MODELING

Mountain Goat Habitat Supply Modeling, with Preliminary Application in the Ospika River Drainage, North-Central B.C.

Version 1 DRAFT

PAMELA E. HENGEVELD[1], MARI WOOD[2], RICK ELLIS[3], AND ROSS LENNOX[4]

MARCH 31, 2003

[1]Wildlife Infometrics Inc, P.O. Box 308, Mackenzie, B.C., V0J 2C0, wild_info@cablerocket.com

[2]Peace/Williston Fish & Wildlife Compensation Program, 1011 Fourth Ave, 3rd Flr, Prince George, B.C., V2L 3H9

[3]R. Ellis and Associates Inc., 10967 Madrona Dr., Sidney, B.C., V8L 5R7

[4]Slocan Forest Products Ltd, P.O. Box 310, Mackenzie, B.C., V0J 2C0

Prepared for Slocan Forest Products Ltd., Mackenzie Operations under contract #FII-02-01 (R2003-0208)

CITATION: Hengeveld, P.E., M. Wood, R. Ellis, R. Lennox. 2003. Mountain goat habitat supply modeling, with preliminary application in the Ospika River drainage, north-central B.C. Wildlife Infometrics Inc Report No. 46. 44 pp. plus appendices.

The Ospika Mountain Goat Project

Adaptive Management & Habitat Supply Modeling

The Ospika Mountain Goat Project is a 5 year (2002-2007) study funded and administered by Slocan Forest Products Ltd. and the Peace/Williston Fish and Wildlife Compensation Program. The project proposes a concurrent, multi-phase approach to developing and implementing effective forest management strategies that are considerate of mountain goat habitat values. Project components include an Adaptive Management Trial; Habitat Supply Modeling; Resource Inventory; and Policy Development.

This report is reproduced in the PWFWCP report series as:

Slocan

Peace/Williston FISH & WILDLIFE COMPENSATION PROGRAM

BRITISH COLUMBIA

ABSTRACT

Slocan Forest Products – Mackenzie Operations (Slocan) secured Forestry Innovation Investment (FII) funds to initiate development of a Habitat Supply Model for mountain goats (*Oreamnos americanus*) between January and March, 2003.

Representatives from the forest industry, government ministries, and wildlife research groups participated in a series of 3 workshops hosted by Slocan. The intent of the workshops was to construct a preliminary, Netica©-based (http://www.norsys.com/) Mineral Lick Habitat Supply Model to address concerns of habitat supply and alternative mineral sources for mountain goat populations potentially impacted by forest harvesting. The Mountain Goat Mineral Lick Habitat Supply Model was completed as the initial step in developing a formal, comprehensive Mountain Goat Habitat Supply Model that will ultimately link mountain goat and habitat monitoring information, forest development planning, and forest management activities.

Project deliverables to FII (included herein):

1. An agenda and post-workshop summary for each modeling workshop
2. An annotated, Netica©-based, mineral lick habitat supply model for mountain goats
3. A technical report discussing model development and application
4. A demonstration of the trial application to stakeholders (slide presentation)

We expect to continue model development & application beyond March 2003 through a large-scale, collaborative, and comprehensive mountain goat habitat modeling effort similar in scope to the Omineca Northern Caribou Project (see http://www.slocan.com/irm/projects/caribou/model/index.html). Our long-range goal is to provide a mountain goat habitat supply model that can be used by the forest industry at a regional and provincial level to plan the provision of mountain goat habitat in the context of sustainable forest management.

ACKNOWLEDGMENTS

This project was conducted by a cooperative, multi-agency working group. The following people were key contributors in determining ecological relationships and developing the model:

Participant	Affiliation	Role
Scott McNay	Slocan Forest Products – Mackenzie Operations (Forest Biologist)	Project Proponent
Pamela Hengeveld	Wildlife Infometrics Inc (Wildlife Ecologist)	Project Leader, Author
Mari Wood	Peace/Williston Fish & Wildlife Compensation Program (Senior Wildlife Biologist)	Collaborator, Author
Fraser Corbould	Peace/Williston Fish & Wildlife Compensation Program (Wildlife Biologist)	Collaborator
Rick Ellis	R. Ellis and Associates Inc.	Facilitator, Author
Ross Lennox	Slocan Forest Products – Mackenzie Operations (Planning Forester - Buffalohead/Ospika)	Collaborator, Author
Dale Seip	Ministry of Forests – Mackenzie District (Zone 1 Forester)	Collaborator
Doug Heard	Ministry of Water, Land and Air Protection (Wildlife Specialist)	Collaborator
Doug Wilson	Ministry of Water, Land and Air Protection (Wildlife Biologist)	Collaborator
Bill Arthur	Ministry of Water, Land and Air Protection (Senior Ecosystem Specialist)	Collaborator
Glen Watts	Ministry of Water, Land and Air Protection (Wildlife Biologist)	Collaborator
Laurence Turney	Ardea Consulting	Advisor
Jeremy Ayotte	UNBC MSc candidate	Advisor
Rob McCann	Wildlife Infometrics Inc (Wildlife Ecologist)	Data Advisor
Andrea Doucette	Wildlife Infometrics Inc (GIS Specialist)	GIS Advisor

Portions of this document (specifically, Chapters 4 and 5) are based on ideas presented in the CHASE model documentation; see McNay, R.S., K. Zimmerman, R. Ellis (editors). 2003 [Draft]. Caribou Habitat Assessment and Supply Estimator (CHASE): Using Modeling and Adaptive Management to Assist Implementation of the Mackenzie LRMP in Strategic and Operational Forestry Planning. Unpublished. 101pp plus appendices.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Mountain goat ecology and management in the Mackenzie TSA

Mountain goats (*Oreamnos americanus*) are habitat specialists. Although they are found primarily in rugged terrain at high-elevations, some populations show significant dependence on and fidelity to lower elevation habitats. Mountain goats use forested areas to access low-elevation mineral licks from early spring to late fall (Clare 2001), and for forage and cover during the winter. Mineral licks and their access trails are traditionally used by successive generations of goats (Fox and Smith 1988).

Mountain goat fidelity to critical habitats renders goats particularly sensitive to disturbance from, and displacement by, various industrial activities (Hebert and Cowan 1971, Chadwick 1983, Pendergast and Bindernagel 1977, Foster and Rahs 1983, Singer and Doherty 1985, Cote 1996, Shackleton 1999). Forest development has the potential to reduce or eliminate access to mineral licks, cause disturbance to goats on their winter range, and create access for hunters to previously un-hunted and vulnerable goat populations.

With the continued demand for wood supply, forest development is expanding throughout the Mackenzie Timber Supply Area (TSA), into additional tributary watersheds and higher-elevation forests. Within the last two years, management concerns regarding mountain goats have been raised, as forest harvesting has begun to encroach on low elevation mountain goat habitat in the lower Ospika River drainage.

The BC Identified Wildlife Management Strategy (B.C. MWLAP in prep.), recently incorporated into the Forest Practices Code (FPC), and the Mackenzie Land and Resource Management Plan (LRMP; B.C. Government 2000) identify the mountain goat as a regionally important species of special management interest. While the LRMP identifies the need to appropriately manage mountain goats and their habitats, it defers all management to policies defined at a regional level. Currently, no firm management policies have been developed. The FPC provides some management direction in the form of General Wildlife Measures, Ungulate Winter Range, and Identified Wildlife Management Strategy recommendations, however, the recommendations are generalized, static, and limited in scope. There is a recognized need for developing mountain goat management guidelines that consider the full range of habitat types used by mountain goats, incorporate some evaluation of industrial disturbance and cumulative effects over time, and facilitate operational planning for the sustainability of forest values.

Mountain goat fidelity to critical habitats and the potential for impact by forest development, coupled with declining populations of mountain goats (Smith 1988, Ballard 1977, Phelps et al. 1976), suggests that mountain goats have high potential as an indicator to assess the sustainability of forest values over time.

Relative to other ungulates, little is known about mountain goat ecology generally, and few data exist for mountain goat populations in the Mackenzie TSA. Data on the distribution and abundance of mountain goats in the Ospika River drainage is sparse; only one formal inventory has been conducted (Hatler 1988). The Ospika Mountain Goat Project, initiated in 2001 by Slocan Forest Products – Mackenzie Operations (Slocan) and the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP), includes an Adaptive Management Trial in the lower Ospika (focused on forestry impacts on mountain goat use of low-elevation mineral licks), resource inventory, policy development, and habitat supply modeling, that are intended to contribute toward sustaining both mountain goat habitat and forest harvesting.

Slocan has initiated development of a mountain goat Habitat Supply Model (HSM) to address concerns of habitat supply and alternative mineral sources for mountain goat populations potentially impacted by forest harvesting. The long-term goal is to develop a Goat HSM that is a useful operational planning tool at the Forest Stewardship Plan level, and that will contribute to developing adaptive management strategies that can be applied to other geographical areas (regionally and provincially).

Initial model development was accomplished through a collaborative effort during a series of three workshops held in February and March 2003. A trial application of the preliminary model was conducted for the lower Ospika River drainage, Mackenzie TSA.

Project activities completed in February and March are documented by the preparation of:

1. An agenda and post-workshop summary for each modeling workshop
2. An annotated, Netica©-based, mineral lick habitat supply model for mountain goats
3. A technical report discussing model development and application
4. A demonstration of the trial application to stakeholders (slide presentation)

This document is intended as a progress report to present the results of the preliminary model development and application activities, and to establish a framework for further model development.

1.2 Project Objectives

The Goat HSM project has the following 6 objectives:

1. Develop a common understanding among researchers and managers to aid in ongoing policy development and management of mountain goats.
2. Develop planning tools to be incorporated into operational planning (forest stewardship plans) and policy development.
3. Develop analytical approaches that will incorporate and utilize fieldwork results in an effective manner.
4. Develop modeling tools that will allow informed and testable predictions of mountain goat responses to managed and natural changes (i.e., disturbances) in the area. These predictions can then be tested through management trials and the results monitored.
5. Develop models that incorporate the spatial components of habitat selection by the animals linked to the changes in the forests and habitats. In the future this may be linked to a model of the population dynamics of goats.
6. Make learning about how to improve management a key goal of forestry and wildlife programs in the area. Do this by:
    a. developing a shared understanding of the goat management issues and potential solutions;
    b. designing management alternatives that test the most promising solutions;
    c. implementing these alternatives in different areas through operational management programs;
    d. maximizing the value of monitoring dollars spent and field data collected in terms of ecological and managerial understanding gained; and
    e. evaluating outcomes of the management alternatives and using the resulting new knowledge to improve future management decisions.

1.3 Management Application

Results from applying the Goat HSM will be used in two main ways. Firstly, results will be used to evaluate the strategic effectiveness, and alternatives to the current Management Strategy. Secondly, results will be used as a guide in road and cut-block placement in the preparation of operational development plans (e.g., Forest Stewardship Plans) so as to promote consistency with the desired long-term management strategy.

1.4 Modeling Approach

Goat HSM is a type of habitat supply model. In the Strategy for Habitat Supply Modeling for British Columbia (Jones *et al*. 2002), 6 types of habitat supply models were identified. Goat HSM fits within the category of "Single Species, Large Area Home Range, All/Most Life Requisites", however since it considers the interaction of predation it is, in some ways, a multi species model.

1.4.1 Goat HSM as a Type of Habitat Supply Model

Goat HSM can be presented in a graphical representation similar to that presented by Jones *et al*. (2002). Figure 1 is used to depict Goat HSM in the overall context of modeling and management. In general, habitat supply models depend on expressions of "habitat relationships" which are typically formed on the basis of "resource inventory" projects (ref). Provided there are forecasts of "predicted forest and stand conditions" available, these can then be translated into "predicted habitat supply". "Population response" to habitat supply can then be modeled or inferred from the supply of habitat and "interpretations" made.

Habitat supply models are greatly enhanced if the predicted future conditions of the forest come from a "disturbance scheduler" or forest estate model (ref) because the estimates of habitat supply and timber supply can then be interpreted together to enable decisions about "trade-offs". The desire to understand, or ask questions about such trade-offs, usually comes from attempting to introduce or implement a "policy or management alternative" (i.e., to consider the implications of doing so). The policy information can be used as input to the disturbance simulator in scenario runs to form the basis for use of habitat supply model. Finally, a useful and often-requested comparison in habitat supply analyses is a "natural disturbance" base case that can be simply input to the disturbance simulator and used in the habitat supply model to make predictions about habitat supply.

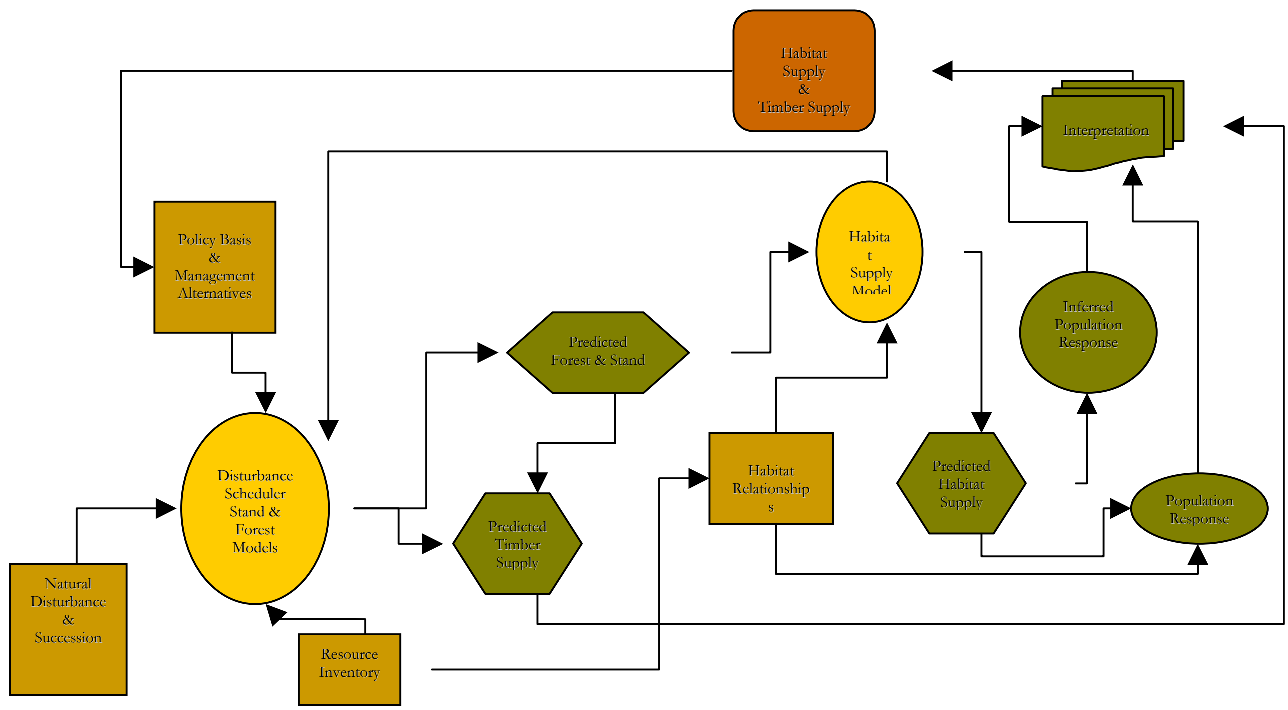

Figure 1. A general illustration depicting the relationship among components of a habitat supply model (adapted from Jones *et al.* 2002).

