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Assessing Risks to Indigenous and Non-Indigenous Values in Forest Management

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Abstract

The impact of integrating non-fibre values in forest management has been of issue of late with the awareness that conventional forest management plans may not lead to healthy, sustainable forests. The development of co-management agreements between forestry companies and aboriginal communities has heightened the need for research whose directive is to investigate the compatibility of traditional and non-fibre forest management values. Specifically, although parties are eager to work together, aboriginal people feel their values are not recognized and included in forest management plans and forestry companies fear incorporating non-fibre values will affect the profit generated from operations. In northern Alberta, Little Red River Tall Cree First Nations and/or Tolko Industries – High Level manage six forest management units. We analyzed the compatibility of indigenous values, identified by the community members of Little Red River Tall Cree First Nations as moose population size and caribou habitat suitability, and non-indigenous values, identified by Tolko Industries – High Level as profit generated from logging operations, in forest management. Caribou and moose habitat suitability maps were generated for the forest management units and models representing the relationship between the amount of suitable habitat and population size were developed. A variety of different forest management plans were investigated to determine the effect of various logging operations on indigenous and non-indigenous values and thus to determine the relationships that exist between the values of interest. We found (i) regardless of the value endpoints, moose and caribou population size will likely decrease if logging operations continue in the area; (ii) caribou habitat suitability and profit have a negative relationship and are not compatible in forest management;

and(iii) moose population size and profit have either no relationship or have a slightly positive relationship. Additional analysis should be carried out to (i) quantify the relationship between caribou habitat suitability and population size; and (ii) strengthen our conclusion regarding the relationship between profit and moose population size.

Abstract

L'impact des valeurs d'intégration de non-fibre dans la gestion de forêt a été d'issue de tard avec la conscience que les plans traditionnels de gestion de forêt peuvent ne pas mener aux forêts saines et soutenables. Le développement des accords de Co-gestion entre les compagnies de sylviculture et les communautés indigènes a intensifié le besoin de recherche dont la directive doit étudier la compatibilité des valeurs traditionnelles et de non-fibre de forêt de gestion. Spécifiquement, bien que les parties soient désireuses de travailler ensemble, la sensation de peuples indigènes leurs valeurs ne sont pas identifiées et inclus aux plans de gestion de forêt et aux compagnies de sylviculture que les valeurs d'incorporation de non-fibre de crainte affecteront le bénéfice s'est produit des opérations. Dans Alberta nordique, peu de premières nations de cree grand rouge de fleuve et/ou industries de Tolko - le niveau élevé contrôlent six unités de gestion de forêt. Nous avons analysé la compatibilité des valeurs indigènes, identifiée par membre de la Communauté de peu de premières nations de cree grand rouge de fleuve comme taille de population d'orignaux et convenance d'habitat de caribou, et des valeurs non-indigènes, identifiées par Tolko Industries - niveau élevé comme bénéfice produit des opérations de notation, dans la gestion de forêt. Des cartes de convenance d'habitat de caribou et d'orignaux ont été produites pour les unités de gestion de forêt et des modèles représentant le rapport entre la quantité d'habitat approprié et la taille de population ont été développés. Une variété de différents plans de gestion de forêt ont été étudiées pour déterminer l'effet de diverses opérations de notation sur des valeurs indigènes et non-indigènes et pour déterminer ainsi les rapports qui existent entre les valeurs d'intérêt. Nous avons trouvé (i) indépendamment des points finaux de valeur, orignal et la taille de

population de caribou diminuera probablement si les opérations de notation continuent dans le secteur ; (ii) la convenance et le bénéfice d'habitat de caribou ont un rapport négatif et ne sont pas compatibles dans la gestion de forêt ; et (iii) la taille et le bénéfice de population d'orignaux n'ont aucun rapport ou ont un rapport légèrement positif. L'analyse additionnelle devrait être effectuée à (i) mesurent le rapport entre la convenance d'habitat de caribou et la taille de population; et
(ii) renforcent notre conclusion concernant le rapport entre le bénéfice et la taille de population d'orignaux.

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Chapter 1: Forest Management and Project Outline

1.1. Forestry

Forests, specifically forest resources and functions, have both economical and environmental benefits. Forests are carbon fixers, they provide wildlife habitat, have a key role in the water cycle, regulate climate, build soil, serve as environmental health indicators and represent economic value (Thompson and Webb 1994). Forests are also very important to the survival of humans and to the wealth of countries; they provide essentials such as timber, medicine, food, water and jobs. In the past, forest management plans, a forest company's chosen cutting strategy, solely focused on the economic ramifications of a cut. These plans were aimed at producing younger, more evenly balanced forests that would grow a maximum amount of wood fibre, also known as the perpetual sustained yield model of forest management (Daishowa-Marubeni International 1999). However, this philosophy of forest management led to low forest health, low disease resistance, and reduced diversity (Reiger and Baskerville 1986, Christensen et al. 1996, Chapin et al. 1996, Chapin and Whiteman 1998). New forestry practices were needed for logging to be sustained into the future. In addition, the public became increasingly aware of environmental problems and forests began to be valued for a range of attributes including fish and wildlife habitat, water quality and recreational opportunities. In response to these issues the international community and forest industry set out to develop guidelines to direct forestry operations that would take into account a broader range of forest resources and functions that could be practiced on a long term basis.

Sustainable forestry is a complex idea involving economic, environmental and social factors. Sustainable forestry gained international acceptance at the 1992 Rio Summit when world leaders adopted the "Statement of Forest Principles and Agenda 21", also known as the international sustainable development action plan. However, at this time a common definition and meaning of sustainable forestry had not been reached and there were no guidelines for measuring the sustainability of a management plan. This debate has continued to the present day and has hindered the growth and acceptance of sustainable forest practices (Thiollay 2002). Scientists have had difficulty developing a operationally useful definition of biophysical sustainability that groups with differing values, political preferences, or assumptions about human nature can agree upon and use (Brooks 1992, Lele and Norgaard 1996). Most definitions encompass the ideal of managing forested landscapes to provide a sustained production of a variety of goods and services for society (Kimmis 1997). The advancement of the field of sustainable forestry has been further limited by gaps in scientific understanding, insufficient transformation of research results into usable information, lack of tools to measure and evaluate the sustainability of forest management plans and insufficient communication between researchers in the forestry industry (National Commission on Science for Sustainable Forestry 2002). Despite this, Canada has made advancements in the understanding and utilization of sustainable forestry within the country. Canada is dedicated to the advancement and use of sustainable forestry; indeed the Canadian Forest Service mission is "To promote the sustainable development of Canada's forest sector for the well-being of present and future generations of Canadians" (Canadian Forest Service 2002). Organizations that direct sustainable forestry practices within Canada are the Sustainable

Forestry Initiatives, International Standards Organization, the Forest Stewardship Council, Greenpeace, The Canadian Forest Service and Canada's National Sustainable Forest Management Standard, among others. Most of these groups follow sustainable guidelines produced by the Montreal Process or the Canadian Council of Forest Ministers.

The Montreal process began in 1994 and refers to countries that work together on developing internationally agreed upon criteria and indicators for the conservation and sustainable management of boreal and temperate forests. In sustainable forestry a criterion is defined as "a category of conditions or processes by which sustainable forest management may be assessed" and are characterized by a set of indicators which are monitored to assess change (National Association of State Foresters 2002). An indicator is a quantitative or qualitative variable which can be measured or described and demonstrates trends through time (National Association of State Foresters 2002). Countries involved in the Montreal process include Argentina, Australia, Canada, China, Japan, Korea, Mexico, New Zealand, the Russian Federation, United States and Uruguay (Walsh 2001). These nations represent 60% of all the forests in the world and 90% of the temperate and boreal forests (Walsh 2001). The group, originated in Montreal, Canada, developed seven criteria and 67 indicators of sustainable forestry at the national level.

The Canadian Council of Forest Ministers (CCFM) is an organization of federal, provincial and territorial forest ministers in Canada whose aim is to work closely together in national and international matters (CCFM 1998). The organization was formed in the mid 1980's to outline concerns and objectives concerning the Canadian forest industry, however, after the 1992 Rio Summit the CCFM recognized that forest management was becoming a broader issue and that sustainable forest practices were becoming a concern. In 1995 CCFM produced a document that outlined a set of criteria and indicators for sustainable management in Canadian forests. Six criteria and over 83 indicators of sustainable management were outlined to provide Canadians, and specifically the forest industry operating within the country, with an understanding and definition of sustainable forest management. These were also used to guide the development of policies and business activities regarding forestry (CCFM 1998).

Table 1.1.1 : Criteria and indicators for sustainable forestry produced by the Montreal Process.

Criteria	Indicators
Conservation of biological diversity	1. Extent of area by forest type relative to total forest area 2. Extent of area by forest type and by age class or successional stage 3. Extent of area by forest type in protected area categories 4. Extent of area by forest type in protected areas defined by age class or successional stage 5. Fragmentation of forest types 6. The number of forest dependant species 7. The status of forest dependent species at risk of not maintaining a viable breeding population 8. The number of forest dependent species that occupy a small portion of their former range 9. Population levels of representative species from diverse habitats monitored across their range
Maintenance of productive capacity of forest ecosystems	1. Area of forest land and net area of forest land available for timber production 2. Total growing stock of both merchantable and non-merchantable tree species on forest land available for timber production 3. The area and growing stock of plantations of native and exotic species 4. Annual removal of wood products compared to volume determined to be sustainable Annual removal of non-timber forest products compared to the level determined to be sustainable

Criteria	Indicators
Conservation and maintenance of soil and water resources	1. Area and percent of forest land with significant soil erosion 2. Area and percent of forest land managed primarily for protective functions 3. Percent of stream kilometers in forested catchments in which stream flow and timing has significantly deviated from the historical range of variation 4. Area and percent of forest land with significantly diminished soil organic matter and and/or changes in other soil chemical properties 5. Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities 6. Percent of water bodies in forest areas with significance variance from the historic range of variability in pH, dissolved oxygen, level of chemicals, sedimentation or temperature change 7. Area and percent of forest land experiencing an accumulating of persistent toxic substance
Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies	1. Value and volume of wood production, including value added through downstream processing 2. Value and quantity of production of non-wood forest products 3. Supply and consumption of wood and wood products, including consumption per capita 4. Value of wood and non-wood products production as percentage of GDP 5. Degree of recycling of forest products 6. Supply and consumption/use of non-wood products 7. Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land 8. Number and type of facilities available for general recreation and tourism in relation to population and forest area 9. Number of visitor days attributed to recreation and tourism, in relation to population and forest area 10. Value of investment, including investment in forest growth, forest health, management, planted forests, wood processing, recreation and tourism 11. Level of expenditure on research, development, and education 12. Extension and use of new and improved technologies 13. Rates of return on investment 14. Area and percent of forest land managed in relation to the total area of forest land to protect the range of cultural, social and spiritual needs and values 15. Non-consumptive use forest values 16. Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment 17. Average wage rates and injury rates in major employment categories within the forest sector 18. Viability and adaptability to changing economic conditions, of forest dependent communities, including indigenous communities 19. Area and percent of forest land used for subsistence purposes
Maintenance of forest contribution to global carbon cycles	1. Total forest ecosystem biomass and carbon pool 2. Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon 3. Contribution of forest products to the global carbon budget

Table 1.1.2 : Criteria and indicators for sustainable forestry produced by the Canadian council of forest ministers.

Criteria	Indicators
Conservation of biological, specifically ecosystem, species and genetic, diversity	1. Percentage and extent, in area, of forest types relative to historical condition and to total forest area 2. Percentage and extent of area by forest type and age class 3. Area, percentage and representative ness of forest types in protected areas 4. Level of fragmentation and connectedness of forest ecosystem components 5. Number of known forest-dependent species classified as extinct, threatened, endangered, rare or vulnerable relative to total number of known forest-dependent species 6. Population levels and changes over time of selected species and species guilds 7. Number of known forest-dependent species that occupy only a small portion of their former range 8. Implementation of an in situ/ex situ genetic conservation strategy for commercial and endangered forest vegetation species
Ecosystem condition and productivity demonstrated through disturbance and stress, ecosystem resilience and extant biomass	1. Area and severity of insect attack 2. Area and severity of disease infestation 3. Area and severity of fire damage 4. Rates of pollutant deposition 5. Ozone concentrations in forested regions 6. Crown transparency in percentage by class 7. Area and severity of occurrence of exotic species detrimental to forest condition 8. Climate change as measured by temperature sums 9. Percentage and extent of area by forest type and age class 10. Percentage of area successfully naturally regenerated and artificially regenerated 11. Mean annual increment by forest type and age class 12. Frequency of occurrence within selected indicator species
Soil and water conservation including physical and environmental factors and policy and protection of forest factors	1. Percentage of harvested area having significant soil compaction, displacement, erosion, puddling, loss of organic matter, etc. 2. Area of forest converted to non-forest land use 3. Water quality as measured by water chemistry, turbidity, etc. 4. Trends and timing of events in stream flows from forest catchments 5. Changes in distribution and abundance of aquatic fauna 6. Percentage of forest managed primarily for soil and water protection 7. Percentage of forest area having road construction and stream crossing guidelines in place 8. Area, percentage and representative ness of forest types in protected areas

Criteria	Indicators
Multiple benefits including productive capacity, competitiveness, contribution to the economy and non-timber values	1. Annual removal of forest products relative to the volume of removals determined to be sustainable 2. Distribution of, and changes in, the land base available for timber production 3. Animal population trends for selected species of economic importance 4. Management and development expenditures 5. Availability of habitat for selected wildlife species of economic importance 6. Net profitability 7. Trends in global market share 8. Trends in research and development expenditures in forest products and processing technologies 9. Contribution to gross domestic product (GDP) of timber and non-timber sectors of the forest economy 10. Total employment in all forest-related sectors 11. Utilization of forests for non-market goods and services, including forest land use for subsistence purposes 12. Economic value of non-market goods and services 13. Availability and use of recreational opportunities 14. Total expenditures by individuals on activities related to non-timber use 15. Membership and expenditures in forest recreation-oriented organizations and clubs 16. Area and percentage of protected forest by degree of protection
Society's responsibility comprising aboriginal and treaty rights, participation by aboriginal communities, sustainability and forest communities and fair, effective and informed decision making	1. Extent to which forest planning and management processes consider and meet legal obligations with respect to duly established Aboriginal and treaty rights 2. Extent of Aboriginal participation in forest-based economic opportunities 3. Extent to which forest management planning takes into account the protection of unique or significant Aboriginal social, cultural or spiritual sites 4. Number of Aboriginal communities with a significant forestry component in the economic base and the diversity of forest use at the community level 5. Area of forest land available for subsistence purposes 6. Area of Indian reserve forest lands under integrated management plans 7. Number of communities with a significant forestry component in the economic base 8. Index of the diversity of the local industrial base 9. Diversity of forest use at the community level 10. Number of communities with stewardship or co-management responsibilities 11. Degree of public participation in the design of decision-making processes 12. Degree of public participation in decision-making processes 13. Degree of public participation in implementation of decisions and monitoring of progress toward sustainable forest management 14. Percentage of area covered by multi-attribute resource inventories 15. Investments in forest-based research and development and information 16. Total effective expenditure on public forestry education 17. Percentage of forest area under completed management plans/programs/guidelines which have included public participation 18. Expenditure on international forestry 19. Mutual learning mechanisms and processes

Forestry companies operating within Canada must develop forest management plans that use sustainable practices and these plans are submitted to the provincial government for approval before logging operations can proceed. For example, the provincial government in Alberta has published a set of guidelines concerning timber harvesting and operating ground rules within the province. These guidelines, at least in principal, are meant to ensure that sustainable operations are included in a forestry company's forest management plan. Some of these guidelines include (i) giving priority to stands that are in the oldest and poorest condition for harvest; (ii) using clear cutting under normal silviculture practices; (iii) to be cut stands must pass a basic utilization standard; (iv) clear block size depends on species composition, and minimum and maximum cut block size is clearly defined within the document; (v) cut block boundaries should follow natural terrain features to minimize the impact of logging; and (vi) reforested tree species should match the site conditions (Alberta Sustainable Resource Development 1994). Forest management plans that do not follow these provincial guidelines are evaluated as not sustainable and operations are not allowed to proceed. Forest companies in part comply with these guidelines because they believe sustainable forestry is beneficial for the continued prosperity of forests, however, there is also concern within the industry that the non-fibre values that must be integrated into management plans will affect profitability and will have an impact on historical fibre values as well (Daishowa-Marubeni International 1999). Tolko Industries, in spite of concerns about profitability, have adopted environmental laws and regulations into their management plans and aim to improve or sustain the health and productivity of forest ecosystems and biological diversity (Tolko Industries 2002).

1.2 Traditional Environmental Knowledge (TEK) and Western Scientific Knowledge (WSK)

Science is defined as the state of knowing, acquired by study, mastery and trained skill (Oxford 2002). In North America science that is relied upon by scientists in disciplines ranging from engineering to chemistry and biology, is western science. However, another type of science exists, traditional ecological knowledge (TEK) defined as a collective knowledge developed and based on the cumulative experiences of the aboriginal peoples with the natural environment (Environment Canada 1999). Despite the fact that many acknowledge that using both sciences in research, specifically environmental work, would increase the knowledge base and lead to better predictions and conclusions, TEK and WS have rarely been used together (Colorado 1998, Berkes et al. 2000). The two sciences are similar in many ways; however, there are many perceived (imaginary and real) differences that have led to a lack of joint ventures to date (Table 1.2.1) (Agrawal 1995).

Table 1.2.1 : A summary of the similarities and differences of western science and traditional ecological knowledge.

Difference	***Reference***	***Similarity***	***Reference***
WS concrete, TEK abstract	*Levi-Strauss 1962, Environment Canada 1999*	Based on accumulation of observations	*Berkes et al 2000*
WS quantitative, TEK qualitative	*Kimmerman 2002, Augustine 1999*	Tested by trial and error	*Berkes et al 2000*
TEK holistic, WS views things as separate	*Environment Canada 1999, Augustine 1999*	Monitoring of status of resource and change in this status	*Berkes et al 2000, Sadler and Bothroyd 1994*
Communication: WS written, TEK oral	*Environment Canada 1999*	Protection of certain species	*Berkes et al 2000*
WS tries to manage/control resources and the natural world, TEK believes humans are not in control of the natural world	*Augustine, Pierotti and Wildcat 2000*	Predictive	*Kimmerman 2002*
TEK is spatially orientated, WS temporally orientated		Yields empirical information of natural phenomena and relationships among ecosystem components	*Kimmerman 2002*
TEK has a spiritual and social connection to the land, WS has removed all spiritual and social context	*Kimmermand 2002, Sadler and Bothroyd 1994*	Temporal restriction of harvests	*Berkes et al 2000, Sadler and Bothroyd 1994*
TEK based on observations, WS based on the scientific method	*Environment Canada 1999, Alcock 1998*	Dynamic	*Berkes et al 2000*
		Classification systems	*Sadler and Bothroyd 1994*
TEK: generations add to the stories through their own personal observations which increases what is known about the system studied; WS: researchers conduct experiences to validate or disprove theories to increase what is known about a subject	*Environment Canada 1999*		

The perceived differences listed in Table 1.2.1 have lead to the lack of research involving TEK and WS, as well as (i) continued inertia and inflexibility: the established scientific community are in favor of keeping long-established practices, there is a concern as to the reliability of traditional knowledge since it involves a spiritual component and has not been documented; (ii) the resentment among aboriginal people that TEK is incorporated into WS instead of using the two forms of knowledge together; (iii) difficulty assessing TEK in the traditional western scientific practices; and (iv) difficulty with research involving TEK; it is a multidisciplinary undertaking thus researchers from other disciplines, especially social scientists, must be involved (Huntington 2000, Lalonde and Akhter 1994). However, similar practices are used by western scientific researchers and aboriginal communities including (i) monitoring resource abundance and change in ecosystems; (ii) giving protection to certain species that are of concern; (iii) protection of vulnerable life history stages; (iv) protection of specific habitats; (v) temporal restrictions of harvest; (vi) and management of landscape patchiness (Berkes et al 2000). Therefore there seems to be a potential for collaboration between TEK and WS in environmental research.

In recent years there has been increasing demand by local, national and international organizations to use WS and TEK together. The general consensus is if TEK and WS do represent two independent ways of knowing, then combining both sources of knowledge should increase our understanding of the natural world (Walker et al 1995). Demand for doing so has arisen for several reasons. First, with increased attention and concern about environmental degradation has come the belief (in some quarters) that insight into the resolution of these problems may come from the accumulated wisdom of people who were able, apparently, to live in harmony with their environment for thousands of years (Cardova 1997). The Bruntland report from the United Nation's World Commission on the Environment and Development notes "the world could learn from aboriginal people's ability to sustainably manage complex ecosystems" (UN 1987). Similarly, the 1992 Rio Summit mentioned that aboriginal people have developed a holistic traditional scientific knowledge of their lands, natural resources and the environment (UN 1992). A second motivation is less philosophical and more political: policies and agreements at provincial, federal and international levels oblige decision makers to take TEK into account. For example, the United Nations Convention on Biological Diversity (Agenda 21, Article 8) explicitly has as it's objective "the preservation and integration of traditional knowledge and practices relevant to biodiversity convention". Within Canada CCFM, an agency responsible for sustainable forestry guidelines, has as a criterion "Society's responsibility comprising aboriginal and treaty rights, participation by aboriginal communities, sustainability and forest communities and fair, effective and informed decision making" (refer to Table 1.1.2) (CCFM 2000). A third motivation is purely pragmatic: recent settling of a number of land claims both in Canada and elsewhere give aboriginal people at least partial – and in some cases, total, control over natural resource management. The 1975 *James Bay and Northern Quebec Agreement* established the legal right of native groups to participate in resource management decisions (Berkes 1994). In 1990 the *Sparrow* case in British Columbia limited the authority of government managers to restrict aboriginal rights to hunt and fish (Berkes 1994). And in 1997 the Canadian Supreme Court ruled that aboriginal title was a right to the land itself and this included the right to determine land use (*Delgamuukw v. British Columbia).*

Recent regulations and land claims within Canada have given aboriginal communities the right to determine land use on reserve land. Forest companies are concerned since Indian reserves cover a total of 7.4 million acres across Canada, and 1.9 million acres are timber producing (Ryz and Schell 2002). In some cases the settlements have forced forest companies, operating in the area before land claims were settled, to establish joint ventures with First Nation communities and developing forest management plans with input from aboriginal people and traditional knowledge. In ideal conditions, these ventures improve the economic situation of aboriginal communities and the profit generated from logging operations. Native bands can claim exemption from income tax, provincial sales tax, and the goods and services tax. Ventures of this type are called co-management which is a broad term referring to inclusionary, consensus-based approach to resource use and development (Campbell 1996). Theoretically decisions are shared equally among all members of the group and negotiation, not litigation, resolves conflicts that arise. Unfortunately the idea and practice of "co-management" is relatively new; there are few published papers on the subject and groups in co-management ventures are not at a point yet to say if the exercise has been successful. To date problems that have arisen in co-management situations include: (i) aboriginal people feeling they are not appropriately consulted and overwhelmed by decisions since most large-scale resource extraction occur in areas where small, isolated communities generally exist; (ii) resource development threatening to affect traditional hunting, trapping and fishing activities which play a vital role in the subsistence lifestyle of aboriginal people; and (iii) power struggles and confusion within co-management groups because rights of First Nations to traditional territories and natural resources are ill-defined (Campbell 1996).

Despite the associated difficulties with integrating WS and TEK, participation by aboriginal peoples is now considered a touchstone for forest management in Canada, and a key criterion for sustainability (CCFM 1997, Montreal Process Working Group 1998, UN, 1987 – Rio Summit, UN, 1987 - United Nations Convention on Biological Diversity Agenda 21, Article 8). However, the full integration of aboriginal values generally, and TEK specifically, into forest management has been hampered on several fronts. A major challenge is the lack of trust between forest companies and indigenous people. Aboriginal people feel there are few resources available to make informed forest management decisions (Environment Canada 1999). There is also the perception that aboriginal groups do not want to share their knowledge with others, especially people who are involved in resource extraction (Environment Canada 1999). These problems have been highlighted in the Canadian Model Forest Program. The Canadian Forest Service launched the program in 1992 to get Canadians working together to develop leading-edge sustainable forest management practices. One initiative, called the "Enhanced Aboriginal Involvement Strategic", encourage participation of aboriginal communities to incorporate traditional and contemporary aboriginal knowledge into the ongoing model forest goals and objectives. At the beginning First Nations were hesitant to become involved with the program (Model Forest Network 1998). Since 70% of the forests involved in the program include aboriginal people. However, forming relationships between scientists, industry types and aboriginal people has been difficult; one concern is the lack of knowledge on behalf of the aboriginal people regarding the technical aspects of forest management and with forestry terminology, the aboriginal people involved feel they are not adequately represented on the board of directors, and miscommunication is common between the board and natives (Model Forest Network 1998). Some of these issues have developed between Little Red River Tall Cree and Tolko Industries and there have been numerous delays in obtaining data because of disagreements between the two groups. If indigenous values are to be incorporated into forest management plans these issues need to be dealt with and both parties must be committed to making the exercise work.

1.3. Risk Assessment

Policymakers and regulatory agencies use risk assessment to assign magnitudes and probabilities to the adverse effects of human activities (Suter et al 1993). Ecological risk assessment (ERA) is concerned with environmental protection through the evaluation of ecological risks associated with anthropogenic environmental hazards or stressors (Graham et al. 1991, Suter et al 1993). The principal goals are to provide (i) a quantitative basis for balancing and comparing risks associated with environmental problems; and (ii) a systematic means of improving the estimation and understanding of those risks (Graham et al. 1991). Risk assessment involves two stages: (i) a risk analysis stage, whereby the probability of some (undesired) environmental effect of a specified magnitude is estimated; and (ii) a risk characterization stage, whereby the risk analysis is combined with other information to determine the extent to which the calculated risks from (i) are (or are not) acceptable; and if not acceptable, how they might be mitigated.

In the ERA, the ecological effects are referred to as endpoints and should be selected according to their societal and biological relevance, unambiguous operational definition, accessibility to prediction and measurement, and susceptibility to the stressor (Suter et al., 1993). There are two types of endpoints. Assessment endpoints are "an explicit expression of the environmental value to be protected, operationally defined by an ecological entity and its attributes", that is, valued attributes or components of the environment that are considered to be at risk from the stressor in question (U.S. Environmental Protection Agency, Guidelines for Ecological Risk Assessment, Risk Assessment Forum, Washington D.C., 1998, p.B-1). Examples may include species richness of a fish community in a specific reach of a river or recruitment rates in a vulnerable population. In many instances, selected assessment endpoints either (a) cannot be measured directly in the field at the relevant spatio-temporal scale; or (b) the cost of such measurements is prohibitive. In either case, ERA relies on measurement endpoints. These are (feasibly) measurable attributes of the environment that are not of direct concern, but for which their measurement allows us to draw inferences about the assessment endpoint. In principal, measurement endpoints (such as LD_{50} of fathead minnows in a standard laboratory assessment of the toxicity of some contaminant) are predictive of assessment endpoints (e.g. the survival of lake trout exposed to similar concentrations of the same contaminant in a lake). There are two key elements in risk analysis: (1) determining the relationship between exposure to a stressor and the value of the measurement endpoint (e.g. the dose-response relationship in a standard toxicity test); and (2) the relationship between the measurement and assessment endpoints, i.e. the extrapolation relationship (if any). If the relationship between exposure and the measurement endpoint can be estimated, as can the relationship between exposure and the measurement and assessment endpoints, then the distribution of possible effects on the assessment, given a specified exposure, can be estimated.

