for 19 individual moose (n = 931). Relocations were obtained between 0630 and 2000 hours with mean triangulation error of all survey location sites calculated to be $\pm$ 0.74 degrees. The average distance travelled between relocations for the sample population was 1.51 $\pm$ 0.04 SE km, and the mean home range size was 68.77 $\pm$ 5.38 SE km^2.

3.4.2 Habitat Use and/or Availability

Habitat selection was detected for the population using all data layers (Table 3.1 - Table 3.4). The population selected forest stand composition non-randomly ($X^2 = 48.37$, $P < 0.001$, df = 8) (Table 3.1).

trembling aspen dominant stands were avoided ($P < 0.05$). Stands classified as browse were preferred ($P < 0.05$). The remainder of available stands were used in relation to availability ($P < 0.05$). Browse stands received optimal HSI value (1.00). Trembling aspen received the lowest HSI value (0.49).

The population expressed selection of forest stands based on soil moisture regime ($X^2 = 16.45$, $P < 0.001$, df = 3) (Table 3.2). Confidence interval analysis demonstrated that moose avoided aquatic areas ($P < 0.05$) and mesic stands ($P < 0.05$). Aquatic areas received the lowest moisture regime HSI value (0.16). Wet stands were preferred ($P < 0.05$) and received optimal HSI value. No preference or avoidance ($P < 0.05$) was demonstrated for stands not receiving an AVI moisture classification.

When selecting for stand % canopy closure class, moose used forest stands randomly ($X^2 = 6.49$, $P > 0.05$, df = 4) (Table 3.3). Avoidance was demonstrated for stands with 71 - 100 % canopy closure (Class D) ($P < 0.05$). The highest HSI value was for class A (6 - 30%) (1.00), and the lowest HSI value was for class D stands (0.65). Trend analysis of the distance between observed and expected use (Figure 3.3a), and HSI vales (Figure 3.3) with % canopy closure class indicated that stands with less % canopy closure were of greater value to moose.

Tree height was selected non-randomly ($X^2 = 11.42$, $P < 0.05$, df = 5) (Table 3.4). Class 5 (25-29.99 m) stands were preferred ($P < 0.05$) and received optimal HSI value (1.00). Indifference was demonstrated for all lesser height classes ($P < 0.05$). The least suitable height class was class 4 (20 - 24.99 m) (HSI = 0.53).

In estimation of habitat supply analysis, four habitat variables were considered. Since aquatic areas are frozen lakes during winter with little habitat potential, the limiting function was applied. Frozen bodies of water have no overstory, canopy closure or tree height. To represent biological value, aquatic areas were not aggregated with other habitat variables and were assigned the calculated value of 0.15 (Table 3.5)

Within the study area, the # of stand types was greater than the # selected. Those habitat attributes not used were given an HSI value of 0.00 as they did not influence the population as assessed. The aggregate HSI model estimated that the lowest HSI value was 0.0 (Table 3.5, Figure 3.4a-j). The highest HSI value was 0.95.

Table 3.1: Population use, availability, X^2, relative preference and HSI by moose for 9 dominant overstory species habitat types, west-central Alberta, January - March 1997.

Species	Home Range Area (km^2)	Observed	Expected	X^2 Contribution	Relative Preference ($P < 0.05$) [1]	HSI
balsam poplar	4.9	23	19	4.62	0	0.76
browse	13.6	85	53	39.56	+	1.00
clearing	40.8	138	158	-19.43	0	0.54
trembling aspen	74.3	227	289	-54.31	--	0.49
tamarack/w. larch	27.0	134	105	33.59	0	0.80
undifferentiated pine	12.8	40	50	-8.62	0	0.51
lodgepole pine	11.6	55	45	10.97	0	0.77
black spruce	41.4	165	161	4.02	0	0.64
white spruce	13.3	64	52	13.78	0	0.78
Total	**239.7** [2]	**931**	**931**	**48.37** [3]		

[1] "+" indicates use was greater than availability, "—" indicates use less than availability, "0" indicates use not different than availability. Simultaneous confidence level = 95%.

[2] Home range area = footprint of all individual home range areas.

[3] $P < 0.001$, df = 8.

Table 3.2: Population use, availability, X^2, relative preference and HSI by moose for 4 moisture regime classes, west-central Alberta, January - March 1997.

Moisture Regime	Home Range Area (km^2)	Observed	Expected	X^2 Contribution	Relative Preference ($P < 0.05$)[1]	HSI
No Overstory	7.1	28	28	0.70	0	0.83
Aquatic	2.2	2	8	-2.71	--	0.16
Mesic	147.1	503	572	-64.21	--	0.72
Wet	83.2	398	323	82.67	+	1.00
Total	**239.6**[2]	**931**	**931**	**16.45**[3]		

[1] "+" indicates use was greater than availability, "—" indicates use less than availability, "0" indicates use not different than availability. Simultaneous confidence level = 95%.

[2] Home range area = footprint of all individual home range areas.

[3] $P < 0.001$, $df = 3$.

Table 3.3: Population use, availability, X^2, relative preference and HSI by moose for 5 % canopy closure classes, west-central Alberta, January - March 1997.

%CC Class	Home Range Area (km^2)	Observed	Expected	X^2 Contribution	Relative Preference ($P < 0.05$)[1]	HSI
(0) 0 - 5	54.4	222	211	10.74	0	0.92
(A) 6 - 30	29.7	132	116	17.53	0	1.00
(B) 31 - 50	51.2	214	199	16.11	0	0.94
(C) 51 - 70	74.8	278	291	-12.35	0	0.84
(D) 71 - 100	29.5	85	115	-25.54	--	0.65
Total	**239.6**[2]	**931**	**931**	**6.49**[3]		

[1] "+" indicates use was greater than availability, "—" indicates use less than availability, "0" indicates use not different than availability. Simultaneous confidence level = 95%.

[2] Home range area = footprint of all individual home range areas.

[3] $P > 0.05$, df = 4.

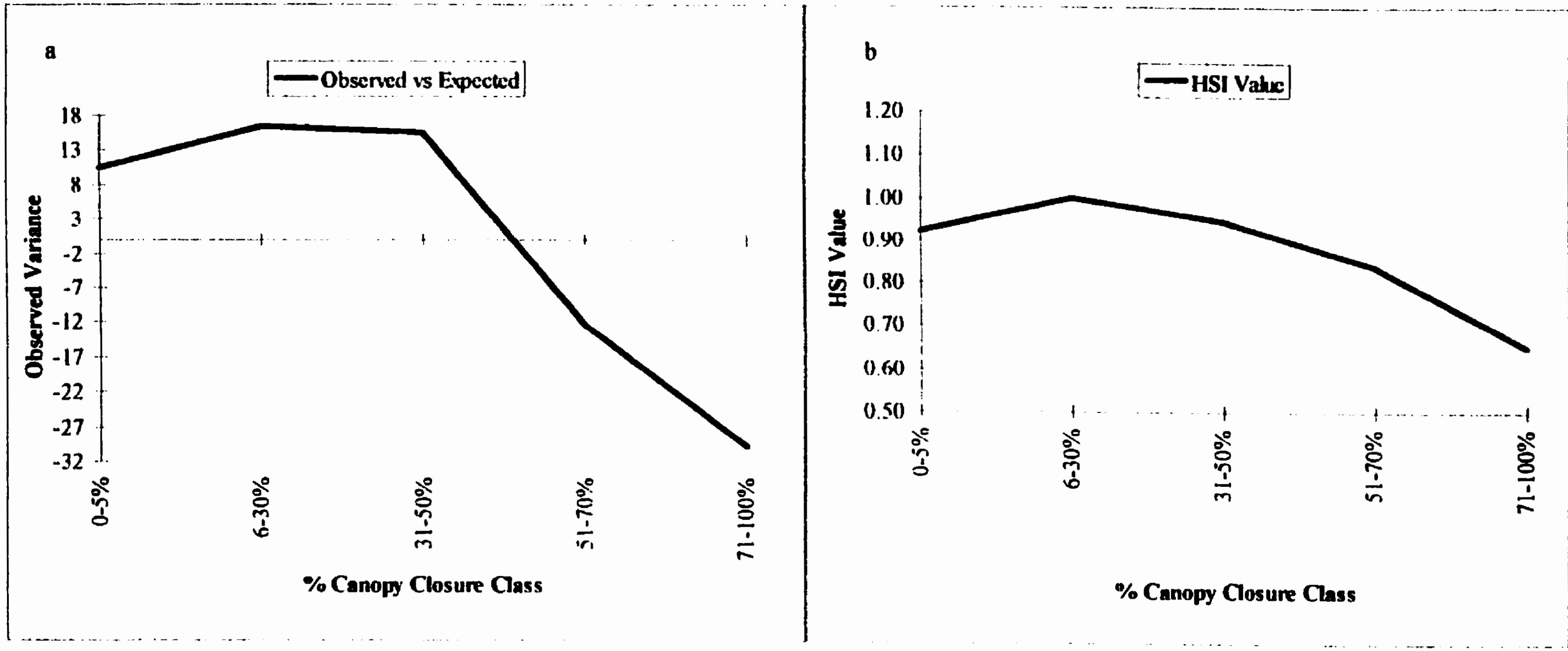

Figure 3.3a: Trend analysis demonstrating selection of lesser canopy closure classes based on expected and observed habitat use.

Figure 3.3b: Trend analysis demonstrating selection of lesser canopy closure classes based on HSI value.

Table 3.4: Population use, availability, X^2, relative preference and HSI by moose for 6 height classes, west-central Alberta, January - March 1997.

Height Class (m)	**Home Range Area (km^2)**	**Observed**	**Expected**	**X^2 Contribution**	**Relative Preference ($P < 0.05$)[1]**	**HSI**
(0) 0 -4.99	69.0	260	268	-8.57	0	0.59
(1) 5 -9.99	27.9	116	108	8.35	0	0.66
(2) 10-14.99	34.2	118	133	-13.65	0	0.54
(3) 15 - 19.99	35.0	165	136	31.98	0	0.74
(4) 20 - 24.99	65.8	223	256	-30.67	0	0.53
(5) 25 - 29.99	7.6	49	30	23.97	+	1.00
Total	**239.6[2]**	**931**	**931**	**11.42[3]**		

[1] "+" indicates use was greater than availability, "—" indicates use less than availability, "0" indicates use not different than availability. Simultaneous confidence level = 95%.