1.4.2 Goat HSM Model Design

In developing a conceptual representation (i.e., a model) of an ecological and management system of the complexity known in this area, it is tempting to include all known factors and relationships in the model. This can lead to long model development time, an expensive and time-consuming product to use, and a loss of focus on developing a working management tool. In order to avoid this pitfall, the initial set of models includes only the "major" components of known ecological significance. These "major" factors were chosen because they were thought to have the most impact, are of key interest, have data available, and are currently within the realm of management action. In future model refinements additional detail can be included, and other factors and relationships included as necessary.

1.4.2.1 Aspects of Goat Ecology and Habitat Considered

Limiting factors for goats: Accidents, Avalanches, Predation, Starvation, Hunting, and Disturbance / Harassment

- Accidents – goats stay close to steep escape terrain; accidental falls may be common
- Avalanches – goats live on steep terrain and can deal with a wide range of snow depths (steep terrain and deep snow = predator barriers); avalanches are common
- Predation – goats are effective anti-predator strategists, but same issue as with caribou (goats are an alternate prey; changes in predator-prey relationships and abundance may impact goats).

- Starvation – goats have a generalist diet; not restricted by food requirements but predator avoidance takes precedence over forage availability
- Hunting – goats live in small populations; significant hunting has potential to impact population viability, particular if harvest is concentrated at mineral licks
- Disturbance / Harassment – aircraft disturbance can impact the whole goat population (direct impact, short-term); recreational activities may have long term impacts

It is thought that predator avoidance (rather than forage availability) is the dominant factor in goat habitat use. Thus, proximity to escape terrain is considered to be important in all aspects of mountain goat habitat. The presence of steep, rough terrain is an important habitat feature common to natal areas, alpine summer range, alpine winter range, and forested escape habitats. A single model for escape habitat can generally represent all four habitat/range types; each type can be distinguished as a sub-set of the general model by simple addition of 1 or 2 parameters unique to each (e.g., restricted to south aspects in winter).

Some mountain goat populations show high fidelity to low-elevation mineral licks. These licks and their associated access trails are used seasonally (April through October) by successive generations of goats. The licks themselves are thought to provide minerals that satisfy important physiological requirements of mountain goats. As such, low elevation licks and their access trails are considered to be important components of mountain goat habitat. Concerns have been raised regarding the potential impacts of forest harvesting activities on mountain goat populations using low elevation mineral licks in forested habitats.

Four habitat type / range models have been developed as tools to predict the ecological value of various habitat types to mountain goats in the Mackenzie TSA. These models were based on habitat range types considered most likely to be either limiting or important to mountain goat populations in the area. These included:

1. Low Elevation Mineral Licks
2. Trails to Low Elevation Mineral Licks
3. Summer Escape Habitat
4. Winter Escape habitat

Four management factors have been considered in the models. These factors have been determined to be the ones that have the largest potential impact on both the value of a habitat area and the goat population using the area. The management factors are:

1. Ground based activity causing disturbance to goats. The Ground Disturbance sub-model was developed to evaluate the impacts of ground based human activity on goats.
2. Aerial based activity causing disturbance to goats. The Aerial Disturbance sub-model was developed to evaluate the impact of aerial activities adjacent to goat ranges.
3. Hunting of goats. The Hunting sub-model was developed to assess the impact of regulated and unregulated hunting on goats and the influence of road access on hunting impacts.
4. Predation of goats. The Predation sub-model was developed to predict the risk of predation associated with habitats based on the impact of adjacent management activities on predation.

1.4.2.2 Underlying Philosophy Regarding Modeling

All modeling activities contain an inherent philosophy. The philosophy used in this project is summarized in the following 3 general assumptions:

1. No model is going to be "the true or complete model", therefore it is important to formulate the model explicitly, incorporate empirical data and the recognition of uncertainty into the model, and adapt the model to new empirical information;
2. Alternatively, no finite amount of empirical data or science will form an exact characterization of the ecological situation or relationships, therefore it is important to develop a model that will bridge the gaps in the data and empirical understanding in order to create a more comprehensive and consistent, albeit theoretical, understanding of the ecological system;
3. No model, will be readily implemented at the operations level; therefore it is important to incorporate an interpretive component into the overall project product.

An ideal model would be precise, general, and realistic, however one of these elements must be sacrificed if the other two are to be met (ref). This modeling approach is built upon a desire for generality and realism and, as such, it would:

- Serve as a basis for communication regarding the causal relationships involved in the ecology of caribou, moose, wolves and logging.
- Consider operational management factors relevant to the area.
- Incorporate data from fieldwork.
- Include a framework for analysis and decision-making.
- Consist of an open architecture for the evaluation of results (rather than a “black box” approach).
- Provide a mechanism for the choice of alternative adaptive management experiments that includes the consideration of costs ($ and social), uncertainty, sensitivity of the ecosystem, and the likelihood of getting reliable results.

1.5 Modeling Tools Used

There were a number of modeling tools used to construct the overall modeling framework. These tools were used to:

- Represent the spatial aspects of the landscape (ArcView® 3.2, ESRI Corp.)
- Represent the ecological relationships involved in determining habitat value of caribou seasonal ranges (Netica®, Norsys Corp.).
- Additional data management that links modeling systems together and calculates stand and timber information and operational considerations was carried out using Access® (Microsoft Inc.).

These modeling tools are described in general in following sections and in detail by Goat HSM Users guide (in prep). The User’s Guide is intended to provide an in-depth background to Goat HSM model tools, software, data requirements, and “run” procedures. Step-by-step operating instructions for Goat HSM are identified. There are XX basic modeling steps (Figure 1.1):

1.5.1 Spatial Data Handling

All spatial data handling and processing for Goat HSM was performed using ArcView®, either through custom computer programs (henceforth referred to as scripts) or the graphical user interface. ArcView® is a desktop computer based Geographic Information System (GIS) developed by Environmental System Research Institute (ESRI). This particular system was chosen for its low cost, portability, existing widespread use, advanced analysis functions, and ability to handle vector and raster data types.

Goat HSM used primarily a raster data model to store the spatial data and perform analysis. The raster data model divided the study area into 1-ha pixels, the result of laying a grid of rows and columns over the landscape. The advantages of raster data are the simple data storage structure and ease in performing spatial overlays and analysis.

To perform most of the spatial data analysis, custom scripts were created using ArcView's® proprietary macro language: Avenue®. This is an object orientated programming language that has access to a wider array of spatial analysis functions and tools when compared to the simple graphical user interface.

(Figure to be inserted)

Figure 2. Flow diagram for running the Goat HSM.

1.5.2 Ecological Relationships Network

One of the goals of the project was to represent the ecological relationships relative to goat in a way that was transparent (the actual ecological factors and relations were shown), and allowed the incorporation of both professional judgement and data results. It was also important that the model could be built on a modeling platform that was readily available, supported, and accessible to the modeling team (non-proprietary). In light of these criteria an evaluation of alternative modeling platforms was conducted and a Bayesian Belief Network (BBN) approach chosen. Of the BBN approaches available, Netica® (Norsys Inc.) was chosen. This choice allowed close cooperation with researchers and managers working in Washington and Oregon, since they are successfully using similar approaches (ref).

A BBN is a form of influence diagram which, as applied in ecology, depicts the logical or causal relations among ecological factors that influence the likelihood of outcome states of some parameter(s) of interest, such as forest condition or wildlife habitat. BBN's can be used to represent 'causal webs' of major influences, such as factors that most affect population abundance and distribution. BBN's have been used in a variety of applications in ecology and forest management. For example the Interior Columbia Basin Ecosystem Management Project of the USDA Forest Service and USDI Bureau of Land Management used numerous BBN models (B. Marcot pers. comm.).

BBNs also met the objective of providing a useful communications medium that: (1) clearly displays major influences, and facilitates an explicit representation of how a system works; (2) combines categorical and continuous variables; (3) combines empirical data with expert judgment, often from multiple experts, and uses categorical, ordinal scale, and continuous data in the same model, (4) can be easily updated with new data and from expert review, and (4) expresses predicted outcomes as likelihood's as a basis for risk analysis and risk management (Marcot 1998).

The BBN approach using Netica facilitated the effective development of habitat relationships in a workshop environment since it provided a relatively fast, interactive and easily understood visual structure for exploring factors, and allowed professional expertise to be used to array factors into a causal web even if quantitative, statistically-based information was lacking. Likewise, professional expertise was used to depict the probability structures of the degree to which various factors affect habitat or other variables of interest. In addition, relative sensitivity analysis can be conducted to determine the sensitivity of the outcome to various factors considered important. This approach allowed different types of uncertainty to be explicitly acknowledged and evaluated (B. Marcot pers. comm.).

Using the BBN / Netica approach entails: (1) identifying important ecological factors that contribute to habitat value or other factor of interest; (2) developing a "causal web" model that depicts how the ecological factors and management options influence the potential distribution and abundance of the species of interest; and (3) developing a set of probabilities that quantify those factors that influence species.

The habitat models developed using Netica are described in Section 3.

1.5.3 Evaluation of Management Over Time

The key features of goat habitat are specific geographic features (escape areas, licks, and trails). Consequently unlike other types of habitat, for other species, there is little opportunity to “rotate” habitat or habitat use, but rather the specific features must be managed and the impact of management activities assessed. This requires a modeling approach that can assess the impact of any specific management activity and also assess the cumulative impacts of activities occurring over time.

The management application of the model is described in Section 2.

1.6 Literature Cited

BC Ministries. 1995. Biodiversity Guidebook. Forest Practices Code of British Columbia. B.C. Ministry of Forests and B.C. Environment, Victoria, B.C. 99pp.

COSEWIC. 2000.

Jones et al 2002.

2.0 MODEL APPLICATION TO LAND USE PLANNING

The Goat HSM model was developed primarily as an operational planning tool to be applied as part of forest development / stewardship planning. The model can also be used at a strategic level to compare different areas with respect to the status of goat habitat. Each of these applications is described in subsequent sections below. The anticipated users or audience for the model are:

- Forest Industry: Planners, engineers, and professional foresters in the preparation of operational plans that consider goats in site level decision-making regarding road location, block location, and timing of activities.
- Statutory decision makers: Forest District Managers
- Third party “auditors”: Those who investigate issues of compliance, or forest certification.
- *Ad hoc* Committees: eg. Recovery Action Groups.
- General Public: Those viewing or reviewing strategic or operational development plans.
- Scientific community/technical experts: Those interested in new methods and application of techniques.
- Educational: Extension or teaching (University of Northern B.C. or others).

2.1 Forest Development (Forest Stewardship) Planning

The primary management applications for the model are as a predictive tool to identify goat habitat, and as a tool to assist planners in assessing / developing operational planning scenarios that consider the management of goat habitat. Foresters and engineers are faced with numerous challenges such as: (1) locating roads and cut-blocks in a design that meets management objectives for goats; (2) providing the mills with the volume, species and size of timber they desire; (3) managing costs of development and logging through equipment choice, seasonal timing, amount of road constructed; silvicultural treatment options; and other factors. The model was designed to be used to assist operational planning in the following 8 ways:

1) As a predictive tool that identifies areas of potential goat habitat. This would facilitate proactive management by improving forest planner awareness of habitat potential prior to the commencement of development planning activities. If goat habitat was confirmed in the field, cutblock and access road configurations would consider key habitat features at the “proposed” stage (i.e. the presence of goat habitat would be known to government during consideration for approval). It would reduce situations of reactive management, where government and industry work to reach agreement on appropriate management under more onerous time pressures (harvest schedule), and typically after significant operational investments have already been made (layout activities, cutting permit approval, etc.).
2) Where goat habitat has been identified, any operational plan, (specifically 5 year development plans) can be used in the model to compare results with alternative development options. This information would be used by industry to demonstrate that proposed blocks and roads “adequately manage and conserve” forest resources (section 41.1(b) of the Forest Practices Code), as they pertain to mountain goats and their habitat. The sequence could be: (1) develop a plan of development of an area; (2) prepare road and cutblock data information corresponding to the plan; (3) run the modeling tool to predict results; (4) evaluate the predicted results (indicators) against targets, and compare predicted results with available field monitoring data; (5) review and revise the development plan; and (6) repeat the cycle.
3) Location, and season of use of roads and cut-blocks can be evaluated with respect to their effect on the various types of goat habitat in the model.

4) The effects of an individual years activities can be evaluated, the cumulative effects of the current activities can be assessed in combination with past activities, and likewise the combined effects of past, present and future (5 year) plans can be assessed.
5) The following set of management activities can be used as management "levers" in developing or modifying plans:
   - Avoid or buffer goat habitats (escape, lick, trail)
   - Manage the season of activity (summer or winter) around goat habitats (escape, lick, trail). This would include aerial and ground activity – reconnaissance, layout, road building, road traffic, logging and hauling.
   - Establishing barriers to access (ex. road rehabilitation)
   - Manage human access
   - Manage the timing / intensity of ground activities in an area
   - Manage the timing / intensity of aerial activities in an area
   - Implement alternative goat hunting regulations and / or closures to compliment habitat management
   - Implement WHA or Resource Feature designation for an area, where appropriate.
6) Other types of "gaming" (trying alternatives) can be conducted with the model to explore the implications that alternative forest management activities have on goat habitat and operational considerations.
7) The model could also be used to design adaptive management experiments to test alternative stand management activities and their implication to goat habitat value. For example, AMT project.
8) So that licensees can demonstrate that they are upholding the intent of the Mackenzie LRMP.

The model is designed to test alternative management scenarios of interest to managers and planners. In order to have the model behave as realistically as possible the starting point for all scenarios was the landscape situation (roads and cut-blocks) as of 2002. For simplicity, the planned roads and cut-blocks are assessed, and results determined for each year over the life of the plan of interest (normally 5 years).

Over time it is anticipated that targets and / or limits regarding the amount of "impact" that is considered acceptable regarding each type of goat habitat will be developed. These targets will be based on the determination of what is "significant" impact to the various types of goat habitat. The model will assist in promoting this discussion and focusing efforts to acquire additional field information. Once developed these targets or limits could be used to guide decisions regarding when change is required in an operational plan, however in the interim the model provides a mechanism for prediction of site specific impacts on goat habitats.

2.2 Strategic Planning

The model can be used to determine the value of specific areas as habitat and the ability of an overall landscape to support goats. Comparisons of habitat can be made within areas to assess the implications of management in one part of a range compared to another. Comparisons can also be made between goat population areas. As part of the strategic planning application, the model can be used to assess macro level strategies of disturbance, hunting and access management.

