Northern Wild Sheep and Goat Council

PROCEEDINGS OF THE 14TH BIENNIAL SYMPOSIUM

May 15-22, 2004
Alaska's Inside Passage

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Northern Wild Sheep and Goat Council

Northern Wild Sheep and Goat Council Symposia

Date	**Symposium**	**Location**	**Symposium Coordinator/Chair**	**Proceedings Editor(s)**	**NWSGC Executive Director**
May 26-28, 1970	NWSC 1	Williams Lake, BC	Harold Mitchell		
April 14-15, 1971	NAWSC 1	Fort Collins, CO	Eugene Decker/Wayne Sandfort	Eugene Decker	
April 11-13, 1972	NWSC 2	Hinton, AB	E.G. Scheffler		
April 23-25, 1974	NWSC 3	Great Falls, MT	Kerry Constan/James Mitchell		
Feb. 10-12, 1976	NWSC 4	Jackson, WY	E. Tom Thorne		
April 2-4, 1978	NWSGC 1	Penticton, BC	Daryll Hebert/M. Nation	Daryll Hebert/M. Nation	
April 23-25, 1980	NWSGC 2	Salmon, ID	Bill Hickey		
March 17-19, 1982	NWSGC 3	Fort Collins, CO	Gene Schoonveld	James Bailey/Gene Schooneveld	
Apr. 30-May 3, 1984	NWSGC 4	Whitehorse, YK	Manfred Hoefs	Manfred Hoefs	Wayne Heimer
April 14-17, 1986	NWSGC 5	Missoula, MT	Jerry Brown	Gayle Joslin	Wayne Heimer
April 11-15, 1988	NWSGC 6	Banff, AB	Bill Wishart	Bill Samuel	Wayne Heimer
May 14-18, 1990	NWSGC 7	Clarkston, WA	Lloyd Oldenburg	James Bailey	Wayne Heimer
Apr. 27-May 1, 1992	NWSGC 8	Cody, WY	Kevin Hurley	John Emmerich/Bill Hepworth	Wayne Heimer
May 2-6, 1994	NWSGC 9	Cranbrook, BC	Anna Fontana	Margo Pybus/Bill Wishart	Kevin Hurley
Apr. 30-May 3, 1996	NWSGC 10	Silverthorne, CO	Dale Reed	Kevin Hurley/Dale Reed/Nancy Wild (compilers)	Kevin Hurley
April 16-20, 1998	NWSGC 11	Whitefish, MT	John McCarthy	John McCarthy/Richard Harris/Fay Moore (compilers)	Kevin Hurley
May 31-June 4, 2000	NWSGC 12	Whitehorse, YK	Jean Carey	Jean Carey	Kevin Hurley
April 23-27, 2002	NWSGC 13	Rapid City, SD	Ted Benzon	Gary Brundige	Kevin Hurley
May 15-22, 2004	NWSGC 14	Coastal Alaska	Wayne Heimer	Wayne Heimer/Dale Toweill/Kevin Hurley	Kevin Hurley

GUIDELINES OF THE NORTHERN WILD SHEEP AND GOAT COUNCIL

The purpose of the Northern Wild Sheep and Goat Council is to foster wise management and conservation of northern wild sheep and goat populations and their habitats.

This purpose will be achieved by:

1) Providing for timely exchange of research and management information;

2) Promoting high standards in research and management; and

3) Providing professional advice on issues involving wild sheep and goat conservation and management.

I The membership shall include professional research and management biologists and others active in the conservation of wild sheep and goats. Membership in the Council will be achieved either by registering at, or purchasing proceedings of, the biennial conference. Only members may vote at the biennial meeting.

II The affairs of the Council will be conducted by an Executive Committee consisting of: three elected members from Canada; three elected members from the United States; one ad hoc member from the state, province, or territory hosting the biennial meeting; and the past chairperson of the Executive Committee. The Executive Committee elects it's chairperson.

III Members of the Council will be nominated and elected to the executive committee at the biennial meeting. Executive Committee members, excluding the ad hoc member, will serve for four years, with alternating election of two persons and one person of each country, respectively. The ad hoc member will only serve for two years.

The biennial meeting of members of the Council shall include a symposium and business meeting. The location of the biennial meeting shall rotate among the members' provinces, territories and states. Members in the host state, province or territory will plan, publicize and conduct the symposium and meeting; will handle its financial matters; and will prepare and distribute the proceedings of the symposium.

The symposium may include presentations, panel discussions, poster sessions, and field trips related to research and management of wild sheep, mountain goats, and related species. Should any member's proposal for presenting a paper at the symposium be rejected by members of the host province, territory or state, the rejected member may appeal to the Council's executive committee. Subsequently, the committee will make its recommendations to the members of the host state, territory or province for a final decision.

The symposium proceedings shall be numbered with 1978 being No. 1, 1980 being No. 2, etc. The members in the province, territory or state hosting the biennial meeting shall select the editor(s) of the proceedings. Responsibility for quality of the proceedings shall rest with the editor(s). The editors shall strive for uniformity of manuscript style and printing, both within and among proceedings.

The proceedings shall include edited papers from presentations, panel discussions or posters given at the symposium. Full papers will be emphasized in the proceedings. The editor will set a deadline for submission of manuscripts.

Members of the host province, territory, or state shall distribute copies of the proceedings to members and other purchasers. In addition, funds will be solicited for distributing a copy to each major wildlife library within the Council's states, provinces, and territories.

IV Resolutions on issues involving conservation and management of wild sheep and goats will be received by the chairperson of the Executive Committee before the biennial meeting. The Executive Committee will review all resolutions, and present them with recommendations at the business meeting. Resolutions will be adopted by a plurality vote. The Executive Committee may also adopt resolutions on behalf of the Council between biennial meetings.

V Changes in these guidelines may be accomplished by plurality vote at the biennial meeting.

2004 NWSGC Symposium FOREWORD

The majority of papers/abstracts included in these proceedings were presented during the 14th Biennial Symposium of the Northern Wild Sheep and Goat Council, held May 15-22, 2004 along Alaska's Inside Passage. Additional papers/abstracts were included herein to provide NWSGC members and other readers with pertinent information on the management of wild sheep and mountain goats.

Manuscripts published herein were reviewed by session moderators. Some papers were submitted to additional peer biologists/researchers for review. This ensured that all manuscripts received independent review prior to publication. Reviews were returned to authors, and final papers were forwarded to editors for incorporation. Final content was left to the authors and therefore, readers are responsible for the critical evaluation of information presented in these proceedings.

A heartfelt thanks is extended to the sponsors of, and participants in, the 14th Biennial NWSGC Symposium. Wayne Heimer organized the sessions, led the program and editing of these proceedings; Ms. Karen Gordon arranged many logistical elements of this symposium; our thanks to them both for their efforts.

Kevin Hurley
NWSGC Executive Director
February 28, 2006

14th Biennial Symposium Northern Wild Sheep and Goat Council

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PROGRAM CHAIR’S OPENING REMARKS NWSGC SYMPOSIUM 2004

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> *"Clement Greenburg wrote the gospel and the word on universal form and beauty. Since the post moderns came, its never been the same, 'cause they don't give a flyin' fig newtie. From No-Fi Soul Rebellions "The Artists" (The Chocolate Demos, by No-Fi Soul Rebellion, 2001)*

While it may be seem harsh to suggest that wildlife biologists or agency leaders "don't give a flyin' fig newtie," I argue that wildlife management is now in what we may properly understand as a "postmodern" period.

The term, postmodern, reflects divergence from the observational, experimental, and sensual bases which have characterized what we (at least the living fossils among us) were taught define the "scientific method." Most basically, postmodern thinking does not recognize truth or fact as existing apart from the observer. Instead, the basis of postmodernism is the concept that the "scientific method," while an interesting concept, is functionally obsolete, and that a higher and purer truth is defined by each individual for him or her self. Plainly put, intuitive feelings trump data-based facts (which can always be interpreted by any observer through his subjective lens). Postmodernism has demonstrably affected every discipline from art to theology. In these disciplines postmodern influences have redefined "beauty" and, in the end, "truth" in subjective rather than objective terms.

Having progressed from, art ("A") through theology ("T") it would be highly unusual in the human experience if wildlife management had escaped the effects of postmodern thought. It seems bound to have happened sooner or later. I suggest it happened "sooner," and our collective profession simply failed to recognize it. I think we, collectively, overlooked the postmodern influence because those of us in the field considered the scientific method above question. Our naivete as compounded by idealistically-driven disciples **[**Alaska friends: here I think of Haber, Joslin, Kline, Cline, Vanballenberghe, Schoen, etc.--it may be possible to relate this (postmodernism) to the emergence of "conservation biology" as an alternative to wildlife management WEH**]** of postmodern thought who argued, while cloaked in their scientific credentials, that data mean anything any "scientist" wants/interprets it to mean. Hence, we struggle to make fact-based management relevant to a postmodern world. It's a tough job.

Through archaic application of empirical observations, I hypothesize the impetus for postmodern thought in wildlife management came from postmodernists who rose to leadership positions in management agencies. This, I suggest, was not a conscious abandonment of their training as scientists, but a subtle erosion of "modern (but socially archaic, i.e. scientific), principles occasioned by the perceived need to make their agencies appear relevant to a sociopolitical system which was generally trending toward postmodernism. This sociopolitical system has influenced our profession because it controls budgets and allocated effort. I suggest our leaders simply didn't recognize it for what it was.

The relevance of these societal trends to this symposium is that they define the context of the working hypothesis concept embraced by this (and the Desert) Council in 1999 at the 2nd North American Wild Sheep Conference.

One of the primary goals for our "drinking together" (the literal meaning of the Greek word, symposion, from which we derive the English, symposium) of ideas is articulation of a working hypothesis for mountain goats. The other is to share new findings from our collegial efforts to better define and refine the working hypotheses articulated previously for wild sheep.

In retrospect, I see the conception and evolution of the working hypothesis as the field biologists' attempt to mitigate the effects of postmodernism in wildlife management.

Wildlife management may fairly be said to have begun with the Roosevelt Doctrine. This Doctrine held that the best management would be based on the best science. This would be archaic "modern science" as opposed to what has resulted from the marriage of science with postmodernism.

Well after postmodern thought had began to affect wildlife management, the first definable call back toward "modernism" was Val Geist's notion of managing within the framework of species adaptation to environment. This call to manage on the basis of species autecology was all but lost on the management community because it had, by then, set its course toward ever iterative definition of the responses of populations to stochastic events. That is, "our professional focus" had been narrowed to defining the statistical probability of occurrence or recurrence of measurable individual or population behaviors to environmental variables.

Without the guidance of a broader, "modern," but not necessarily contemporary perspective of species management, "ecosystem management" became the postmodern manager’s mantra. As a result, our discipline, lead by its researchers began to drift from what we would call "applied research" today. Collectively we began to pursue the esoteric.

I argue this charge, while it may rankle us collectively, should be considered as though legitimate; and should come as no surprise. The trend toward the esoteric research is, after all, a natural result of life in those academic institutions that trained and credentialed us as scientific wildlife managers. These colleges and universities are, after all, modeled on the great German research universities where learning for its own sake was initially codified. The results have included ever-more iterative quantitative studies cloaked in the rubric of "hypothesis testing," which came into vogue almost 20 years ago.

At the time, "hypothesis testing" seemed a rational return to the then-dying "modernism" of the scientific method, but the effort did not produce the anticipated results. In broader retrospect, I suggest management success declined due to absence of a vision with greater breadth than "doing the next experiment" required by the logic of sequential learning.

Through bitter experience, I finally tumbled to the notion that the search for a safe probability envelope in which to manage was not succeeding. Without any clue as to the cause (postmodern influence) I speculated that management success would follow a return to the "modernism" of a working management hypothesis. I argued management success should attend synthesis of the species-specific knowledge generally predicting responses of any managed species to the challenges/opportunities which seemed certain to arise in the course of day to day management. Our existing working hypotheses for wild sheep were designed to fill this need for a "digest" of what we know, and what a manager or planner unfamiliar with species autecology might expect from any challenged species based on its suite of adaptations and specific case studies.

There are, however, at least two weaknesses in this system.

First, we may succumb to our inherent prejudices and simply define a working hypothesis as a listing of facts or studies which have the imprimatur of reviewed publication. The great risk here is that we may come up with a composite recipe for species management that may not be consistent with the suite of adaptations evolution has broadly conferred on wild sheep and mountain goats. Most of these studies are "small" and site specific, and produced focused results. Should we pursue this course increased management success will be unlikely to follow.

The second great risk is that we will simply give up on management according to the Roosevelt Doctrine because it is considered archaic in the postmodern world. Attempting to turn the clock back almost a century to reestablish "modern" scientific management as foreseen by Teddy Roosevelt and his Canadian friends is an arduous task, and could prove hazardous to your career.

With these perspectives and possibilities in mind, let us continue the great adventure which has always been, and remains modern (but is now considered archaic) science. It has, after all, been the engine producing the most productive wildlife conservation system in the history of our planet.

Let the games begin!

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A WORKING HYPOTHESIS FOR MANAGEMENT OF MOUNTAIN GOATS

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Abstract: Mountain goats are unique to western North America, where they occupy steep and mountainous terrain from sea level to over 12,000 foot elevations, and are adapted to harsh climates featuring high winds, rain, and snow. Intermediate browsers, mountain goats feed on grasses and forbs when available but turn to shrubs and browse seasonally. By exploiting steep rocky habitats not favored by other ungulates, mountain goats face little competition from other herbivores. Although mountain goat populations may expand rapidly where food resources are abundant, continuous occupation of limited terrain often results in low density somewhat stable populations across large areas of suitable habitat. Population growth following herd reduction is slow, due to relatively low reproductive rates, high mortality, and a low propensity for dispersal. As a result, mortality associated with hunting can be entirely additive to population losses from natural events, making management of hunted mountain goat populations challenging. In addition, population information is difficult to obtain due to low population density, difficult terrain, and adverse behavioral impacts associated with aerial surveys. We review recent mountain goat management literature, with special emphasis on harvest management, diseases and parasites of mountain goats, and behavioral responses to human-related disturbance, and summarize mountain goat management approaches.

Mountain goats (*Oreamnos americanus*) are restricted to North America. All mountain goats are considered to be a single species. A second species, *Oreamnos harringtoni* existed south of current mountain goat ranges in the southwestern United States until about 11,000 years BP (Kurten and Anderson 1980). Subspecies (four have been proposed) are not currently recognized (Côté and Festa-Bianchet 2003).

Mountain goats are not true goats (which belong to the genus *Capra*). Rather, mountain goats are grouped with the ghoral (*Nemorhaedus goral*) and serow (*Capricornis* sp.) of Asia and the chamois (*Rupicapra* sp.) of Europe into the tribe **Rupicaprini**, referred to as 'goat-antelopes'

(Eisenberg 1981). Pielou (1979) identified ancestral forms of the mountain goats among the many species of large mammals that evolved in Asia and moved across Beringia into North America in the mid- to late Pleistocene, only to be forced southward by later glaciations. Subsequent isolation allowed mountain goats to diverge from ancestral forms and evolve as a habitat specialist in the absence of true goats.

Ecological Niche

Mountain goats in North America fill the niche occupied by true goats in Asia and Europe, that of a short-legged, sure-footed grazer of rocky, steep slopes. Geist (1974) cited physiological (lack of sexual dimorphism, primitive horn shape) and behavioral (female dominance, primitive fighting strategies) evidence to hypothesize that mountain goats are primitive ungulates that evolved in response to severe climate and predation pressures.

Habitat Selection

Mountain goats typically select steep slopes and adjacent alpine areas at 4,500 to 8,000 feet in elevation, typically occupying subalpine and alpine habitats where trees are either absent or scattered (Smith 1977). However, mountain goats winter near sea level in the rugged ranges of southeast Alaska and British Columbia (Hebert and Turnbull 1977), and occur at elevations >12,000 feet in Colorado's Rocky Mountain Range (Hibbs 1967). Unlike bighorn sheep, mountain goats are tolerant of western slopes receiving high amounts of precipitation as rainfall, although their northern range is limited above the Arctic Circle, perhaps because of the long periods of extended darkness that precludes their moving about in steep, snow and ice-covered habitats (Geist 1971).

Habitats selected by mountain goats are often characterized by harsh climates-frequent strong winds, high snowfall, and snow accumulations persisting >8 months annually. Mountain goats may move to lower elevations to escape the most severe of winter weather, but animals often winter in small, protected micro-habitats characterized by steep snow-shedding slopes, where high winds preclude snow accumulation and south-facing slopes warm quickly when exposed to the sun. In some habitats, wind action reduces snow cover at higher elevations, and in these areas mountain goats may winter at higher elevations than used during summer months.

Diet and Nutrition

Mountain goats are intermediate browsers, feeding primarily on grasses during the summer (Laundré 1994). Alpine shrubs and browse constitute nearly half of the summer diet. Grass is also used preferentially during fall and winter when it is exposed, but in areas where grasses are covered by snow, mountain goats readily switch to a diet of browse including curlleaf mountain-mahogany (*Cercocarpus ledifolius*) and conifers such as Engleman spruce (*Picea englemannii*) and alpine fir (*Abies lasiocarpa*). Where available, mosses and lichens may also be selected (Cowan 1944, Harmon 1944, Casebeer 1948, Brandborg 1955, Saunders 1955, Geist 1971, Hjeljord 1971, Peck 1972, Hjeljord 1973, Bailey et al. 1977, Adams 1981, Adams and Bailey 1983, Fox and Smith 1988; *for reviews, see* Laundré 1994, Côté and Festa-Bianchet 2003).

Perhaps due in part to the shallow, undeveloped soils typical of many mountain goat habitats, mountain goats seem very sensitive to nutrition level and availability of supplemental minerals. Smith (1976) reported a correlation between female nutrition and kid:nanny ratios, and Bailey (1986) reported that availability of summer forage was related to pregnancy rate. Fox et al. (1989) reported that winter forage was critical both to adult over-winter survival and fetal development. Mountain goats may travel long distances to obtain trace minerals from the soil at natural or artificial 'mineral licks' (Hebert and Cowan 1971, Adams 1981, Singer and Doherty 1985, Hopkins et al. 1992), and may be particularly susceptible to selenium deficiency (Hebert and Cowan 1971).

Movement Patterns and Dispersal

As habitat specialists, mountain goats evolved to occupy steep rocky terrain where there was little competition with other ungulates for forage and little risk from predators. However, as pointed out by Geist (1982), such a predator-avoidance strategy inevitably limits the size of mountain goat populations. If mountain goats are limited by distance to escape cover, only a fixed amount of habitat is available—and increases in population size must be associated with reduced resources available per animal, or population density. To avoid over-crowding, mountain goats must defend individual territories. Further, to maximize reproductive fitness in a polygamous mating system, females and their offspring must be able to select the best and most secure habitats. All of these hypotheses appear to apply to mountain goat populations.

Population fitness can be optimized by strategies that include maximizing the amount of area used daily and seasonally (i.e., relatively large daily movement patterns and seasonal migrations) and behaviors that segregate areas used by females and kids from those used by males.

Nursery groups (females and their offspring including males to 2 years of age) typically move greater distances daily (2-5 km) than males (<1 km/day) (Singer and Doherty 1985, Côté and Festa-Bianchet 2003). Females were reported to move nearly twice as far each day (~1 km) as males (Singer and Doherty 1985), and to have much larger home ranges (25 km^2 as compared with 5 km^2 for males) in Alberta (Côté *in* Côté and Festa-Bianchet 2003), although such a large discrepancy was not noted in some other studies (Rideout 1977, Singer and Doherty 1985).

Seasonal migrations of mountain goats have been widely reported where more-or-less continuous habitat exists. Most commonly, seasonal movements result in the animals moving to lower elevations at or just above tree-line or slopes with southern exposures (Brandborg 1955, Hjeljord 1973, Smith 1976, 1977, Rideout 1977). In coastal Alaska and British Columbia, mountain goats may descend to near sea level and winter in coniferous forests (Hebert and Turnbull 1977, Fox 1983).

In summer, males may venture into forested areas away from steep slopes to feed, while females and kids usually feed on or in immediate proximity to steep slopes used to escape potential predators. Even during winter, the sexes may separate. Males may occupy areas with deeper snow than females, and individuals of either sex may select a favorable microhabitat (such as a monolith or rocky slope surrounded by timber) and over-winter individually in tiny (0.5 to 1.5 km^2) seasonal home ranges (Keim 2004).

In addition to such repeatable movements associated with daily foraging, trips to mineral licks outside of normal home range areas, and seasonal migrations, mountain goats may make extended 'exploratory' movements through unoccupied terrain. Although young males (ages 1-3) are most likely to disperse into unoccupied habitats (Stevens 1983), adult animals of either sex may make such moves. These movements often take the form of searching apparently suitable habitats visible from occupied habitat; i.e., an individual animal of either sex may move from an occupied habitat to a visible rocky monolith or step slope, passing through miles of forested land to do so.

The ability of mountain goats to cross apparently unsuitable low-elevation and forested terrain to establish new populations was recently documented by Lemke (2004) in southern Montana, where mountain goats have expanded their range into a previously unoccupied area (the Gallatin Mountain Range) and southward into Yellowstone National Park in Wyoming. Another well-documented example is the colonization of the Olympic Peninsula (Houston et al. 1994).

As habitat specialists, mountain goats are superb colonizers (Kuck 1977, Adams and Bailey 1982, Swenson 1985, Kuck 1986, Houston and Stevens 1988, Hayden 1989, Houston et al. 1994, Lemke 2004). Mountain goats readily adapt to new habitats following transplants, and they readily colonize habitats formerly inaccessible because of snow and ice cover (i.e., retreating glaciers and snowfields) or vegetation (occupying burned-over habitats formerly forested). In these situations, mountain goat populations typically exhibit high pregnancy and twinning rates (associated with a high plane of nutrition) along with high rates of survival. During the initial expansion phase of population growth (Caughley 1970), the annual growth rate in Idaho was 22% (Hayden 1989) and was 35% in Wyoming's Yellowstone National Park (although this estimate was likely inflated by continued immigration). Similarly, rapid population increases have been noted in other states (North Dakota, Oregon, Utah, and Wyoming) following transplants.

The period of initial expansion is followed (Caughley 1970) by a period of population stabilization as available habitat becomes fully occupied and density-dependent factors begin limiting further population expansion, followed typically by a phase of population decline as mountain goats become limited by food resources, predators, and diseases. Older populations persist at some 'post-decline' level dictated by range condition (Bailey 1991), weather, predators and disease. Data from Idaho (Toweill 2004) indicates that this cycle, from transplant to post-decline, may occur over a period of 30-40 years.

Population Biology

Mountain goats breed between early November and mid-December (Geist 1964), with males moving among groups of females and tending estrous nannies for 2-3 days (DeBock 1970, Chadwick 1983). In most populations, nannies reach sexual maturity at age two and produce their first kid at age three (Peck 1972, Stevens 1980, Bailey 1991), while in others age at first breeding is three years (Festa-Bianchet et al. 1994). This delay in sexual maturity dramatically reduces the potential for rapid growth in mountain goat populations (Lentfer 1955, Hayden 1990). Twinning rates are generally low, but can be higher in expanding populations on good ranges (Holroyd 1967, Hibbs et al. 1969, Hayden 1989, Foster and Rahs 1985, Houston and Stevens 1988). Nannies rarely bear triplets (Hayden 1989, Hanna 1989, Lentfer 1955, Hoefs and Nowlan 1998).

Mountain goat kids are precocious and begin to forage and ruminate within days after birth (Brandborg 1955, Chadwick 1983). After approximately 2 weeks of seclusion, nannies with new kids form nursery groups with other nannies and kids, which often include yearlings. During this period, 2 year-old billies generally leave the nursery herd and remain solitary or form small groups of males. Kids remain with their mothers through their first winter, and although the presence of the mother is thought to increase survival of kids, orphaned kids can survive (Foster and Rahs 1982). Once sexually mature, reproductive success generally increases and peaks at 8 years of age, at which point it declines (Stevens 1980, C.A. Smith 1984, Bailey 1991).

Productivity is often presented in the form of kid:100 adult ratios, kid:100 non-kids (kid:100 older goats), or kids:100 females. Care must be taken interpreting such data, as kid:100 adult ratios are frequently reported when yearlings and two-year-olds are not separated from adults in classifications, meaning they are actually kid:100 older goat ratios. Substantial variation exists among locations and among years within a single location (Table 1). Bailey and Johnson (1977) found productivity of introduced herds ranged from 36-100 kids:100 non-kids (average 59:100), while kid:non-kid ratios in native herds ranged from 9-52:100 (average 28:100) and postulated population density influenced goat reproduction. Adams and Bailey (1982) documented kid production declines as populations increased in Colorado.

Because the representation of males and females is unknown when goats are classified as kids and non-kids, variable male abundance can affect interpretations of productivity based on kid:100 adult ratios. For example, a comparison of unhunted or lightly hunted mountain goat herds with heavily hunted herds revealed kid:100 non-kid ratios of 32:100 and 31:100, respectively (Hebert and Turnbull 1977). However, the unhunted/lightly hunted herd had a kid:100 female ratio of 82:100, while the heavily hunted herd had a kid:100 female ratio of 52:100. As a result, where effort is made to gather more detailed classification information, kid:100 female and yearling:100 female ratios can be of additional help when monitoring populations.

Reported ratios of kids:100 females (Table 1) ranged from 15-73:100 and averaged 40:100 in British Columbia (Hebert and Turnbull 1977). In Idaho, Brandborg (1955) found kid:100 female ratios from 22-79:100; Hayden (1989) reported 57-83 kids per 100 nannies in a rapidly-growing herd in the Snake River Range. Anderson (1940) found 73 kids:100 females in Washington. Kid:100 female ratios in the Sawtooth Range of Montana ranged from 46-78:100 (M.J. Thompson 1981) and 49-67:100 in the Absaroka Range (Varley 1996). Yearling:100 female ratios in British Columbia were 3-41:100 and averaged 16:100 (Hebert and Turnbull 1977). Brandborg (1955) documented yearling:100 female ratios of 10-39:100 along the Salmon and Selway Rivers in Idaho. Varley (1996) found yearling:100 female ratios that ranged from 17-47:100 in the Absaroka Mountains of Montana.

Mortality

Mountain goats have adapted to harsh environments through a strategy that focuses more on the survival of individual goats than on production of offspring (Hayden 1990). Severe winters and their impact upon availability of winter forage and energy expenditure (Dailey and Hobbs 1989) have been frequently hypothesized as the primary factor leading to mortality among mountain goats. A negative correlation has been found between snow depth and kid:adult ratios (Adams and Bailey 1982), while a positive relationship was found between reproductive rates and total winter precipitation 1.5 years prior to birth (Stevens 1983). In Alaska, severe winters were correlated with poor reproduction the following spring (Hjeljord 1973).