Measurement endpoints, as the name suggests, are endpoints that can be measured and are used to represent the assessment endpoints, which are sometimes difficult to quantify. These endpoints should be chosen depending on if there is a noticeable effect present and if they have a known relationship with the assessment endpoint of interest. Measurement endpoints are based either on hypothesis testing or describing a level of effect. In hypothesis testing a statistical test is used to determine if the null hypothesis will be rejected or if the alternative hypothesis will be accepted. Statistical tests, however, depend on the size of the sample for an effect to be detected. Therefore unless a large sample size is available, hypothesis testing may not be a reliable procedure for detecting an effect. The other option available in risk assessment is to describe the level of effect. In this method a function is fit through a set of points relating the measured effects (mortality of fathead minnows) and measurement of exposure (dose of toxic stress). A gradient can then be established relating the measured effect and the measurement of the exposure. The regression coefficient is examined to determine the measure or size of the effect. If a limited number of samples are attainable a measure of the effect can still be determined using this procedure.

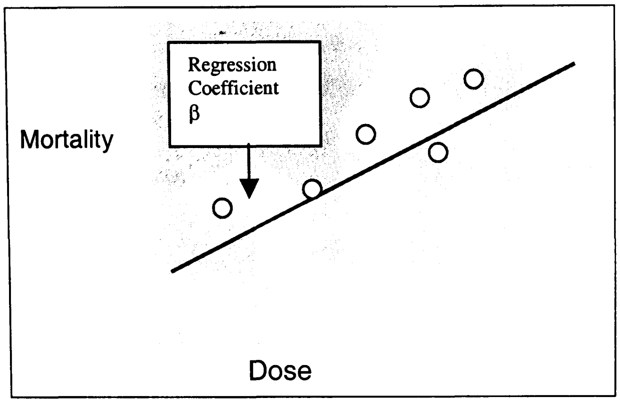


Figure 1.3.1 : The relationship between dose of toxic and mortality of fathead minnow. The regression coefficient (β) is examined to quantify the effect.

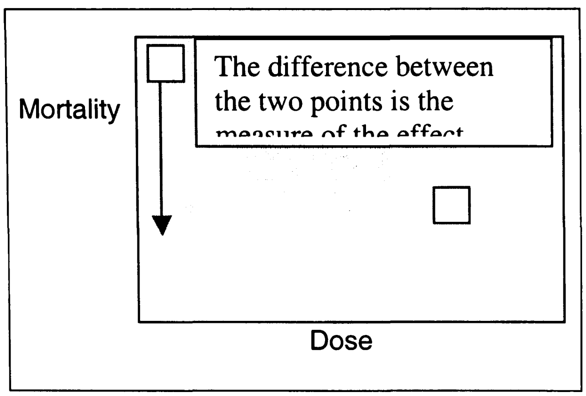


Figure 1.3.2 : When a low sample size is available the level of effect can still be determined as demonstrated in this figure. In this instance the level or size of the effect would be the difference between the two points.

Indicators are also sometimes used in risk assessments. Indicators are necessary when the measurement endpoints are also difficult to quantify. Indicators are chosen since they can be measured easily and have a known relationship with the measurement endpoint used in the exercise. A performance objective, a desired level of the indicator, is then defined. The performance objective is a quantified level of exposure that is permitted under a specific environmental hazard.

1.4. Rationale and objectives

With the ongoing drive for self-government, aboriginal communities in Canada are becoming increasingly involved in natural resource management. Several recent land claim settlements (e.g. *Delgamuukw v. British Columbia)* have transferred increasing responsibility for natural resource management out of the hands of provincial regulatory authorities and into the hands of indigenous governments. While laudable, this more equitable sharing of regulatory and management authority has created a number of problems and more loom on the horizon.

Nowhere are these problems more evident than in the forestry sector. Indigenous communities are not, in general, particularly pleased about the way forest resources have traditionally been managed because, in their view, most forest management plans have not sustained forest attributes which are of value to indigenous communities and indigenous cultures (Campbell 1996). On the other hand, the forest products industry and provincial regulators have concerns of: (1) the capacity of indigenous communities to manage forests in a sustainable fashion; and (2) the effects of management for other endpoints ("non-fibre" values) on the traditional endpoints of forest management. The latter is of particular concern because virtually all provincial regulatory authorities are bound, through the CCFM agreement, to have regard for the non-timber values of Crown forests, and there is a belief that this will have a negative impact on the forestry sector (Daishowa-Marubeni International 1999). Not surprisingly, the possibility that yet another set of values may enter the forest management equation is viewed with trepidation.

At issue are two basic questions: (1) how does forest management for indigenous values differ from forest management for other values? And (2) what is the impact of management for indigenous values on other forest values? The principal tool for forest management in Canada is the forest management plan and therefore, at an operational level, these questions boil down to determining the differences between FMPs designed with the objective of sustaining indigenous forest values, and conventional FMPs where such values are not explicitly taken into account. All FMPs purport to operationalize forest sustainability: at issue is what precisely is meant by sustainability, and there is no question that sustainability criteria today are quite different than those of the past.

All existing sustainability criteria for forest management (e.g. CCFM) have associated performance criteria, that is, statements about the levels that certain forest attributes must achieve if management is to be considered sustainable. Hence, FMPs are, in principal at least, formulated such that these sustainability performance criteria will be met. However, our knowledge of the impact of forestry operations on many forest attributes – in particular forest ecosystem function – is incomplete at best (Davies and Nelson 1994, Berube and Levesque 1998, Brown et al 1997, Flavia and Magnusson 2002, Laiho et al 2003). In view of this uncertainty, rational decision-making involves making choices based on the distribution of possible outcomes, that is, on the assessment of risk. So the question of the impact of incorporation of indigenous values in FMPs boils down to the assessment of risk (likelihood) that (1) a given FMP will not meet specific indigenous performance objectives and (2) the relationship between this risk and the risks of not achieving other (non-indigenous) performance objectives. That is, if elements of an FMP are changed to reduce the risk of not achieving certain indigenous performance criteria, how do these changes affect the risk to other performance criteria (for example, those associated with conventional fibre values).

To answer this question, I began by defining two sets of measurement endpoints, one (S_I) that explicitly takes into account indigenous values and one (S_{NI}) that does not. Each set has a corresponding set of performance objectives (P_I, P_{NI}); if the current value of a given measurement endpoint is greater than or equal to the corresponding performance objective (P^*_I, P^*_{NI}), then we say the objective has been met. Thus, I can assign a value representing the probability (risk) that a given (either indigenous or non-indigenous) performance objective will be met under the existing FMP. This risk will be large (small) if the current – or projected – level of the measurement endpoint is far away from (close to) the corresponding performance objective (Fig.1.4.1).

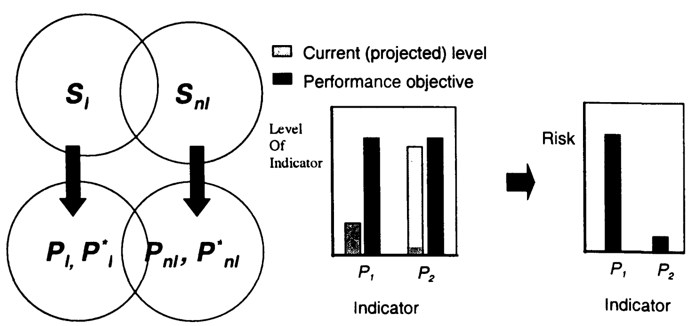


Fig.1.4.1 The elaboration of a set of indigenous (I) and non-indigenous (NI) values and goals (S) generates a corresponding set of performance indicators (P) and objectives (P*). If the relationship between FMP elements and the level of performance indicators is

known, then we can estimate the risk to each indicator posed by the FMP. Here the current FMP is likely to generate a level of indicator PI that is well below its performance objective. Hence, the corresponding risk is high. On the other hand, for P2, the FMP generates a current or projected level close to its performance objective, and the corresponding risk is low.

The risk estimation is based on empirical data relating one or more operational elements of an FMP (e.g. the location, amount and attributes of land that will be cut etc) to the appropriate endpoints, e.g. the distribution of annual yield for a particular commercial species under a given harvesting regime. If the relationship between an FMP component and a specific measurement endpoint can be measured, then we can predict how a specified change in operational components will affect the value of the endpoint, and hence, the likelihood of not achieving a performance objective. This can be done for elements of both S_I and S_{NI}; in so doing, we can estimate how a change in some FMP element will affect the risk of not achieving any specified set of both indigenous and non-indigenous performance objectives. We can, therefore, answer the question: if an FMP is changed so as to reduce the risk of not achieving a (specified) indigenous value performance objective, what is the effect on the risk of not achieving a specified non-indigenous performance objective?

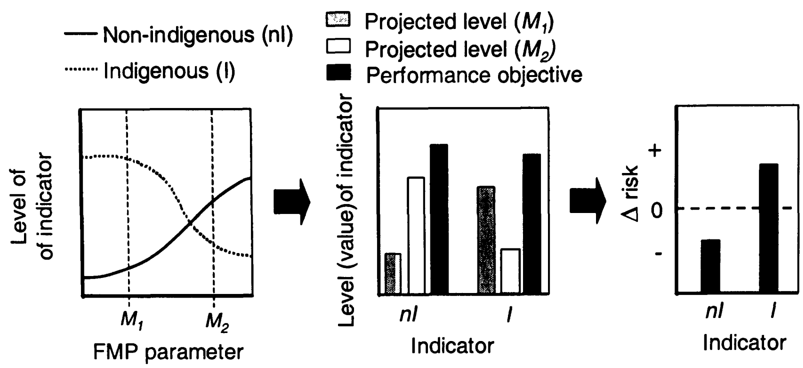
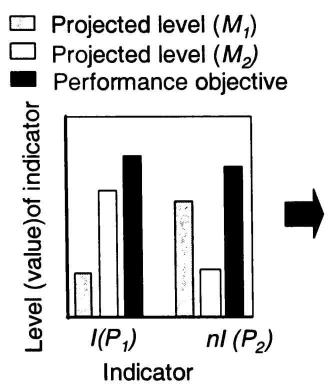


Fig.1.4.2 Knowledge of the relationship between the level of an indicator (indigenous or non-indigenous) and some FMP parameter allows us to estimate changes in the level of the indicator associated with changes in the parameter from M_1 to M_2. In this case, the change results in a projected level for the non-indigenous indicator that is closer to its performance objective. Hence, the associated risk under M_2 is smaller than that under M_1, and the change in risk is negative. By contrast, for the indigenous indicator, the change from M_1 to M_2 leads to a projected level that is much lower, relative to its performance objective, than that obtained under M_2. In this instance, the change from M_1 to M_2 increases the risk, i.e. the associated change in risk is positive.

For the region covered by an FMP, the above approach will provide qualitative, semi-quantitative or quantitative (depending on the quality and quantity of available data) estimates of the risks and opportunities associated with the incorporation of indigenous values into FMPs. Specifically, it will permit the construction of *value compatibility matrices* as shown in Fig. 1.4.3. The ij^{th} element of these matrices represents the standardized change in the risk to *non-indigenous* performance objective *j* given a FMP modification resulting in a unit *decrease* in risk to *indigenous* performance objective *i*. From such a matrix, one can immediately identify instances of management incompatibility (*risks*) i.e. when an FMP modification designed to *decrease* the risk to an indigenous performance objective results in a *increased* risk to a non-indigenous objective, so that the corresponding matrix entry is positive; as well as instances of management compatibility (*opportunities)* where the corresponding entry is negative, that is, where an FMP modification results in a decreased risk to both indigenous and non-indigenous performance objectives (Fig. 1.4.3)



Indigenous performance objectives	Non-indigenous performance objective P_1	P_2	P_3	P_4
P_1	-	+	-	-
P_2	0	+	+	-
P_3	0	0	+	-

Fig.1.4.3. The value compatibility matrix. A change in the FMP from M_1 to M_2 reduces the risk to indigenous (I) performance indicator P_1, since the projected level of the indicator under M_2 is closer to its performance objective. However, the same change increases the risk to non-indigenous (nI) indicator P_2. The corresponding element in the matrix is therefore positive, indicating that a management change which mitigates the risk to indigenous performance objective P_1 increases the risk to non-indigenous performance objective P_2. A negative entry in the matrix indicates management opportunities, i.e. management changes which result in a reduced risk to both indigenous and non-indigenous performance indicators. A zero entry occurs only when the corresponding indicators are independent, such that a management change reducing the risk has no effect on the risk to the other.

The FMP compatibility matrix shows at a glance the points of potential conflict and cooperation between stakeholders for whom the forest holds different values. As such, it represents a potentially important tool for inclusive and consultative forest management planning.

1.5 Approach

In what follows, I shall identify a set of aboriginal and non-aboriginal assessment endpoints, associated measurement endpoints, and performance criteria. With these in hand, I will estimate the risks of not achieving one or the other sets of performance criteria under different FMP scenarios. This will allow me to determine whether, over the set of different FMP scenarios, risks to aboriginal and non-aboriginal endpoints are positively or negatively correlated, that is, whether the corresponding elements in the value compatibility matrix are positive or negative.

Chapter 2: Identifying Indigenous and Non-Indigenous Values: Little Red River Tall Cree First Nations and Tolko Industries – High Level

2.1 Background

Little Red River - Tall Cree First Nations (LRRCN) is a collection of five aboriginal communities in northwest Alberta; John D'Or, Garden River, Little Red River, Tall Cree North and Tall Cree South. Currently LRRCN holds tenure rights for 200 000 cubic meters of conifer and 200 000 cubic meters of deciduous trees within forest management units (FMUs) 2, 4 and 6 (Figure 2.1). Little Red River Forestry Ltd, owned by LRRCN, develops the forest management plans and manages woodland operations within these FMUs. However, a co-management agreement between Tolko Industries - High Level and LRRCN has been worked out and the conifer rights for FMUs 2, 4, and 6 have been sold by Little Red River forestry to the forestry company. Also Tolko Industries - High Level holds the forest tenure for forest management units 3, 5 and 7 (Figure 2.1). In these FMUs Tolko is responsible for developing the forest management plans and managing operations.

Under the cooperative (or co-management) agreement both party's forest management plans and operations must be compatible. The participants also have agreed to use one "landscape assessment" and one "resource management philosophy and goal statement" for the development of management plans. Landscape assessments are used to identify relevant ecological, economic and social aspects that are required to be addressed in FMPs (Jim Webb pers comm.). Resource management philosophy and goal statement is the identification of priorities that FMPs will respond to (Jim Webb pers comm.).

Specifically the agreement between LRRCN and Tolko Industries – High Level includes (1) to establish resource use priorities within the forest management units which are compatible with sustainable development and ongoing traditional use of the area by LRRCN community members; (2) to establish guidelines for implementation of these priorities; (3) to identify business development, employment and training opportunities for the people of LRRCN; and (4) to identify initiatives for responding to LRRCN concerns regarding wildlife and wildlife habitat.

In the summer of 2000 Dr. Cliff Hickey and Dr. Dave Natcher, both from the University of Alberta, surveyed the community members of Little Red River Tall Cree First Nations to aid in the development of FMPs which incorporate issues (1) through (4).

2.2 Hickey and Natcher (2000)

Information was collected from the community members of LRRCN regarding indigenous values that should be incorporated into future forest management plans and cutting strategies. Three main items were identified: (1) modifying forest management operations to reduce negative impacts to wildlife species, (2) modifying forest operations to ensure continued access to lands and resources, and (3) protection of areas identified as having cultural or historical significance (Appendix Table 2.2.1). These items were further broken down, for example explicit species, resources, and areas the community members would like to be recognized in future FMPs were mentioned and are within the "Local Value" column (Appendix Table 2.21.). Participants also suggested ways to reduce negative impacts of forestry operations on wildlife, resources and land and methods of incorporating the specific "local values" within future FMPs were mentioned (in the indicator and objective columns respectively of Table 2.2.1, appendix). This information was used to define the indigenous values to be used in this study.

2.3 Indigenous and Non-indigenous Values

We decided to work with the Table 2.2.1 (appendix) to select the indigenous values to be used in the project. We decided to focus on the most biologically relevant criteria, modifying forest management operations in order to reduce negative impacts to wildlife species. The participants mentioned a variety of wildlife species they would like to see maintained within the area, include woodland caribou (*Rangifer tarandus caribou)*, woodland bison (*Bison bison athabascae)*, moose (*Alces alces*), fish (various species), marten (*Martes americana)*, fox (*Vulpes vulpes)*, coyote (*Canis latrans)*, mink (*Mustela vison)* , fisher (*Martes pennanti*), lynx (*Lynx lynx*), beaver (*Castor Canadensi*), bear (*Ursus americanus* and *Ursus arctos*), birds (*Anas*, various species) and squirrels (*Glaucomys sabrinus* and *Tamiasciurus hudsonicus*). From this list we chose species based on the following criteria: (1) how sensitive they would be to forestry operations; (2) existing knowledge of habitat specifications; (3) importance to the community; and (4) reliable population estimates within Alberta. Based on these criteria, moose (*A.alces*) and caribou (*Rangifer tarandus caribou*) were chosen; both had sufficiently high abundance in northern Alberta so impacts of forestry operations could be measured, there was a large amount of published literature on both species and their availability was important to community members. Population estimates were available for moose from the provincial government, and we also believed this to be true for caribou at the beginning of the project. In addition since *Rangifer tarandus caribou* is considered endangered in Alberta, we felt a study examining the impacts of forestry operations on this species population would be of value to the people of LRRCN and help to approximate the future status of the northern Alberta caribou population.

The non-indigenous value used in this project was the economic ramification of a cut, specifically the profit generated from the volume of trees cut. Profit is an extremely important value to forestry operators. Typically companies try to generate as much money as possible from a cut and therefore target commercially important tree species, stands that have not been damaged by insects or disease and areas with high tree volumes (Timberline 2001). Forest operators are extremely cautious with incorporating indigenous values into management plans out of concern that profit will be influenced (Daishowa-Marubeni International LTD 1999). Therefore we hypothesized that profit would be one of the most important aspects to include in a study examining the compatibility of indigenous and non-indigenous values in forest management.

Chapter 3: Moose (*Alces alces*) and Caribou (*Rangifer tarandus caribou*)

3.1: Moose

The moose (*Alces alces*) is the largest animal in the deer (*Cervidea*) family, with bulls ranging from 405-630 kg and cows from 315-495 kg. *A.alces* is distributed throughout the northern hemisphere, and in Canada is found throughout the boreal forest from the Yukon to Newfoundland. In Alberta, moose are an important game species and a resource of considerable cultural significance. Both recreational hunters and aboriginal peoples would like the current population size of moose maintained or increased (Hickey and Natcher 2000, Rippin 2001). Within Alberta moose are currently considered "not at risk under current conditions"; nonetheless it is a species of some concern not only because of its high recreational and cultural value, but also because of concerns about declining habitat availability and quality arising, in part, from extensive resource exploitation (Hauge and Keith 1981, McDougall 1986, Alberta Wildlife Management Division 1996). In particular, logging operations have been shown to have a diverse affect on moose population size; certain factors determining survival are adversely affected while others are positively influenced (Telfer 1974, Peek et al 1976, Hamilton et al 1980).

3.1.1 Habitat Quantity

Moose are not social animals and tend to distance themselves from each other and other species (Lynch and Morgantini 1984). Home ranges are typically between 5-10 km^2 (Le Resche 1974). Messier (1991) reported that densities greater than 1-2 animals/km^2

resulted in intense competition for food resources: in North America moose eat 18-25 kg of forage per day (OMNR 1988). Thus a large amount of foraging habitat is needed to satisfy this requirement. Food competition appears to be a regulatory factor in population growth, with low forage availability resulting in negative population growth (Messier 1991).

In Alberta moose distributions often overlap those of white tailed deer (*Odocoileus viriginianus*), another large ungulate. Both species have similar foraging requirements, leading to the possibility of competition (Belovsky 1986, Pruss and Pekins 1992). Deer also carry meningeal worm, *Pneumostrongylus tenuis*, which is fatal to moose but harmless to deer (Karns 1967). Larvae, produced by the adult worms, are shed in deer feces. Slugs present in the soil become infected with the larva and act as an intermediate host. The slugs are inadvertently eaten by moose while foraging and cause the animals to develop cerebrospinal nematodiasis, a fatal neurological brain disorder. *P.tenuis* is density dependent: as the deer density increases so does the infection rate (Parker 1966, Karns 1967). Meningeal worm has been identified as a cause of population decline and moose distance themselves from deer to decrease the probability of being infected (Anderson 1965, Anderson 1972, Gilbert 1973, Karns 1967, Gilbert 1974, Prescott 1974, Kearney and Gilbert 1976 Schmitz and Nudds 1994). Moose are often found in areas that are not used by deer, presumably to avoid contracting meningeal worm (Karns 1967, Schmitz and Nudds 1994).

Moose also avoid habitat used by predators, such as bobcats, lynx, coyotes, wolverines, cougars, black and brown bears, grizzlies and wolves, to avoid encounters (Stephens and Peterson 1984, Kunkel and Pletscher 2000). This may be a successful strategy when population densities of moose are low; however, as densities increase avoiding areas where predators may possibly be present becomes more difficult. Mortality rates are high in times of elevated population densities (Hauge and Keith 1981). In North America, moose densities typically range from 0.38 moose/km^2 to 2.3 moose/km^2 (Mawhinney and Mahoney 1993). Densities found between 1.5 moose/km^2 to 2.0 moose/km^2 in the boreal forest fall within this acceptable range (Mawhinney and Mahoney 1993). The area surrounding Little Red River -Tall Cree First Nation has moose densities ranging from 0.054 moose/km^2 to 0.509 moose/km^2, low for the boreal forest habitat (Alberta Environment, 1995). These estimates were based on aerial surveys conducted by the provincial government at the level of Wildlife Management Units (WMUs) (Gasaway 1986, Alberta Environment 1995).

3.1.2 Habitat Quality

A.alces is a habitat generalist species that tends to use lowland areas throughout the year in part because high(er) quality forage is available over longer periods (Hauge and Fuller 1981). Home ranges are a mix of old growth habitat, which is used for shelter and to escape predator detection, and young forest stands for forage (Ontario Ministry of Natural Resources 1988).

Moose forage on early successional shrubs year round; thus, this vegetation type represents an important moose habitat (Ontario Ministry of Natural Resources 1988). In the spring moose tend to forage in areas of high sodium concentrations, called mineral licks (Ontario Ministry of Natural Resources 1988). Sodium, needed to maintain osmotic and pH balance, blood fluid volume, aid muscle contractions and nerve transmissions, is an essential part of the diet during this time (Miller and Litracaitis 1992). Sodium is scarce in most ecosystems but can be found in high concentrations in roadside ditches. Moose also forage on aquatic plants in the spring and their ranges during this time include marshes, bogs and/or small lakes (Ontario Ministry of Natural Resources 1988).

Dense conifer stands represent another important habitat for moose in northern Alberta. Since visibility is reduced in dense stands, the risk of being seen by a predator is low. Stephens and Peterson (1984) found that the survival of moose increase when dense stands are present (Stephens and Peterson 1984). Coniferous stands are also important for thermoregulation (Manitoba Model Forest 1995). Moose experience heat stress in extreme temperatures and dense stands provide more cover and higher or cooler ambient temperatures, depending on the season, than more open stands (Schwab and Pitt 1991).

Females are very selective in determining where to give birth and usually decide on areas that have less chance of being visited by other animals and have a sufficient amount of food available. Bowyer (1999) found that pregnant females may move over 5 kilometers before giving birth, suggesting that birthing sites are carefully chosen. Typically these sites are on southerly exposures in elevated areas where soil moisture is low and visibility is high (Bowyer 1999). Crete and Jordan (1982) found that small home ranges led to higher neonatal mortality. Development was slower for individuals living in smaller home ranges because vital resources could not be fully accessed as well (Crete and Jordan 1982).

3.1.3 Roads

Roads are a source of mortality for some species, and a barrier to movement for others. Roads represent barriers to movement either because some species avoid unforested areas or because they avoid roads altogether (Oxley et al. 1974, Garland & Bradley 1984, Mader 1984, Bakowski and Kozakiewicz 1988, Merriam et al. 1989). Roads are a source of mortality for a variety of reasons: (1) they facilitate the movement of predators, wolves in particular, and therefore increase the predation rate (James 1999); (2) they are a direct source of mortality caused by vehicle collisions (Ashley and Robinson 1996); and (3) they grant access to hunters into areas that were previously inaccessible (Bergerud 1974, Johnson 1985, James 1999). A study by Rempel et al (1997) in northwest Ontario examined the impact of disturbances on the population size of moose. In one area, which had a higher incidence of roads, they also found a lower density of moose and hypothesized that road density and moose density may have an inverse relationship (Rempel et al 1997).

3.1.4 Hunting

Moose are an important harvestable species in Alberta and provincial regulatory agencies manage moose populations largely through the sport hunt. Fuller and Keith (1980) report, from hunter responses and aerial population surveys, that 10% of the adult population is lost to hunting each year in Alberta.

Harvest intensity, or the number of people that are sold licenses for an area and participate in the hunt, is suggested to have a strong influence on moose density (Gasaway et al 1986). Hunter intensity in a given area can increase by increasing the number of tags sold or possibly by increasing the number of roads (Rempel et al 1997). One reason specified for the decline in moose population size in Ontario in the 1970's was increased hunter access due to road construction (Timmerman and Gollat 1983).

3.1.5 Winter conditions

Moving is difficult for moose during winter months because of the deep snow (Telfer 1970). Moose are too heavy for the snow surface to support and therefore their hooves continually sink to the ground. Sinking may be several inches, depending on the height of the snow and the habitat that the snow is located in (Telfer 1970). Individuals constantly have to pull their feet out of the snow to take a stride forward and therefore moving is energetically costly in the winter. These costs increase during times of deep snow and severe snow crust, the layer of ice that forms on top of the snow pack. Predation rates increase during times of restricted movement since individuals cannot escape as quickly; Huggard (1993) found that mortality rates from predation increases from 1 ungulate per 5.4 days during periods of no snow accumulation, to 1 ungulate per 1.1 days when there is 60 cm of snow on the ground.

During the winter, moose find it difficult to search for forage because their movements are hampered and because food is scarce. New growth from early successional shrub species, such as trembling aspen, willow and cherry trees, is unavailable in the winter and moose rely on lower quality browse in conifer stands (Ontario Ministry of Natural Resources 1988). The combination of high-energy expenditures, low forage quality and the difficulty in finding food, results in decreased body fat during times of snow (Bergerud et al 1983). Low body fat means the animals are weaker, more prone to starvation and less able to escape predation (Gasaway et al 1986). During the winter moose can lose a substantial amount of heat very quickly in cold habitat and must pant to dissipate metabolic heat in locations where the temperature exceeds 8 degrees Celsius (Schwab and Pitt 1991). This has been found to further decrease fat stores because energy is being used and less time is spent foraging (Renecker and Hudson 1986).

3.1.6 Predation

The greatest predation threat to moose in northwest Alberta is wolves. In the Fort McMurry area, wolf density is .006 km2, with home ranges of 73-273 km^2 (Fuller and Keith 1980). Wolves are comparatively efficient hunters; they cover 8 kilometers per day on average and harvest 1 moose every 4.7 days annually (Fuller and Keith 1980). Predation rates are high for moose since both species use similar geographical locations, specifically lowland habitat (Fuller and Keith 1980). Hayes et al (2000) found that 94% of the ungulates killed by wolves were moose in the Yukon. In Alberta wolves are responsible for 29% of the total moose mortality (Fuller and Keith 1980). Wolf predation of moose is generally age specific, with greater predation rates among calves and yearlings (Crete et al 1981).