As part of the strategic planning application of the model, the following can be accomplished:

- Assess any area and describe its current habitat quality for goat, and how this might change over time under alternative management scenarios.
- Assess macro level strategies of disturbance, hunting and access management.

The following types of questions could be evaluated:
- What is the overall risk/outlook for various groups or populations of goats?
- What type of habitat is limiting for each group or population?

In addition to the application of the tools to the Mackenzie study area, more generalized products such as guidebooks could be developed to transfer general landscape management guidelines derived from the model results to a broader geographic area.

2.3 Literature Cited

3.0 MODEL RATIONALES

This section describes the 4 management factors sub-models and the 4 habitat models that were used to predict the ecological value of range types used by goats in the Mackenzie TSA.

Throughout these range-type models, reference is often made to “habitat”, as in “habitat value” or “habitat preference”. Habitat is defined to include three commonly stated requisites for survival of a species or an individual: procurement of food, avoidance of predators, and the ability to undergo those activities without being displaced or excessively interrupted by human activity or management. One common resultant from each model is an estimate of habitat preference. Preference is deemed to occur any time an animal is located in a habitat type more frequently than would be expected from random locations (ref). Another common resultant from each model is an estimate of habitat value, which incorporates the influence of disturbance impacts on the expected value of the habitat. Generally, the resultant from each model is determined by factors and relationships depending on a variety of primary ecological inputs or ecological correlates (ref) that can be measured or estimated in land-based inventories.

3.1 Management Factors Sub-Models

Many factors affect the survival of mountain goats including forage availability, habitat loss, predation, disease, weather, and human impacts. We included in our models those factors that we can manage or manipulate: human ground disturbance (roads, traffic, machinery, human presence), aerial disturbance, predation, and hunting. We determined that disease transfer from domestic animals to mountain goats is not a current issue of concern. Transmission of the Pasteurella bacteria from domestic to wild sheep can be fatal for the wild sheep (ref), however, there is no evidence to suggest that Pasteurella is transmitted between domestic sheep and mountain goats (B. Foreyt, pers. comm.). In addition, there are no domestic sheep grazing tenures in the Ospika valley or throughout the range of mountain goats in the Mackenzie TSA.

3.1.1 Ground Disturbance Sub-Model

Ground disturbance considers impacts from industrial activities (noise from heavy machinery), vehicular traffic (on roads crossing or adjacent to goat habitat), and human presence, on or near mineral licks, lick access trails, or escape terrain. These disturbances are primarily associated with forest harvesting, mining, and oil and gas exploration, although human presence can also result from recreational and research activities (hiking, hunting, forestry/wildlife research). Ground disturbances can result in both direct mortality (through vehicle collisions) and indirect mortality (avoidance of important habitat feature e.g. mineral lick/natal area/escape terrain, thus reduced energy or mineral intake resulting in poor reproduction and adult and/or kid survival). Geist (1971) states that disturbance can modify behaviour, thus impacting physiology, population productivity, and habitat use. Stress caused by human activities can also make goats more susceptible to disease (Joslin 1986).

The Ground Disturbance sub-model feeds directly into the Mineral Lick and Trail habitat models. We considered a high degree of Ground Disturbance in the absence of any other factors (e.g. predation, hunting etc), to reduce the value of the habitat in question to 100% Moderate value habitat. The Ground Disturbance sub-model is combined with the Aerial Disturbance sub-model (see section 3.1.2) into a Total Disturbance sub-model which factors into the Summer Escape Terrain and Winter Escape Terrain habitat models.

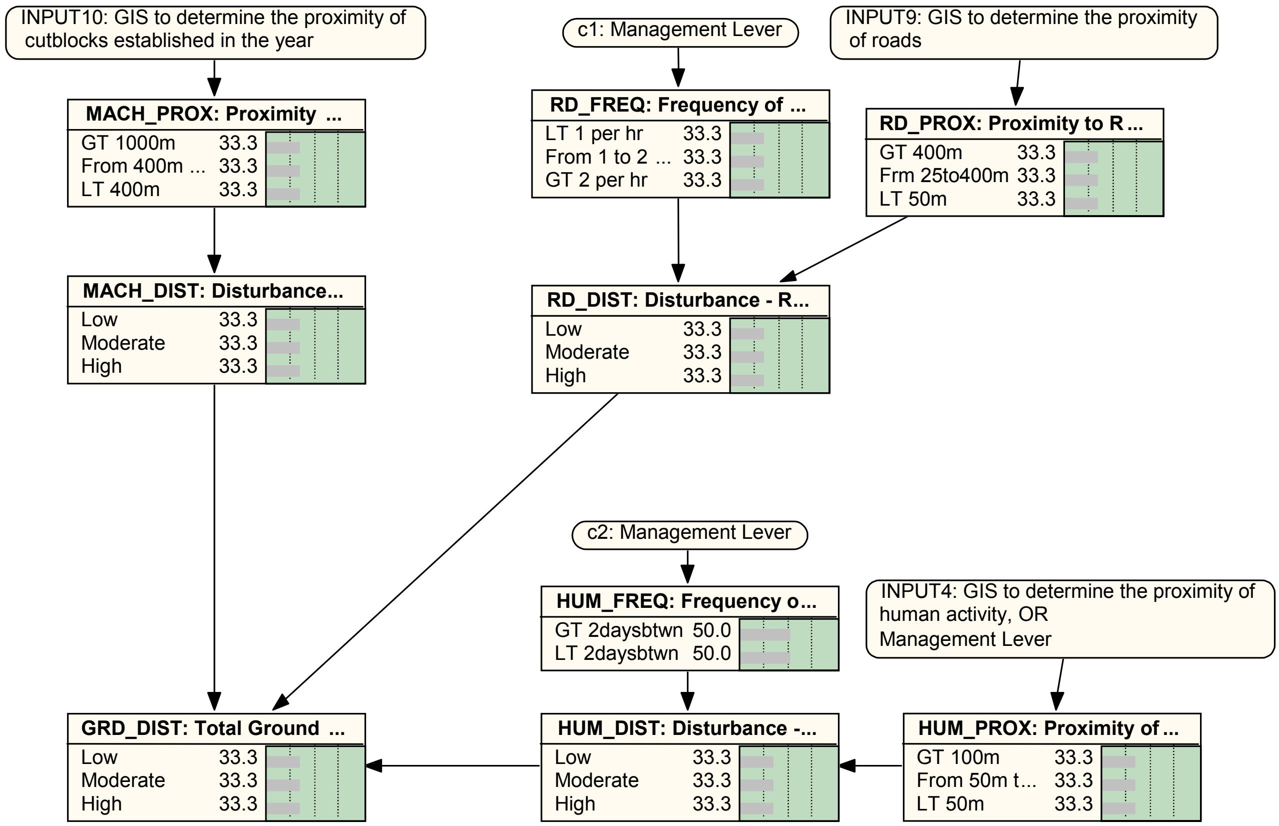

Figure 3. Factors and relationships contributing to total ground-based disturbance that may influence habitat use by mountain goats.

3.1.1.1 Industrial Disturbance

Industrial disturbance includes noise emitted from heavy machinery or equipment used during road building, timber harvesting, mineral exploration, and well-site development. The factor considered most important for this sub-model was the proximity of this noise disturbance to goat habitat. Although we are unable to predict the exact location of the machinery, and the length of time the machine is working at that location, we assume that disturbance will be present if the general site (road, cutblock, well-site) is within a specific distance of goat habitat. The seasonal timing of the industrial activity is not an actual factor, but part of the input data to the model.

The few documented studies in the literature on the effects of industrial disturbance on mountain goats show conflicting results, although it appears that at least some level of negative effect is likely. Foster and Rahs (1980) documented temporary range abandonment by goats subjected to noise disturbance from drilling activity. Joslin (1986) noted no abandonment of ranges by goats subjected to seismic activities for energy exploration, however, the cumulative years of stress on the goats resulted in decreased population numbers and productivity. Foster and Rahs (1983) concluded that goats did not demonstrate any habituation to noise during the drilling activity period. However, through trials where goats were subjected to noise representative of gas exploration activities, Penner (1988) concluded that goats can habituate to continuous predictable noises. (He also noted however, that goats are disturbed by sudden unpredictable noises.) Goats in dense vegetation (i.e. along trails or near mineral licks) were found to exhibit more severe stress responses to noise than those on escape terrain (Foster and Rahs 1983), and females during the kidding and post-kidding periods were found to be sensitive to both predictable and unpredictable noises (Penner 1988).

Rationale for States:

Proximity (MACH_*PROX)*:

- *Greater than 1000m from goat habitat (trail, lick, or escape terrain)*
- *From 400 to 1000m from goat habitat (trail, lick, or escape terrain)*
- *Less than 400m from goat habitat (trail, lick, or escape terrain)*
    - Distances refer to the proximity of roads built, cutblocks harvested, or well-sites drilled in the current year (i.e. where machinery is working) as determined by GIS analysis
    - Foster and Rahs (1983) noted a significant relationship between the distance of industrial disturbance and the level of goat stress response.
    - Although Penner (1988) states that goats can habituate to continuous predictable disturbance (more typical of drilling rigs), the industrial disturbance our goats may be subjected to will not likely be continuous and predictable, specifically road building and harvesting operations where equipment is constantly moving to new locations.
    - IWMS recommends that no roads or timber harvesting occur within 400m of a mineral lick used by goats, thus we adopted 400m as a critical threshold
    - We assume that the closer the noise disturbance is to goat habitat, the more impact there will be to the goat population. Machinery noise will likely be inaudible or at least relatively insignificant greater than 1 km away.

3.1.1.2 Road/Traffic Disturbance

Road/traffic disturbance includes any vehicular traffic along roads (primarily passenger vehicles to logging trucks, but can include ATV's), and can have both direct and indirect impacts on mountain goats. Collisions with vehicular traffic causing death directly impacts goat numbers, while consistent traffic and noise disturbance may indirectly affect goats by preventing or reducing their visits to important habitat (escape terrain, mineral licks, trails). As previously mentioned, goat response to noise disturbance is variable according to the literature. Singer (1975) states that goats using a mineral lick along a major highway habituated to both human visitors and trains, but still perceived vehicles as a threat. The unpredictable nature of vehicular traffic on logging roads suggests it is unlikely goats will habituate to this type of disturbance readily. The proximity and frequency of vehicular disturbance are the factors we considered most important to goats. Proximity is determined by GIS analysis, while frequency is considered as a management lever. The seasonal timing of vehicular disturbance is not an actual model factor, but part of the model input data.

Rationale for States:

Proximity (RD_*PROX)*:

- *Greater than 400m from goat habitat (trail, lick, or escape terrain)*
- *From 50 to 400m from goat habitat (trail, lick, or escape terrain)*
- *Less 50m from goat habitat (trail, lick, or escape terrain)*
    - Distances refer to the proximity of roads to goat habitat (as determined by GIS analysis)

- The closer the vehicular traffic is to goat habitat, the more likely direct mortalities will result from vehicle collisions
- IWMS guidelines recommend no timber harvesting or road building occur within a 400m buffer around a mineral lick or WHA's
- We assume that noise disturbance from vehicular traffic will be relatively insignificant beyond 400m from goat habitat

Frequency (RD_FREQ):

- *Less than 1 vehicle per hour*
- *From 1 to 2 vehicles per hour*
- *Greater than 2 vehicles per hour*
    - Frequency refers to the number of vehicle passes (empty and loaded) on the road per hour
    - Frequency is included in the model as a management lever
    - Estimates may be based on wood volume or area harvested and transported down the road
    - The greater the frequency of vehicular traffic, the greater the risk of mortality to goats
    - Goats may be reluctant to cross a road to access other goat habitat if the frequency of disturbance is >2 trucks/hr

3.1.1.3 Human Presence Disturbance:

Human disturbance includes visits by humans near goat habitat primarily for the purposes of timber cruising, road and block layout, silviculture activities, research activities, and recreational activities. Mountain goats are generally known to be more alert and less readily approached than even mountain sheep (Geist 1978). It is unlikely that human visitation would cause permanent abandonment of a habitat, but temporary abandonment, including deterring visits to mineral licks, is likely. Results of remote camera work along trails to mineral licks in the lower Ospika valley in 2001 suggested that goats did not use trails within 24 hrs (**need to confirm this*) of a visit to the remote camera site by a researcher (Clare 2001). The mechanism for this result is unknown, but lingering human scent may possibly play a role. The proximity and frequency of human disturbance are the factors we considered to be most important to goats; the seasonal timing of disturbance is not factor but part of the model input data. Proximity is determined by GIS analysis or is used as a management lever, while frequency is considered as a management lever.

Rationale for States:

Proximity (HUM_*PROX)*:

- *Greater than 100m from goat habitat (trail, lick, or escape terrain)*
- *From 50 to 100m from goat habitat (trail, lick, or escape terrain)*
- *Less 50m from goat habitat (trail, lick, or escape terrain)*
    - Distances refer to the proximity of human presence to goat habitat
    - We presume that human presence within 50 m of goat habitat would be most disturbing to goats
    - Beyond 50m, the presence of trees around licks and trails would provide a visual buffer and would lessen the impact of human presence, however, humans would likely be heard up to 100m away
    - Although the forested visual buffer may be lacking around higher elevation escape terrain and goats could detect humans much further away than 100m, the perceived threat is reduced since goats are on their escape terrain rather than in forested areas and thus less vulnerable

- Human scent in the immediate habitat area may play a role in deterring use of that habitat by goats for a short period
- Although goats may be able to habituate to human presence (Singer 1975), it is unlikely they would habituate to the sporadic, unpredictable types of human presence likely to be encountered in these more remote watersheds.

Frequency (HUM_FREQ):

- *Greater than 2 days between human visits*
- *Less than 2 days between human visits*
  - Frequency refers to the frequency of human visits to goat habitat
  - Frequency is included in the model as a management lever
  - If goats avoid visiting an area for ~24 hrs after a human visit (as suggested by Clare 2001), then goats may potentially abandon that habitat if humans visit that area every day

3.1.1.4 CPT Logic for Ground Disturbance Sub-Model

The ground disturbance sub-model was structured such that Industrial, Road/Traffic, and Human Presence disturbance types could be additive. The conditional probability table that was used to configure how the 3 disturbance types contribute to Total Ground Disturbance (GRD_DIST) was based on the following:

- Disturbance impact (GRD_DIST) increases with increased proximity and frequency of each activity.
- Road/Traffic disturbance has a slightly more negative impact than Industrial disturbance, and a much greater negative impact than Human Presence disturbance. Although likely infrequent, the possibility of being killed in a collision with a vehicle slightly increases the negative impact of Road/Traffic disturbance over Industrial disturbance. The impact of Human Presence disturbance is much lower than both the other disturbance types due to the reduced duration and intensity of this type of impact
- If Road/Traffic disturbance is determined to be HIGH due to the proximity and frequency of the activity, and Industrial and Human Presence disturbances are LOW, the resultant disturbance impact is 100% HIGH.
- If Industrial disturbance is determined to be HIGH due to the proximity of the activity, and Road/Traffic and Human Presence disturbances are LOW, the resultant disturbance impact is 90% HIGH and 10% MODERATE.
- If Human Presence disturbance is determined to be HIGH due to the proximity and frequency of the activity, and Road/Traffic and Industrial disturbances are LOW, the resultant disturbance impact is only 100% MODERATE.

