Assessing the Feasibility of Effectiveness Monitoring for Mountain Goat Winter Ranges in Forested Areas of British Columbia

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Abstract: Mountain goats (*Oreamnos americanus*) are a relatively common resident of British Columbia's most rugged habitats. Winter is a critical period due to nutritional deprivation and high energy expenditure related to thermoregulation and mobility in snow. As a result, B.C. is legally establishing winter ranges to provide critical life requisites for wintering mountain goats. I developed monitoring protocols and ecological baselines associated with selected indicators for assessing effectiveness of winter ranges, and tested the feasibility of their implementation in 2 areas: 35 km southeast of Houston, B.C. and a coastal site approximately 20 km southwest of Squamish, B.C. The following indicators were monitored: proportion of suitable/capable habitat managed as mountain goat winter range, forest cover characteristics, movement among winter ranges, forage availability, snow depth and consolidation, and sustained winter use. In general, field methods were practical, although the ability to navigate steep or broken terrain limits field sampling in many areas. In addition, assessing forage availability was deemed impractical because of the broad diets of mountain goats. Extensive monitoring increases overall robustness of mountain goat management by examining the full range of suitable ecological conditions and appropriate practices. As a result, management can move beyond attempting to achieve a single optimum condition and can focus on managing to a range of acceptable outcomes.

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British Columbia has a significant responsibility for managing mountain goats (*Oreamnos americanus*) because >50% of the world's population resides in the province (Shackleton 1999). The winter season is a critical period for mountain goats due to nutritional deprivation and high energy expenditure related to thermoregulation and mobility in snow (Wilson 2005a). As a result, provincial legislation allows for legal designation of mountain goat winter ranges. Wilson (2005a) identified a suite of indicators in relation to key questions to monitor effectiveness of mountain goat habitat management. The next steps in developing an effectiveness monitoring programme was to develop protocols based on the suite of indicators, to establish ecological baselines, and to test the methods in pilot project areas. I developed office and field monitoring procedures and herein present results of pilot implementation of the field procedures in two study areas.

Assessment criteria and proposed monitoring protocols

This project included developing monitoring protocols for effectiveness indicators related to mountain goat winter range (Wilson 2005a). Protocols included: assessment criteria, methods regarding collection and analysis, and ecological baselines against which to monitor trends. Wilson (2005a) provided broad "desired conditions" for each potential indicator, some of which provide obvious ecological baselines while others needed to have baselines established. Baselines generally are unavailable in the literature and were inferred from measures of current conditions. Current conditions were determined from field investigations on the pilot study areas, where extensive and intensive indicator data were collected. In some cases, ecological baselines are impractical to establish and monitoring must be based simply on year-to-year comparisons.

Proportion of Suitable or Capable Habitat Managed as Mountain Goat Winter Range

The proportion of suitable or capable habitat under management is a measure of the effectiveness of the overall management strategy because such areas generally are not at risk from human activities. Use of suitable or capable habitat as the basis for the calculation depends on the population goal (i.e., maintenance or recovery of the local mountain goat population). Determining the proportion of suitable or capable habitat protected and/or managed as mountain goat winter range is an office procedure dependent on availability of maps of winter range boundaries and other constrained areas such as parks and protected areas, as well as maps of all suitable or capable mountain goat winter range. This is expected to be a one-time calculation when winter ranges are established.

Maps of suitable or capable mountain goat winter range can be derived using a variety of methods (Wilson 2005b). A systematic aerial inventory (Rochetta 2002) provides the opportunity to characterize both fine-scale habitat characteristics as well as the presence of mountain goats. Habitat models also have been used to identify "potential" winter range areas based on topographic and forest cover characteristics (Gross et al. 2002, Heinemeyer et al. 2003). However, these models typically over-estimate the availability of suitable winter ranges and reconnaissance to confirm habitat characteristics and occupancy by goats is still necessary. Also, the detailed terrain characteristics of microsites used by wintering goats cannot be resolved by available mapping (Jex 2004). A blend of methods using maps, aerial photo interpretation, and survey flights also is an option (Pollard 2002, Dunsworth 2004).