Documented annual mortality rates in Alaska were 29% for yearlings, 0-9% for age classes 2-8, and 32% for goats older than 8 years (C.A. Smith 1986). Goats older than 8 died primarily from predation or other natural factors, while hunting was the primary cause of mortality among prime-aged goats. Annual mortality in Alberta was 28% for yearling males and 16% for yearling females (Festa-Bianchet and Cote' 2002). Mortality of males from 4-7 years was 5%, but increased dramatically after 8 years. Between ages 2 and 7, mortality of females was 6%. As a result of mortality and emigration, only 39% of yearling males were still present in the population as 4 year olds. In a rapidly growing population in Idaho, kid mortality was only 12% and yearling mortality only 5% (Hayden 1989). Forty percent mortality was documented among marked kids in the Black Hills of South Dakota; yearling and older goat mortality was estimated to be 14% (Benzon and Rice 1988).

Mortality of young goats can be high during their first winter. Kid and yearling mortality during a severe winter was 73% and 59%, respectfully, while only 27% and 2%, respectively during a mild winter (Rideout 1974*b*). During a series of severe winters in Colorado, kid mortality reached 56% and kid:adult ratios dropped from 48:100 to 14:100 (R.W. Thompson 1981). Total population declines of 82-92% occurred following severe winters in coastal British Columbia (Hebert and Langin 1982).

Grizzly bears (Festa-Bianchet et al. 1994, Jorgenson and Quinlan 1996, Cote' and Beaudoin 1997), wolves (Fox and Streveler 1986, C.A. Smith 1986, Jorgenson and Quinlan 1996, Cote' et al. 1997), mountain lions (Brandborg 1955, Rideout and Hoffman 1975, Johnson 1983), coyotes (Brandborg 1955), golden eagles (Brandborg 1955, B.L. Smith 1976), and wolverines (Guiguet 1951) have all been identified as predators of mountain goats. In west-central Alberta, juvenile annual mortality was 42%, with most mortality occurring prior to November (Smith et al. 1992). A total of 88% of this mortality was predation by wolves, grizzly bears, and mountain lions. Upon completion of this project, a majority of kid mortality was attributed to grizzly bears (Festa-Bianchet et al. 1994). In Alaska, goat remains were found in 62% of wolf scats (Fox and Streveler 1986), while only 2% of wolf scats from Banff National Park in Alberta contained goat remains (Huggard 1993). In Yellowstone National Park, there have been 2 confirmed wolf kills of mountain goats out of approximately 3,000 confirmed kills (D.W. Smith, National Park Service, personal communication).

Population Monitoring

Preseason aerial classification and trend surveys are the most cost effective and practical method for collecting data on population status. Managers use classification data to monitor productivity, while population trends are established through trend counts. Ground classifications can provide more detailed information on productivity and yearling recruitment, as determination of sex and age is possible.

Throughout most of the year goats tend to be scattered widely in rugged, partially timbered terrain, making it difficult and costly to obtain adequate samples. Many goat populations have average group sizes of 5 or less (Hebert and Wood 1984, Varley 1996, Poole et al. 2000), which can make detection difficult. However, goats tend to congregate in larger groups in late spring to early summer as they stage on windswept, grassy plateaus before moving to summer range at higher elevations. In Wyoming, larger groups of goats can usually be found and classified in early to mid July. Weather influences goat activity, habitat use, and sightability, as goats experience activity peaks during clear weather at sunrise and sunset and use more gentle topography farther from secure terrain (Fox 1978). Mornings after severe storms with lightning should be avoided since goats will move to lower elevations with denser vegetative cover to avoid these events. Similarly, periods when goats seek thermal cover in timber should also be avoided when conducting surveys.

Sex cannot be reliably distinguished among goats < 1 year, and horn characteristics used to distinguish sex are not apparent until 2 years of age. Methods used to classify sex of goats in the field are: 1) observation of genitals – the male's scrotum can be seen in summer but the goat's long pelage obscures the scrotum in winter, and a black vulva patch is visible on females $\geq$ 1 year when the tail is raised; 2) urination posture – male goats "stretch" when urinating whereas females "squat"; 3) horn morphology – horns of the male are generally more massive throughout their length than those of the female, and curve gently backward for the entire length; the horns of females are more slender and are straighter with a backward "crook" approximately 50-70 mm from the tip.

Adult males are generally 10-30% larger than adult females (Brandborg 1955, Houston et al. 1989) and males appear stockier or heavier in the chest and shoulders than the female and the beards of males are heavier and broader than those of the females. During breeding season males urinate on themselves and paw dirt onto their body, giving them a dirty appearance. Adult males two years and older are normally solitary or with small groups of other males. Generally, adult animals alone and away from the nanny-kid-yearling herds are adult males, though this isn't entirely reliable (B.L. Smith 1988, Hibbs 1965). In some cases, the stage of hair molt can be used to determine sex and reproductive status (Brandborg 1955, Chadwick 1983). Adult males are the first to begin (usually in May) and complete shedding their winter coat, while nannies with kids are the last, often not shedding until August. Both males and females possess crescent-shaped glands at the base of their horns thought to be used in mating behaviors (Geist 1964). Upon close examination, these glands are more prominent in males.

Slow moving fixed-wing aircraft or helicopters are required for aerial goat surveys, but helicopters are known to cause disturbance, displacement, and even goat mortality (Cote' 1996). Aerial surveys should be conducted only when weather conditions permit low-level flying in alpine areas, when goat fidelity to spring/summer range is at a maximum, and movements are at a minimum. Because age and sex of goats are difficult to accurately classify, the most reliable counts achieved from aircraft are the number of kids and non-kids. Survey results are typically reported as kid:adult ratios even though the adult segment often includes subadults. Larger groups, typically composed of nannies, kids and subadults, may have to be counted two or three times because kids tend to hide under the nannies when the group is disturbed or agitated by survey aircraft. During the spring/summer period males are usually solitary or in small bachelor groups and harder to find; only subadult males are typically seen with the maternal groups.

Aerial classification of yearlings is difficult. Only 50% of known yearlings were correctly classified during aerial surveys in Alberta, and many yearlings were mistakenly classified as kids (Gonzalez-Voyer et al. 2001). Mountain goat kids stay with the nanny until over one year old and by their second summer are about half adult size and 1.5 times larger than kids. Any goat followed by a kid is a female at least 3 years old.

Population status (minimum population size) is assessed periodically through aerial trend counts. During years in which trend counts are scheduled, they can be combined with aerial classification counts, but trend counts require expanded coverage of goat habitats. Aerial monitoring efforts designed to examine sightability of mountain goats have revealed detection rates between 46% and 70% (Smith and Bovee 1984, Cichowski et al. 1994, Poole et al. 2000, Gonzalez-Voyer et al. 2001).

Ground classifications at close range enable managers to more accurately distinguish goat sex and age, including identification of yearlings. Knowledge of kid:100 female and yearling:100 female ratios allow for assessment of kid survival/yearling recruitment and may result in increased confidence in population monitoring. Larger sample sizes are typically obtained from ground classifications in late spring or summer when goats grouped on traditional ranges are more accessible. Sex and age are more easily distinguished when goats are in short summer pelage rather than in long winter coats. Limited ground counts may be useful to classify scattered groups missed on aerial counts or large groups difficult to classify from the air.

From classification surveys, kid:100 adult ratios can be calculated. If surveys are obtained from ground classifications, yearling:adult ratios, and male:female ratios can also be determined. Productivity and recruitment information should be compared to data from previous years in order to detect changes in population parameters. Trend count results should be used in conjunction with classification data to determine minimum population size and assess population performance.
Marked animals allow for habitat use and seasonal movements to be determined. This is extremely important for species such as mountain goats that are distributed throughout occupied habitats in distinct sub-populations. In some cases, marked animals are used to estimate goat population sizes through mark-recapture techniques and development of sightability models (Cichowski et al. 1994, Smith and Bovee 1984, Poole et al. 2000, Gonzalez-Voyer et al. 2001).

Harvest Monitoring

Mountain goat populations are very susceptible to overharvest, and although there are some examples of compensatory reproduction on ranges where animals feed primarily on grasses and forbs rather than shrubs

(Swenson 1985, Williams 1999), hunter harvest has been shown to be almost entirely additive in many herds (Hebert and Turnbull 1977, Kuck 1977, C.A. Smith 1986, K.G. Smith 1988). Cote' et al. (2001) urged caution when interpreting mountain goat population data demonstrating compensatory reproduction. Delayed sexual maturation, low productivity, and potential for high natural mortality combine to produce a relatively small harvestable surplus when compared to most other ungulates. Overexploited goat herds and herds subjected to extreme weather events often exhibit greatly depressed reproduction. Productivity and population declines often continue after hunting seasons are closed (Kuck 1977, K.G. Smith 1988). Differential response of goat herds to hunting may be related to their position along the ungulate irruption scale that includes initial increase, stabilization, decline, and post decline (Caughley 1970). In addition, due to the prolonged period required for recovery in shrub-dominated habitats, goat populations that inhabit shrub-dominated ranges may not respond in a compensatory manner if habitats have been damaged (Swenson 1985).

Although the impacts of harvest are very herd-specific, many recommendations have been made relative to the appropriate harvest rate for mountain goats. Goat populations increased in west-central Alberta under a constant harvest rate of 4.5-9.0%, but then dramatically declined (K.G. Smith 1988). Harvest rate averaged 20% in an introduced population in central Montana with no decline in total counts (Williams 1999). Similar results were seen under harvest rates than ranged from 5.7-23.1% and averaged 15.7% in another introduced population in Montana (Swenson 1985). Recent studies in Alberta recommend much more conservative harvest rates of 1% (Festa-Bianchet and Cote' 2002). Harvest rates in British Columbia ranged from 0.36-9.0%, but reportedly could have been increased if harvest was homogeneously distributed (Hebert and Smith 1986). Most states and provinces manage for harvest rates of 3-7% and try to minimize female harvest. Some jurisdictions have set female harvest thresholds of < 30-50%. In order to meet population management and harvest goals, frequent trend counts and annual productivity surveys must be done. Mandatory checks of harvested goats are also essential to determine hunter success and sex ratios in the harvest. Because goats are polygamous and productivity is comparatively low, emphasis should be placed on harvesting male goats. Most wildlife management agencies now provide mountain goat hunters with information on sex identification and where to find billies in an effort to encourage the harvest of male goats.

Diseases

There are very few reports of infectious diseases in mountain goats, which is probably more a reflection of how little we know of this species than its actual health status. Because of their remote habitat preferences, sick or dead goats are rarely observed or found. This section will discuss known, as well as speculated or potential diseases, in mountain goats.

Contagious Ecythema

Etiology--Contagious ecthyma (CE) is caused by a virus of the genus *Orthopoxvirus* (Thorne et al. 1982, Robinson and Kerr 2001). It is a member of the pox group of viruses, which include cowpox and viral myxoma. CE has been reported in mountain goats (Samuel et al. 1975, Hebert et al. 1977), wild bighorn sheep (*Ovis canadensis*), and thinhorn (Dall's) sheep (*O. dalli*; Robinson and Kerr 2001).

Transmission and Epidemiology--Transmission is by contact with affected animals or contaminated objects. Infection usually occurs through broken skin, such that might occur following exposure to thistles or rough feed. The virus is highly resistant to environmental deterioration and can be virulent for many months at room temperature (Robinson and Kerr 2001). Transmission in mountain goats was thought to be exacerbated by use of artificial sources of salt (Samuel et al., 1975) or natural mineral licks where animals gather; however the virus could not be transmitted experimentally when placed on salt blocks (Thorne et al. 1982).

Pathogenesis-- A papule-type lesion is produced within 48 hours after the virus invades epithelial tissue. This papule rapidly progresses through vesicular and pustular stages, then secondary bacterial infection results in characteristic scabs in 7–19 days. The scab covers a proliferation of epithelial cells and is composed of serum exudate, erythrocytes, and inflammatory cells. The scab contains large numbers of infective viral particles. The lesions begin to resolve after 3 weeks and scabs start to detach after 4 weeks. The lesions usually heal without scarring, but depigmentation of the affected portions of the nose and oral mucocutaneous junction have been seen in bighorn sheep up to 6 months post infection (Thorne et al. 1982, Robinson and Kerr 2001). This loss of pigment could serve as an indicator of past exposure.

Clinical Signs--Lesions can range from a few, small crusts to thick, hard, coalescing scabs that cover the entire face or lower limbs. Scabs are most commonly found on the lips and face as well as udder, vulva, pizzle, and oral mucosa, but can occur elsewhere. When scabs are on the eyelids, secondary blindness may occur due to excoriation of the cornea. Rubbing the eyes on the lower legs may transfer the infection there. Infection can result in intense itching and animals appear restless and nervous. Affected animals show increased licking of the lips and nostrils and constantly rub lesions of the head against objects or other animals. Grazing or suckling can be difficult when severe oral lesions are present and weight loss and mortality have been observed.

Diagnosis--Diagnosis can be made on gross lesions; by electron microscopy of the parapox particles in negatively stained preparations; virus isolation in tissue culture; or by transmission of the disease to domestic sheep or goats using fresh lesion material. Past exposure and prevalence can be detected by a range of serologic techniques including serum neutralization, complement fixation, immunodiffusion, or enzyme-linked immunosorbent assay (ELISA). Complement fixation titers of ≥1:16 indicate recent exposure (Thorne et al. 1982, Robinson and Kerr 2001).

Immunity--The duration of immunity in mountain goats is unknown, but is probably similar to domestic sheep. Immunity to reinfection of the mouth or feet persists up to 5 months following recovery from natural disease and subsequent exposure may result in small lesions of little consequence. Lesions can occur on the udder of domestic animals immune to infection on the mouth and this may occur with wild animals. Maternal antibody in the colostrum is probably not protective. Protective immunity is most likely entirely cell mediated (Robinson and Kerr 2001).

Control and Treatment--In domestic sheep and goats, control is achieved by the use of a live, virulent virus vaccine placed in scarified area of the inner flank, usually in lambs or kids. Not only is this method of vaccination impractical for free-ranging mountain goats, it would probably be unwise to introduce a virulent virus into the environment. The disease will probably become extinct in small, isolated flocks, but reintroduction from other wild or domestic species is always possible. Domestic goats and sheep should be prevented from coming into contact with mountain goats.

Public Health Concerns--Contagious ecthyma is a zoonotic disease, but is seldom serious in humans. Affected lymph nodes may become swollen and painful and mild fever may occur. Cutaneous lesions usually resolve in 6 weeks without extensive scarring. Latex or rubber gloves should be worn when handling infected mountain goats or when examining lesions. A hunter in Alaska acquired ecthyma from handling an infected mountain goat (Carr 1968). Meat from affected animal is safe for human consumption if all lesions are trimmed away.

Management Implications--Contagious ecthyma has been documented in mountain goats in Alaska (Dieterich 1981) and British Columbia (Samuel et al. 1975, Hebert et al. 1977), but probably could be found anywhere bighorn sheep with CE are sympatric with mountain goats. Although Thorne et al. (1982) stated that “contagious ecthyma is probably not a major mortality factor of bighorn sheep,” Samuel et al. (1975) stated that “several sheep and goats severely infected with CE have been found dead or moribund.” Contagious ecthyma probably should be considered a significant health hazard to mountain goats because of its ease of transmission and effect on nutrition and fitness.

Risk Potential--High, because of the known pathogenicity of CE and the potential for infection from infected bighorn sheep and domestic sheep and goats.

<u>West Nile Virus</u>

Etiology--West Nile virus (WNV) is a flavivirus that affects birds, humans, horses, and some wild mammals. The virus was originally isolated in Uganda in 1937, arrived in New York in 1999, and spread rapidly across the U.S. and Canada. In 2002, 7 of 12 captive mountain goats in Nebraska died from WNV (Wilmot 2002).

Transmission and Epidemiology--WNV is transmitted by mosquitoes feeding on infected hosts, most likely birds. WNV has been isolated in more than 25 mosquito species, mostly *Culex* spp., but ticks may also serve as vectors. Corvids (jays, crows) have been shown to have high levels of virus in their blood and probably serve as important reservoirs for WNV.

Pathogenesis-- Incubation in mountain goats is unknown, but based on the single report (Wilmot 2002), it appeared to be relatively short (< 2 weeks). A white-tailed deer (*Odocoileus virginianus*) showed clinical signs for four days before death (Miller et al. 2005). The pathogenesis of WNV in mountain goats has also not been described. But in horses, gross lesions such as submeningeal edema, meningeal congestion, cerebral surface congestion and congestion within the spinal cord have been recorded (McLean 2004).

Clinical Signs--During a 2-week period, 7 of 12 mountain goats in Nebraska showed neurological signs and died. Signs included horizontal nystagmus (involuntary rhythmic oscillation of the eyeballs), ataxia (uncoordinated voluntary movement), head tilt, and lateral recumbency. The 5 unaffected goats showed no clinical signs.

Diagnosis--The WNV infection of the mountain goats was confirmed in the brain by reverse transcriptase polymerase chain reaction, immunohistochemistry, virus isolation, and appropriate microscopic lesions (Cornish 2002).

Immunity--Many mammals apparently can become infected with the WNV and not develop any signs of the disease, or develop signs and then recover. In horses, signs usually resolved in survivors in 2─7 days; however, abnormalities of gait and/or behavior remained in 40% of horses 6 months after the initial diagnosis of WNV infection (McLean 2004). Nothing is known relative to immunity in mountain goats.

Control and Treatment--Control of WNV has universally been a program of integrated mosquito management, but this would be impractical, if not impossible, for free-ranging species such as the mountain goat. Killed and recombinant vaccines have been developed for horses, but their efficacy in wildlife has not been investigated. Treatment of individual cases is probably not practical, but experimental intravenous immunoglobulins have been used with some success in humans and laboratory mammals (McLean 2004).

Public Health Concerns--WNV is a zoonotic disease with approximately 1 in 5 infected humans developing a mild illness (fever, headache). About 1 in 150 human infections result in severe neurological disease, sometimes ending in death or with lifelong deficits. Humans handling mountain goats suspected of having WNV should wear rubber/latex gloves and avoid tissue or blood from contacting the mouth, eyes, nose, or cuts.

Management Implications--There is little from a management perspective that can be done to prevent WNV infection of mountain goats. Surveillance for WNV in mosquitoes and birds should be conducted or results monitored if conducted by another agency (e.g., human health) in order to assess potential risk to goat populations. Mountain goats in northern latitudes may be relatively safe because as the mosquito season approaches (late spring, summer), goats move to higher elevations which usually preclude mosquito activity. There is no evidence that temperatures at northern latitudes are suitable for development of WNV in mosquitoes. However, goats unable to move to higher elevations, such as those found in the Black Hills of South Dakota or portions of Wyoming, or those in more southerly latitudes, may be at risk.

Risk Potential--Potentially very high. With a mortality rate approaching 60%, WNV may be the most pathogenic organism of mountain goats. Habitat and altitude use by goats, however, may significantly reduce the probability of exposure to infected mosquitoes.

Paratuberculosis (Johne's Disease)

Etiology--Paratuberculosis, more commonly known as Johne's (yo-neez) disease, is caused by the bacterium, *Mycobacterium avium* ssp. *paratuberculosis* (formerly named *M. paratuberculosis*). Paratuberculosis has been reported in free-ranging mountain goats and bighorn sheep (Williams et al. 1979) as well as tule elk (*Cervus elaphus nannodes*) in California (Jessup et al. 1981).

Transmission and Epidemiology--The most common route of infection is by a susceptible animal ingesting the bacterium shed in the feces from an infected host. The mycobacteria can survive in feces, soil, or water for up to a year, but survival is probably shorter under most environmental conditions. Young animals appear to be more susceptible than adults, but host characteristics such as age and immunocompetence may also play a role in transmission likelihood. Transmission may occur *in utero* in bighorn sheep, which also may be true for mountain goats (Williams 2001). Infected, but otherwise healthy, animals can shed the bacteria in their feces and infect other in the herd or flock for years. The probability of transmission increases under conditions of high animal densities or limited range (e.g., captivity, traditional bedding areas).

Pathogenesis-- The mycobacterium infects and proliferates in the small intestine, colon, and associated lymph nodes. Granulomatous inflammation caused by the bacteria results in thickened intestinal walls and lymphatics and enlarged mesenteric and ileocecal lymph nodes. Sometimes other organs, such as the liver and lungs, may become infected and inflamed. Extensive intestinal inflammation results in diarrhea, malabsorption, and malnutrition (Williams 2001).

Clinical Signs--Emaciation and poor hair coat are constant signs with Johne's disease in virtually all species (Thorne et al. 1982; Williams 2001). Although common in domestic species, diarrhea may only be present in the terminal stages of the disease in bighorn sheep (Thorne et al. 1982). Diarrhea was present in the single reported mountain goat case (Williams et al. 1979). Submandibular edema (bottle jaw) and abnormal horn growth are other inconsistent signs. Paratuberculosis is fatal once clinical signs appear.

Diagnosis--Antemortem diagnosis of paratuberculosis is problematic because serologic tests that measure antibodies to the mycobacterium are not very sensitive prior to clinical signs. None of the various serologic tests (ELISA, complement fixation, agar gel diffusion) have been validated for wild species. Culture of tissues, feces, or environmental samples is probably the best method to confirm paratuberculosis, but cultures can take weeks to months to grow. Newer, more sensitive tests, such as polymerase chain reaction, are being developed for domestic animal diagnoses and may have applications to wildlife once validated.

Immunity--There have been no studies of the immune response of wild species to *M. avium paratuberculosis*, but it is probably like domestic animals in that it involves both humoral and cell-mediated immunity. There may be some genetic resistance in some individual wild goats, as suggested with cattle (Williams 2001).

Control and Treatment--Control of paratuberculosis in the wild has not been attempted, as far as is known. Prevention is likely better than any control measures. Veterinary oversight of a flock would be advisable. Quarantine, testing, culling, and increased hunting have been employed to control paratuberculosis in tule elk and Colorado bighorn sheep, but despite these efforts, the disease has persisted in these populations for more than two decades (Jessup and Williams 1999).

Public Health Concerns--A possible relationship between *M. avium paratuberculosis* and human Crohn's disease (chronic ileocolitis) has been investigated for years, but findings are equivocal (Chiodini and Rossiter 1996).

Management Implications--Management of paratuberculosis in mountain goats would be to prevent the introduction of the disease by either preventing exposure to domestic sheep or goats or by inadvertently introducing the disease from translocating infected mountain goats. There also has been concern that pack goats could expose vulnerable populations, but it would be unlikely that a domestic goat with clinical signs of Johne's disease would be used for packing. Also, clinically healthy animals shed little bacteria; the bacteria is unlikely to persist long in the environments where mountain goats are normally found; and it is not likely that a susceptible goat would ingest adequate numbers of the organism to become infected.

Risk Potential--Medium. Paratuberculosis would be a persistent, significant threat to mountain goat populations once introduced, but the probability of introduction is probably low.

Exertional (Capture) Myopathy

Etiology--Exertional myopathy (EM) isn't a disease in the sense that there is an infectious organism, rather it is a physical and pathophysiologic syndrome resulting from extreme muscular exertion and stress. EM is also known as capture myopathy, white muscle disease, muscular dystrophy, exertional rhabdomyolysis, muscle necrosis, and stress myopathy.

Epidemiology--EM has been documented in many species, primarily ungulates (Williams and Thorne, 1996) and it has been reported in mountain goats (Hebert and Cowan 1971, Chalmers and Barrett 1982).

Pathogenesis-- EM occurs whenever there has been prolonged or severe muscular exertion. Examples include being chased, net gunned, physically restrained, or transported. Some authors feel that psychological stress can be an important contributor to the development of EM (Spraker, 1982). Anaerobic muscle metabolism, due to exertion or shock, results in a buildup of lactic acid, which leads to acidosis (decreased blood pH) and cell death. Cell death leads to muscle damage, renal failure, or hyperkalemia (increased blood potassium).

Clinical Signs--Animals may die suddenly (acute EM) or develop signs days (subacute EM), or weeks (chronic EM) later. Signs include increased body temperatures (42 C; Kock et al. 1987), lack of response to the environment, ataxia, weakness, unsteady movement, depression, increased pulse and respiration, knuckling of the fetlocks (ruptured gastrocnemius muscle), dark-colored urine (due to myoglobin from cell death), and acute or delayed death (Williams and Thorne 1996).

Diagnosis--Diagnosis can be made on history of physical exertion, clinical signs, clinical pathology, and necropsy. The two most important enzymes for clinical pathology are elevated serum concentrations of creatine kinase (CK) and aspartate aminotransferase (AST). In addition to CK and AST, elevations in lactate dehydrogenase (LDH), blood urea nitrogen (BUN), and creatinine (Cr) may support a diagnosis of EM. For animals that die acutely, there may be few grossly observable lesions upon necropsy. Pulmonary edema and multifocal pulmonary hemorrhage may be observed on animals that have been intensely pursued. Gross lesions on animals that survive long enough following exertion include hemorrhage, edema, and paleness of the muscles (particularly the large muscles of the hindquarters). In more advanced case, pale streaking of the musculature may be apparent (Williams and Thorne 1996).

Immunity--There is no immunity *per se* from EM as there is no infectious agent involved. However, environmental conditions may cause animals to be more susceptible to EM. Low levels of dietary selenium have long been suspected of contributing to EM (Hebert and Cowan 1971; Tramontin et al. 1983), but this has not been proven experimentally.

Control and Treatment--The only real control or treatment of EM is prevention. Animals should not be pursued, restrained, or transported for extended periods, if at all possible. When net gunning or darting, animals should be pursued for less than 3 minutes and released (or drugs antagonized) as quickly as possible after processing. Treatments have included injections of sodium bicarbonate (to reverse acidosis), selenium/vitamin E, prednisolone sodium succinate, dantrolene sodium, ketanserin, and lactated Ringers solution (Williams and Thorne 1996; Woodbury 2005), but none of these have been proven definitive treatments for EM.

Public Health Concerns--There are no public health concerns with EM.

Management Implications--EM should always by a major concern when physically handling mountain goats. Capture techniques should be carefully planned and analyzed. Helicopter pilots and capture crews should be apprised of the risk of EM and instructed to limit chase and handling times. If using drop nets, always insure enough personnel are on hand to restrain every goat caught as prolonged struggling in the net often leads to EM. Try to avoid prolonged transport; consider tranquilizing to decrease pacing and straining (Kreeger et al. 2002).

Risk Potential--Always high when physically handling mountain goats.

<u>Other Diseases</u>

Mountain goats have been sampled for a variety of diseases of potential importance, but none have been implicated as significant threats to mountain goat health. Pneumonia caused by bacteria (particularly *Pasteurella* or *Manheimia*) is a serious disease problem in wild sheep. Biovariants of *Pasteurella* have been found in mountain goats (Jaworski et al. 1998). However, no reports of die-offs due to pneumonia have been reported in mountain goats.

Antibodies to malignant catarrhal fever (MCF) virus were not found in 54 mountain goats, despite being found in 37% of bighorn sheep examined (Li et al. 1996). No pathology associated with MCF has been reported in wild mountain goats.

There was a single report of antibodies against respiratory syncytial virus (RSV) found in 29 of 69 (42%) mountain goats of all age classes in Washington state. No clinical disease or pathology was noted with the sampled animals (Dunbar and Foreyt 1986).

Other miscellaneous diseases such as bovine viral diarrhea, parainfluenza 3 virus, epizootic hemorrhagic disease and others have been examined in mountain goats, but with no apparent clinical significance (Frolich 2000). There was a single report of starvation in a mountain goat due to an oral fibroma neoplasm (Foreyt and Leathers 1985).