3.1.2 Aerial Disturbance Sub-Model

The Aerial Disturbance sub-model considers impacts of both rotary and fixed-wing flights over mountain goat habitat. These aerial activities are primarily associated with forest harvesting, mining, oil and gas exploration, heli-hiking, heli-skiing, and wildlife research. Mountain goats and mountain sheep (high elevation cliff-dwelling ungulates) are highly susceptible to aerial disturbance particularly by helicopters which have been demonstrated to elicit very strong stress responses (Horejsi 1976, Foster and Rahs 1981,,Penner 1988, Bleich et al 1994, Cote 1996, Frid 1999). Over-flights by fixed-wing aircraft also cause disturbance to goats and sheep though to a lesser degree (Bleich et al 1994, Poole 1998, Frid XXXX). Although our Aerial Disturbance sub-model includes both helicopter and fixed-wing disturbance types, over-flights by fixed-wing aircraft will rarely if ever rate as High Disturbance by default since:

a) They rarely fly within 500 m of the ground or cliff habitat
b) They rarely remain in an area for >1 minute since they can not hover
c) They rarely have reason to visit the same area on a repetitive daily basis

The only exception to the rule may be fixed-wing radio-telemetry flights which require multiple passes at close range to obtain a positional fix on the radio-tagged goat, however, these flights are still likely to be relatively infrequent (1 flight weekly or biweekly on average). In contrast, helicopters (particularly those involved in heli-hiking or heli-skiing operations) may use the same flight paths on a regular and frequent basis, and have the ability to hover for long periods at close range to goat habitat. A number of negative consequences of helicopter disturbance have been reported for wild goats and sheep, many of which can affect reproduction and survival (Foster and Rahs 1983, Joslin 1986, Cote 1996, Frid 1998, 1999) including:

- Direct mortality (jumping off or falling off cliffs)
- Separation of females from young
- Increased energy expenditures due to fleeing
- Reduced energy intake (less time spent foraging, and/or more time spent close to escape terrain where less forage is available)
- Range abandonment (temporary or permanent)
- Increased susceptibility to disease resulting from chronic stress

Aerial disturbance was considered only in the Summer Escape Terrain (heli-hiking, research activities, industrial activities) and Winter Escape Terrain (heli-skiing, research activities, industrial activities) models. It is first combined with Ground Disturbance (see section 3.1.1) into a Total Disturbance sub-model. Aerial Disturbance is considered to have a significantly greater negative impact on goats than Ground Disturbance. HIGH Ground Disturbance in the absence of Aerial Disturbance results in a 100% Moderate impact to goats, however, HIGH Aerial Disturbance in the absence of Ground Disturbance results in a 100% High impact.

Aerial disturbance in the immediate vicinity of mineral licks and forested access trails was considered negligible. Heli-logging is unlikely to be used in harvesting low elevation forests on gentle terrain. Direct mortality is also unlikely since the response by goats would be to simply flee into the forest. Although Aerial Disturbance is included in the Escape Terrain models, there are no input data and it is not a dynamic factor (thus it is essentially trivial in a spatial-dynamic model). However, it is retained in the models to identify over-flights as an issue of concern. It is best considered as a “rule” (i.e., don’t fly within 500 m of goat escape habitat) rather than a management lever.

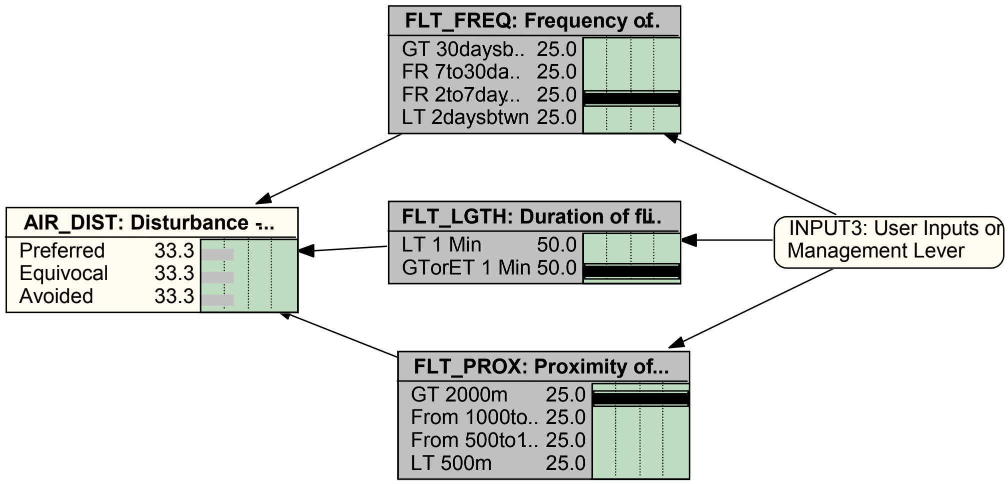

Figure 4. Factors and relationships contributing to total aerial disturbance that may influence habitat use by mountain goats.

Rationale for States:

The impact of aerial disturbance on mountain goats on escape habitats is a function of the proximity, frequency, and duration of flights. The risk to goat populations caused by helicopters is reported to increase with increased frequency and duration of flights, and decreased proximity (Wilson and Shackleton 2001). We considered proximity to be of greater significance to goats based on studies that concluded that the most important factor affecting goat (or sheep) responses was the distance between the helicopter and the animals (Cote 1996, Foster and Rahs 1983, Frid 1998, 1999). The proximity, frequency, and duration of flights are used as management levers, or as user inputs.

Flight Proximity (FLT_PROX)

- *Greater than 2000m from escape terrain*
- *From 1000 – 2000m from escape terrain*
- *From 500 – 1000m from escape terrain*
- *Less than 500m from escape terrain*
  - Goats exhibited movements or vigilant behaviours 85% of the time when helicopter approached within 500m (Cote 1996)
  - Goats are rarely >500m from escape terrain thus any flight approaching within 500m laterally will likely have an impact (CITE)
  - Goats will be more aware but will likely stay in same place during aerial approaches between 500 to 1,000m, whereas goats approached within 500m will likely walk or run along their escape terrain in an attempt to escape (greater chance of falling, greater stress)
  - Rocky Mtn sheep often fled from a helicopter 1.6 km away (Horejsi 1976)
  - 2 km is max. distance at which heli's begin to affect goat behaviour
  - intensity of response by Dall's sheep was negatively correlated with distance <3km (Frid 1998, 1999)
  - studies have recommended a 2 km buffer around goat range to avoid aerial disturbance to goats (Foster and Rahs 1983, Cote 1996)

- Wilson and Shackleton's Interim Recommendations for Heli Operation Near Mountain Goats (Appendix 3 in Wilson & Shackleton 2001) recommended a 2 km buffer for helicopter activities near goat range
- IWMS recommends 2 km limit for proximity of heli-logging to WHA's
- Current provincial guidelines stipulate a minimum separation distance of 500m for existing heli-ski and heli-hiking tenures, and 2km for new tenures
- We concluded that 2 km is the maximum distance at which aerial activity will affect goat behaviour, but that aerial activity within 500 m of goat habitat will cause significant disturbance to goats.

Flight Frequency (FLT_FREQ)

- *Greater than 30 days between flights*
- *From 7 to 30 days between flights*
- *From 2 to 7 days between flights*
- *Less than 2 days between flights*
    - Days between flights rather than number of flights per week was considered to best represent flight frequency (E.G. 7 flights/week could mean once/day for 7 days, or 7 flights in one day, the latter having significantly more impact
    - Other studies have found that goats and sheep do not habituate to helicopter activity (Bleich et al 1994, Cote 1996, Frid 1999)
    - Goats didn't habituate to sudden unpredictable noises (i.e. helicopters), only to consistent, predictable noise that was introduced gradually (Penner 1988)
    - Foster and Rahs (1983) concluded that disturbance effects were additive – not only did they not habituate to disturbances but they became sensitized reacting even more strongly
    - We concluded that the more frequent the exposure to aerial disturbance, the more negative the effect on the goat population. We concluded that less than one flight per month would have a negligible effect on goats.
    - Negative effects could be even more significant on goats on natal areas and winter ranges

Flight Duration (FLT_LGTH)

- *Less than 1 minute in duration*
- *Greater than or equal to 1 minute in duration*
    - Duration refers to the amount of time spent over the escape terrain (intended to distinguish between an "overhead hover" and a "fly-by")
    - No literature was found that addresses duration of flight presence
    - We included 2 levels of duration: <1 minute (i.e. a passing of a helicopter or fixed-wing) vs. ≥1 minute duration (i.e. hovering or tight circling by helicopter) based on our assumption that aerial disturbance for greater than 1 minute has a prolonged and thus more negative effect on the goat population.

3.1.2.1 CPT Logic for Aerial Disturbance Sub-Model

The conditional probability table that was used to configure how flight *Frequency*, *Duration*, and *Proximity* interact to calculate the impact of Aerial Disturbance (AIR_DIST) was based on the following:

- Disturbance impact (AIR_DIST) increases primarily with increased proximity of aerial activity which is the factor of greatest significance to goats (Cote 1996).

- If Proximity is HIGH (<500m from escape terrain) but Frequency and Duration are both LOW impacts, the resultant impact is 50% HIGH and 50% MODERATE.
- Even the most intense Frequency (<2 days between flights) or Duration (>1 minute long) of flights has no impact if the Proximity of such flights is >2 km away. If either Frequency or Duration are determined to be HIGH, and all others factors are LOW, there is no impact (100% LOW impact).

3.1.3 Hunting Sub-Model

Hunting affects mountain goat populations both directly through the removal of goats, and indirectly through reducing the population's productivity (Smith 1988). Several factors render goat populations particularly sensitive to over-hunting (Eastman 1977, Hebert & Turnbull 1977, Adams & Bailey 1982, Swenson 1985, Smith 1988, Festa-Bianchet et al 1994):

- Late sexual maturity of adults
- Low kid production and survival
- High female harvest since difficult for inexperienced hunters to differentiate between the sexes
- Importance of social structure – survival of yearlings and kids may be reduced if dominant nanny in family group killed; also, breeding success of dominant nannies is often higher

Hunting mortality is considered additive to other types of mortality, and is blamed for goat population declines in many areas (Hebert and Turnbull 1977, Kuck 1977, Pendergast and Bindernagel 1977, Chadwick 1983, Phelps et al 1983, Smith 1988). When human access to goat populations is provided, populations previously in balance with other mortality factors can be rapidly depleted (Foster 1977, Kuck 1977, MacGregor 1977, Hoefs et al 1977, Pendergast and Bindernagel 1977, Adams and Bailey 1982, Chadwick 1983, Child and King 1988).

The 1988 Regional Wildlife Plan for the Omineca sub-region (Child and King 1988) acknowledged that hunter access in the Williston watershed in the late 80's was generally poor, and that most goat populations were still healthy and largely an "untapped resource". A potentially large degree of change was anticipated as logging roads extended northwards and into side drainages, particularly an increase in resident harvest of goats. The management objective for goats was to sustain a conservative level of annual harvest of 4 - 6% (Child and King 1988).

The Hunting sub-model includes guided, resident, and unregulated (subsistence and poaching) hunting, and pertains only to the Mineral Lick and Summer Escape Terrain habitat models. Although mineral licks are not typically targeted by hunters due to the sporadic nature of goat visits, goats can be concentrated at licks thus the potential for significant over-harvest of a local population is high. Access (primarily road proximity rather than road density) to low elevation mineral licks greatly increases the chance of this impact. A greater degree of hunting occurs in alpine goat summer range, with almost all guided hunts occurring in these areas. However, guided hunting is not typically related to road proximity thus it is not expected to increase with increased road proximity. In addition, goats are more accurately sexed during guided hunts resulting in fewer female goats harvested, thus guided hunting is considered to have a less significant impact on the goat population than resident and unregulated hunting. Proximity of roads to alpine goat range would however increase resident and unregulated hunting with the potential for significant local impacts. In addition, basic road deactivation will not prevent hunter access; only complete reclamation would be effective. HIGH Hunting impact in the absence of other factors (e.g.

predation, ground disturbance) automatically reduces the value of the habitat in question to 100% Low Value habitat for goats.

The Hunting sub-model was not included in the Trails or Winter Escape Terrain habitat models. Since mineral licks are the endpoints of the access trails, and goats are more concentrated (spatially and temporally) at the licks than on the access trails, the impacts of increased goat harvest along trails is considered negligible. In addition, mineral lick trail locations would likely be largely unknown to hunters and would provide a much lower success rate than the licks themselves. An insignificant amount of poaching and subsistence hunting is thought to occur in winter, and on steep escape terrain.

Rationale for States:

Based on the existing literature, we considered that proximity of roads to goat habitat (mineral licks or escape terrain) was the single most important factor affecting the degree of hunting (primarily resident and unregulated hunting), and that the degree of that hunting would have local population effects. We expect no increase in the level of hunting activity if roads are >2 km from goat habitat. The average resident hunter is thought to be deterred by distances >2 km; IWMS also recommends a 2 km management buffer around mineral licks. An increase of 0–3% hunting is expected when roads approach within 500 - 2,000 m of goat habitat (the area is more easily accessed by the average hunter), while an increase in local goat harvest of >3% is expected when roads or cutblocks are <500m from mineral licks or escape terrain. Access to within 500m of escape terrain actually places hunters right at the edge of goat summer range since goats are seldom found more than 500m from escape terrain. Providing a visual screen or buffer around goat habitat is not thought to be effective – the site will become known in time as local knowledge is shared, and the existing access will make the population vulnerable. Proximity of roads will be determined by GIS analysis.

Local Goat Harvest (HUNT)

- *No increase in local goat harvest*
- *Local goat harvest increased by 0-3%*
- *Local goat harvest increased by >3%*
    - The proximity of roads to goat habitat (as determined by GIS analysis) will determine the degree of increase in local goat harvest
    - This represents harvest over and above the current harvest level in absence of road access
    - The 1988 goat management objective for the Omineca Region was to sustain an annual goat harvest of 4-6% (Child and King 1988)
    - Hebert and Turnbull (1977) recommended harvest levels of no more than 4% of a total goat population, or <5% of the adult goat population
    - Youds et al (1980) recommended goat harvest levels of 5% of the minimum population estimate for a given area
    - Conservative ungulate harvest levels are considered to be <10% (Child and King 1988)
    - Assuming the local goat harvest is between 4–6%, an increase of 0-3% will still maintain the harvest within somewhat “conservative” levels, while an increase >3% is assumed to be detrimental

3.1.4 Predation Risk Sub-Model

Goats typically exist at low densities, which combined with their effective anti-predator strategy of remaining within or near escape terrain, reduces their importance to predators as a major prey source (Geist 1971, Fox and Streveler 1986). However, changes in abundance of alternate prey species and consequently predators, can significantly affect goat populations. Primary mountain goat predators in our study area include wolves, grizzly bears, wolverines, eagles, and to a lesser degree, black bears. Although wolves are generally thought to prey on goats opportunistically (Smith 1986, Festa-Bianchet et al 1994), they can be a significant predator in areas of higher goat densities and/or few alternate large ungulates (Fox and Streveler 1986), and individual packs may even specialize on specific goat populations (Cote et al, XXXX).