There is no ecological baseline associated with the proportion of suitable or capable habitat managed as mountain goat winter range; rather, this statistic provides a management baseline that reflects the landscape-level potential for managing and protecting mountain goat winter range. The goal of capturing all winter ranges can be justified by the relative paucity of suitable or capable winter habitat for mountain goats.

Forest Cover Characteristics

Forest cover is an important characteristic of some mountain goat winter ranges, particularly in coastal regions where deep, unconsolidated snow forces mountain goats to elevations below treeline where dense canopies intercept snowfall and reduce snow depths on the ground (Wilson 2005b). Ensuring that forest canopy conditions are sufficient to moderate snow depths on winter ranges, and ensuring that canopy conditions persist over the long-term, are the reasons for monitoring forest cover characteristics. Monitoring is focused on forested buffers surrounding suitable escape terrain because there are outstanding questions related to the required extent of forested buffers in terms of snow interception cover and buffers from disturbance. Although trees associated with escape terrain are important features on some ranges (e.g., in coastal areas), they usually are not threatened by harvest plans and generally it is too dangerous to assess such areas on the ground.

The main function of forest cover on mountain goat winter ranges is to reduce snow depth on the ground, thus percent canopy cover of different strata is the most important variable. Abundance of arboreal lichens also is important because lichen litterfall can provide an important food source when other forage is unavailable due to deep snow conditions, particularly in coastal areas (Fox and Smith 1988).

Forest characteristics of a winter range at the time of legal establishment form the ecological baseline against which future monitoring results should be assessed, unless recovery of forest characteristics is an objective for the winter range.

Movement Among Winter Ranges

Winter ranges usually are established only where suitable habitat exists. Therefore, they tend to be small and distributed within a matrix of less suitable habitat. Although some mountain goats remain within areas smaller than most established winter ranges for large parts of the season, more typically animals move between patches of suitable habitat (Taylor et al. 2004). As a result, it is important that forest harvesting activities in areas between ranges do not interfere with movements of mountain goats. However, there has been little research on the effects of harvesting on movement of mountain goats between winter ranges. Given the absence of data, it also is important to document movements of goats between patches of suitable winter habitat, wherever possible.

Ecological baselines related to movement among winter ranges are difficult to establish. Failure to detect movements among winter ranges does not necessarily indicate that the ranges are ineffective. Nor does it necessarily mean that the intervening forest matrix is unsuitable for goats. Mountain goat movements are highly variable and there is no reason to assume that every goat would necessarily use 2 or more ranges. If detecting the movements of only a few goats is expected, the resulting data would be a poor indicator of movement patterns of the local population.

Forage Availability

Mountain goats are generalist herbivores with varied diets (Laundré 1994). Characteristics of the forest understorey determine the availability of forage for wintering mountain goats. Goats in coastal ranges subsist on forbs, ferns, conifers, lichens, and mosses (Hjeljord 1973). As snow depths increase, the proportion of forbs and ferns in the diet declines (Fox and Smith 1988). At snow depths of >50 cm, forbs and ferns become unavailable and goats forage on conifer leaves and lichens from standing trees and litterfall, and on mosses from substrates not covered by snow (Fox and Smith 1988). Older forests generally are associated with more abundant arboreal lichens and litterfall (Rochetta 2002). In interior regions where snow depths on high-elevation, windswept winter ranges are shallow, winter diets of mountain goats are dominated by grasses and shrubs (Laundré 1994).

In general, ranges with adequate forage are expected to have tall and vigorous shrub growth above the snow line and abundant literfall for periods of deep snow fall. Given the varied diets of mountain goats and the relative paucity of evidence of feeding expected in the field, ecological baselines related to forage availability generally are impractical.

Snow Depth and Consolidation

Mountain goat winter ranges are characterized by features that moderate snow depths. This allows goats adequate mobility while minimizing their energy expenditure. Interior mountain goat populations tend to winter at high elevations on windswept south and southwest-facing slopes, but heavy snowloads in coastal mountains force goats to move to low elevation areas in search of food sources not buried by deep snow (Fox and Smith 1988, Fox et al. 1989, Shackleton 1999). Mountain goats in the Cascades have habitat use characteristics intermediate between coastal and interior ecotypes (Gilbert and Raedeke 1992).

