

Monitoring the Effectiveness of Mountain Goat Habitat Management

Prepared by:

Steven F. Wilson, Ph.D., R.P.Bio.

EcoLogic Research

406 Hemlock Avenue

Gabriola Island, BC V0R 1X1

sfwilson@shaw.ca

Prepared for:

BC Ministry of Water, Land and Air Protection

Biodiversity Branch

4th Floor, 2975 Jutland Road

Victoria, BC V8T 5J9

31 March 2005

Executive Summary

Mountain goats (*Oreamnos americanus*) are a relatively common resident of British Columbia's most rugged, mountain habitat. BC has a significant responsibility for conservation of mountain goats because >50% of the world's population occurs in the Province and recent history has shown that the species is sensitive to a variety of stressors. Although still widely distributed, populations were reduced considerably in parts of the Lower Mainland and Kootenay regions by overhunting in the 1960's and 1970's, and populations and habitat in the southern interior are generally small and fragmented.

I developed a series of indicators to measure the effectiveness of habitat management for mountain goats under the Forest and Ranges Practices Act (FRPA). The Act allows for designation and management of *Ungulate Winter Range* to ensure the over-winter survival of mountain goats, and also allows for the possible designation of mountain goats as *Identified Wildlife*, which permits further habitat protection in *Wildlife Habitat Areas* and *Wildlife Habitat Features*. A comprehensive habitat management strategy requires the protection of natal ranges, escape terrain, winter ranges, traditional trails and important point features such as mineral licks. Access and related human-caused disturbances can be only partly addressed under FRPA.

Recommended effectiveness indicators address a number of key monitoring questions and are stratified by the resources required to measure. *Routine* indicators are generally based on data collected for other purposes and require only office procedures. *Extensive* indicators require low-intensity qualitative or quantitative field assessments, while *Intensive* indicators require the collection of detailed field data. Indicators are further stratified by whether they monitor mountain goat habitat, demography, or assess the status of various threats to mountain goat habitat or populations.

Although the recommended indicators address all key monitoring questions, not all questions are addressed comprehensively. In general, the required distribution and abundance of different habitats, as well as the significance of habitat alteration in creating barriers to movement between habitats, are unknown. Monitoring questions related to these issues can be addressed indirectly by monitoring mountain goat occupancy of different habitats.

Monitoring the effectiveness of habitat management for mountain goats should involve: 1) establishing a regional or subregional management objective (i.e., population maintenance or recovery); 2) implementing procedures to collect, warehouse and analyze routine indicator data; 3) allocating resources to collect extensive indicator data in areas of greatest management concern; and, 4) collaborating with other agencies to collect intensive indicator data and to address knowledge gaps.

Table of Contents

Executive Summary	ii
Table of Contents	iii
List of Tables.....	iv
Acknowledgements	iv
Introduction	1
Objectives.....	1
Approach	1
Life History	2
Distribution.....	2
Habitat Use.....	2
Natal Ranges.....	2
Escape Terrain	2
Winter Range	3
Traditional Trails	3
Mineral Licks.....	3
Habitat Management under the Forest and Range Practices Act	3
Ungulate Winter Ranges.....	4
Wildlife Habitat Areas.....	4
Wildlife Habitat Features.....	4
Gaps in Management of Mountain Goat Habitat.....	4
Threats	5
Natural Stressors.....	5
Human-induced Stressors	5
Key Effectiveness Monitoring Questions.....	6
Small Scale (Individual Ungulate Winter Ranges, Wildlife Habitat Areas or Features).....	6
Medium Scale (Watershed or Management Unit)	6
Large Scale (Subregional or Regional Populations).....	6
Effectiveness Indicators	7
Overview of Inventory and Monitoring Methods	7
Population Inventory	7
Habitat Inventory	7
Recommended Indicators.....	8
Knowledge Gaps	13
Management Recommendations	14
Literature Cited	15

List of Tables

Table 1. Recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of Ungulate Winter Ranges (UWR) established for mountain goats in BC.	8
Table 2. Recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of wildlife habitat areas (WHAs) established for mountain goats in BC. WHAs are intended to protect critical natal ranges and patches of escape terrain.	9
Table 3. Recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of wildlife habitat features (WHFs) established for mountain goats in BC. Wildlife habitat features are intended to protect linear features such as traditional trails and mineral licks.	10
Table 4. Recommended demographic indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of mountain goat management in BC.	11
Table 5. Threat parameters and associated recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of mountain goat management in BC.	11
Table 6. Monitoring questions in relation to recommended indicators, minimum monitoring intensity and frequency for monitoring the effectiveness of habitat management for mountain goats in BC.	12
Table 7. Key monitoring questions related to management of mountain goat habitat and associated knowledge gaps.	13

Acknowledgements

Funding for this report was provided by the Forest Investment Account through the BC Ministry of Water, Land and Air Protection (WLAP). The report benefited greatly from comments provided by Wayne Erickson (BC Ministry of Forests), Steve Gordon (WLAP), Bill Jex (WLAP), Rick Marshall (WLAP), Kathy Paige (WLAP), George Shultze (WLAP) and Richard Thompson (WLAP).

Introduction

The mountain goat (*Oreamnos americanus*) is a relatively common inhabitant of British Columbia's most rugged mountain habitats. Provincially the species is "yellow-listed" or considered "apparently secure and not at risk of extinction" (BC Conservation Data Centre; srmwww.gov.bc.ca/cdc). This status is based on the fact that the BC population numbers approximately 50,000, that mountain goats are widely distributed, and that most of their habitat is not under imminent threat.

Although mountain goats are not considered threatened, there are several reasons for developing a comprehensive strategy for managing and monitoring mountain goat habitat. First, approximately 50% of the world's population of mountain goats resides in BC (Shackleton 1999) and, as a result, BC has a significant global responsibility for the conservation of the species. Second, recent history has demonstrated that mountain goats are sensitive to a variety of stressors. For example, increasing access during the 1960's in the Kootenay region led to over-hunting from which populations never fully recovered (Phelps et al. 1983). Similarly, increasing access led to local extirpations in the Chilliwack District and hunting there was closed in 1984 due to conservation concerns. Third, although mountain goats generally inhabit remote and precipitous terrain, they also make use of critical, low-elevation features that put them in direct conflict with a number of land uses. Finally, backcountry activity of all kinds is increasing, even in remote alpine areas, and this activity has the potential to affect the effectiveness of mountain goat habitat.