The presence of roads and cutblocks greatly influences the numbers and distribution of predators in an area. Bears use roads for travel and roadside feeding, and early seral cutblocks for summer foraging. Wolves use roads as year-round travel corridors, and they are attracted to the higher densities of ungulates (primarily moose) using early seral cutblocks for year-round forage. Bears may pose a higher risk to goats due to a greater chance of a random encounter at licks and along trails. Mineral lick access trails themselves might be more attractive to predators as travel corridors. Early seral habitats also favour a variety of prey species that support other potential goat predators, e.g., rabbits (lynx) and deer (cougars).

The Predation sub-model was considered in the Mineral Lick, Trails, and Summer Escape Terrain habitat models. In the Mineral Lick and Trails models, a HIGH Predation risk in the absence of other factors (e.g. ground disturbance, hunting) reduces the value of the habitat in question to 100% Low Value habitat for goats. Goats are more susceptible to predation when they are far from escape terrain, and in treed areas (Geist 1971, Rideout 1978, Festa-Bianchet et al 1994, Smith et al 1992, Cote and Beaudoin 1997). The ability of goats to detect predators in forested habitats is reduced, likely due to decreased visibility. Goats use treed areas for obtaining forage, to access low elevation mineral licks, and for snow interception in winter. In the Summer Escape Terrain model however, HIGH Predation risk only reduces the habitat value to 100% Moderate Value habitat since predation poses a less significant risk to goats on escape terrain than to goats in forests. Predation was not considered to be a significant risk to goats on winter escape terrain since deep snows often preclude goats from venturing far from escape terrain.

Rationale for States:

For our modeling purposes, we hypothesized that predation risk is correlated to the proportion of high value predator habitat present within a specified radial buffer around goat habitat. “High value predator habitat” is defined as habitat that provides year-round forage for alternate prey species, (primarily large ungulates) which in turn benefits predators, and for summer foraging by bears. This includes clearcuts and other early seral habitats on mesic or hygric sites with forest cover <40 years old. The presence of these moist, early seral habitats in close proximity to goat habitat can be is detrimental for goats.

Predation Risk (PRED)

- *Less than 10% of area within 2 km buffer is high predator habitat*
- *From 10-30% of area within 2 km buffer is high predator habitat*
- *Greater than 30% of area within 2 km buffer is high predator habitat*
    - The proportion of high value predator habitat within 2 km of goat habitat (as determined by GIS analysis) will determine the degree of increase in predation

- We selected a 2 km radial buffer (roughly 1200 ha area) around each grid cell: this distance was considered reasonable in terms of a predators' ability to travel between high value predator habitat and mountain goat habitat
- We identified 30% as the upper limit because if timber harvest is completed using a 3 pass rotation system then a maximum of 1/3 of an area could be harvested at a time. This amount of harvest would have a big impact with respect to early seral habitats, edge effects, etc.

3.2 Habitat Models

3.2.1 Low Elevation Mineral Lick Habitat Model (LICK)

Low elevation mineral licks are typically used by mountain goats between April and November (Cite). Goats rely heavily on mineral licks presumably to replenish sodium reserves that are flushed from the body due to the intake of potassium-rich green spring forage. Mountain goats show strong fidelity to specific mineral licks, and demonstrate traditional use over successive generations (Fox and Smith 1988). Valley bottom mineral licks can be up to 10 km from typical alpine summer escape terrain. This fidelity to mineral licks can render goats sensitive to disturbance from and displacement by various industrial activities (Hebert and Cowan 1971, Chadwick 1973, Pendergast and Bindernagel 1977, Foster and Rahs 1983, Singer and Doherty 1985, Cote 1996, Shackleton 1999). Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to reduce or eliminate goat access to mineral licks, cause avoidance of licks by goats due to noise or traffic disturbance, create habitat conditions favourable for other prey species and consequently predators, and create access to licks for hunters. Removal of forested cover immediately adjacent to mineral licks is not thought to be of significant concern compared to the previously listed factors. PWFWCP's Adaptive Management Trial in the lower Ospika River drainage (part of the larger Ospika Goat Project) is focusing on the impacts of forest harvesting on the use of mineral licks and their associated forest access trails by mountain goats (Wood et al, in prep). The project aims to determine differences, if any, in the timing, duration, and frequency of visits to low elevation mineral licks by radio-collared goats before and after forest harvesting. Data from the Adaptive Management Trial will be used to test the Low Elevation Mineral Lick model.

3.2.1.1 Description of Model Components

The Low Elevation Mineral Lick (LICK) habitat model characterizes the factors that define low elevation mineral licks and that influence their use by mountain goats. Four primary factors are considered in this model: Lick Habitat Preference, Predation, Hunting, and Ground Disturbance, which feed into a final Lick Habitat Value node. Aerial disturbance was not considered in this model since aerial activity in the immediate vicinity of mineral licks was considered negligible. Heli-logging is unlikely to be employed in harvesting low elevation forests on gentle terrain. Direct goat mortality is also unlikely since goat response to aerial activity would be to simply flee into the forest.

The preference that mountain goats are expected to show for low elevation mineral lick habitats was based on access to appropriate mineral sources. The value of these low elevation mineral lick habitats is reduced by:

- Increased predation risk (a function of the amount of high value predator habitat within a 2km radius of the lick)

- Increased local goat harvest (due to the proximity of roads and cutblocks providing access to the lick)
- Increased ground-based disturbance (caused by industrial and human activity in proximity to the lick).

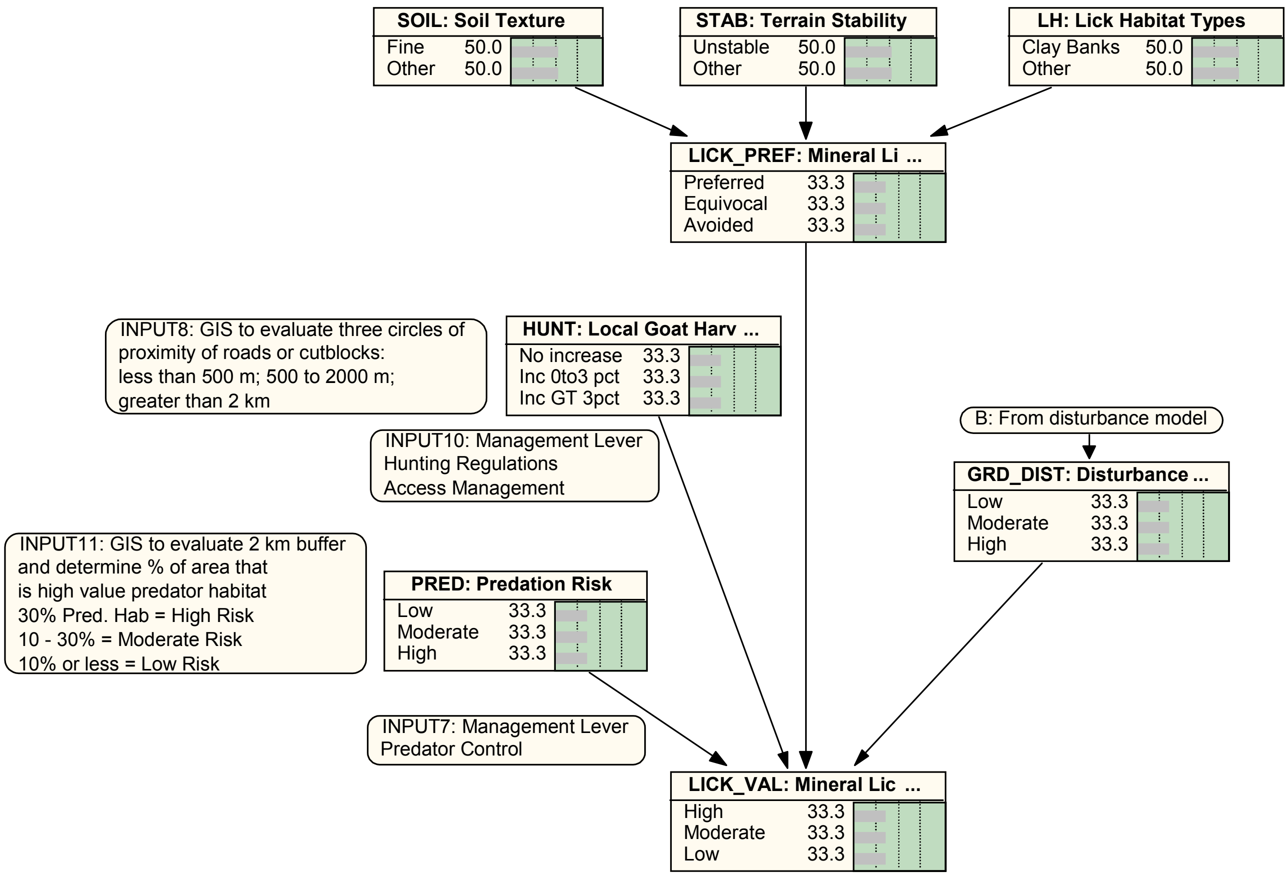

Figure 5. Ecological factors and relationships characterizing habitat value for low elevation mineral licks used by mountain goats.

a. Habitat Preference (LICK_PREF)

The potential for an area to provide suitable mineral lick habitat for mountain goats is dependent on the presence of unstable (failed) slopes that are clay banks and/or have fine/lacustrine soils. These sites are defined by the physical attributes *Terrain Stability* (STAB), *Clay Banks* (LH), and *Soils* (SOIL). Identifying both clay banks and fine, lacustrine soils as important attributes appears to be a duplication, but both are considered because they are specified by separate data sources (forest inventory mapping and terrain stability mapping, respectively). Since the physiological importance of mineral licks to mountain goats is unclear according to the literature, mineral composition was not considered to be a useful criteria in defining mineral licks.

Terrain Stability (STAB)
Unstable; Other

Slope failures expose mineral soils, providing wildlife with access to minerals. Terrain stability mapping identifies failed slopes as 'unstable' habitat polygons.

Clay Banks (LH)
Clay bank; Other
Clay banks are failed slopes that expose a clay mineral substrate. Clays contain fine-textured hydrous silicates of iron, manganese, magnesium, and other metals that may be of importance to mountain goats. Forest inventory (forest cover) mapping identifies 'clay banks' as unique habitat polygons. Mineral licks in the lower Ospika drainage were originally identified based on their designation as clay banks on forest cover maps. Subsequent field investigations found evidence of significant use by mountain goats of some but not all clay bank sites (M. Wood, pers. comm.).

Soils (SOIL)
Fine; Other
Presumably fine soils provide an accessible source of minerals desired by mountain goats. Fine-textured soils may include lacustrine sediments, clays, mud, and silt; these are identified on terrain stability maps.

CPT Logic for Low Elevation Mineral Lick Habitat Preference (LICK_PREF):
The conditional probability table that was used to configure how the ecological factors of Terrain Stability, Clay Banks, and Soils interact to determine Low Elevation Mineral Lick Preference was based on the following:

- Unstable terrain was considered to be more important than either clay banks or fine soils; if terrain stability is determined to be "Other", the habitat preference is considered 100% Avoided
- Unstable terrain combined with EITHER clay banks OR fine soils results in a Habitat Preference of 100% Equivocal
- Unstable terrain combined with BOTH clay banks and fine soils results in 100% Preferred habitat.

b. Ground Disturbance (GRD_DIST)

See section 3.1.1 Ground Disturbance Sub-Model under Management Factors.

c. Hunting (HUNT)

See section 3.1.3 Hunting Disturbance Sub-Model under Management Factors.

d. Predation Risk (PRED)

See section 3.1.4 Predation Risk Sub-Model under Management Factors.

e. Habitat Value (LICK_VAL)

CPT Logic for Low Elevation Mineral Lick Habitat Value (LICK_VAL):

The conditional probability table that was used to configure how Low Elevation Mineral Lick Habitat Preference, Ground Disturbance, Hunting, and Predation influence Low Elevation Mineral Lick Habitat Value (LICK_VAL) was based on the following:

- Predation Risk and Hunting are considered more significant than Ground Disturbance since they both have the ability to reduce actual populations through the direct removal of animals (not just through displacement)
- For Preferred Habitats, if Predation Risk OR Hunting is HIGH regardless of the influence of the other factors, the habitat value is automatically reduced to 100% Low value habitat.
- For Preferred Habitats, if Ground Disturbance is HIGH and other factors are low, the habitat value is only reduced to 100% Moderate value habitat.
- The maximum habitat value of any Equivocal habitat is 100% Moderate value.

3.2.1.2 Management Factors and Options

- Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, and human presence to reduce impact of ground-based disturbance, predation, and hunting on mountain goats using low elevation mineral licks.

3.2.2 Trails to Low Elevation Mineral Licks Habitat Model (TRL)

Low elevation mineral licks are typically used by mountain goats between April and November, and are accessed using trails through forested habitats. Goats rely heavily on mineral licks presumably to replenish sodium reserves that are flushed from the body due to the intake of potassium-rich green spring forage. Low elevation mineral licks can be up to 10 km away from alpine summer habitat (though most are probably within 5 km), and well-used trails worn down to mineral soil have resulted from traditional use of the same routes by successive generations of goats (Fox and Smith 1988). Trails seldom lead directly from summer habitat to low elevation licks but appear to be influenced by topography (following creek draws and ridges) and the presence of small areas of escape terrain referred to as “staging areas” (small rock outcrops, bluffs, cliffs). Goats are known to show strong fidelity to specific forested access trails. This fidelity to forested access trails leading to mineral licks can render goats sensitive to disturbance from and displacement by various industrial activities (Hebert and Cowan 1971, Chadwick 1973, Pendergast and Bindernagel 1977, Foster and Rahs 1983, Singer and Doherty 1985, Cote 1996, Shackleton 1999). Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to reduce or eliminate goat access to mineral licks, cause avoidance of trails due to noise or traffic disturbance, and create habitat conditions favourable for other prey species and consequently predators. Removal of forest cover immediately adjacent to trails is also of significant concern. PWFWCP’s Adaptive Management Trial in the lower Ospika River drainage (part of the larger Ospika Goat Project) is focusing on the impacts of forest harvesting on the use of mineral licks and their associated forest access trails by mountain goats (Wood et al, in prep). The project aims to determine differences, if any, in the timing, duration, and frequency of visits to low elevation mineral licks by radio-collared goats before and after forest harvesting. The effectiveness of a 100m forested buffer on either side of a mineral lick access trail versus no buffer is being evaluated in this trial. Data from the Adaptive Management Trial will be used to test the Trails to Low Elevation Mineral Lick habitat model.