[2] Home range area = footprint of all individual home range areas.

[3] $P < 0.05$, df = 5.

Table 3.5: Area of HSI by data source and example potential population/HSI value class.

HSI	Area WC (km^2)	Area RDD (km^2)	Area (km^2)	Potential Population @ e.g. 2.0 moose/km^2
0.00	20.17	0.18	20.35	0.00
0.15	0.00	6.32	6.32	0.95
0.35	0.00	0.11	0.11	0.04
0.40	0.00	0.43	0.43	0.17
0.60	26.37	166.04	192.41	115.45
0.65	179.94	181.52	361.46	234.95
0.70	144.61	339.96	484.57	339.20
0.75	98.15	81.00	179.15	134.36
0.80	620.18	163.42	783.60	626.88
0.85	123.86	121.61	245.47	208.64
0.90	26.82	78.24	105.06	94.55
0.95	22.24	64.81	87.05	82.69
Total	**1496.65**	**1203.62**	**2700.27**	**1837.88**

3.5 DISCUSSION

For the analysis of resource selection and subsequent determination of habitat suitability for female moose, many habitat variables were available. Given resources available for this study, it was not feasible to collect temperature and snow depth data equal to the resolution provided by the AVI database. However, site specific temperature and snow depth data were available via Environment Canada (EC) for 2 locations; Shiningbank and Entrance (Appendix I) (Figure 3.1). Due to variation in altitude, slope, aspect, and vegetative composition within the study area, as well as missing data values, EC temperature and snow condition information could only be used to provide general reference regarding potential affects on moose habitat use. Records indicated that temperature did not deviate from the long term mean for the area, but snow depth was greater than average. Moose movements become restricted when snow depth > 0.65 m (Telfer 1970, Coady 1974, Krefting 1974) a condition that was recorded at Shiningbank for three consecutive days in March (Appendix I).

Resource selection analysis of dominant overstory species composition (Table 3.1) indicated preference for browse, avoidance of trembling aspen, and indifference toward the remaining stand types. The preference of browse reaffirms that snow depth was not a hindrance to movement. Preference for browse indicated that moose spend the winter in areas of high browse production (Telfer 1978). This is an expected response given that these areas receive greater snow accumulation, but may be used as bedding sites on warm sunny days (Eastman and Ritcey 1987, Joyal 1987). However, the demonstrated preference would indicate that more time was spent in browse areas than bedding alone. Trembling aspen was avoided, which may be due to lack of cover and/or thermal protection. Given the number of sample counts for trembling aspen (n = 227), it can be presumed that these stands provided little in the form of cover or food availability (HSI = 0.49) (Table 3.1). As conifer stands were not selected over deciduous stands or browse and clearing areas, it is evident that moose were less interested in cover quality than forage abundance. (Stelfox 1988, Hundertmank et al. 1990).

Analysis indicated selection of stands based on moisture regime was non-random ($P < 0.05$). Wet areas were preferred, suggesting that they may have been used as travel corridors with potential for both cover and forage resources (Eastman and Ritcey 1987, Joyal 1987). As snow depth was greater than average, forage resource availability on wet sites may have been less than optimal. Though only including 2 records, avoidance of aquatic areas during winter was an expected response as these areas are ice covered in winter, have no cover and forage potential, and receive greater amounts of snow accumulation. However, given that there were only 2 observations and 8, expected, this data should be interpreted with caution. The avoidance of mesic forest stands is surprising as both cover and forage potential should be enhanced due to site structure (Beckingham et al. 1996). Moose demonstrated indifference to stands not receiving a moisture regime qualification as per AVI protocol. As these areas were calculated to receive an optimal SI of 0.83 (Table 3.2, it is evident that this deficiency in the data set greatly influences the results of analysis and hinders management decisions based on contemporary AVI standards.

Log-likelihood X^2 analysis indicated random selection of stands based on % canopy closure, and avoidance occurred for only the densest stands (class D, 71 - 100 %, table 3.3). Eastman and Ritcey (1987) and Joyal (1987) suggest that lower % canopy closure classes may provide suitable travel corridors and bedding sites during warmer periods. The FMF draft moose habitat model (Romito et al. 1995) used % canopy closure for the qualification of moose cover suitability. The FMF model suggests that 0-6% canopy closure is of minimum value (0.0). In contrast, this study calculated the % canopy closure class 0 (0 - 5 %) HSI vale to be 0.92. Class C, providing 31-50 % canopy closure was preferred with an optimal SI of 1.0. This information supports the FMF model that indicated that optimal canopy closure is 30%. Following Stelfox (1988), this was likely due to a balance between snow deflection and the ability for the understory to produce suitable browse. The FMF model (Romito et al. 1995) further suggests that optimal canopy closure conditions persist from 30% - 100%. However, results of this study indicated that when % canopy closure exceeds 50%, HSI values decreased (Table 3.3). Though increasing canopy closure will deflect more snow and making movement easier, the effect will also be decreased light penetration to the understory, reducing the potential for forage production.

Moose expressed no preference or avoidance to forest stands with tree heights ranging from 0-24.99 m (classes 0 - 4), but the X^2 analysis indicated non-random selection. Romito et al (1995) indicated a correlation between % canopy closure and tree height. This feature was not evident in this study. It is believed that the sample size was insufficient to detect variance among the 6 height classes.

Manly et al. (1993) provided 5 assumptions that must be considered when conducting resource selection analysis. Regarding assumption 1, the distributions of forage and cover availability to the population will have changed due to competition with non-radio collared individuals for the resource. Concerning the correct identification of available resource units, the use of mean distance travelled/day as the basis for definition of available habitat introduces error. This is because moose were relocated once daily, with calculations likely underestimating actual travel. The third assumption concerns accurate census of used and available habitat. The small # of samples collected through radio-relocation limits the ability of statistical analysis to detect variance. Regarding assumptions 4, concerning correct identification of variables influencing the selection, the use of height class may be questionable. Again, however, results may be a function of sample size. The AVI data set was designed for management of woody vegetation at the commercial scale. This factor, combined with the differing scale of the 2 data sets used for analysis (as seen in Figures 3.3a-j), brings into question the accuracy of the AVI data for determining moose resource selection. As with assumption 1, moose will not have received equal access to all available resources, assumption 5. Reasons for this include inter- and intra-specific competition for resources as well as through the presence of man-induced disturbances.

Assuming that the integrity of the resource selection analysis was correct, the relative areas of forest stand HSI scores were identified (Table 3.5). Through observation of Table 3.5 and Figures 3.4a-j, it can be noted that the distribution of habitat quality for the study area between data sources differs some degree. The RDD and WC have different needs of the data and thus require different levels of resolution. The disparity in distribution of HSI values may be partially accounted for by the different levels of data resolution and subsequent classification differences. However, land use practice would be a more likely cause. The results of the habitat supply analysis is incomplete without the definition of a performance measure; # moose/km^2. Population to determine the performance measure was unavailable to this study, and should be used to test the utility of the tested methodology.

4.0 CONCLUSIONS & MANAGEMENT IMPLICATIONS

4.1 CONCLUSIONS

The use of radiotelemetry in combination with AVI data did not produce robust statistical results, but was able to identity and quantify moose habitat preference during the winter. Statistical and trended analysis indicated that moose preferred areas classified as browse, wet areas, low to medium % canopy closure, and tall trees when selecting winter habitat. The selection of tall trees as preferred would seem to be at variance with other findings and should be interpreted with caution.

Analysis indicated that AVI data can be used to determine habitat preference of female moose. However, if AVI data is to be effectively used as a tool for moose management, refinement of the AVI protocol is required. Specifically, significant information was lost because stands dominated by non-commercial wood fibre were not classified, and these stands may prove to be important moose habitat.

This research did identify habitats that need to be provided for in forest management plans. Regenerating forests following harvest or fire create browse areas. Wet areas and % overstory canopy cover are other important habitat types. This study was unable to define the association between the above habitat types, and thus cannot prescribe the desired interspersion and juxtaposition of forest cover within the landscape.

4.2 MANAGEMENT IMPLICATIONS

The use of radiotelemetry in large study areas dictates long travel distances and large labour input, thereby limiting the number of relocations and thus sample size. GPS/DGPS technology provides for frequent location captures, reduced error of relocation and enhanced sample size. Habitat use studies that are GPS/DGPS driven, while being higher in capital cost, produce enhanced data with reduced labour and operations cost input. Therefore, future moose habitat use studies should employ GPS/DGPS technology for the accurate and efficient collection of data.

The AVI data used for this research has the potential to assist resource managers in determining baseline information required for effective moose management. Current AVI protocol does not account for the classification of vegetative stands dominated by non-commercial wood fibre. This data deficiency represents a small portion of the overall data set, but its absence significantly limits the use of AVI data for the determination of stand attributes of some important habitat used by moose. The AVI data should be revisited by the Government of Alberta to overcome this data deficiency and provide for enhanced ability to practice sustainable forest management.

The moose of west-central Alberta are forest edge species inhabiting a highly heterogeneous habitat. The heterogeneity of this habitat indicates that moose likely respond to a multitude of environmental factors when selecting habitat. Thus, multivariate statistical techniques should be employed to: 1) cross correlate the influences of various habitat attributes, incorporating both time and spatial scales, and the associated effect on moose habitat selection, and 2) enhance or modify habitat model development.

Edge species are known to be influenced by the proximity of different habitats. Consequently, the value of individual habitat types are influenced by the proximity and value of adjacent habitat areas. Therefore, to enhance moose productivity, land use and forest planning should maintain medium % canopy closure stands in close proximity to wet browse areas.