I developed a series of indicators to measure the effectiveness of habitat management for mountain goats under the Forest and Ranges Practices Act (FRPA). The Act allows for designation and management of *Ungulate Winter Range* to ensure the over-winter survival of mountain goats, and also allows for the possible designation of mountain goats as *Identified Wildlife*, which permits further habitat protection in *Wildlife Habitat Areas* and *Wildlife Habitat Features*.

Objectives

The specific objectives of this report were to:

1. Review existing information related to the habitat requirements of mountain goats;
2. Assemble information on natural and human-related "stressors" that have the potential to affect the viability of mountain goat populations;
3. Describe life history requisites of mountain goats in relation to management tools available to protect their habitats;
4. Develop indicators to monitor the effectiveness of habitat managed for mountain goats under FRPA; and,
5. Identify knowledge and management gaps in BC's strategy to sustain mountain goat populations.

Approach

My approach to developing indicators to monitor the effectiveness of habitat management for mountain goats involved the following steps:

1. Identify limiting habitat and habitat attributes required to fulfil critical life requisites of mountain goats;
2. Outline mechanisms for managing important habitats under FRPA;
3. Identify threats to mountain goat habitat and populations;
4. Develop key monitoring questions at small, medium and large spatial scales;
5. Summarize population and habitat monitoring methods;

6. Propose indicators based on a series of desirable criteria that address: a) different levels of monitoring intensity; b) desired outcomes or results (in relation to a stated management goal); and, c) required frequency of measurement;
7. Identify of knowledge gaps; and,
8. Develop recommendations for implementation.

Life History

Distribution

Mountain goats are restricted to North America and the majority occur in BC and Alaska. Small, populations also occur in Yukon, Northwest Territories, Alberta, Washington, Idaho and Montana. Mountain goats have been successfully introduced to Oregon, Nevada, Utah, Wyoming, Colorado and South Dakota (Shackleton 1997).

Mountain goats are widely distributed in varying densities throughout the mountainous regions of British Columbia, with the exception of Vancouver Island and the Queen Charlotte Islands. They are generally absent from the Interior Plateau and Peace River Lowlands. They are most common in the northwestern ranges of the Coast Mountains and in the Rocky Mountain ranges of the Kootenay region. Suitable and occupied mountain goat range in the southern interior (e.g., South Okanagan and Similkameen) is relatively small and discontinuous (Shackleton 1999).

Habitat Use

Mountain goats throughout their range generally occupy high-elevation, relatively precipitous and rugged terrain (Lemke 1999, Shackleton 1999, Gross et al. 2002), although some populations occupy canyons (Foster and Rahe 1985). Mountain goats will use lower-elevation terrain (occasionally as low as sea level; Gordon and Reynolds 2000) to escape deep snow on the coast (e.g. Taylor et al. 2004) and to access low-elevation mineral licks (Shackleton 1999). Mountain goats are generalist herbivores and will eat whatever forage is available, including grasses, sedges, forbes, shrubs, ferns, mosses, lichens and conifers (Hjeljord 1973, Laundré 1994)

Natal Ranges

Nannies isolate themselves in late spring (May-June) and give birth in high-elevation, steep and rugged terrain consisting commonly of rock outcrops, cliffs and ridges (Lemke 1999, Shackleton 1999, Côté and Festa-Bianchet 2001a). Nannies and kids remain isolated for <2 weeks before aggregating into nursery groups on spring and summer range (Côté and Festa-Bianchet 2001a).

Escape Terrain

The principle anti-predator strategy of mountain goats is the use of escape terrain; namely, rock bluffs and cliffs that provide good visibility and that are generally inaccessible to predators (Fox and Streveler 1986, Fox et al. 1989, Shackleton 1999). Goat generally remain <400 m from suitable escape terrain unless travelling between important features such as mineral licks (Fox et al. 1989, Gross et al. 2002, Keim 2004a). Males will sometimes forage >400 m from escape terrain, often in conifer forests (Hebert and Turnbull 1977).

In general, escape terrain can be described as (Wilson 2004):

- Rock outcrops or cliffs that provide good visibility for vigilant goats and are sufficiently rugged to be generally inaccessible to predators; and,
- Slopes generally >30° and <60°.

Winter Range

In general, the habitat requirements of wintering goats can be described as (adapted from Wilson 2004):

- Escape terrain (described above);
- Accessible and abundant forage in close proximity to escape terrain provided by:
 - High-exposure, windswept slopes and/or warm, southerly aspects with high melt and snow-shedding characteristics;
 - Forest canopies with high snow interception characteristics;
 - Areas that provide rooted forage not buried by snow and/or abundant litterfall; and,
- Evidence of winter use by mountain goats or use by mountain goats in nearby areas.

Home ranges of individual mountain goats are generally <250 ha (Taylor et al. 2004).

The relative importance of exposed sites with low snow loads and forested areas with high snow interception varies broadly among different mountain goat ecotypes. Coastal goats are most dependent on snow interception cover because windswept sites are rare due to deep snow (Hebert and Turnbull 1977, Fox and Smith 1988, Fox et al. 1989, Shackleton 1999) and rain-on-snow events are more common than in the interior, resulting in wet, heavy snow accumulations that severely restrict the mobility of mountain goats. Interior goats are more likely to use high-exposure, windswept sites but still seek out lower elevations areas for snow interception cover and foraging, particularly during severe winter conditions (Shackleton 1999, Hengeveld et al. 2003). Mountain goats in the Cascades have habitat use characteristics intermediate between coastal and interior ecotypes (Hebert and Turnbull 1977, Gilbert and Raedeke 1992).

Suitable topography for winter ranges can occur in very small microsites within a matrix of less suitable terrain. For example, Jex (2004) found mountain goats using areas with shallower slopes and some cooler aspects than might be expected from the literature; however, these areas were often associated with small rock outcrops. Coastal mountain goats are also known to use microsites such as caves under overhanging rock and snow bowls under mature tree canopies (Leigh-Spencer 1997).

Traditional Trails

Mountain goat movements occur at different scales. In winter, coastal mountain goats can remain on isolated patches of suitable habitat (often only a few hectares in size) for several months (Taylor et al. 2004). Longer movements occur when goats move between these isolated patches. Mountain goats are known to use traditional trails to move between seasonal ranges. In coastal Alaska the distance moved between winter and summer ranges averaged 1.2 km (Schoen and Kirchhoff 1982). Mountain goats also use traditional trails to move between seasonal ranges and mineral licks (Shackleton 1999, Hengeveld et al. 2003, Turney and Roberts 2004).