Objectives for winter ranges managed for mountain goats usually emphasize retention of forest canopy to intercept snow; therefore, monitoring should be focused on whether forest characteristics on the range are sufficient to moderate snow depth to an extent that mobility of mountain goats within the winter range is higher than areas outside the winter range.

Snow depths vary considerably within and between years. As a result, a key measure of the moderating effects of winter range characteristics is the difference between snow depths in open reference areas and under canopy within the boundaries of the winter range. Snow depth is not the only factor affecting mobility of mountain goats; snow consolidation also can vary considerably with snowfall patterns, freeze-thaw dynamics, and other variables.

Deep snows impose higher energetic costs through reduced mobility and reduced forage availability. Mobility of similarly-sized ungulates (e.g., mule deer; *Odocoileus hemionus hemionus*) becomes restricted as snow depths exceed 25 cm and significantly so if depths exceed 50 cm (Ungulate Winter Range Technical Advisory Team 2005 and references therein).

I propose an ecological baseline of ensuring that conditions on winter ranges result in snow depths generally <40 cm and sinking depths of <25 cm. Establishing ecological baselines for snow depths related to forage availability is more difficult because of adaptability of mountain goat diets and lack of information on energetic or fitness consequences of switching food sources as snow depths increase.

Evidence of Sustained Winter Use

Consistent winter use over many years is the most important indicator of effectiveness of winter areas established for mountain goats. Where local goat populations are monitored by telemetry, use of winter ranges can be determined through analysis of point location data. These analyses will under-estimate actual use because usually only a small and unrepresentative sample of the population is radio-collared. Telemetry data can confirm occupancy but can not establish whether winter ranges have been abandoned. Monitoring based on radio-collared animals is not a practical long-term strategy because most telemetry studies last only a few years.

Use also can be determined from annual aerial reconnaissance flights; however, animals and tracks are difficult to locate under canopy. Ground reconnaissance can determine use under forest canopy reliably because tracks, pellets, and browse can be measured directly. But only a subset of winter ranges are practical and safe to survey on the ground.

The ecological baseline for sustained winter use should simply be continued relative use over time, based on track count density or, where permanent pellet removal sites can be established, pellet density (no statistically significant change over >2 yr).

Methods for pilot program

Office Procedures

Proportion of Suitable or Capable Habitat Managed as Mountain Goat Winter Range- This involves a simple GIS area comparison between the final mountain goat habitat map and the final policy map illustrating legal winter ranges. Maps illustrating suitable or capable mountain goat habitat are not available for all areas; therefore, this criterion can not be applied everywhere.

Forest Cover Characteristics - Evidence of blowdown or forest health can be assessed either qualitatively or quantitatively by comparing digital orthophotos taken at different times.

Movement Among Winter Ranges - Movements between winter range areas can be documented through analysis of telemetry location databases. These databases are unlikely to provide information on travel routes but can confirm goats travel between winter ranges.

Sustained Winter Use - Point location data can be plotted in relation to winter range boundaries in a GIS framework.

Field Procedures

Field procedures include data collected from aerial reconnaissance and ground surveys. The following data can be collected during aerial survey flights:

Forest Cover Characteristics - Blowdown and forest health can be assessed qualitatively.

Movement Among Winter Ranges - Tracks of mountain goats usually are separated from those of other ungulates by the terrain in which they are found. Tracks usually are observed in areas above treeline and provide limited information on use of the forest matrix between winter ranges areas. Although tracks can be inventoried during fieldwork (see procedures below), it is impractical to confirm travel between winter ranges because of the area involved.

Sustained Winter Use - Winter aerial inventory surveys (RIC 2002) are used most commonly to establish occupancy of mountain goat winter ranges, but goats frequently are missed. Ground surveys are more reliable but are impractical to conduct on every winter range.