Parasites

Most information about the parasite fauna of mountain goats comes from work in the 1950's to 1970's on a few populations in Canada (Alberta and British Columbia) and the United States (South Dakota, Idaho, and Montana). There has been little recent investigation into the parasite fauna of mountain goats, and in fact "there is currently insufficient information available to complete an accurate [health] risk assessment for this species" (Garde et al. 2005). Parasites and other pathogens previously identified in mountain goats are summarized in the appendices of Garde et al. (2005). Recent reviews of the parasite fauna of mountain goats include Hoberg et al. (2001) and Jenkins et al. (2004).

Mountain goats may commonly share parasite species with sympatric wild ungulates, including bighorn sheep (Samuel et al. 1977). For example, *Parelaphostrongylus odocoilei*, a muscle-dwelling roundworm, may be transmitted among mountain goats, thinhorn sheep, and black tailed deer, all of which could potentially share range in coastal mountains of north-central North America. Transmission of parasites, unlike most bacterial or viral pathogens, does not require direct contact; instead, shared range use (even seasonally) may result in transmission. This has implications for management (especially if animals are translocated), and may have significance for the health of these populations.

Differences among presence and prevalence of parasites among different mountain goat populations (Samuel et al. 1977) may occur as a result of parasite sharing with other wildlife or differences in habitat and climate. For example, *Marshallagia* spp. does not appear to be established in one population of mountain goats in coastal British Columbia (Jenkins et al. 2004). If mountain goats with different parasite communities are translocated, parasites introduced into naïve goat populations could have more harmful effects than in populations with established immunity. Assessing the risks of parasite introduction is greatly complicated by the lack of knowledge about the parasite status of individual populations of mountain goats, as well as by hidden parasite biodiversity. For example, morphologically similar parasites may actually represent different species, such as the *Teladorsagia circumcincta*/*T. boreoarcticus* complex (Hoberg et al. 1999).

Transmission of pathogens, including parasites, from domestic livestock poses a risk for many wildlife populations. It is not known if mountain goats share the same susceptibility to pneumonic pasteurellosis as bighorn sheep, but they are susceptible to several gastrointestinal parasites of domestic livestock (Boddicker et al. 1971), as well as respiratory viruses characteristically associated with domestic livestock (Dunbar et al. 1986). Until further information is available regarding the parasite and disease status of mountain goats, managers are encouraged to act conservatively, and consider that mountain goats may be susceptible to potentially virulent pathogens of domestic livestock (Garde et al. 2005).

The specific effects of parasitism on the health of mountain goats are largely unknown. Gastrointestinal coccidial organisms, which may include several species of *Eimeria*, are present at high prevalence and intensity in several mountain goat populations, and may have contributed to the death of an emaciated mountain goat with severe dental disease (Jenkins et al. 2004). Mountain goats can harbor at least three species of tissue-dwelling roundworms, two lungworms (*Protostrongylus stilesi* and *P. rushi*) and the muscleworm *P. odocoilei*, in which eggs and larvae pass through the lungs as part of the life cycle. These parasites, either individually or collectively, could contribute to respiratory disease in mountain goats. In two instances, carcasses of emaciated mountain goats bore evidence of verminous pneumonia (due to *P. odocoilei* and/or *Protostrongylus* spp.), suggesting that these parasites may contribute to poor body condition and perhaps even mortality (Pybus et al. 1984; Samuel et al. 1977). In experimentally infected Dall's sheep, *P. odocoilei* caused respiratory failure in the end stages, as well as weight loss and neurological signs (Jenkins et al. 2005).

Gastrointestinal nematodes are rarely associated with specific disease syndromes, but in wild sheep, nematodes that invade the lining of the true stomach (such as *Marshallagia* sp.) or the large intestine (such as the whipworm *Trichuris* sp.) may cause visible damage (Neilson and Neiland 1974; Uhazy and Holmes 1971; Kutz 2001). The cumulative effects of heavy burdens of gastrointestinal parasites may be significant, especially in combination with nutritional stress. In Dall's sheep, animals with higher numbers of parasites were less likely to be pregnant and more likely to be in poor body condition (Kutz 2001). In one population of feral domestic sheep, gastro-intestinal parasites regulated sheep population density and were associated with cyclical population crashes (Gulland 1992). More work is needed to determine the effects of parasitism on the health status of mountain goats, especially in light of climate change, habitat fragmentation, and the possibility of pathogen introduction from domestic livestock.

There is also a need to better characterize the native parasite fauna of mountain goats, especially in populations where translocation is contemplated, in herds in close proximity to threatened bighorn sheep populations, or where local declines in mountain goat numbers have been documented. For example, in the Yukon Territory, there is recent evidence that some populations of mountain goats have vanished due to unknown causes (Hoefs et al. 1977). Definitive identification of parasites has traditionally required microscopic examination of adult parasites recovered from carcasses, which has been logistically difficult for many wildlife hosts, especially in isolated, high altitude habitats. Recently, molecular techniques, validated for specific parasites, have been applied to identify both adult and juvenile parasite stages (including those shed in feces), and hold great promise as a less-invasive diagnostic tool. Therefore, surveys based on recovery and molecular identification of parasite eggs and larvae from fecal samples may become increasingly useful in characterizing parasite fauna of wildlife.

Until such tests are widely available, and in order to validate these tests, definitive identification currently relies on collection of adult parasites from carcasses. This can be opportunistic, for example when a mortality signal is detected during monitoring of collared animals, or targeted, with seasonally appropriate collections of animals, or from hunter-harvested mountain goats. If there is local expertise or established protocols, samples can be collected in the field. Otherwise, whole carcasses can be shipped to regional laboratories. Detailed parasitological examination is not usually included in routine post-mortem examination, and requires the collaboration of experts from diverse backgrounds (including biology, veterinary medicine, parasitology, pathology, and molecular techniques) and multiple agencies, often crossing provincial, state, and national borders. Fortunately, there is considerable precedent for the benefits of such multidisciplinary work.

Capture and Handling

Mountain goats have been captured in self-tripping nylon mesh Clover traps or remotely-controlled Stevenson's box traps baited with salt (Hebert and Cowan 1971, Rideout 1974*a*, Haviernick et al. 1998). Goats caught in such traps can be manually restrained with hobbles and blindfolds or can be given a tranquilizer (Haviernick et al. 1998) or anesthetic (Kreeger et al. 2002).

Drive nets, consisting of 100-foot sections of 10- to 14-inch stretch mesh, can be placed across escape routes and goats driven into them, usually with helicopters (Jessup 1999). Nets should be camouflaged as best as possible so that the animals don't see them until too late to avoid entanglement. Only a small number of goats (≤ 6) should be driven into the nets and there should be a minimum of two persons available to restrain each goat captured. However, goats generally do not "herd" well and usually seek escape by climbing to higher ground, thus avoiding set traps. The same problem applies to drive corrals (fixed corrals with wings to direct driven animals into the trap).

Probably the most successful fixed trap is a drop net, which is a large net suspended above the ground (2-3 m), held by poles with release devices that are triggered manually by a hidden observer. Drop nets are usually set up and baited (salt, apple pomace, hay) underneath for days before the capture to allow goats to find the bait and acclimate to the net. Once animals are acclimated, they are usually quite relaxed under the net, often eating and then laying down while still under the net. This condition obviously changes quite suddenly once the net is dropped on them. There should be a minimum of two people per goat to hold them down. If there are more goats then available personnel, do not drop the net. When the net is dropped, hidden personnel run out and restrain the goats. Try to run around the net as much as possible before approaching the goats; running straight to the goat over the net usually results in your tripping and falling. Animals should not be allowed to struggle for more than a few minutes in order to minimize capture myopathy (Hebert and Cowan 1971). In a mixed flock, kids can be injured by struggling adults, but even adults can break legs in the net. To reduce risk of injury, a lift net has been successfully used at Snow Peak in Idaho (Idaho Fish and Game file data).

Rocket nets (Thompson and McCarthy 1980) are employed like drop nets, but offer few, if any, advantages other that a little more flexibility in location. All the considerations and problems of drop nets apply to rocket nets.

Net gunning from helicopters offers the most flexibility in selecting specific animals. It is most effective in open terrain away from precipices and cliff faces. Snow cover can affect net gun efficiency because goats can slip underneath the net. Goats should be pursued for short periods (< 3 min) to avoid capture myopathy. Handlers should be equipped with all necessary supplies to quickly process the goat (syringes and blood tubes, ear tags, radio collars, etc.) and release it. If done correctly, net gunning should result in little mortality (Jorgenson and Quinlan 1996) and less stress than other capture techniques (Kock et al. 1987).

Whenever goats are physically restrained, they should be hobbled and blindfolded, which serve to calm the animal and reduce struggling and lessen chances of capture myopathy. Goats will hook with their horns, even when hobbled, so they should be covered with sections of rubber hose to avoid injury to personnel (Jessup 1999).

Chemical-assisted capture using tranquilizers, such as xylazine (5 mg/kg), have been used to calm goats captured in Clover traps or drop nets (Haviernick et al. 1998). The effects of xylazine can be antagonized with idazoxan (0.1 mg/kg), tolazoline (2 mg/kg), or atipamezole (0.35 mg/kg). However, Côté et al. (1998) found deleterious life-history consequences of handling and drugging goats, including decreased kid production and increased kid abandonment. They recommended not to use xylazine on young (≤ 4 yr old) and lactating females. Some goats required multiple injections of xylazine resulting in very high total doses, which may explain some of the adverse effects. If drugs are necessary to handle physically captured animals, it would probably be more efficient and safer to use a potent immobilizing drug that can be antagonized, such as carfentanil (see below). Under no circumstance should xylazine be used as a sole agent to dart free-ranging (i.e., not trapped) mountain goats.

Goats can be darted from the air or ground. When helicopters are used, pursuit times should be < 3 min and once darted, the helicopter should get as far away from the goat as possible without losing continual sight of it. When under the influence of capture drugs, goats lose directional control, coordination, and perception of hazards. Careful consideration must be given to terrain conditions and possible escape routes used by the goat once darted; avoid nearby (< 500 m) precipices, scree slopes, or other hazards. However, under some circumstances of terrain and conditions, helicopter darting may be preferable to net-gunning (Jessup 1999). Far and away, the best drug for immobilizing mountain goats is carfentanil at 0.35 mg/kg (Jessup, 1999), which can be antagonized with 100 mg naltrexone for each mg of carfentanil administered (Kreeger et al. 2002). Carfentanil usually results in quick induction times (< 4 min) and once down, the animals do not "play possum" and run away as they do with other drug combinations. Carfentanil is a potent opioid and human safety is a concern, but there have been no human fatalities in thousands of drugging events.

If available, etorphine can been used to immobilize mountain goats (Carpenter and Lance 1983). Etorphine (4 mg total dose) is administered with xylazine (30 mg total dose). Etorphine can be antagonized with 8 mg diprenorphine and the xylazine can be antagonized with idazoxan (0.1 mg/kg), tolazoline (2 mg/kg), or atipamezole (0.35 mg/kg). Induction times with this combination tend to be longer than with carfentanil.

A combination of a cyclohexane drug and an alpha-adrenergic tranquilizer has been used to capture mountain goats. However, experience with these drugs in wild sheep has been problematic, regardless of the drug combination. Inductions tend to be long (6-15 min); the animal may not be completely immobilized and gets up and runs away when approached; animals continuously struggle even when hobbled and blindfolded; and recoveries are prolonged and characterized by uncontrolled staggering and falling. Probably the only such combination that can be recommended is ketamine (1.5 mg/kg) and medetomidine (0.07 mg/kg); the medetomidine can be antagonized with 0.35 mg/kg atipamezole. This combination is preferable over a ketamine/xylazine combination because the use of medetomidine greatly reduces the amount of ketamine required, which results in smoother, quicker recoveries.

All the above immobilizing drug combinations can be mixed in one dart; antagonists can be given intravenously or intramuscularly. Antibiotics (benzathine penicillin, oxytetracycline) should be given to any goat that has been darted to avoid infection and abscesses.

Human Disturbance

Anthropogenic disturbance of ungulates is postulated to have a variety of effects, including habitat abandonment, changes in seasonal habitat use, alarm responses, lowered foraging and resting rates, increased rates of movement and reduced productivity (Pendergast and Bindernagel 1976, MacArthur et al. 1979, Foster and Rahs 1981, Hook 1986, Joslin, 1986, Pedevillano and Wright 1987, Dailey and Hobbs 1989, Frid 1997, Duchense et al. 2000, Phillips and Alldredge 2000, Dyer et al. 2001, Frid 2003, Gordon and Wilson 2004, Keim 2004). Non-lethal disturbance stimuli (such as helicopter activity) can impact fitness-enhancing activities such as feeding, parental care, and mating, and can significantly affect survival and reproduction through trade-offs between perceived risk and energy intake, even when overt reactions to disturbance are not visible (Bunnell and Harestad 1989, Frid and Dill 2002). Increased vigilance resulting from disturbance may also reduce the physiological fitness of affected animals through stress, increased locomotion costs (particularly deep snow conditions during winter), or through reduced time spent in necessary behavior such as foraging or ruminating (Frid 2003). Physiological responses (such as elevated heart rates) to disturbance stimuli may not be reflected in overt behavioral responses to disturbance (Macarthur et al. 1979, Stemp 1983, Harlow et al. 1986, Chabot 1991), but are nonetheless costly to individual animals, and ultimately, to populations.

The increasing use of aircraft near occupied mountain goat habitat is of particular concern. While the short-term, acute responses of mountain goats to helicopters has been documented (Côté 1996, Gordon and Reynolds 2000, Gordon 2003) and repeatedly observed by wildlife managers, the medium and longer term effects of aircraft activity on mountain goat behavior and habitat use remains unclear (Wilson and Shackleton 2001). Helicopter-supported recreation is increasing in or near occupied mountain goat habitats across North America, exacerbating concerns (Hurley 2004) regarding the long-term effects of such activity on mountain goats.

The degree to which aircraft overflights influence wildlife is thought to depend on both the characteristics of the aircraft and flight activities and species or individual specific factors (National Park Service 1994, Maier 1996 *in:* Goldstein et al. 2004). Recent studies have shown that management of approach distances may ameliorate behavioral disruption due to helicopter activity (Goldstein et al. 2004). How flight vectors and topographic variables affect mountain goat short-term overt reactions to helicopters, however, remains poorly understood. The timing of disturbance is likely a key factor determining the strength of mountain goat overt disturbance reactions and the overall effect of helicopter activity on activity patterns; the potential impacts of helicopter activity on mountain goats must be considered in the context of the ecological season and time of year. Fox et al. (1989) found that winter was a period of severe nutritional deprivation for mountain goats; winter is thus of particular concern for the management of disturbance stimuli, because periods of deep snow can reduce food availability and increase locomotion costs (Dailey and Hobbs 1989). Fixed-wing aircraft and ground-based disturbances are generally thought to be less disruptive compared to helicopters (Foster and Rahs 1983, Pedevillano and Wright 1987, Poole and Heard 1998). Ground-based recreation, particularly motorized recreation such as the use of All Terrain Vehicles (ATVs) and snowmobiles, can disrupt use of habitats by mountain goats or result in behavioral disruptions.

Mountain goats seasonally occupy habitats associated with high timber values, particularly in coastal ecosystems (Hebert and Turnbull 1977). The use of helicopters by the forest industry to access previously in inaccessible areas is increasing. 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 coniferous forest canopy is required to intercept snow and to provide litterfall forage to sustain goats through periods of nutritional deprivation, particularly in coastal ecosystems (Hebert and Turnbull 1977). Forest harvesting might also disrupt dispersal movements, movements between seasonal ranges, and use of mineral licks accessed via traditional trails (Wilson 2004). Forest harvesting in and near goat winter ranges has increased in coastal and transitional ecosystems as the economics of harvesting previously unmerchantable wood has improved (B. Jex, S. Gordon, *pers. comm.*). Forest cover adjacent to traditional low-elevation trails is also considered important for visual protection from predators (Hengeveld et al. 2003).

Access to areas occupied by mountain goats via logging roads is a key factor in the success of goat hunters (Phelps et al. 1983). Proximity of roads to mountain goat habitat is the most important determinant of hunting pressure; hunters are generally deterred from hunting distances less than 2 km from roads (Hengeveld et al. 2003 *in:* Wilson 2004).The continuing expansion of industrial road networks is eroding the *de facto* protection provided by the remote terrain used by mountain goats (Wilson 2004). Increasing road access near mountain goat habitat has resulted in local extirpations due to hunting in several areas in British Columbia. Increasing road access during the 1960's in the Kootenay region, for example, led to over-hunting from which populations never fully recovered (Phelps et al. 1983 *in*: Wilson 2004). Increasing access has also led to reductions in mountain goat populations (and even local extirpations in some areas of British Columbia) and has resulted in hunting closures due to conservation concerns.

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 including forestry, road building, and mineral exploration. 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 *in:* Wilson 2004). Blasting activities associated with road construction, mineral extraction or other industrial activities can also directly affect the suitability of mountain goat habitat by precluding use of critical escape terrain. Blasting might also disturb mountain goats during critical periods (such as kidding) or increase the risk of avalanches on winter ranges (Wilson 2004).

Mountain goats have been found to have a lower recruitment rate compared to other ungulates (Festa-Bianchet et al. 1994). Mountain goats in some areas have been noted not to produce young until four to five years of age (as compared to bighorn sheep, which typically produce young at two or three years of age). Reduced fitness or vigor or indirect mortality resulting from disturbance stimuli may present a greater risk to mountain goat population viability compared to other ungulates, supporting application of species-specific mitigation strategies to reduce disturbance effects. Previous studies have found that human displacement reduced elk reproductive success, supporting maintenance of disturbance-free areas during parturition periods (Phillips and Alldredge 2000). Nannies and kid mountain goats typically occupy remote, inaccessible portions of their home range during the kidding period in May/June (DeBock 1970, Chadwick 1973, Rideout 1978, Shackleton 1999, Gordon 2003) and may be at increased risk due to accidental mortality during this period. Because nannies are the dominant animals in the mountain goat social hierarchy and represent the potential for recruitment of new individuals into a given population (Chadwick 1973, Côté 1996), the effects of helicopter disturbance on adult female goats is of particular interest. Ungulates have been shown to be particularly sensitive to disturbance during parturition and early rearing of young (Penner 1988, Dyer et al. 2001). Given the highly synchronous birthing in mountain goats (DeBock 1970, Côté and Festa-Bianchet 2001) and the high fidelity of goats to the habitats they inhabit (Chadwick 1973, Fox 1983, Stevens 1983) development and application of mitigation measures (Hurley 2004) near habitats occupied by nannies and kids should be feasible from a management perspective.

State and Provincial Management

Key stronghold areas for mountain goats in North America are British Columbia, with a population estimated at about 50,000 animals, and Alaska, with 12,000 to 20,000 mountain goats (Shackleton et al. 1997). In both areas, management is very conservative, with harvest rates ranging from 2 to 5 percent of the estimated population in each management area (Table 2). With an estimated 80,000 animals in North America (over 55,000 in Canada and 25,000 in the United States), the species is believed to be internationally secure from a conservation standpoint (Shackleton et al. 1997).

However, mountain goat management is beset by many challenges. Throughout North America, populations are small and widely dispersed throughout difficult terrain. Obtaining accurate population estimates is challenging and costly. In addition, mountain goat populations are subject to wide natural variation due to fragmented populations, delayed sexual maturation, low productivity, potential for high rates of mortality due to natural causes (such as weather and disease), and adverse behavioral responses to human activity in mountain goat habitat. In years when natural mortality is high, additional mortality associated with hunting seasons can long depress populations. In addition, there is increasing evidence that a warming climate may further fragment mountain goat populations as longer growing seasons will allow undesirable plant species to invade subalpine and alpine habitats preferred by mountain goats. If this trend continues, populations could become increasingly fragmented, dispersal of mountain goats from one herd range to another could become more difficult, and individual herd segments could become smaller and more vulnerable to losses associated with natural events such as wildfires, severe winter weather, or exposure to new diseases or parasites. Much work is needed to determine the pathogens and parasites present in mountain goat populations, and what role they play in the health of individual animals and populations. This effort will enable detection of new diseases and parasites in a future of habitat disturbance and climate change.

Until more is known about the risks of transmission of pathogens between domestic livestock and mountain goats we recommend that contact between domestic animals and mountain goats be avoided. If contact is unavoidable, risk analyses should be performed and the health and parasite status of animals in contact or sharing a common range should be carefully monitored.

In order to address these challenges, we recommend that wildlife managers regularly monitor mountain goat population trend and habitat conditions. Hunting is appropriate for populations including >50 adults, but harvest should be conservative and focused primarily on males. Hunter education (to aid in male identification), protection of adults accompanied by young-of-the-year, and long seasons within restricted, well-defined hunt areas are appropriate and widely applied (Table 2). New measures may also be appropriate, including using satellite or aerial imagery to monitor changes in subalpine and alpine vegetation, reducing human disturbance within mountain goat habitat (specially during winter months when individual mountain goats face high levels of environmental stress), and relocating mountain goats within suitable habitat (mimicking natural dispersal).

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Table 1. Productivity (kid:100 non-kid ratios) values from various locations across the range of the mountain goat.

Location	Kids:100 non-kids	Source
Kenai Peninsula, Alaska	20-44	Del Frate and Spraker (1994)
Southeast Alaska	15-47 (avg.=28.6)	Porter (2002)
Southeast Alaska	2-36 (avg.=22.9)	Barten (2002)
British Columbia (various locations)	7.7 – 27.5 (avg.=18.2)	Hebert and Turnbull (1977)
Similkameen Mountains, British Columbia	8-60 (avg.=25.8)	Bone (1978)
Eagles Nest Wilderness, Colorado	48	Thompson and Guenzel (1978)
Selway River, Idaho	28	Brandborg (1955)
Absaroka Mountains, Montana	29-60 (avg.=38.4)	Swenson (1985)
Absaroka Mountains, Montana	25-47 (avg.=34.6)	Varley (1996)
Absaroka Mountains, Montana	17-39	Lemke (2004)
Gallatin Mountains, Montana	13-48	Lemke (2004)
Square Butte, Montana	29-70 (avg.=47.8)	Williams (1999)
Glacier National Park, Montana	42	Petrides (1948)
Yellowstone National Park, Montana/Wyoming	36	White (2003)
Wallowa Mountains, Oregon	0-61 (avg.=28.7)	Coggins and Matthews (2002)
Washington (various locations)	27-58 (avg.=35.0)	Michalovic (1984) from Johnson (1983)

Table 2. Mountain goat management approaches used in North American jurisdictions.

	Alaska	**Alberta**	**British Columbia**	**Colorado**	**Idaho**	**Montana**	Nevada	**Oregon**	**South Dakota**	**Utah**	**Washington**	**Wyoming**
Estimated Population[1]	10-12,000	3,350	50,000	1,000	3,060	5,000	100	60	160	270	5,000	160
Survey Timing	Summer	Summer	Summer	Summer	Winter	Summer		Summer	Spring	Summer	July-Sept.	July-Aug
Survey Method	Aerial	Aerial	Aerial	Aerial	Aerial	Aerial		Ground	Aerial	Aerial		Aerial
Data Gathered	Kid:non kid	Kids, yrlgs, adults[2]	Kid:non kid	Kids, yrlgs, adults	Kid:non-kid[2]	Kid:non-kid		Kid:non-kid			Kid:non-kid	Kid:non-kid[2]
Harvest Rate	2.2%-10%	3%	2%-5%		5% (excluding kids)	5%		5% of total population			4% (excluding kids)	5-8%
% Females	30%-40%[3]	<33% [4]	20%-35%					<50%			≤ 30%	<33%
Season Length	30-153 days	47 days	20-107 days	11-32 days	75 days	75 days	65 days	12 days	22 days	37 days	47 days	61 days
Restrictions	Any goat (some no kid/no nanny w/ kid areas)	Goats of either sex with horns longer than the ear	Any Goat	Any Goat older than 1 year	Any Goat (see comments)	Any Goat	Any Goat	Any Goat	Any Goat	Any adult goat	Any goat w/ horns < 4 inches (see comments)	Any goat
Hunter Orientation?	Yes	Yes	Yes	Yes	Yes	Yes		Yes		Yes	Yes	Yes
Additional Comments	2 goat bag limit in some areas	May not harvest from group ≥ 4; No permits in herds < 50 goats	No permits in herds < 50 goats		Nannies w/ kids protected; No permits in herds < 50 goats			No permits in herds < 50 goats		Some nanny only seasons	Nannies w/ kids at side protected; No permits in herds < 50 goats	

[1] Population estimates from Shackleton et al. 1997; who also reported 100-250 mountain goats in the Northwest Territories and 2000 in the Yukon. More recent data indicates approximately 400 in Oregon, and increases in Nevada, Utah and Wyoming.

[2] More detailed classification data obtained from ground surveys.

[3] Weighted sex comp. of harvest, males= 1 point, females= 2 points, manage for < 6 points/100 goats in population.

[4] When female harvest exceeds 33%, detailed male:female ratio population data will be collected with a goal of maintaining 1 male:3 females

Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:47

NON-ALPINE HABITAT USE AND MOVEMENTS BY MOUNTAIN GOATS IN NORTH-CENTRAL BRITISH COLUMBIA

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*Abstract***:** We monitored mountain goats (*Oreamnos americanus*) in scattered non-alpine forested terrain to document habitat use within forested rock cliff complexes and canyons, as well as movements between the forested rock complexes. In January and March 2003, 27 mountain goats on 6 different study sites were captured by aerial net-gunning methods and were fitted with either VHF or GPS telemetry collars. The study sites were contained within a discrete study area of approximately 800 square kilometers with distances between study sites ranging from 3 to 15 kilometers. The collared animals were relocated by aerial telemetry approximately once every 2 to 4 weeks until March 2004. GPS collars were retrieved between 8 and 12 months after deployment and their data recovered. Mountain goat movement distances varied greatly within the study sites over the year, and movement by a small number of animals between study sites was observed. Preliminary analysis of the habitat use indicates selection of steep slopes (41-60º) in early spring to summer, and moderate slopes (21-40º slope) in winter. Forested GPS locations were dominated by subalpine fir/hybrid white spruce during the winter months and by lodgepole pine subalpine fir during the spring and summer months. Winter locations were in mature (141-250 yrs) forests with tall trees (>28.5 m) and high canopy closure (46-65%), while spring, summer and fall GPS locations were in middle age class (81-140 yrs) forests with shorter trees (10.5-19.4 m) and moderate canopy closure (26-45%). Preliminary movement analysis showed a wide range of daily movements within and between study sites. During deep snow, mountain goats were found to be relatively stationary, moving less than 10m between successive GPS re-locations. During non-snow periods, individuals were found to move distances ranging from 3 to 30 kilometers within and between study sites over several days. Hair and tissue samples were collected for DNA analysis to compare the reliability of detecting individuals using hair samples.