Mineral Licks

Mineral licks are areas where ungulates congregate, particularly in spring and early summer, to acquire critical minerals by licking exposed substrates rich in sodium, calcium and magnesium (Hebert and Cowan 1971, Jones and Hanson 1985). Mountain goats will travel long distances along traditional trails, sometimes crossing terrain associated with a high risk of predation or injury (e.g., forests and rivers), to reach mineral licks (Hebert and Cowan 1971, Shackleton 1999). The functional significance of mineral licks is unknown; however, animals might be attempting to address sodium or magnesium deficiencies resulting from the ingestion of potassium-rich, early spring green vegetation (leading to the excretion of essential minerals; Shackleton 1999).

Habitat Management under the Forest and Range Practices Act

Protection of mountain goat habitat is available under a suite of policy tools in FRPA. *Ungulate Winter Ranges* for mountain goats can be established under Section 12 of the Government Actions Regulation. As an

Identified Wildlife Species, *Wildlife Habitat Areas* and *Wildlife Habitat Features* could be established to protect specific areas associated with habitat attributes required to meet specific life requisites. Objectives related to management within designated areas are expressed in *General Wildlife Measures*.

Ungulate Winter Ranges

Ungulate Winter Ranges are areas established to ensure the over-winter survival of mountain goats, recognizing that this is a critical season for ungulates due to nutritional deprivation and high energy expenditure related to thermoregulation and mobility in snow.

Wildlife Habitat Areas

Wildlife Habitat Areas can be established to protect critical non-winter habitats such as escape terrain and natal areas.

Wildlife Habitat Features

Wildlife Habitat Features are intended to protect point or linear resources such as mineral licks and traditional trails. Policy related to *Wildlife Habitat Features* has not been fully developed.

Gaps in Management of Mountain Goat Habitat

Although important mountain goat habitats can be protected under FRPA, management is restricted to the boundaries of the *Ungulate Winter Range*, *Wildlife Habitat Area* or *Feature*. There is no opportunity provided by regulations to manage the context in which habitats are located. For example, forest harvesting and road-building adjacent to an *Ungulate Winter Range* can reduce its effectiveness because forest cover within the Range boundaries might be more susceptible to blowdown, and human-related activity enabled by roads might increase in and near the Range.

Human access can be a critical aspect of habitat management for mountain goats. Industrial forestry access can be restricted through *General Wildlife Measures* under FRPA. Commercial recreational access can be restricted through management plans required by tenure holders under the *Land Act*. Revised guidelines for commercial recreation operations in the backcountry are currently being developed by the Province (Wilson and Hamilton 2005).

Aircraft, particularly helicopters, are also a significant concern with respect to disturbance of mountain goats (Wilson and Shackleton 2001). Aircraft use related to industrial activities and commercial recreation can be regulated through relevant provincial statutes; however, general private and commercial aviation are under federal jurisdiction.

In general, public access to mountain goat habitat on crown land is difficult to restrict. Access via logging roads is a key factor in the success of goat hunters (Phelps et al. 1983), and public recreationalists, particularly those using motorized access, can disrupt use of habitats by mountain goats. Motorized access to specific areas can be restricted under the *Wildlife Act*. Access can be restricted indirectly by discouraging road-building near important habitats. In the past, the remote terrain used by mountain goats provided a measure of protection; however, the continuing expansion of industrial road networks is eroding this protection.

Important habitat for mountain goats exists in protected areas. These areas are not considered in this report because they are not covered under FRPA; however, medium- and large-scale assessments of the distribution and abundance of habitat managed for mountain goats should include an inventory of mountain goat habitat in protected areas.

Mountain goats are a hunted species in BC; therefore, adequate management relies not only on adequate protection and management of important habitats but also on population management (i.e., harvest regulations).

Threats

The following are significant threats to mountain goat populations and habitats.

Natural Stressors

- Disease and parasites: Diseases (e.g., contagious ecthyma; Hebert et al. 1977) and parasites (e.g., lungworm; Boddicker et al. 1971) have been documented in mountain goats, but the extent of their impact on populations is unknown (Shackleton 1999). Infection resulting from interactions with domestic livestock is unlikely because mountain goats occupy remote habitats not generally used as crown range.
- Predation: The main predators of mountain goats are cougars (*Puma concolor*) in southern BC and wolves (*Canis lupus*) in northern BC; Fox and Streveler 1986, Shackleton 1999). Grizzly bears are also important predators (Festa-Bianchet et al. 1994, Côté and Beaudoin 1997). The risk of predation is likely higher where tree or shrub cover conceals ambush predators (Festa-Bianchet et al. 1994, Côté and Beaudoin 1997).
- Winter severity: Starvation is most likely during severe winters, when deep snow limits access to forage and low temperatures increase metabolic demands. The effects of severe winters are difficult to assess in the field because carcasses are hard to retrieve and are often scavenged, complicating necropsies to determine the cause of death. Deep snow during late winter has been correlated with low summer kid-to-nanny ratios (Adams and Bailey 1982).
- Accidents: Because of the precipitous terrain occupied by mountain goats, accidental falls and avalanches are thought to be a significant mortality factor (Fox and Streveler 1986).

Human-induced Stressors

- Disturbance: Most mountain goat habitat is relatively inaccessible, but aircraft (particularly helicopters) have the potential to displace mountain goats from preferred habitats; in particular, winter ranges, escape terrain and natal areas (Wilson and Shackleton 2001). Behavioural changes resulting from aircraft disturbance have been documented (Côté 1996, Gordon and Wilson 2004); however, longer-term demographic effects are unknown (Wilson and Shackleton 2001). Fixed-wing (Poole and Heard 1998) and ground-based disturbances are less disruptive (Foster and Rahe 1983, Pedevillano and Wright 1987). Because mountain goats travel long distances along traditional trails to access low-elevation mineral licks, industrial activity near trails and licks has the potential to disturb and displace goats from critical habitat features (Hebert and Cowan 1971, Hengeveld et al. 2003).
- Harvest: Mountain goats are a game species in BC and are regulated under both general open seasons and limited entry permits. Access is an important determinant of hunting pressure and populations are sensitive to the harvest of nannies, which can be difficult to distinguish in the field (Schoen and Kirchhoff 1982, Phelps et al. 1983). Because age of first reproduction is late and birth rates are relatively low, mountain goat populations may be unable to sustain annual harvests of >2-3% of the population per year (Côté and Festa-Bianchet 2001b). Regulations (including harvest quotas) are usually set by Management Units; however, MU-specific population estimates are highly uncertain, and the limited distribution of mountain goats within most Management Units makes them susceptible to over-harvest. In addition to the regulated harvest, mountain goats are subject to First Nations harvest and poaching. The impact of the unregulated harvest on the sustainability of mountain goat populations is difficult to determine.
- Habitat alteration and destruction: Although mountain goats remain in alpine and subalpine habitats throughout most of the year, they are still sensitive to human-related habitat alteration and destruction, which tends to be concentrated at lower elevations. Threats to mountain goat habitat include:

- o Forest harvesting: The most significant threat associated with forest harvesting is the removal of old and mature forest from coastal mountain goat winter ranges (Wilson 2004). A dense, mature canopy is required to intercept snow and to provide abundant litterfall. Forest harvesting adjacent to winter ranges can also affect their suitability by reducing the windfirmness of trees within winter ranges or by increasing snow depths under the canopy through wind action. The extent to which clearcuts create barriers to movement is unknown. Harvesting activities might inhibit movements of mountain goats between winter ranges by creating barriers of deep snow and/or slash, or might funnel mountain goats into areas where they are more susceptible to predation. Forest harvesting might also disrupt dispersal movements, movements between seasonal ranges or between seasonal ranges and mineral licks along traditional trails. Forest harvesting in and near goat winter ranges has increased on the coast as the economics of harvesting previously unmerchantable wood has improved (B. Jex, *pers. comm.*). Young (<15 years) or mature-old (>80 years) forests adjacent to traditional low-elevation trails is considered important for visual protection from predators (Hengeveld et al. 2003).
- o Blasting: Blasting activities associated with road construction, mineral extraction or other industrial activities can directly affect the suitability of mountain goat habitat by destroying critical escape terrain. Blasting might also disturb mountain goats during critical periods (e.g., kidding) or increase the risk of avalanches on winter ranges.
- o Road-building: Effects of road-building are mostly indirect because increasing road density is correlated with other human-induced stressors, including disturbance (from the ground), hunting pressure and forest harvesting. Proximity of roads to mountain goat habitat is the most important determinant of hunting pressure; hunters are generally deterred from hunting distances >2 km from roads (Hengeveld et al. 2003).

Key Effectiveness Monitoring Questions

The following are key monitoring questions related to assessing the effectiveness of habitat management under FRPA.

Small Scale (Individual Ungulate Winter Ranges, Wildlife Habitat Areas or Features)

1. Does the Range, Area or Feature provide the habitat elements required to fulfil the life requisites of mountain goats for which it was established?
2. Is the Range, Area or Feature receiving sustained use by mountain goats?
3. Is human-related disturbance affecting use of the Range, Area or Feature by mountain goats?

Medium Scale (Watershed or Management Unit)

1. Are there barriers outside of the Range, Area or Feature that prevent the movements of mountain goats between and among Ranges, Areas and Features?
2. Is the distribution and abundance of *Ungulate Winter Ranges* established for mountain goats sufficient to ensure over-winter survival in typical and severe winters?
3. Is the distribution and abundance of *Wildlife Habitat Areas* and *Features* sufficient to meet the life requisites of mountain goats (for which the Areas and Features were established) resident to the area?

Large Scale (Subregional or Regional Populations)

1. Is the distribution and abundance of Ranges, Areas and Features established for mountain goats sufficient to sustain the regional mountain goat population?
2. Is the current suite of management practices sufficient to meet regional mountain goat objectives (e.g., maintenance or recovery)?

Effectiveness Indicators

Overview of Inventory and Monitoring Methods

Population Inventory

Aerial survey methods for mountain goats are well-developed (RIC 2002); however, population surveys are expensive because they normally involve many hours of helicopter time (Thompson and Baker 1981). As a result, population surveys are practical only at a Management Unit or subregional scale. A total count survey is the only practical method available to census mountain goats because populations are rarely marked (Cichowski et al. 1991). Sightability corrections, like those developed for elk surveys (Samuel et al. 1987), have not been adapted to mountain goat inventories (RIC 2002). Mountain goats are usually found in discrete patches of rocky terrain and can be highly visible during snow-free periods; however, an unknown proportion of the population is likely to be found in atypical terrain and/or below tree line. Winter surveys are often preferred because tracks are often visible where animals can not be seen.

Because of the challenges related to mountain goat inventories, calculating absolute abundance is not possible and monitoring must be based on relative changes in population indices. Useful indices of population status include: 1) changes in sex and age ratios; and, 2) changes in relative abundance (RIC 2002).

Surveys are associated with considerable uncertainty because it can be difficult to classify animals by age and sex from the air (Gonzalez-Voyer et al. 2001). To make more confident classifications requires additional flying time and additional stress to mountain goats. Also, interpretation of classified counts (i.e., sex and age ratios) is based on the assumption of stable adult female survival in relation to adult males and kids and this assumption might be violated in hunted populations (McCullough 1994). This, along with the fact that marked animals are generally unavailable, limits the confidence of year-to-year comparisons of indices. As a result, populations might decline for several years before a significant change is detected (Wilson and Shackleton 2001).

Ground-based census methods are more precise but are time-consuming and can be impractical in remote regions (Smith 1988, Gordon 2003).

Harvest data can be an important source of population trend information, particularly at the regional scale. Total harvest and hunter effort (as well as their ratio, hunter success), and sex ratio of the harvest can be used to index trends in mountain goat populations. Although it has not yet been attempted with mountain goats, cohort reconstruction analysis could be used to estimate population sizes and trends based on characteristics of the harvest and estimates of several population parameters. The technique has been used to estimate populations of elk and other game species (e.g., Bender and Spencer 1999). These methods have been expanded recently to measure confidence around various input parameters and population estimates (Bender and Spencer 1999, Gove et al. 2002, Skalski and Millspaugh 2002).