3.2 Caribou (*Rangifer tarandus caribou*)

Caribou (*Rangifer tarandus caribou*) are medium sized, highly social ungulates; males typically reach 180 kg and females 115 kg (Bergerud 1978, Wynes 2000). Caribou have a low reproductive output compared to other ungulates of similar size. Individuals only start reproducing after three years of age and on average have one calf per year (Dzus 2001).

In Alberta, there are two recognized woodland caribou ecotypes ("boreal" and "mountain" caribou); the latter winters in forested foothills and migrates to alpine mountains during the summer, while the former remains year round in forested habitat in elevated locations, typically above 700 m (Edmonds 1991, Wynes 2000). The current study area falls within the geographical distribution of boreal woodland caribou (Wynes 2000).

Due to their generally wide dispersal, clumped distribution, cryptic coloration and tendency to stay in coniferous forests during the winter, caribou populations are difficult to estimate. Currently there is no systematic estimate of caribou population size in Alberta (Wynes 2000). Nonetheless, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), based on indices such as calf recruitment, lists woodland caribou as threatened in Alberta, meaning that the species is likely to become endangered if limiting factors are not reduced (COSEWIC 2002). As a result, there is no recreational (sport) hunt. Aboriginal peoples are allowed to hunt, regardless of the status of the game species, but in many cases choose not to if they believe the population cannot withstand hunting pressure. This is currently the situation in Little Red River/Tall Cree. The population of caribou, estimated by the people, is approximately 1200 individuals, a number considered too low to withstand any aboriginal hunting pressure (Jim Webb pers.comm.). As a result, there is a tacit agreement among hunters in the aboriginal communities to refrain from hunting until the population increases (Jim Webb pers.comm.).

The threatened status of woodland caribou in Alberta is due in part to habitat loss and degradation. Caribou favor higher altitude elevated old growth coniferous stands both for protection from predators and for food. Lichen, found primarily in old growth stands, makes up a large component of their diet (Ouellet et al 1996). Moreover, predation rates are generally lower when old-growth conifer habitat is abundant (Fuller 1991). Yet the government of Alberta suggests that old growth habitat should be given priority for harvest, the rationale being that targeting this stand type increases the health of the forest (Alberta Environmental Protection 1994). Resource exploitation, specifically operations that remove old growth habitat, has been linked with declining caribou populations within this province (Dzus 2001).

3.2.1 Habitat Quantity

Although caribou are highly social, individual home ranges can be very large, in part because of the specificity of their habitat and foraging requirements. Stuart-Smith et al (1997) reported that the average home range of caribou in northeast Alberta was 711.44 km^2, and because of this population densities are low. Woodland caribou population densities for mid-continent locations range from 0.03 to 0.12 caribou/km^2 (Seip 1991, Bergerud 1992, Stuart-Smith et al 1997). Based on a life history table approach to compare adult and juvenile survival in a 20,000-km^2 area around Fort McMurry the rate of increase for the population was calculated to be –0.08, and therefore declining (Stuart-Smith 1997, Wynes 2000).

Caribou do not avoid contact with other *R.tarandus* individuals but try to spatially distance themselves from other species, particularly other ungulates. Caribou eat lichen partly because no other ungulate feeds on it, and therefore their foraging requirement aids segregation.

Habitat loss has been implicated in caribou population decline. Edmonds (1988), after speaking with numerous wildlife management personnel from Alberta and reviewing provincial population estimates, suggests that habitat loss over the past 20-30 years has caused a 50% reduction in caribou populations. In particular, forestry operations reduce habitat availability, as caribou tend to avoid newly cut areas. Fifty percent of caribou within 15 kilometers of a cut moved away once an area had been harvested, with females moving farther than males (Chubbs and Keith 1993). Caribou will only use logged habitat after it has regrown; in Ontario Cummings and Beange (1993) provided evidence that woodland caribou will not venture into areas cut less than 12 years previously, and will not make general use of cut areas until about 40 years post cut.

3.2.3 Habitat Quality

Habitat chosen by caribou throughout the year has lichen available, mature trees (dbh greater than 21 centimeters), extensive under story cover and canopy closures that range anywhere from 70% (in the spring) to 26% (in the winter) (Servheen and Jyon 1989). Caribou avoid mixed forests and tend to use mature conifer stands, especially stands greater than 120 years old that have not been disturbed for the last 25 years (Fuller and Keith 1981, Rominger and Oldemeyer 1989). While caribou will eat fungi, moss, herbaceous growth and shrubs they prefer lichen (Peterson 1966). Stands that are less than 60 years old have little foraging value and are usually avoided by individuals (Snow and Mahoney 1995). Lichen is extremely slow growing and is only available for caribou consumption after a tree is approximately 60 years old (Dzus 2001). However, new cutovers less than 4 years old have sufficient blow-overs and fallen trees with lichen on them to sustain an individual's foraging requirements and can be used by caribou (Snow and Mahoney 1995). Birthing sites are usually in mature conifer stands with available lichen and low canopy closure, and are typically found in muskeg bogs and fens (Servheen and Jyon 1989, Dzus 2001).

3.2.4 Roads

Dzus (2001) found that caribou avoid habitat that is within 200 meters of a road. Caribou avoidance of the habitat adjacent to roads may result from the increased risk of predation along linear corridors. Wynes (2000) showed that wolves travel 2.8 times faster on linear corridors than in other habitat and caribou experience increased mortality from wolves near these features (Wynes 2000). Caribou also may avoid roads because of the high risk of vehicle collisions (Ashley and Robinson 1996). A negative relationship between caribou population density and road density has been documented (Nelleman and Cameron 1998). Thirty-two caribou were hit by cars along highway 40 in central Alberta and this resulted in 27 known caribou deaths (Brown and Ross 1994).

3.2.5 Winter Conditions

Winter weather creates harsh conditions for caribou. In particular snow and ice create a variety of problems for caribou in terms of foraging, moving and escaping predators.

Once snow depths reach 50 to 60 centimeters individuals move into old growth timber stands for the remainder of the winter, as these areas tend to have lower snow accumulation (Ozoga 1968, Peterson and Allen 1974, Edmonds 1988). Caribou rely primarily on arboreal lichen for winter forage (Edmonds 1988, Rominger and Oldemeyer 1990). This type of lichen is not covered by snow in the winter since it does not grow below 3 meters (Rominger and Oldemeyer 1990). When snow is less that 50 centimeters deep caribou can crater or dig to reach lichen and low growing herbaceous plants below the snow pack (Fancy and White 1985). As snow depth increases individuals cannot smell the food under the snow and searching becomes too costly (Fancy and White 1985).

Caribou must also contend with snow crust, which can cause animals to increase energy expenditure while foraging. Thing (1977) found that the cost of pawing in uncrusted snow doubled when snow was dense and crusted. An increase in energy expenditure can cause body fat to decrease, especially when food is more difficult to obtain during the winter. Individuals with a lower body fat are at greater risk of predation or starvation (Gasaway et al 1986). Snow crust is not as severe in dense stands compared to more open, cooler habitats (Bradshaw et al 1995).

Snow hinders caribou mobility and hence, their ability to escape predators. Several studies have shown positive relationships between snow depth and wolf predation rates, with resulting population declines following years of large snow accumulation (van Bellenberghe 1985, Bergerud and Elliot 1986, Huggard 1993). A lower proportion of calves in the population has been found in years when the winter was prolonged, partially because of wolf predation on the young caribou (Bergerud and Elliot 1986, Cameron et al 1993).

3.2.6 Predation

Both wolves (*Canis lupus*) and lynx (*Lynx lynx*) in northern Alberta prey on caribou, with wolves being the primary predator (Wynes 2000). Survival of caribou adults is fairly high because of their predator avoidance strategies, but calves are more vulnerable (Wynes 2000). The annual survival for calves has been estimated at 21.9% for calves in northeast Alberta and herds lose 50% of their young within the first six months to wolf predation (Bergerud 1980, Bergerud and Elliot 1986, Stuart-Smith et al 1997). As a result recruitment is low, averaging 20 calves per 100 females and calf : adult ratios of less than 0.10 in the late winter and early spring are indicative of declining populations (Bergerud 1974, Bergerud and Elliot 1986, Wynes 2000).

Caribou are also very sensitive to wolf predation and consequently exist in low densities in locations far from other ungulates, such as moose and deer, as a strategy for reducing predation (Dzus 2001). Caribou are easier to kill than deer and moose and wolves will switch to caribou when available (Stephenson 1978, Bergerud 1974, Bergerud 1985, Manitoba Model Forest 1995). An increase in moose populations is typically followed by an increase in the number of wolves since enough food is present to support an growing predator population (Bergerud 1974). Typically when populations increase, ranges expand and this causes a decrease in the distance between moose, wolves and caribou. Therefore if moose populations experience an increase in size due to logging operations, caribou populations may decline. However, wolf populations may increase on their own, as a result of favorable conditions that are present in areas that are logged. Wolves flourish in disturbed areas, specifically where there is garbage from humans and where there are roads built (Fuller and Keith 1980, Crete et al 1981). Therefore forestry operations may increase wolf populations within the study area.

Chapter 4: Forest Management in Alberta and Habitat Suitability Maps

4.1: Forest management in Alberta

Alberta is covered by almost 38 million hectares of forest, approximately 61 thousand of which is harvested each year (The Alberta Center for Boreal Studies 2001). In 1999, forestry operations produced 80.3 million dollars in revenue for the government of Alberta (The Alberta Center for Boreal Studies 2001). Since the province's economy is built largely on natural resource extraction, regulations and monitoring are in place to ensure that ungoverned exploitation of resources does not occur (McDougall 1986).

In an attempt to regulate forestry, in 1954 the government of Alberta implemented the Forest Management Agreements (FMAs), which allows a private operator to use public lands for the purposes of establishing, growing and harvesting timber. Under these forest management agreements, a forest company must submit to the provincial government a forest management plan (FMP) which outlines the company's management objectives (when, where, how much to cut), determines how these objectives will be achieved, provides a record of past harvesting and related activities, and provides an updated summary of the forest's progress (Kimmins 1997). The FMPs are based on a forest inventory that provides detailed information on the state of the forest, in particular, the age structure, species composition and size/volume of the individual stands. These data, with the information on site conditions and published growth yield relationships, enables the operator to produce projections of future wood/fibre supply. FMPs must receive government regulatory approval before being implemented. If a management plan is approved, the operator must still submit an annual operating plan (AOP) to the province. These plans give detailed information regarding timber operations for the next twelve months, and, as with the FMP, must be approved before cutting operations proceed. In Alberta, the tenure of an FMP is 20 years, but each plan is re-evaluated every five years, principally to assess how the forest is responding to the cutting regime.

A key element of any FMP is an assessment of the quantity of each species of timber that will be removed annually by the forest company on a sustained level. Using a method determined by the province, the operator determines this quantity and provides the regulator with a document describing the estimation procedure, referred to as the annual allowable cut (AAC). This document is mandatory and details the annual quantity allowed to be cut on a sustained basis within a forest management area. Forest management areas, also referred to as forest management units, are public forestland managed as a unit for wood fiber production and other renewable resources. The province of Alberta sets the boundaries to these units.

Forest companies must also obtain timber quotas from the provincial government to begin forestry operations. Timber quotas are long-term rights to harvest a percentage of the allowable cut in a forest management unit. These quotas are issued for a 20-year renewable term. Timber quotas are purely volume agreements between the provincial government and forest companies.

The objective of forest management in Alberta is “to manage forest lands in a manner guaranteeing a constant supply of benefits and products while maintaining a high quality forest environment” (Alberta Sustainable Resource Development 2002). However, the government recognizes that timber is only one of the resources available within their provincial forests. Others valuable resources include fish, wildlife, water and agriculture, which are important for wilderness environment, recreation opportunities, natural features and forest aesthetics. People within Alberta expect that as resource extraction practices occur, these other non-timber values are recognized as well. Therefore timber harvesting in Alberta proceeds in such a way as to not endanger these other values that the forest ecosystem provides. Timber is managed according to the principles of sustained yield. Operationally sustained yield means that coniferous, deciduous and mixed wood forests are to be maintained in approximately the same proportion as they exist at the present time in perpetuity (Alberta Sustainable Resource Development 1994). Acceptable levels of timber use are based on the ability of the environment to absorb the impacts of harvesting (Alberta Sustainable Resource Development 1994). The government has produced guidelines to aid sustainable harvesting. Alberta’s Timber Harvest Planning and Operating Ground Rules lists a number of suggestions for forestry companies. Among the main suggestions are timber that is in the oldest and poorest condition should be given priority for harvest while healthy, vigorous stands should be retained, harvested areas must be treated within two years, and clear cutting be the primary method of timber extraction (Alberta Sustainable Resource Development 1994).

4.2 Alberta Vegetation Inventory

In the 1980's the government of Alberta recognized the need to develop a province-wide forest inventory database that could be used by provincial workers and forest management agreement holders to develop and evaluate forest management plans. The "Alberta Vegetation Inventory" (AVI) defined as "a system for describing the quantity and quality of vegetation present" was created, to meet the needs of the forest users, specifically forestry companies and to ensure that the same quality/quantity of forest information was provided to all potential users (Alberta Forestry, Lands and Wildlife 1992, Alberta Sustainable Resource Development 2002). The Alberta Vegetation Inventory was designed and developed by a team of natural resource specialists in 1991 and is now the provincial standard to be used in the development of forest management plans in Alberta. Production involved the stratification and mapping of existing vegetation information to produce digital data and volume tables. Information was collected from three main sources; aerial photos, orthophoto base maps, and field studies (Alberta Forestry, Lands and Wildlife 1992). Data were obtained from sources that used a number of different scales but a 1:20000 standard working scale was chosen to allow for generalization to smaller scales and incorporation of more detailed information if required (Alberta Forestry, Lands and Wildlife 1992). Data were collected from polygons greater than 2 hectares in size (Alberta Forestry, Lands and Wildlife 1992). In the field, an effort-area approach was used to ensure that representative samples were collected. Data were recorded for both vegetated and non-vegetated areas, with vegetation polygons identified as having at least 6% plant cover (Alberta Forestry, Lands and Wildlife 1992). The inventory includes information such as area of the polygon or stand, species composition, height, age, moisture regime, canopy closure, timber productivity rating, stand structure, and stand condition (Alberta Forestry, Lands and Wildlife 1992).

The Alberta Vegetation Inventory is used to predict forest fire risk, to calculate the annual allowable cuts, and to determine the province's timber supply status. AVI is a continuous inventory, meaning that an average of 1/20th of the land area is to be re-inventoried annually, to keep the database current. A summary of the information contained in the AVI is given in Table 4.2.1.

Table 4.2.1: A summary of the information included in the Alberta vegetation inventory.

Cover Type Information	**Definition**	**Category**	**Code**
Crown Closure	Percentage of ground area covered by the vertical projection of the tree crown	6%-30% 31%-50% 51%-70% 71%-100%	A B C D
Height	Average height of the dominant and co-dominant trees of the leading species, in meters	N/A	N/A

Cover Type Information	Definition	Category	Code
Moisture Regime	Based on plant indicators or environmental factors and soil properties	1. Dry: well drained areas 2. Mesic: moderately well drained locations 3. Wet: poorly drained to flooded locals with the water table at or close to the surface, or covered in shallow water 4. Aquatic: permanent deep water areas where the predominant growth medium is water, vegetation is characterized by hydrophytic vegetation that grows in or at the surface	D M W A
Age	Stand age, recorded in ten-year age classes, determined from 1:60 000 air photos interpreted with the aid of field and other existing data	N/A	N/A
4.1.4 Timber Productivity Rating (TPR)	Based on the height and age of the dominant and co-dominant trees of the leading species in the stand. This rating reflects factors affecting tree growth such as soil condition, topography, climate, elevation etc; recorded for stands that are less than 20 years old or if a proportion of the over story has been recently removed; determined from a TPR formula	Good Medium Fair Unproductive	G M F U
Cover Type Information	**Definition**	**Category**	**Code**
Stand Condition	Additional information about the origin or condition of the cover type	Clear cut/ partial cut Burn Windfall Clearing Disease Insect kill Unknown kill Weather Discolored / dead tree tops Broken tops Snags Scattered timber	CC BU WF CL DI IK UK WE DT BT SN ST

4.3. Habitat Classification

I created caribou and moose habitat suitability maps for the forest management units managed by Little Red River Tall Cree First Nations and Tolko Industries – High Level to determine the quantity and quality of suitable habitat. Habitat suitability maps were generated by first identifying environmental factors that, on the basis of published literature, are expected to affect reproduction or survival. In some cases, these factors were inferred from AVI variables already present in the AVI; in other cases, factors were inferred from AVI variables (e.g. winter snow depth, as inferred from AVI variables quantifying canopy closure, species composition, and moisture regimes) based on published empirical relationships between the factor in question and AVI variables (Table 4.3). Finally, published empirical relationships were used to produce a categorical habitat classification for each environmental factor, for both moose and caribou, ranging from high habitat quality (rank 1, suitable habitat) to unsuitable habitat (rank 4) (Appendix Table 4.3.1 to 4.3.34) (e.g. highly suitable habitat (rank 1) winter moose habitat contains a mix of *Larix laricina*, *Picea glauca* and a wet or aquatic moisture classification). In this way, for each environmental factor, the spatial distribution and total amount of habitat in each category was calculated for every forest management unit in the study area (Appendix, Table 4.3.1 to 4.3.34).

Table 4.3: Relationship between Habitat Dimension and Alberta Vegetation Inventory variables.

Habitat dimension	AVI variables	Rationale	Demographic effect	Reference
Summer moose habitat	tree species, soil moisture, canopy closure, stand condition	To spatially segregate themselves from others; to fulfill habitat requirements	Mortality from predation, starvation or disease	Schmitz and Nudds 1994, Messier 1991,Lynch and Morgantini 1984, Stephens and Peterson 1984, Fuller and Keith 1980, Le Resche 1974, Karns 1967
Winter moose habitat	tree species, soil moisture, canopy closure, stand condition	To spatially segregate themselves from others; to fulfill habitat requirements	Mortality from predation, starvation or disease	Schmitz and Nudds 1994, Messier 1991, Lynch and Morgantini 1984, Stephens and Peterson 1984, Fuller and Keith 1980, Le Resche 1974, Karns 1967
Snow Depth	tree species, age, soil moisture, canopy closure, stand condition	To increase mobility and decrease energy expenditure	Winter mortality and reserve allocation for reproduction	Collins and Helm 1997, Mech et al 1997, Telfer 1997, Huggard 1993, Schwab and Pitt 1991, Bergerud et al 1983
Snow Hardness	tree species, soil, age, moisture, canopy closure, stand condition	To increase mobility and decrease energy expenditure	Winter mortality and reserve allocation for reproduction	Collins and Helm 1997
Summer moose predation	tree species, soil moisture, canopy closure, stand condition	Avoid predators	Mortality from predation	Stephens and Peterson 1984
Winter moose predation	tree species, soil moisture, canopy closure, stand condition	Avoid predators	Mortality from predation	Mech et al 1997, Stephens and Peterson 1984
Summer temperature	tree species, soil moisture, age, canopy closure, stand condition	Decrease energy expenditure	Mortality	Cameron et al 1993, Schwab and Pitt 1991, Renecker and Hudson 1986
Spring moose forage	Shrub species, canopy closure, stand condition, moisture regime	To fulfill foraging and nutritional requirements	Mortality from starvation	Miller and Litracaitis 1992, Ontario Ministry of Natural Resources 1988

Habitat dimension	AVI variables	Rationale	Demographic effect	Reference
Summer moose forage	Shrub species, canopy closure, stand condition, moisture regime	To fulfill foraging requirements	Mortality from starvation	Ontario Ministry of Natural Resources 1988
Winter moose forage	Shrub species, canopy closure, stand condition, moisture regime	To fulfill foraging requirements	Winter mortality (starvation), reserve allocation for reproduction	Ontario Ministry of Natural Resources 1988
Summer caribou habitat	tree species, age, soil moisture, age, canopy closure, stand condition, elevation	To spatially segregate themselves from others; to fulfill habitat requirements	Mortality from predation, starvation or disease	Ouellet et al 1996, Snow and Mahoney 1995, Seip 1992, Rominger and Oldemeyer 1989, Servheen and Jyon 1989, Fuller and Keith 1981, Proulx and Joyal 1981
Winter caribou habitat	tree species, soil moisture, age, canopy closure, stand condition, elevation	To spatially segregate themselves from others; to fulfill habitat requirements	Mortality from predation, starvation or disease	Ouellet et al 1996, Snow and Mahoney 1995, Seip 1992, Servheen and Jyon 1989, Fuller and Keith 1981, Proulx and Joyal 1981
Summer caribou predation	tree species, soil moisture, age, canopy closure, stand condition, elevation	Avoid predators	Mortality from predation	Dzus 2001
Winter caribou predation	tree species, soil moisture, age, canopy closure, stand condition, elevation	Avoid predators	Mortality from predation	Dzus 2001, Ballenberghe 1985
Forage	tree species, age, canopy closure, stand condition	To fulfill foraging requirements	Mortality from starvation	Snow and Mahoney 1995, Racey et al 1991, Proulx and Joyal 1981

Chapter 5: Habitat suitability and population density

Forest management leads to changes in the distribution of vegetation communities. To the extent that such changes affect – either directly or indirectly – moose or caribou fecundity or survival, they will affect population size within a forest management unit. One such effect is on habitat quality and quantity (i.e. habitat suitability); as the quality and quantity of suitable habitat increases (decreases) in a given geographical area, we expect population size to increase (decrease). Thus, to estimate the effect of a particular forest management scenario on (say) moose population size, we need to (a) estimate the relationship between vegetation type and habitat quality in a given area; (b) estimate the relationship between habitat quality and moose population size in a given area; and (c) estimate how the distribution of different vegetation types will change under a given management scenario. With (a) – (c) in hand, we can estimate the effect of a specified scenario on habitat quality and quantity within a given area, and hence, on population size. In what follows we will attempt to establish steps (a) to (c) in order to assess the influence of the various forest management plan scenarios on moose and caribou population size within the study area.

5.1. Estimating habitat quality at the FMU level

A digital map (coverage) of the study area was obtained from Timberline Consultants and Tolko Industries. The area of each forest management unit and the area of each forest stand were calculated in ArcView by projecting this coverage into Albers equal area conic. Area calculations are more accurate using this projection as distortions are kept to a minimum (Patterson 2000). Within the coverage, individual forest management units (FMUs) are represented by polygons, each with an associated AVI table. These tables contain habitat information for the various forest stands, including the species composition, canopy closure, moisture regime etc (Table 4.2.1). Once the coverage has been projected the area of the stands can be calculated in ArcView and using the discrete habitat classification criteria for a particular habitat dimension shown in Tables 4.3.1 to 4.3.34 (appendix) each stand in a given FMU was assigned a habitat rank (1-4, see Appendix tables 4.3.1 to 4.3.34) based on the stand characteristics. The weighted average habitat quality/suitability for the FMU was then calculated as:

$$(5.1.1)\quad S_{ij} = \frac{\sum_{k=1}^{4} ka_{k,ij}}{A_j}$$

where S_{ij} is the habitat quality score for FMU j based on the habitat dimension i, k=1,..,4 is the habitat rank, $a_{k,ij}$ is the total area of habitat rank k, based on habitat dimension i in FMU j, and A_j is the area of FMU j. Thus the habitat quality score for a particular habitat dimension is the (area) weighted average of habitat ranks throughout the FMU: this average score will change as the area of different vegetation associations (and hence, habitat quality ranks) change under different management scenarios. This procedure was carried out for both moose and caribou habitat dimensions within the six forest management units (Appendix Table 4.3.1 to 4.3.34).

Because of the manner in which ranks for particular habitat dimensions were assigned based on stand characteristics (Appendix Table 4.3.1 to 4.3.34), ranks for some habitat dimensions will be strongly spatially correlated: for example, areas that have high (low) ranking with respect to snow depth will also have a high (low) ranking with respect to winter temperature, because the AVI variables that define the ranks along these two dimensions are quite similar (Appendix Table 4.3.1 to 4.3.34). As a consequence, there will also be strong correlations among the area-weighted average habitat scores for particular habitat dimensions across FMUs (Table 5.1.1 and Table 5.1.3).

Examination of the moose correlation matrix (Table 5.1.1) showed two subsets of habitat dimensions with large intercorrelations; one (snow depth, snow hardness, winter temperature and winter predation) reflecting the severity of winter conditions, a second (spring habitat, summer habitat, summer predation) reflecting the quality of spring and summer habitat. Principal component analysis was used to reduce the dimensionality of these two subsets: in both cases, the first principal component explained at least 83% of the within-subset variation (Table 5.1.1) and the correlation between the two extracted components was low (r = 0.268). The principal component representing winter conditions has a positive relationship with density (r = 0.38), signifying that densities increase when there is little of low rank habitat available (low ranked habitat is more suitable for the species for the particular habitat dimension of interest). The stand characteristics for these habitat dimensions are very similar; particularly rank 3 habitat (lower quality habitat) involves immature stands, clear cuts and stands with densities less than 30% (Appendix table 4.3.7, 4.3.11 and 4.3.13). These stands may be important to moose for other requirements, such as foraging and other vital necessities. The other principal component has a negative relationship with moose densities (r = -0.5), which indicates that density increases when there is more low ranking, or good, spring/summer habitat available.

I decided to use the two principal components, and ignore the other habitat dimensions I had initially investigated, in the model relating habitat suitability and moose density. The rationale for this decision was two fold; (1) when the other habitat dimension variables were added, the model did not improve (R^2, in fact, greatly decreased), and (2) we wanted to reduce the dimensionality of the data, since the sample size was so small.

Table 5.1.1 : Correlation matrix of area – weighted average habitat scores for different habitat dimensions across forest management units (moose).

	Snow depth	Snow hard	Spring Hab.	Summer Pred	Summer Hab.	Summer Temp.	Winter Pred.	Winter Hab.	Winter Temp.	Summer Forage	Spring Forage	Winter Forage
Snow depth	N/a											
Snow hard	0.78	N/a										
Spring Hab.	0.27	0.01	N/a									
Summer Pred.	0.46	0.36	0.95	N/a								
Summer Hab.	0.46	0.53	0.7	0.86	N/a							
Summer Temp.	0.47	0.06	0.63	0.53	0.26	N/a						
Winter Pred.	0.32	0.67	0.1	0.36	0.72	-0.41	N/a					
Winter Hab.	0.11	-0.47	0.06	0.02	-0.31	0.16	-0.43	N/a				
Winter Temp.	0.61	0.84	-0.29	0.02	0.4	-0.33	0.79	-0.23	N/a			
Summer Forage	-0.38	-0.03	-0.28	-0.13	0.2	-0.84	0.66	-0.14	0.4	N/a		
Spring Forage	-0.5	-0.23	-0.56	-0.46	-0.21	-0.93	0.37	0.07	0.27	0.91	N/a	
Winter Forage	-0.08	0.28	0.00	0.22	0.55	-0.65	0.9	-0.3	0.56	0.91	0.68	N/a

Table 5.1.2 : Principal component analysis of subsets of habitat dimensions for moose

Principal component	***Habitat dimension subset***	***Percent of Total Variance Explained***	***Coefficient***	***Squared Multiple R***
P_1^W	Snow depth, snow hardness, winter temperature	89	0.015	0.534
P_2^S	Spring habitat, summer predation, summer habitat	83	-0.017	

Examination of the caribou correlation matrix (Table 5.1.3) shows that all of the habitat dimensions were largely correlated, except for summer temperature. Principal component analysis was used to reduce the dimensionality of the data, specifically snow depth, snow hardness, winter temperature, winter habitat, summer habitat, winter predation, summer predation and forage were used to create a principal component, which explained 78% of the total variation.