To further the study of moose habitat use, and define a moose model such that it could be used as a management tool, base file (topography, water courses, rights of way, man induced structures, etc.) information should be combined with AVI data to determine the influence of other factors potentially affecting moose habitat selection. Variables include habitat selection in proximity to roads, seismic lines, pipelines, well sites, batteries, transmission lines, and residential dwellings. To this end, image processing technology should also be incorporated to create a Digital Elevation Model (DEM) for the area. From the DEM, slope, aspect and altitude variables should be classified and analysed in reference to moose relocation data to determine selection. The inclusion of the above variables into analysis will further classify potential habitat, dramatically influence the outcome of habitat supply analysis, and provide managers with a better understanding of the limiting factors affecting moose. To accommodate these additional variables, the number of relocation sites used for analysis would have to be much larger, a factor provided for in the use of GPS/DGPS collars as suggested above. The added cost of modelling analysis would be partially contained within costs associated with enhanced relocation technology.

A moose population management strategy can be simple or complex, but must consider all the various influences on the population. Review of population management efforts identified that fundamental consideration of habitat quality and associated quantity was lacking. In real systems, density-dependent limitations between a moose population and its habitat exist wherein the density of moose affects the habitat and the habitat in turn dictates the welfare of the moose population. Therefore, habitat assessment should be combined with population data to create an effective moose management plan.

LITERATURE CITED

Alberta Fish and Wildlife Division. 1992. 1992 Alberta guide to big game hunting. Department of Forestry, Lands and Wildlife, Fish and Wildlife Division. Publication Number Reference 68. ISBN 0-86499-904-6.

_____. 1993. 1993 Alberta guide to hunting. Department of Environmental Protection, Fish and Wildlife Services. Publication Number Reference 77. ISBN 0-86499-955-0.

_____. 1994. 1994 Alberta guide to hunting. Department of Environmental Protection, Fish and Wildlife Services. Publication Number Reference 83. ISBN 0-7732-1291-4.

Alberta Natural Resources Service. 1995. 1995 Alberta guide to hunting. Alberta Environmental Protection, Natural Resources Service. Publication Number Reference 98. ISBN 0-7732-1430-5.

_____. 1996. 1996 Alberta guide to hunting. Alberta Environmental Protection, Natural Resources Service. Publication Number Reference 103. ISBN 0-7732-5016-6.

_____. 1998a. Northern Moose Management Program progress report, January 1998. Alberta Environmental Protection, Natural Resources Service. Unpublished report.

_____. 1998b. 1998 Alberta guide to hunting regulations. Alberta Environmental Protection, Natural Resources Service. Sports Scene Publications Inc., Edmonton. 116p.

Alldredge, J. R., R. D. Deblinger, and J. Peterson. 1991. Birth and bedsite selection by pronghorns in a sagebrush steppe community. Journal of Wildlife Management 55:222-227.

Alldredge, J. R., and J. T. Ratti. 1986. Comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 50:157-165.

_____, and _____. 1992. Further comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 56:1-9.

Allen, A. W., P. A. Jordan, and J. W. Terrell. 1987. Habitat suitability index models: Moose, Lake Superior Region. U.S. Department of the Interior, Fish and Wildlife Service. Washington, D. C. Biological Report 82(10.155), September, 1987.

_____, J. W. Terrell, W. L. Mangus, and E. L. Lindquist. 1991. Application and partial validation of a habitat model for moose in the Lake Superior Region. Alces 27:50-64.

Aronoff, S. 1993. Geographic information systems: A management perspective. WDL Publications. Ottawa, Ontario. 294pp.

Beckingham, J. D., I. G. W. Corns, and J. H. Archibald. 1996. Field guide to ecosites of west-central Alberta. Natural Resources Canada, Canadian Forest Service, Northwest Region, Northern Forestry Centre, Edmonton, Alberta. Special Report 9.

Berkes, F. 1989. Cooperation from the perspective of human ecology. Pages 70-88 *in* F. Berkes, editor. Common property resources: Ecology and community-based sustainable development. Belhaven Press. London.

Berry, K. H. 1986. Introduction: Development, testing, and application of wildlife-habitat models. Pages 3-4 *in* J. Verner, M. L. Morrison, and C. J. Ralph, editors. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates.

Bonar, R. L. 1985. Moose winter foods in the interior of British Columbia: A preliminary analysis. Alces 21:37-53.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Classification of a technique for analysis of utilization-availability data. Journal of Wildlife Management 48:1050-1053.

Cairns, A. L., and E. S. Telfer. 1980. Habitat use by 4 sympatric ungulates in boreal mixed wood forest. Journal of Wildlife Management 44(4):849-857.

Clark, J. D., J. E. Dunn, and K. G. Smith. 1993a. A multivariate model of female black bear habitat use for a geographic information system. Journal of Wildlife Management 57(3):519-526.

_____, K. G. Smith, and J. E. Dunn. 1993b. Modelling wildlife habitat requirements from environmental and radiotelemetry data using GIS. *in* 7th annual symposium on geographic information systems in forestry, environment and natural resources management. Volume 1. February 15-18, 1993, Vancouver, British Columbia, Canada.

Coady, J. W. 1974. Influence of snow on behaviour of moose. Naturaliste Canada 101:417-436.

Cochran, W. W. 1980. Wildlife telemetry. Pages 507-520 in S. D. Schemnitz, editor. Wildlife management techniques manual. Fourth edition, review. The Wildlife Society, Washington, D. C.

Cox, and D. V. Hinkley. 1974. Theoretical Statistics. Chapman and Hall, London.

Crete, M. 1974. Importance of the logging operations on the winter habitat of moose in southwestern Quebec. Proceedings of the North American Moose Conference Workshop 12:31-53.

Crichton, V. F. 1977. Hecla Island - Manitoba's answer to Isle Royale. Proceedings of the North American Moose Conference Workshop 13:191-199.

Davis, F. W., D. M. Stoms, J. E. Estes, and J. M. Scott. 1990. An information systems approach to the preservation of biological diversity. International Journal of Geographical Information Systems 4:55-78.

Donovan, M. L., D. L. Rabe, and C. E. Olson, JR. 1987. Use of geographic information systems to develop habitat suitability index models. Wildlife Society Bulletin 15:574-579.

Duncan, B. W., D. R. Breininger, P. A. Schmalzer, and V. L. Larson. 1995. Validating a Florida scrub Jay habitat suitability model, using demography data on Kennedy Space Center. Photogrammetric Engineering & Remote Sensing 61(11):1361-1369.

Dunn, P. O. and C. E. Braun. 1986. Summer habitat use by adult female and juvenile sage grouse. Journal of Wildlife Management 50:228-235.

Eastman, D.S., and R. Ritcey. 1987. Moose habitat relationships and management in British Columbia. Swedish Wildlife Research Supplemental 1:101-117.

Edge, W. D., C. L. Marcum, and S. L. Olsen-Edge. 1987. Summer habitat selection by elk in Western Montana: a multivariate approach. Journal of Wildlife Management 51:844-851.

Edwards, T. C. And M. W. Collopy. 1988. Nest tree performance of osprey in Northcentral Florida. Journal of Wildlife Management 52:103-107.

Ellis, R.M. 1986. The role of wildlife habitat research in forest management in Canada. 18th IUFRO World Congress. Division 1, Volume II, Forest Environment and Silviculture. Ljubljana, Yugoslavia.

Friedman, M. 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. Journal of the American Statistical Association 32:675-701.

Giles, R. H. Jr. 1978. Wildlife Management. W. H. Freeman and Company, San Francisco, Calif. 416pp.

Gray, J. A. 1994. Forest valuation methodologies. Proceedings of the Economics of Fire Management Workshop. Winnipeg, Manitoba, November 28-30, 1994.

Grover, K. E. And M. J. Thompson. 1986. Factors influencing spring feeding site selection by elk in Elkhorn, Montana. Journal of Wildlife Management 50:466-470.

Hauge, T. M., and L. B. Keith. 1981. Dynamics of moose populations in northeastern Alberta. Journal of Wildlife Management 45:573-579.

Heisey, D. M. 1986. Analyzing selection experiments with log-linear models. Ecology 66:1744-1748.

Hillman, G. R., J. M. Powell, and R. L. Bothwell. 1978. Hydrometerology of the Hinton-Edsson area, Alberta, 1972-1975. Information Report NOR-X-202, Northern Forest Research Centre, Edmonton, Alberta.

Holroyd, G. L., and K. J. Van Tighem. 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Vol. III. Part A: The wildlife inventory. Canadian Wildlife Service report to Parks Canada, Western Region. March 1983. 444 pp.

Hudgins, J. E., G. L. Storm, and J. S. Wakely. 1985. Local movements and diurnal-habitat selection by male American woodcock in Pennsylvania. Journal of Wildlife Management 49:614-619.

Irwin, L. L. 1985. Foods of moose (Alces alces), and white-tailed deer (Odocoileus virginianus), on a burn in boreal forest. Canadian Field Naturalist 99:240-245.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

_____. 1981. The use and misuse of statistics in wildlife habitat studies. Pages 11-19 in D. E. Capen, editor. The use of multivariate statistics in studies of wildlife habitat. U. S. Forest Service, General Technical Report RM-87.

Joyal,, R. 1987. Moose habitat investigations in Quebec and management implications. Swedish Wildlife Research Supplemental 1:139-152.

Kohler, C. C. And Ney, J. J. 1982. A comparison of methods for quantitative analysis of feeding selection of fishes. Environmental Biology of Fishes 7:363-368.

Krefting, L. W. 1974. Moose distribution and habitat selection in north central North America.

Lagory, M. K., K. E. Lagory, and D. H. Taylor. 1985. Winter browse availability and use by white-tailed deer in southeastern Indiana. Journal of Wildlife Management 49:120-124.

LeResche, R.H. 1974. Moose migrations in North America. Naturaliste Canada 101:393-415.

Lynch, G. M. 1997. Using GPS and GIS to enhance performance of a portable telemetry system. Alces 33:177-180.