Ground collection of field data related to forage availability, snow depth and consolidation, and evidence of use can be collected in aggregate. Candidate winter ranges for sampling should be determined from all available information, including recent aerial photos/digital orthophotos. Mountain goats live in steep and often treacherous terrain and many areas can not be accessed safely, particularly in winter. Safety is the primary concern in all field sampling. It might not be obvious from photos whether winter ranges can be navigated safely and local knowledge should be canvassed before selecting a winter range for sampling. As mentioned previously, field monitoring is focused on forested buffers that surround suitable escape terrain. These forested areas generally are safer for surveyors but safety can not be assumed.

The number of winter ranges sampled depends on available resources and costs associated with field work (e.g., helicopter transit costs). Winter ranges with recent clearcuts along at least one edge are useful for sampling because they provide an opportunity to assess any blowdown effects and also provide good reference points for assessing snow depths.

Ideal locations for transect sampling are in clearcuts near the winter range boundary on shallow slopes and on an aspect similar to most of the winter range. Points should have navigable transects at ~45° up or downslope, if practicable. More than one point of origin can be identified if resources allow more extensive sampling. Points of origin should be flagged so they can be located in future years.

Field sampling involves the following tasks:

1. Navigate to point of origin and select area for plot approximately 20 m from winter range boundary with no forest overstorey, if possible. Record plot data (Table 1).

2. Mountain goat tracks encountered along transects can be followed to look for evidence of browse, beds, hair, etc. Effort spent backtracking depends on the abundance of tracks and time available.

3. If areas of intense use (see below) by goats are encountered (e.g., large pellet concentrations and hair, often on rocky outcrops with little or snow cover), note GPS location and take photographs. Mark the area with paint blazes and a tree marker, and make detailed notes of the location. Areas of intense use can be further monitored by clearing pellets from small plots (e.g., 1 m^2) at the beginning of winter and returning in spring to assess use. Pellets can be dried and weighed, counted or simply photographed to assess relative use.

4. Return to the plot location and take a bearing that traverses the winter range at ~45° angle (upslope or downslope). Establish next plot 20 m inside winter range boundary and repeat steps 1-3.

5. Continue establishing plots at either 20 or 50 m intervals, depending on size of the winter range and feasibility of navigating the transect. The objective should be at least 5 plots along the transect within the winter range boundary. The number of transects and, hence, the sampling intensity will differ among winter ranges.

Data Analysis

Most monitoring data require only summary statistics and qualitative comparisons. The exceptions are snow and sinking depths, crown closure, and pellet removal data. The relationship between snow and sinking depths and canopy characteristics can be explored using regression analyses by forest type. Relative use of intensive use sites, as measured at pellet removal plots, can be compared among years using frequency analyses if pellets are counted (e.g., chi-squared or g-tests, or log-linear analyses where additional variables are considered), or comparisons among means (t-tests, ANOVA) where pellets are weighed and data are available for several sites and/or years.

A variety of techniques for analysis of telemetry data can illustrate movement among winter ranges. For this project I illustrated the spatial relationship among telemetry locations by generating a “spanning tree” by mountain goat and year. Spanning trees do not connect consecutive locations but rather create a network of

Table 1. Monitoring information collected at plot transects in mountain goat winter ranges.

Indicator	Variable	Methods
Plot context	Site characteristics	Estimate slope with clinometer, aspect with compass, elevation from altimeter or GPS; UTMs from GPS, take photograph.
Snow depth and consolidation	Depth	Measure to nearest 5 cm with graduated pole at 10 locations within 20 x 20 m plot; note depth of crust layers
	Consolidation	Sink graduated ski pole into snow using strength of one arm, record sinking depth to nearest 5 cm at 10 locations within 20 x 20 m plot
Forest cover characteristics	Canopy	Percent cover for tree layer; dominant species in A1, A2, and A3 layers within 20 x 20 m plot
Forage availability	Shrub, herb, and moss abundance	Percent cover for shrub, herb, and moss layers above snow line within 20 x 20 m plot
	Lichen/litterfall	Estimate lichen abundance, estimate lichen-bearing branch litterfall within 20 x 20 m plot
Use by mountain goats	Visible sign	Record all tracks (and sinking depth), pellets, and hair in 20 x 20 m plot and number of tracks along transects

points based on minimum Euclidean distances without loops. The resulting network is relatively simple to interpret for the purposes of assessing movements among winter ranges.