Habitat Inventory

A systematic aerial inventory is the best way to identify mountain goat habitat because fine-scale topographic and vegetative characteristics as well as the presence of mountain goats can be determined from inventory flights. Unfortunately, the resources required for this level of inventory are impractical for many regions of the Province. In these areas, it might be necessary to identify “potential” habitat based on a topographic and forest cover model (e.g., Gross et al. 2002, Heinemeyer et al. 2003, Keim 2004b). These models often over-estimate the availability of suitable habitat and reconnaissance to confirm habitat characteristics and occupancy by mountain goats is still necessary. Multi-year inventories of the same areas might be required because mountain goat use of specific terrain can vary from year to year. Also, the detailed terrain characteristics of microsites used by goats can not be adequately resolved by available mapping (e.g., Jex 2004). A blend of methods using maps, aerial photo interpretation and survey flights can be effective (e.g., Pollard 2002).

Identifying winter range areas, particularly on the coast, has been a provincial priority (e.g., Gordon and Reynolds 2000, Heinemeyer et al. 2003, Jex 2004, Wilson 2004) because winter is the critical season for

mountain goats and the suitability of some low-elevation winter ranges are threatened by planned forest development.

Recommended Indicators

Indicators can measure the function (e.g., snow depth, forage accessibility), structure (e.g., terrain characteristics) or use (e.g., direct inventory) of Ranges, Areas or Features. Indicators should be:

- Measurable (accurately and precisely);
- Cost-effective to monitor; and,
- Sensitive to management or stressor change.

Different indicators require different levels of resources to measure and monitor. Indicators can be classified as:

- Routine: Generally measured through office procedures from data collected for other purposes (e.g., map interpretation);
- Extensive: Requires low-intensity qualitative or quantitative field assessments (e.g., blow-down assessments); and,
- Intensive: Requires detailed, quantitative fieldwork (e.g., population inventory).

Assessing the effectiveness of habitat management at medium and large spatial scales also requires interpretation in relation to broad management objectives:

1. Population maintenance: Maintain the current approximate pattern of habitat occupancy (medium scale) and abundance and distribution (large scale) of mountain goats. Use currently occupied habitat and indices of abundance as the basis for defining desired conditions.
2. Population recovery: Increase rates of occupancy of suitable habitat and increase the abundance and possibly the regional distribution of mountain goats. Use habitat capability and recovery objectives related to abundance and distribution as the basis for defining desired conditions.

Finally, effectiveness indicators can be stratified by whether they monitor habitat (Tables 1-3) or demographic (Table 4) characteristics, or instead assess the status of various threats (Table 5).

Table 1. Recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of Ungulate Winter Ranges (UWR) established for mountain goats in BC.

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
Proportion of area in established Ungulate Winter Range relative to available suitable winter range habitat	Routine	All suitable and occupied winter ranges protected/all capable winter ranges protected (depending on management objective, see text)	Once when winter ranges are being legally established	All suitable and occupied winter range habitat should be within boundaries of established Ungulate Winter Range or otherwise protected if the management objective is population maintenance. Additional habitat should be protected if the objective is to recover the local population.
Forest cover characteristics	Extensive	Contiguous old forest on ranges below tree line except for small openings associated with rock outcrops	Every 5 years	Forest cover is susceptible to blow-down, senescence of veteran trees and salvage (where allowed). Aerial or ground-based assessments are required.
Forage availability	Extensive	Abundant and available preferred	Every 5 years	Requires qualitative ground assessments. Forage availability is

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
		rooted forage and litterfall		influenced by growing conditions for rooted forage, forest canopy characteristics (amount and characteristics of litterfall – particularly Douglas-fir and lichen), and snow interception characteristics – shallower snow provides better access to available forage. Quantitative forage assessments could also be considered.
Snow depth and consolidation	Intensive	Shallow snows that do not affect the mobility of mountain goats or access to available, preferred forage	Depends on the frequency of severe winter conditions	The importance of winter ranges increases with winter severity; therefore, snow conditions should be assessed during average and severe winter conditions. General qualitative assessments can be made from the air or on the ground, but quantitative assessments, requiring ground reconnaissance (e.g., actual snow depth and sinking depth measures), are recommended.
Evidence of sustained winter use by mountain goats	Routine	Observations of mountain goats in designated UWR by commercial backcountry recreation operators	Annually	Commercial backcountry tenure holders are usually required to report wildlife sightings. These data can be used to determine occupancy of some winter ranges, although data will be incomplete and quality will vary. Information from other backcountry users can be gathered on an <i>ad hoc</i> basis.
Evidence of sustained winter use by mountain goats	Extensive	Evidence of browse, presence of pellet groups, tracks, direct observations	Every 3 years	Requires aerial surveys or ground reconnaissance.
Evidence of movement among winter range areas	Intensive	Telemetry locations indicating movement among winter range areas through different habitat conditions	In cooperation with research or inventory projects	Relocation frequency must be high to capture movements between winter ranges. Some information can also be inferred from track observations on winter survey flights, although this will be incomplete.

Table 2. Recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of wildlife habitat areas (WHAs) established for mountain goats in BC. WHAs are intended to protect critical natal ranges and patches of escape terrain.

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
Proportion of area in WHAs relative to abundance of natal range and escape terrain	Routine	Suitable and occupied natal range and escape terrain protected	Every 5 years	Preferably, all suitable natal ranges and escape terrain known to be used by mountain goats should be within the boundaries of WHAs, UWRs, or otherwise protected. The location of WHAs should be reviewed periodically and correlated with known mountain

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
				goat distributions (considering disturbance and other factors that could influence use).
Evidence of sustained use by mountain goats	Routine	Observations of mountain goats in designated WHAs by commercial backcountry recreation operators	Annually	Commercial backcountry tenure holders are usually required to report wildlife sightings. These data can be used to determine occupancy of some WHAs, although data will be incomplete and quality will vary. Information from other backcountry users can be gathered on an <i>ad hoc</i> basis.
Evidence of sustained use by mountain goats	Extensive	Pellet groups or direct observations of animals in WHAs	Every 3 years	Natal ranges should be surveyed on the ground in summer (i.e., post-kidding). Escape terrain can be surveyed by aerial reconnaissance.
Evidence of movement among WHAs and other suitable habitat	Intensive	Telemetry location indicating movement among WHAs and other suitable habitat	In cooperation with research or inventory projects	Relocation frequency must be high to capture detailed movements.

Table 3. Recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of wildlife habitat features (WHFs) established for mountain goats in BC. Wildlife habitat features are intended to protect linear features such as traditional trails and mineral licks.