_____, and G. E. Shumaker. 1995. GPS and GIS assisted moose surveys. Alces 31:145-151.

_____, and L. E. Morgantini. 1984. Sex and age differential in seasonal home range size of moose in north central Alberta, 1971-1979. Alces 20: 61-78.

Lyon, J. G., J. T. Heinen, R. A. Mead, and N. E. G. Roller. 1987. Spatial data for modelling habitat. Journal of Survey Engineering 113(2):88-100.

Manly, B. F. J., L. L. McDonald, and D. L. Thomas. 1993. Resource selection by animals: Statistical design and analysis for field studies. Chapman & Hall, London.

Marcum, C. L. And D. O. Loftsgaarden. 1980. A non-mapping technique for studying habitat preferences. Journal of Wildlife Management 44:963-968.

Matchett, M. R. 1985. Habitat selection by moose in the Yaak River drainage, northwestern Montana. Alces 21:161-189.

McNicol, J.G., and F.F. Gilbert. 1987. Effect of policies on moose habitat management in Ontario forests. Swedish Wildlife Research Supplemental 1:153-161.

Moss, E.H. 1955. The Vegetation of Alberta. Botany Review 21(9):493-567.

Mytton, W. R., and L. B. Keith. 1981. Dynamics of moose populations near Rochester, Alberta. 1975-1978. Canadian Field Naturalist 95:39-49.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

Neitfeld, M., J. Wild, K. Woolrough, and B. Hoskin. 1984. Wildlife species of Alberta. Alberta Energy and Natural Resources, Fish and Wildlife Division, Wildlife Resources Inventory Unit.

Nowlin, R. A. 1978. Habitat selection and food habits of moose in northeastern Alberta. Proceedings of the North American Moose Conference Workshop 14:178-193.

Ormsby, J. P., and R. S. Lunetta. 1987. Whitetail deer food availability maps from Thematic Mapper data. Photogrammetric Engineering & Remote Sensing 53(8):1081-1085.

Peek, J. M. 1974. On the nature of winter habitats of Shiras moose. Naturaliste Canada 101:131-141.

_____, D. L. Urich, and R. J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildlife Monographs 48. 65 pp.

_____, D. J. Pierce, D. C. Graham, and D. L. Davis. 1987. Moose habitat use and implications for forest management in northcentral Idaho. Swedish Wildlife Research Supplemental 1:195-200.

_____, R. J. Mackie, and G. I. Dusek.. 1992. Over-winter survival strategies of north american cervidae. Alces Supplemental 1:156-161.

Pereira, J. M. C., and R. M. Itami. 1991. GIS-based habitat modeling using logistic multiple regression: A study of the Mt. Graham red squirrel. Photogrammetric Engineering & Remote Sensing 57(11):1475-1486.

Petersen, M. R. 1990. Nest-site selection by emperor geese and crackling Canada geese. Wilson Bulletin 102:413-426.

Pietz, P. J. and J. R. Tester. 1982. Habitat selection by sympatric spruce and ruffed grouse in north central Minnesota. Journal of Wildlife Management 46:391-403.

Pietz, P. J. and J. R. Tester. 1983. Habitat selection by snowshoe hares in north central Minnesota. Journal of Wildlife Management 47:686-696.

Powell, J. M., and D. C. MacIver. 1976. Summer climate of the Hinton-Edson area, west-central Alberta. 1961-1970. Northern Forest Research Centre, Edmonton, Alberta. Information Report NOR-X-149.

_____. 1977. Precipitation climatology of the Eastern Slopes area of Alberta. Pp. 187-204. Alberta Watershed Research Program Symposium Proceedings, 1977. Compiled by R. H. Swanson and P. A. Logan. Northern Forest Research Centre, Edmonton, Alberta. Information Report NOR-X-176: 187-204.

Prescott, W. H. 1974. Interrelationships of moose and deer of the genus Odocoileus. Naturaliste Canada 101:493-504.

Quade, D. 1979. Using weighted rankings in the analysis of complete blocks with additive block effects. Journal of the American Statistical Association 74:680-683.

Quinlan, R. W., W. A. Hunt, K. Wilson, and J. Kerr. 1990. Habitat requirements of selected wildlife species in the Weldwood Forest Management Agreement Area. A final report submitted to the Weldwood Forest Management Area Integrated Resource Management Steering Committee. 189 p.

Raley, C. M. And S. H. Anderson. 1990. Availability and use of arthropod food resources by Wilson's warblers and Lincoln's sparrows in southeastern Wyoming. Condor 92:141-150.

Renecker, L. A., R. J. Hudson, M. K. Christopher, and C. Arelis. 1978. Effect of posture, feeding, low temperature and wind on energy expenditures of moose calves. Proceedings of the North American Moose Conference Workshop 14:126-140.

Risenhoover, K. L. 1989. Composition and quality of moose winter diets in interior Alaska. Journal of Wildlife Management 53(3):568-577.

Rexstad, E. A., D. D. Miller, C. H. Flather, E. M. Anderson, W. W. Hupp, and D. R. Anderson. 1988. Questionable multivariate statistical inference in wildlife habitat and community studies. Journal of Wildlife Management 52:794-798.

______, ______, ______, ______, ______, and ______. 1990. Questionable multivariate statistical inference in wildlife habitat and community studies: a reply. Journal of Wildlife Management 54:189-193

Rolley, R. E., and L. B. Keith. 1980. Moose population dynamics and winter habitat use at Rochester, Alberta. 1965-1979. Canadian Field Naturalist 94:9-18.

Romito, T., K. Smith, B. Beck, J. Beck, M. Todd, R. Bonar, and R. Quinlan. 1995. Moose (*Alces alces*) winter habitat: Draft habitat suitability index (HSI) model. Unpublished Report.

Roscoe, J. T., and J. A. Byars. 1971. An investigation of the restraints with respect to sample size commonly imposed on the use of the chi-squared statistic. Journal of the American Statistical Association 66(336):755-759.

Schamberger, J. L., and L. J. O'Neil. 1986. Concepts and constraints of habitat-model testing. Pp. 177-182. *in* J. Verner, M. Morrison, and C. J. Ralph, editors. Wildlife 2000: Modelling habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison.

Slauson, W. L. 1988. Graphical and statistical procedures for comparing habitat suitability data. U. S. Department of the Interior, Fish and Wildlife Service. Biological Report 89(6). 57p.

Smith, K. 1982. An evaluation of the impact of petroleum activity on ungulate distribution in TWP. 52 - RGE. 14 - W5M. Alberta Energy & Natural Resources, Fish and Wildlife Division, Edson, Alberta. Unpublished Report.

Soper, J. D. 1964. The mammals of Alberta. The Department of Industry and Development, Government of Alberta. 402pp.

Stauffer, D. F. And S. R. Peterson. 1985. Ruffed and blue grouse habitat use in southeastern Idaho. Journal of Wildlife Management 49:459-466.

Stelfox, J. G. 1974. Browse production and utilization during 17 years of regeneration. Proceedings of the North American Moose Conference Workshop 10:135-144.

_____. 1984. Effects of clear-cut logging and scarification on wildlife habitats in west-central Alberta. Canadian Wildlife Service Report. September 1984. 176 pp.

_____. 1988. Forest succession and wildlife abundance following clear-cut logging in west-central Alberta. Government of Alberta technical report. 152pp.

Stiehl, R. B. (ed.), 1995. Habitat Evaluation Procedures Workbook, U.S. National Biological Service, Mid-continent Ecological Science Center, Fort Collins, Colorado.

Strong, W. L., and K. R. Leggat. 1981. Ecoregions of Alberta. Alberta Energy and Natural Resources, Resource Evaluation and Planning Division, Edmonton, Alberta. Technical Report T/4. 64 pp.

Talent, L. G., G. L. Krapu, and R. L. Jarvis. 1982. Habitat use by mallard broods in south central North Dakota. Journal of Wildlife Management 46:629-635.

Telfer, E. S. 1978. Winter habitat selection by moose and white-tailed deer. Journal of Wildlife Management 34:553-559.

Telfer, E. S. 1978. Habitat requirements of moose - the principal Taiga range animal. Proceedings of the 1st International Range Congress. Denver, CO.

_____. 1984. Circumpolar distribution and habitat requirements of moose (*Alces alces*). Pages 145-182 *in* R. Olson, R. Hastins, and F. Geddes, editors, Northern Ecology and Resource Management. University of Alberta Press. 438 pp.

Thomas, D. L., and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322-330.

Thomasma, L. E., T. D. Drummer, and R. O. Peterson. 1991. Testing the Habitat Suitability Index for the fisher. Wildlife Society Bulletin 19:291-297.

Thompson, I. D., and D. L. Euler. 1987. Moose habitat in Ontario: A decade of change in perception. Swedish Wildlife Research Supplemental 1:181-194.

Timmermann, H. R., M. E. Buss. 1995. The status and management of moose in North America - Early 1990's. Alces 31:1-14.

Timmermann, H. R., and J. G. McNicol. 1988. Moose habitat needs. pp. 238-245. *in* Forestry and wildlife management in the boreal forest. An Ontario Workshop. Thunder Bay, Ontario. December 7-9, 1987. Ontario Ministry of Natural Resources. Forestry Chronicle June 1988.

Tomm, H. O., J. A. Beck and R. J. Hudson. 1981. Responses of wild ungulates to logging practices in Alberta. Canadian Journal of Forest Research 11:606-614.

Trottier, G. C. 1981. Beaked hazelnut - a key browse species for moose in the boreal forest region of western Canada? Alces 17:257-281.

US Fish and Wildlife Services, 1980. Habitat Evaluation Procedures (HEP): ESM 102. Division of Ecological Services, Department of the Interior, Washington, DC. 1980. Release 2-80.

Westworth, D. A., L. M. Brusnyk, and G. R. Burns. 1984. Impact on wildlife of short-rotation management of boreal aspen stands. Unpublished Report for Canadian Forestry Service, Western & Northern Region, Edmonton by D. A. Westworth & Associates Ltd. Edmonton.