Table 5.1.3 : Correlation matrix of area – weighted average habitat scores for different habitat dimensions across forest management units (caribou).

	Snow depth	Snow hard	Winter temp.	Summer temp.	Summer hab,	Summer pred.	Winter hab.	Winter pred.	Forage
Snow depth	N/a								
Snow hard	0.78	N/a							
Winter temp.	0.62	0.85	N/a						
Summer temp.	0.48	0.08	-0.3	N/a					
Summer hab.	0.88	0.76	0.66	0.19	N/a				
Summer pred.	0.90	0.63	0.43	0.46	0.95	N/a			
Winter hab.	0.84	0.82	0.83	0.02	0.96	0.84	N/a		
Winter pred.	0.57	0.75	0.92	-0.39	0.79	0.56	0.91	N/a	
Forage	0.37	0.70	0.76	-0.39	0.68	0.45	0.79	0.9	N/a

Table 5.1.4 : Principal component analysis of subsets of habitat dimensions for caribou

Principal component	*Habitat dimension subset*	*Percent of Total Variance Explained*
P_1	Summer habitat, summer predation, winter habitat, winter predation, winter temperature, forage, snow depth, snow hardness	78

5.2. Moose population density

Moose population estimates were derived from aerial surveys conducted in 1995 by the provincial government of Alberta (Alberta Fish and Wildlife). In Alberta, estimates of moose population density based on aerial surveys are available at the WMU scale. A WMU digital file, obtained from Alberta Sustainable Development, was overlaid with the FMU coverage to determine which wildlife management units overlapped with the forest management units. The portion (in km^2) of each WMU that fell within a FMU was then calculated in Arc View. The estimated density of moose in a given FMU was then calculated as

$$(5.2.1)\ D_j = \frac{1}{A_j}\sum_k a_{kj} d_k$$

with D_j, A_j the estimated moose density and area of FMU j respectively, a_{ij} the area of WMU k within FMU j, and d_k the estimated (from aerial surveys) density of moose in WMU k. These estimates are shown in Table 5.2.1.

Table 5.2.1: Estimated density (individuals / km^2) in each forest management unit.

FMU	***Area (km^2)***	***WMU***	***Area of WMU falling with FMU (km^2)***	***WMU density (moose/km^2)***	***Estimated FMU density (moose/km^2)***	***Estimated total population***
2	3039	540	1494.716	0.176	0.345	1049
		528	1543.811	0.509		
3	3039	540	3038.527	0.176	0.176	585
4	2933	540	2932.729	0.176	0.176	516
5	3098	534	436.722	0.135	0.262	784
		535	3.348	0.054		
		528	593.684	0.509		
		540	2574.891	0.176		
6	3463	534	3462.872	0.135	0.135	468
7	96	540	95.365	0.176	0.176	17

5.3 Caribou Population Estimates

Caribou population size is notoriously difficult to measure, in part because of the cryptic coloration of caribou, their avoidance of open areas and clumped distribution (Wynes 2001). Some have tried to estimate caribou population density within Alberta, however, results have been widely varying and thus can be used within a project of this nature with little confidence (Fuller and Keith 1981, Bjorge 1984, Edmonds 1988, Stuart-Smith et al 1997). Therefore, unfortunately, reliable estimates of caribou population size for northern Alberta were not available (Wynes 2001).

5.4 Habitat quality and moose density

The predictive model ($R^2 = 0.53$) to calculate the number of moose in a FMU for various logging scenarios is as follows:

(5.4.1) density (individuals / km^2) = $0.21 + 0.015\ (P_1) - 0.017\ (P_2)$

density = number of moose found in a FMU per km^2

P_1 = Principal component 1 factor score (winter temperature, snow depth and snow hardness)

P_2 = Principal component 2 factor score (spring habitat, summer habitat and summer predation)

Table 5.4.1: Results of the population density linear regression

Effect	*Coefficient*	*Std error*	*Std coef*	*Tolerance*	*T value*
Constant	0.21	0.03	0		7.65
F1	0.015	0.01	0.55	0.93	1.35
F2	-0.017	0.01	0.65	0.93	-1.58

This equation will allow us to calculate the moose density after a forest management plan scenario has been implemented by using habitat suitability values.

5.5 Habitat quality and caribou density

Since reliable estimates of caribou population size did not exist for the study area we were forced to develop another method for assessing the impact of forestry operations on caribou population size. Theoretically, we can ascertain that as habitat suitability increases (decreases) within an area, the number of caribou individuals that can be supported increases (decreases). Since we are trying to estimate the effect of a particular forest management scenario on caribou population size, we decided to examine the impact of the forest management scenario on the forest management units' habitat suitability. Specifically, we used the summer temperature and principal component information to determine what effect the forest management scenarios had on the caribou population size by investigating if the habitat suitability increased (population would decrease) or decreased (population would increase) after the proposed cutting had occurred. However, the degree of population change could not be quantified, as it was with moose.

Table 5.5.1: Present Day Caribou Habitat Suitability

	FMU 2	**FMU 3**	**FMU 4**	**FMU 5**	**FMU 6**	**FMU 7**
Habitat Suitability	3.22	3.16	3.29	3.47	2.92	3.46

* Habitat suitability = (weighted averages) within the forest management units, averaged over habitat dimensions

Chapter 6: Forest Management Plan Scenarios

With the relationship between caribou/moose population size and habitat suitability estimated, I then wanted to investigate the impact of various forest management plans on the indigenous and non-indigenous values. This would allow me to access the compatibility (or lack thereof) of indigenous and non-indigenous forest values. To this end, I (a) constructed a set of possible forest management plan scenarios; (b) evaluated the risks to both indigenous and non-indigenous endpoints associated with each scenario; and finally (c) investigated the relationship between the risk estimates obtained.

6.1 Forest Management in Canada

The principal tool for forestry in Canada is the forest management plan, a document in which the operational elements of future logging rotations are given for a specific forest company (Kimmins 1997). FMPs are based on a forest inventory that provides – a least in principal - comparatively detailed information on forest stand age structure, species composition, and size/volume relationships (Daishowa-Marubeni International LTD 1999). The forest inventory, along with published growth-yield relationships and site condition data (e.g. stand tree volume, composition and density, presence of past disturbances, and soil moisture), surrounding landscape features (e.g. elevation, slope), and guidelines developed by the provincial governments and forestry companies are used by timber operators and regulators to determine which stands are potentially harvestable within a forest management area. The forestry company identifies the harvestable stands within their FMAs and stores data pertaining to these stands in land base tables. In

Alberta, provincial standards for forestry operations include specifications concerning, for example, the minimum volume of trees within a harvestable stand and the maximum cut block size (Alberta Environment 1994). Guidelines produced by individual forestry companies generally pertain to where logging operations occur and what the company has determined to be profitable to extract. For example, some companies choose to target a specific tree species or harvest stands with a moisture regime that is traditionally not compatible with forestry operations. These guidelines vary among companies but all guidelines must be included within the forest management plan and approved by the province before operations proceed.

In Alberta, all forestry companies use the stand information available in the Alberta Vegetation Inventory, provincial guidelines and standards (specifically "Timber harvest planning and operating ground rules"; Alberta Environment 1994) and their own criteria to determine where and when stands will be harvested. The AVI contains forest inventory and site condition information (see section 4.2). The provincial guidelines include: (i) timber that is in the oldest and poorest condition should be given priority for harvest while healthy, vigorous stands should be retained; (ii) harvested areas must be treated within two years; (iii) the primary method of timber extraction is clear cutting; (iv) merchantable coniferous trees have a minimum diameter of 15 cm outside the bark at breast height and a 11 cm diameter inside the bark at the top of the tree; (v) merchantable coniferous stands must have a net merchantable volume of trees 50 m^3/ha or greater; (vi) merchantable deciduous trees have a minimum diameter of 15 cm outside the bark at breast height and a 10 cm diameter inside the bark at the top of the tree; (vii) merchantable deciduous stands must have a net merchantable volume of trees 50 m^3/ha or greater with a conifer volume less than 50 m^3/ha; (viii) cut blocks in deciduous stands or stands where pine comprises 40% or more of the merchantable timber may be up to 100 ha in size; (ix) cut blocks in spruce timber may be up to 24 ha in patches or up to 32 ha if cuts are designed as strips; (x) cut block boundaries should follow natural terrain; (xi) white spruce is given priority for protection in the under story; and (xii) protective buffers must be placed around watercourses, among others (Alberta Sustainable Resource Development 1994). Tolko Industries also has additional internal criteria and guidelines. For example, Tolko Industries is interested in cutting black spruce, *Picea mariana*, a species not traditionally harvested in northern Alberta (Frank Oberle pers. comm.). These guidelines and the government's regulations were used to determine the harvestable land base within the study area.

6.2 Determining the harvestable land base

Each forest company produce land base tables to identify stands that have passed government and in house guidelines and are suitable for cutting. Forestry companies must include the land base tables and the amount they propose to cut within a specific timeline to the government when forest management plans and annual allowable cut documents are submitted. Timberline Forest Inventory Consultants were employed by Little Red River/ Tall Cree First Nations in 2001 to determine the harvestable land base in forest management units 3, 4 and 6. The document "Landbase Determination Process: Technical Report" details the methodology used; specifically information contained within the Alberta vegetation inventory was utilize to categorize stands as being harvestable based on the Alberta timber harvest planning and operating ground rules and the criteria developed by the forest company operating in the area. Table 6.2.1 summarizes the applicable land base exclusions (Timberline 2001). Stands retained (i.e. stands not excluded by virtue of exclusion criteria in Table 6.2.1) by Timberline, and therefore deemed harvestable in the land base tables, were dominated by *Pinus banksiana, Picea mariana, Picea glauca, Abies lasiocarpa, Populus tremuloides, Populus balsamifera,* or *Betula papyrifera* and had densities greater than 30%. The land base table created by Timberline for F3, F4 and F6 were identical to the AVI database for this area, except that individual stands were identified as being harvestable or excluded from logging operations.

Table 6.2.1: Exclusion criteria for determination of the harvestable land base in forest management units 3, 4, and 6. If stands possessed any of the criteria listed below they would be excluded from logging operations.

Land Class	***Tree Species***	***Over story density***	***Under story density***
Agricultural land: crop or pasture land			
Industrial land: well sites, pipelines etc			
Non-forested land: shrubby and herbaceous areas			
Areas created by humans including roads, mines, industrial plants, cites and towns etc			
Land that naturally has <6% vegetation			
Stands modified by forestry operations, burns, wind, disease etc.			
	Pinus banksiana, Picea mariana, Picea glauca, Abies lasiocarpa, Populus tremuloides, Populus balsamifera, Betula papyrifera	6%-30%	None or 6%-30%
	Larix sp.		
	Picea mariana	6%-50%	
Sites with an unproductive rating			

6.3 Methodology

Land base tables were needed for all the FMUs (F2 – F7) in order to determine which stands were harvestable for the forest management plan scenarios. Unfortunately, Tolko did not supply the land base tables for F3, F5 and F7. Therefore, we decided generate land base tables for all the FMUs by applying the classification scheme denoted in Table 6.2.1, or some variation thereof depending on the FMP scenario, to the respective AVI tables. The main motivation behind this was to insure that the same method of classification was used for all the FMUs land base tables.

Land base tables were created for each forest management unit for each FMP scenario investigated. The classification scheme used to determine which stands could be harvested and which stands should be excluded from logging changed for each forest management plan. In total, six different forest management plan scenarios were created; (1) when the classification scheme denoted in Table 6.2.1 was applied; (2) when black spruce stands were targeted for harvesting; (3) when "a" density stands were allowed to be harvested; (4) when larch was cut; (5) when older conifer stands were retained; and (6) when white spruce stands were not cut. The impact of each of the FMPs on the endpoints, specifically the population density of moose, the population size of caribou, and profit, were then quantified to determine the overall compatibility of indigenous and non-indigenous values in forestry operations.

6.4 Forest management plans

6.4.1 Endpoint 1: *Alces alces* density

The FMP scenarios that I created differ in (a) the total amount of forest harvested; and (b) the attributes of those stands that are harvested. In section 4.3 a classification scheme for moose habitat was derived that mapped stand characteristics, based on the amount and the attributes of the stand, into a habitat suitability index for various habitat dimensions. In section 5.1.1 a model was constructed which related the density of moose and the suitability of habitat within a FMU on two orthogonal composite habitat dimensions based on a principal component analysis of six habitat variables (snow depth, snow hardness, winter temperature, spring moose habitat, summer moose habitat, and summer moose predation). The implementation of a forest management plan will change a the habitat suitability of a forest management unit and thus alter the density of moose within the area.

6.4.2 Endpoint 2 - *Rangifer tarandus caribou* population size

Since FMP scenarios will differ in the amount and type of habitat that is retained, the number of caribou that can be sustained in an area after a plan is implemented will also change. In section 4.3, a classification scheme for caribou habitat was derived which mapped stand characteristics, based on the amount and the attributes of stand, into a habitat suitability index for various habitat dimensions. To determine if the population size of caribou will increase or decrease within a FMU once a forest management plan has been implemented, the habitat suitability of the area will be calculated. This will be accomplished by determining how many stands of rank 1, rank 2, rank 3 and rank 4 habitat is left in the forest management units once cutting has occured. If the suitability values increases (decrease) we can conclude that the population size of caribou within the area will decrease (increase).

6.4.3 Endpoint 3 – Profit Generated

Most profit equations include parameters for the volume of trees harvested, the estimated market price of various tree species, and the stand composition. However, it is not feasible from the information listed in the Alberta Vegetation Inventory to estimate any of these three parameters. AVI gives the average height of the dominant tree species and the area of the stand, using this information to calculate the volume of the stand would assume that the entire stand is comprised of the same size and species of tree. To calculate an accurate estimate of stand volume, the average diameter at breast height (dbh) would be needed. Market prices are given for tree species when the bark and branches are removed. Trees in this state are referred to as lumber, standing tree are called timber. AVI tables, however, list dimension for timber only. Lumber dimensions are generally calculated at a mill after the trees have been cut (this would not have been possible for this study since trees are being hypothetically harvested). In terms of species composition, AVI lists the five dominant species in the stand but does not quantify the proportion, which makes it impossible to quantify the total amount of each species in a cut block. Therefore, estimating the profit generated from logging operations was problematic since data were lacking for this calculation.

Individual forestry companies calculate the stand volumes during site checks to estimate profit generated from harvesting certain locations (Frank Oberle pers.comm.). Unfortunately this information did not exist or could not be supplied by either Timberline Forest Inventory Consultants or Tolko Industries – High Level. However, we became aware that a common practice within forestry companies when parameters were unknown in conventional profit calculations was to use a value of $1750 per hectare to estimate profit generated from logging operations (Tim Gautier pers.comm.). This value is an average and can be applied to timber and to stands of all compositions (Tim Gautier, pers comm.). I used this to estimate the profit generated from each forest management plan scenario, specifically:

(6.4.3) Profit = area * $1750/ha

area = total area (ha) of the stands identified as being

I recognize that this value is not species specific and therefore the profit generated from a model using this information depends solely on the area cut. However, since (i) data was lacking; (ii) because the goal of the project was to determine the compatibility, qualitatively, between indigenous and non-indigenous values; and (iii) because the operator within the study area also used this practice to estimate profit, I decided it would be acceptable.

6.4.4 Scenario: Forest Management Plan – Standard

In this FMP, stands that had characteristics listed in Table 6.2.1 were categorized as being retained and stands with dominant tree species including *Pinus banksiana, Picea mariana, Picea glauca, Abies lasiocarpa, Populus tremuloides, Populus balsamifera,* or *Betula papyrifera*, densities greater than 30%, and were not excluded by virtue of the exclusion criteria in Table 6.2.1, were categorized as harvested. As you may remember this was the classification scheme used by Timberline and therefore represented a standard or conventional FMP. This classification scheme was applied to all FMUs and therefore land base tables were produced for all the areas within the study area (F2, F3, F4, F5, F6, F7). This scenario reflected the standard land base table that would be created by a forestry company and was conservative in comparison to some of the other FMP scenarios we investigated. This scenario, the black spruce, larch and "A" density scenario were all developed with the forestry sectors interests in mind (i.e. cutting operations were designed to maximize profit).

Table 6.4.1: Results of the original forest management plan outline in the "Land base Determination Process: Technical Report"

	FMU 2	*FMU 3*	*FMU 4*	*FMU 5*	*FMU 6*	*FMU 7*
Area (km^2)	3133.37	3322.77	2932.73	3705.04	3439.03	95.09
Amount cut (km^2)	196.26	185.49	133.37	311.25	448.02	10.82
Moose density	0.253	0.105	0.136	0.191	0.149	0.191
Caribou habitat suitability	3.26	3.21	3.34	3.56	3.07	3.64
Profit generated ($)	34.35 M	32.16 M	23.34 M	54.47 M	78.4 M	1.89 M

Table 6.4.2: Caribou habitat suitability (weighted averages) within the forest management units for the various habitat dimensions.

Habitat Dimension	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
Snow depth	2.72	2.76	2.54	3.00	2.52	3.07
Winter temperature	2.84	2.39	2.71	3.26	2.72	3.26
Snow depth	2.97	2.83	2.92	3.27	2.82	3.52
Summer habitat	3.72	3.72	3.86	3.95	3.26	3.91
Summer predation	3.77	3.95	3.94	3.94	3.52	3.91
Winter habitat	3.58	3.46	3.69	3.91	3.13	3.79
Winter predation	3.55	3.21	3.65	3.81	3.26	3.77
Forage	3.20	3.11	3.61	3.57	3.20	3.61
Summer temperature	2.95	3.48	3.11	3.31	3.19	3.93

This FMP scenario cuts, on average, 8.2% of the total area within a forest management unit. F6 has the largest proportion cut, at 13%. However, even though this scenario is conservative, the profit generated by logging operations is immense (Table 6.4.1). Also, as expected, FMUs with a larger harvestable land base (i.e. more stands identified as being harvestable) generate a higher profit for the forestry company.

The density of moose within the forest management units decrease after this FMP has been implemented, anywhere from 13% (F2) to 26% (F3) compared to present day conditions (Table 5.2.1 and 6.4.1). However, the density of *A.alces* is higher when this FMP is used in the study area than it is when the "A"density scenario is used, less than it is when the black spruce scenario is applied and approximately the same as it is for the larch scenario (reasons for these changes will be discussed in forthcoming sections).

Caribou habitat suitability is higher (meaning weighted average values are lower) for this FMP scenario than it is for the other scenarios designed to maximize profit (the standard, black spruce, "A" density and larch FMPs). This is likely due to the fact that less area is harvested in this scenario than the others (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7). There are no large changes in habitat suitability when comparing this scenario to present day conditions, the largest occurs in F7 (approximately 0.18) (Table 5.5.1 and 6.4.2).

6.4.5 Forest Management Plan – Black Spruce

Picea mariana is traditionally not an economically viable species to harvest in northern Alberta since it grows in wet locations that typically hinder logging operations (Frank Oberle pers comm.). However, it is also one of the most important pulpwood species in Canada and Tolko is interested in harvesting this species in the future (Frank Oberle pers.comm.). Therefore, a forest management plan was developed that explored the impact of removing stands of *P.mariana* from the study area on Tolko's and the aboriginal community's interests. The classification scheme developed by Timberline (i.e. Table 6.2.1) and used in the standard FMP scenario was used, however, stands with *P.mariana* as the primary species could also be harvested, as long as they were not categorized as being unprofitable or prohibited for cutting for reasons listed in the Table 6.2.1 (e.g. it was agricultural land or was less than 6% vegetated).

Table 6.4.3: Black spruce scenario results

	FMU 2	*FMU 3*	*FMU 4*	*FMU 5*	*FMU 6*	*FMU 7*
Area (km^2)	3133.37	3322.77	2932.73	3705.04	3439.03	95.09
Amount cut (km^2)	549.8	1823.10	689.86	502.32	1759.5	19.38
Moose density	0.268	0.134	0.147	0.198	0.181	0.191
Caribou habitat suitability	3.42	3.75	3.55	3.62	3.65	3.53
Profit generated ($)	96.21 M	319.04 M	120.73 M	87.91M	307.91 M	3.39 M

Table 6.4.4: Caribou habitat suitability (weighted averages) within the forest management units for the various habitat dimensions.

Habitat Dimension	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
Snow depth	2.89	3.54	2.85	3.10	3.25	3.21
Winter temperature	3.37	3.65	3.19	3.40	3.55	3.51
Snow depth	3.45	3.69	3.25	3.41	3.61	3.67
Summer habitat	3.90	3.89	3.94	3.98	3.77	3.95
Summer predation	3.82	3.95	3.94	3.94	3.75	3.91
Winter habitat	3.82	3.85	3.88	3.94	3.84	3.90
Winter predation	3.72	3.65	3.83	3.84	3.82	3.81
Forage	3.65	3.95	3.93	3.67	3.93	2.34
Summer temperature	2.16	3.60	3.16	3.32	3.35	3.44

Harvesting black spruce dramatically increases the number of harvestable stands within the study area (Table 6.4.1 and Table 6.4.3). As a result, the profit generated from each of the forest management units increased compared to the standard FMP (the land base increases by approximately 4 times). However, since *P.mariana* is difficult to harvest in northern Alberta, using $1750 per hectare in the profit equation may lead to an overestimation of revenue. Regardless of whether a value less than $1750/ha was used, the profit would still likely be higher than it was for the standard FMP scenario because of the large increase in the number of harvestable stands.

The density of moose is lower in all the forest management units (compared to present day conditions), in the case of F7 by as much as 0.058 individuals/km^2, when black spruce stands are harvested (Table 6.2.1 and 6.4.3). Removing black spruce stands is detrimental to the population of *A.alces* primarily because these stands are considered high-ranking habitat in the spring and summer months (Appendix Table 4.3.1 and Table 4.3.5). Thus removing black spruce dominated stands decreases the amount of rank 1 habitat and increases the amount of rank 4 habitat (stands that are cut are reassigned to this rank). This will decrease the overall suitability of habitat for these particular habitat dimensions. Since the spring/summer habitat principal component is negatively related to the density of moose, decreasing the habitat suitability (ie. increasing the weighted average for that habitat dimension) would cause a decline in moose density.

The density of moose increases within the FMUs compared to the original, or standard, forest management plan (Table 6.4.1 and Table 6.4.3). Black spruce stands are also classified as highly suitable habitat (either rank 1 or rank 2) for the winter habitat dimensions (Appendix Table 4.3.7, 4.3.11, and 4.3.13). Removing these stands will decrease the amount of rank 1 habitat in the study area and increases the amount of rank 4 habitat. This will lead to a decrease in the overall suitability. The winter conditions principal component has a positive relationship with moose density in the study area, meaning that as the weighted average increases (suitability decreases), the density of moose increases. The weighted averages values for the winter conditions habitat dimensions are greater in this scenario than they were for the original forest management plan, leading to a heightened density of moose in the FMUs.

The weighted average, representing caribou habitat suitability, increases (meaning habitat becomes less suitable) when black spruce stands are harvested. Again, this is mostly due to additional stands, or a larger area, being harvested in this FMP scenario than the standard forest management plan. If this FMP scenario was implemented caribou population size would decrease since there is less suitable habitat for the species in the study area. The largest change in habitat suitability values compared to the standard FMP scenario is approximately 0.6 (for FMU 6). The average difference between black spruce weighted averages and present day conditions weighted average values is 0.33 (Table 5.5.1 and 6.4.4). This does not represent a large change in habitat suitability (8%); however, this may greatly affect the population status of caribou within northern Alberta given the fact that caribou are considered endangered in the province (COSEWIC, 2002). Also *P.mariana* stands are typically classified as higher ranking habitat for caribou (Appendix, Table 4.3.25 to 4.3.34) and therefore harvesting these stands may alter the availability of high quality habitat. This may have dramatic repercussions for a species that is already in a delicate condition.

6.4.6 Forest Management Plan 3 – "A" Density

High density, fully stocked stands are generally targeted by forestry companies for harvesting. These stands generate more money than harvesting low-density areas because either (a) larger or (b) more trees can be removed, which increases the volume of lumber being sent to the mill. In fact, the land base determination report for the study area states that stands with densities ranging from 6% to 30% are considered non-commercial, or unprofitable (Timberline 2001). It is feasible, however, that depending on the stands that remain in the future, that forestry companies may need to harvest these sites. Therefore we created a FMP scenario that would target low density, or "A" density, stands to determine the impact to the indigenous and non-indigenous values of interest. Again the classification scheme used in the standard FMP was applied (Table

6.2.1), however, locations that had an overstory or understory density ranging from 6%-30% were available for future cutting rotations, as long as they were not categorized as being unprofitable or cutting was prohibited for other reasons (Table 6.2.1).

Table 6.4.5: Results of the "A" density scenario

	FMU 2	*FMU 3*	*FMU 4*	*FMU 5*	*FMU 6*	*FMU 7*
Area (km^2)	3133.37	3322.77	2932.73	3705.04	3439.03	95.09
Amount cut (km^2)	1179.86	1208.54	1560.45	1625.18	1840.16	41.41
Moose density	0.115	0.027	0.046	0.011	0.014	0.075
Caribou habitat suitability	3.44	3.47	3.80	3.88	3.42	3.70
Profit generated ($)	206.47 M	211.49 M	273.08 M	284.41 M	322.03 M	7.25 M

Table 6.4.6: Caribou habitat suitability (weighted averages) within the forest management units for the various habitat dimensions

Habitat Dimension	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
Snow depth	3.39	3.32	3.74	3.88	3.42	3.80
Winter temperature	3.34	2.93	3.58	3.87	3.32	3.74
Snow depth	3.40	3.21	3.68	3.84	3.32	3.80
Summer habitat	3.84	3.75	3.92	3.97	3.45	3.95
Summer predation	3.91	4.00	4.00	4.00	3.71	3.98
Winter habitat	3.75	3.61	3.81	3.96	3.33	3.88
Winter predation	3.75	3.37	3.81	3.88	3.46	3.91
Forage	3.39	3.26	3.71	3.62	3.37	2.24
Summer temperature	2.18	3.80	3.91	3.94	3.43	3.98

This scenario generates the largest profit from timber operations (Tables 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9, 6.4.11). This is largely due to the large number of stands that can potentially be harvested (again, compared to the other scenarios, this has the largest harvestable land base associated with it) (Tables 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9, 6.4.11). There would be a sufficient amount of "A" density stands to harvest in the future if these stands were targeted for harvesting operations. Again, the profit may be overestimated since some of these stands are likely not profitable to the forestry (i.e. there are just too few trees in the stand to make a profit from harvesting the area). However, this is the most profitable scenario explored.