3.2.2.1 Description of Model Components

The Trails (to low elevation mineral licks) (TRL) habitat model characterizes the factors that define mineral lick forested access trails and that influence their use by mountain goats. Three primary factors are considered in this model: Trail Habitat Preference, Ground Disturbance and Predation Risk, which feed into a final Trail Habitat Value node. Aerial disturbance was not considered in this model since aerial activity in the immediate vicinity of lick access trails was considered negligible. Heli-logging is unlikely to be employed in harvesting low elevation forests on gentle terrain. Direct goat mortality is also unlikely since goat response to aerial activity would be to simply flee into the forest. Hunting was also not considered to be a significant influence in this model. Since mineral licks are the endpoints of the access trails, and goats are more concentrated (spatially and temporally) at the licks than on the access trails, the impacts of increased goat harvest along trails is considered negligible.

The preference that mountain goats are expected to show for trails to low elevation mineral licks is based on access to appropriate mineral sources and stand age. The value of trails used to access low elevation mineral licks is reduced by:

- Increased predation risk (a function of the amount of high value predator habitat within a 2km radius of the trail)
- Increased ground-based disturbance (caused by industrial and human activity in proximity to the trail)

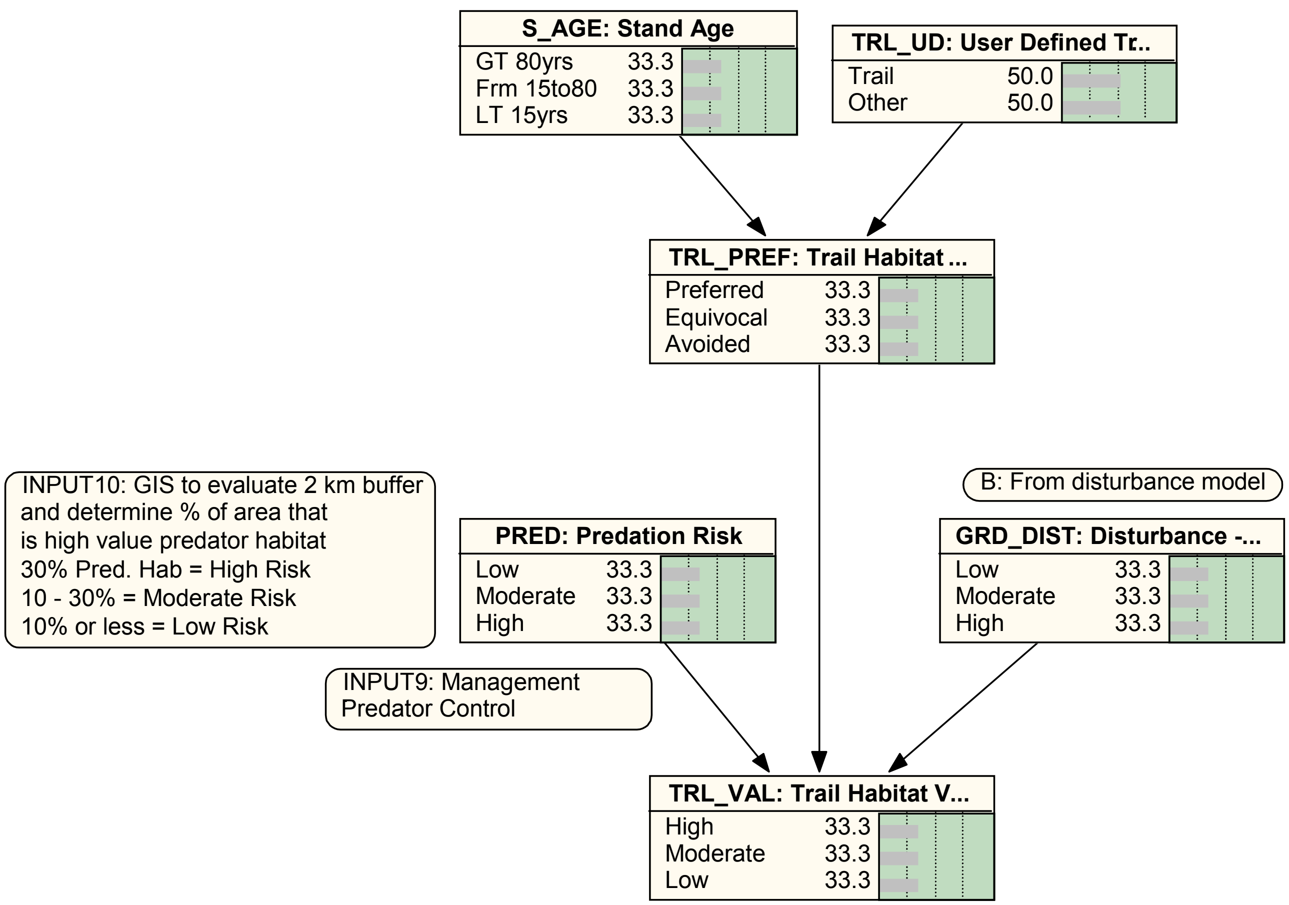

Figure 6. Ecological factors and relationships characterizing habitat value for trails to low-elevation mineral licks used by mountain goats.

a. Trail Habitat Preference (TRL_PREF)

Mineral lick access trail habitat preference is primarily a user-defined input to this model based on known trail locations to known goat mineral licks *(User Defined Trails,* TRL_UD). Trail preference is also influenced by *Stand Age* (S_AGE). Attempting to predict preferred trail locations using GIS has not been considered at this point. An attempt may be made to define trails in the future by using GIS to link known mineral licks through “staging areas” (though many of these are likely too small to identify on maps) to the nearest high elevation escape terrain. Input nodes will then feed the preference node rather than having just a single user-defined input. In terms of trail use, a goat might preferentially use one trail over another, and use a third trail equivocally, thus three states are identified (preferred, equivocal, avoided) for trail habitat preference. Trail preference may be identified / monitored by whether or not radio-collared goats are using the trail(s).

User Defined Trails (TRL_UD))
Trail; Other
Locations of access trails to known goat mineral licks in the lower Ospika drainage were originally identified by the PWFWCP in 1999 and mapped in 2000. Field investigations found evidence of significant use of the trails by mountain goats (M. Wood, pers. comm.). Typically only one primary access trail from alpine summer habitat to the mineral lick was located.

Stand Age (S_AGE)
LT 15 years; From 15 – 80 years; GT 80 years
Stand age of greater than 80 years (mature forest) adjacent to access trails is considered preferential for goats. Young forests less than 15 years old would also provide some visibility, however stands between 15 – 80 years will result in poor visibility due to forest regeneration. Poor visibility may make goats more susceptible to predation. Stand age will be identified through Forest inventory (forest cover) mapping.

CPT Logic for Trails (to Low Elevation Mineral Licks) Habitat Preference (TRL_PREF):
The conditional probability table that was used to configure how the factors of User Defined Trails and Stand Age interact to determine Trail Habitat Preference was based on the following:

- If User Defined Trail is determined as “Other”, habitat preference is 100% Avoided
- If Stand Age along a User Defined Trail is GT 80 years, the habitat is 100% Preferred
- If Stand Age is LT 15 years, the habitat is considered 50% Preferred and 50% Equivocal, and if Stand Age if between 15 – 80 years old the habitat preference is reduced to 50% Equivocal and 50% Avoided

b. Ground Disturbance (GRD_DIST)

See section 3.1.1 Ground Disturbance Sub-Model under Management Factors.

c. Predation Risk (PRED)

See section 3.1.4 Predation Risk Sub-Model under Management Factors.

d. Trail Habitat Value (TRL_VAL)

CPT Logic for Trails (to Low Elevation Mineral Licks) Habitat Value (TRL_VAL):
The conditional probability table that was used to configure how Trails Habitat Preference, Ground Disturbance and Predation Risk influence Trail Habitat Value (TRL_VAL) was based on the following:

- Predation Risk has a higher impact on Trail Habitat Value than Ground Disturbance does due to the more direct impact in terms of potential goat mortality
- HIGH Predation Risk in Preferred Habitats automatically reduces the Trail Habitat Value to 100% Low value habitat.
- HIGH Ground Disturbance in Preferred Habitats (with LOW Predation Risk) only reduces the habitat value to 100% Moderate value habitat.
  - All Equivocal and Avoided Habitats are reduced to 100% Low Value Trail Habitat except Equivocal Habitats with LOW Predation and LOW Ground Disturbance (100% Moderate Value), and Equivocal Habitats with LOW Predation and MODERATE Ground Disturbance (50% Moderate, 50 % Low).

3.2.2.2 Management Factors and Options

- Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, and human presence to reduce impact of ground-based disturbance and predation on mountain goats using trails to access low elevation mineral licks.

3.2.3 Summer Escape Terrain Habitat Model (SE)

The primary predator avoidance strategy of mountain goats is to use high elevation steep escape terrain. Predator avoidance exerts a significant influence on goat behaviour, and they seldom venture more than 500m from escape terrain to obtain forage. Steep escape terrain is used during the natal period for kidding, and throughout the summer. Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to significantly disturb goats on summer escape terrain, cause avoidance of preferred escape terrain due to noise or traffic disturbance, create habitat conditions favourable for other prey species and consequently predators nearby, and create access to summer goat habitat for hunters.

3.2.3.1 Description of Model Components

The Summer Escape Terrain habitat model characterizes the factors that define summer escape terrain habitats and that influence their use by mountain goats. Four factors are considered in this model: Summer Escape Terrain Habitat Preference, Total Disturbance (a combination of Ground and Aerial Disturbance), Hunting, and Predation Risk, which feed into a final Summer Escape Terrain Habitat Value node.

The preference that mountain goats are expected to show for summer escape terrain is based on the presence of steep, rough, non-forested habitats (exclusive of glaciers). The value of summer escape terrain is reduced by:

- Increased predation risk (a function of the amount of high value predator habitat within a 2km radius of the trail)

- Increased local goat harvest (due to the proximity of roads and cutblocks providing access to the escape habitat)
- Increased total disturbance (ground-based disturbance caused by human activity in proximity to the escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights)

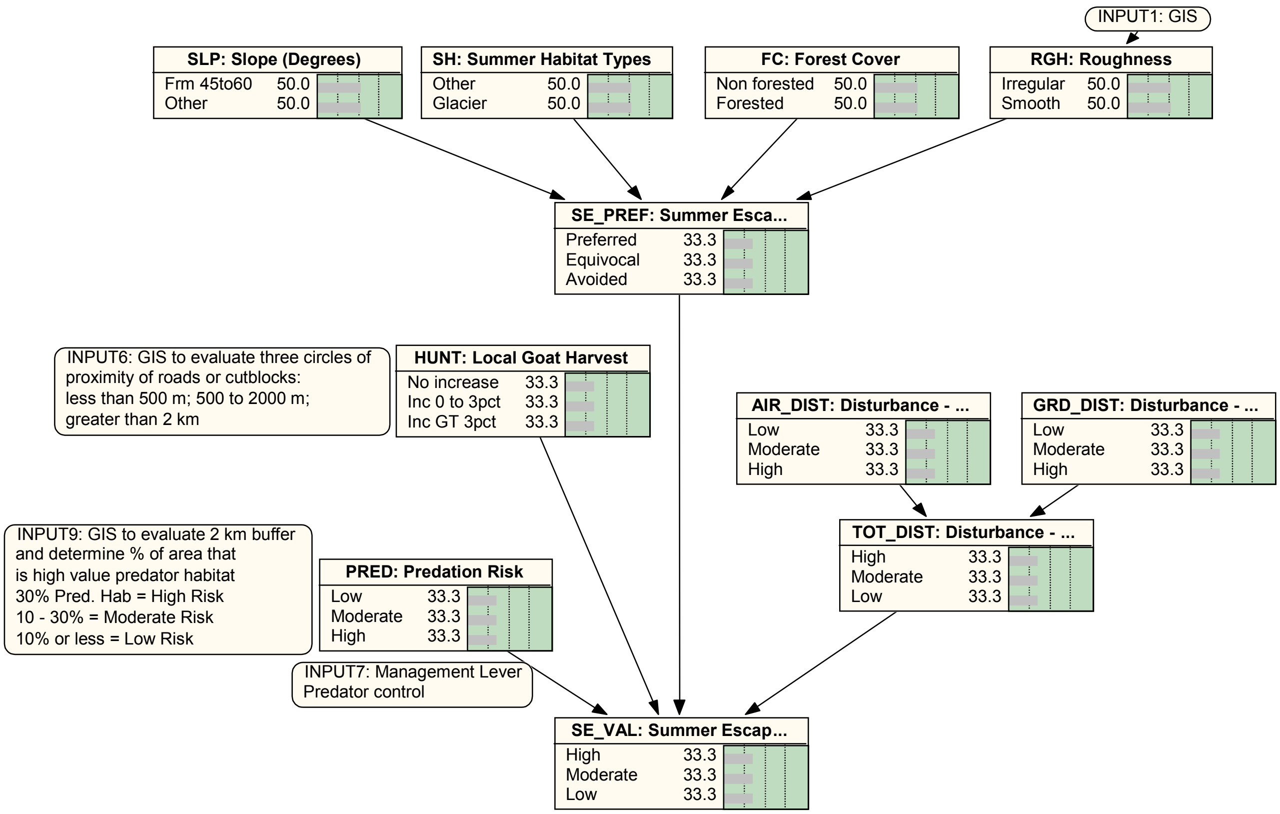

Figure 7. Ecological factors and relationships characterizing mountain goat summer escape habitat value.

a. Summer Escape Terrain Habitat Preference (SE_PREF)

The potential for an area to provide suitable summer escape terrain for mountain goats is dependent on the presence of appropriate conditions of *Slope* (SLP), *Forest Cover* (FC), and *Roughness* (RGH), and *Summer Habitat Type* (SH).

Slope (SLP)
From 45 – 60 degrees; Other
A fundamental characteristic of mountain goat escape terrain is moderate to steep slope.

Forest Cover (FC)
Non-forested; Forested
Typical escape terrain is primarily non-forested. This includes alpine, subalpine parkland, non-productive brush, etc.

Roughness (RGH)
Irregular; Smooth
Roughness is considered because slope alone isn't enough to gauge high value habitat. Roughness provides ledges for cover and travel, and also reduces the risk of avalanches (relative to smooth terrain). Roughness will be assessed using a GIS script with Arcview Spatial Analyst to assess variation in local topography. Using TRIM data, changes of 20-30 degrees within 100 m of a 25m grid cell will be assessed, and coupled with a steepness rating.

Summer Habitat Type (SH)
Other; Glacier
Any habitat type may be used, exclusive of glaciers.