Pilot program study sites

Two pilot study areas were established, one for interior ecotype mountain goats and one for coastal ecotype goats (Hebert and Turnbull 1977). Foxy Canyon is an “interior” site located 35 km southeast of Houston, BC (Figure 1). A continuous section of canyon extends for approximately 13 km at depths of 50-150 m along Foxy Creek. The canyon consists of discontinuous bedrock cliffs and steep forested slopes. Surrounding forest is comprised primarily of lodgepole pine (*Pinus contorta*) and hybrid white spruce (*Picea glauca x engelmannii*). The climate is northern continental, with long, relatively cold and dry winters and short, warm summers.

The canyon supports a minimum population of 37 goats (as of September 2000), with use concentrated near the canyon rim (Turney et al. 2001, Mahon and Turney 2002). Twenty-seven mountain goats were radio-collared (8 GPS and 19 VHF) in Foxy Canyon and nearby areas in January and March 2003 (Turney and Roberts 2004, Turney 2005). Some collars were still active in winter 2005-6 (L. Turney, pers. comm.).

Howe Sound winter ranges are located on the south coast of British Columbia, approximately 20 km southwest of Squamish, B.C. (Figure 1). Winter ranges are located on warm aspects that extend from lower elevations in Douglas-fir (*Pseudotsuga menziesii*) and western hemlock forest (*Tsuga heterophylla*), up through higher-elevation western and mountain hemlock (*Tsuga mertensiana*) forests and into the alpine. The climate on the south coast is maritime, with very wet but mild winters producing shallow or absent snow packs at low elevations and very deep snow packs at higher elevations.

Pilot program results

Field procedures were applied in 2 locations within Foxy Canyon on 23

February 2006. Data were collected at 10 field plots along 2 transects on either side of the canyon. Within the Howe Sound area, data were collected from 5 plots along one transect in McNab Creek. Sampling transects did not follow a 45° angle upslope during any of the surveys because Foxy Canyon slopes were gentle and variable, and Howe Sound slopes were very steep (often >80%) and progress was governed by navigable terrain.

Proportion of Suitable/Capable Habitat Managed as Mountain Goat Winter Range

This indicator was not completed because data were not available; however, there also were practical limitations to completing the analysis that might be relevant to other areas. In Foxy Canyon, linework was still being negotiated on the basis of a preliminary habitat model (Turney 2004, R. Heinrichs, pers. comm.). The habitat model also required revision (L. Turney, pers. comm.). Legally-established mountain goat winter ranges in Howe Sound were not yet approved, so the final policy layer was not available. The map of winter ranges had undergone many revisions, based on improving biological knowledge and on negotiations with forest licensees.

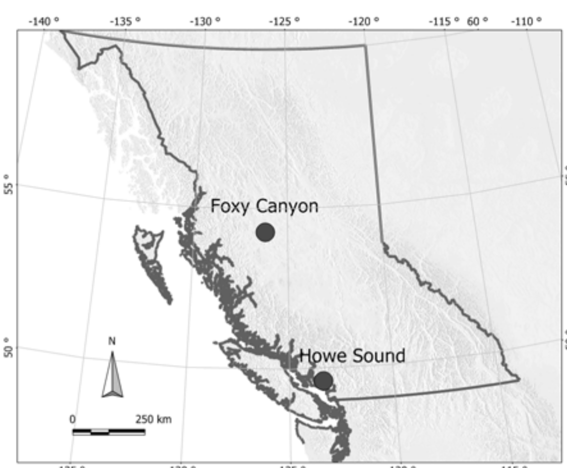

Figure 1. Study areas where protocols assessing effectiveness of mountain goat winter range areas were tested.

Forest Cover Characteristics

Forest cover characteristics were monitored to ensure forests contribute to winter range persistence and reduce snow depths on the ground. Procedures related to range persistence are either office-based or require extensive aerial inventory, both of which were beyond the scope of the pilot project. The snow monitoring component is addressed (with ecological baselines) below.