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
Proportion of area in WHFs relative to abundance of known traditional trails and mineral licks	Routine	Traditional trails among range areas and between ranges and mineral licks protected	Every 5 years	Preferably, all traditional trails and mineral licks should be within the boundaries of WHFs or otherwise protected. The location of WHFs should be reviewed periodically and correlated with known mountain goat use (considering disturbance and other factors that could influence use). Not all trails and mineral licks will be known and the proportion protected will always be underestimated.
Evidence of sustained use by mountain goats	Extensive	Pellet groups or direct observations of animals using trails and mineral licks	Every 3 years	Use of trails might be difficult to capture without more intensive surveys.
Evidence of sustained use by mountain goats	Intensive	Telemetry locations or photo evidence of animals using trails and mineral licks	In cooperation with research or inventory projects	Telemetry or remote cameras can be used to monitor use of WHFs.
Forest cover characteristics adjacent to low-elevation trails	Extensive	Visual barrier adjacent to trails created by forests	Every 5 years	This is best provided by young or mature forest stands.

Table 4. Recommended demographic indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of mountain goat management in BC.

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
Absolute harvest by region	Routine	Neutral trend over time	Annually	Absolute harvest alone is insufficient to detect changes in population because it depends on hunting effort.
Hunting success (ratio of harvest to hunting effort) by region	Routine	Neutral or positive trend over time	Annually	This indicator can be confounded with increasing access (see text) and must be considered in relation to other indicators.
Index of population change by total count surveys (using a standard methodology) by Management Unit(s) or subregion(s)	Intensive	Neutral or positive trends over time	Every 3 years	Total counts are the most accurate indicator of population trends but are still subject to considerable uncertainty (see text). Areas to be surveyed need to be stratified to be practical because of the resources required. Generally requires aerial reconnaissance.
Proportion of adult females and kids in population	Intensive	Neutral or positive trend over time	Every 3 years	Indicator is sensitive to harvest and uncertainty regarding classification (see text). Requires aerial surveys or ground reconnaissance. Can be confounded by stochastic mortality factors (e.g., severe winters).

Table 5. Threat parameters and associated recommended indicators by level of intensity, desired conditions and monitoring frequency for assessing the effectiveness of mountain goat management in BC.

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
Mitigation, monitoring and reporting strategies for commercial recreation tenures using aircraft	Routine	Strategies in place and annual reports provided to WLAP for review	Annually	All commercial recreation tenure holders who operate near designated goat habitat should have mitigation strategies approved by WLAP in place that include a monitoring and reporting component.
Mitigation strategies for industrial activities	Routine	Strategies in place and reports provided to WLAP for review	Every 3 years	Mitigation strategies approved by WLAP for forestry, oil and gas and mineral exploration activities should be in place for all who operate near mountain goat habitat. Activity near designated habitats is expected to be lower than with tenured commercial recreation operators.
Presence/absence of roads near designated Ranges, Areas and Features	Routine	No permanent roads and minimal temporary roads <2 km of Ranges, Areas and Features, preferably no accessible roads <500 m	Every 3 years	The probability of disturbance and hunting vulnerability increases with the presence of roads <2 km from occupied mountain goat habitat (see text).
Proportion of females in the harvest	Routine	Neutral or negative trend over time	Annually	This indicator is largely dependent on hunting management strategies that attempt to minimize the

Indicator	Level of Intensity	Desired Condition/Result	Minimum Monitoring Frequency	Rationale and Comments
				proportion of females in the harvest.
Proportion of watershed harvested	Routine	Not available	Every 5 years	The degree of habitat modification outside designated Ranges, Areas and Features might influence movement of goats; however, thresholds or benchmarks are not known.
Density of roads in watershed	Routine	Not available	Every 5 years	The density of roads can be used as an index of the degree of industrial activity and the level of disturbance outside of designated areas. As with habitat modification, thresholds and benchmarks associated with mountain goat movements are unknown.

Recommended indicators can be cross-referenced with monitoring questions to provide an overview of monitoring requirements and their intensity and frequency (Table 6). No monitoring question can be addressed adequately by considering only routine indicators and additional monitoring will need to be adjusted on the basis of available resources.

Table 6. Monitoring questions in relation to recommended indicators, minimum monitoring intensity and frequency for monitoring the effectiveness of habitat management for mountain goats in BC.

Monitoring Frequency/Intensity	Routine	Extensive	Intensive
Annually			
Every 3 years			
Every 5 years or less frequently			

Monitoring Questions	Indicator
Small Scale: Does the Range, Area or Feature provide the habitat elements required to fulfil the life requisites of mountain goats for which it was established?	Forest cover characteristics (UWR and trails only)
	Forage availability (UWR only)
	Snow depth and consolidation (UWR only)
Small Scale: Is the Range, Area or Feature receiving sustained use by mountain goats?	Evidence of sustained use by mountain goats
Small Scale: Is human-related disturbance affecting use of the Range, Area or Feature by mountain goats?	Strategies for commercial recreation tenures using aircraft
	Strategies for industrial activities
	Presence/absence of roads near designated Winter Ranges
	Evidence of sustained winter use by mountain goats
Medium Scale: Are there barriers outside the Range, Area or Feature that prevent the movements of mountain goats between and among Ranges, Areas and Features?	Proportion of watershed harvested
	Density of roads in watershed
	Evidence of movement among managed areas
Medium Scale: Is the distribution and abundance of Ungulate Winter Ranges established for mountain goats sufficient to ensure sufficient over-winter survival in typical and severe winters?	Proportion of area managed in Ranges, Areas or Features relative to abundance
	Index of population change by total count surveys
	Proportion of adult females and kids
Medium Scale: Is the distribution and abundance of Wildlife Habitat Areas and Features sufficient to meet the life requisites of mountain goats (for which the Areas and Features were established) resident to the area of interest?	Index of population change by total count surveys

Monitoring Questions	Indicator
Large Scale: Is the distribution and abundance of Ranges, Areas and Features established for mountain goats sufficient to sustain the regional mountain goat population?	Proportion of area managed in Ranges, Areas or Features relative to abundance
	Absolute harvest
	Hunting success
	Index of population change by total count surveys
	Proportion of adult females and kids
Large Scale: Is the current suite of management practices sufficient to meet regional mountain goat objectives (e.g., maintenance or recovery)?	Proportion of females in the harvest
	Absolute harvest
	Hunting success
	Index of population change by total count surveys
	Proportion of adult females and kids

Knowledge Gaps

Although the recommended indicators address all key effectiveness monitoring questions, not all questions are addressed comprehensively. In general, knowledge gaps are more significant in relation to questions at broader spatial scales (Table 7).