Harvesting "A" density stands has a dramatic effect on the availability of moose in the study area, in large part due to the amount of habitat being cut. Winter condition habitat dimensions, specifically snow depth, snow hardness and winter temperature, classify "A" density stands as low suitability habitat. If this FMP is implemented these stands will move from the rank 3 category to be reclassified as rank 4 habitat. Therefore we can conclude that it is not this particular principal component (or these habitat dimensions) that is driving the decrease in population size. Specifically low-density stands are classified as highly suitable habitat in the summer and spring and when escaping from predators during the summer. This scenario reclassifies a large amount of high-ranking stands (rank 1 or 2) for habitat dimensions which are represented by the summer/spring season principal component into lower ranks (rank 3 or 4). This principal component has a negative relationship with moose density and therefore an increase in the weighted averages of these habitat dimensions (a decrease in suitability) would cause a decrease in the population of moose in the study area.

Weighted averages of caribou habitat suitability increase when "A" density stands are harvested, meaning there is less suitable habitat for caribou in the study area after this FMP scenario has been implemented. This stand type is classified as high ranking locations for habitat dimensions forage, winter habitat, winter predation and summer predation (Appendix Table 4.3.25, 4.3.29, 4.3.31, 4.3.33). Because thinner stands are considered more suitable habitat for caribou and because this scenario harvests the most area, weighted averages are largest for this forest management plan (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9, 6.4.11). Compared with the original FMP scenario the largest change in habitat suitability occurs in F4 (0.46) (Table 5.5.1 and 6.4.5). When examining the difference between present day values and the suitability of habitat that exists after "A" density stands have been harvested, the largest change in weighted average habitat values occur in F6 (0.5).

6.4.7 Forest Management Plan Scenario 4 – Larch

Larch (*Larix laricina*) generally grows in wet, swampy areas that are not compatible with logging operations, and specifically with logging machines (Frak Oberle, pers comm.). As a result, this species has been determined to be "non-commercial" by the forestry operators in northern Alberta (Timberline 2001). As previously mentioned, Tolko is interested in harvesting black spruce (*P.mariana*) stands. *P.mariana* is also found in wet locations and therefore similar difficulties would be associated with harvesting *P.mariana* and *L. laricina* stands. Therefore, if Tolko could log black spruce stands they may also harvest tamarack stands in the future. A FMP scenario was created to explore the effect of cutting *L. laricina* stands on the indigenous and non-indigenous values. Specifically, in the original classification (Table 6.2.1) stands that listed *Larix sp.* as the primary species were not considered for harvesting in the future. In this forest management plan, the classification scheme used in the standard FMP (table 6.2.1) was used, however, as long as the stands were not categorized as being unprofitable or if cutting was prohibited for other reasons, stands which listed *Larix* sp. as the primary species could potentially be harvested.

Table 6.4.7: Results of the *L. laricina* scenario

	FMU 2	*FMU 3*	*FMU 4*	*FMU 5*	*FMU 6*	*FMU 7*
Area (km^2)	3133.37	3322.77	2932.73	3705.04	3439.03	95.09
Amount cut (km^2)	405.73	783.67	475.19	432.73	609.07	19.41
Moose density	0.249	0.108	0.137	0.193	0.152	0.184
Caribou habitat suitability	3.31	3.38	3.45	3.59	3.12	3.67
Profit generated ($)	71.0 M	137.14 M	83.16 M	75.73 M	106.59 M	3.4 M

Table 6.4.8: Caribou habitat suitability (weighted averages) within the forest management units for the various habitat dimensions

Habitat Dimension	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
Snow depth	2.82	3.00	2.70	3.05	2.60	3.20
Winter temperature	2.95	2.79	2.96	3.32	2.82	3.46
Snow hard	3.07	3.09	3.08	3.35	2.91	3.65
Summer habitat	3.75	3.76	3.90	3.96	3.29	3.94
Summer predation	3.78	3.95	3.94	3.94	3.53	3.91
Winter habitat	3.65	3.58	3.81	3.94	3.19	3.89
Winter predation	3.75	3.36	3.76	3.83	3.31	3.80
Forage	3.29	3.31	3.74	3.60	3.26	3.70
Summer temperature	2.72	3.55	3.16	3.32	3.21	3.47

The profit generated is greater than it was in the standard forest management plan (also for the old conifer and white spruce scenarios) but less than when black spruce and "A" density stands were logged (Tables 6.4.1 to 6.4.6). Of all the scenarios created to sustain non-indigenous forest values (i.e. to increase the profit for forestry companies), this is the least profitable. This is likely due to the fact that there is less larch dominated stands in the study area than black spruce or "A" density stands (Table 6.4.1, 6.4.3, 6.4.5).

Harvesting larch seems to have little effect on the availability of moose in the forest management units, compared to the standard FMP scenario, even though a larger area is harvested (Table 6.4.1 and Table 6.4.5). This may in part be because *Larix sp.* stands are classified as low suitability summer/spring habitat for moose (rank 3 habitat specifically) (Appendix Table 4.3.1 and 4.3.5), and therefore harvesting these areas (removing stands from the rank 3 category and adding them to the fourth rank) did not greatly change the weighted average of these habitat dimensions. However, these stands are classified as rank 1 or 2 habitat for winter conditions snow depth, snow hardness and winter temperature (Appendix Table 4.3.7, Table 4.3.11 and Table 4.3.13). When this FMP scenario is executed the weighted averages of these winter habitat dimensions increase, meaning that habitat in the forest management units become less suitable for moose. However, because there are fewer larch dominated stands in the study area than there are stands dominated by black spruce or "A" densities, the weighted average is not as drastically changed from the original FMP scenario as it is for the others. As a result there is not a great difference between the density of moose in the FMUs after the original FMP is implemented and when larch stands are harvested.

Habitat is most suitable for caribou in this scenario compared with the other forest management plans created with the non-indigenous value in mind (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7). The average change in suitability from the original FMP scenario is 0.07, the largest change occurs in F2 (0.17). The average change in suitability compared to present conditions is 0.015, the largest difference again happens in forest management unit 2 (0.22). Also this FMP scenario has the least change in habitat suitability compared to the black spruce and "A" density stand scenario (Table 6.4.3, 6.4.5, 6.4.7). Therefore caribou population size will likely not decrease as much from harvesting larch dominated stands as it will when removing "A" density and black spruce stands.

6.4.8 Forest Management Plan Scenario 5 – Old Growth Conifer

In Alberta, the government advises that timber that is in the oldest and poorest condition should be given priority for harvest by forestry operators (Alberta Sustainable Resource Development 1994). This suggests that older stands should be removed before younger stands. This may benefit the overall health of the forest; however, *Alces alces* and *Rangifer tarandus caribou* both rely heavily on older conifer stands for survival (Fuller and Keith 1981, Stephens and Peterson 1984, Edmonds 1988, Rominger and Oldemeyer 1989, Schwab and Pitt 1991, Manitoba Model Forest 1995). Thus, removing this stand type from the area may reduce the population size of moose and caribou. The community members of Little Red River Tall Cree recognize the importance of older stands for the survival of wildlife, specifically caribou, and suggest that stands dominated by older conifer should be protected in the study area to maintain the population size of this species (Hickey and Natcher 2000). A forest management plan scenario was developed that would examine the impact of harvesting older conifer stands on the population size of moose and caribou. This FMP scenario would also test the LRRCN theory that retaining older conifer stands maintains the population size of caribou in northern Alberta. Again the criteria listed in Table 6.2.1 was applied to the AVI tables, but this time conifer stands of a certain size were not harvested. Specifically, we were able to determine the approximate age of the trees based on the height listed in the AVI tables from known species-specific size/age graphs (Burns et al, 1990).

Table 6.4.9: Results of old conifer scenario

	FMU 2	*FMU 3*	*FMU 4*	*FMU 5*	*FMU 6*	*FMU 7*
Area (km^2)	3133.37	3322.77	2932.73	3705.04	3439.03	95.09
Amount cut (km^2)	135.54	128.36	107.02	305.02	234.35	10.82
Moose density	0.268	0.12	0.146	0.192	0.141	0.191
Caribou habitat suitability	3.25	3.20	3.30	3.56	3.05	3.59
Profit generated ($)	23.72 M	22.46 M	18.73 M	53.38 M	41.01 M	1.9 M

Table 6.4.10: Caribou habitat suitability (weighted averages) within the forest management units for the various habitat dimensions

Habitat Dimension	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
Snow depth	2.68	2.72	2.53	3.00	2.34	3.07
Winter temperature	2.83	2.39	2.76	3.26	2.72	3.26
Snow hard	2.97	2.83	2.91	3.27	2.87	3.52
Summer habitat	3.72	3.69	3.56	3.95	3.26	3.91
Summer predation	3.75	3.93	3.93	3.94	3.52	3.91
Winter habitat	3.56	3.44	3.68	3.91	3.13	3.79
Winter predation	3.54	3.20	3.64	3.81	3.25	3.77
Forage	3.20	3.11	3.61	3.57	3.20	3.61
Summer temperature	2.99	3.45	3.09	3.31	3.19	3.43

The profit generated from logging is lower in this FMP scenario than it was in the previous forest management plans (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9). The reduction in profit is largely due to fewer stands being included in the harvestable land base (Table 6.4.1 to 6.4.5). Since coniferous trees dominate the landscape in northern Alberta, retaining older conifer stands has a large impact on the revenue generated from logging operations. This scenario demonstrates just how important the harvesting of older conifer stands is to forestry operators in the area. However, the profit generated in this forest management scenario is still considerable, ranging anywhere from 1.9 to 41 million dollars.

In this forest management plan, the effect of logging on moose density is minimized (Table 5.2.1, 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9). In particular, the density of moose increases in all the forest management units, compared to the standard FMU scenario, except F6 (Table 6.4.1 and 6.4.5). The increase in population size is likely due to the decrease in area that is harvested in this forest management plan (Table 6.4.1 and 6.4.5). Mature conifer stands are classified as highly suitable habitat for moose in the winter; they moderate the severity of snow depth and hardness and also regulate cold temperatures (Ozoga 1968, Peterson and Allen 1974, Edmonds 1988). The weighted averages for these habitat dimensions change little from the original FMP to this scenario. However, it appears that FMU 6 is heavily stocked with older conifer stands, and as a result the weighted average for this FMU has a higher degree of variation between scenarios (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9). This is especially true for the weighted average of F6 for the snow depth habitat dimension. As discussed, the winter habitat dimensions snow depth has a negative relationship with moose population size. Therefore, since the F6 weight average decreases for this habitat dimension, the population size of moose will also decrease. The retention of conifer stands will also impact the spring/summer principal component since they are important for spring and summer habitat and for escaping predators (Appendix Table 4.3.1 to 4.3.17). An increase in the suitability of these habitat dimensions (a decrease in their weighted averages) will cause an increase in the density of moose.

A much larger area is harvested in the black spruce scenario than this scenario (Table 6.4.3 and Table 6.4.9). Thus the profit generated from the *P.mariana* scenario is much greater than the profit from retaining older conifer stands in the study area. However, the density of moose is greater in the *P.mariana* scenario as well. As mentioned previously black spruce stands are classified as highly suitable (rank 1 or 2) habitat for the winter habitat dimensions. As the weighted averages for these habitat dimensions increase (there is a large change in the habitat suitability values once black spruce are harvested since there are so many of these stands present in the FMUs), the density of moose also increase. The weighted averages for winter habitat dimensions are larger for the *P.mariana* scenario than they are in this scenario. Moose population size has a negative relationship with winter habitat dimensions and therefore this explains why the density of moose is higher in the *P.mariana* scenario. Also the weighted averages for spring/summer habitat dimensions are larger in this scenario than they are in the black spruce scenario. These dimensions have a positive relationship with moose population size, therefore adding to the lower densities we find in the FMUs in this scenario.

Habitat suitability is higher in this FMP scenario than any of the previous FMPs explored for caribou (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9). This is likely due to the fact that less area is harvested in this modeling exercise and that older stands are considered preferred caribou habitat. Habitat suitability values are still greater (meaning habitat is less suitable) than present day conditions, however, the difference between the weighted averages are very small, averaging 0.07 (Table 5.5.1 and 6.6.10). Therefore this FMP scenario will not drastically reduce the population size of caribou in the study areas as some of the other forest management plans most likely will.

As mentioned, this plan is less harmful to caribou, compared with the previous FMP scenarios (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9). A 2001 report stated that resource exploitation, specifically operations that remove old growth habitat, has been linked with declining caribou populations within Alberta (Dzus 2001). This is a reflection of the dependence of caribou on older conifer stands for their foraging requirements and for predator avoidance (Rominger and Oldemeyer 1990, Fuller 1991). As hypothesized by Dzus and the community members of LRRCN, to maintain the availability of caribou forest management plans should avoid logging of these stand types.

6.4.9 Forest Management Plan 6 – White Spruce

White spruce, *Picea glauca*, is a valuable commercial species that is of great important to aboriginal people. Besides being used by aboriginal people to make canoes and snowshoes and treat wounds they believe it is important for the survival of wildlife (Kershaw 2001). The government of Alberta has developed regulations to protect understory white spruce trees from harvesting; however, these regulations do not apply to the canopy trees (Alberta Sustainable Resource Development 1994). LRRCN members suggested to Hickey and Natcher that limiting the harvest of *P.glauca* may help to maintain the availability of moose in the study area (2000).

A forest management plan was developed that would examine the impact of harvesting white spruce dominated stands on the population size of moose and caribou. This FMP scenario would also test an indigenous theory; that retaining *P.glauca* stands maintains the availability of moose in northern Alberta (Hickey and Natcher 2000). The criteria for determining which stands would be harvested and which would be retained outlined in Table 6.2.1 was used to classify stands, however, those with *P.glauca* as the primary species could not be considered for cutting.

Table 6.4.11: Results of white spruce scenario

	FMU 2	*FMU 3*	*FMU 4*	*FMU 5*	*FMU 6*	*FMU 7*
Area (km^2)	3133.37	3322.77	2932.73	3705.04	3439.03	95.09
Amount cut (km^2)	36.4	112.23	87.23	295.03	441.74	10.57
Moose density	0.276	0.122	0.145	0.218	0.156	0.198
Caribou habitat suitability	3.24	3.13	3.32	3.55	3.06	3.58
Profit generated ($)	6.37 M	19.64 M	15.27 M	51.63 M	77.31 M	1.85

Table 6.4.12: Caribou habitat suitability (weighted averages) within the forest management units for the various habitat dimensions

Habitat Dimension	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
Snow depth	2.66	2.81	2.51	2.99	2.52	3.06
Winter temperature	2.82	2.38	2.70	3.26	2.71	3.26
Snow hard	2.96	2.82	2.91	3.27	2.82	3.52
Summer habitat	3.71	3.69	3.86	3.95	3.26	3.90
Summer predation	3.74	2.82	3.93	3.93	3.51	3.90
Winter habitat	3.54	3.44	3.68	3.91	3.12	3.78
Winter predation	3.53	3.62	3.64	3.81	3.25	3.76
Forage	3.20	3.10	3.61	3.56	3.19	3.61
Summer temperature	3.02	3.49	3.08	3.30	3.18	3.42

This scenario generated the least revenue for Tolko and harvested the smallest area (Table 6.4.1 to 6.4.6). Thus, this scenario may not favorable to forest companies and may be unlikely to be implemented. However, this scenario also has the smallest decline in the moose population size compared to present day conditions (Table 5.2.1, 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9, 6.4.11). Indeed it appears that the population is largely unaffected by logging operations used in this management plan. This may suggest that when white spruce is retained in an area being harvested, moose populations are not as detrimentally affected. However, this high population size may be just the result of the reduction in harvestable forest stands (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9, 6.4.11). Regardless of the reason, this FMP is the best scenario for maintaining the density of moose within the study area; densities are close to those observed when there is no logging at all.

This plan is also beneficial for caribou, compared with the original FMP, black spruce and "A" density scenarios (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9, 6.4.11). The small weighted average values are a reflection of the conservative forest management plan, very little area is harvested in this scenario (Table 6.4.11). The largest difference between the weighted averages resulting from this FMP and present day conditions is 0.07 (Table 5.5.1 and 6.6.12). Again this FMP scenario appears to have little influence on the overall suitability of caribou habitat in the study area and therefore may have little impact on population size as well.

6.5 Probability Distribution and Compatibility of Indigenous and Non-Indigenous Values

Probability distributions were constructed for (1) moose density, (2) caribou factor score data, (3) caribou summer temperature data and, (4) profit. These distributions were used to quantify the probability of attaining the indigenous and non-indigenous values for each FMP scenario and to analyze the compatibility of the values in forest management.

A method that would be consistent among values was desired to build probability distributions and to analyze the results. Since the only predictive equation that generated residual errors was available for moose, I decided to use the confidence interval (t distribution and assuming 95% confidence) to solve for standard deviation. These standard deviation values were then used in a Monty Carlo analysis to build probability distributions.

6.5.1 Probability Distribution – Moose

Equation 5.4.1 was used to construct the moose density probability distributions. In particular, the mean and the standard deviation of the model coefficients were used in a random number generator to produce 1000 runs of coefficient values. The mean was the coefficient of the principal component, taken from predictive equation 5.4.1, and the standard deviation was calculated from the coefficient's confidence interval (assuming

95% confidence). In particular, we defined the upper limit of the confidence interval by multiplying the coefficients by either 25% or 50%, depending on the scenario (this will be discussed in greater detail in the next paragraph). This value was then added to the coefficient to generate the upper limit of the confidence interval. Now that the confidence interval was defined, the standard deviation could be determined from the confidence interval equation. This process was completed for both coefficients in the model, specifically 0.015 and –0.017.

Two different avenues were investigated, one using 25% and the other using 50% to define the upper limit of the confidence interval. For the sake this write up, we will refer to these as the 25% standard deviation and the 50% standard deviation scenarios. In total four runs of 1000 values were produced for each forest management plan explored, one for each coefficient for each standard deviation scenario. The values were entered into equation 5.4.1 to calculate the density of moose within a forest management unit and probability distributions were constructed from this information. Distributions were created for each forest management unit for each forest management plan explored. The density of moose within each FMU was calculated for each run (therefore in total 1000 density values were produced for each FMU) and these values were compared to (i) the current density of moose within each FMU and (ii) the density of moose which resulted after the standard forest management plan had been implemented. The probability of attaining (i) and (ii) were calculated for each forest management unit for each forest management plan by examining how many values produced were equal to or greater the desired number of moose.

Probability distributions were also constructed for the density of moose in the study area. The forest management units' moose density values (1000 for each FMU) and the area of each forest management unit were used in a weighted average calculation to determine the density of moose within the study area at the present time and after the standard FMP had been used. The desired number of moose was calculated using the same method as above except the moose density estimates from Table 6.4.1 or 6.4.3 (and not the runs of density values) were used. Again probability values were calculated for each forest management plan explored.

6.5.2 Probability Distribution - Profit

Equation 6.4.3 was used to construct the probability distributions for profit. In particular \$1750 and the standard deviation of this value were entered into a random number generator to produce 1000 runs of profit values. As with the moose probability distribution, the standard deviation was determined from the confidence interval (assuming 95% confidence). In particular, 25% or 50% were multiplied by \$1250 and this value was then added to \$1250 to determine the upper limit of the confidence interval for the scenario in question. Since the upper limit of the confidence interval was defined, the confidence interval equation could be manipulated to solve for the standard deviation. This value was then used in the random number generator. Again two scenarios were investigated, specifically 25% and 50% standard deviation. Each profit value produced by the random number generator was plugged back into equation 6.4.3 and multiplied by the area cut in the forest management units for each forest management plan. The number of values greater than or equal to the profit gained by Tolko (i) determined from the limited cut block information supplied; and (ii) in the standard FMP scenario were quantified.

Probability distributions were constructed for the study area as well. The profit generated in each forest management unit (1000 profit values for each FMU) were added together to estimate the profit generated by the various forest management plans. Probability values were calculated for each of the forest management plans representing the likelihood of obtaining (i) the current level of profit (determined from the cut block information) and (ii) the profit generated from the standard forest management plan.

6.5.3 Probability Distribution – Caribou

To determine if the population size of caribou will increase (or decrease) we examined the difference between habitat suitability values before cutting had commenced and after a forest management plan had been implemented. If the factor score of the principal component (which represented forage, winter temperature, summer habitat, winter habitat, summer predation, winter predation, snow depth, and snow crust) decreased and if summer temperature habitat suitability values decreased, habitat suitability would increase (habitat is ranked from 1 (highly suitable) to 4 (unsuitable)). A decrease in habitat suitability values means there is more habitat caribou could potentially use. If there is an abundance of suitable caribou habitat, population size would likely increase or remain stable. If habitat suitability values were to increase (meaning there is an increase in rank 3 or 4 habitat) the population would likely decline.

The habitat dimensions' suitability values calculated for each forest management unit were used in the random number generator as well as the suitability values' standard deviation. In this analysis, 5% and 10% standard deviation scenarios were examined. Smaller errors were used in the caribou probability distributions analysis because we felt fairly confident in our designation of habitat into ranks. Larger errors were used in the moose and profit analyses because (1) two steps were used in the moose analysis where error could be introduced (one was assigning habitat to a specific rank ant the other was building the model relating habitat suitability to moose density); and (2) the equation for profit was a gross approximation and therefore we felt it was appropriate to use a large error in the analysis.

Either 5% or 10% was multiplied by the habitat suitability value for a particular habitat dimension and this value was added to the habitat suitability value in question to determine the upper limit of the confidence interval. The standard deviation was then calculated from the confidence interval (assuming 95% confidence). A run of 1000 values was produced for each habitat dimension in each forest management unit. In total each forest management plan scenario had 108 runs of values (one for each habitat dimension examined within the forest management units for the particular standard deviation value used (either 5% or 10%)). Each value was multiplied by the applicable habitat dimension component loading generated from the principal component analysis. These values then represented the factor score of each forest management unit's habitat dimension. The values were summed across habitat dimensions (except summer temperature) to produce 1000 runs of factor score values per forest management unit. This process was repeated for each of the forest management plans. Again the probability distributions were created and probability values were calculated for each FMU. The probability of (i) maintaining the current level of habitat suitability and (ii) achieving the level of habitat suitability once the standard forest management plan had been implemented was quantified by comparing the factor score values to those produced under current conditions and to those calculated after the standard FMP had been applied.

The habitat dimension summer temperature was the only dimension not included in the principal component. To examine the probability of attaining the current level and the level produced from the standard FMP of summer temperature habitat suitability after the various forest management plans had been implemented in the study area the previous process was repeated. However, for this analysis we did not calculate factor scores and used the habitat suitability values produced from the random number generator instead.

Probability distributions were constructed across the study area for the habitat dimension summer temperature and the principal component factor scores. The forest management units' factor score values (1000 for each FMU) and the area of each forest management unit were used in a weighted average calculation to determine the factor score value within the study area. This was done for each FMP explored and the factor scores that resulted were compared to those generated from present day conditions and after the standard FMP had been used. This process was repeated for the summer temperature habitat suitability values.

6.6 Results

6.6.1 Probability of obtaining the current level of moose within the study area

The probability of maintaining the current population size of moose in the study area if logging operations proceed is low (Appendix Figure 6.6.1 and 6.6.2).

In the 25% standard deviation scenario the risk of not achieving the desired population size of moose is greatest in forest management unit 2 (Appendix Figure 6.6.1). It appears that the population of moose in this forest management area will likely decrease if any kind of harvesting occurs. The weighted average values associated with the summer habitat dimensions increase in this forest management unit once the FMPs are implemented. Since there less habitat is available for moose within the area (this principal component has a negative relationship with population size), the population declines. On the other hand FMU 5 has some of the highest probability values associated with it (Appendix Figure 6.6.1). However, the probability values associated with F5 are not extremely high, the largest being 0.4.

In the 25% standard deviation scenario the black spruce forest management plan generates the largest probabilities of maintaining the current population size of moose, ranging from 0.09 (F7) to 0.45 (F5) (Appendix Figure 6.6.1). As previously discussed (section 6.5.5), black spruce stands are classified as highly suitable habitat (either rank 1 or rank 2) for moose in the winter (Appendix Table 4.3.5, 4.3.10, and 4.3.12). Targeting these stands for cutting will decreases the amount of rank 1 habitat in the study area and increases the amount of rank 4 habitat. Habitat suitability will decrease which will cause an increase in moose density within the forest management units (the winter conditions principal component has a positive relationship with moose density, meaning that as the weighted average increases (suitability decreases), the density of moose increases). Not surprisingly, this forest management scenario also had the least risk associated with it for not achieving this indigenous value when calculated across the entire study area (Appendix Figure 6.6.3).

The probability of maintaining the current population size of moose within the forest management units if the "A" density forest management plan is implemented is very low (Appendix Figure 6.6.1). As explained in section 6.5.6, this is possibly due to the large area that is harvested when this plan is executed (Table 6.4.5). However, when calculated across the entire study area, the old conifer scenario had the lowest probability associated with it (Appendix Figure 6.6.3). Though the old conifer scenario does not have a high probability of decreasing the population size of moose dramatically (minimum study area population size = 0.128, maximum study area population size = 0.215), it also does not have a high probability of increasing the population of *A.alces* either. The percent change probability curve for old conifer is quite narrow, indicating that this forest management plan should not change the population size of moose dramatically within the study area (Appendix Figure 6.1 and 6.1). Since a large change in moose density is not expected if the old conifer FMP is used, the probability of decreasing the population size of moose is low. This cannot be said for the "A" density

FMP. The study area's population density range is much wider, from 0 to 0.281, when the "A" density forest management plan is used. Since the range of values is wider for this FMP scenario, there is a higher probability of achieving the indigenous value of interest. However, there is also a greater risk of decreasing the population size of moose in the area (Appendix Figure 6.65 and 6.66). We suggest that the "A" density scenario should not be used since it can dramatically reduce the population size of moose. The old growth and white spruce scenarios would likely achieve a higher, more stable population size of moose in the study area (Appendix Figure 6.65 and 6.66).

Using the 25% standard deviation data, the current population of moose will likely decrease within the area if any type of logging occurs in the future.

When the 50% standard deviation values are utilized the risk of not achieving the desired population size of moose is greatest in forest management unit 6 (Appendix Figure 6.6.2). In particular, low probability values are associated with the old conifer and white spruce scenarios compared to the other forest management plans. These low p values may be a result of the large area cut in F6 when these FMPs are used. It appears that this FMU has a large harvestable land base within it.

As was the case in the 25% standard deviation exercise, the largest probability value occurs in F3 when the black spruce forest management plan in implemented (0.47).

However, forest management unit 5 has the lowest risk of not achieving this indigenous endpoint when the 50% standard deviation values are used (Appendix Figure 6.6.2). The largest probability value for this FMU is still rather low (0.43).

The logging operations prescribed in the black spruce scenario are the most likely to maintain the population size of moose within each of the forest management units (Appendix Figure 6.6.2). Again, this forest management plan has the least risk associated with it of not achieving the indigenous endpoint across the study area (Appendix Figure 6.6.4). The standard forest management plan, the old conifer scenario and white spruce FMP produce higher risks of not maintaining the current moose density within the study area. These forest management plan scenarios also have the smallest range in population densities (Appendix Figure 6.65 and 6.66). Therefore they may not reach the desired population size but the population size will not dramatically decrease if these forest management plans are utilized. These FMPs will more likely maintain a stable population close to the current state than the other forest management plans.

When the 50% standard deviation values are used (Appendix Figure 6.6.2) the probability of maintaining the density of moose within the forest management units after forestry operations transpire is quite low.

6.6.2 Probability of maintaining the population size of moose after the conventional FMP has been implemented

Similar trends are evident when I used the population size achieved after the standard forest management plan too define the indigenous endpoint (Appendix Figure 6.6.5 and

6.6.6). However, probability values are generally larger since the desired population size is lower compared to the present population size. Therefore, it is more likely to achieve this indigenous endpoint than the previous endpoint defined for moose.