Movement Among Winter Ranges

Telemetry data from January to April 2003 (n = 8 goats and 2651 locations) and November 2003 to March 2004 (n = 5 goats and 1056 locations) indicated that mountain goat movements in Foxy Canyon were restricted largely to a single winter range area, although there was evidence of movements between ranges in consecutive winters (Figure 2). A complete aerial reconnaissance was not completed.

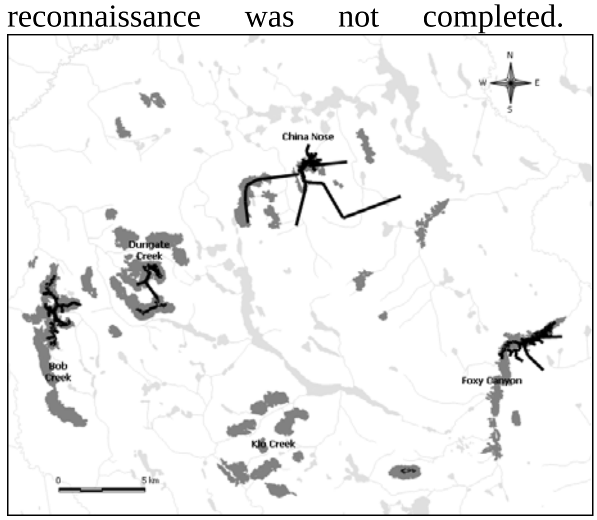

Figure 2. Spanning tree diagrams from data of radio-collared mountain goats (L. Turney, *unpubl. data*) January to April 2003 (n = 8 goats, 2651 locations) and November 2003 to March 2004 (n = 5 goats, 1056 locations). Spanning trees restricted to single winter season. Winter range areas are in dark grey.

Although tracks were visible during flights over and near Foxy Canyon, no tracks were detected between winter areas because the terrain was low elevation forest. No telemetry data were available for the Howe Sound area. Tracks within the winter range were visible from the air, but flight times were inadequate to inventory the surrounding area for evidence of tracks between ranges.

Forage Availability

Following mountain goat tracks resulted in evidence of feeding on subalpine fir (*Abies lasiocarpa*) blowdown in a partially harvested site in Foxy Canyon. Otherwise, shrub cover was variable but evidence of feeding was not detected, nor was feeding on the sparse lichen litterfall evident. I found evidence of browse throughout the area surveyed in Howe Sound; however, species-specific use could not be identified because the area was used extensively by wintering black-tailed deer (*Odocoileus hemionus columbianus*).

Snow Depth and Consolidation

Snow at Foxy Creek habitat plots (n = 7) was 23 to 62 cm deep and depths correlated with crown closure (Figure 3). Sinking depths (n = 7) were 13 to 23 cm and did not change significantly with crown closure (Figure 3). Sinking depths of tracks observed in plots (n = 4) were 10 to 25 cm. Snow depths in plots where mountain goat tracks were observed at Foxy Creek (n = 3) were <40 cm, while plots where tracks were not observed (n=4) had snow depths exceeding 40 cm. The role of snow depth in restricting forage opportunities is unclear, primarily because feeding was relatively rare. Feeding