White, G. C., and R. A. Garrott. 1986. Effects of biotelemetry triangulation error on detecting habitat selection. Journal of Wildlife Management 50:509-513.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press. San Diego. 383 pp.

Wildlife Working Group. 1991. Guidelines for the integration of wildlife and habitat evaluations with ecological land survey. Wildlife Working Group of the Canada Committee on Ecological Land

Classification. Edited by H. A. Stelfox, G. R. Ironside, and J. L. Kansas. Ottawa, Ontario: Wildlife Habitat Canada and Canadian Wildlife Service (Environment Canada). 107p.

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APPENDIX I:

Temperature and snow depth data collected by Environment Canada for the Shiningbank and Entrance monitoring stations, January - March 1997.

Shiningbank **January 1997**

Regional Identifier: 215AL **Elevation: 829m**
Environment Canada Identifier: 3065885

DAY	TEMPERATURE			TOTAL			SNOW
	MAX	MIN	MEAN	RAIN	SNOW	PCP	GND (cm)
1	-17.0	-26.0	-21.5				45
2	-12.0	-24.0	-18.0				45
3	-16.0	-23.0	-19.5				44
4	-11.0	-29.0	-20.0				44
5	-2.0	-27.0	-14.5				44
6	1.0	-23.0	-11.0		T	T	42
7	4.0	-11.0	-3.5		T	T	41
8	-11.0	-14.0	-12.5		4.0	4.0	41
9	-20.0	-24.0	-22.0		1.0	1.0	41
10	-19.0	-25.0	-22.0		T	T	42
11	-20.0	-38.0	-29.0				42
12	-12.0	-33.0	-22.0				42
13	1.0	-30.0	-14.5				42
14	2.0	-21.0	-9.5		T	T	42
15	-13.0	-15.0	-14.0		1.0	1.0	42
16	-11.0	-30.0	-20.5	T		T	43
17	2.5	-26.0	-11.8	T		T	43
18	4.0	-15.0	-5.5				42
19	2.0	-5.0	-1.5	T		T	41
20	-2.0	-5.0	-3.5		5.0	5.0	41
21	-11.0	-15.0	-13.0		9.0	9.0	46
22	-13.0	-16.0	-14.5		3.0	3.0	55
23	-23.0	-25.0	-24.0		2.0	2.0	55
24	-23.0	-31.0	-27.0				54
25	-24.0	-46.5	-35.3				54
26	-22.0	-47.0	-34.5				53
27	-20.0	-40.0	-30.0		1.0	1.0	53
28	1.5	-29.0	-13.8				53
29	5.0	-22.0	-8.5	T		T	53
30	10.0	-7.0	1.5				51
31	6.5	0.0	3.3				49
TOTAL	**-262.5**	**-722.5**		**TR**	**26.0**	**26.0**	
MEAN	**-8.5**	**-23.3**	**-15.9**				

EXTREME MAXIMUM TEMPERATURE WAS 10.0 on day 30
EXTREME MANIMUM TEMPERATURE WAS -47.0 ON DAT 26

HEATING DEGREE-DAYS 1050.6
FREEZING DEGREE-DAYS 497.4
THAWING DEGREE-DAYS 4.8

HIGHEST RAINFALL WAS TR ON DAY 29
HIGHEST SNOWFALL WAS 9.0 ON DAY 21

Shiningbank **February 1997**
Regional Identifier: 215AL **Elevation: 829m**
Environment Canada Identifier: 3065885

DAY	TEMPERATURE			TOTAL			SNOW
	MAX	MIN	MEAN	RAIN	SNOW	PCP	GND (cm)
1	5.0	-15.0	-5.0				49
2	5.0	-15.0	-5.0				49
3	2.5	-14.0	-5.8				49
4	2.0	-24.0	-11.0				49
5	3.0	-23.0	-10.0				49
6	2.0	-21.0	-9.5				49
7	7.0	-18.0	-5.5				49
8	4.0	-15.0	-5.5				49
9	2.0	-15.0	-6.5				48
10	-0.5	-20.0	-10.3				48
11	-6.0	-27.0	-16.5				48
12	2.0	-23.0	-10.5		T	T	48
13	-1.0	-15.5	-8.3		2.0	2.0	48
14	1.0	-15.0	-7.0		6.0	6.0	48
15	-5.0	-11.0	-8.0		5.0	5.0	52
16	5.0	-11.0	-3.0				57
17	-5.0	-7.0	-6.0		6.0	6.0	57
18	4.0	-15.0	-5.5				60
19	6.5	-12.0	-2.8				59
20	4.0	-15.0	-5.5		T	T	58
21	3.5	-10.0	-3.3				57
22	7.0	-12.0	-2.5				57
23	9.0	-12.0	-1.5				57
24	13.5	-2.0	5.8				56
25	4.0	-3.0	0.5				51
26	3.0	-15.0	-6.0		3.0	3.0	50
27	-2.0	-[illegible].0	-5.5		1.0	1.0	51
28	-1.0	-22.0	-11.5		T	T	51
TOTAL	**74.5**	**-416.5**		**0.0**	**23.0**	**23.0**	
MEAN	**2.7**	**-14.9**	**-6.1**				

EXTREME MAXIMUM TEMPERATURE WAS 13.5 on day 24
EXTREME MANIMUM TEMPERATURE WAS -27.0 ON DAT 11

HEATING DEGREE-DAYS 675.2
GROWING DEGREE-DAYS 0.8
FREEZING DEGREE-DAYS 177.5
THAWING DEGREE-DAYS 6.3

HIGHEST SNOWFALL WAS 6.0 ON DAY 14,17

Shiningbank **March 1997**
Regional Identifier: 215AL **Elevation: 829m**
Environment Canada Identifier: 3065885

DAY	TEMPERATURE				TOTAL		SNOW
	MAX	MIN	MEAN	RAIN	SNOW	PCP	GND (cm)
1	-11.0	-17.0	-14.0		10.0	10.0	51
2	-12.0	-17.0	-14.5		7.0	7.0	61
3	-12.0	-17.0	-14.5		2.0	2.0	67
4	-10.0	-19.0	-14.5		T	T	67
5	-6.0	-23.0	-14.5				66
6	-3.0	-22.0	-12.5				65
7	-1.0	-25.0	-13.0		1.0	1.0	65
8	4.0	-16.0	-6.0				64
9	2.0	-10.0	-4.0				62
10	2.0	-11.0	-4.5				61
11	-7.0	-12.0	-9.5		6.0	6.0	61
12	-11.0	-15.0	-13.0		2.0	2.0	65
13	-9.0	-29.0	-19.0				63
14	-7.0	-33.0	-20.0				62
15	-5.0	-30.0	-17.5				62
16	-3.0	-24.0	-13.5				62
17	-3.0	-22.0	-12.5				62
18	10.0	-12.0	-1.0	T		T	62
19	11.0	-8.0	1.5	T		T	61
20	5.0	1.0	3.0	3.2		3.2	57
21	7.0	-6.0	0.5				56
22	9.0	-7.0	1.0				55
23	5.0	-3.0	1.0	1.4		1.4	54
24	6.0	-7.0	-0.5				52
25	12.0	-5.0	3.5	T		T	47
26	4.0	-1.0	1.5				44
27	8.0	-7.0	0.5				42
28	7.0	-4.0	1.5				38
29	8.5	-9.0	-0.3				38
30	11.0	-7.0	2.0				34
31	10.0	-3.0	3.5				34
TOTAL	**21.5**	**-420.0**		**4.6**	**28.0**	**32.6**	
MEAN	**0.7**	**-13.5**	**-6.4**				

EXTREME MAXIMUM TEMPERATURE WAS 12.0 on day 25
EXTREME MANIMUM TEMPERATURE WAS -33.0 ON DAT 14

HEATING DEGREE-DAYS 757.3
FREEZING DEGREE-DAYS 218.8
THAWING DEGREE-DAYS 19.5

HIGHEST RAINFALL WAS 3.2 ON DAY 20
HIGHEST SNOWFALL WAS 10.0 ON DAY 1

Entrance **January 1997**
Regional Identifier: 140AL **Elevation: 1003m**
Environment Canada Identifier: 3062440

DAY	TEMPERATURE			TOTAL			SNOW
	MAX	MIN	MEAN	RAIN	SNOW	PCP	GND (cm)
1	-10.0	-22.0	-16.0				32
2	-9.0	-18.0	-13.5				32
3	-12.0	-24.0	-18.0				M
4	-3.0	-26.0	-14.5				M
5	-1.0	-26.0	-13.5				M
6	2.0	-6.0	-2.0				M
7	3.0	-2.5	0.3				M
8	-7.0	-13.0	-10.0		9.2	9.2	30
9	-16.0	-18.0	-17.0		14.2	14.2	33
10	-18.0E	-20.0	-19.0				50
11	-15.0	-20.5	-17.8				M
12	-8.5	-28.0	-18.3				46
13	-8.0	-24.0	-16.0				44
14	-2.0	-21.0	-11.5		T	T	M
15	-8.0	-19.0	-13.5		0.2	0.2	40
16	6.0	-30.0	-12.0				43
17	7.0	-10.0	-1.5				34
18	5.0	-6.0	-0.5				M
19	2.0	-4.0	-1.0				M
20	2.0	-4.0	-1.0		16.8	16.8	M
21	-10.5	-13.0	-11.8		0.8	0.8	49
22	-13.0	-21.0	-17.0		2.8	2.8	45
23	-21.0	-25.5	-23.3		0.8	0.8	49
24	-26.0	-38.5	-32.3				48
25	-28.5	-48.0	-38.3				M
26	-21.5	-45.0	-33.3				M
27	-18.0	-36.0	-27.0				M
28	5.5	-22.5	-8.5				45
29	8.0	-1.0	3.5				45
30	8.0	3.0	5.5				45
31	7.0	0.0	3.5				45
TOTAL	**-200.5**	**589.5**		**0.0**	**44.8**	**44.8**	
MEAN	**-6.5**	**-19.0**	**-12.8**				