In this analysis, probability values are more consistent among forest management units (Appendix Figure 6.6.5 and 6.6.6). This was not the case when the previous indigenous endpoint was examined, especially when the 25% standard deviation values were used (Appendix Figure 6.6.1). The forest management plan that is most likely to achieve the desired population size of moose with the FMUs appears to be the white spruce scenario (Appendix Figure 6.6.5 and 6.6.6). The black spruce scenario has a high probability of achieving this desired population size within the study area and the old conifer scenario has the lowest probability (Appendix Figure 6.6.7 and 6.6.8). For the reasons of and interpretation of these results see section 6.6.1.

6.6.3 Probability of obtaining the current population size of caribou within the study area

The probability of maintaining the current population size of caribou in the study area if logging operations proceed is low.

The 5% standard deviation analysis using factor score information shows that there is a large risk of not achieving the current state of habitat suitability within the forest management units if any type of logging occurs in the future (Appendix Figure 6.6.9). The probability of achieving the current state of summer temperature caribou habitat suitability within the study area is a little higher, but the probability of achieving this indigenous endpoint is still quite small (Appendix Figure 6.6.10). In the 5% standard deviation scenario using factor score data the largest probabilities occurs in FMU 3 when the white spruce FMP scenario, is implemented (Appendix Figure 6.6.9). When using the summer temperature data the largest probability values are associated with F7 for the standard FMP and F2 for the black spruce management plan (Appendix Figure 6.6.10). However, these large probability values are an anomaly among forest management units. The average probability of maintaining the current level of summer temperature habitat suitability and factor score habitat suitability within the forest management units after logging operations proceeds is 0.23 and 0.09 respectively.

Forest management unit 6 is unlikely to achieve the indigenous endpoint if logging operations occur (Appendix Figure 6.6.9 and 6.6.10). The habitat suitability values for this FMU change dramatically for habitat dimensions summer predation, winter habitat and winter predation when the various forest management plans are implemented. As evident in tables 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9 and 6.4.11 the largest change in habitat suitability compared to present day conditions occurs in this FMU (see also Table 5.2.1 for present day conditions). This forest management unit contains a large number of harvestable stands and a large area is harvested, regardless of the FMP scenario.

Using the factor scores, F3 appears to be the most likely to achieving the indigenous endpoint (Appendix Figure 6.6.9 and 6.6.11). However, the average probability value for this FMU is low, specifically 0.21 using 5% standard deviation values and 0.24 using 10% standard deviation values, since some forest management plans have very small values associated with them. In particular, when the white spruce FMP is implemented, the risk of not achieving this indigenous endpoint is quite low but the risk is much higher when other forest management plans are applied. Forest management unit 2 is the most likely FMU to achieve the current state of summer temperature habitat suitability within the study area; however, the probability is small (0.4 using 5% standard deviation values and 0.43 using 10% standard deviation values) (Appendix Figure 6.6.10 and 6.6.12).

When using the factor score information the old conifer and white spruce forest management plans have the least risk of not maintaining the current level of habitat suitability within the forest management units (Appendix Figure 6.6.9 and 6.6.11). These forest management plans were developed with the aboriginal community's interests in mind, so it is not surprising that such results are generated for these plans. Even though there is little habitat cut within the forest management units (Appendix Table 6.4.9 and 6.4.11) when these FMPs are utilized, the probability of maintaining the current level of caribou habitat suitability is still quite small. When examined across all forest management units, old conifer had a probability of 0.05 and the white spruce scenario had a value of 0.04 associated with it for achieving this endpoint (Appendix Figure 6.6.13 and 6.6.14). Therefore, even though these FMPs had the highest probability values associated with them when calculated across the study area, the current level of habitat suitability (represented by the principal component) will not be maintained if logging operations proceed. The standard FMP is most likely to maintain the current level of summer temperature habitat suitability within the forest management units. This is largely to do with the large probability value that results in F7 when this forest management plan is implemented. When examined across the study area, the white spruce and old conifer FMPs have the lowest risks of not achieving this indigenous endpoint, however, these values are extremely small (especially when 5% standard deviation values are used) (Appendix Figure 6.6.15 and 6.6.16).

The conventional forest management plans, meaning those developed to maximize profit, have some of the lowest probabilities of maintaining the current level of caribou habitat suitability within the forest management units (Appendix Figure 6.6.19, 6.6.10, 6.6.11 and 6.6.12). Indeed there are many instances when the black spruce, "A" density and larch scenarios are applied to the forest management units when there is a zero probability of achieving the desired factor scores, meaning that habitat suitability will surely decrease (compared to present day conditions) if these forest management plans are used. This could be a reflection of the large area that is harvested within the forest management units when these forest management plans are used. When examined across the entire study area, the probability of maintaining the current factor score values or the current level of summer temperature habitat suitability is lowest for these FMPs compared to the other scenarios examined (regardless of the standard deviation scenario).

Therefore, it is extremely unlikely that the current level of caribou habitat suitability will be maintained if logging operations proceed within the study area. This may have dramatic consequences for the population of caribou within the study area, whose status is already endangered.

6.6.4 Probability of maintaining the population size of caribou after the standard FMP has been implemented

The probability of achieving the degree of caribou habitat suitability created after the standard forest management plan had been implemented is low, however, this indigenous endpoint is more attainable than the one examined previously.

The white spruce and old conifer FMPs have some of the highest probability values when examining the likelihood of achieving the desired factor score values within the FMUs (Appendix Figure 6.6.17 and 6.6.18). Probability values are also high for these forest management plans when examining the likelihood of achieving the desired level of summer temperature habitat suitability within the forest management units (Appendix Figure 6.6.19 and 6.6.20). The conventional forest management plans are still the least likely to achieve the desired caribou habitat suitability, compared to the old conifer and white spruce FMPs.

Forest management unit 4 has the highest risk across all forest management plans of not achieving the desired factor score value. This forest management unit's habitat suitability values change dramatically for habitat dimensions snow hardness and winter temperature when the various forest management plans are examined (Table 6.4.1, 6.4.3, 6.4.5, 6.4.7, 6.4.9, and 6.4.11). F7 is the least likely forest management unit to achieve the desired level of summer temperature habitat suitability. However, these forest management unit does not stand out as being particularly bad for achieving the desired level of habitat suitability (either represented by factor score or summer temperature habitat suitability values); indeed all forest management units have low probability values associated with them. When 5% standard deviation values were used F3 has the highest probability value of achieving the desired factor score value (0.31) and F5 is the most likely to achieve the desired level of summer temperature habitat suitability (0.39). When 10% standard deviation values were used and factor scores were examined, the high probability exists in F7 (0.44). When summer temperature habitat suitability values were analyzed, F5 had the largest probability values (0.43).

It is evident that this indigenous endpoint will not be attained if conventional forest management plans are utilized. As was the case with the previous caribou habitat suitability endpoint, if the forest management plans black spruce, "A" density and larch are used for harvesting in the study area there is little to no chance of achieving the desired level of habitat suitability (Appendix Figure 6.6.21, 6.6.22, 6.6.23, and 6.6.24). This is evident in both the factor score and summer temperature habitat suitability analysis (Appendix Figure 6.6.21, 6.6.22, 6.6.23, and 6.6.24). Again, this is likely because of the large area harvested within the study area when these forest management plans are used. The old conifer and white spruce FMPs have larger probability values associated with them, especially when examining the factor score values for a given FMP before and after logging operations proceed (Appendix Figure 6.6.21, 6.6.22, 6.6.23, and 6.6.24).

It is more likely to achieve this indigenous endpoint than the one examined in section 6.6.3 since the desired level of habitat suitability is defined by a conventional forest management plan and thus habitat is of lower suitability (habitat suitability values are higher than they were in section 6.6.3 or present day conditions). However, this means that the desired endpoint reflects a reduction in the amount and quality of caribou habitat that exists presently. The current population of caribou in the area is endangered and LRRCN is not satisfied with the current number of caribou within the area and would like the population to increase to a point where hunting was possible (Jim Webb pers comm.). Therefore, even though it appears that this endpoint is more likely to be achieved within the study area, the amount and quality of caribou habitat may not be acceptable to the community of LRRCN.

6.6.5. The probability of achieving the profit level calculated from the cut block information

The cut block information obtained from Tolko Industries – High Level was extremely limited and therefore this endpoint underestimate the profit generated from logging operations within the study area. Therefore, the risk of not achieving this non-indigenous endpoint is extremely small, in the majority of instances 0% to 1% (Appendix Figure 6.6.25 and 6.6.26). By using the cutting operations prescribed in the various forest management plan scenarios the profit desired by Tolko is certain to be achieved. These results are mostly due to the fact that the forest management plans we created cut a much larger area than the area calculated from the cut block information. When the white spruce FMP is applied in forest management unit 2 (0.88) the lowest probability value is generated using the 25% standard deviation values. All forest management units are extremely unlikely to not achieve the desired non-indigenous endpoint, values range from 0.98 to 0.99 (Appendix Figure 6.6.25 and 6.6.26).

The probability values calculated for each of the FMP scenarios across the study area are very similar to those generated when calculated for individual forest management units. All forest management plans have less than 2% risk that they will not achieve the profit desired by Tolko (Appendix Figure 6.6.27 and 6.6.28). The old conifer, white spruce and standard FMP appear to have higher risks associated with them compared to the other forest management plans, but the difference being about 1%. Since the range of probability values is quite narrow it is hard to discern which forest management units and FMP scenarios are more likely to achieve the non-indigenous value (Appendix Figure 6.6.25, 6.6.26, 6.6.27, and 6.6.28). If this level of profit is an accurate reflection of the desired endpoint then even the FMPs designed with the indigenous values in mind would be feasible for implementation by Tolko.

6.6.6 The probability of achieving the profit level that the conventional forest management plan generated

Using the profit generated from the standard forest management plan may be more realistic of the profit desired by Tolko. The level of profit used in section 6.6.5 to calculate the risk of not achieving the non-indigenous value may have been underestimated, which would cause the extremely high probability values in the analysis.

Unsurprisingly, the risk is greater for not achieving this non-indigenous endpoint than it was when the desired level of profit was calculated from the cut block information. In the 25% standard deviation scenario the risk of not achieving the desired level of profit for forest management plans "A" density, black spruce and larch are generally less than 10% (Appendix Figure 6.6.29). In fact there are many instances when the probability of achieving the desired profit endpoint is 100% (Appendix Figure 6.6.29). The lowest value associated with these forest management plans is generated when the larch FMP is applied in forest management unit 6, 0.76. For the 50% standard deviation analysis the largest probability is associated with F3 for the black spruce scenario (Appendix Figure 6.6.30). The lowest probability value for the conventional FMPs is generated in F6 for the larch scenario (0.72). Again the risk of not achieving the non-indigenous endpoint is low for these forest management plans; the majority of probability values are greater than 0.9. These results are likely a reflection of the large area that is harvested in these forest management plans (Table 6.4.5). Therefore all the forest management plans designed to take into account the values of the forestry operators have high probabilities of achieving the desired level of profit within the forest management units as well as the study area. However, these values are less than those generated when the previous profit endpoint was examined. The most notable difference between the previous profit endpoint (section 6.6.5) and this endpoint, is in the risk associated with forest management plans white spruce and old conifer (Appendix Figure 6.6.25, 6.6.26, 6.6.27, and 6.6.28). The largest probability value for the old conifer and white spruce scenarios is approximately 0.5, meaning there is a 50% chance of achieving this non-indigenous endpoint if these forest management plans are used (Appendix Figure 6.6.29 and 6.6.30). Thus, if using the profit generated from the conventional FMP scenario is more reflective of the non-indigenous endpoint for forestry companies, the FMP created with the indigenous community's interests in mind may not guarantee the level of profit Tolko desires.

Not surprisingly the conventional FMPs have lower risks of not achieving the desired profit level across the study area, close to 0% (Appendix Figure 6.6.31 and 6.6.32). The white spruce and old conifer FMPs has much larger risks of not achieving this non-indigenous endpoint, specifically greater than 75% (Appendix Figure 6.6.31 and 6.6.32).

If the level of profit used as the non-indigenous endpoint in this section is closer to the profit desired by a forestry company it appears that the FMP scenarios designed with the indigenous values in mind will not be as profitable for the forestry company than some of the forest management plans will be.

Chapter 7: Compatibility, Management Implications and Conclusions

7.1 Compatibility

The purpose of the project was to assess the compatibility of indigenous and non-indigenous values in forest management. We chose to examine the relationships between (i) moose population size and profit; and (ii) the amount of suitable caribou habitat and profit.

In figure 7.1.1 and 7.1.2 (Appendix) the probability of achieving the indigenous and non-indigenous values' present day conditions are shown for a variety of forest management plans. While the risk of not achieving the non-indigenous endpoint is quite small (close to 0%), the risk of not achieving the desired moose population size and caribou habitat suitability is comparatively larger (Appendix Figure 7.1.1 and 7.1.2). As was pointed out in chapter 6, the probability of achieving the current moose population size and the current level of caribou habitat suitability is quite small, regardless of the operational elements a forest management plan prescribes. Therefore, it is highly unlikely that the current level of caribou habitat suitability and the current moose population size will be maintained in the study area if forestry operations proceed.

Figure 7.1.3 and 7.1.4 (Appendix) demonstrate the relationship between indigenous and non-indigenous values when the population of moose, the level of caribou habitat suitability and the profit generated from the standard forest management plan are desired. In this analysis the desired profit is higher, the amount of suitable habitat for caribou in the study area is less and population size of moose is lower than when present day conditions defined the endpoints. As shown in figures 7.1.3 and 7.1.4 (appendix) the probability of achieving the desired profit level is high when the conventional forest management plans are applied, however, the risk of not achieving this endpoint is much greater when the old conifer and white spruce FMPs are examined. The probability of achieving the desired level of caribou habitat suitability is low when the conventional FMPs are used in the study area and increase when the FMPs white spruce and old conifer are implemented (Appendix Figure 7.1.3 and 7.1.4). The risk of not achieving the desired population size of moose within the study area is higher when forest management plans white spruce and old conifer are applied compared to the other, conventional scenarios (Appendix Figure 7.1.3 and 7.1.4). In fact, the black spruce scenario generates the highest probabilities of achieving this indigenous endpoint (Appendix Figure 7.1.3 and 7.1.4).

When the black spruce, "A" density and larch forest management plans are used in the study area the risk of not achieving the desired level of profit is small compared to the risk of not achieving the indigenous endpoints (which are much larger). When the old conifer and white spruce FMPs are used, the risk of not achieving the desired profit is much greater than the risk of not achieving the desired level of caribou habitat suitability. The probability of achieving the desired population size of moose in the study area is small regardless of the forest management plan. However, the probability of achieving this indigenous endpoint has the same trend as the probability of achieving the non-indigenous endpoint.

I observed no relationship between profit, moose population size and caribou habitat suitability when current conditions are used as endpoints (Appendix Figure 7.1.1 and 7.1.2). Since the profit desired in this analysis (because of the limited cut block information we received) is much lower than what was generated by the various forest management plan, the probability that the desired level of profit will be achieved is consistently 100%. However, the risk of achieving the desired moose population size and caribou habitat suitability changes depending on the forest management plan examined.

When endpoints are defined by conditions generated from the standard forest management plan, the relationship between values are easier to decipher and more evident. In particular, the risk of not attaining the desired profit is low for the conventional forest management plans but the risk of not attaining the desired level of caribou habitat suitability is high for these plans (Appendix Figure 7.1.3 and 7.1.4). When examining the old conifer and white spruce scenario, the risk of not achieving the desired profit is high and the risk of not attaining the desired level of caribou habitat suitability is much smaller, compared to when the conventional FMPs were implemented (Appendix Figure 7.1.3 and 7.1.4). Therefore it appears that these two values have an inverse relationship and are not compatible in forest management. On the other hand, the forest management plans that are the most likely to achieve the desired profit are also the most likely to achieve the desired population size of moose within the study area (Appendix Figure 7.1.3 and 7.1.4). The black spruce scenario, which has a very small risk of not achieving the non-indigenous endpoint, also has the least risk, compared to the other forest management plans, of not achieving the desired population size of moose. However, the probability of achieving the non-indigenous endpoint changes dramatically between FMP scenarios (specifically "A" density and larch forest management plans and white spruce and old conifer scenarios) whereas the probability of attaining the desired moose population size changes modestly. We therefore suggest, based on these results, that moose and profit may either have (i) no or (ii) a slight positive relationship in forest management. To make a more conclusive statement regarding the compatibility of these values would require additional analysis.

7.2 Implications

It is unlikely that the population of moose compared to (i) present day; and (ii) conditions resulting from the standard forest management plan will be attained under any of the forest management plans explored. Forest management plans designed with forestry operators' interests in mind will cause a decline the amount of suitable caribou habitat available compared to both (i) and (ii) as well. The probability of achieving the desired level of caribou habitat suitability is more likely when forest management plans such as white spruce and old conifer are used and when the level of caribou habitat suitability is defined by the standard FMP. If LRRCN so desires that these indigenous value be integrated into Tolko's future forest management plan, Tolko must decrease the number of stands that are harvested as well as targeting stands that moose and caribou find unsuitable. However, my results indicate that if harvesting does occur in the future, the desired levels of caribou habitat suitability and moose population size will not likely be maintained in the study area (Appendix Figure 7.1.1, 7.1.2, 7.1.3 and 7.1.4).

As mentioned in section 7.1 the probability of achieving the desired population size of moose is higher when conventional forest management plans, or those designed to maximize profit, are used (Appendix Figure 7.1.1, 7.1.2, 7.1.3, 7.1.4). The forest management plan, that generates the highest probability values, is the black spruce scenario (Appendix Figure 7.1.1, 7.1.2, 7.1.3, 7.1.4). While the conventional FMPs have a greater probability than old conifer and white spruce scenarios for attaining the desired indigenous endpoint, they also have a greater probability of causing a large decline in population size as well (Appendix Figure 6.1 and 6.2). Thus the old conifer and white spruce FMPs may be better for integrating indigenous and non-indigenous values in forest management, because there is little chance of a population crash if these operational elements are utilized (Appendix Figure 6.65 and 6.66). Therefore if the goal is to maintain a large population of moose in the area, close to the size that exists presently, we suggest that the old conifer and white spruce scenarios be used. When the community of LRRCN was surveyed for this project, they mentioned they would like forestry operations to proceed in the study area, but they also requested that the current population size of moose be maintained (Hickey and Natcher 2000).

Moose are important for the way of life and for the culture of indigenous people. In LRRCN the moose hunt is used to transfer indigenous knowledge from older generations to younger people, to collect food for the winter and for make clothing and other items (Jim Webb pers.comm.). We examined if the forest management plans used in this study would decrease the population size of moose to a level where the community hunt could not proceed. We used LRRCN population projections (slow, medium and rapid population growth scenarios) to determine the number of households that would exist in the future within the community, given the fact that the average number of people per household is seven (Jim Webb pers comm, Woodrow and Campa 2001). Jim Webb (pers comm.) has suggested that one moose per household should ideally be harvested (Jim Webb pers comm). Figure 7.2.1 (Appendix) shows that the community will harvest between 13% or 17% of the population per year, using the 2006 population projections, based on the number of moose which remain in the area after the various forest management plans have been used. However, the "A" density FMP causes a dramatic decline in the area's moose population and the community would have to harvest approximately 66% of the population to satisfy the needs of the community. The same trends are evident using the 2016 population projections. If the standard FMP, black spruce, larch, old conifer or white spruce scenarios are used in the area, the aboriginal community will harvest 16% to 21% of the moose population size (Appendix Figure 7.2.2). Again, using the population size of moose that exists after the "A" density FMP has been implemented, anywhere from 82% to 86% of the moose population will be harvested (Appendix Figure 7.2.2). From 1995 to 1998 the greatest number of tags issued by the Alberta government for this area was 274 (Lynch 1998). LRRCN would like to harvest a much larger number than the government will even distribute in tags; from 448 to 451 moose in 2006 and in 2016 from 560 to 582 individuals. Luoma et al found that the risk of a population decline was substantial when hunting rates exceeded 25% for cows and 37.5% for calves and bulls. The results we generated imply that just the hunting activities alone of LRRCN would remove approximately 20% of the moose population. We suggest that the number of moose LRRCN would like to kill each year is not sustainable.

Woodland caribou are endangered in Alberta and our results suggest that logging operations will have an effect on the availability of suitable habitat within northeast Alberta. Figure 7.1.1 and 7.1.2 (appendix) demonstrate that the current level of caribou habitat suitability will definitely decline if logging operations proceed in the area. Probability values are higher when conditions resulting from the standard FMP are used to define this indigenous endpoint (Appendix Figure 7.1.3 and 7.1.4). However, the population size associated with this endpoint may be much lower than present day conditions and below what the community of LRRCN desires. We suggest the amount of habitat harvested by Tolko be dramatically reduced, compared with conventional forestry operations, and harvesting of low suitability habitat or habitat that is not suitable for caribou be practiced. These suggestions will surely decrease the profit generated from logging operations though, and therefore may not be readily applied to forest management plans.

7.3 Conclusions

Integrating non-fibre values in forest management has been a contentious issues in recent years, especially with the current development of co-management agreements between indigenous communities and forest companies. Working with Little Red River Tall Cree First Nation and Tolko Industries – High Level we were able to examine the compatibility of moose population size, caribou habitat suitability and profit in forest management. Caribou and moose habitat classification schemes were developed for a variety of habitat dimensions based on published literature. Maps of the study area were created showing the location of suitable moose and caribou habitat by applying these classification schemes to the study area's Alberta vegetation inventory database. Rankings from 1 (highly suitable habitat) to 4 (low suitability/not suitable) were assigned to each record (a record represented a stand) within the AVI tables based stand information contained within the tables such as species composition, canopy closure, and moisture regime (Table 4.2.1).

The habitat quality/suitability for the FMUs within the study area was calculated as a weighted average:

$$S_{ij} = \frac{\sum_{k=1}^{4} k a_{k,ij}}{A_j}$$

where S_{ij} is the habitat quality score for FMU j based on the habitat dimension i, k=1,..,4 is the habitat rank, $a_{k,ij}$ is the total area of habitat rank k, based on habitat dimension i in FMU j, and A_j is the area of FMU j. Thus the habitat quality score for a particular habitat dimension was the (area) weighted average of habitat ranks throughout the FMU. This score changed as the area of different vegetation associations (and hence, habitat quality ranks) changed under different management scenarios. Therefore we were able to calculate the forest management unit's habitat suitability before and after forest management plans had been implemented in the study area. Habitat suitability values were used in a factor analysis to reduce the dimensionality of the data and to create principal components representing habitat conditions for moose and caribou. The resulting principal components were used to develop a model relating the amount of suitable habitat in a FMU with the population density of moose. The model is as follows:

$$\text{density (individuals / km}^2\text{)} = 0.21 + 0.015\,(P_1) - 0.017\,(P_2)$$

density = number of moose found in a FMU per km^2

P_1 = Principal component 1 factor score

P_2 = Principal component 2 factor score

Principal component one represented winter conditions and the other principal component represent summer/spring habitat. The factor analysis performed on caribou habitat suitability reduced the number of variables from nine to two. Specifically one principal component was created and the only habitat dimension that was not included was summer temperature. Estimates were not available for the area's caribou population and instead we examined if habitat suitability increased or decreased in an area once a forest management plan had been utilized to determine the effect on caribou population size. We assumed that if habitat suitability increased (decreased) within an area, the number of caribou individuals supported also decreased (increased). The model used to calculate profit is as follows:

Profit = area * $1750/ha

area = total area (ha) of the stands identified as being harvested

A number of different forest management plans were examined to determine the effect of operational elements on moose population size, caribou habitat suitability and profit. A standard or typical forest management plan was examined as well as forest management plans developed with the forestry sectors and with the aboriginal community's interests in mind. The greatest amount of profit was generated from forest management plans designed with the forestry sectors interests in mind, specifically black spruce, "A" density and larch FMPs. However, the probability of not achieving the desired profit is extremely low, regardless of the forest management plan. Caribou habitat suitability was highest in forest management plans white spruce and old conifer. These FMPs were designed with the indigenous community's interests in mind. Moose density was highest when the black spruce, old conifer and white spruce FMPs were used. When using present day conditions to define the indigenous and non-indigenous endpoints the probability of achieving the desired level of profit is greater than 98% for all forest management units and all forest management plans examined. The probability of maintaining the current level of caribou habitat suitability is low regardless of the forest management plans, however, the highest probability values are generated from the old conifer and white spruce scenarios. Moose density is closest to present day conditions when either the black spruce or white spruce scenario is implemented. Compared to present day conditions, moose density and caribou habitat suitability will likely decrease if logging operations proceed within the study area.

When using the standard FMP to define the indigenous and non-indigenous endpoints the probability of achieving the desired level of profit is once again highest for FMPs designed with the forestry sector in mind (close to 100%). The risk of not achieving this non-indigenous endpoint is much greater for forest management plans old conifer and white spruce. The probability of achieving the desired level of caribou habitat suitability is low. The probability of achieving the desired level of caribou habitat suitability is higher for the white spruce and old conifer scenarios than the other FMPs explored. The white spruce FMP has the lowest risk associated with it of not achieving the desired density of moose within the forest management units. However, calculated across the entire study area the black spruce scenario is the most probable forest management plan for (i) maintaining the current density of moose, and (ii) for achieving the density of moose after the standard FMP had been applied. The old conifer and white spruce scenarios are the least likely to achieve (i) and (ii) across the study area. However, it should be noted that the old conifer and white spruce scenarios have the narrowest range of density values associated with them, meaning that these FMPs will have the least change in moose population size in the study area.

Using current conditions to determine the compatibility of indigenous and non-indigenous values in forest management is quite difficult since profit is consistent between FMPs and forest management units. Examining the risk of not achieving the moose, caribou and profit conditions generated from the standard FMP reveal that caribou and profit have an inverse relationship and are therefore not compatible. Moose and profit may be compatible, however, further analysis is needed to examine this relationship.

I feel that this project has developed many usable products. In particular the habitat classification scheme developed for moose and caribou will help determine the location of suitable habitat for these species in northern Alberta. Alberta, especially the northern portion, is heavily used for resource extraction, and the operations associated with these industries can destroy wildlife habitat. If resource extraction companies used habitat suitability maps, or develop their own classification scheme, this could potentially mitigate some of the harmful effects on wildlife populations. In particular the maps we produced will help Tolko identify areas suitable for caribou and moose that cutting should be minimized in, if they want to incorporate these indigenous values into their forest management. As well, I feel a clear method of examining the compatibility of indigenous and non-indigenous values in forest management has been outlined. This project also gives the parties involved in co-management agreements a tool to use for incorporating non-fibre values in forest management. I hope that this will ease tensions between groups and encourage a working relationship.

My analysis demonstrates that forestry operations are not compatible with caribou. My results show that if logging operations proceed, caribou population size may further decline. However, this species is endangered within Alberta and therefore these results are of particular importance. If the profit desired by Tolko is reflected by the cut block information we received, all the forest management plans explored will be profitable including those developed with the aboriginal community's interests in mind. If the profit desired is similar to that generated from the standard FMP only the "A" density, larch and black spruce will likely be profitable. In this situation, forest management plans like the white spruce and old conifer scenarios are unlikely to be used by forestry companies. If this is the case, the impact on the caribou population will be compounded.

Interestingly, my results show that moose population size and profit may have a positive relationship. Of note, especially, are the results generated from the black spruce forest management plan. However, further analysis is needed to determine the full extent of this relationship. Specifically, additional forest management plans should be examined to see if there is a true positive relationship between these two values. It does appear, however, that the current population size of moose will decline within the study area if logging operations proceed. As well the number of moose that LRRCN would like to hunt each year is not sustainable if logging operations proceed and will cause the population of moose to further decline.