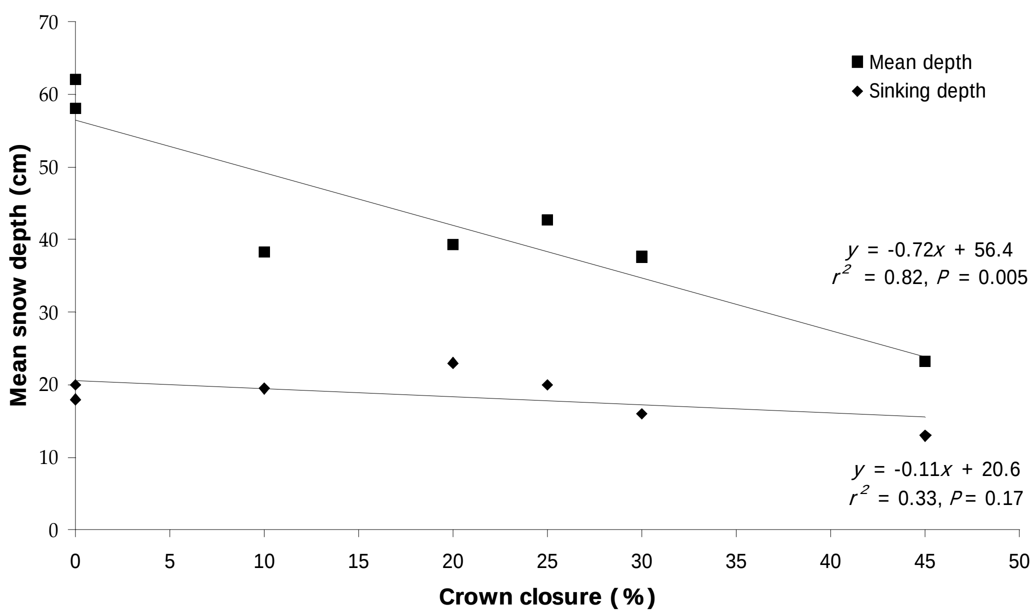

Figure 3. Effect of canopy closure on mean snow depth and sinking depth in assessment plots at the Foxy Creek study area.

evidence varied between cratering for ground forage and browsing blowdown.

Low elevation portions surveyed in Howe Sound had very limited snow cover, due in part to timing of the survey (23 March). Under canopy, snow cover was completely absent below 450 m and but was continuous above 750 m. Without canopy closure there were intermittent snow patches 11 to 20 cm deep at 432 m elevation and >1 m deep at 774 m. Although there were no tracks in deep snow at 774 m, there were tracks sinking 10 cm under canopy in snow depths of 30 to 60 cm with a crust layer at 30 cm.

Sustained Winter Use

Mountain goat use was clearly evident in the Foxy Canyon area. Recent tracks were common and pellets, urination, and feeding sites were seen. In addition, sites of intense use near the canyon rim could be used to establish pellet removal plots to monitor use between years. Nearly all use was under forest canopy. Use in partially-logged forest stands was rare and restricted to a few tracks and evidence of feeding. Identifying mountain goat use in Howe Sound was more difficult because of use by black-tailed deer, particularly at lower elevations. Pellets of deer and goats could be distinguished with some certainty and presence of hair in some instances confirmed the identification. Use by mountain goats was not detected below 600 m. Tracks also were common but could not be identified to species because the snow was melting.

Pilot program discussion

Although the pilot project focused on the field component of the monitoring protocols, office protocols are equally important and may constitute the majority of monitoring activities in some areas. Field monitoring is expensive and technically difficult or impossible in some areas. However, there is no substitute for ground-based work when assessing habitat characteristics and use by mountain goats under the forest canopy. The mix of office and field monitoring will differ among areas and perhaps years as resources are available.

Similarly, determining proportion of suitable/capable habitat managed as mountain goat winter range may or may not be possible for a given area. In areas where winter ranges were mapped for many years, the original biological or policy rationale may not be obvious. In areas where winter ranges were mapped recently, or are in the process of being mapped, there usually is an independent biology-based map generated by a habitat model and then verified through field investigation. In these situations, the proportion of suitable or capable winter range habitat under management can be calculated.

Monitoring forest cover changes is a relatively simple procedure. Forest cover on goat winter ranges is most threatened by blowdown along edges with recent cutblocks. Catastrophic events such as insect-kill or fire also are risks that vary. Forest cover *per se* is not a critical variable for mountain goats but serves a number of critical purposes. Dense canopy closure can moderate energetic costs by reducing snow depths on the ground. Older forests can be an important source of lichens, which goats eat when more palatable foods are unavailable. Forested buffers around escape terrain can provide protection against disturbance, to which mountain goats appear to be particularly sensitive (Wilson and Shackleton 2001). In Foxy Canyon (away from the Canyon rim) and Howe Sound, forest cover was critical for moderating snow depths and allowing mountain goats to move throughout the winter range.

Monitoring movement among winter ranges is a significant challenge in determining the effectiveness of habitat managed for wintering mountain goats. Sparse, short-term telemetry data are insufficient to monitor movements over the long-term as the forest matrix changes. Aerial survey flights provide anecdotal information because tracks are visible only in unforested areas. Even where winter ranges are separated by expanses of unforested habitat, movements are difficult to detect because mountain goats can remain on specific ranges for long periods and move to different areas infrequently (Taylor et al. 2004).