Key words: mountain goat, non-alpine habitat use, landscape-level movements, GPS and VHF radiotelemetry, DNA analysis, meta-populations

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and Goat Counc. 14:49-63

EFFECT OF HELICOPTER LOGGING ON MOUNTAIN GOAT BEHAVIOUR IN COASTAL BRITISH COLUMBIA

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Abstract: We examined the effect of helicopter activity associated with industrial forestry on the behaviour of coastal mountain goats (*Oreamnos americanus*) during spring, summer and autumn 2001 and 2002. We collected 959 hours of instantaneous scan data on 2 herds over 95 field days in the upper Powell River watershed in south-western BC. The "sightability" of mountain goats (proportion of scans where at least one goat was observed versus no goat observations when visibility was favourable) was lower in 2002 during disturbance phases associated with helicopter activity than during other phases. The proportion of time adult females and kids spent engaged in different behaviours differed among disturbance phases and year. No obvious pattern was observed in 2001 but both age-sex classes spent less time bedded during phases associated with helicopter activity than during other phases in 2002. Overt changes in behaviour were also observed anecdotally during helicopter yarding activities in both 2001 and 2002.

Our results support the research hypothesis that helicopter logging activity affects mountain goat behaviour and we recommend that helicopter activity <1.5 km from occupied mountain goat habitat be managed to reduce behavioural disruptions.

Key words: Mountain goats, *Oreamnos americanus*, instantaneous scan surveys, behaviour, log-linear analysis, disturbance, helicopter logging

Disturbance of ungulates by helicopters can result in a variety of negative effects, including: habitat abandonment, changes in seasonal habitat use, alarm responses, lowered foraging and resting rates, increased rates of movement and reduced productivity (Pendergast and Bindernagel 1976, MacArthur et al. 1979, Foster and Rahs 1981, Hook 1986, Joslin, 1986, Pedevillano and Wright 1987, Dailey and Hobbs 1989, Côté 1996, Frid 1999, Duchense et al. 2000, Gordon and Reynolds 2000, Phillips and Alldredge 2000, Dyer et al. 2001, Frid 2003, Gordon 2003, Keim 2004). Mountain goats (*Oreamnos americanus*) in coastal British Columbia seasonally occupy habitats associated with high timber values, and the use of helicopters by the forest industry to access these otherwise inaccessible trees is increasing.

We examined the effect of helicopter activity associated with industrial forestry on the behaviour of mountain goats near Powell River, BC. We tested the following research hypotheses:

1. Helicopter logging activity affects the "sightability" of mountain goats by increasing their tendency to hide, bed, or use forested habitats; and,
2. Helicopter logging activity affects the proportion of time mountain goats spend engaged in different categories of behaviour.

METHODS

The study area was located 60 km north-east of Powell River, BC (Figure 1). The area is dominated by granite rock faces interspersed with stands of Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) at low elevations, and mountain hemlock (*Tsuga mertensiana*) and yellow-cedar (*Chamaecyparis nootkatensis*) at higher elevations. Industrial forestry is the dominant land use.

We conducted instantaneous scans (Hurley and Irwin 1986, Martin and Bateson 1993) of mountain goats using 20-60x spotting scopes at distances of 1-3 km during 5 phases of helicopter logging: pre-falling (no activity), falling (chainsaw, tree-falling and twice-daily helicopter activity), post-falling (no activity), yarding (frequent heavy-lift helicopter activity), and post-yarding (no activity). We also collected observations from a herd located approximately 4 km from the treatment herd. The two herds of mountain goats were subjected to varying degrees of helicopter logging activity during the falling and yarding phases (Table 1). Data were collected 27 April-16 November 2001 and 3 May-13 October 2002 (Figure 2).

Scans were conducted at 5-min intervals (during daylight hours and favourable visibility) and goat behaviours were classified into different categories: 1) not visible (obscured by terrain); 2) bedded (including ruminating, pawing at beds, sleeping); 3) feeding; 4) walking; 5) running; and 6) other (including vigilance, standing, fighting or any activities not captured in the other categories).

Goats were classified by age and sex: adult, adult female, adult male, sub-adult, sub-adult female, sub-adult male, juvenile, kid and unclassified. Adult females and kids were readily identifiable (Chadwick 1973, Smith 1988) but classifying sub-adults and juveniles with certainty was difficult, although these animals could be confidently classified as non-adults.

We used log-linear analysis (Agresti 1996) to infer relationships between logging phases and year and the "sightability" of goats (proportion of scans where at least one goat was observed versus no goat observations when visibility was favourable). We also used log-linear analysis to infer relationships between behaviour categories and disturbance phase, year, and age-sex class. Interactions were included in final models if the omission of the interaction resulted in a significantly poorer fit, based on differences between log-likelihood χ^2 values. All interactions between design variables were retained in final models.

A conservative alpha of 0.01 was used for all statistical analyses because the sampling unit was considered either an individual scan (for sightability analyses) or an individual goat-observation (for behavioural analyses). Ideally, analyses would have considered an individual goat to be the sampling unit; however, the population was unmarked and individuals could not be consistently identified. As a result, sample sizes were inflated and statistical tests were oversensitive (i.e., the null hypothesis was more likely to be rejected).

RESULTS

We conducted 11,510 scans over 959 hours of observation time. Of the 10,191 scans not obscured due to weather conditions, 5,144 (50.5%) yielded actual goat sightings. The majority of observations consisted of bedding (47.4%) and feeding (35.4%) behaviours.

There was a significant interaction between sightability (i.e., successful versus unsuccessful scans) and disturbance phase (partial association $\chi^2 = 1275$, $df = 4$, $P = 0.000$) and year (partial association $\chi^2 = 331$, $df = 1$, $P = 0.000$) for the treatment herd. Sightability declined with each disturbance phase in 2001, but in 2002 sightability was lowest for disturbance phases associated with falling and yarding activities (Figure 3). Results for the treatment herd in 2001 were consistent with a sightability trend by season for the control herd (Figure 4) in 2002.

Analyses of behavioural observations were restricted to adult females and kids because these classes could be identified most confidently in the field and because sample sizes were sufficient among disturbance phases, years and behaviour categories to perform a log-linear analysis. There was a significant interaction between the frequencies of different behaviours and disturbance phase (partial association $\chi^2 = 63$, $df = 12$, $P = 0.000$), year, (partial association $\chi^2 = 1$, $df = 3$, $P = 0.012$) and among adult females and kids (partial association $\chi^2 = 3$, $df = 3$, $P = 0.004$). There was also a significant higher-order interaction among behaviour classes, disturbance phases and year (partial association $\chi^2 = 112$, $df = 12$, $P = 0.000$).

There was no obvious pattern between behaviour and disturbance phases in 2001 for either adult females or kids (Figure 5, Figure 6), but in 2002 both adult females and kids spent less time bedded and more time engaged in other behaviours during disturbance phases when falling or yarding activities were occurring, compared to other disturbance phases (Figure 5, Figure 6).

DISCUSSION

This is the first observational study of mountain goat behaviour in relation to helicopter logging activity in coastal British Columbia. Studying an unmarked herd in a remote location provided some assurance that the animals had not previously been sensitized, or were habituated to, helicopter activity. The drawback was that animals could not be identified individually, which complicated data analysis. Also, the instantaneous scan method failed to capture many interesting behaviours. We observed numerous intra-specific interactions, including dominance displays, agonistic encounters and adult female dominance. We also observed inter-specific interactions including predator avoidance, aggression and vigilance postures, consistent with observations elsewhere (DeBock 1970, Chadwick 1973, Foster and Rahs 1981, Foster 1982, Masteller and Bailey 1987, Fournier and Festa-Bianchet 1995, Côté et al. 1997, Dane 2002).

In both years, adult females were observed with new kids in late May and early June, consistent with the highly synchronous birthing in mountain goats noted elsewhere (DeBock 1970, Côté and Festa-Bianchet 2001). Adult female mountain goats have been documented to behave differently than other age/sex classifications (Foster 1982) and are particularly sensitive to disturbance during the parturition and early rearing periods (Penner 1988, Dyer et al. 2001). Adult female goats also show a higher degree of habitat fidelity relative to other age/sex classifications (Chadwick 1973, Fox 1983, Stevens 1983, Gordon 2003).

Few adult male goats were sighted during the course of this study; habitat use patterns observed for the adult male class were consistent with previous research, with usually solitary billies occupying higher elevation habitats compared to nannies (Geist 1964, Rideout 1974, Chadwick 1977, Masteller 1980, Foster 1982, Risenhoover and Bailey 1982, Main et al. 1996, Frid 2003).

Whether mountain goats were even visible to the observers was itself an important aspect of our research. Although no obvious trend was observed in 2001 data, a significantly lower proportion of scans during 2002 resulted in mountain goat observations during disturbance phases that involved helicopter activity than during other phases. In fact, there were no sightings of goats at all during a 5-day period of helicopter yarding in 2002, even though goats had been visible for the previous 4 days. Sightability was lower because animals increased their use of forest or other cover, and/or moved farther from the helicopter disturbance. This was contrary to our expectation that goats would perceive helicopters as a predation risk and would increase their use of precipitous terrain (DeBock 1970, Geist 1971, Chadwick 1983, Fox and Streveler 1986, Côté et al.1997, Shackleton 1999). We opportunistically observed the response of mountain goats to the presence of a black bear (*Ursus americanus*) and watched the goats move immediately to escape terrain. Our observations suggested that mountain goats perceive and respond to helicopters differently than they do to predators, contrary to what has been suggested by some researchers (Foster and Rahs 1981, Joslin 1986, Côté 1996, Frid 1999, Wilson and Shackleton 2001).

Results from 2001 were most consistent with the seasonal trend we observed for the control herd in 2002; mountain goats were generally less visible as the year progressed. There were insufficient data to consider season in our log-linear analyses; however, the observed trend for the treatment herd in 2002 was more consistent with the disturbance hypotheses than with expected seasonal trends in sightability.

The reason we observed a relationship between helicopter activity and sightability in 2002 and not 2001 is unknown; however, it may be that mountain goats were sensitized by the activities in 2001 and increased their response to the disturbance stimuli in 2002 (Penner 1988, Frid 1999, Wilson and Shackleton 2001). Flight initiation distance or vigilance may actually increase with repeated exposure to non-lethal stimulus if the stimulus is sufficiently averse (DeBock 1970, Frid and Dill 2002).

Results from our analysis of mountain goat behaviour showed a similar pattern to that observed for sightability. In 2001, there was no consistent trend between the behaviour of adult females or kids and disturbance phase. In 2002, adult females and kids both showed a high proportion of walking relative to other behaviours in the helicopter-yarding phase and an increase in bedding in the post-yarding phase.

Bedding behaviour is associated with rumination, which is an important activity for the physiological health of ungulates (Chadwick 1973, Frid 1999). The proportion of time spent bedding increased for adult females and kids immediately following disturbance phases that were associated with helicopter activity (Figures 5, 6).

Anecdotal observations of the responses of mountain goats to the presence of helicopters were more dramatic than the instantaneous scan data suggested. Upon initiation of helicopter-yarding activity adjacent to the treatment herd in 2001, we observed alarm responses, including raised tails, vigilance postures, and flight responses. We also observed a herd of 5 goats (a nursery group composed of an adult female, three sub-adult or juveniles and one kid) aggregate and move quickly uphill, gaining approximately 500 m elevation in approximately 1 h. While alpine habitats are often used by mountain goats in the summer (Hebert 1967), the reaction of the treatment herd to the start of the helicopter yarding activity in 2001 suggested habitat displacement resulted from the helicopter-yarding activity. After the first full day of yarding, goats returned to their original location 1.25 h after the end of helicopter activity; however, during subsequent days of helicopter yarding, the herd did not return to lower elevations. Though animals choose habitats that maximize their chances for survival and reproduction (Schoener 1987), disturbance stimuli may cause animals to utilize sub-optimal habitats and increase locomotion costs (Bunnel and Harestad 1989, Bradshaw et al. 1998). We suggest that movements of goats to the top of the mountain coincident with the start of helicopter yarding in 2001 were an avoidance response to disturbance stimuli and not due to habitat selection.

There was no evidence that mountain goats habituated to the disturbance during the course of the study. Habituation to disturbance stimuli is often partial or negligible (Bleich et al. 1994, Steidl and Anthony 2000, Frid 2003), particularly if the disturbance is irregular and unpredictable (Bergerund 1978, Risenhoover and Bailey 1982, Penner 1988). Results of the behaviour analysis suggested, as did the sightability analysis, that goats were sensitized to the helicopter activity, rather than habituated to it.

Behavioural responses to disturbance may not be evident through observations. Researchers involved in physical capture of goats (G. Schultze *pers. comm.*, Keim 2004, S. Taylor *pers. comm.*) have noted that goats often do not exhibit overt reactions to high-stress helicopter net-gun capture and can remain perfectly still during handling. Longer-term behavioural effects may be more important that short-term reactions (Lima and Dill 1989), affecting overall vitality or survival of goats by affecting habitat selection, including displacement from preferred habitats. Physiological responses to disturbance also may not result in observable behavioural responses to disturbance (Macarthur et al. 1982, Stemp 1983, Chabot 1991, Millspaugh et al. 2001, Creel et al. 2002).

Controlled experimental manipulation of exposure to helicopter disturbance is required to better understand the effects of helicopter activity on mountain goat behaviour. Control over helicopter activity is needed to determine threshold distances at which behavioural disturbance effects are evident and to assess the effects of other variables, such as: relative elevation, approach speed, and type of helicopter. Researcher control over the helicopter variable will also increase the robustness of statistical tests and reduce the field time required to collect adequate behavioural data. Further research is also needed to assess the importance of topography in mitigating disturbance effects of helicopter activities on goats and other ungulates.

In combination with instantaneous scans, focal observations of individual animals could allow a more detailed assessment of whether the degree and duration of disturbance effects on behaviour varies according to age/sex classification and group size and also allow for a more detailed assessment of the effects of disturbance on daily activity patterns.

Paired studies are required to enhance scientific understanding of both the behavioural and physiological effects of helicopter activity on mountain goats; opportunities to employ techniques such as examination of faecal glucocorticoid levels, heart-rate telemetry technology paired with behavioural studies should be explored.

MANAGEMENT RECOMMENDATIONS

Helicopter activity should be managed within 1.5 km of areas occupied by nursery herds of adult females and kids between May 15 and June 15, to reduce the possible effects of disturbance on the recruitment potential of local mountain goat populations. Helicopter yarding activity adjacent to occupied mountain goat habitat should occur during the summer period when goats occupy the highest-available portions of their seasonal ranges and thus have greater opportunity to spatially avoid disturbance.

The management of disturbance stimuli should be based on the distance between the stimuli and the mountain goats, the type and duration of disturbance, and the presence of topographic features to ameliorate auditory and visual effects. Monitoring of the effectiveness of management strategies for the maintenance of goat populations and habitat use is essential.

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Table 1. Logging and helicopter activity during yarding phases for two mountain goat herds in the upper Powell River, 2001-2002.

Year	Herd	Helicopter	Helicopter time (h)	Distance to goats (km)
2001	Treatment	Boeing 234	125.6	0.5-1.0
	Treatment	Hughes 500/ Bell 206	71.2	0.5-1.0
	Control	Boeing 234	16.6	>1.0
	Control	Hughes 500/ Bell 206	10.0	>1.0
2002	Treatment	Sikorsky 64	102.0	1.0-1.5
	Treatment	Hughes 500	18.0	1.0-1.5
	Control	No activity		

Figure 1. Study area location map, upper Powell River, Sunshine Coast, British Columbia, Canada.

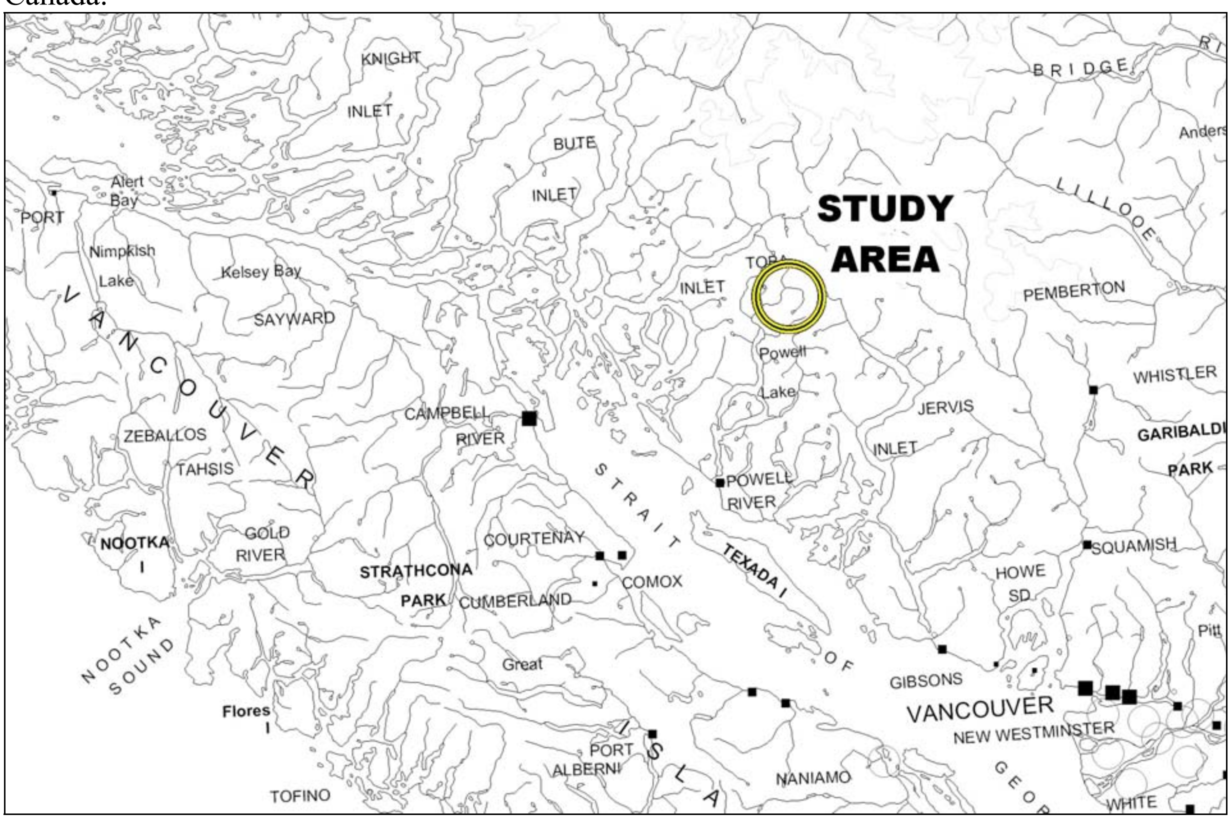


Figure 2. Timing of disturbance phases for 2001 and 2002, showing the number of scans conducted in each phase.

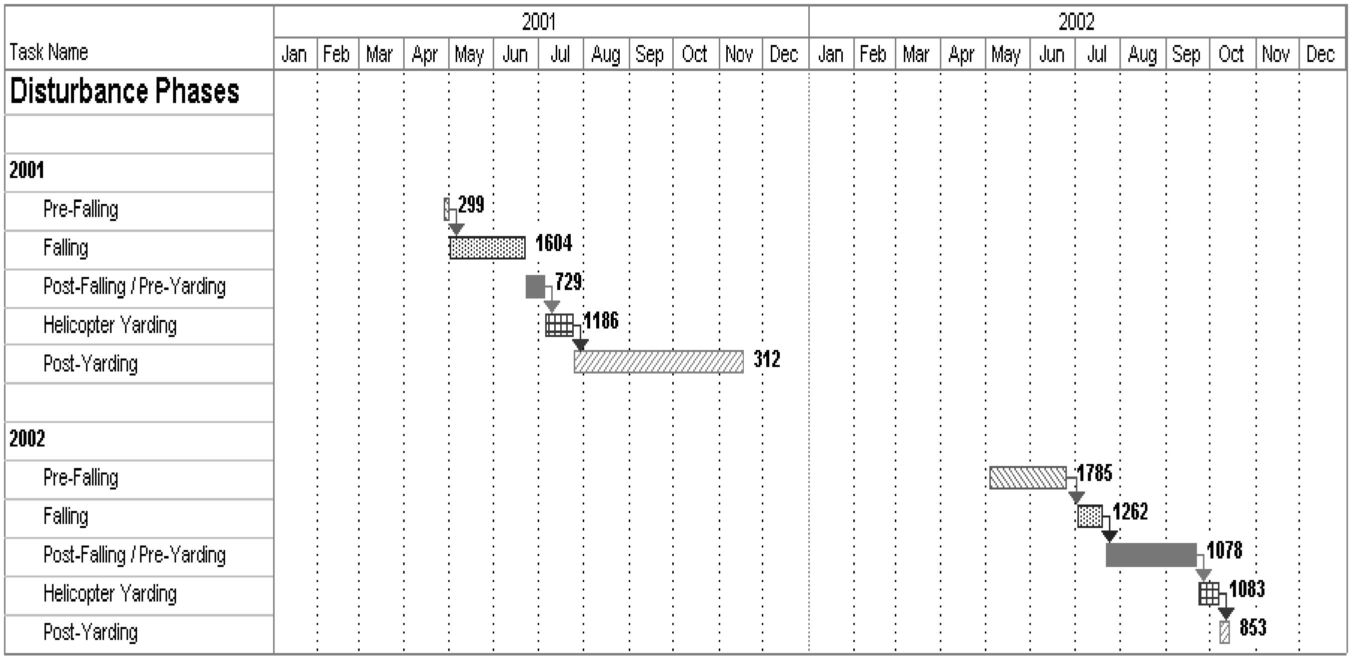
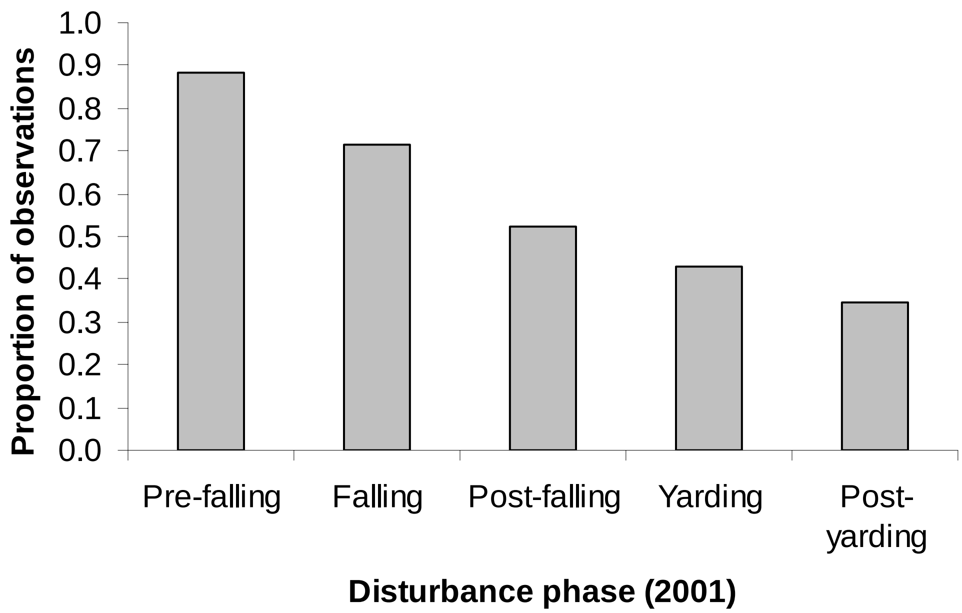


Figure 3. Proportion of scans during which mountain goats were observed, 2001 and 2002, treatment herd.



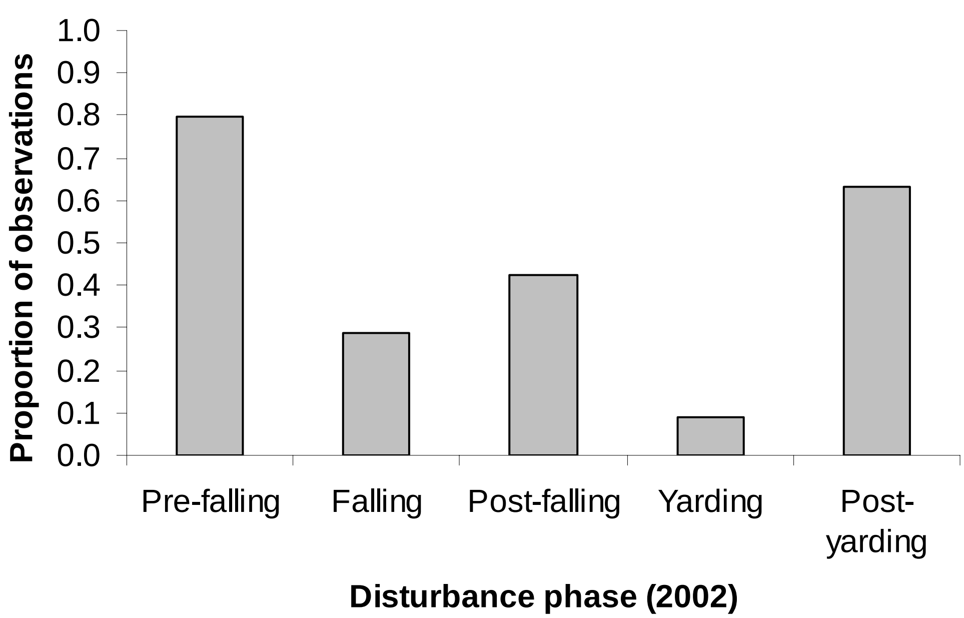


Figure 4. Control herd proportion of instantaneous scans containing mountain goat observations by season, upper Powell River, 2002.

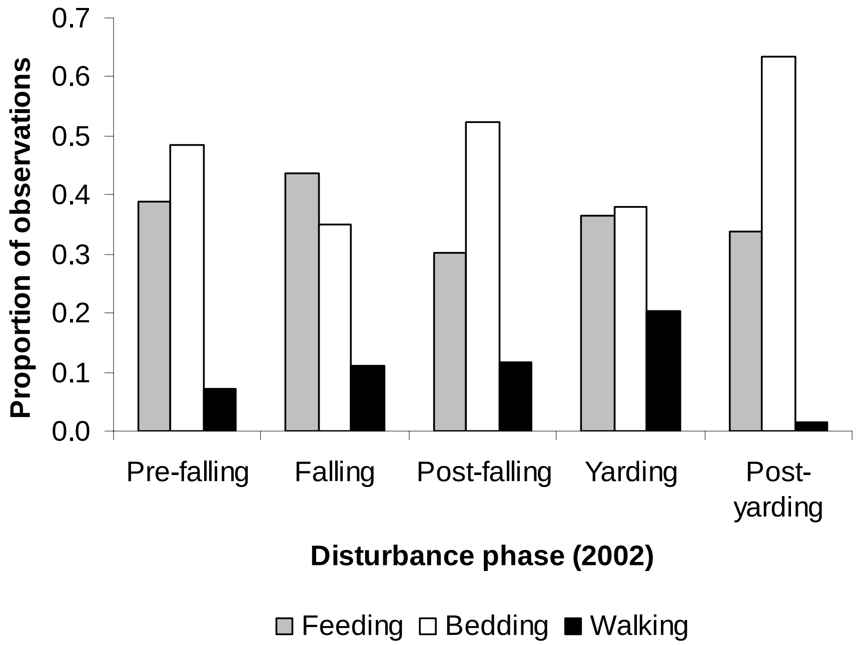


Figure 5. Proportion of observations of adult females in each behaviour category, by disturbance phase (treatment herd).