One of the main limitations of the study was the low sample size, specifically only having six forest management units to include in our analysis. We suggest that additional forest management units be added to strengthen the analysis, specifically the relationship between the habitat suitability and population size. In addition, the lack of caribou population estimates for this area was very restrictive in the analysis and in our conclusions. A model, similar to that developed for moose, could have been created and a more comprehensive analysis could be performed in this data was available. With the data we had in hand we were only able to suggest that population size would increase or decrease as habitat suitability increased or decreased. Estimates of profit may also have been inaccurate since our data were not suitable for a standard profit calculation. A better approximation of the profit generated from each of the forest management plans could be attained if a standard profit calculation could be used. More conclusive results regarding the compatibility of moose and caribou population size and profit in forest management can be generated if these suggestions are heeded.

Given the limitations, we feel that this project will be extremely helpful for incorporating indigenous values in forest management. Even though some of the data used in the analysis may be insufficient we feel that we have outlined a clear methodology that should be used in an exercise of this nature. This will hopefully ease some tensions that exist between aboriginal communities and forestry companies when working together in forest management.

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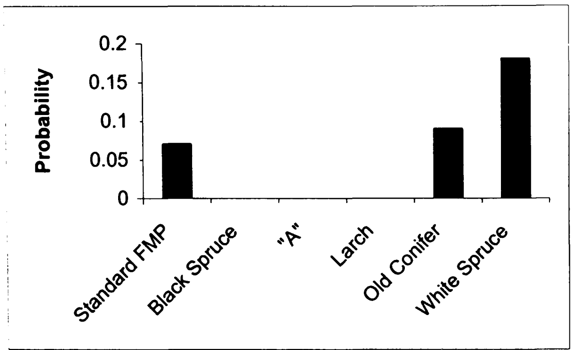

Figure 6.6.14: Probability of Maintaining the Current Factor Score Values within the Study Area for the Various Forest Management Plan Scenarios (10% Standard Deviation)

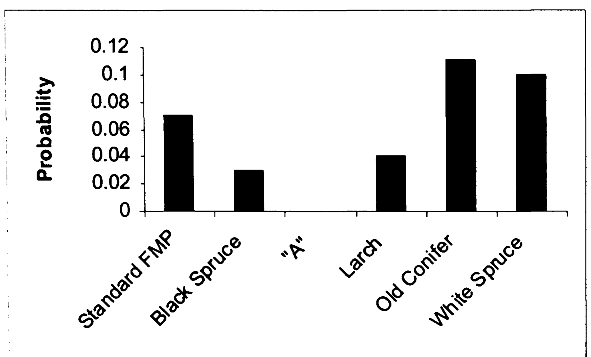

Figure 6.6.15: Probability of Maintaining the Current Level of Caribou Summer Temperature Habitat Suitability within the Study Area for the Various Forest Management Plans (5% Standard Deviation)

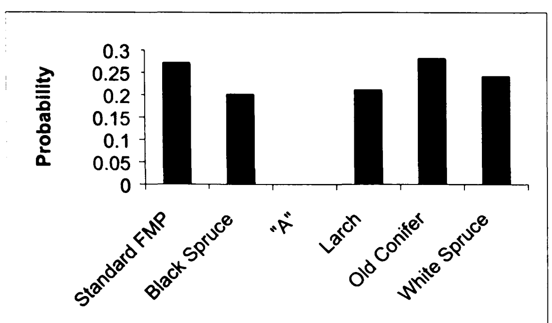

Figure 6.6.16: Probability of Maintaining the Current Level of Caribou Summer Temperature Habitat Suitability within the Study Area for the Various Forest Management Plans (10% Standard Deviation)

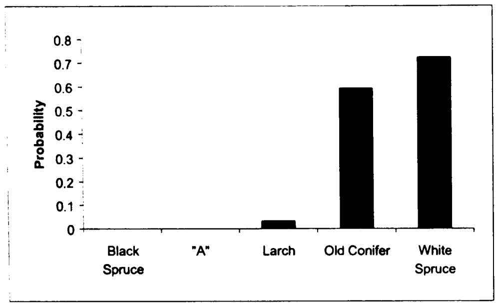

Figure 6.6.22: Probability of Achieving the Factor Score Values generated from the Standard Forest Management Plan within the Study Area for the Various Forest Management Plan Scenarios (10% Standard Deviation)

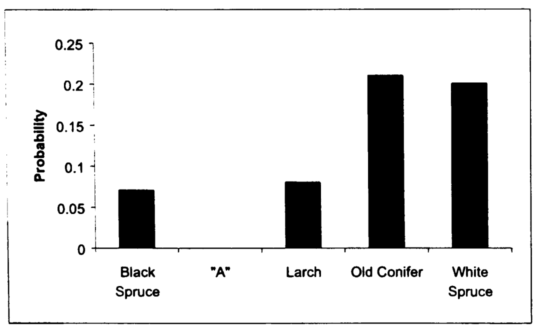

Figure 6.6.23: Probability of Achieving the Caribou Summer Temperature Habitat Suitability Values generated from the Standard Forest Management Plan within the Study Area for the Various Forest Management Plans (5% Standard Deviation)

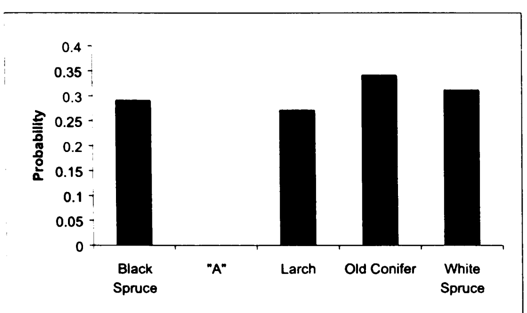

Figure 6.6.24: Probability of Achieving the Caribou Summer Temperature Habitat Suitability Values generated from the Standard Forest Management Plan within the Study Area for the Various Forest Management Plans (10% Standard Deviation)

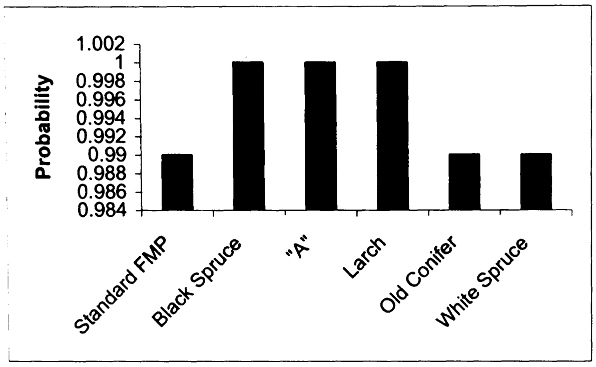

Figure 6.6.27: Probability of Achieving the Profit calculated from the Cut Block Information within the Study Area for the Forest Management Plan Scenarios (25% Standard Deviation Scenario).

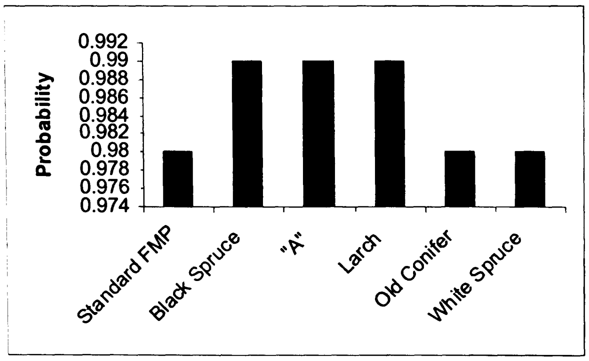

Figure 6.6.28: Probability of Achieving the Profit calculated from the Cut Block Information within the Study Area for the Forest Management Plan Scenarios (50% Standard Deviation Scenario).

Table 2.2.1 **Criteria and Indicators for Forest Sustainability**

Little Red River First Nation

Criteria I. Modify Forest Management Operations in Order to Reduce Negative Impacts to Wildlife Species.

Criteria II. Modify Forest Operations so as to Ensure Continued Access to Lands and Resources.

Criteria III. Provide Protection to All Areas Identified by LRR/TC Band Members as Having Cultural or Historical Significance. Note: these areas do not require physical qualifications.

Criteria I	Critical Element	Local Value	Goal	Indicator	Objective
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of woodland caribou.	Enhance critical habitat for woodland caribou.	Protection of critical habitat blocks of old growth conifer along the Caribou Mt. slope.	Long-term harvest rotation of critical conifer habitat along the Caribou Mt. slope. specifically in elevations between 1500-2000 feet.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of woodland caribou	Enhance critical habitat for ranging woodland caribou.	Avoid sensory disturbances (forest operations) along the Caribou Mt. slope, specifically during winter months when access to old-growth conifer stands is most critical (thermal protection).	Limit harvesting operations and thus sensory disturbance along the Caribou Mt. slope in winter months when mature forest cover is most critical for thermal protection.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of caribou in the management area.	Limit access to the approx. 1,000 caribou ranging throughout the Margaret Lake, north Margaret Lake regions.	Limit road access and travel corridors to the Margaret Lake regions.	Limit reclaim land access to the Margaret Lake and north Margaret Lake regions.

I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of caribou in the management area.	Limit access to the approx. 1,000 caribou ranging throughout the northeast Wenzel Lake area.	Limit road access and travel corridors to the Wenzel Lake area.	Limit reclaim road access to Wenzel Lake.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of woodland caribou.	Enhance critical habitat for woodland caribou.	Limit access of both human and non-human predators to ranging woodland caribou along the Caribou Mt. slope.	Long-term rotation of cutblocks along the Caribou Mt. slope in order to limit predator access to key habitat areas.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of woodland caribou.	Enhance critical habitat for woodland caribou	Protection of critical habitat blocks of old growth conifer along the Caribou Mt. slope.	Implement a process of selective logging along the Caribou Mt. slope in order to maintain the availability of old growth conifer.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of woodland caribou.	Enhance critical habitat for woodland caribou	Protection of critical habitat blocks of old growth conifer along the Caribou Mt. slope.	Intensive fire control along the Caribou Mt. slope
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of caribou in the management area.	Limit human and non-human access to woodland caribou that range throughout the Caribou Mt slope	Limit access to the Caribou Mts. slope. * Such access enhances prey upon caribou that utilize these travel corridors in	Limit road access to the Caribou Mts. slope and reclaim existing access corridors.

				winter months.	
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of caribou in the management area.	Maintain old growth conifer forest along the Caribou Mt. plateau and upper-slope.	Reduce harvesting of conifer stands along the Caribou Mt. slope.	Maintain the amount of forested land on the Caribou Mt. slope that is characterized as old-growth conifer stands, treed-muskeg conifer stands, that are interspersed with pockets of aspen and mixed-wood forest.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of caribou throughout the management area.	Limit access to the Caribou Mt. slope and adjacent plateau area.	Limit accessibility to the Caribou Mt. plateau.	Limit/reclaim access corridors connecting Highway 58 to Caribou Mt plateau.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of woodland bison.	Enhance critical habitat for woodland bison.	Maintain critical habitat characterized by shrub-grasslands, willows and sages in close proximity to mature forest cover necessary during winter months for thermal protection.	Increase critical habitat along the southern slopes of the Caribou Mts. and adjacent river valleys in the vicinity of Wenzel Creek
I. Modify Forest Management Operations so as to Reduce Negative	Species Diversity and Availability	Healthy population of woodland bison.	Enhance critical habitat for woodland bison.	Maintain critical habitat of shrub-grasslands, willows and sages in close	Maintain critical habitat along in the shrub meadows (Wabasca Meadows)

Impacts to Wildlife Species.				proximity to mature forest cover necessary in winter months for thermal protection.	between the Wabasca and Mikkwa Rivers.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of woodland bison.	Enhance critical habitat for woodland bison.	Maintain critical habitat characterized by shrub-grasslands, willows and sages with close proximity to mature forest cover necessary during winter months for thermal protection.	Maintain critical habitat along the Peace River area between Garden River and Peace Point.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of bison.	Enhance critical habitat of bison in the management area.	Limit road access and travel corridors to Martin Lake during summer month when bison range throughout the area.	Limit road access and reclaim existing travel corridors to the Martin Lake area. * Need for long-term road access plan for management area.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of bison in the Caribou Mt. lowlands and drainage.	Limit clearcut activity along the Caribou Mt slope so as to ensure turbidity of drainage is not adversely affected. * A preferred bison habitat is one consisting of willows and sage. These micro-environments	Reduce timber harvesting along the Caribou Mts slope.	Reduce harvesting along the Caribou Mt. slope and increase streamside buffers to no less than 300 meters in order to offset increased drainage caused by clearcuts.

			are often created by the cut-back effects of meandering drainages flowing from the Caribou Mts.. Clearcuts are believed by band members to increase stream flow thereby altering and negatively affecting the preferred habitat of woodland bison in the lowland areas.		
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of bison throughout the management area.	Allow/promote the expanded range of bison throughout the management area.	Modify forestry operations so as to allow for range expansion of bison.	Reduce harvesting activity south of Wenzel Lake (near Highway 58) to allow bison to range southward.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of bison throughout the management area.	Allow/promote range expansion of bison throughout the management area.	Limit/reclaim road access throughout the management area so as to allow for range expansion of bison.	Limit/reclaim road access west of Wenzel Lake so as to allow for range expansion of bison onto the CM slope.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of bison throughout the management area.	Expand bison range throughout the management area.	Bison range expanded east of reserve lands.	Expand bison range through a reintroduction program in Deep Lake area.

I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of bison throughout the management area.	Protect and enhance bison range throughout the management area.	Protect bison migration routes.	Placement of protective zones along bison migration routes that run north-south between Fox Lake and Tall Cree.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Protection of bison in the management area.	Protection of bison from hunting as well as the negative effects of forestry operations.	Protective zone within the management area for bison population enhancement.	Bison Protection Zone extending from the Margarette and Wenzel Lake area east to the Wood Buffalo Park boundary.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species	Species Diversity and Availability	Healthy Population of moose in the management area	Enhance necessary habitat for moose	Actual increase in necessary habitat – Eliminate the practice of scarification following forestry operations.	Eliminate the practice of scarification in the management area. * Utilize alternative silviculture methods: Controlled burns and hand scalping followed by hand seeding and planting.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of moose in the management area.	Reduce human non-human pressure on the moose population the management area	Limit road access in the management area.	Limit reclaim road access to Duck Lake area.

I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of moose in the management area.	Modify forestry operations so as to ensure the continued availability of moose in the management area.	Limit human and non-human access corridors to critical moose habitat areas.	Limit access to the Harper Creek area south of Fox Lake. Protective buffers no less than 300 meters on Harper Creek and its tributaries.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of moose in the management area.	Modify forestry operations so as to ensure the continued availability of moose in the management area.	Limit human and non-human access corridors to critical moose habitat areas.	Limit access to Moose Lake and surrounding area (south of Fox Lake). Protective buffer no less than 300 meters around Moose Lake.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of moose.	Enhance critical habitat for moose ranging throughout the management area.	Limit the harvesting of white spruce along river drainages.	Limit harvesting operations along the Mikkwa River and expand stream-side buffers to no less than 300 meters from each shoreline.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of moose.	Enhance critical habitat for moose ranging throughout the management area.	Maintain foraging needs consisting of duckweeds, pondweeds, and yellow water lilies found in sloughs and wetland areas.	Protective buffers no less than 300 meters around pound, sloughs and wetland areas located in the southeast Peace River region of the management area. The duckweeds, pondweeds,

					water lilies in this area provide critical summer forage for grazing moose.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability.	Healthy population and continued availability of fish.	Reduce run-off caused by clearcuts into primary fisheries.	Increase buffers on rivers that serve as primary fisheries.	Increase buffers to no less than 300 meters from each shoreline of the Wenzel River as it flows from the Caribou Mts. into the Peace River.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population and continued availability of fish.	Reduce run-off caused by clearcuts into primary fisheries.	Increase buffers on rivers that serve as primary fisheries.	Increase buffers to no less than 300 meters from each shoreline of the Lawrence River as it flows from the Caribou Mts. into the Peace River.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population and continued availability of fish.	Reduce run-off caused by clearcuts into primary fisheries.	Increase buffers on rivers that serve as primary fisheries.	Increase buffers to no less than 300 meters from each shoreline of Harper Creek south of Fox Lake
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population and continued availability of fish.	Reduce run-off caused by clearcuts into primary fisheries.	Modify forestry operations along the Caribou Mt. slope.	Implement a program of selective logging along the Caribou Mt. slope in order to reduce run-off

I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of martin.	Enhance critical habitat for martin in the management area.	Protection of critical habitat blocks of old growth conifer along the Caribou Mt. slope.	Long-term harvest rotation and/or selective logging of critical conifer habitat along the Caribou Mt. slope.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of fox, coyote, mink, fischer, and lynx.	Maintain critical habitat for primary prey species (squirrels).	Protection of critical habitat of blocks of spruce (availability of cones) necessary for squirrel habitat.	Long-term harvesting rotation and staggering of cutblocks to ensure the continued availability of spruce cones for squirrels – and thus predator species.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of beaver in the management area.	Maintain critical habitat for beaver in the management area.	Protection of spruce stands in proximity to riparian zones	Expand protective buffers along lakes, creeks and streams to no less than 300 meters. Implement a program of selective logging of spruce when in close proximity to riparian zones in order to minimize the growth of aspen.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife	Species Diversity and Availability	Healthy population of bear.	Maintain critical habitat for bear in the management area.	Availability of and access to riparian areas for browsing bear, specifically during fall when berries	Expand buffers on primary rivers drainages (i.e., the Peace, Wenzel, Mikkwa, Harper, and

Species.				are most abundant and serve as a primary food source.	Lawrence Rivers) to no less than 300 meters from each shoreline. Modify the timing of forest operations in the above areas so as to ensure bears have access to these areas in the late summer and fall months.
I. Modify Forest Management Operations so **as to Reduce Negative Impacts to Wildlife Species.**	Species Diversity and Availability	Healthy population of bear.	Maintain critical habitat for bear in the management area.	Availability of undisturbed travel corridors for ranging bear	Protection of undisturbed travel corridors from the Caribou Mts. to the lowland areas.
I. Modify Forest Management Operations so **as to Reduce Negative Impacts to Wildlife Species.**	Species Diversity and Availability	Healthy population of bear.	Maintain critical habitat for bear in the management area.	Protection of critical habitat blocks of old growth conifer along the Caribou Mt slope necessary for winter denning.	Long-term harvest rotation and/or selective logging along the Caribou Mt. slope.
I. Modify Forest Management Operations so **as to Reduce Negative Impacts to Wildlife Species.**	Species Diversity and Availability	Healthy population of waterfowl.	Maintain critical habitat for nesting and staging waterfowl in the management area.	Protection of critical habitat of sloughs and wetland areas in order to maintain water table	Expand buffers around sloughs and ponds to no less than 200 meters.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to	Species Diversity and Availability	Healthy population of squirrels	Maintain critical habitat/food source for squirrels in the management area.	Primary food source: spruce cones. Secondary food source Mushrooms found in poplar	* Staggered layout of cutblocks that leave stands of spruce. * Cutblock layout that

Wildlife Species.				stands.	leaves stands of poplar in close proximity to harvested spruce.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Healthy population of mink.	Maintain water table of creeks and streams necessary for mink habitat. * The drying up of creeks and streams following harvesting activities has resulted in mink altering their range and expanding into upland areas of the bush.	Maintain watertable of creeks and streams to help ensure availability of mink habitat.	Expand buffers along creeks and streams to no less than 300 m. Additional precautions should be taken so as to ensure road access to cutblocks do not negatively affect the flow of creeks and streams
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Availability of song birds throughout the management area.	Enhance the availability of berries found within riparian zones	Placement of protective buffers around riparian areas to promote the growth of berries and thus the availability of song birds	Protective buffers no less than 300 meters along riparian zones found throughout the management area.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Continued presence of the red-throated loon in the management area.	Modify forest operations so as to ensure harvesting activites to not adversely affect the nesting habits of the red-throated loon.	Nesting areas of the red-throated loon are not adversely affected by forestry operations	Protective buffers no less than 300 meters around lakes known to be used by the red-throated loon for nesting (sites yet to be determined). Modify harvesting schedule so as to ensure forestry activities do

					not adversely affect the nesting habits and breeding requirements of the red-throated loon.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Continued presence of bald eagles in the management area.	Modify forest operations so as to ensure the nesting and feeding requirements of bald eagles are not adversely affected by harvesting activites.	Nesting and primary feeding areas of the bald eagle are not adversely affected by forestry operations.	Maintain and enhance riparian areas located along the Peace River and other primary waterways so as to ensure the availability of primary breeding habitat for bald eagles.
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Protection of critical denning sites of furbearer species.	Protect critical denning sites of furbearers, including wolves and bear from forestry operations.	Protective buffers placed around critical denning sites of furbearers, including wolves and bear.	Protective buffers of no less than 200 meters should be placed around critical denning sites of furbearers, including wolves and bear (Sites yet to be determined)
I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Protection of critical nesting sites of upland birds, raptors and waterfowl.	Critical nesting sites used by upland birds, raptors and waterfowl protected from forestry operations.	Protective buffers placed around nesting sites of upland birds, raptors and waterfowl.	Protective buffers of no less than 200 meters should be placed around the nesting sites of upland birds, raptors and waterfowl (Sites yet to be determined)

I. Modify Forest Management Operations so as to Reduce Negative Impacts to Wildlife Species.	Species Diversity and Availability	Protection of mineral licks throughout the management area.	Modify forestry operations so as to ensure mineral licks are protected from harvesting activites.	Protective buffers placed around mineral licks that are located throughout the management area	Protective buffers of no less than 300 meters should be placed around mineral licks (Sites yet to be determined).
Criteria II	**Critical Element**	**Local Value**	**Goal**	**Indicator**	**Objective**
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Ensure forestry operations do not limit and/or negatively influence community land and resource use.	Maintain or enhance opportunities to participate subsistence activities.	Modify existing annual allowable cut so as to ensure subsistence activities are not limited by forestry operations.	Implement a selective logging program for the management area.
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Ensure travel is not impeded by forestry operations.	Modify silviculture methods so as to ensure continued access to lands and resources.	Discontinue the practice of scarification following harvesting as it impedes travel	* Utilize alternative silviculture methods: - Controlled Burns. - Hand scalping followed by hand seeding and planting
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Ensure travel is not impeded by forestry operations.	Modify silviculture methods as the current practice of scarification creates an unfamiliar landscape to local residents. Further, this practice is considered by band members as being disrespectful to plant and animal species.	Discontinue the practice of scarification following harvesting in the management area	* Utilize alternative silviculture methods: - Controlled Burns - Hand scalping followed by hand seeding and planting

II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Ensure travel and access to resources is not impeded by forestry operations.	Modify harvesting techniques so as to ensure travel is not impeded.	Discontinue the practice of v-cutting in the management area as it impedes both human and non-human mobility.	Utilize alternative harvesting methods. * Selective logging and hand-falling.
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Ensure travel is not impeded by forestry operations.	Maintain travel corridors throughout the management area for local hunters and trappers.	Expand buffers along creeks and streams to limit windfall across waterways.	Expand buffers on creeks, streams and rivers to no less than 300 meters from each shoreline.
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Trapline areas remain productive and readily accessible to LRR/TC trappers. * Trappers noted that over-harvesting within a single trapline has forced trappers to expand their trapping area in order to maintain prior levels of trapping success. Over-harvesting from a single trapline has also added to the cost (i.e., fuel, supplies) of trapping, as well as the time required to cover productive	Maintain existing age structure and species diversity found within trapline areas	Long-term harvesting rotation in registered trapline areas.	Long-term sequencing and cutblock rotation within trapline areas. * Implement a consultative framework involving LRR trappers prior to the finalization FMP. * Implement a trappers compensation program for trappers affected adversely by forestry operations.

		(uncut) areas.			
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Continued availability of balsam poplar throughout the management area.	Modify forest operations so as to ensure the availability of balsam poplar near trapline cabins and camps as balsam polar burns well when green with little sparking.	Continued availability of balsam poplar near trapline cabins and camps.	Protective buffer of no less than 200 meters around trapline cabins and camps so as to ensure the continued availability of balsam poplar. Modify harvesting plans to ensure the availability of balsam poplar around trapline cabins and camps (Sites yet to be determined).
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Limit blow-down (wind velocity) of protective buffers in order to protect critical habitat and travel corridors.	Modify harvesting sequence and cutblock layout in order to limit blow-down.	Maintain stand integrity of buffers along critical habitat areas and travel corridors	Stagger cutblocks and expand buffers to no less than 300 m. from each shoreline along eastern end of cutblock.
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Forestry operations should in no way obstruct hunting, trapping and camping trails.	Ensure that forestry operations do not obstruct community access trails.	Buffers along all known hunting, trapping and camping trails used by LRR/TC band members.	Buffers no less than 200 meters should be placed along all known hunting, trapping and camping trails used by LRR/TC band members (Trails yet to be determined)

II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Protection of trapping cabins used by LRR/TC band members.	Ensure forestry operations do not obstruct trapline cabins located throughout the management area.	Protective buffers placed around trapping cabins, shelters and camps.	Buffers of no less than 200 meters should be placed around all trapping cabins, shelters and camps. Implement a consultative framework between trappers, band council and industry prior to harvesting activity.
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Availability of medicinal plants and herbs.	Ensure forestry operations do not adversely affect the availability of medicinal plants and herbs found throughout the management area. Specifically through adverse changes in shade, soil composition, and erosion.	Modify forestry operation so as to ensure medicinal plants and herbs are not adversely affected by forestry operations.	Protective buffers no less than 300 meters placed along riparian zones. Selective logging in order to preserve moisture content of soil. limit erosion and run-off. and maintain shade composition in forest stands.
II. Modify forest operations so as to ensure continued access to lands and resources	Continued access to lands and resources.	Availability of mint throughout the management area.	Ensure forestry operations to not adversely affect the availability of mint found through the management area.	Modify forestry operations so as to ensure the continued availability of mint is not adversely affected by harvesting activity.	Protective buffers no less than 300 meters along riparian areas where mint can generally be found.

Criteria III.	Critical Element	Local Value	Goal	Indicator	Objective
III. Provide protection to all areas identified by LRR/TC band members of having cultural significance. Note: these areas do not require physical qualifications.	Areas of cultural significance are protected from forestry operations.	Protection of historical cabins and traditional settlements.	Cabins and settlements of historical and cultural significance are protected from forestry operations.	Protective buffers are placed around all cabins and settlements of historical and cultural significance.	Protective buffers of no less than 500 meters should be placed around all cabins and settlements of historical and cultural significance (Sites yet to be determined). However some include: * Settlement site located at the confluence of the Mikkwa and Peace Rivers. * Peace River Portage – located near the Vermilion Chutes. * Fifth Meridian as it served as a HBC Post.
III. Provide protection to all areas identified by LRR/TC band members of having cultural significance.	Areas of cultural significance are protected from forestry operations.	Protection of areas of natural and/or environmental sensitivity.	Modify forestry operations so as to ensure areas of natural and/or environmental sensitivity are not adversely affected by forestry operations	Protective buffers placed around areas of natural and or environmental sensitivity	Protective buffer of no less than 300 meters around areas of natural and/or environmental sensitivity (sites yet to be determined). * Known site to be the bat caves located along Harper Creek south of Fox Lake.