Table 7. Key monitoring questions related to management of mountain goat habitat and associated knowledge gaps.

Monitoring Question	Knowledge Gap
Does the Range, Area or Feature provide the habitat elements required to fulfil the life requisites of mountain goats for which it was established?	<ul style="list-style-type: none"> Studies of basic mountain goat biology (movements, home range sizes, habitat use) have not been completed in some ecosystems in BC (e.g., Kispiox/Nass)
Is the Range, Area or Feature receiving sustained use by mountain goats?	<ul style="list-style-type: none"> None
Is the level of human-related disturbance tolerated by mountain goats using the Range, Area or Feature?	<ul style="list-style-type: none"> Tolerance of mountain goats for human-related activities is variable and definitive research related to all activities under all circumstances will likely never be available (Wilson and Shackleton 2001); however, evidence of sustained use addresses the monitoring question adequately
Are there barriers outside the Range, Area or Feature that prevent the movements of mountain goats between and among Ranges, Areas and Features?	<ul style="list-style-type: none"> The extent to which clearcuts and associated slash (and deep snow in winter), roads, immature forests and other landscape modifications create barriers to mountain goat movements is generally unknown (although relationships could be inferred from GPS telemetry studies; e.g., Taylor et al. 2004)
Is the distribution and abundance of Ungulate Winter Ranges established for mountain goats sufficient to ensure sufficient over-winter survival in typical and severe winters?	<ul style="list-style-type: none"> The distribution and abundance of different habitats required by a mountain goat population of a given size is not known; however, management can be based on either maintaining all suitable and occupied Ranges, Areas and Features (population maintenance objective) or all capable habitat (population recovery objective)
Is the distribution and abundance of Wildlife Habitat Areas and Features sufficient to meet the life requisites of mountain goats (for which the Areas and Features were established) resident to the area of interest?	
Is the distribution and abundance of Ranges, Areas and Features established for mountain goats sufficient for the regional mountain goat population?	
Is the current suite of management practices sufficient to meet regional mountain goat objectives (e.g., maintenance or recovery)?	<ul style="list-style-type: none"> Population indices are effective indicators of overall mountain goat management, but in the event of declining populations, the indices will not provide

Monitoring Question	Knowledge Gap
	information on which factors (e.g., insufficient winter range, movement or dispersal barriers, over-hunting, disturbance) are causing the declines

Management Recommendations

Monitoring the effectiveness of habitat management for mountain goats should involve the following components:

1. Establishing a regional or subregional management objective (i.e., population maintenance or population recovery);
2. Implementing procedures to collect, warehouse and analyze routine indicator data;
3. Allocating resources to collect extensive indicator data in areas of greatest management concern (e.g., evidence of sustained use data in Ranges, Areas or Features where the surrounding habitat is being modified extensively); and,
4. Collaborating with other agencies and researchers to collect intensive indicator data and to address knowledge gaps.

Literature Cited

- Adams, L. G., and J. A. Bailey. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. *Journal of Wildlife Management* 46:1003-1009.
- Bender, L. C., and Spencer, R. D. 1999. Estimating elk population size by reconstruction from harvest data and herd ratios. *Wildlife Society Bulletin* 27:636-645.
- Cichowski, D. B., D. Haas, and G. Schultze, 1991. A method used for estimating mountain goat numbers in the Babine Mountains Recreation Area, British Columbia. *Proceedings, Northern Wild Sheep and Goat Council Biennial Symposium* 9:56-64.
- Côté, S. D. 1996. Mountain goat responses to helicopter disturbance. *Wildlife Society Bulletin* 24:681-685.
- Côté, S. D., and C. Beaudoin. 1997. Grizzly bear (*Ursus arctos*) attacks and nanny-kid separation on mountain goats (*Oreamnos americanus*). *Mammalia* 61:614-617.
- Côté, S. D., and M. Festa-Bianchet. 2001a. Birthdate, mass and survival in mountain goat kids: effects of maternal characteristics and forage quality. *Oecologia* 127:230-238.
- Côté, S. D., and M. Festa-Bianchet. 2001b. Reproductive success in female mountain goats: the influence of maternal age and social rank. *Animal Behaviour* 62:173-181.
- Festa-Bianchet, M., M. Urquhart, and K. G. Smith. 1994. Mountain goat recruitment: kid production and survival to breeding age. *Canadian Journal of Zoology* 72:22-27.
- Foster, B. R., and E. Y. Raahs. 1983. Mountain goat response to hydroelectric exploration in northwestern British Columbia. *Environmental Management* 7:189-197.
- Foster, B. R., and E. Y. Raahs. 1985. A study of canyon-dwelling mountain goats in relation to proposed hydroelectric development in northwestern British Columbia, Canada. *Biological Conservation* 33:209-228.
- Fox, J. L., and C. A. Smith. 1988. Winter mountain goat diets in southeast Alaska. *Journal of Wildlife Management* 52: 362-365.
- Fox, J. L., C. A. Smith, and J. W. Schoen. 1989. Relation between mountain goats and their habitat in southeastern Alaska. US Department of Agriculture Forest Service General Technical Report PNW-GTR-246.
- Fox, J. L., and G. P. Streveler. 1986. Wolf predation on mountain goats in southeastern Alaska. *Journal of Mammalogy* 67:192-195.
- Gilbert, B. A., and K. J. Raedeke. 1992. Winter habitat selection of mountain goats in the North Tolt and Mine Creek drainages of the North Cascades. *Proceedings of the Eighth Biennial Symposium of the Northern Wild Sheep and Goat Council* 8:305-324.
- Gonzalez-Voyer, A., M. Festa-Bianchet, and K. G. Smith. 2001. Efficiency of aerial surveys of mountain goats. *Wildlife Society Bulletin* 29:140-144.
- Gordon, S. M. 2003. The behavioural effects of helicopter logging activity on mountain goat (*Oreamnos americanus*) behaviour. M.Sc. thesis, Royal Roads University, Victoria, BC.
- Gordon, S. M., and D. M. Reynolds. 2000. The use of video for mountain goat winter range inventory and assessment of overt helicopter disturbance. *Proceedings, Northern Wild Sheep and Goat Council Biennial Symposium* 12:26-35.
- Gordon, S. M. and S. F. Wilson. 2004. Effect of helicopter logging on mountain goat behaviour in coastal British Columbia. *Proceedings, 14th Northern Wild Sheep and Goat Council Biennial Symposium*, in press.