CPT Logic for Summer Escape Terrain Habitat Preference (SE_PREF):
The conditional probability table that was used to configure how the Slope, Forest Cover, Roughness, and Summer Habitat Type interact to determine Summer Escape Terrain Habitat Preference was based on the following:

- Any habitat defined as Forested, Smooth, or as a Glacier, regardless of slope, automatically reduces the preference of that habitat to 100% Avoided
- Steep, Non-Forested, Irregular habitats exclusive of glaciers are 100% Preferred summer escape terrain habitats

b. Total Disturbance (TOT_DIST)

Total disturbance includes ground-based disturbance caused by human activity in proximity to summer escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights near summer escape habitat.

See sections 3.1.1 Ground Disturbance Sub-Model, and 3.1.2 Aerial Disturbance Sub-Model for details pertaining to each sub-model.

CPT Logic for Total Disturbance (TOT_DIST):
The conditional probability table that was used to configure how Aerial Disturbance (AIR_DIST) and Ground Disturbance (GRD_DIST) influence Total Disturbance was based on the following:

- The impact of Aerial Disturbance is considered to be greater than Ground Disturbance on summer escape terrain due to the potential of causing direct goat mortality, and the very strong stress responses of goats elicited by aircraft
- HIGH Aerial Disturbance in the absence of Ground Disturbance results in a 100% High impact on summer escape terrain
- HIGH Ground Disturbance in the absence of Aerial Disturbance results in only a 100% Moderate impact on summer escape terrain

c. Hunting (HUNT)

See section 3.1.3 Hunting Disturbance Sub-Model under Management Factors.

d. Predation Risk (PRED)

See section 3.1.4 Predation Risk Sub-Model under Management Factors.

e. Summer Escape Habitat Value (SE_VAL)

CPT Logic for Summer Escape Habitat Value (SE_VAL):
The conditional probability table that was used to configure how Summer Escape Habitat Preference, Total Disturbance, Hunting, and Predation Risk interact to determine Summer Escape Habitat Value to mountain goats was based on:

- Hunting and Total Disturbance have equal and greater impacts on Summer Escape Habitat Value than Predation
- Predation Risk is considered to be lower since goats on steep escape terrain are more difficult to capture (compared to when in forested habitats)
- HIGH Hunting OR HIGH Total Disturbance on Preferred Habitats regardless of other factors automatically reduces the Summer Escape Terrain Value to 100% Low value habitat.
- HIGH Predation, combined with LOW Hunting and LOW Total Disturbance on Preferred Habitats, only reduces the habitat value to 100% Moderate value habitat.

3.2.3.2 Management Factors and Options

- Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, human presence, and aerial traffic, to reduce impact of ground and aerial disturbance, hunting, and predation on mountain goats using summer escape terrain.

3.2.4 Winter Escape Terrain Habitat Model

The primary predator avoidance strategy of mountain goats is to use high elevation steep escape terrain. Predator avoidance exerts a significant influence on goat behaviour, and they seldom venture more than 500m from escape terrain to obtain forage. Although high elevation steep escape terrain near windswept slopes are commonly used by goats in winter, steep escape terrain surrounded by forested habitat at lower elevations are also preferred. Forested habitat in close proximity to steep, rough terrain, provides both snow interception and forage availability. Stands that support arboreal lichens and are tall enough for snow interception are favourable. Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to significantly disturb goats on winter escape terrain, particularly mid-elevation winter ranges, and cause avoidance of preferred escape terrain due to noise or traffic disturbance.

3.2.4.1 Description of Model Components

The Winter Escape Terrain habitat model characterizes the factors that define winter escape terrain habitats and that influence their use by mountain goats. Two factors are considered in this model: Winter Escape Terrain Habitat Preference, and Total Disturbance (a combination of Ground and Aerial Disturbance), which feed into a final Winter Escape Terrain Habitat Value node. Hunting was not considered to be a significant influence in this model since only unregulated (subsistence and poaching) hunting would occur in winter. Given the nature of the steep, rough terrain that goats typically use during winter, combined with the presence of snow, would likely preclude most unregulated hunting from occurring. Predation was also excluded from this model. Predation of goats residing on steep, snow-bound winter escape habitats by wolves is also likely to be relatively unsuccessful. Predation by wolverines may be somewhat more significant, however, the predation risk is assumed to be a constant and independent of human activity thus difficult to manage or monitor. Snowmobiling was also not considered an activity of significant impact to goats due to the steep nature of goat winter escape terrain.

The preference that mountain goats are expected to show for winter escape terrain is based on the presence of steep, south-facing, rough, non-forested habitats (exclusive of glaciers or avalanche chutes). The value of winter escape terrain is reduced by:

- Increased total disturbance (ground-based disturbance caused by human activity in proximity to the escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights)

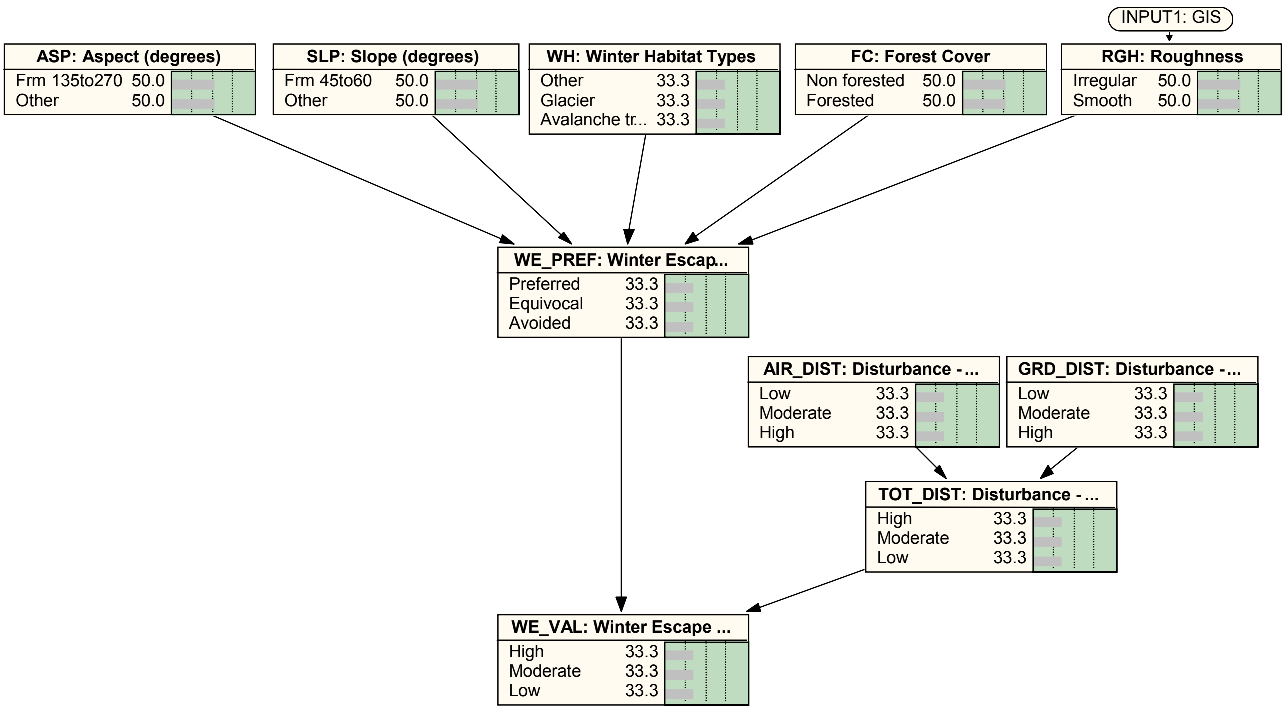

Figure 8. Ecological factors and relationships characterizing mountain goat winter escape habitat value.

a. Winter Escape Terrain Habitat Preference (WE_PREF)

The potential for an area to provide suitable winter escape terrain for mountain goats is dependent on the presence of appropriate conditions of *Slope* (SLP), *Aspect* (ASP), *Forest Cover* (FC), and *Roughness* (RGH), and Winter *Habitat Type* (WH).

<u>*Slope (SLP)*</u>
From 45 – 60 degrees; Other
A fundamental characteristic of mountain goat escape terrain is moderate to steep slope.

<u>*Aspect (ASP)*</u>
From 135 – 270 degrees; Other
Preferred aspects in winter offering increased solar radiation range from SE to W.

Forest Cover (FC)
Non-forested; Forested
Typical escape terrain is primarily non-forested. This includes alpine, subalpine parkland, non-productive brush, etc.

Roughness (RGH)
Irregular; Smooth
Roughness is considered because slope alone isn't enough to gauge high value habitat. Roughness provides ledges for cover and travel, and also reduces the risk of avalanches (relative to smooth terrain). Roughness will be assessed using a GIS script with Arcview Spatial Analyst to assess variation in local topography. Using TRIM data, changes of 20-30 degrees within 100 m of a 25m grid cell will be assessed, and coupled with a steepness rating.

Winter Habitat Type (WH)
Other; Glacier; Avalanche Track
Any habitat type may be used, exclusive of glaciers and avalanche tracks in winter.

CPT Logic for Winter Escape Terrain Habitat Preference (WE_PREF):
The conditional probability table that was used to configure how Slope, Aspect, Forest Cover, Roughness, and Winter Habitat Type interact to determine Winter Escape Terrain Habitat Preference was based on the following:

- Any habitat defined as Gentle Slope, Forested, Smooth, or as a Glacier or Avalanche, automatically reduces the preference of that habitat to 100% Avoided
- Steep, Non-Forested, Irregular habitats exclusive of glaciers and avalanches on SE to W facing aspects are 100% Preferred winter escape terrain habitats
- Steep, Non-Forested, Irregular habitats exclusive of glaciers and avalanches on Other aspects are reduced to 50% Preferred and 50% Equivocal winter escape terrain habitats

b. Total Disturbance (TOT_DIST)

Total disturbance includes ground-based disturbance caused by human activity in proximity to winter escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights near winter escape habitat.

See sections 3.1.1 Ground Disturbance Sub-Model, and 3.1.2 Aerial Disturbance Sub-Model for details pertaining to each sub-model.

CPT Logic for Total Disturbance (TOT_DIST):
The conditional probability table that was used to configure how Aerial Disturbance (AIR_DIST) and Ground Disturbance (GRD_DIST) influence Total Disturbance was based on the following:

- The impact of Aerial Disturbance is considered to be greater than Ground Disturbance on winter escape terrain due to the potential of causing direct goat mortality, and the very strong stress responses of goats elicited by aircraft
- HIGH Aerial Disturbance in the absence of Ground Disturbance results in a 100% High impact on winter escape terrain
- HIGH Ground Disturbance in the absence of Aerial Disturbance results in only a 100% Moderate impact on winter escape terrain

c. Winter Escape Habitat Value (WE_VAL)

CPT Logic for Winter Escape Habitat Value (SE_VAL):
The conditional probability table that was used to configure how Winter Escape Habitat Preference and Total Disturbance interact to determine Winter Escape Habitat Value to mountain goats was based on:

- HIGH Total Disturbance on Preferred Habitats automatically reduces the Winter Escape Terrain Value to 100% Low value habitat.

3.2.4.2 Management Factors and Options

- Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, human presence, and aerial traffic, to reduce impact of ground and aerial disturbance on mountain goats using winter escape terrain.

3.3 Literature Cited

Adams, L.G. and J.A. Bailey. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 46(4): 1003-1009.

Bleich, V.C., R.T. Bowyer, A.M. Pauli, M.C. Nicholson, and R.W. Anthes. 1994. Mountain sheep *Ovis canadensis* and helicopter surveys: ramifications for the conservation of large mammals. Biological Conservation 70:1-7.

Chadwick, D.H. 1983. A beast the color of winter

Child, K.N. and D. King. 1988. (1991??) Regional wildlife plan for the Omineca Sub-Region, Northern Region. Ministry of Environment, Wildlife Branch, Prince George, BC. 237 pp.

Clare, Shari. 2001

Cote, S.D. 1996. Mountain goat responses to helicopter disturbance. Wildl. Soc. Bull. 24(4): 681-685.

Cote, S.D., and C. Beaudoin. 1997. Grizzly bear (*Ursus arctos*) attacks and nanny-kid separation on mountain goats (*Oreamnos americanus*). Mammalia 61(4): 614-617.

Cote, S.D., A. Peracino, and G. Simard. XXXX. Wolf (*Canis lupus*) predation and maternal defensive behavior in mountain goats (*Oreamnos americanus*).

Eastman 1977

Festa-Bianchet, M., M. Urquhart, and K.G. Smith. 1994. Mountain goat recruitment: kid production and survival to breeding age. Can. J. Zool. 72: 22-27.

Foster 1977

Foster, B.R. and E.Y. Rahs. 1980.

Foster, B.R., and E.Y. Rahs. 1981. Relationships between mountain goat ecology and proposed hydroelectric development on the Stikine River, BC.

Foster, B.R., and E.Y. Rahs. 1983. Mountain goat response to hydroelectric exploration in northwestern British Columbia. Environ. Manage. 7(2): 189-197.

Fox, J.L. and G.P. Streveler. 1986. Wolf predation on mountain goats in southeastern Alaska. J. Mammal. 67(1): 192-195.

Frid, A. 1998. Responses to helicopter disturbance by Dall's sheep: determinants of escape decisions. Yukon Fish and Wildlife Branch, Whitehorse, YT.

Frid, A. 1999.

Geist, V. 1971. Mountain sheep, a study in behavior and evolution. Univ. Chicago Press, Chicago and London. 371 pp.

Geist, V. 1978.

Hebert, D.M. and Turnbull. 1977.

Hoefs et al 1977

Horejsi, B. 1976. Some thoughts on harassment and bighorn sheep. Biennial Symposium of the Northern Wild Sheep and Goat Council 1: 149-155.

Joslin, G. 1986. Mountain goat population changes in relation to energy exploration along Montana's Rocky Mountain Front. Fifth Bienn. Symp. North. Wild Sheep and Goat Counc. 5:253-268.

Kuck, 1977

McGregor 1977

Pendergast and Bindernagel 1977

Penner, D.F. 1988. Behavioural response and habituation of mountain goats in relation to petroleum exploration at Pinto Creek, Alberta. Bienn. Symp. of the North. Wild Sheep and Goat Counc. 6:141-158.

Phelps, D.E., R. Jamieson, and R.A. Demarchi. 1983. The history of mountain goat management in the Kootenay Region of British Columbia. Fish and Wildlife Bulletin No. B-20. Ministry of Environment, Cranbrook, BC. 29 pp plus appendices.

Poole, K.G. 1998. Low elevation forest use by mountain goats in the Robson Valley Forest District. Unpublished Report. Prepared for Ministry of Environment, Lands, and Parks, Prince George, BC. 19pp.

*Rideout 1978. big game of n.a.

Singer, F.J. 1978. Behaviour of mountain goats in relation to U.S. highway 2, Glacier National Park, Montana. Journal of Wildlife Management 42:591-597.

Smith, C.A. 1986. Rates and causes or mortality in mountain goats in southeast Alaska. J. Wildl. Manage. 50(4): 743-746.