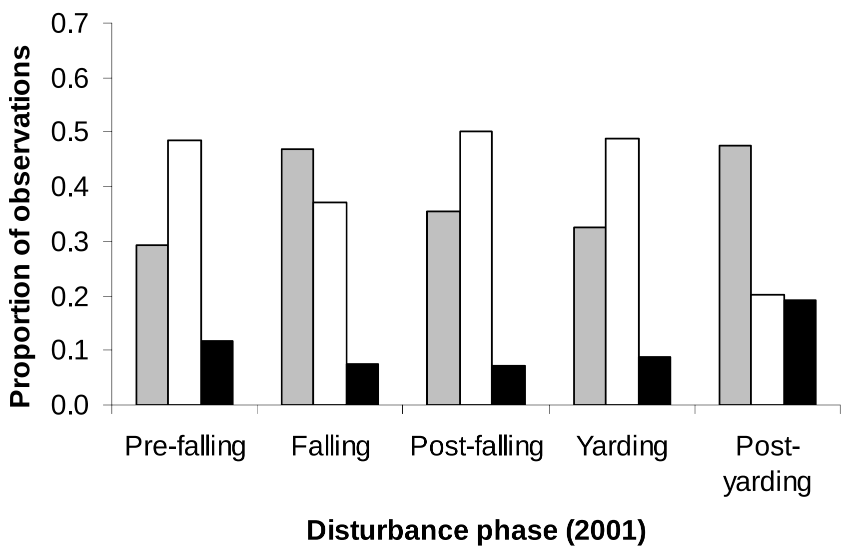
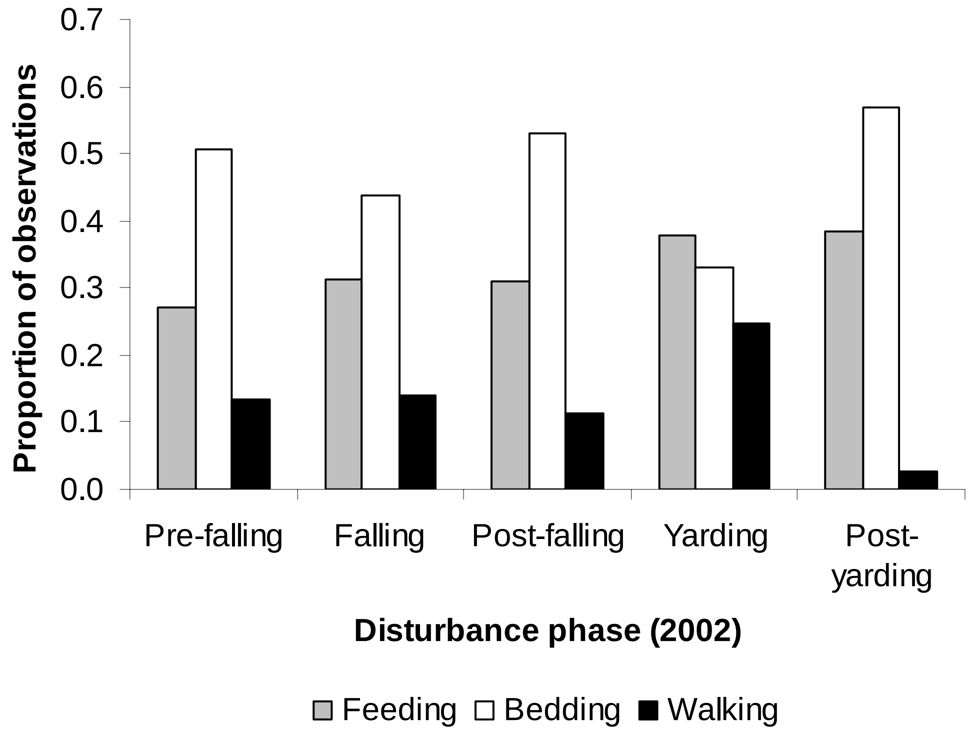


Figure 6. Proportion of observations of kids in each behaviour category, by disturbance phase (treatment herd).



Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:64

DAILY AND SEASONAL MOVEMENT PATTERNS OF MOUNTAIN GOATS TO A MINERAL LICK IN NORTH-CENTRAL BRITISH COLUMBIA

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Abstract: We monitored mountain goats (*Oreamnos americanus*) along a four km trail to a mineral lick over three years using remote camera systems. The objective of the study was to monitor the behaviours and movement patterns of the mountain goats prior to forest harvesting activities that would be taking place near the trail, and determine if there were any changes to behaviour or movement patterns after forest harvest activities. This report outlines the results of the pre-harvest behaviour and movement patterns. Movements of mountain goats initiated in late May and increased rapidly through early June. By late August the number of movements had decreased significantly, with no movements occurring after mid-October. Single mountain goats accounted for 73% of the photographs from remote camera monitoring, with groups of two animals accounting for 22% of the photographs and groups of three or more animals making up the remaining 5%. The proportions of males and females photographed in the 2001 monitoring year were similar to those found in the 1999 and 2000 monitoring years, with almost three times as many females being photographed as males. A significantly higher proportion of kids were photographed in 2000 (26.1%) than in 1999 (2%) or 2001 (6.6%). Peak movement times varied greatly through the study, with daily movement events occurred more often during the daytime than at night. The post-harvest monitoring is scheduled to commence in the spring of 2004 and will be compared to pre-harvest behaviours and movements to determine any effects of the forest harvesting and roads on movements to the mineral lick.

Key words: mountain goat, mineral licks, remote camera monitoring, trail movements, daily and seasonal movement behaviour

MODELING CORE WINTER HABITAT AND SPATIAL MOVEMENTS OF COLLARED MOUNTAIN GOATS

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and Goat Counc. 14:65-86

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Abstract: A total of 6,337 winter locations from 10 GPS collared mountain goats during three winter seasons (January 1 to April 30, 2000 to 2002) were used to determine winter movements, winter habitat selection, and derive a core winter habitat algorithm for mountain goats in the Taku River drainage. Collared mountain goats moved on average 20.41 ±1.24m/hr in the 2000 season, and 34.03 ±1.24m/hr in the 2001/2002 seasons. Winter home range sizes of GPS collared mountain goats ranged from 0.24km^2 for a winter season to 3.9km^2 for a period from February 14 to April 30 using a 95% adaptive kernel home range methodology. A total of 322 aerial telemetry locations from 16 to 18 radio collared mountain goats over three winter seasons in the study area were used to determine the average distance between center points of Jennrich-Turner (1969) bivariate normal home range areas for each individual in multiple years. Mountain goats used winter habitats that had center points that were on average 1284 ±703m to 1878 ±1045m distances apart in multiple years. A total of 774 mountain goat observation locations were taken during a helicopter survey in the study area on March 9-11, 2000. Mountain goats were observed at elevations ranging from 400m to 2200m (average 1264m). Habitat selection tests were used to test expected (5° slope classes, 20° aspect classes, and forest canopy height classes) against observed habitat proportions from winter GPS collar locations. Slope steepness, aspect classes, and non-forested habitats were selected for. An exponential relationship was found for the number of GPS collar locations verses distance from slopes from 45° to 60° steep at 100m intervals. A GIS algorithm was developed to identify core winter habitats for mountain goats based upon GPS collar findings in the study area. The derived model was tested against the 322 VHF aerial telemetry locations and against the 774 winter survey locations for validity. Significant differences between expected proportions from modeled habitats verses observed proportions from both VHF telemetry locations and winter survey locations were found. The derived model correctly identified 82.82% of all winter mountain goat, GPS locations.

INTRODUCTION

Repeated helicopter and fixed-wing aircraft over-flights and or direct interactions with people are well documented to adversely impact mountain wildlife populations by creating energetic costs to animals (Wilson and Shackleton, 2001; Frid, 1999; Stockwell et al., 1991; Côté, 1996; Sutherland, 1996; Gill et al. 1996; Maier et al. 1998; White et al. 1999; Macarthur et al., 1982). Understanding wildlife behaviours and identifying critical seasonal habitats can contribute to a sustainable management strategy that integrates the conservation of wildlife species with human resource development and land use. The objectives of this study were to measure spatial movements made by collared mountain goats, define winter habitat selection by collared mountain goats, and develop an algorithm that would identify core winter habitat areas selected by mountain goats in the Taku river drainage of north-west British Columbia.

STUDY AREA

This study was conducted in the Coastal Mountains of northwest British Columbia, Canada (58° 40' – 59° 15' N, 133° 45' - 133° 59' W). The study area is found approximately 60km to 100km distance from the coast of the Pacific Ocean near Juneau, Alaska. This area encompasses a variety of ecological parameters between interior N.W. British Columbia and coastal S.E. Alaska. The study area is located in the Boundary and the Teslin Plateau ecosections as identified by the British Columbia biogeoclimatic ecosystem classification system (Meidinger and Pojar, 1991). It encompasses the Englemann Spruce-Subalpine Fir, Sub Boreal-Spruce, and Alpine tundra ecozones in the Teslin Plateau ecosection and the Coastal Western Hemlock, Mountain Hemlock, and Alpine Tundra ecozones in the Boundary ecosection. In general, the Alpine Tundra ecozone occurs above 1400m elevations in the study area.

Winter temperatures can drop to -40°C with snow accumulations often reaching depths greater than 4.0m. Snow arrival is often dependent upon topographic relief but generally snow arrives in October or early November and remains into the following May or June. The area is frequented by strong up-flow winds that are most common from the south or southwest direction, resulting from pressure differences between coastal and interior climates.

An inventory of late-winter mountain goat abundance conducted in March 2000 for this study area reported a minimum population estimate of 890 mountain goats with an overall density of 0.45 mountain goats per square kilometer (Keim, 2001).

Although there is an application for a mine and access road development inside the study area, there currently is little to no human development. Currently, the only human caused impacts to mountain goats result from aerial and or riverboat travel most commonly used for wilderness recreation (including big-game hunting, fishing, and helicopter skiing) and reconnaissance inventory for resource development.

METHODS

Data Acquisitions

Data on mountain goat habitat use was acquired in three separate methods: VHF radio collar tracking, GPS collar tracking, and a winter helicopter survey.

For the first two, mountain goats were captured from a Hues 500 helicopter using a net gun and wildlife-capture team. This was done during winter when snow accumulations aided capture technique. Mountain goats were captured in a variety of habitat areas across the study area. A total of 19 mountain goats were fitted with VHF radio collars and 11 mountain goats were fitted with Lotek GPS_2000 model GPS collars (Lotek GPS_2000 manual, 1999). Mountain goats fitted with VHF radio collars were monitored for three consecutive winter seasons (January 1 to April 30, 2000 - 2002). Bi-monthly fixed-wing telemetry flights were conducted during the first year commencing in January 2000. Monthly telemetry flights were conducted during the second two years. Telemetry locations were taken using a GPS unit and observations for location, group size, and habitat features were recorded during each telemetry flight.

GPS collars were programmed to attempt to acquire GPS locations 6 times per day at four-hour intervals for one year. Each collar was equipped with a blow-away mechanism (Lotek, 1999) that was set to trigger on a fifty-two week clock. Data could be acquired only after the collar was retrieved from the field. On January 1-4, 2000 the first set of 5 GPS collars were deployed on mountain goats. These collars attempted to acquire GPS locations at 0:00, 4:00, 8:00, 12:00, 16:00, and 20:00 hours (Keim, 2001b). On February 4, 2001 a second set of 6 GPS collars were deployed on 6 additional mountain goats. These collars attempted to acquire GPS locations at 3:00, 7:00, 11:00, 15:00, 19:00 and 23:00 hours.

Locations taken from GPS collars were tested for an overall GPS fix rate for each collar using the formula:

Fix Rate = total fixes acquired / total fix attempts

An average fix rate ± standard error (SE) was determined for all 10 GPS collars.

Locations taken from GPS collars were also tested for missed or lost GPS fixes through an analysis of the average ±SE number of hours between GPS fix acquisitions and the range of the number of hours between GPS acquisitions (the difference in hours between fix acquisitions should be no less than 4 hours).

Late-winter mountain goat observations and subsequent GPS locations acquired during a helicopter inventory for the study area in March 2000 were also utilized for habitat use and habitat selection analysis for model verifications. Keim (2001), describes methodologies used during this winter mountain goat inventory.

Winter Home Range Size

Winter locations (January 1 to April 30) collected from 10 GPS collars were imported to point files for home range analysis in the Animal Movement Version 2.0 (Spatial Analyst) extension of Arc/View 3.2 (Hooge and Eichenlaub, 1997). Home range analysis was completed using a 95% probability, adaptive kernel method (Worton, 1989). These same adaptive kernel home ranges were used to identify patch habitat selection within winter home ranges.

Hourly Movements

GPS winter locations with a four-hour interval between consecutive locations were utilized for analysis of hourly movements. The distance (m) between consecutive locations was determined using an extension to Spatial Analyst 2.0 in Arc/View 3.2. The rate of movement (m/hr) was then determined between consecutive locations. The average hourly movements and SE were identified for movements made during different periods of the day (0:00 to 4:00, 3:00 to 7:00, 4:00 to 8:00, 7:00 to 11:00, 8:00 to 12:00, 11:00 to 15:00, 12:00 to 16:00, 15:00 to 19:00, 16:00 to 20:00, 19:00 to 23:00, 20:00 to 24:00, and 23:00 to 3:00) in the winter by GPS collared mountain goats.

Winter Home Range Re-use in Multiple Years

Winter locations collected from 16 to 18 VHF radio collared individuals (12 females: 6 males or 11 females: 5 males) were utilized to determine the distance between multiple winter home range habitat areas and home range re-use in three multiple winter seasons (2000, 2001, and 2002). A home range analysis was completed for each individual for each winter season using Animal Movement Version 2.0 (Spatial Analyst) extension of Arc/View 3.2. The Jennrich-Turner (1969) Bivariate Normal Home Range method was used to calculate the center point of each home range area. The distance between the center points of winter home ranges in multiple years among individuals was then determined. The average distance between the center points of home range areas was then determined for the three winter seasons. Visual comparisons of the calculated Jennrich Turner Bivariate Normal Home Range Areas were then compared for home range overlap by each individual in three multiple winter seasons (2000 vs. 2001, 2000 vs. 2002, and 2001 vs. 2002).

Identifying Patch Habitat Selection within Winter Home Ranges

Habitat selection tests were conducted for each GPS collared individual based upon GPS locations within habitat proportions of identified 95% adaptive kernel home range areas. Habitat proportions included categorized 5° slope classes, 20° aspect classes, and forest cover height classes as available within each 95% adaptive kernel home range area. Slope and aspect classes were determined from a digital elevation model (DEM) of 20m-pixel size. Forest cover age class data was determined from 1:20,000 forest-cover mapping for the province of British Columbia, Canada. Significant difference in use between habitat proportions was determined using a log-likelihood chi-square test (Manly et al, 1993). If a significant difference of use was determined, significant selection for or against a particular habitat proportion was then determined by comparing expected habitat use (as determined from habitat proportion areas within the 95% adaptive kernel home range areas) against observed habitat use (GPS collar locations) using a Bonferroni correction (Manly et al, 1993) with a 95% confidence limit.

Slopes between 45° and 60°, were considered “deemed escape terrain” (steep slopes with rocky outcrops utilized as security cover) for mountain goats. The distance to “deemed escape terrain” was tested with GPS mountain goat locations using an exponential regression analysis for the number of locations verses the distance to “deemed escape terrain” in 100m increments.

Generating the Model Algorithm

A model algorithm for mapping core winter mountain goat habitats was generated using a weighted-overlay grid from the model builder extension in Arc/View 3.2 (Environmental Research Institute Inc., 1999). Algorithm variables included; distance to escape terrain, slope, aspect, and elevation. Each variable was weighted, with the total of all variables measuring 100%.

Each variable consisted of internal values ranked on a scale from one to five. The model output scored core winter mountain goat habitats from 0 (unsuitable habitat) to 5 (optimal habitat) over the entire study area in a grid layout.

Model Verifications

The effectiveness of this model was tested against 322 winter VHF radio collar telemetry locations (from three winter seasons and 18 individuals) and 774 winter mountain goat survey observations (Keim, 2001) in two separate habitat selection tests. A standardized selection ratio for the scored habitats was determined based upon analysis for both VHF radio collar locations and survey observations using methods from Neu et al (1974). Significant difference in use between habitat proportions was determined using a log-likelihood chi-square test (Manly et al, 1993). If a significant difference in use was determined, significant selection for or against a particular habitat proportion was then determined by comparing expected habitat use against observed habitat use. Habitat proportions were measured based upon the habitat model scores (areas of each) within a study area defined by a minimum convex polygon (MCP) home range method (Mohr, 1947) compiled around (1) all VHF telemetry locations and (2) all survey observations using the Animal Movement Version 2.0 extension of Arc/View 3.2 (Hooge and Eichenlaub, 1997). Observed habitat use was measured from (1) VHF telemetry locations and (2) survey observation locations using a Bonferroni correction (Manly et al, 1993) with a 95% confidence limit.

RESULTS

Data Acquisitions

A sum of 322 aerial telemetry locations were collected from 19 VHF radio collared mountain goats (12 females: 7 males) during three winter seasons. Locations from 18 of the 19 VHF radio collared mountain goats were used for determining winter home range reuse in multiple years. All 322 aerial telemetry locations were used for model verification.

A total of 6,337 locations were collected from 10 of the 11 GPS collared mountain goats (7 females: 3 males) during three winter seasons. One GPS collar malfunctioned and did not record GPS locations. For the 2000 winter season (January 1 to April 30) 2723 locations were collected from 5 GPS collared females. During the 2001 winter season (data could only be collected from February 12 to April 30) 2,151 GPS locations were collected from 2 females and 3 males. During the 2002 winter season (data could only be collected from January 1 to March 13) 1,463 GPS locations were collected from the same 2 females and 3 males studied in 2001.

On average ±SE GPS collars had a GPS fix rate of 0.81 ±0.01. The average ±SE number of hours between GPS fixes taken was 7.8 ±0.2 hours (range: 4 – 56).

A total of 774 mountain goat observations during a late winter mountain goat inventory were collected from helicopter on March 9 to 11, 2000 (Keim, 2001). Observation locations were utilized to verify the habitat model and elevation data for mountain goat observations was used for model generation.

Winter Home Range Size

The 95% probability adaptive kernel home range estimates in the 2000 winter season (January 1 to April 30) for the 5 GPS collared females (range: n= 313 – n=702) averaged 0.56 ± 0.23 km^2 (range: 0.24–0.82 km^2).

The 95% probability adaptive kernel home range estimates for the five GPS collared mountain goats in the 2001 winter season averaged ±SE 1.56 ±1.20km^2 measured during 75 ±2 days (Table 1).

Table 1. Mountain goat 95% probability adaptive kernel home range estimates derived from GPS collar data, 2001.

Sex	Area (km^2)	n	Timeframe
F	0.47	444	2/14/01 – 4/30/01
F	0.85	421	2/12/01 – 4/30/01
M	1.63	435	2/13/01 – 4/30/01
M	0.96	441	2/14/01 – 4/30/01
M	3.9	410	2/14/01 – 4/30/01

The 95% adaptive kernel home range estimates ranged from 0.01 to 3.60km^2 (Table 2)

Table 2. Mountain goat 95% probability adaptive kernel home range estimates derived from GPS collar data, 2002.

Sex	Area (km^2)	n	Timeframe
F	0.78	253	1/1/02 – 3/13/02
F	3.60	313	1/1/02 – 3/13/02
M	2.02	363	1/1/02 – 3/13/02
M	0.01	293	1/1/02 – 2/25/02
M	0.11	241	1/1/02 – 2/27/02

Hourly Movements

In the 2000 year, 2,376 sessions were obtained for measuring hourly movements, mountain goats moved on average ±SE 20.41 ±1.45m/hr. In the 2001 and 2002 years 3,219 sessions were obtained for measuring hourly movements, mountain goats moved on average ±SE 34.03 ±1.24m/hr (Figure 1).

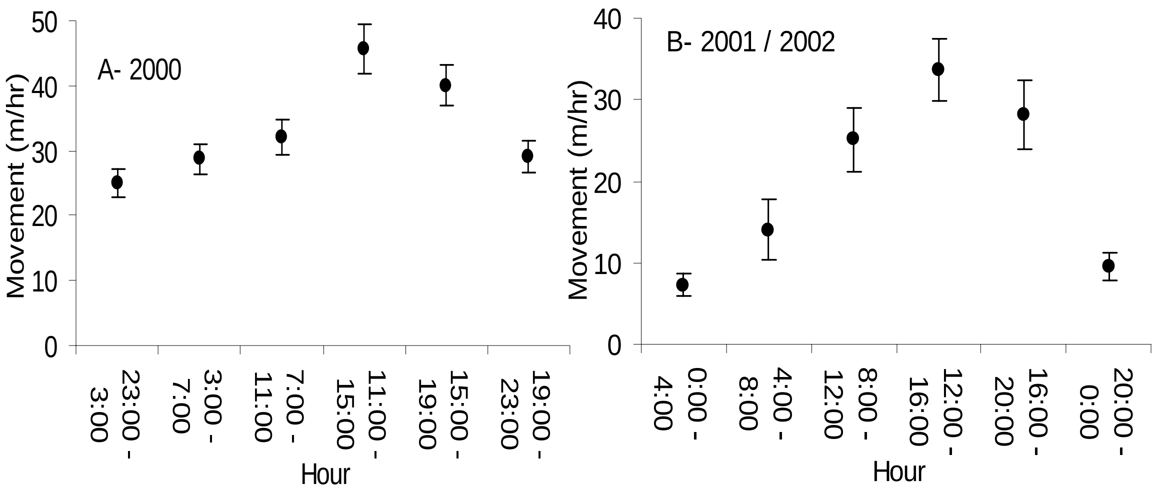

Figure 1. Average ± SE rates of movement (m/hr) measured between locations taken at 4-hour intervals of the day. All locations were acquired from GPS collared mountain goats (n=5 for A / n=5 for B) in the winter seasons of A, 2000 and of B, 2001 and 2002.

Winter Home Range Re-use in Multiple Years

Winter home range center points were compared among 16 (11 females: 5 males) to 18 (12 females: 6 males) VHF radio collared mountain goats (50 home range center points) during three separate winter seasons (Table 3). In 48 of the 50 comparisons, individual mountain goats had overlapping winter home range areas in multiple years.

Table 3. Average distances ± SE between the center points of Jennrich-Turner Bivariate Normal home range areas of individual mountain goats in multiple winter seasons.

Years	N	Average distance ± SE
2000 – 2001	18	1284 ± 703m
2000 – 2002	16	1486 ± 585m
2001 – 2002	16	1878 ± 1045m

Identifying Patch Habitat Selection within Winter Home Ranges

A total of 10 GPS collared mountain goats were tested for selection of slope, aspect, and forest cover classes. There was a significant difference found between habitat proportions available and use of habitat proportions in 9 of the 10 mountain goats tested against 5° slope classes (X^2= 32.2, 7.4, 175.3, 30.7, 187.6, 622.2, 422.5, 53.8, 253.1, 272.7 / df= 9, 12, 13, 13, 13, 13, 9, 14, 14, 14 / P=0.05) (Table 4). A significant difference was found between habitat proportions available and habitat proportions used in 9 of the 10 mountain goats tested against 20° aspect classes (X^2= 47.4, 18.8, 128.9, 34.4, 214.6, 125.3, 169.6, 192.2, 234.3, 331.7 / df= 9, 12, 13, 13, 13, 13, 9, 14, 14, 14 / P= 0.05) (Table 5). It was only possible to test for significant selection of forest cover habitats in 6 of the 10 mountain goats because the remaining 4 mountain goats did not have identifiable forest cover in their 95% probability adaptive kernel home range areas. There was a significant difference in habitat proportions available and habitat proportions used in 4 of the 6 mountain goats tested against forest cover classes (X^2= 6.0, 8.7, 60.3, 2.75, 12.5, 20.4 /df= 2 / P= 0.05). For selection tests for or against forest cover habitat types, never was an identifiable forested habitat selected for.

A total of 6,337 winter locations from 10 GPS collared mountain goats were used to measure distances (in 100m intervals) from 45 to 60° slopes (Figure 2). On average ±SE mountain goat GPS collar locations were 100 ±1.3m (range: 0 – 700m) from 45 to 60° slopes, measured in 100m intervals.

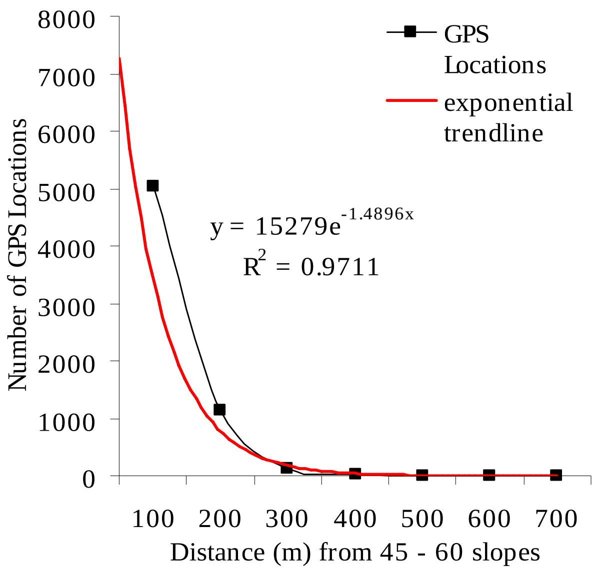

Figure 2. An exponential regression analysis for the number of locations from GPS collared mountain goats to 45 - 60° slopes measured at 100m intervals.

Mountain goats were observed at elevations ranging from 400m to 2200m with an average elevation of 1264m in the late-winter helicopter survey (Keim, 2001) (Figure 3).

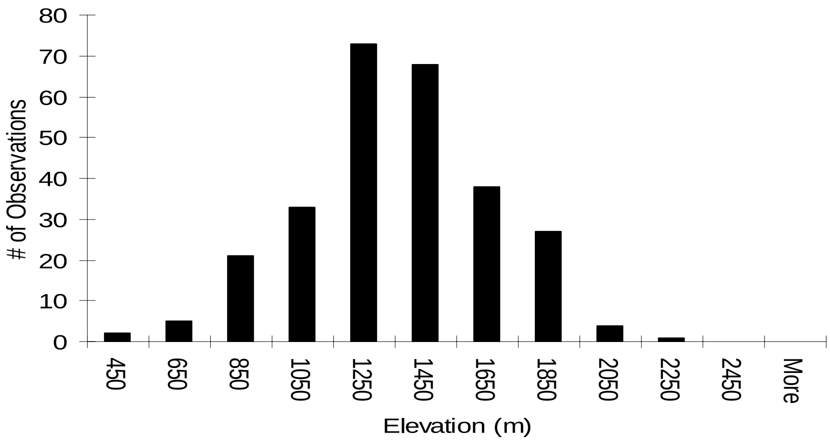

Figure 3. A frequency distribution table for elevations of mountain goat group observations in a late-winter helicopter inventory survey (Keim, 2001).