- Gove, N. E., Skalski, J. R., Zager, P., and Townsend, R. L. 2002. Statistical models for population reconstruction using age-at-harvest data. *Journal of Wildlife Management* 66:310-320.
- Gross, J. E., M. C. Kneeland, D. F. Reed, and R. M. Reich. 2002. GIS-based habitat models for mountain goats. *Journal of Mammalogy* 83:218-228.
- Hebert, D. M., and I. McT. Cowan. 1971. Natural salt licks as a part of the ecology of the mountain goat. *Canadian Journal of Zoology* 49:605-610.
- Hebert, D. M., W. M. Samuel, and G. W. Smith. 1977. Contagious ecthyma in mountain goat of coastal British Columbia. *Journal of Wildlife Diseases* 13:135-6.
- Hebert, D. M., and W. G. Turnbull. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia. *International Mountain Goat Symposium* 1:126-146.
- Hengeveld, P. E., M. D. Wood, R. Ellis, and R. Lennox. 2003. Mountain goat habitat supply modeling in the Mackenzie Timber Supply Area, north-central British Columbia. Version 1 – December 2003. Peace/Williston Fish & Wildlife Compensation Program Report Number 271.
- Hjeljord, O. 1973. Mountain goat forage and habitat preference in Alaska. *Journal of Wildlife Management* 37:353-362.
- Heinemeyer, K., T. Lind, and R. Tingey. 2003. Potential goat winter habitat model for the Central and North Coast Regions of British Columbia. Draft. Prepared for: The Coast Information Team and Ecological Spatial Analysis Team.
- Jex, B. 2004. Analysis of the topographic habitat attributes for mountain goat (*Oreamnos americanus*) winter ranges on the south-coast of British Columbia. BC Ministry of Water, Land and Air Protection, Surrey.
- Jones, R. L., and H. C. Hanson. 1985. Mineral licks, geophagy, and biogeochemistry of North American ungulates. Iowa University Press, Ames.
- Keim, J. 2004a. Confirming winter mountain goat habitats from a habitat suitability model in the Bell II study area. Proceedings, 14th Northern Wild Sheep and Goat Council Biennial Symposium, in press.
- Keim, J. 2004b. Modeling core winter habitats from habitat selection and spatial movements of collared mountain goats in the Taku River drainage of north-west British Columbia. Proceedings, 14th Northern Wild Sheep and Goat Council Biennial Symposium, in press.
- Leigh-Spencer, S. 1997. Mountain goat and black-tailed deer winter habitat assessment in the Potlach, McNab, Sechelt, Rainy, and McNair drainages. Prepared for: Canadian Forest Products Limited, Howe Sound Operations, Mainland Logging Division, Port Mellon, BC.
- Lemke, S. L. 1999. Cayoosh range mountain goat study results and recommendations. Prepared for: BC Ministry of Environment, Lands and Parks, and Ainsworth Lumber Company Limited, Savona, BC.
- McCullough, D. R. 1994. What do herd composition counts tell us? *Wildlife Society Bulletin* 22:295-300.
- Pedevillano, C., and R. G. Wright. 1987. The influence of visitors on mountain goat activities in Glacier National Park, Montana. *Biological Conservation* 39:1-11.
- Phelps, D. E., B. Jamieson, and R. A. Demarchi. 1983. The history of mountain goat management in the Kootenay Region of British Columbia. BC Fish and Wildlife Branch, Fish and Wildlife Bulletin No. B-20.
- Pollard, B. T. 2002. Mountain goat winter range mapping for the North Coast Forest District. Prepared for: The North Coast Land and Resources Management Planning Team and the Land Use Coordination Office, Victoria, BC.
- Poole, K., and D. C. Heard. 1998. Habitat use and movements of mountain goats as determined by prototype GPS collars, Robson Valley, British Columbia. Unpublished manuscript.

- RIC (Resources Inventory Committee). 2002. Aerial-based inventory methods for selected ungulates: bison, mountain goat, mountain sheep, moose, elk, deer and caribou. BC Ministry of Sustainable Resource Management, Victoria.
- Samuel, M D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. *Journal of Wildlife Management* 51:622-630.
- Schoen, J. W., and M. D. Kirchhoff. 1982. Habitat use by mountain goats in southeast Alaska. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Project.
- Shackleton, D. M. [editor]. 1997. Wild sheep and goats and their relatives. Status survey and conservation action plan for Caprinae. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland and Cambridge, UK.
- Shackleton, D. M. 1999. Hoofed mammals of British Columbia. Royal British Columbia Museum, Victoria, and UBC Press, Vancouver, BC.
- Skalski, J. R., and Millspaugh, J. J. 2002. Genetic variance expressions, precision, and sampling optimization for the sex-age-kill model of population reconstruction. *Journal of Wildlife Management* 66:1308-1316.
- Smith, B. L. 1988. Criteria for determining age and sex of American mountain goats in the field. *Journal of Mammalogy* 69:395-402.
- Taylor, S. D., W. Wall and Y. Kulis. 2004. A GPS-telemetry study of mountain goat habitat use in south coastal B. C. Interfor, Campbell River, BC and Forest Investment Account, British Columbia.
- Thompson, B. C., and B. W. Baker. 1981. Helicopter use by wildlife agencies in North America. *Wildlife Society Bulletin* 9:319-323.
- Turney, L., and R. Blume. 2004. Daily and seasonal movement patterns of mountain goats to a mineral lick in north-central British Columbia. Proceedings, 14th North Wild Sheep and Goat Council Biennial Symposium, in press.
- Wilson, S. F. 2004. Desired conditions for coastal mountain goat winter range. Prepared for: BC Ministry of Water, Land and Air Protection, Victoria.
- Wilson, S. F., and D. M. Shackleton. 2001. Backcountry recreation and mountain goats: a proposed research and adaptive management plan. BC Ministry of Environment, Lands and Parks Wildlife Bulletin B-103.
- Wilson, S. F., and D. Hamilton. 2005. A strategy to manage backcountry recreation in relation to wildlife and habitats. Version 1.0. Prepared for BC Ministry of Water, Land and Air Protection, Victoria.