III. Provide protection to all areas identified by LRR/TC band members of having cultural significance.	Areas of cultural significance are protected from forestry operations.	Protection of traditional trails leading to historical settlements.	Modify forestry operations so as to ensure historical trails leading to settlement area are not adversely affected by forestry operations.	Protective buffers placed along historically used trails that lead to settlement sites.	Protective buffers of no less than 200 meters should be placed along historically used trails leading to historic settlement (These trails have yet to be determined).
III. Provide protection to all areas identified by LRR/TC band members of having cultural significance.	Areas of cultural significance are protected from forestry operations.	Protection of all burial sites located through the management area.	All burials sites located throughout the management area are protected from forestry operations.	Protective buffers are placed around all burial sites located throughout the management area.	Protective buffers of no less than 200 meters should be placed around burial sites known to be located within the management area (Sites yet to be determined)
III. Provide protection to all areas identified by LRR/TC band members of having cultural significance.	Areas of cultural significance are protected from forestry operations.	Protection of rare, endangered and medicinal plants.	Plants known to be rare, endangered, or used for medicinal purposes by LRR TC band members should be protected from forestry operations.	Protective buffers placed around areas known to support rare, endangered and medicinal plants.	Protective buffers of no less than 100 meters should be placed around upland areas known to support rare, endangered and medicinal plants and no less than 300 meters for riparian zones (Sites yet to be determined).

III. Provide protection to all areas identified by LRR/TC band members of having cultural significance.	Areas of cultural significance are protected from forestry operations.	Protection of ceremonial sites located within the management area	Modify forestry operations so as to ensure that ceremonial sites used by LRR/TC band members are not adversely affected by harvesting activites.	Protective buffers placed around ceremonial sites.	Protective buffers no less than 200 meters placed around ceremonial sites (Sites yet to be determined).

Many of the concerns expressed by band members related most directly to the protection and stewardship of specific sites located throughout the management area. Most notably, community concerns dealt with the protection of gravesites, ceremonial sites, historic landmarks, and potential archaeological sites that are known locally to exist throughout the Caribou-Lower Peace River Valley. In addition, considerable concern was expressed regarding the protection of seasonal camps once used by Little Red River band members. While these areas may not be in continued use they nonetheless represent important subsistence focal points and perhaps more importantly convey a temporal depth that link the past, present and future through memories and oral tradition; thus in the opinion of band members warranting considerable attention in forest management planning. Also of concern was the protection of critical habitat sites such as mineral licks, denning sites, yarding areas and nesting/staging areas. However, because these, as well as the cultural sites noted above, have yet to be mapped, let alone GPSs for geographical accuracy, specific locations have yet to recorded. Although LRR is now beginning to explore how such research should be undertaken, to date such information remains lacking. Owing to this limitation site-specific information could not be incorporated into this values assessment. However, due to the nature of C&I research and the need for continued monitoring and periodic evaluation, site-specific information can be added as it becomes available.

Table 4.3.1 : Summer moose habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat classification rank	Species composition	Canopy closure	Moisture	Stand condition
1	*Picea sp., Populus tremuloides, Betula papyrifera*, or *Abies balsamea*	6%-50%	Dry or moist	
2	*Picea sp., Populus tremuloides,Pinus albicaulis*, or *Pinus banksiana*	6%-50%	Dry or moist	
	Deciduous/Coniferous Mix, deciduous dominant	6%-50%	Dry or moist	
	Populus tremuloides, Picea glauca mix, *Populus tremuloides* dominant	6%-50%	Dry or moist	
	Larix laricina, Picea mariana mix	6%-50%	Dry or moist	
		6%-30%	Wet or aquatic	
3				Clear cut
			Aquatic	
	Picea sp.	51%-100%	Dry, moist, or wet	
	Deciduous	31%-100%	Dry, moist, or wet	
	Deciduous/Coniferous Mix	51%-100%	Dry, moist, or wet	
	Larix laricina		Wet or aquatic	
	Picea mariana		Wet or aquatic	
	Pinus banksiana	51%-100%	Dry, moist or wet	

Table 4.3.2 : Summer moose habitat in each forest management unit in the study area

Habitat classification rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2) (%)	Amount (km^2) (%)	Amount (km^2) (%)	Amount (km^2) (%)	Amount (km^2) (%)	Amount (km^2) (%)
1	525.6 (17)	322.36 (9)	260.77 (9)	163.18 (4)	287.1 (8)	6.32 (7)
2	1190.91 (38)	426.97 (13)	545.24 (19)	1364.42 (37)	770.93 (21)	28.10 (30)
3	547.21 (17)	1885.94 (57)	1244.86 (42)	339.27 (9)	1913.04 (51)	20.3 (21)
4	869.65 (28)	687.5 (21)	881.85 (30)	1838.18 (50)	467.96 (13)	40.36 (42)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	95.09

Table 4.3.3 : Winter moose habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	**Species composition**	**Canopy closure**	**Moisture**	**Stand condition**
1	Deciduous	51%-100%	Dry or moist	
	Coniferous	6%-30%	Dry or moist	
	Larix laricina, Picea glauca mix		Wet or aquatic	
2	*Picea sp.*	31%-100%	Dry, moist, or wet	
	Deciduous/Coniferous Mix, deciduous dominant	51%-100%	Dry or moist	
	Coniferous	51%-100%	Dry or moist	
	Populus tremuloides	6%-50%	Dry or moist	
3	*Pinus banksiana*	31%-100%	Dry, moist, or wet	
				Clear cut
	Larix laricina	31%-50%	Dry or moist	
			Aquatic	
				Burn
	Populus tremuloides, Coniferous mix		Dry or moist	
	Deciduous	6%-50%	Dry or moist	

Table 4.3.4: Winter moose habitat in each forest management unit in the study area

Habitat Classification Rank	**FMU 2**	**FMU 3**	**FMU 4**	**FMU 5**	**FMU 6**	**FMU 7**
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	690.93 (22.1)	596.98 (18)	1130.52 (33.9)	1225.89(33.9)	996.39 (29)	63.57 (70.6)
2	424.17(13.5)	990.62(20.8)	574.22(19.6)	380.75(10.3)	1369.13(39.8)	10.99(12.2)
3	855.58(27.3)	370.84(11.2)	23.35(0.8)	126.98(3.4)	290.65(8.5)	3.86(4.3)
4	1162.69(32.1)	1364.33(41.1)	1204.73(41.1)	1971.41(53.3)	782.86(22.8)	16.67(18.5)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

Table 4.3.5: Spring moose habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	**Species composition**	**Canopy closure**	**Moisture**	**Stand condition**
1	Deciduous/Coniferous Mix, deciduous dominant	31%-70%	Dry or moist	
	Coniferous	51%-100%	Dry or moist	
	Deciduous	31%-70%	Dry or moist	
2	Coniferous	6%-50%	Dry or moist	
	Populus tremuloides	6%-100%	Dry or moist	
	Pinus banksiana, Populus tremuloides mix	6%-100%	Dry or moist	
3			Wet or aquatic	
				Clear cut
	Deciduous	6%-30%, 71%-100%	Dry or moist	
	Deciduous/Coniferous Mix, deciduous dominant	6%-30%, 71%-100%	Dry or moist	

Table 4.3.6: Winter moose habitat in each forest management unit in the study area

Habitat Classification Rank	**FMU 2**	**FMU 3**	**FMU 4**	**FMU 5**	**FMU 6**	**FMU 7**
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	624.37 (19.9)	354.49 (10.7)	495.33 (16.9)	719.96 (19.4)	729.86 (21.2)	16.86 (17.7)
2	571.61 (18.2)	234.11 (7.0)	130.77 (4.5)	717.80 (19.4)	249.79 (7.2)	20.17 (21.2)
3	1747.42 (55.8)	2675.56 (80.5)	2141.85 (73.0)	1507.20 (40.7)	2335.75 (67.7)	41.39 (43.5)
4	189.97 (6.1)	58.62 (1.8)	164.78 (5.6)	760.08 (20.5)	134.47 (3.9)	16.67 (17.5)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

4.3.7 Winter temperature habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Structure	Canopy closure	Moisture	Stand condition
1	Deciduous/Coniferous Mix, deciduous dominant	Mature deciduous trees	51%-100%	Dry or moist	
	Coniferous	Mature coniferous trees		Wet or aquatic	
2	Deciduous		31%-100%	Dry or moist	
3	All	Immature			
					Clear cut
			6%-30%	Dry, moist, or wet	

Table 4.3.8: Winter temperature habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	651.44 (20.8)	1433.92 (43.2)	614.23 (20.9)	319.68 (8.6)	940.88 (27.4)	11.69 (13)
2	457.56(13.5)	215.34(6.5)	779.25(26.6)	973.3(26.3)1	590.73(17.2)	24.1(26.8)2
3	1017.57(27.3)	846.17(15.5)	576.33(19.7)	514.56(13.9)	1260.69(36.7)	12.3(13.7)
4	1006.81(32.1)	827.34(24.9)	962.92(32.8)	1897.49(51.2)	646.73(18.8)	46.98(52.1)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

Table 4.3.9: Summer temperature habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Structure	Canopy closure	Moisture	Stand condition
1	Coniferous	Mature coniferous trees	51%-100%	Dry or moist	
2	Coniferous		31%-50%	Dry or moist	
			6%-30%	Dry or moist	
3	All	Immature			
					Clear cut
	Deciduous		31%-100%	Dry or moist	

Table 4.3.10: Summer temperature habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	58.45 (11.9)	41.82 (1.3)	60.38 (2.1)	54.98(1.5)	68.63(2)	0.13(0.1)
2	1002.45(32)	530.06(16)	1100.78(37.5)	1301.10(35.1)	908.72(26.4)	29.85(33.1)
3	690.24(22)	735.75(22.1)	45.46(15.4)	358.42(9.7)	1214.98(35.3)	16.85(18.7)
4	1381.94(44.1)	2015.14(60.6)	1320.10(45)	1990.53(53.7)	1257.35(36.6)	48.26(53.6)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

Table 4.3.11 : Snow depth habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Structure	Canopy closure	Moisture	Stand condition
1	Coniferous	Mature	51%-100%	Dry or moist	
	Deciduous	Mature	51%-100%	Dry or moist	
	Coniferous	Mature		Wet or aquatic	
2	All	Immature			
			31%-50%		
3					Clear cut
			6%-30%		

Table 4.3.12: Snow depth habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	611.39 (19.5)	501.07 (15.1)	1008.94 (34.6)	1145.48(30.9)	1057.37(30.7)	28.36 (34.5)
2	909.54(29)	878.37(26.4)	458.82(15.6)	398.0(10.7)	1210.61(35.2)	9.26(10.3)
3	779.63(24.9)	1271.01(38.3)	616.07(21)	355.84(9.6)	723.18(21)	17.3(19.2)
4	832.81(26.6)	672.32(20.2)	848.89(28.9)	1805.71(48.7)	458.71(13.3)	40.17(44.6)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

Table 4.3.13: Snow hardness habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Structure	Canopy closure	Moisture	Stand condition
1	Coniferous	Mature		Wet or aquatic	
2	Coniferous	Immature		Wet or aquatic	
	Picea sp., Betula papyrifera mix				
	Populus tremuloides	Immature			
3	All	Immature			
					Clear cut
			6%-30%		
	Deciduous				
	Deciduous/Coniferous Mix				

Table 4.3.14: Snow hardness habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	373.86 (11.9)	484.21(14.6)	187.79(6.4)	152.67(4.1)	488.33(14.2)	2.65(2.9)
2	757.65(24.2)	683.3(20.6)	1091.47(37.2)	1295.09(35)	1295.22(37.7)	1.69(1.9)
3	795.59(25.4)	1276.33(38.4)	623.33(21.3)	250.49(6.8)	773.65(22.5)	45.73(50.8)
4	1206.29(38.5)	878.93(26.5)	1030.15(35.1)	2006.79(54.2)	892.67(26)	45.02(50)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

Table 4.3.15: Winter moose predation habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Canopy closure	Moisture	Stand condition
1	Deciduous/Coniferous Mix	6%-70%	Dry or moist	
2	Deciduous	6%-70%	Dry or moist	
		6%-70%	Wet or aquatic	
3	Coniferous	51%-100%	Dry or moist	
			Aquatic	

Table 4.3.16: Winter moose predation habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	521.01(16.6)	390.17(11.7)	316.73(10.8)	316.43(8.5)	519.74(15.1)	8.67(9.6)
2	1278.09(40.8)	1841.97(55.4)	762.84(26)	889.49(24)	1267.93(36.9)	24.73(27.5)
3	85.82(2.7)	33.60(1)	53.79(1.8)	43.35(1.2)	128.85(3.7)	1.06(1)
4	1248.46(39.8)	1057.03(31.8)	1799.37(61.4)	2455.77(83.7)	1522.5(44.3)	60.63(67.3)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

Table 4.3.17: Summer moose predation habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	**Species composition**	**Canopy closure**	**Moisture**	**Stand condition**
1	*Larix laricina, Pinus banksiana, Pinus albicaulis,* or *Pinus flexilis*	6%-70%	Dry or moist	
2	*Picea sp., Abies sp., Pseudotsuga sp.*		Dry or moist	
3	Deciduous	6%-70%	Dry or moist	
	Coniferous	51%-100%	Dry or moist	
			Aquatic	

Table 4.3.18: Summer moose predation habitat in each forest management unit in the study area

Habitat Classification Rank	**FMU 2**	**FMU 3**	**FMU 4**	**FMU 5**	**FMU 6**	**FMU 7**
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	97.45(3.1)	55.61(1.7)	48.8(1.7)	32.12(0.9)	55.21(1.6)	0.00(0)
2	426.46(13.6)	246.03(7.4)	170.8(5.8)	218.42(5.9)	534.67(15.5)	10.23(11.4)
3	604.55(19.3)	332.28(10)	475.05(16.2)	712.55(19.2)	519.41(15.1)	15.76(17.5)
4	2004.9(64)	2688.85(80.9)	2238.08(76.3)	2741.94(74)	2340.59(68.1)	69.1(76.7)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	3449.88

Table 4.3.19: Spring moose foraging habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	**Canopy closure**	**Moisture**
1	31%-50%	
		Wet or aquatic
		Aquatic/Marsh areas
2	51%-70%	
3	6%-30%, 71%-100%	

Table 4.3.20: Spring moose foraging habitat in each forest management unit in the study area

Habitat Classification Rank	**FMU 2**	**FMU 3**	**FMU 4**	**FMU 5**	**FMU 6**	**FMU 7**
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	1342.27(42.8)	2142.81 (64.5)	1193.82 (40.7)	1199.00(32.4)	1345.60(39.1)	42.76(47.5)
2	52.31(1.7)	36.92(1.1)	37.96(1.3)	62.91(1.7)	64.11(1.9)	5.89(6.5)
3	25.68(0.8)	24.18(0.7)	16.79(0.6)	7.22(0.2)	17.34(0.5)	10.68(11.9)
4	1713.11(54.7)	1118.86(33.7)	1684.16(57.4)	2435.91(65.7)	2011.98(58.5)	30.76(34.1)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

Table 4.3.21: Summer moose foraging habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Canopy closure	Moisture	Stand condition
1	31%-50%		
			Clear Cut
			Burns
2	51%-70%		
		Wet or aquatic	
3	6%-30%, 71%-100%		

Table 4.3.22: Summer moose foraging habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	638.98(20.4)	708.28 (21.3)	152.78(5.2)	66.68(1.8)	398.72(11.6)	0.23(0.3)
2	896.97(28.6)	1472.99(44.3)	1076.70(36.7)	1205.11(32.5)	1014.76(29.5)	48.92(54.3)
3	22.50(0.7)	21.40(0.6)	15.06(0.5)	7.12(0.2)	10.42(0.3)	10.68(11.9)
4	1574.92(50.3)	1120.10(33.7)	1688.19(57.6)	2426.15(65.5)	2015.13(58.6)	30.26(33.6)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

Table 4.3.23: Winter moose foraging habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Canopy closure	Stand condition
1	31%-50%	
		Clear Cut
		Burn
2	51%-70%	
3	6%-30%, 71%-100%	

Table 4.3.24: Winter moose foraging habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	643.38(20.5)	708.28(21.3)	152.54(5.2)	67.23(1.8)	398.76(11.6)	1.91 (2.1)
2	278.74(8.9)	270.57(8.1)	121.41(4.1)	131.30(3.5)	464.22(13.5)	6.39(7.1)
3	659.74(21.1)	1225.05(36.9)	974.61(33.2)	1201.59(32.4)	564.04(16.4)	51.52(57.5)
4	1551.51(49.5)	1118.87(33.7)	1684.17(57.4)	2304.92(62.2)	2012.01(58.5)	30.27(33.6)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

Table 4.3.25: Caribou foraging habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Canopy closure	Stand condition
1	31%-70%	
2	71%-100%	
3	6%-30%	
		Clear Cut

Table 4.3.26: Caribou foraging habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	. Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	331.89(10.6)	737.48(22.2)	272.69(9.2)	90.99(2.5)	775.10(22.5)	1.68(1.9)
2	225.61(7.2)	20.08(0.6)	10.34(0.3)	97.12(2.6)	74.71(2.2)	2.05(2.3)
3	1049.73(33.5)	836.39(25.2)	321.09(11)	1172.62(31.6)	312.79(9.1)	29.31(32.5)
4	1526.14(48.7)	1738.82(52.3)	2328.91(79.4)	2344.31(63.3)	2276.43(66.2)	62.05(68.9)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

Table 4.3.27: Summer caribou habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat classification rank	Species composition	Structure	Canopy closure	Moisture	Stand condition	Elevation
1	*Pinus banksiana, Picea* sp. mix	Mature Jack Pine	51%-100%	Moist or wet		≥ 700 m
2	*Picea mariana, Pinus banksiana* mix	Mature Jack Pine	31%-100%	Moist or wet		≥ 700 m
			31%-100%	Wet or aquatic		≥ 700 m
3			6%-30%	Wet or aquatic		≥ 700 m
	Pinus banksiana	Immature				≥ 700 m
	Populus tremuloides/ Coniferous mix, *P.tremuloides* dominant		6%-50%, 51%-100%	Dry or moist		≥ 700 m
					Burned	≥ 700 m
	Pinus banksiana, Picea sp. mix	Mature Jack Pine	51%-100%	Moist or wet		< 700 m
	Picea mariana, Pinus banksiana mix	Mature Jack Pine	31%-100%	Moist or wet		< 700 m
			31%-100%	Wet or aquatic		< 700 m
4			6%-30%	Wet or aquatic		< 700 m
	Pinus banksiana	Immature				< 700 m
	Populus tremuloides/ Coniferous mix, *P.tremuloides* dominant		6%-50%, 51%-100%	Dry or moist		< 700 m
					Burned	< 700 m

Table 4.3.28: Summer caribou habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	24.87(0.8)	0.02(0)	0.00(0)	0.04(0)	363.88(10.6)	0.00(0)
2	140.01(4.5)	0.41(0)	0.00(0)	2.11(0.1)	250.77(7.3)	0.00(0)
3	565.26(18)	1084.96(32.7)	439.72(15)	197.72(5.3)	1029.97(29.9)	9.34(9.8)
4	2403.23(76.7)	2247.38(67.6)	2493.01(85)	3505.45(94.6)	1794.41(52.2)	85.74(90.2)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

Table 4.3.29: Winter caribou habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Canopy closure	Moisture	Stand condition	Elevation
1	Coniferous	6%-50%	Moist, wet or aquatic		≥ 700 m
		6%-30%	Wet or aquatic		≥ 700 m
2			Aquatic		≥ 700 m
	Picea mariana	51%-100%	Dry, moist or wet		≥ 700 m
3				Burn	≥ 700 m
		51%-100%	Wet or aquatic		≥ 700 m
				Clear Cut	≥ 700 m
	Coniferous	6%-50%	Moist, wet or aquatic		< 700 m
		6%-30%	Wet or aquatic		< 700 m
			Aquatic		< 700 m
	Picea mariana	51%-100%	Dry, moist or wet		< 700 m
4				Burn	< 700 m
		51%-100%	Wet or aquatic		< 700 m
				Clear Cut	< 700 m

Table 4.3.30: Winter caribou habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	102.74(3.3)	0.53(0)	0.00	1.4(0)	460.35(13.4)	0.00(0)
2	104.06(3.3)	0.00(0)	0.00	0.00(0)	317.52(9.2)	0.00(0)
3	939.27(30)	1921.42(57.8)	956.13(32.6)	335.46(9.1)	991.19(28.8)	20.94(22)
4	1987.3(63.4)	1410.82(42.5)	1976.6(67.4)	3368.43(90.90	1669.96(48.6)	74.14(78)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

Table 4.3.31: Winter caribou predation habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Canopy closure	Moisture	Stand condition	Elevation
1	Coniferous/Deciduous mix	6%-70%	Dry or moist		≥ 700 m
				Clear cut	≥ 700 m
2	Deciduous	6%-70%	Dry or moist		≥ 700 m
		31%-100%	Wet or aquatic		≥ 700 m
3		6%-30%	Wet or aquatic		≥ 700 m
	Coniferous	71%-100%	Moist, wet or aquatic		≥ 700 m
	Coniferous/Deciduous mix	6%-70%	Dry or moist		< 700 m
				Clear cut	< 700 m
	Deciduous	6%-70%	Dry or moist		< 700 m
		31%-100%	Wet or aquatic		< 700 m
4		6%-30%	Wet or aquatic		< 700 m
	Coniferous	71%-100%	Moist, wet or aquatic		< 700 m

Table 4.3.32: Winter caribou predation habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	58.4(9.9)	0.79(0)	0.00(0)	1.59(0)	36.95(1.1)	0.00(0)
2	173.54(5.5)	0.00(0)	0.00(0)	2.33(0.1)	786.56(22.9)	0.00(0)
3	1050.00(33.5)	2781.97(83.7)	1092.95(37.3)	845.06(22.8)	1018.69(29.6)	33.24(35)
4	1851.44(59.1)	550.01(66.3)	1939.78(63.7)	2856.06(77.1)	1596.82(46.4)	61.85(65)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

Table 4.3.33: Summer caribou predation habitat classification based on AVI canopy closure, species composition, and moisture regime.

Habitat Classification Rank	Species composition	Canopy closure	Moisture	Stand condition	Elevation
1	*Larix laricina, Pinus banksiana, Pinus albicaulis, Pinus flexilis* mix	6%-70%	Dry or moist		≥ 700 m
				Clear cut	≥ 700 m
2	*Picea sp., Abies sp.,* or *Pseudotsuga mensiesii*		Dry or moist		≥ 700 m
3	Deciduous	6%-70%	Dry or moist		≥ 700 m
			Wet or aquatic		≥ 700 m
	Larix laricina, Pinus banksiana, Pinus albicaulis, Pinus flexilis mix	6%-70%	Dry or moist		< 700 m
				Clear cut	< 700 m
	Picea sp., Abies sp., or *Pseudotsuga mensiesii*		Dry or moist		< 700 m
4	Deciduous	6%-70%	Dry or moist		< 700 m
			Wet or aquatic		< 700 m

Table 4.3.34: Summer caribou predation habitat in each forest management unit in the study area

Habitat Classification Rank	FMU 2	FMU 3	FMU 4	FMU 5	FMU 6	FMU 7
	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)	Amount (km^2)
1	35.51(1.1)	0.43(0)	0.00(0)	7.64(0.2)	42.15(1.2)	0.00(0)
2	76.57(2.4)	0.12(0)	0.00(0)	1.32(0)	17.34(0.5)	0.00(0)
3	572.98(18.3)	301.18(9)	220.79(7.5)	217.96(5.9)	1548.40(45.1)	9.64(10.1)
4	2448.31(78.2)	3031.04(91)	2711.94(92.5)	3478.13(93.9)	1831.16(53.2)	85.44(89.9)
Total	3133.37	3322.77	2932.73	3705.04	3439.03	90.09

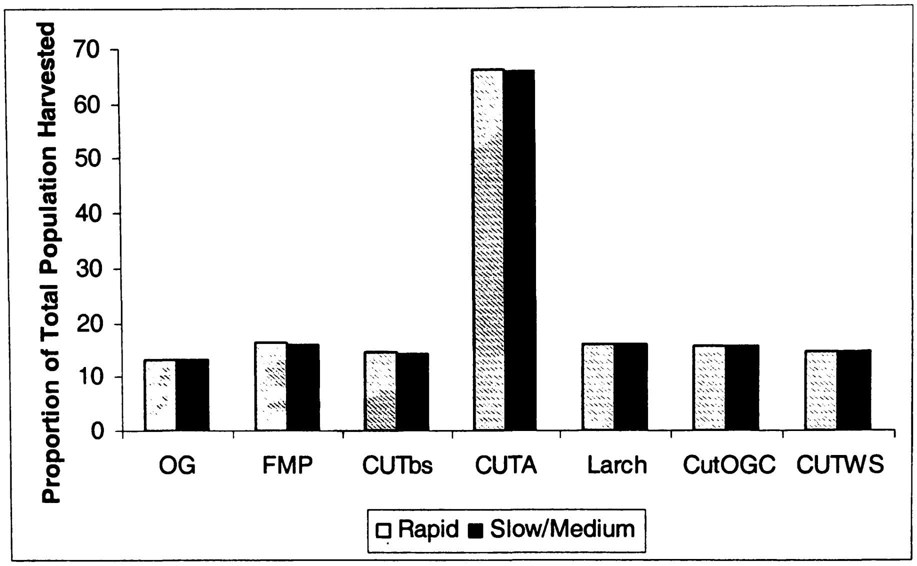

Figure 7.2.1: Proportion of Moose Population Harvested by Community Members of Little Red River Tall Cree Nation in 2006 (rapid and slow/medium population projections)

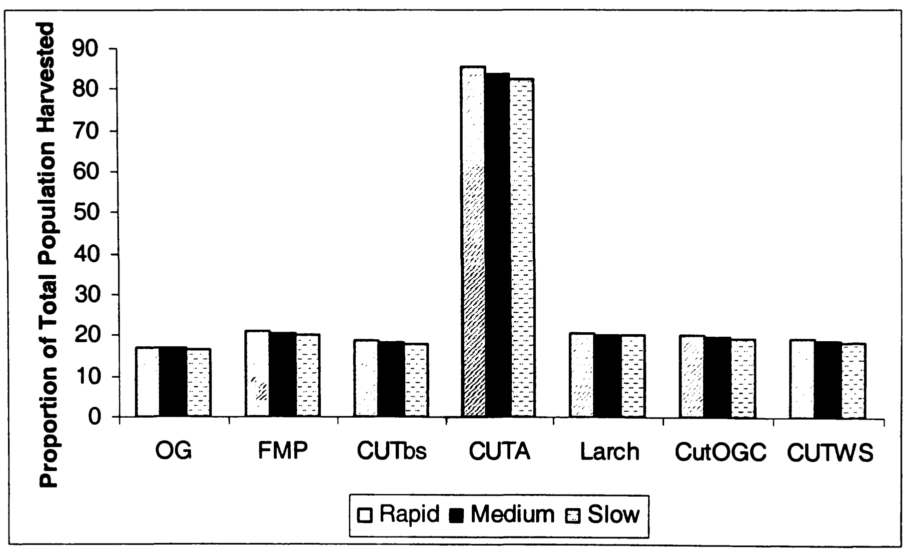

Figure 7.2.2: Proportion of Moose Population Harvested by Community Members of Little Red River Tall Cree Nation in 2016 (rapid, medium, and slow population projections)