Smith, K.G. 1988 Proceedings

Smith K.G. et al 1992.

Swenson, J.E. 1985. Compensatory reproduction in an introduced mountain goat population in the Absaroka Mountains, Montana. J. Wildl. Manage. 49(4): 837-843.

Wilson and Shackleton 2001

Wood, M.D., P. E. Hengeveld, S. Clare, and R.S. McNay. In prep. The Ospika Mountain Goat Project: Adaptive Management and Habitat Supply Modeling. Project Work Plan.

Youds et al 1980

IWMS guidelines

4.0 RESULTS AND INTERPRETATIONS

As described in chapter 2 of this report, the model can be used for operational and strategic level planning. While specific applications of the goat model will likely vary, there are a number of results that will likely be of interest in most applications. These typical results have been developed into "standard" products in the form of posters that depict the amount and spatial distribution of the range types (by habitat value classes) over time. These standard results are presented in section 4.1. The type of questions to be assessed in the interpretation of results is presented in section 4.2. The "standard" model results can be applied to typical management decision-making. Additional applications of the model are described in section 4.3.

An example of results is presented to demonstrate the capability of the model.

4.1 Presentation of Results

The results that have been presented to date use are based on the Lower Ospika study area. These results have been used to test the presentation format to determine what information and format is most useful.

Two formats were used to present the model results:

1. Digital versions of the maps of the various ranges (Low Elevation Mineral Licks, Trails, Summer Escape and Winter Escape) are available in annual time steps for the duration of the model analysis period (5 year development plan). For demonstration purposes maps were generated for two specified time steps (2002 and 2007) for each model and for the management factors. Maps were produced in ArcView then exported as an image in jpeg format. Each script that has an 'Output' of a grid, will export a jpeg (see Fig. 5.1.1 for an example map product).
2. Graphs and tables of the area of the final output nodes of each model were produced by state value.

Maps, graphs, and tables were compiled and posters produced for presentation. For each of the range types and factors of interest in the model, a format for the presentation of results was developed. Sections 5.1.1 to 5.1.8 describe the material presented as results for each model.

An example of a poster is presented in figure 5.1.1 depicting results for a model run for the Trails.

4.1.1 Predation Risk

Results presented for Predation Risk included:

- Year 2002 and 2007 maps of predation risk levels;
- Tables of the area of each predation risk class

4.1.2 Roads and Cut-blocks

Results presented for roads and cut-blocks included:

- Map of roads and cut-blocks developed in the 40 years previous to, and including, 2002 (the current set of cutblocks having influence)
- Map of roads and cutblocks proposed to be in place in 2007
- Tables of the area in roads and cutblocks in 2002 and 2007

4.1.3 Ground and Aerial Disturbance

Results presented for ground disturbance included:
- Map of the current areas influenced by ground disturbance - 2002
- Map of the area influenced by ground disturbance in 2007

4.1.4 Hunting

Results presented for hunting included:
- Map of the area where local hunting is likely to be concentrated as a result of management activities (both regulated and unregulated) in 2002 and 2007

4.1.5 Trails

Results presented for the Trail model included:
- Year 2002 and 2007 maps of trail area and the habitat value of the areas
- Trail Netica model;
- Table of the area of preferred, equivocal and avoided habitat value class for each year

4.1.6 Low Elevation Mineral Licks

Results presented for the Low Elevation Mineral Lick model included:
- Year 2002 and 2007 maps of low elevation mineral lick area and the habitat value of the areas
- Low Elevation Mineral Lick Netica model;
- Table of the area of preferred, equivocal and avoided habitat value class for each year

4.1.7 Summer Escape

Results presented for the Summer Escape model included:
- Year 2002 and 2007 maps of Summer Escape area and the habitat value of the areas
- Summer Escape Netica model;
- Table of the area of preferred, equivocal and avoided habitat value class for each year

4.1.8 Winter Escape

Results presented for the Winter Escape model included:
- Year 2002 and 2007 maps of Winter Escape area and the habitat value of the areas
- Winter Escape Netica model;
- Table of the area of preferred, equivocal and avoided habitat value class for each year

4.2 Potential for Evaluation and Interpretation of Model Results

4.2.1 General Evaluation and Interpretation Criteria

Model interpretations are guided by questions of interest to resource managers. The following 7 questions were the focus of the general model interpretations:

1. How much of each range type (by habitat value class – preferred, equivocal, avoided) will there be in a management area?
    a. This can be evaluated quantitatively from tables of the area (ha) of each habitat value class (where applicable). In addition, this can be evaluated visually by looking at the maps.
2. How have the amounts of each range type changed over the time horizon of the model?
    a. This can be evaluated by comparing the area of each range type (by habitat value class where applicable) over time using the tables provided.
3. How has the overall spatial distribution of each range type changed across the management area over time?
    a. Although there are a number of possible statistical ways of presenting distribution information, at this time a visual scan of the maps is considered the best evaluation technique (maps are available for annual timesteps of the model and can be run as a "movie" to see changes in distribution of habitats over time). If there are areas of concern regarding distribution of habitat then these can be explored in more detail.
4. How does the amount of habitat in each range type compare with what might be possible under a management regime designed to optimize the amount of the range type?
    a. In order to evaluate the "capability" of the area with respect to the various range types, a map with no reduction of habitat value from management activities is presented for comparison. This depicts the maximum amount of habitat (usually the high habitat value class) that would be available if there were no reduction of habitat value due to any of the management factors.
5. As the amounts of habitat, by value class in each range type changes, when should managers become concerned?
    a. The proposed approach to determining important or critical changes in habitat is via a set of "red flags" – a set of criteria that would indicate significant events in the predicted future supply of habitat. This raises the question of what magnitude of change constitutes a red flag? Since so little is know regarding goat habitat relations the precautionary principle is recommended. The following types of red flags are proposed for discussion as the model is being developed:
        i. When the amount of the preferred habitat value class of any range type change; this is a flag of concern
        ii. Since mineral licks are scarce, specific features that appear to not be "replaceable" if impacted by management; if preferred mineral lick habitat is reduced to equivocal or avoided this is a red flag.
        iii. Since trails link escape and lick habitat, and appear to be used traditionally, but other routes may be used; if preferred trail habitat is reduced to avoided this is a red flag. Whereas, if preferred trail habitat is reduced to equivocal this is a yellow flag.
        iv. Since Winter Escape habitat is a potentially significant factor in winter goat survival, but this type of habitat is relatively more abundant than licks or trails; if 30% of preferred winter escape habitat is reduced to avoided than this is a red flag. If 50% is reduced to equivocal then this is a yellow flag.
        v. Since Summer Escape habitat is likely the abundant of the range types and unlikely to be limiting; if 50% of preferred summer escape habitat is reduced to avoided than this is a red flag. If 50% is reduced to equivocal then this is a yellow flag
6. Is the amount of one range type limiting the numbers of goats (i.e. the limiting factor)? If so, which range type is limiting? If one range type is limiting, and others are in "abundance"

does this mean that the abundant range types can be managed "down" to levels that support the numbers of goat supported by the limiting range type?

   a. It is likely that one range type is limiting population numbers, however this hasn't been determined in the model as yet. It is likely that the number of goats that can be supported is limited by one type of habitat that is less abundant. Specific interpretations for individual range types are further developed in section 4.2.2.

7. How is the amount of habitat in each range type linked to the numbers of goats?
   a. This question cannot really be answered without considering whole herd level population responses. Follow-up modeling regarding whole herd population response to habitat could address the question of the carrying capacities of the range types and consequently the linkage of habitat change to population change.

4.2.2 Evaluation and Interpretation Criteria of Specific Model Results

The following model interpretations are based on the results of the specific range type models.

4.2.2.1 Low Elevation Mineral Lick Model

To be developed by the workshop team

4.2.2.2 Trails Model

To be developed by the workshop team

4.2.2.3 Summer Escape Model

To be developed by the workshop team

4.2.2.4 Winter Escape Model

To be developed by the workshop team

4.3 Other Model Applications

There are a number of possible additional applications of the model. For example:

(To be developed by the workshop team)

5.0 MODEL TESTING

5.1 The General Approach to Testing

Protocols for reporting, testing, and accrediting habitat supply models in B.C. do not exist. This lack of procedure is likely in part due to philosophical debate on the proper use of models, and hence how testing might proceed. Testing should consider the context under which the model is intended to be used. For example, a standard and accepted, or valid, modeling technique may be completely inappropriate when applied to a set of modeling goals that differ for the ones the model was designed to address. Most people using habitat supply models acknowledge the goal generally as an aid to making decisions about resource management and not as a calculation to predict outcomes of management actions (i.e., strategic rather than operational). Hence, a major conclusion about assessing habitat supply models generally should simply be whether the model is effective in achieving the overall goals. Using "effectiveness" as a part of model testing embraces the commonly expressed, general characteristic of models – no model is correct but some are useful (e.g. useful as an aid in making decisions about management as discussed in general by ref).

Nevertheless, demand for more technical model testing remains strong (ref). For example, the suite of models fundamental to the Timber Supply Analysis in British Columbia (ref) form the basis for an important provincial policy that has important and widespread economic implications on site-specific management around the province. It is proposed that the goat models undergo testing and review to the extent that it achieves at least the same credibility as the TSR models. Presumably, a credible model is one that is judged to be effective and has strong technical merits (ref). Technical testing of models has given rise to a number of terms that are sometimes used indiscriminately. The plan for testing the goat model focuses on the following:

- Effectiveness, where the primary concern is whether applications are determined generally to be useful and advantageous;
- Validation, where relationships used in the model are determined to have some empirical evidence to support or justify the use of the relationship;
- Calibration, where validated relationships are used in a way that is judged to be suitable for the specific application;

Some discussions regarding model testing refer to the terms verification or veracity; here these terms are considered redundant with the process of validation and calibration.

5.2 Effectiveness: Determining the Degree of Success in Applying the Goat Model

Fundamentally, the most important test of the goat model is whether the tool is determined to be effective or useful as an aid to managing forests in a manner that maintains the sustainable supply of habitat for goats and if, by using the tool for that purpose, goat populations remain healthy. Because this result cannot be measured quickly (or perhaps even precisely), effectiveness must be judged on the basis of other, more measurable results; some of which are technical (discussed in 4.3) and some of which are not. The non-technical results are simply to confirm that the goat model meets the following of the goals originally targeted:

- It is commonly accepted as addressing a high priority resource management issue;
- It provides the necessary functional links among inventory, policy, and management (i.e., has a functional feedback from management to policy, with appropriate indicators that are measurable through a monitoring protocol);

- It is adaptable (i.e. easy to update with new information about basic resources or relationships);
- The ecological relationships used and the associated assumptions are made explicit; and
- It is used and is usable (i.e., gains a track-record for being used) to address Operational plans (Forest Stewardship Plans); and is relatively easy to run and interpret.

One key goal of the goat model, for example, was to make one common set of explicit rules for habitat management available to all stakeholders. If the goat model was effective at this, then management decisions would become easier to make and presumably, more consistent across jurisdictional boundaries and among resource managers.

5.3 Validation and Calibration: Determining the Degree of Technical Merit

Future supply of habitat and the health of goat herds are essentially a theoretical construct insofar as monitoring is concerned. The goat model develops indicators of these constructs through the modeling process. These are likely to be used as indicators at an operational level. For this reason, all ecological relationships within the goat model need to be valid and calibrated to the region of application. Validation should address at least the following two major assumptions:

1. Are the assumptions valid?
    a. An explicit list of assumptions and their implications should be available for review;
    b. Assumptions should not over-ride applicability or usefulness of results;
2. Are the relationships measurable and accurate?
    a. Dependant and independent variables are defined in measurable units;
    b. Outputs are consistent with observations (i.e., >50% of variance explained by the independent variables, 9 times out of 10);
    c. Outputs are tested against independent predictions (e.g., ancillary information supports the logic of primary predictions, predictions remain robust in new applications).

The task of validation is intended to be conducted on the goat model as a future phase of model development. To the extent possible, data collected as part of the Ospika Goat Project will be used to assess the validity of ecological relationships.

5.3.1 Opportunities for Using Empirical Data to Update the Goat Model

The goat model was constructed in a way that insured both the model inputs and the model results could be measured and monitored. Furthermore, although data collection associated with the Ospika Goat Project was independent of the modeling, it was designed to be a set of data that could be used to assess the model relationships. This association between modeling and fieldwork has been referred to as "model-motivated data collection" after Turchin (1998).

Description of the data collected in the Ospika Goat Project and how it can be used to test the goat model

5.3.2 Opportunities to Design Tests of the Goat Model: Adaptive Management

Adaptive management is defined to mean a systematic process for continually improving forestry policies and practices by learning from the outcomes of operational programs. The process typically includes the following 6 steps (Taylor and Nyberg 1999):

1. Assessing the problem or opportunity to be investigated;

2. Designing a management approach that achieves resource goals and also advances learning about how to improve management in the future;
3. Implementing the management approach in operational, not research, settings;
4. Monitoring the outcomes;
5. Evaluating the results to determine if they match forecasts made at the design stage; and
6. Adapting future management decisions to incorporate what was learned.

Adaptive management (AM) can take two forms: passive and active. In passive AM, a policy or prescription for goats would be implemented, outcomes would be monitored and evaluated, and the policy would be modified as necessary to increase its success in the future. This cycle might be repeated numerous times.

In active AM, two or more policy alternatives (e.g., different sets of operational regimes at the stand level) would be implemented in different areas to compare their success. Again, results would be monitored and evaluated, and the preferred policy would be selected based on the results of the management experiment[1].

The Ospika Goat Project offers several opportunities for both passive and active AM as explained below. The goat model will be useful for most or all of these adaptive management applications. For example:

- Current Trail project
- Other possible AM projects for goats
- Researchers could use sensitivity analyses to prioritize field work aimed at improving understanding of key relations;

For any AM application, the project team should ensure that an adaptive management project plan is written and made available to participants over the whole term of the project.

5.4 Literature Cited

Taylor, B. and B. Nyberg. 1999. An introductory guide to adaptive management for project leaders and participants. Unpubl. Report, Forest Practices Branch, BC Forest Service, Victoria B.C. 20 pages.

Turchin, P. 1998. Quantitative analysis of movement. Sinauer Associates, Inc. Publishers. Sunderland, Mass. 396pp.

[1] Throughout this section, “experiment” means a test of an unproven technique or policy and does not imply the use of the full rigor normally expected of scientific experiments. All policies and practices to be tested through AM are recognized as experiments in this broad sense, because their outcomes can not be predicted with confidence.

APPENDIX A. MODELING WORKSHOP AGENDAS AND SUMMARIES

APPENDIX B. POSTERS DEPICTING RESULTS OF TRIAL APPLICATION OF THE MODEL TO THE OSPIKA RIVER DRAINAGE

APPENDIX C. PRESENTATION TO STAKEHOLDERS: GOAT HSM AS A FOREST MANAGEMENT AND PLANNING TOOL