EXTREME MAXIMUM TEMPERATURE WAS 8.0 on day 29,30
EXTREME MANIMUM TEMPERATURE WAS -48.0 ON DAT 25

HEATING DEGREE-DAYS 953.3
GROWING DEGREE-DAYS 0.5
FREEZING DEGREE-DAYS 408.1
THAWING DEGREE-DAYS 12.8

HIGHEST SNOWFALL WAS 16.8 ON DAY 20

Entrance **February 1997**
Regional Identifier: 140AL **Elevation: 1003m**
Environment Canada Identifier: 3062440

DAY	TEMPERATURE				TOTAL		SNOW
	MAX	MIN	MEAN	RAIN	SNOW	PCP	GND (cm)
1	4.0	-12.5	-4.3				M
2	4.0	-8.0	-2.0				M
3	2.0	-15.0	-6.5				M
4	3.0	-18.5	-7.8				M
5	0.0	-18.0	-9.0				M
6	3.0	-21.0	-9.0				M
7	3.0	-17.0E	-7.0				40
8	2.0E	-16.0E	-7.0				M
9	0.0	-14.0	-7.0				M
10	0.0	-16.0	-8.0				M
11	-4.0	-25.0	-14.5				M
12	4.0	-11.5	-3.8				M
13	3.0	-4.0	-0.5				39
14	6.5	-5.5	0.5		T	T	M
15	7.0	-6.0	0.5				M
16	15.5	7.0	11.3		2.0	2.0	M
17	-3.5	-5.0	-4.3		0.8	0.8	M
18	6.0	-13.0	-3.5				36
19	4.0	-12.5	-4.3				35
20	6.0	-10.0	-2.0				M
21	5.0	-12.0	-3.5				M
22	11.0	-11.0	0.0				M
23	11.0	-2.0	4.5				M
24	13.5	-3.0	5.3				M
25	4.0	-4.0	0.0				M
26	4.0	-6.0	-1.0		0.2	0.2	M
27	-1.5	-7.0	-4.3				M
28	1.0	-17.0	-8.0		9.8	9.8	M
TOTAL	**113.5**	**303.5**		**0.0**	**12.8**	**12.8**	
MEAN	**4.1**	**-10.8**	**-3.4**				

EXTREME MAXIMUM TEMPERATURE WAS 15.5 on day 16
EXTREME MANIMUM TEMPERATURE WAS -25.0 ON DAT 11

HEATING DEGREE-DAYS 599.2
CORN HEAT UNITS 1.3
GROWING DEGREE-DAYS 6.6
FREEZING DEGREE-DAYS 117.3
THAWING DEGREE-DAYS 22.1

HIGHEST SNOWFALL WAS 9.8 ON DAY 28

Entrance | **March 1997**
Regional Identifier: 140AL | **Elevation: 1003m**
Environment Canada Identifier: 3062440

DAY	TEMPERATURE			TOTAL			SNOW
	MAX	MIN	MEAN	RAIN	SNOW	PCP	GND (cm)
1	-9.0	-13.5	-11.3		5.4	5.4	M
2	-10.5	-16.0	-13.3		2.8	2.8	33
3	-10.0	-18.0	-14.0		2.2	2.2	35
4	-8.0	-18.5	-13.3				35
5	-2.0	-23.0	-12.5				35E
6	3.0E	-20.0	-8.5				34
7	8.0	-14.5E	-3.3				33E
8	3.0	-11.0E	-4.0				33
9	6.0	-7.5	-0.8				M
10	5.0	-2.0	1.5		4.0	4.0	M
11	-6.5	-11.0	-8.8		3.4	3.4	M
12	-9.5	-16.0	-12.8		1.8	1.8	M
13	-10.0	-25.5	-17.8		T	T	39
14	-3.0	-23.0	-13.0				38
15	-1.0	-29.0	-15.0		T	T	38E
16	-1.5	-19.0	-10.3				37
17	6.0	-19.5	-6.8				35
18	10.0	-5.0E	2.5				31E
19	13.0	0.0	6.5				26
20	8.0	-1.0	3.5				24E
21	8.0	-7.0	0.5				23
22	8.0E	-5.0	1.5				21E
23	6.0	-3.0	1.5		0.4	0.4	20E
24	8.0	-9.0	-0.5				20E
25	12.0	4.0	8.0		1.2	1.2	19
26	9.0	-3.0	3.0		2.0E	2.0E	M
27	9.0	-9.0	0.0				M
28	7.0	-5.0	1.0				M
29	9.5	-5.5	2.0				M
30	10.5	-2.0	4.3				M
31	10.0	-3.0E	3.5	T	T	T	M
TOTAL	**88.0**	**-340.5**		TR	**23.2**	**23.2**	
MEAN	**2.8**	**-11.0**	**-4.1**				

EXTREME MAXIMUM TEMPERATURE WAS 13.0 on day 19
EXTREME MANIMUM TEMPERATURE WAS -29.0 ON DAT 15

HEATING DEGREE-DAYS 684.7
GROWING DEGREE-DAYS 4.5
FREEZING DEGREE-DAYS 166.0
THAWING DEGREE-DAYS 39.3

HIGHEST RAINFALL WAS TR ON DAY 31
HIGHEST SNOWFALL WAS 5.4 ON DAY 1

APPENDIX II:

Definition of AVI data used for analysis of moose habitat selection in west-central Alberta, January - March 1997.

AVI FORST POLYGON ATTRIBUTES

- polygon area (km^2)
- stand moisture regime classification
  - ⇒ Dry (d)
  - ⇒ Mesic (m)
  - ⇒ Wet (w)
  - ⇒ Aquatic (a)
  - ⇒ No tree species (o)
- stand % canopy closure classification
  - ⇒ 0 - 5% (O)
  - ⇒ 6 - 30% (A)
  - ⇒ 31 - 50% (B)
  - ⇒ 51 - 70% (C)
  - ⇒ 71 - 100% (D)
- dominant overstory species
  - ⇒ White spruce (*Picea glauca*) (Sw)
  - ⇒ Black spruce (*Picea mariana*) (Sb)
  - ⇒ Undifferentiated pine (*Pinus spp.*) (P). May include Lodgepole pine (*Pinus contorta*), Jack pine (*Pinus banksiana*), White bark pine (*Pinus albicaulis*) and/or Limber pine (*Pinus flexilis*)
  - ⇒ Lodgepole pine (*Pinus contorta*) (Pl)
  - ⇒ Balsam fir (*Abies balsamea*) (Fb)
  - ⇒ Tamarak (*Larix laricana*) & Western larch (*Larix occidentalis*) (Lt)
  - ⇒ Trembling aspen (*Populus tremuloides*) (Aw)
  - ⇒ Balsam poplar (*Populus balsamifera*) (Pb)

APPENDIX III:

Moose habitat supply analysis for the study area in west-central Alberta, January - March 1997.

SCOPE AND MODEL APPLICABILITY

Length Of Study.—

Moose capture site collection began in January 1997 and continued until March 1997.

Number Of Individuals.—

During survey, 931 relocation sites were recorded on 19 individual cows of the population

Geographic Area.—

The area of study includes digitised landscape information within WMU 346 of the Edson Forest Region of Alberta; areas represented by private land as well as Forest Management Agreements (FMA) held by Weldwood of Canada Ltd. (WC), Weyerhaeuser Canada Ltd., and Sundance Forest Industries Ltd. The area is characterised by lodgepole pine, black spruce, white spruce, aspen and mixedwood stands, classified as the Upper and Lower Foothills Natural Subregions (Beckingham et al., 1996) of west-central Alberta

Season.—

This model evaluates winter (December to mid-May) habitat use and availability in relation to a managed forest landscape.

Cover Types.—

This model produces positive HSI values when applied to lodgepole pine, black spruce, white spruce, aspen and mixedwood stands of the Upper and Lower Foothills Natural Subregions of Alberta (Beckingham et al. 1996). Cover type classification follows the Alberta Vegetative Index (AVI) protocol version 2.1 (Government of Alberta 1994). Refer to Appendix II for a guide to AVI parameters used in this research.

Minimum Habitat Area.—

Minimum habitat area is defined as the minimum amount of contiguous habitat with which the model will be applied. The resolution provided by the digital data base is area dependant with WC = < 100 km^2 and Government of Alberta = 200 km^2, representing the minimum habitat area for model application.

Model Output.—

The model will produce habitat units based on female moose habitat preferences for each stand area based on HSI value and stand area. The performance measure for the model is a ratio of habitat use/non-use measured in km^2.

Number of Animals/Perfect km^2.—

Data for the determination of number of animals/perfect km^2 was unavailable to this study.

Verification Level.—

Moose relocations and AVI data were used for determination of moose habitat use/non-use. This model was developed by Mr. Jason R. Kerr as partial fulfilment of the Degree Masters of Natural Resources Management. This manuscript was reviewed by Practicum Committee members Dr. R. Stiehl (US Geological Survey Centre), Mr. R. Bonar (Weldwood of Canada Ltd., Hinton Division), Dr. R. Baydack (University of Manitoba, Natural Resources Institute) and Dr. N. Kenkel (University of Manitoba, Department of Botany).

Potential Application Of Results.—

GIS mapping of moose habitat and overall habitat supply of the region in relation to forest structure will provide managers with an evaluation of base-line moose habitat conditions. The results of this research may be used for HSI model refinement and assist co-operating stakeholders in defining an integrated resource management strategy.