In addition, ecological baselines are difficult to establish because movement patterns of mountain goats are highly variable and there is no *a priori* basis for assuming movement between winter ranges is a key life requisite, particularly when the scale of winter range areas varies across the province. It may be better to infer movements between winter ranges from other indicators. For instance, evidence of sustained use indicates goats reach the winter range area and the intervening forest matrix is not a barrier to movement. In areas of declining use by mountain goats, hypotheses can be tested with monitoring data. For example, the decline could be a function of changing ecological conditions in the winter range, the surrounding forest matrix, other anthropogenic features (e.g., new roads or other development), or declines in local mountain goat populations.

The varied diets of goats reduces the utility of monitoring forage availability. In addition, evidence of feeding was rare in the study areas. It was most common in Howe Sound, but could not be attributed definitively to mountain goats. Although expected, energetic or fitness consequences of switching from higher quality items to lower quality food items (forbs and conifers, respectively), have not been quantified. Beyond qualitative assessments of availability, more formal monitoring of forage probably is impractical.

Snow depth and consolidation are key variables on winter ranges. They influence energy balance by restricting mobility and access to some forage (although the consequences are difficult to quantify). Maintaining high canopy closure in order to reduce snow depths on the ground in areas surrounding escape terrain is the principle effect on timber supply to the forest industry. Thus, characterizing and monitoring this relationship is an important focus of effectiveness monitoring. These data also are relatively easy to collect and analyze. Monitoring snow depths in a variety of forest types and structural conditions will provide valuable information. Ecological baselines of snow depth and consolidation are relatively easy to establish based on the relationship between observed tracks and snow depths, and direct measurement of track depths. I recommend snow depths <40 cm and sinking depths <25 cm as preliminary baselines that can be confirmed through additional field sampling.

Use by mountain goats during consecutive winters over the long term is the most important indicator of effectiveness of winter ranges. In areas of low or non-existent canopy closure this can be established relatively easily and quickly using reconnaissance-level aerial surveys to look for tracks and animals. Use of heavily timbered areas cannot be determined from the air; however, use in these areas is most important to establish because retaining forested buffers creates the most significant timber supply impact. Use was relatively easy to confirm on the ground under the forest canopy, although not all areas and conditions are favourable. Nor will it be practical to investigate all winter ranges through field sampling because of safety concerns. The systematic bias created by sampling relatively accessible and safe home ranges should be considered in the interpretation of any results. In addition, areas where winter ranges of mountain goats overlap with those of other species can create challenges for definitively identifying species-specific use.

Adaptive management

Effectiveness monitoring is a key task in adaptive management and results form the basis for adjustments to habitat management for mountain goats. Adaptive management relies on variation in management "treatments" to test different policies and practices (Walters 1986, Sit and Taylor 1998). As a result, the process is most effective where monitoring is extensive and encompasses as broad a range of ecological conditions and management practices as possible. Extensive monitoring also tends to increase overall management robustness because it promotes an understanding of the full range of suitable ecological conditions and appropriate practices. As a result, management can move beyond achieving a single optimum condition and can focus on managing the system within a range of acceptable outcomes using a more extensive policy and practices "toolbox" (Johnson 1999).

Many factors and interactions among factors determine the effectiveness of winter range areas managed for mountain goats. In addition, external factors can influence indicators used to measure effectiveness. For example, sustained use by goats is a function of habitat characteristics and trends in local mountain goat populations, which are each affected by climatic events, disease, and hunting regulations. As a result, the effectiveness of winter ranges must be inferred from the weight of evidence provided by a number of indicators. In this complex system, evidence could be conflicting or contradictory and managers must carefully weigh the different lines of evidence and document the logic of expert-based conclusions.

Although extensive monitoring increases understanding of the ecological system and response to management practices, it generally is impractical to establish controlled and replicated "management experiments" to definitively test the efficacy of all policy and management options. Again, the evidence must be weighed and conclusion documented. Although not the ideal adaptive management scenario, it provides a better basis for decision-making and a framework for continual improvement.

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