Table 4. Summary of the number of GPS collared mountain goats having expected proportion of habitat use less than observed proportion of habitat use ±Bonferroni correction (habitat type selected for), expected proportion of habitat use equal to observed proportion of habitat use ±Bonferroni correction (habitat type not selected for or against), and expected proportion of habitat use greater than observed proportion of habitat use ±Bonferroni correction (habitat type selected against) for 5° slope-classifications between 0° and 80°.

Slope Class	0 To 5°	5 To 10°	10 To 15°	15 To 20°	20 To 25°	25 To 30°	30 To 35°	35 To 40°	40 To 45°	45 To 50°	50 To 55°	55 To 60°	60 To 65°	65 To 70°	70 To 75°	75 To 80°
Expected proportion < Observed proportion	0	0	0	1	0	1	1	0	3	4	7	4	2	1	0	0
Expected proportion = Observed proportion	2	3	3	2	2	3	3	7	5	6	3	3	1	3	1	0
Expected proportion > Observed Proportion	3	2	4	6	8	6	6	3	2	0	0	1	1	0	0	0

Table 5. Summary of the number of GPS collared mountain goats having expected proportion of habitat use less than observed proportion of habitat use ±Bonferroni correction (habitat type selected for), expected proportion of habitat use equal to observed proportion of habitat use ±Bonferroni correction (habitat type not selected for or against), and expected proportion of habitat use greater than observed proportion of habitat use ±Bonferroni correction (habitat type selected against) for 20° aspect-classifications between 0° and 360°.

Aspect Class	0 To 20°	20 To 40°	40 To 60°	60 To 80°	80 To 100°	100 To 120°	120 To 140°	140 To 160°	160 To 180°	180 To 200°	200 To 220°	220 To 240°	240 To 260°	260 To 280°	280 To 300°	300 To 320°	320 To 340°	340 To 360°
Expected proportion < Observed proportion	0	0	0	0	0	0	2	2	2	3	2	3	3	4	2	0	0	0
Expected proportion = Observed proportion	1	1	1	1	1	5	4	5	4	4	7	4	3	2	1	2	0	1
Expected proportion > Observed Proportion	1	3	4	6	6	4	3	2	3	3	1	3	3	2	3	3	2	1

MODEL ALGORITHM

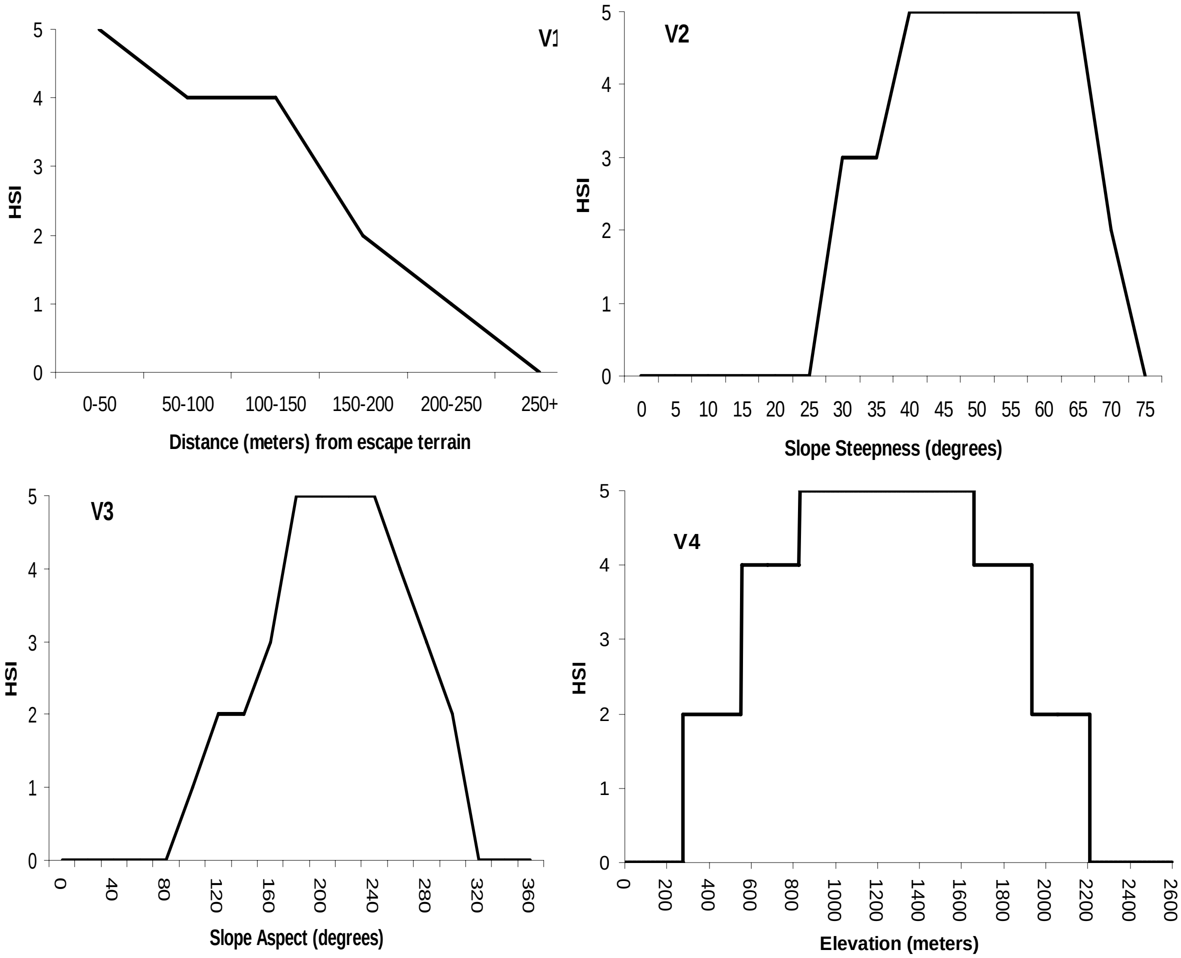

Figure 4. Graphical relationships between habitat variables and habitat suitability values for the mountain goat winter range habitat model.

(Winter Mountain Goat Habitat)

Habitat Suitability Index = (V1 x 0.35) + (V2 x 0.25) +(V3 x 0.25) + (V4 x 0.15)

The HSI algorithm predicts winter mountain goat habitat on a scale between 0 and 5. Habitats predicted to have an HSI value greater than or equal to 3 are defined as suitable winter mountain goat habitat.

For V1 “escape terrain” is defined at slope steepness between 45° and 60°.

All habitat variables (V1 to V4) were identified using data from a digital elevation model as a raster in a GIS with 25m-pixel resolution.

A minimum continuous winter habitat area of 5.0 hectares was used as a final step.

Core winter mountain goat habitat is defined within an elevation range of 278m to 2209m ASL, on aspects facing between 100° and 300°, on slopes that are between 20° and 65° steep, and in areas that are no further than 400m from slopes that are between 45° and 60° steep (Figure 4). Core winter mountain goat habitats within these boundaries are ranked on a scale from 1 (poor habitat) to 5 (optimal habitat) in a GIS grid at 60m-pixel resolution.

Model Verifications

Two separate data sets were used to test and verify the core winter mountain goat habitat model (1. VHF collared mountain goat winter telemetry locations 2. Locations from a winter mountain goat inventory survey from helicopter).

In the first test, 322 winter mountain goat VHF collar telemetry locations over three separate winters were tested for significance (X^2= 148.13, P= 0.05) to the model in an area of 1,357km^2. A standardized selection ratio was used to define which habitat classes were most or least selected for (higher proportions are most selected for, relative to the selection ration value (Table 6).

Table 6. The standardized selection ratio of each habitat class plus expected and observed habitat proportions found within the MCP home range area of all winter telemetry locations.

Winter habitat Value (0-5)	Expected Habitat Proportions (% Area)	Observed Habitat Proportions (*)	Standardized Selection Ratio
0	0.80	0.39 ± 0.07	0.04
1	0.00	0.00 ± 0.00	0.00
2	0.02	0.04 ±0.03	0.12
3	0.07	0.12 ±0.05	0.13
4	0.09	0.30 ±0.07	0.26
5	0.02	0.15 ±0.05	0.45
Total	1.0	1.0	1.0

* Observed proportion of telemetry locations within each habitat area ±Bonferroni correction.

VHF collared mountain goats selected for model classes 4 and 5 (observed proportions ±Bonferroni correction > expected proportions), against model class 0 and 1 (observed proportions ±Bonferroni correction < expected proportions), and neither for or against (observed proportions ±Bonferroni correction = expected proportions) model classes 2 and 3 (Figure 5).

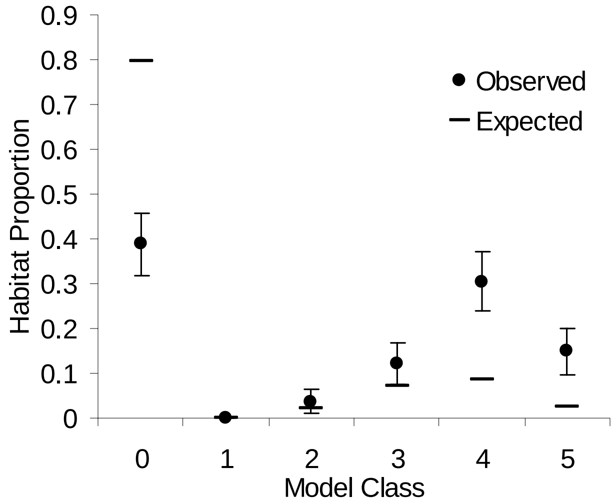

Figure 5. Observed VHF collared mountain goat telemetry locations ±Bonferroni correction and expected habitat proportions (% Area) verses winter habitat model classes (0 – 5).

In the second test, 774 late-winter mountain goat observations were tested for significance (X^2= 575.92, P= 0.05) to the model in an area of 3,031km^2. A standardized selection ratio was used to define which habitat classes were most or least selected for (higher proportions are most selected for, relative to the selection ration value (Table 7).

Table 7. The standardized selection ratio of each habitat class plus expected and observed habitat proportions found within the MCP home range area of all winter survey observations.

Winter habitat Value (0-5)	Expected Habitat Proportions (% Area)	Observed Habitat Proportions (*)	Standardized Selection Ratio
0	0.80	0.31 ±0.04	0.02
1	0.00	0.00 ±0.00	0.00
2	0.02	0.07 ±0.02	0.20
3	0.07	0.09 ±0.03	0.08
4	0.09	0.35 ±0.04	0.25
5	0.02	0.19 ±0.04	0.44
Total	1.0	1.0	1.0

* Observed proportion of observed locations within each habitat area ±Bonferroni correction.

The locations of mountain goat survey observations showed selection for model classes 2, 4, and 5; against model class 0; and neither selected for or against model classes 1 and 3 (Figure 6).

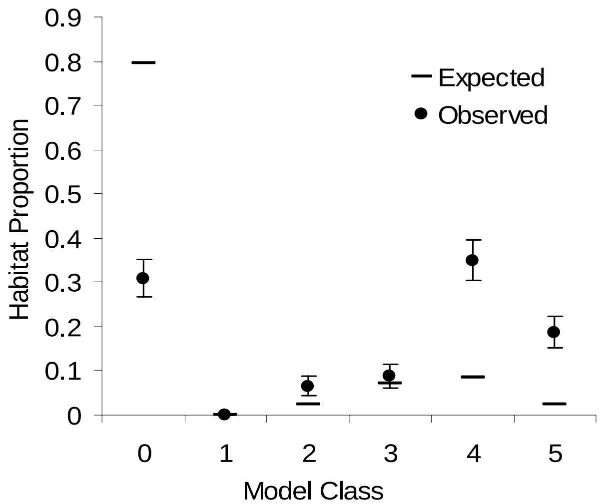

Figure 6. Observed mountain goat survey locations ±Bonferroni correction and expected habitat proportions (% Area) verses winter habitat model classes (0 – 5).

In this model for the Taku study area, habitat classes greater than or equal to 3 were considered suitable mountain goat habitats. As a validation measure, the proportion of the winter GPS collar mountain goat data set found to be located in suitable habitats (HSI classes 3, 4, and 5) was measured for accuracy. The HSI model, using classes 3, 4, and 5 as suitable winter range habitat in the Taku study area, correctly validated 0.83 of the winter GPS collar locations.

DISCUSSION

Data Acquisitions

The GPS tracking studies provided spatial and temporal data on individual mountain goats at an intensity that is difficult, if not impossible, to acquire by conventional radio tracking and observation methodologies.

At a spatial scale, conservative measures on the accuracy of GPS collar locations have found GPS locations to be accurate to at least 65.5m of the actual location (Moen et al, 1997). However, the effects of topographic relief and canopy cover on GPS collars, is well acknowledged (Moen et al 1997, Moen et al 1996, Rodgers et al 1996, Rempel et al 1995). In environments with increased canopy cover and/or increased topographic relief the ability for GPS collars to acquire satellites is reduced. Thus, it is inferred that a positional bias may result for GPS tracking habitat use and habitat selection studies towards open-canopy and or relatively flat habitats (low variability in topographic relief). Given the results of GPS collar performance in this study, there appears low potential for positional bias for several reasons:

1) GPS collars acquired a location at 81 ± 1% of timed fix attempts. Therefore, the only potential for positional bias would result from the remaining 18 to 20% fixes not acquired.
2) The time interval between GPS fix acquisitions was small, averaging 7.8 ±0.2 hours with a maximum interval between locations being 56 hours (14 consecutive GPS fix attempts). Thus, data gaps (times periods

when GPS fixes were not acquired) are both infrequent and short in duration.

3) GPS study animals made minimal movements, on average less than 25m per hour and had home range areas less than $3.9km^2$ during winter season measurements.
4) The reasons for loss of GPS fixes may result from a number of other random events including animal positioning relative to GPS antenna, or a physical loss of available satellites.

Given the high rate of GPS acquisition, the infrequent and short duration of GPS acquisition gaps, and the short distance of movements mountain goats made within a relatively confined home range area any positional habitat bias is low in stature and probably lost due to sample size in this study.

At a temporal scale, GPS collars in this study acquired locations at a rate of approximately 5 per day, providing more than an adequate sample size for habitat selection and home range analysis on individual mountain goats. The drawback of GPS-collar tracking in this study was not the sample size of locations acquired per individual but rather, the small sample size in the number of individuals (only 10 GPS study animals during three winter seasons).

Consequently the GPS tracking study was complimented with conventional aerial telemetry tracking data from 18 additional collared mountain goats and habitat use data from an intensive mountain goat helicopter survey involving 26.6 hours of helicopter survey time during three consecutive late-winter days (Keim, 2001). Unfortunately due to costly telemetry flying expenses, data acquisition from radio collared mountain goats provided only a small sample size for individual mountain goats during the winter seasons (5 to 10 locations per individual per season). Thus insufficient data was available to measure trends in animal movements from radio collared individuals.

In combination (the data acquired from GPS tracking studies, mountain goat survey observations, and the radio telemetry locations) winter habitat selection and animal movement findings determined from an intensive GPS collar study were testable over a broad scale of individuals within the study area.

Winter Home Range Size

Mountain goat studies in S.E. Alaska have found annual home range areas between 10 to $20km^2$ with winter home range areas that are much smaller in scale (as small as $0.2km^2$) and more distinct in habitat characteristics (Schoen and Kirkoff, 1982 and Smith, 1982). Similarly, winter home range areas in the Taku drainage were found to be significantly less than the 10 to $20km^2$ annual home range areas found in Alaska, and measured in area as small as $0.47km^2$ in the late winter season. Geist (1971) interpreted that with wide forage acceptance, mountain goats have the ability to compensate with a narrow habitat preference. It is my interpretation that mountain goats tend to minimize energetic costs in the winter by increasing resting bouts, decreasing movements, and increasing foraging time. Consequently, in the winter mountain goats strategically place themselves into specific (and small) core habitat locations that have the necessary habitat attributes to aid in minimizing energetic costs during the winter.

Hourly Movements

Winter mountain goat movements tended to peak during mid-day to late-afternoon in this study and did not exceed a measured average rate of movement greater than 46m per hour. Fox (1978) observed mountain goat behavior and found average daily movement to be 15 to 30m.

In this study there are several potential sources of error in the hourly movement measurements that were not quantified. First, hourly movements were reduced from measured distances between two points measured four hours apart. Second, errors in point locations could potentially be as far as 65.5m. Lastly, the distance between point measurements does not consider topographic relief.

However, given the observed data and the potential errors considered it would be safe to interpret that; on average, studied mountain goats did not exceed rates of movements greater than 100 to 150m per hour (as a conservative measure), mountain goats tended to be most active during the day from 11:00 to 16:00 and least active from 23:00 to 4:00, and movements as measured (including winter home range areas) indicate that studied mountain goats tend to be relatively inactive during the winter season. Schoen and Kirkoff (1982) and Fox (1978) have made similar observations on winter movements by mountain goats.

Winter Home Range Re-use in Multiple Years

Schoen and Kirkoff (1982) studied a mountain goat population just across the Canada / USA border from this study area for 3 consecutive years and found a winter home range site fidelity rate near 0.66. The average ±SE distance between home range center points was measured for 18 to 16 VHF collared mountain goats in three consecutive winters. Unfortunately, winter home range areas were measured from only 5 to 10 telemetry locations per season. However, the average distances between the center points of these 5 to 10 locations for each individual in multiple years provide an indication of individual presence to similar winter habitat areas in multiple years. Studied mountain goats were found in winter habitats at distances of closest proximity in the winters of 2000 / 2001 (1284 ±703m) and were found in winter habitats at distances of farthest proximity during the winters 2001 / 2002 (1878 ±1045m). In 48 of 50 visual comparisons individual winter mountain goat home range areas overlapped in multiple years. Studied mountain goats tended to re-use, to some degree, core winter habitat areas in multiple years.

Identifying Patch Habitat Selection within Winter Home Ranges

Habitat selection within winter home range areas defined from GPS collar data was tested against variables for slope steepness, aspect direction, and forest cover height class. Preferences were found for slope steepness, and aspect direction. No preference was discovered for forested habitats, however non-forested habitats were selected for over forested habitats by four of the ten mountain goats tested.

Habitat selection tests for GPS collar study animals found selection, by at least one individual, on slopes between 15° and 70° steep. Core habitat selection by collared mountain goats was most frequent on slopes between 35° and 70° steep. The greatest level of selection for the 10 mountain goats was found for slopes between 50° and 55° steep. Core winter mountain goat habitats were most strongly associated on slopes between 45° and 60° steep. An exponential relationship was observed between mountain goat locations and distance to 45° and 60° slopes, for which 80% of all winter locations were found within a 100m distance of such slopes. Previous studies and winter mountain goat habitat modeling have identified slopes greater than 50° steep (and most often between 50° and 65°) to be deemed escape terrain (Pollard, 2000; Demarchi and Johnson, 1998; Smith, 1983; Schoen and Kirkoff, 1982; and Smith, 1981) and the most critical component for identifying winter mountain goat habitats. Mountain goats tend to adopt a strategy of passive avoidance as a means to avoid predators. This infers a selection of habitats where the risk of encountering potential predators is reduced. For mountain goats the resulting habitat is steep rocky terrain (escape terrain). Smith (1986) concluded that mountain goats utilized areas within 0.8km of deemed escape terrain in establishing their home ranges. Demarchi and Johnson (1998) recorded 95% of their mountain goat track locations were observed within less than 50m of deemed escape terrain.

Habitat selection tests for GPS collar study animals found selection, by at least two individuals, on aspects facing between 120° and 300° direction. The prevailing aspect direction was to the south-southwest (180° to 240°) directions. Other studies on mountain goats have observed a trend of habitat selection on mountain slopes facing a southerly direction (Demarchi and Johnson, 1998; Smith, 1983; Schoen and Kirkoff, 1982; and Smith, 1981). In the northern hemisphere, southern aspects receive the greatest amount of solar radiation. Solar radiation can directly impact metabolic rates of mountain goats in the winter by maintaining homeostasis at a time when the seasonal climate may provide for low body temperatures requiring behavioural or physical response factors (shivering, panting or moving) which may contribute to energy loss and imbalance. These behavioural and physical activities can also divert from otherwise important activities, as foraging, and further decrease an animal's metabolic rate. Indirectly, southerly aspects also offer a longer growing season and greater rates of snowmelt than do northerly aspects. In the Taku drainages the prevailing wind direction is from the southwest, providing a mechanism to clear (create wind-swept) southwest facing ridges and slopes of snow. Decreased duration and depth of snow cover results in greater mobility and improved access to forage for longer periods of the year and thus potentially optimizes energy conservation by mountain goats.

Hebert and Turnbull (1977), described southern interior and coastal mountain goat ecotypes in British Columbia. They described coastal winter ranges, within 30 – 50km distance of the ocean, to be characterized and restricted by mature forest canopy cover overhanging steep bluff areas. They believe heavy coastal snow with high water content, restricted winter mountain goat movement to and from these coastal winter habitat ranges. They described southern interior (East Kootenay) mountain goat ranges to include the Englemann Spruce-Subalpine Fir biogeoclimatic zone and up to snow free ridge tops at 2,135+m elevation.

More recent mountain goat habitat work in areas with similar proximity to the Pacific Ocean as the Taku study area have identified mature forest canopy as a crucial component to mountain goat winter ranges (Pollard, 2000; and Demarchi and Johnson, 1998). All mountain goat habitat studies in near by S.E. Alaska have identified mature forest canopy as a crucial component to mountain goat winter ranges (Smith, 1983; Schoen and Kirkoff, 1982; and Smith, 1981).

In three consecutive years of study in the Taku watershed area, I did not at any time observe winter mountain goat habitat use in mature forest canopy cover. Habitat selection data from GPS collar studies found no selection for any forest cover types and in fact, found selection against forest cover by 4 of 10 collared GPS mountain goats. Habitat use occurred only in non-forested habitats, forest cover height class 1 (0.4-10.4m), and forest cover height class 2 (10.5-19.4m) for all 28 collared mountain goats (GPS and VHF) in the study. This said, it is important to realize that collared mountain goats in this study were captured during winter months in locations that were accessible by helicopter. It is quite possible that a bias resulted in mountain goats studied towards individuals that select high elevation, non-forested winter habitats. Further, the sightability of mountain goats under forest canopy is very low and it is possible that mountain goats using mature forest canopy habitats (especially closer to the coast) were not observed during winter wildlife inventory surveys. It is still true however, that mountain goats in this study area utilized high elevation, alpine habitats, above tree line. I believe the strong outflow winds associated with coastal weather systems, as present in the Taku River drainage, provide for wind swept ridges that allow mountain goats to utilize higher elevation habitats in the winter.

Model Algorithm

All inputs to the model algorithm were based upon inventory data collected within the study area, and most often derived from habitat selection analysis of GPS collar tracking studies. The greatest weighted habitat component (0.35 on a scale to 1.0) of the model was the distance to 45° to 60° steep slopes. This factor probably results from a security factor that mountain goats utilize steep slopes to avoid predators. Slope and aspect habitat components were weighted as the second greatest components, each at a factor of 0.25. Elevation was the last habitat component and was weighted at a factor of 0.15, because although important it only appeared to provide a boundary that other habitat components had to be within. Any habitat value outside of the variable range for each habitat component was omitted from the algorithm for core winter mountain goat habitat. Forest cover neither added to, nor was omitted from the habitat value in the model algorithm.

Model verifications provided significant findings for and against modeled winter habitat values, on a scale of 0 to 5. The top two habitat values (4 and 5) when tested against both VHF radio collar locations and observed survey locations accurately identified potential core winter habitat areas preferred by wintering mountain goats. A habitat value of 5 provided for a standardized selection ratio of 0.44 and 0.45 in the habitat selection tests for the 6 habitat value classes. A habitat value of 4 provided for a standardized selection ratio of 0.25 and 0.26 in the habitat selection tests. Together habitat classes 4 and 5 identify winter mountain goat habitat selection with a selection ratio of 0.69 and 0.71 against survey observations and VHF radio collar observations, respectively. Interestingly, the habitat proportions for the analysis in both tests were identical in % area, even though they were different areas of measurement. Classes 4 and 5 represented 9% and 2% of the total area, respectively. In both selection tests and as expected, habitat value 0 was selected against and should be considered an area of unsuitable winter mountain goat habitat. Habitat value 0 made up 80% of the tested area. The testing of habitat value 1 was obviously not important for mountain goats because it occupied 0% of the land base tested. Habitats 2 and 3 were either found to contain the expected proportion of habitat use or to have a reasonably low level of habitat selection by mountain goats in the selection tests. These areas always had a standardized selection ratio below 0.2 for the 6 habitat classes. Habitat values 2 and 3 should be considered low value habitat classes, but when adjacent to habitat classes 4, and or especially 5, of greater value. In this Taku model habitat classes greater than or equal to 3 are considered suitable winter mountain goat habitat, correctly validated by 82.8% of all winter mountain goat GPS collar locations.

MANAGEMENT IMPLICATIONS

Winter mountain goat habitat relationships are identifiable and should be incorporated into the planning and management of winter recreational activities (in particular helicopter skiing), resource development, and flight paths for low flying aircraft. The data indicate that mountain goats in the Taku drainage area are abundant; are relatively inactive during the winter, moving on average only small distances within limited winter home range areas; are found to re-use winter habitats, to some degree; and are found to utilize specific and definable core winter habitat areas. The developed habitat model accurately identifies potential winter mountain goat habitats in the study area and is presumably applicable to nearby mountain goat populations in the Atlin, BC area. This model identifies potential mountain goat habitats at a fine scale (60m pixel resolution) and should be used in conjunction with broader scale mountain goat habitat indices and or winter habitat surveys that identify mountain goat habitat use by an experienced mountain-ungulate, wildlife biologist. The development of management guidelines for areas identified to be winter mountain goat habitat should be required before resource use is considered.

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PRESENT AND FUTURE MOUNTAIN GOAT RESEARCH IN WASHINGTON STATE, USA

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Abstract: Current research on mountain goats in Washington focuses on delineating habitat and the development of a sightability and group size bias model for mountain goat surveys. To that end, in 2002 and 2003, 32 mountain goats in the Cascade Range were captured and fitted with GPS collars. Some preliminary findings are presented here and aspects for further research are identified.

In 2002, the Department of Fish and Wildlife initiated a mountain goat research project. Cooperators in this project include the U.S. Forest Service, the National Park Service, the Sauk-Suiattle Tribe, the Stilliguamish Tribe, and Western Washington University. This study was prompted by concern about declining mountain goat populations in several areas of the state.

In the initial phase of the study, we are focusing on furthering our understanding of mountain goat habitat relations and developing a more robust survey method. Habitat studies will focus on modeling seasonal habitat use and understanding the choices mountain goats make in selecting particular areas. Subsequent areas of research will concern the roles of habitat, environment, and mountain goat social organization on mountain goat populations and evaluate potential population regulatory mechanisms.