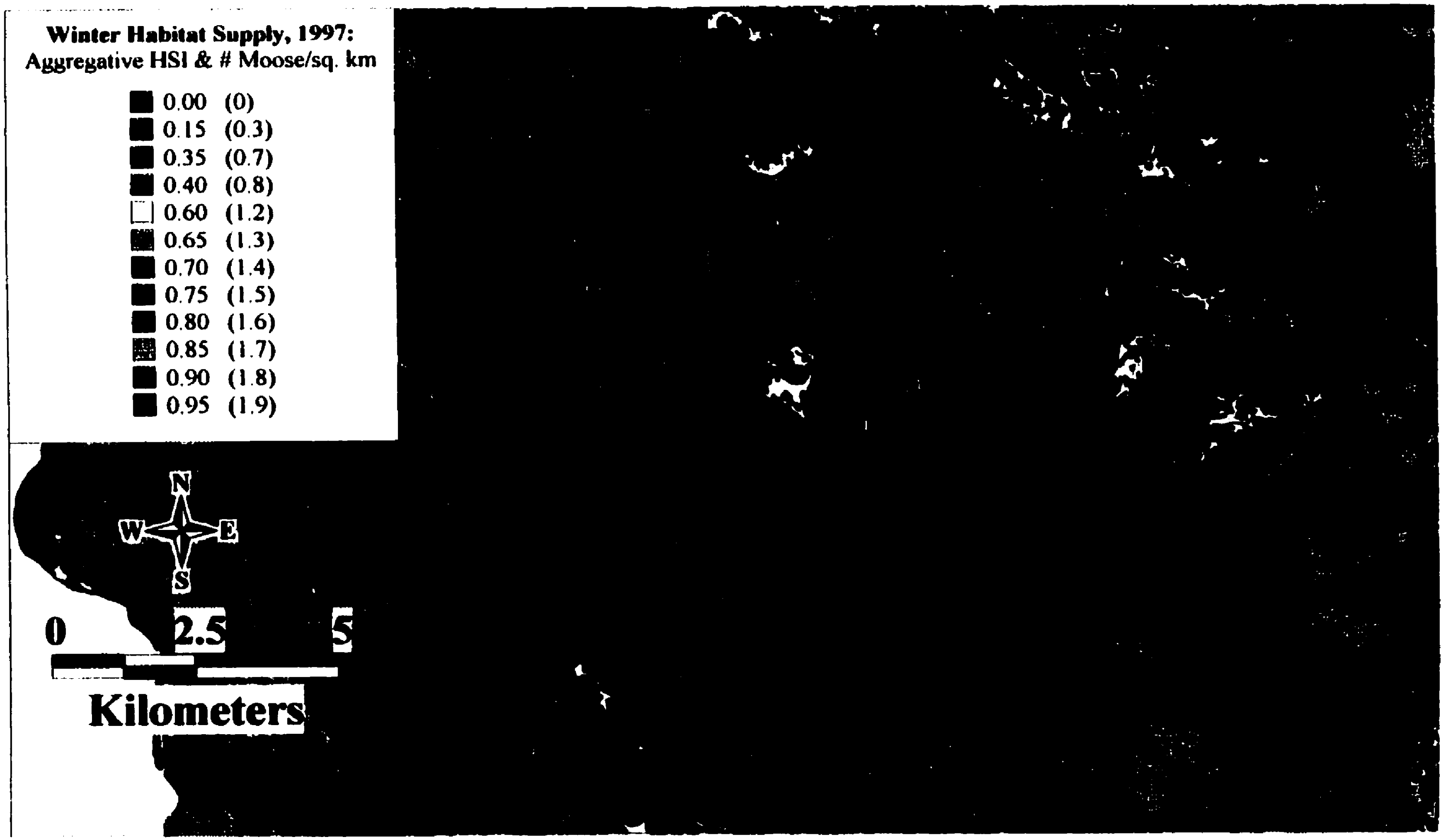

Figure 3.3a: Thematic maps a-j depict aggregative geometric mean HSI-based habitat assessment for forest stands in west-central Alberta, winter 1997. Habitat attributes included AVI dominant overstory species composition, moisture regime and % canopy closure. Order of figures from a-j, beginning in the north-west is west - east, north - south.

Figure 3.3b: Thematic model for moose habitat quality demonstrating the effect of land use practice on moose habitat quality

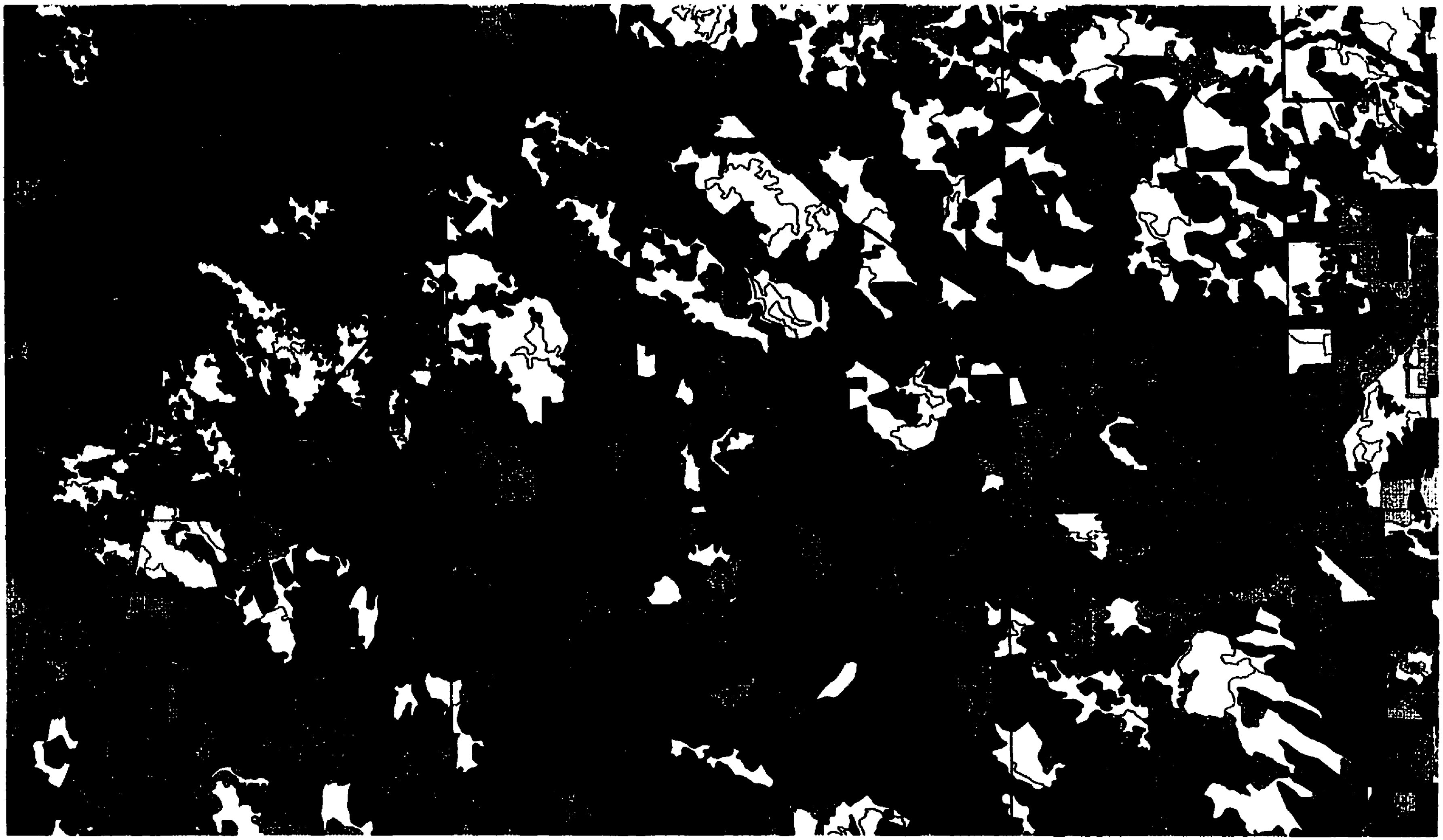

Figure 3.3c: North-east central quadrant of the study area demonstrating differences in land use practice and digital data resolution.

Figure 3.3d: Thematic HSI for the north-east quadrant of the study area.

Figure 3.3e: Thematic HSI demonstrating transition between agriculture and forest resource management, and data resolution variance. This figure represents the west-central quadrant of the study area.

Figure 3.3f: Thematic HSI demonstrating transition between agriculture and forest resource management, and data resolution variance.