Study Area and Methods

Mountain goats are found throughout the Cascade Range in Washington and on the Olympic Peninsula. For the purposes of this study, this range was divided into 4 areas, the Olympic Peninsula, the North Cascades (from Snoqualmie Pass north to the Canadian border and west of the Cascade crest), the South Cascades (from Snoqualmie Pass south to the Oregon border and west of the Cascade crest), and the East Cascades (from the Canadian border to the Oregon Border, east of the Cascade crest). Initial efforts (2002 and 2003) have emphasized the North and South Cascades areas with expansion to the East Cascades expected to take place in 2004 and to the Olympic Peninsula in 2005.

Within each area, a conceptual distinction was made between sites with extensive habitat and substantial numbers of mountain goats (> about 50) and isolated habitats with smaller mountain goat numbers (usually 10-20). This distinction was made for use in study planning to ensure that the results would incorporate potential differences in habitat and survey design considerations for these populations.

The desired distribution of mountain goat collars was determined by convening a working group comprised of study partners for each area. These working groups evaluated the approximate distribution of mountain goats in each area and allocated collars by each habitat area to achieve a representative sample subject to some logistical constraints. One such constraint was the restriction on the use of helicopters for mountain goat capture within designated wilderness. In the North Cascades, the Forest Service supported helicopter captures in wilderness. Due to local concerns, this was not possible in the South Cascades.

Mountain goats were captured by darting with an immobilizing drug, either from a helicopter or on the ground. Generally, we used helicopter darting unless their use was constrained by regulations. Either the experimental drug A3080 (usually 2.5 mg with 50 mg of xylazine) or Carfentenil (usually 1.5 mg) were used. A3080 and Carfentenil were reversed with Naltrexone (usually 250 mg) and the xylazine was reversed with Tolazine (4 ml). Time to recumbency and recovery after reversal were noted when feasible. After helicopter captures, the approximate pursuit path was traced on a topographic map and the distance and elevation change during pursuit and induction were recorded.

Captured mountain goats were fitted with Vectronic GPS Plus 4 D collars, measurements were taken, and many were scored for body condition using the palpation system developed for mule deer by R. Cook (similar to that for elk, Cook 2000). Rump fat thickness and loin muscle depth were measured using an iLook25 portable ultrasound. In some cases, measurements were not taken due to the need to release the animal promptly. Age was estimated based on horn rings.

Herculite was attached to collars to form 3 bands of color on each side to allow individual visual identification. Colors used were red, yellow, black, and light blue. Collars were programmed to attempt a GPS fix every 3 or 5 hours with the exception of 1 collar which was set at a 30 min interval. Fixes stored on the collar were acquired by remote download, usually from fixed-wing aircraft.

GPS fixes were plotted using ArcView (v8.2) and three-dimensional representations were created in ArcScene (3D Analyst extension to ArcView).

During helicopter surveys of Mt. Baker and Mt. Shuksan in the North Cascades, attempts were made to evaluate mountain goat movements in response to survey flights. For the Mt. Shuksan survey, GPS collars on the 2 mountain goats in the survey area were set to collect fixes at 5 minute intervals.

The habitat mapping effort will be involve the development of a statistical model capable of identifying potential mountain goat habitat based on predictor variables derived from satellite imagery and GIS coverages. These spatial databases will provide information about vegetation, escape terrain and other physical characteristics of the environment that may influence habitat quality for mountain goats.

The availability of escape terrain is one of the more important physical attributes of the environment that has been shown to influence mountain goat distribution (Holmes 1993, Gross et al. 2002). The location of escape terrain, as well as elevation and aspect, are derived from Digital Elevation Models (DEMs).

During surveys of mountain goat populations containing collared animals, coviarates of group size and physical terrain attributes will be recorded to develop a sightability model for adjusting mountain goat surveys (Steinhorst and Samuel 1989). As Anderson et al. (1998) pointed out, this approach has the drawback of not including the effects of only partially counting groups. We will evaluate this group size bias by placing ground observers to record (to the extent possible) to actual group sizes during a period before or after the survey flight.

We developed a preliminary population model to explore the potential effects of past harvest on mountain goat population size around Mt. Baker. For this model, we compare survey-based population estimates with a deterministicly modeled population where sport harvest was considered to be additive (Côté and Festa-Bianchet 2003). Population parameters for the model were taken from previous studies.

Past population estimates of mountain goats on Mt. Baker were conducted made in 1961 (Wadkins 1962), and 1985 (unpublished data). However, because the area under consideration varied for the different estimates, there is uncertainty about the size of the population in 1962. While further details will be provided in a subsequent publication, we conducted the model with two likely initial populations of 384 and 419 mountain goats.

Results and Discussion

Captures

Between 26 September 2002 and 26 September 2003, 32 mountain goats were captured between the Canadian border and the southern end of the Goat Rocks Wilderness and fitted with collars during 34 capture operations. One animal was captured in 2002 and again 2003 for collar replacement and one animal (a non-lactating adult female) died during capture. This mortality was the result of an overdose while using the experimental drug A3080 and after this experience we discontinued its use. Helicopter darting was used for 25 of the captures, the remainder were darted from the ground (including the mortality). Despite the precipitous terrain occupied by mountain goats, we had good success in using the helicopter to maneuver them onto safe terrain for darting and constraining their movements during induction.

In the North Cascades, we successfully allocated collars according to the distribution determined desirable by the working group. In the South Cascades, where wilderness captures had to be by ground darting, captured goats in wilderness were underrepresented due to the low efficiency of that method of capture. One female was captured near Easton where its range is expected to overlap with that of collared mountain lions being studied in that area.

Captured mountain goats were of various sex and ages (Table 1). The representation of males was somewhat greater than intended as it proved difficult to distinguish young males from females during approach and pursuit.

The cost of helicopter captures varied greatly depending on the abundance of mountain goats in the area (Table 2). In the vicinity of Mount Baker, captures/hr of flight time were >1, whereas around Darrington, this dropped to <0.5, reflecting costs of about $500-$2,000 per capture.

Table 1. Distribution of mountain goat captures by area, sex, and estimated age.

Area	Sex	Estimated Age 1	2	3	4	5	6	8	Not recorded	Total
North	F	1		3	3	4	1	1	1	14
Cascades	M		3			2				5
	Total	1	3	3	3	6	1	1	1	19
South	F		3	1					1	5
Cascades	M		1	2	2	1				6
	Total		4	3	2	1			1	11
East	F			1						1
Cascades	M				1					1
	Total			1	1					2
All Areas	F	1	3	5	3	4	1	1	2	20
	M		4	2	3	3				12
Total		1	7	7	6	7	1	1	2	32

Table 2. Mountain goat capture costs for 14 captures in the North Cascades.

	September 2003 date					
	2	3	4	5		
Operations	Setup	Mt. Baker	Mt. Baker, Church, Mamie, Whitehorse	Darrington*	Total (w/out ferry time)	Total (incl. ferry time)
Total Time		5.9	4.8	5.7		16.4
Ferry Time		1	0.5	0.7		
Capture Time		4.9	4.3	5.0	14.2	
Ferry Cost		700	346	479	1,525	
Capture Cost		3,430	3,014	3,511	9,955	11,480
Driver Pay	125	125	125	125		
Per diem Driver/Pilot	85	85	85	85		
Fuel Truck Mileage				330		
# Goats		7	5	2	14	
Goats/Hr		1.43	1.16	0.40	0.98	1.17
$$/Goat		490	603	1,756	711	820

*Three Fingers, Whitechuck, Round Lake, Falls Creek, South Cascade Glacier

For body condition, rump scores ranged from 1.5−4.0 (mean=2.58, n=21), rump fat (measured by ultrasound) ranged from 0−0.24 cm (mean=0.68, n=17), withers pinch ranged from 1/8−1 in (mean=0.32, n=21), and loin muscle depth ranged from 2.5−4.5 cm (measured by ultrasound, mean=3.17, n=17). The sample sizes are small for analysis of patterns in condition, but in general showed remarkably low levels of rump fat. In mule deer, rump fat levels typically range 0.5-2cm (W. Myers, pers. comm.). Whether this is due to differential fat deposition between mountain goats and mule deer or a consequence of a relatively dry summer is uncertain.

One hundred percent of the serum samples (*n*=21) from mountain goats captured in 2003 tested positive for 1 or more serovars of Leptospirosis. Leptospirosis affects both humans and other animals and varies in the severity of its affects, but can cause abortion in domestic animals and liver damage, kidney failure and internal bleeding in humans. In addition, 9 animals from around Mt. Baker tested positive for bovine viral diarrhea. However, the effects of these diseases on mountain goat populations may be minimal (K. Masfield pers comm. and T. Kreeger pers comm.). More detailed monitoring of population parameters will be needed to assess this.

The 4 mountain goats captured in 2002 were from isolated ridges west of the Goat Rocks Wilderness. Other captures took place in the summer and fall of 2003, so results reported here are preliminary.

For all collars, of the 41,699 attempted fixes (as of the most recent downloads), 44% achieved 3D fixes, 59% achieved 2D or 3D fixes (41% did not achieve a fix). This differed substantially among collars, range 3D fixes = 13−80%, 3D+2D fixes = 25−86%.

Movements and Habitat Use

Annual information is available for 2 of the mountain goats captured in 2002. The difference in seasonal use for one of these is illustrated in Figs. 1 and 2. During summer, 003SCF generally remained near the crest of Stonewall Ridge, predominately on the west side. During the summer, 003SCF also utilized a rocky knoll on the southern end of the ridge, an area not utilized in the winter. Winter utilization was noteworthy in the large number of locations low on the west side of the ridge near a rock outcrop above a clear cut (as low as 1,150 m). There were 3 smaller areas at low elevations on the east side of the ridge which were also visited in winter. Notably, significant utilization of the ridge top took place during winter months. Areas at low elevation used solely in winter were termed winter zones. Between 28 September 2002 and 14 August 2003, 003SCF visited winter zones on 14 occasions, many of which were not in the winter (Table 3), but most were in the winter or spring, the longest being during the second half of February through March.

I examined the relationship between snow, temperature, and winter zone use by comparing 003SCF's records with snow and temperature data from the Snotel (http://www.wrcc.dri.edu/snotel.html) records from Pigtail Peak, south of White Pass. This station is at the same elevation as the top of Stonewall Ridge and 22 km to the northeast. I computed snow accumulation by subtracting consecutive daily Snow Water Equivalent measures from Pigtail Peak.

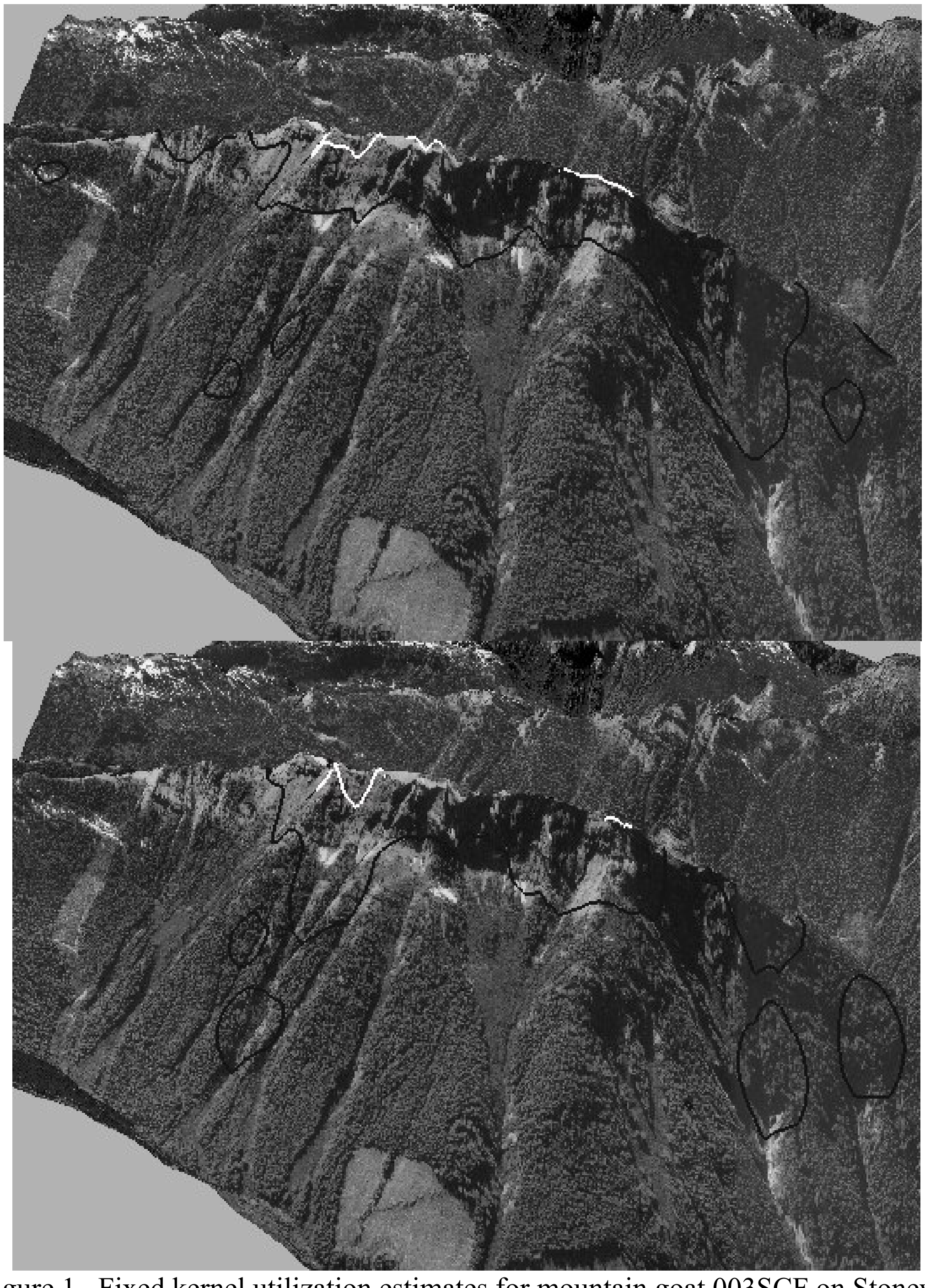

Figure 1. Fixed kernel utilization estimates for mountain goat 003SCF on Stonewall Ridge, Washington during summer (June-August 2003) and winter (December 2002-February 2003) viewed from the east. Contours shown at 0.9 (black) and 0.2 (white) of total volume of utilization. Based on 535 GPS collar locations.

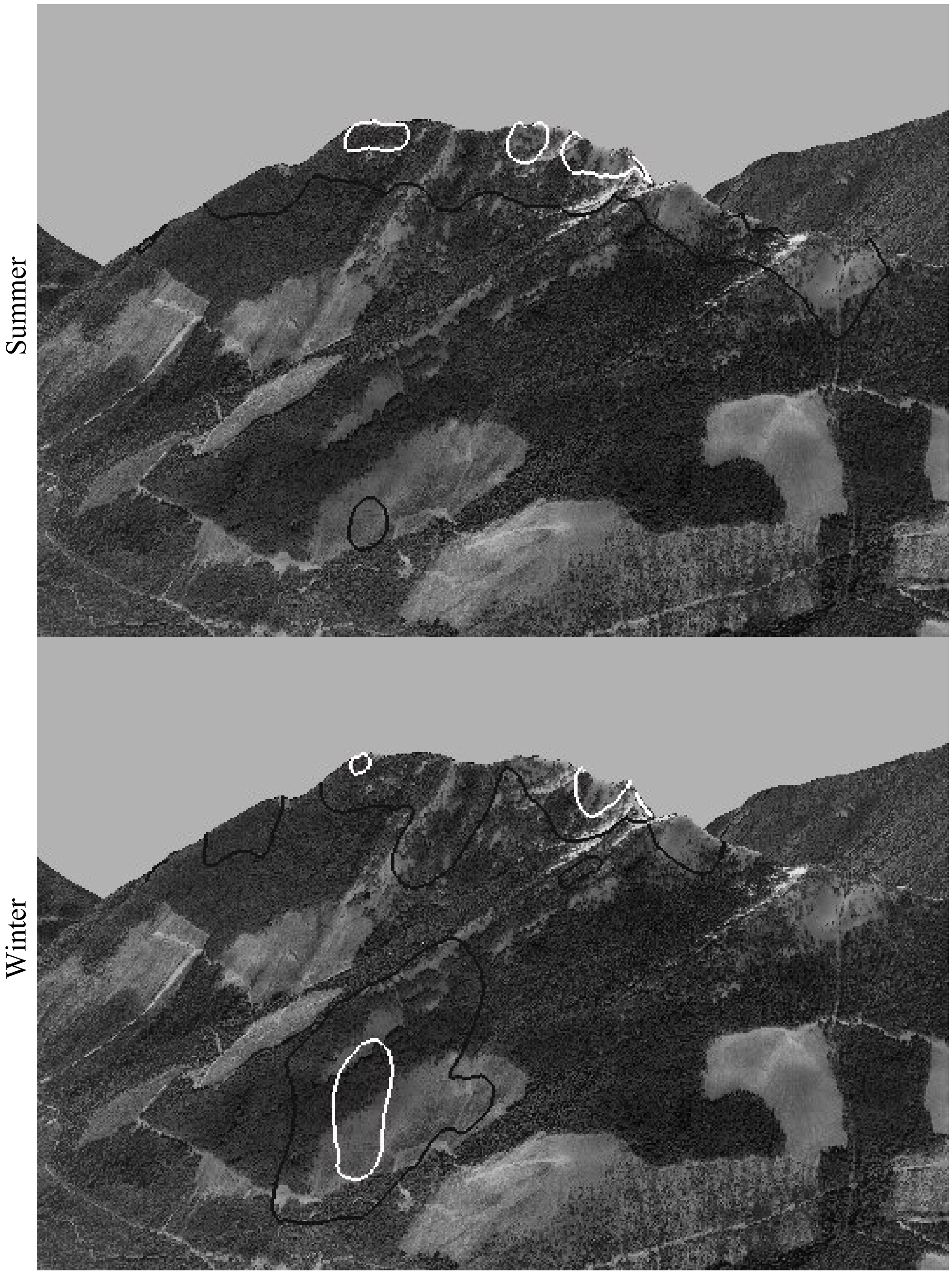

Figure 2. Fixed kernel utilization estimates for mountain goat 003SCF on Stonewall Ridge, Washington during summer (June-August 2003) and winter (December 2002-February 2003) viewed from the west. Contours shown at 0.9 (black) and 0.2 (white) of total volume of utilization. Based on 535 GPS collar locations.

Table 3. Dates of utilization of winter zones for mountain goat 003SCF on Stonewall Ridge.

First Date	Last Date	Days
10Nov2002	14Nov2002	5
11Dec2002	24Dec2002	14
24Dec2002	27Dec2002	4
27Dec2002	01Jan2003	6
12Jan2003	17Jan2003	6
29Jan2003	05Feb2003	8
06Feb2003	07Feb2003	2
18Feb2003	30Mar2003	41
27Apr2003	27Apr2003	1
29Apr2003	01May2003	3
07May2003	07May2003	1
08May2003	08May2003	1
15May2003	22May2003	8
08Aug2003	09Aug2003	2

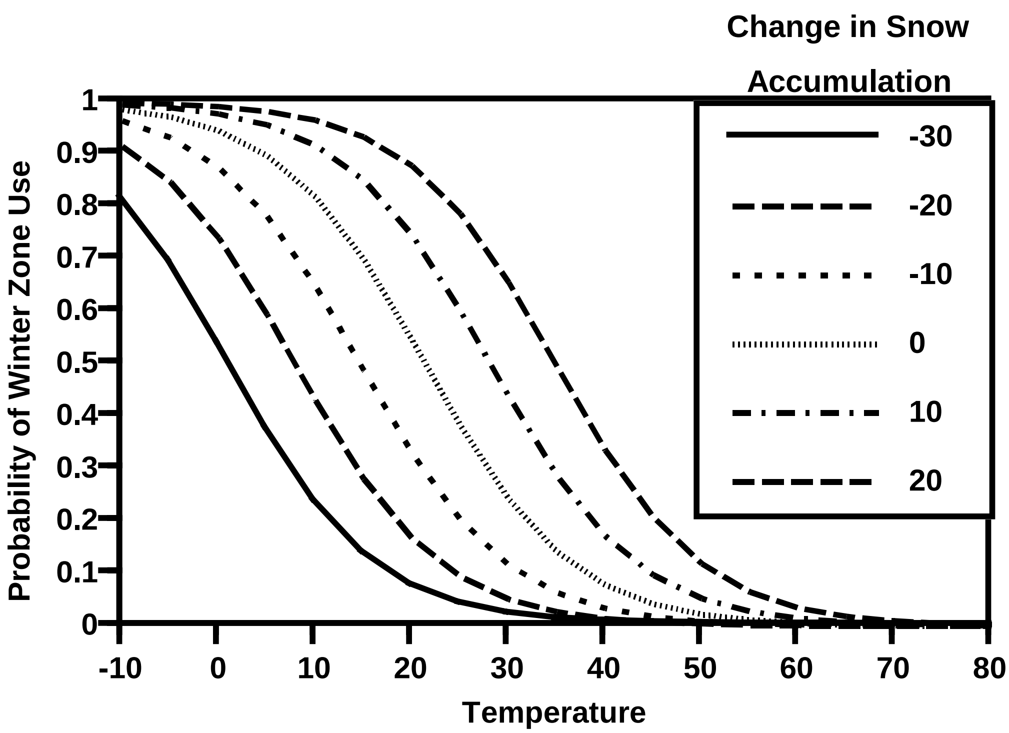

Figure 3. Relationship between probability of use of winter zones by mountain goat 003SCF according to temperature and snow accumulation during September 2002 - August 2003

Both snow accumulation and average daily temperature were significantly related to winter zone use ($P<0.0001$), their respective coefficients in the logistic regression being 0.089 (se 0.021) and –0.132 (se 0.013), indicating that when snow accumulated, use of winter zones increased, whereas it declined with increasing temperature (Fig. 3).

Summer and winter space utilization by mountain goat 003SCF was noteworthy in that there was considerable overlap between the seasons. However, even along the top of the ridge, there was some differentiation in the particular areas used in these 2 seasons. The physiography of the primary winter zone on the west side of Stonewall Ridge agreed with the expected in that it included rocky cliffs at low elevation surrounded by forest, and as was found in the Tolt and Mine Creek drainages in Washington, there was considerable use of a clear cut below the cliffs (Gilbert and Raedeke 1992). 003SCF provides an additional illustration of the complex interplay between slope, exposure, forest cover, forage, snow, and temperature as they affect mountain goat movements and habitat choice (Wright 1977, Reed 1983, Fox et al. 1989). Further observations in 2003 and 2004 from additional goats from isolated habitat patches and those that extensively use high-elevation areas in the summer should further our understanding of these influences.

Response to Helicopter Survey

The helicopter survey of Mt. Shuksan took place on 01 October 2003 and flew over mountain goats 008SHF and 028SHF. Neither was seen during the survey. The response of these goats to helicopter overflight is difficult to determine because the flight track of the helicopter was not available or had the segment missing in the vicinity of the mountain goat. Nevertheless, records of the mountain goat locations show no obvious movements from their center of activity at that time.

The survey of Mt. Baker took place on 22 September 2003. Mountain goats that were observed during the survey moved ¾-1½ km and climbed upwards on the morning of the survey, clearly more than they usually did on September mornings (Table 4). Notably, 015MBF did too even though she was not counted, but was close to the flight path. 011MBM, who was about 480 m from the flight path, moved less than usual. 029MBM did not move very much more than usual, (although it is hard to tell with the small sample), while he was about 1,400 feet below the helicopter.

During surveys, it is typical to closely approach mountain goats that are seen to verify total counts for groups. Hence, these animals are usually disturbed and that they moved more than usual is not surprising, although the magnitude of the movements is, perhaps, more than expected. Detailed records of movements will be of interest in further quantifying this disturbance.

Determining the extent that missed animals move is important in developing procedures for sightability modeling because if missed animals move, their location after the survey cannot be used for collecting information on covariates concerning their location when they were missed. While our sample size is low, these results might suggest that mountain goats somewhat removed from the flight path do not move, but those near to it (015MBF) may do so. This will necessitate activating collars before

Table 4. Response of mountain goats to survey. Time indicates the time frame over which movement after the survey was estimated (PST). Mean and median are for movement and elevation change measurements during September 2003 (22nd excluded) from the same time frames (6-9 for Sight-9 and 6-9 and 6-12 for 6-12). Only 3D-3D GPS fixes were used for elevation measurements.

			Distance				Elevation Change (m)			
Mtn. Goat	Status	Time	22Sep03	Mean	Median	n	22Sep03	Mean	Median	n
010MBM	Missed (outside)	No data[1]		98	95	4		-10	-10	1
011MBM	Missed	6-12	94	461	443	23	26	74	84	22
012MBM	Sighted	Sight-9[2]	1,575	398	251	19	76	-31	-10	16
013MBF	Sighted	Sight-9[2]	1,634	301	258	17		1	-14	14
014MBF	Sighted?	No data[1]		144	122	16		27	44	12
015MBF	Missed	6-9	1,381	303	233	18	174	34	63	13
016MBF	Sighted	Sight-9[2]	1,065	358	304	15	105	40	11	3
019MBF	Sighted	6-9	934	182	32	23	312	34	10	21
029MBM	Missed (low)	6-12	284	204	204	2				0

[1] Consecutive fixes not available.
[2] From time of sighting to 0900 hrs.

each survey to collect frequent fixes, and comparing the flight path and mountain goat movements to determine the location of the mountain goat when it was missed by GPS fix rather than by its location after the survey is complete.

Sport harvest from Mt. Baker during the period covered by our model was substantial, and was often well above the 2-4% that is now considered sustainable for native mountain goat populations (Côté and Festa-Bianchet 2003). The modeled population was quite close to the population estimate at both ends of that period. While these results are preliminary, it seems likely that historic harvest levels played an important role in the decline observed on Mt. Baker. Further work is needed to incorporate uncertainty in the population parameters and incorporating other sites.

Further Research

In addition to further development of population models, there are several aspects of mountain goat ecology which can further our understanding of population regulation in this species, namely:

1. Habitat mapping – Statewide: There is a need to expand the current regional effort to delineate mountain goat seasonal habitat in the rest of the state.
2. Meteorological influences on movements and habitat use: link weather (wind, solar radiation, temperature, precipitation) with habitat/site selection. Use weather from monitoring stations and model archives with GPS locations.

3. Recreation impacts: evaluate the impacts of recreation on mountain goat habitat use. Off-road vehicles, hiking, climbing, and winter sports have the potential of affecting mountain goat populations. The recent development of back-country capable snowmobiles is an emerging issue in this area.
4. Winter habitat: while topography appears to be the dominant factor in mountain goat winter habitat (Keim 2004), but the significance of this for populations can only by understood by characterizing these areas in terms of forage and predation risk.
5. Population studies: in Washington, mountain goats populations have declined in a number of areas. In some of these locales, populations appear to be recovering but this is not evident in all of them. Assessing population parameters for healthy, recovering, and depressed populations will determine if these apparent differences in population trajectory are due to our inability to detect recovery in some areas or are underlain by differences in population processes.
6. Winter habitat and population dynamics: Numerous mountain goat publications have pointed out that the historic perception that mountain goats could be managed assuming a density dependent population response (see Côté and Festa-Bianchet 2003). Yet, a valid management and recovery paradigm has not emerged as is evidenced by Gonzalez Voyer et al.'s (2003) conclusion that all populations need to be managed (and monitored) on an individual basis. In 1971, Kuck outlined a possible mechanism for mountain goat population regulation as a consequence of mountain goat preference for terrain over forage in winter habitat use, resulting in population stagnation at low densities. However, a more thorough test of this is needed before it can be accepted as a general principle. Such a study would investigate the relationship between winter habitat availability and quality on population processes and would link forage, snowfall, population density, and winter movements, with survival and reproduction.