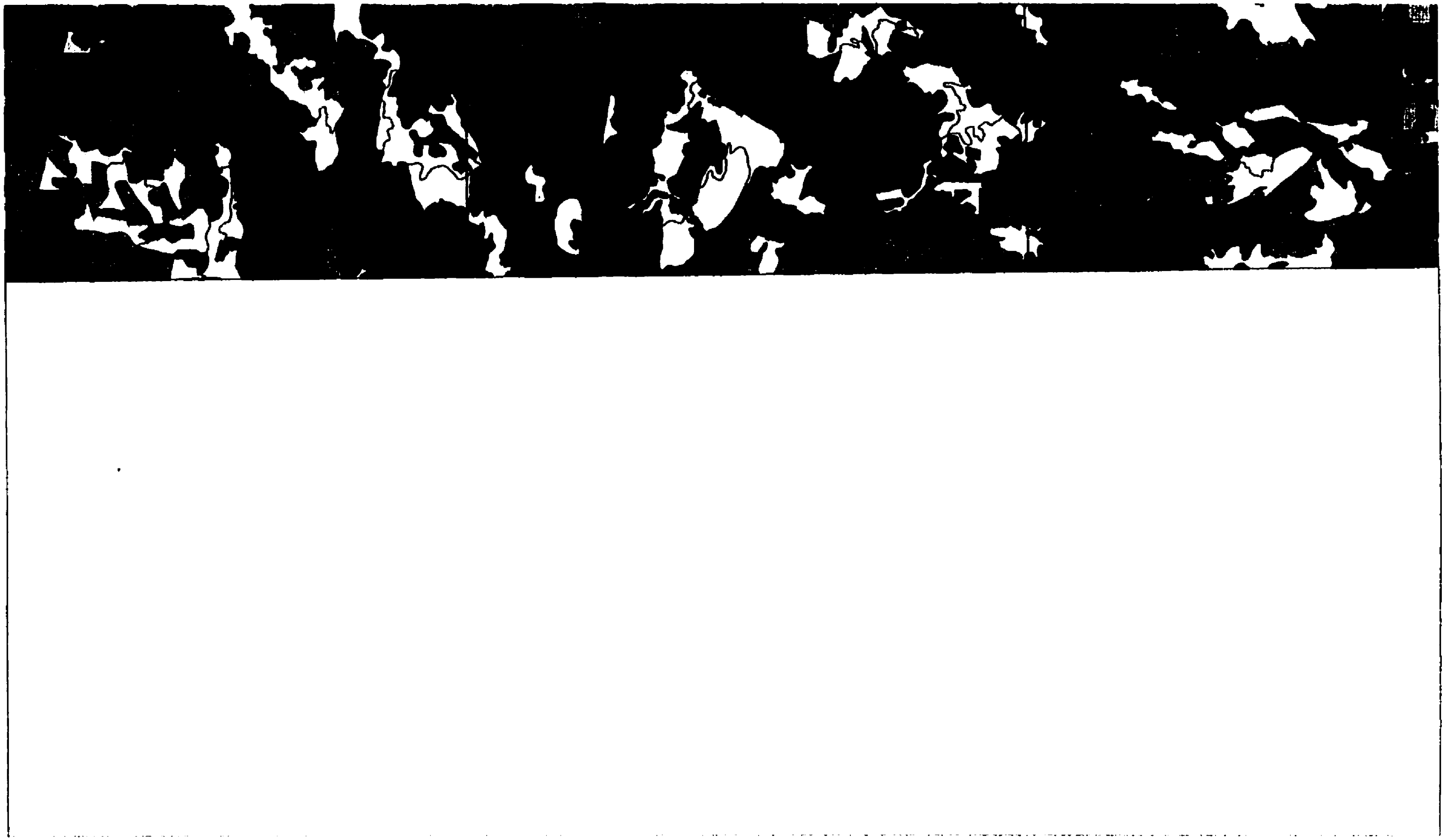

Figure 3.3g: Aggregated geometric mean habitat analysis for the south-east central quadrant of the study area.

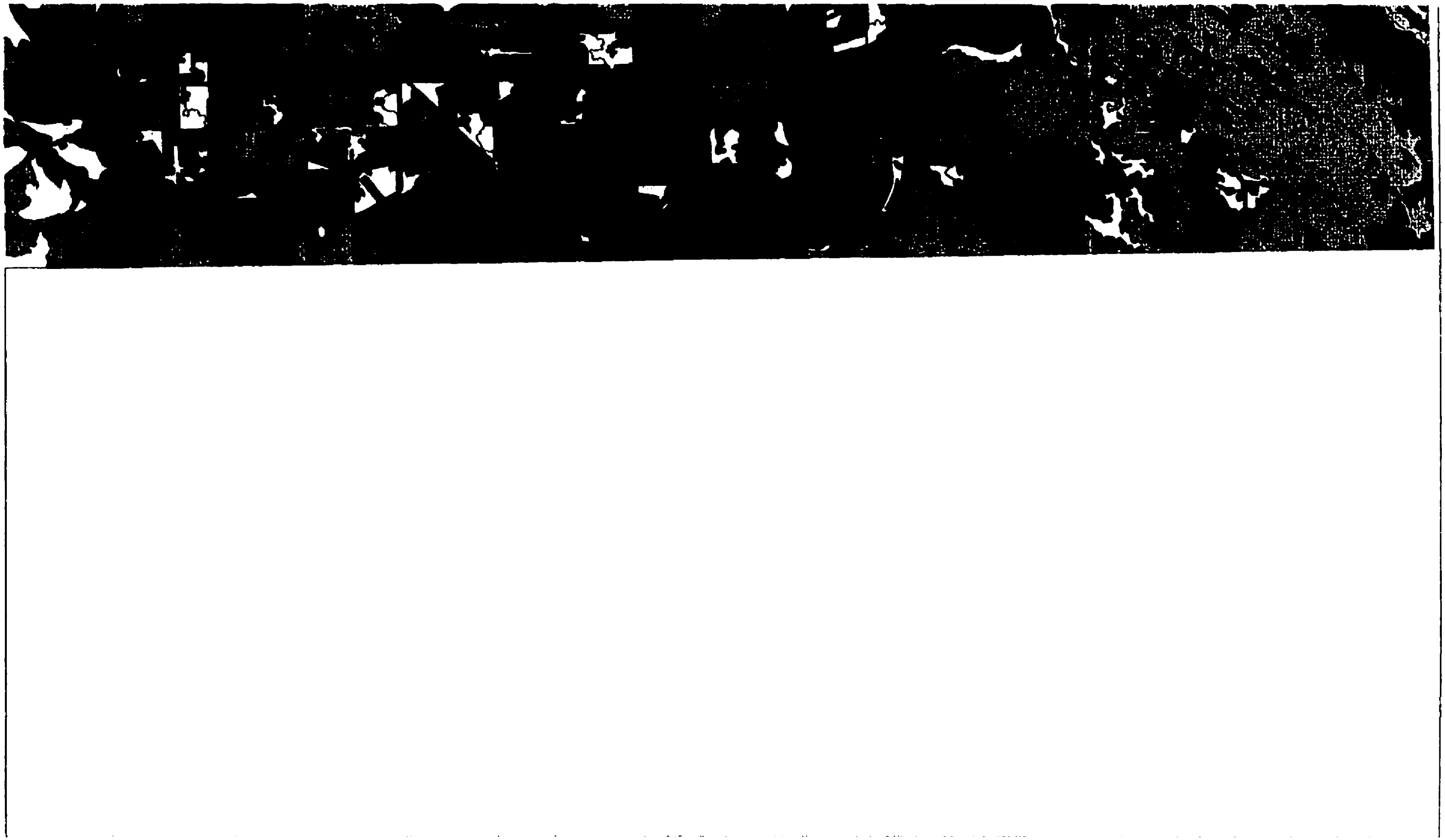

Figure 3.3h: Thematic HSI for south-east corner of study area within WMU 346.

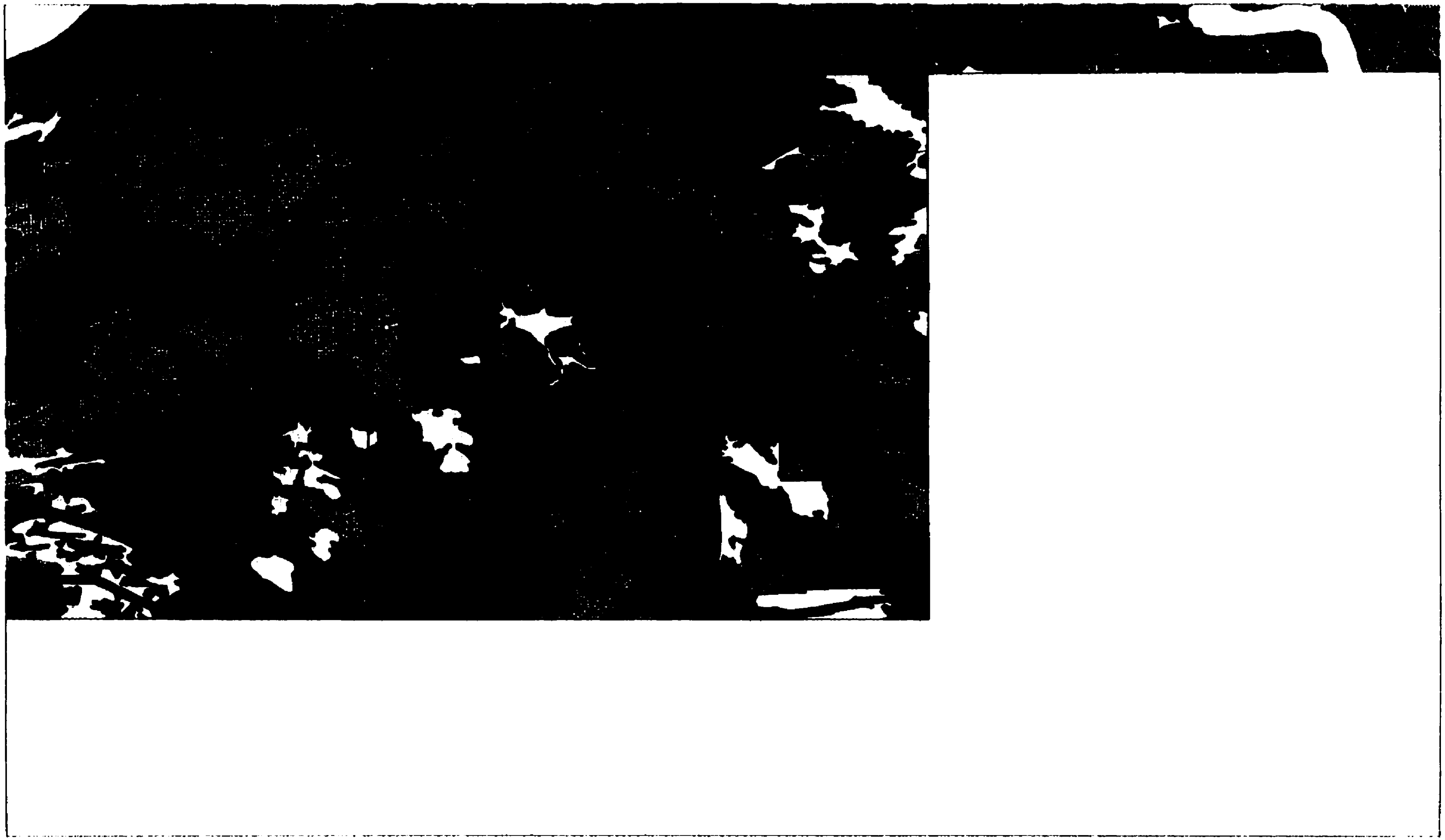

Figure 3.3i: Thematic HSI demonstrating transition between agriculture and forest resource management, and data resolution variance. The Athabasca River is positioned in the north-west corner.

Figure 3.3j: Thematic representation of habitat quality and quantity for the south-central quadrant of the study area.