Conclusions

We captured mountain goats from helicopter and on the ground. Ground captures, however, are labor intensive and provide less opportunity to select where and which mountain goat will be captured. The cost of helicopter captures varies considerably with the circumstances, but are about $1,000 per mountain goat.

The proportion of fixes achieved by the GPS collars were somewhat lower than others have experienced with other species (Frair et al. 2004), which may be related to terrain shielding as our rates are comparable to those of Taylor (2002) for mountain goats in British Columbia. Certainly, a valid approach for compensating for GPS fix bias will need to be developed (Taylor 2002, Frair et al. 2004).

Initial patterns are emerging from fixes obtained to date, but detailed analysis will require observations from more mountain goats over longer time periods than we presently have.

At present, we cannot assume that mountain goats that are missed during helicopter surveys remain in the same place. Sightability model development will consequently require integration with fine-scale GPS tracking of mountain goat movements.

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Bienn. Symp. North. Wild Sheep
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MOUNTAIN GOAT STATUS AND MANAGEMENT IN WYOMING

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Abstract: Mountain goats (*Oreamnos americanus*) are not generally considered native to Wyoming, but originated from transplants in Montana and Idaho. Wyoming currently has two populations of mountain goats, one in the Beartooth and Absaroka Mountains east of Yellowstone National Park (the Beartooth Herd Unit), and one in the Snake River Range south of Grand Teton National Park (the Palisades Herd Unit). Expansion into Wyoming following both transplants was slow, as was population growth once goats became established in Wyoming. Hunting seasons in Wyoming were not initiated until 27 years after the 1942 Montana transplant, and 30 years following the 1969 Idaho transplant. Not until the late 1980s did goats begin to expand their range and increase in number. Trend counts of mountain goats in Wyoming have ranged from 72 to 149 in the Beartooth Herd Unit since aerial surveys began in 1986, and from 54 to 76 goats in the Palisades Herd Unit since aerial surveys began in 1997. Harvest of mountain goats in Wyoming is controlled by issuance of limited quota licenses. Mandatory registration is required for all successful goat hunters to gather sex, age, and distribution information on harvested goats. Hunting licenses for mountain goats in Wyoming are very desirable, and the odds of drawing a mountain goat license are extremely low. Since 1995, Wyoming mountain goat licenses have been once-in-a-lifetime permits. More detailed information on the history and current status of mountain goats in Wyoming is included.

Key words: Wyoming, mountain goat, *Oreamnos*, management, hunting, transplants.

HISTORICAL OCCURRENCE

Similar to other locations in western North America, the historical occurrence of mountain goats (*Oreamnos americanus*) is uncertain. It is clear, however, that mountain goats were present in Wyoming at one point in time. Archaeological evidence shows mountain goats were present in western, central and southeast Wyoming during the late Pleistocene, approximately 10,000 to 15,000 years ago (Laundre' 1990, Guilday et al. 1967, Anderson 1974). More recent evidence, however, is generally lacking, although some historical reports of mountain goats in Wyoming do exist. A U.S. Army hunting party in the southern Teton Range of Wyoming reportedly killed a mountain goat in the 1840s (Cooke 1847-1848), and a map produced by Hornaday (1914) titled "Distribution of the White Mountain Goat", depicts an "actual occurrence" in the Teton Mountains near Jackson, Wyoming.

Additional investigations, however, have failed to substantiate the occurrence of mountain goats in Wyoming in recent history. Many early travelers through

Wyoming kept detailed journals, but few made mention of mountain goats. Those reports that did mention seeing goats have generally been discounted as observations of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) or pronghorn antelope (*Antilocapra americana*). A specific investigation into the occurrence of mountain goats in Wyoming by Skinner (1926) concluded goats were not present historically in Wyoming. Recent investigations have reached the same conclusion (Laundre' 1990).

A review of historical documents lends credibility to the assertion that mountain goats were present in Colorado prior to 1900 (Irby and Chappell 1994), and increases the possibility that goats may have been present in Wyoming as well. Varley and Varley (1996) have suggested that evidence from Colorado and several other locations represents isolated, remnant populations of mountain goats at risk of natural extinction. Although in reference to the Greater Yellowstone Ecosystem, a statement by Schullery and Whittlesey (2001) could be applied to historical occurrence of mountain goats throughout Wyoming; "it is impossible to prove absolutely that there were no goats in the ecosystem prior to modern introductions, but historical evidence demonstrates that if present, such goats must have been exceedingly rare and uncharacteristically unsightable."

INTRODUCTION/COLONIZATION

Although Wyoming currently has two distinct mountain goat herds, no introductions of mountain goats have been conducted in Wyoming. Both the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU) (Figure 1) originated from goat transplants in the neighboring states of Montana and Idaho.

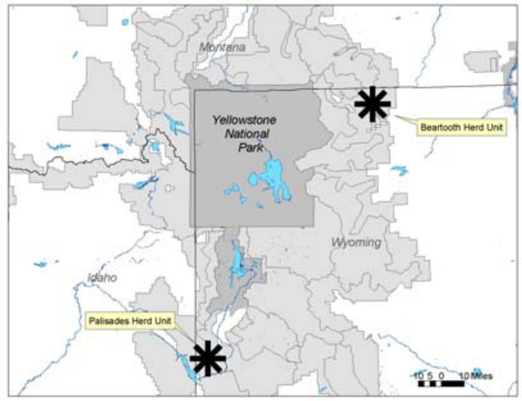

Figure 1. Location of the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU), northwest Wyoming.

Beartooth Herd Unit

The Beartooth population resulted from the release of 12 goats into the Rock Creek drainage of the Beartooth Mountains southwest of Red Lodge, Montana and near the Montana-Wyoming state line in 1942 (Cooney 1946). No information is available on the sex or age composition of released animals. In addition, it is possible that goats from a release of 28 goats between 1949 and 1953 into the East Rosebud Creek drainage also found their way into Wyoming. The source herd for both transplants was the Deep Creek drainage in Teton County, Montana.

The first recorded sightings of mountain goats in Wyoming occurred in 1946, in the Beartooth Mountains along the Montana-Wyoming state line. Although the exact location is not known, this probably represents a movement of less than 8 km (5 mi) from the original release site on Rock Creek. The next recorded sighting was near Deep Lake on the Beartooth Plateau, in the late 1950's by a Shoshone National Forest aerial fire patrol. Observations in this area represent a movement of approximately 16-24 km (10-15 mi) from the release site.

The first formal surveys of the BHU were performed in the early 1970s, when a total of 96 goats were counted (Fenner 1974, Laake 1976). By this time, goats had reached the Clarks Fork of the Yellowstone River, approximately 32 km (20 mi) from the Rock Creek release site. Additional research was not undertaken until the late 1980s (Haynes, 1991, Hanna 1989), when the population was estimated to be near 150 animals and more detailed information was gathered on goat distribution and habitat use. By this time, goats had been observed in the Wind River drainage in the south end of the Absaroka Range, 130 km (80 mi) from the original release site.

The area first colonized in Wyoming is the southernmost extension of the Beartooth Mountain Range, commonly known as the Beartooth Plateau. The Beartooth Mountains are an uplifted fault block oriented in a northwest-southeast direction, with near vertical normal faults near the southern end in Wyoming (Poldervarrt and Bentley 1958). Sedimentary layers covered the Beartooths at one time, but were stripped from most of the higher elevations, leaving a relatively flat, uniform surface, or exhumed peneplane, which was then greatly modified by erosion and glaciation (Hughes 1933). This glaciation dissected the higher elevations, creating five major plateau segments; the East Rosebud, Silver Run, Hellroaring, Line Creek, and Beartooth (Johnson and Billings 1962). Many small glaciers still exist in the Beartooths, but most are stagnant or retreating. The resulting landscape is that of a relatively flat, undulating surface incised by steep, sheer-walled canyons.

Elevations within the BHU range from 3,400 m (11,200 ft) on the Beartooth Plateau to 1,200 m (4,400 ft) at the mouth of the Clarks Fork Canyon. As might be expected with such an elevational range, a diversity of vegetation types is found within the BHU. At higher elevations on the Beartooth Plateau, alpine tundra communities are found, including permafrost and a higher percentage of arctic species than most other alpine ranges in the lower 48 states (Billings 1988). Conifer species range from krummholz-type whitebark pine (*Pinus albicaulis*) at the highest elevations to subalpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea engelmannii*), and lodgepole pine (*Pinus contorta*) as elevations decrease. At lower elevations, including goat winter ranges in the Clarks Fork Canyon, xeric adapted species such as sagebrush (*Artemesia* spp.), yucca (*Yucca glauca*), prickly pear (*Opuntia polyacantha*), and bluebunch wheatgrass (*Pseudoroegneari spicata*) are found. Conifer species at these elevations are limber pine (*Pinus flexilis*) and juniper (*Juniperus* spp.).

Other large mammal species that share habitats within the BHU include bighorn sheep (*Ovis canadensis*), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), moose (*Alces alces shirasi*), grizzly bears (*Ursus arctos horribilis*), black bears (*Ursus americanus*), mountain lions (*Felis concolor*), wolves (*Canis lupus*), coyotes (*Canis latrans*), and wolverine (*Gulo gulo*).

Currently, summer cattle grazing occurs within portions of the BHU, and until 2002, so did domestic sheep grazing on portions of the Beartooth Plateau.

Palisades Herd Unit

The Palisades population resulted from the release of 5 goats (2 males, 3 females) into the Palisades Creek drainage of the Snake River Range, southeast of Swan Valley, Idaho near the Idaho-Wyoming state line (Hayden 1989). In addition, it is possible that animals from a release of 7 goats (5 males, 2 female) in 1970 and 1971 in the Black Canyon drainage also found their way into Wyoming. The source herds for these transplants was the Snow Peak and Black Mountain populations in Shoshone and Clearwater Counties, Idaho.

The first recorded sighting of PHU mountain goats in Wyoming occurred in 1975, when 6 goats were seen on Wolf Mountain in the Snake River Canyon, approximately 32 km (20 mi) from the original release site on Palisades Creek. The next recorded sighting was of 2 goats on Teton Pass west of Jackson, Wyoming in 1977. If these goats were from the Palisades release, it would represent a movement of approximately 26 km (16 mi). If these goats originated from the Black Canyon release, the distance moved would be approximately 43 km (27 mi).

The first formal surveys of the Idaho portion of PHU were performed as part of a Master's Thesis project in the early 1980's (Hayden 1989). A total of 142 goats were counted in 1983; evidence of vigorous population growth following the 1969 transplant. By this time, goats had reached Grand Teton National Park, and observations were reported throughout the length of the Teton Range. The northernmost sighting in the Teton Range (Forellen Peak) represents a movement of approximately 90 km (56 mi) from the Palisades Creek release site. By 1986, the population was estimated at 230 individuals. Still, few goats remained as yearlong residents of Wyoming.

The area inhabited by the Palisades goat population is commonly known as the Snake River Range. Part of the Overthrust Belt, the Snake River Range was formed through compression along the Darby, Absaroka, and St. Johns Thrust Faults (Albee et al. 1977). Deposited marine sediments were folded and thrust eastward (Armstrong and Oriel (1965). Peaks, cirques, and cliffs of the Snake River Range are gray-green limestones, with some white dolomite. Along the Snake River Canyon, black, gray, green, and red shales can be found.

Elevations range from 1,700 m (5,600 ft) to over 3,000 m (9,900 ft). At higher elevations, habitat types consist of dry meadows with scattered timber, primarily Englemann spruce and subalpine fir. As elevations decrease, Douglas fir (*Pseudotsuga menziesii*) and limber pine are found. Compared to the BHU, the PHU contains more shrub-dominated habitats. These shrub communities at low to mid elevations are comprised of bigtooth maple (*Acer grandidenta*), Rocky Mountain maple (*Acer glabrum*), serviceberry (*Amalanchier alnifolia*), ninebark

(*Physocarpus malvaceus*), curl-leaf mountain mahogany (*Cercocarpus ledifolius*), and Utah juniper (*Juniperus osteosperma*). Early seral vegetation found in avalanche chutes, of which there are many, also include shiny-leaf ceanothus (*Ceanothus yelutinus*), chokecherry (*Prunus virginiana*), and red osier dogwood (*Cornus stolonifera*).

Other wildlife species found within the PHU include elk, mule deer, moose , and black bears.

Permittted livestock grazing includes summer grazing of both domestic sheep and cattle.

POPULATION MONITORING

Due to low population densities and other management priorities, mountain goat data were not collected in the BHU until 1986, and 1997 in the PHU. Currently, both Herd Units are systematically surveyed every other year (in summer) by aerial trend count and classification surveys. In alternate years, attempts are made to gather ground classifications in order to obtain productivity information. Although efforts are made to classify goats into adult male, adult female, and juvenile categories, most data collected only differentiates between adult goats and kids. This is particularly true for aerial surveys. No attempt has been made to construct a population simulation model for either herd unit.

In the BHU, results of these surveys show a range in the number of goats seen during trend count flights from 72 in 1991 to 149 in 1992 (Figure 4). This disparity in results between years illustrates the difficulty in gathering consistent goat population data in the BHU. In general, trend counts revealed increased numbers of goats in the early 1990s; an increase that has been maintained since. Based on the amount of the area not flown and poor sightability in some portions of the herd unit, there may be as many as 200 goats in the BHU.

Although the data set for the PHU is rather small, trend counts have yielded relatively similar numbers of goats, ranging from 54 in 1997 to 76 in 2000 (Figure 2). Movement in and out of Idaho could easily explain the slight variation in numbers encountered. The general trend is that of a consistent sample of slightly over 50 goats. The number of goats in the Wyoming portion of this population is not thought to be significantly more than this.

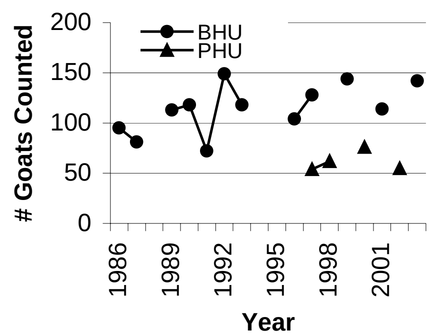

Figure 2. Mountain goat trend counts for the Beartooth Herd Unit (BHU) and Palisades Herd Unit (PHU), 1986-2003.

Classification surveys in the BHU revealed very high productivity in the late 1980's and has been relatively consistent at approximately 30-40 kids:100 adults since 1994 (Figure 3).

Productivity in the PHU has shown a similar trend, dropping from a high of 59 kids:100 adults in 1997 to an average of 31 kids:100 adults from 1998-2002 (Figure 3).

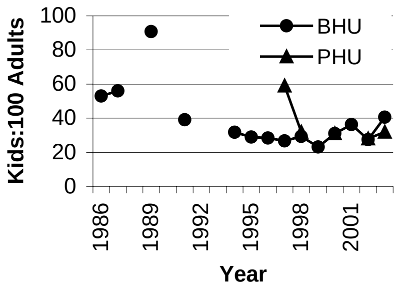

Figure 3. Kid:100 adult ratios for the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU), 1986-2003.

HARVEST MANAGEMENT

Mountain goats licenses in Wyoming are issued on a limited quota basis, for both residents and nonresidents. By Wyoming Statute (23-1-703 (e)), 25% of all mountain goat licenses go to non-residents and 75% to residents, which translates into permits issued by hunt area in increments of 4. Since 1995, mountain goat licenses have been a once-in-a-lifetime permit. In 2004, the cost of a resident mountain goat license was $100 and a non-resident license was $1,800.

Hunting licenses for mountain goats in Wyoming are very desirable, and drawing odds for both residents and non-residents are extremely low. In 2004, 2,621 residents applied for one of the 12 resident permits, representing a 0.46% chance of drawing, or 218:1 odds. Similarly, 294 nonresidents applied for one of the 4 nonresident permits issued in 2004, representing a 1.36% chance of drawing, or 74:1 odds.

Prior to 1998, harvest information was gathered from a mail harvest survey questionnaire, followed by phone interviews of non-respondents. In 1998, a mandatory registration regulation was implemented for successful mountain goat hunters, in order to gather important data on the sex/age and distribution of harvest. Successful hunters must present the skull or horns attached to the skull plate and the hide or cape for registration, within 15 days of harvesting the goat.

Although some of the first hunting seasons in the BHU ran from September 10 through November 15, mountain goat hunting seasons in both the Beartooth and the Palisades Herd Units open September 1 and close October 31. Although not specific to mountain goat hunting, by State Statute (23-2-401 (a)) all non-resident big game hunters must be accompanied by a licensed professional guide or resident guide if hunting in a designated wilderness area. Two U.S. Forest Service wilderness areas are found within the BHU; the North Absaroka and the Absaroka-Beartooth Wildernesses. There is no designated wilderness within the PHU.

The BHU was first hunted in 1969 (27 years after the initial transplant), when the population was felt to be approximately 100 goats. Four permits were issued from 1969-1979. Based on high success rates and low hunter effort, permit numbers were increased to 8 in 1980 even though the population was still estimated to be near 100 individuals. Due to increased trend counts, high productivity rates, and an apparent range expansion, permit levels were increased from 8 to 12 in 1993, where they have remained.
Following survey efforts that determined a minimum population of at least 50

goats resided in Wyoming, the PHU was first hunted in 1999 (30 years following the initial transplant), when four permits were issued. Permit levels have remained at 4 in the PHU.

Goat harvest levels have generally followed permit levels (Figure 4). In the BHU, goat harvest averaged 3.4 goats/year when 4 permits were issued, 7.3 goats/year when 8 permits were issued, and 11.6 goats/year when 12 permits were issued. Every permitted goat hunter in the PHU has been successful to this point.

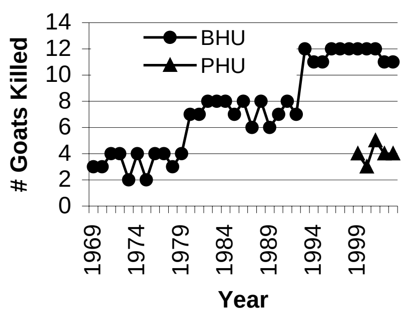

Figure 4. Mountain goat harvest in the Beartooth Herd Unit (BHU) and Palisades Herd Unit (BHU), 1969-2003.

With the exception of a couple years in the early 1970's, hunter success has been quite high (Figure 5). Still, over the last 35 years, hunter success has averaged 92.5% in the BHU. Again, to date, all hunters in the PHU have been successful.

Hunter effort, which is the number of days hunted per goat harvested, shows a similar trend to that of hunter success. With the exception of a very high effort in 1975, hunter effort in the BHU has generally remained less than 5 days per goat harvested, averaging 4.3 days/goat (Figure 6). Similarly, hunter effort in the PHU has also been less than 5 days, averaging 3.1 days per goat harvested.

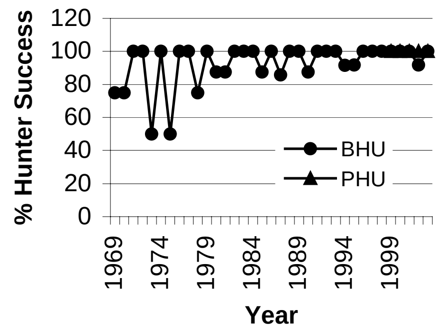

Figure 5. Mountain goat hunter success in the Beartooth Herd Unit (BHU) and Palisades Herd Unit (PHU), 1969-2003.

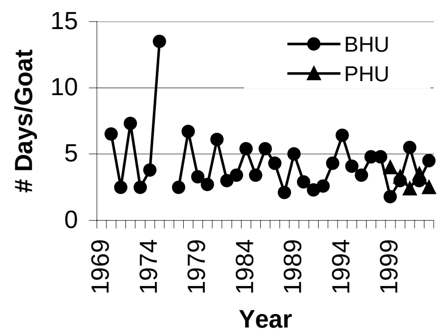

Figure 6. Mountain goat hunter effort in the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU), 1969-2003.

Harvest of female goats has varied in the BHU, with three noticeable peaks occurring in the early to mid 1970s, the late 1980s, and 1997 when females represented more than 40% of the total harvest (Figure 7). Since 1969, females have comprised an average of 29% of the total harvest of mountain goats in the BHU. With the exception of one female taken in the PHU in 2001, all harvested goats have been billies.

Since 1995, mountain goat hunters have been provided advance information on the identification of male and female goats to encourage harvest of billies and minimize harvest of nannies. However, following this effort, average representation of females in the harvest remained unchanged at 29%.

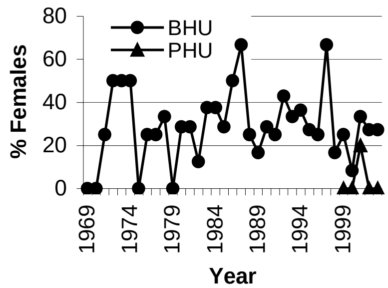

Figure 7. Percent females in mountain goat harvest from the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU), 1969-2003.

Since the first mountain goat season was held in 1969, all hunters, both successful and unsuccessful, have been asked how many different goats they observed during their hunt. There is, of course, some bias in these data due to uncertainty of duplicate sightings and the influence a single hunter might have at such low permit levels, but it does provide some insight into long-term population trends. Although variable from year to year, an increasing trend through time is depicted for the BHU (Figure 8). These data mimic estimated population trends for the Beartooth population. Although a limited number of years are represented, the data from the PHU show some of the same variability seen in the BHU.

Even though mandatory registration was not implemented until 1998, successful hunters were asked to measure the horn

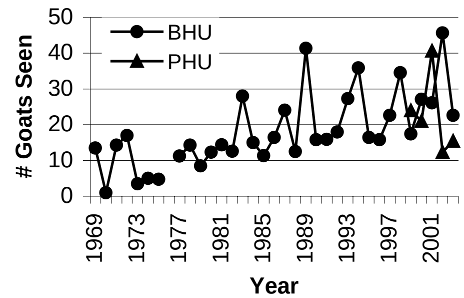

Figure 8. Average number of mountain goats seen by hunters in the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU), 1969-2003.

length of their goat. Although there has been annual variation between 8 and 9 inches, horn length of harvested billies has averaged 222 mm (8 ¾ in) in the BHU and 233 mm (9 ¼ in) in the PHU (Figure 9). It would have been interesting to compare these data versus animal age, but mandatory registrations that allow age determination only began in 1998. Over this short period, however, average age has declined in both the BHU and PHU (Figure 10).

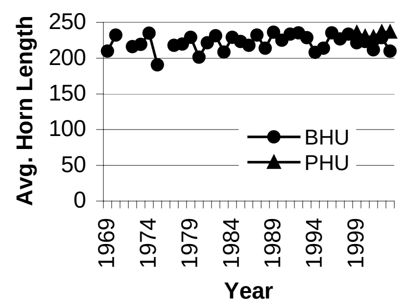

Figure 9. Average horn length of harvested billies in the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU), 1969-2003.

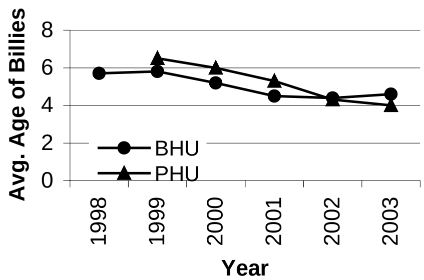

Figure 10. Average age of harvested billies from the Beartooth Herd Unit (BHU) and the Palisades Herd Unit (PHU), 1998-2003.

FUTURE MANAGEMENT ISSUES

Once established in Wyoming, goat populations in both the Beartooth and Palisades Herd Units have done well. Numbers increased, huntable populations were established, and hunting seasons were initiated. Expansion did not cease at Wyoming Game & Fish Department delineated hunt area boundaries, however, but continued into unoccupied habitats in the Shoshone and Bridger-Teton National Forests and Yellowstone and Grand Teton National Parks. This has not been entirely problematic, as the BHU was enlarged in 1996 to accommodate an expanding population and allow additional hunting opportunities. However, outcome of debate over status of the mountain goat as part of the native fauna of the Greater Yellowstone Ecosystem and their future management may prove controversial, as many consider goats a non-native, or exotic species.

Relative to the management of exotic species, the National Park Service must abide by statutory law, regulatory law, and policy (Varley and Varley 1996). Currently, National Park Service policy directs that exotic species be managed (up to and including eradication) if control is prudent and feasible, and if the exotic species interferes with natural processes and the perpetuation of natural features, natives species, or natural habitats (National Park Service 2001:37; section 4.4.4.2).

In response to these questions, Yellowstone National Park (YNP) has initiated alpine vegetation studies in areas of mountain goat colonization, and established systematic aerial mountain goat surveys to determine population trends. Once additional funding is secured to continue these investigations and collect adequate information addressing the potential effects of colonizing mountain goats, various management alternatives will be considered, and a YNP mountain goat management plan will be developed.

The pace and scale of oil and gas development has increased dramatically in Wyoming. Mineral interest in the Beartooth Mountains is not new, but successful natural gas wells have been drilled in the area recently and proposals to conduct 3-dimensional seismic operations have been submitted to federal land management agencies.

Many activities associated with oil and gas development have been shown to be detrimental to mountain goats including seismic exploration (Joslin 1986), roading (Singer 1975, Singer and Doherty 1985), and helicopter supported activities (Cote 1996, Shank 1979, Gordon and Reynolds 2002). Recommendations and mitigation measures for these activities in occupied mountain goat habitat will prove beneficial as oil and gas development continues.

Another potential impact in mountain goat habitats is helicopter-supported recreation. The sensitivity of mountain goats to helicopter disturbance is becoming better understood, and it is clear that helicopters are a significant disturbance factor (Keim 2004, Gordon 2004). The popularity of heli-skiing, heli-hiking, and other helicopter assisted activities in other areas has increased concern regarding these activities in Wyoming goat habitats (Varley 1999). Recently developed recommendations for helicopter activities in mountain goat habitats should help minimize impacts from increasing recreational activities.

In 2002, twelve mountain goats in a captive herd of 16 goats in northwestern Nebraska became ill and subsequently died. Of the 12 deaths, West Nile Virus was isolated as the causative agent in 11 goats (Todd Cornish, Wyoming State Veterinary Laboratory, personal communication). If this small sample is indicative of mountain goat mortalities, they would be more susceptible than equines to West Nile Virus. Plans have been developed to sample harvested mountain goats in Wyoming to determine previous exposure and/or resistance to West Nile Virus.

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MOUNTAIN GOAT STATUS AND MANAGEMENT IN IDAHO

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Abstract: Mountain goats *(Oreamnos americanus)* are native to Idaho, the southernmost portion of their recent distribution in North America. Mountain goat populations apparently declined sharply early in the late nineteenth and early twentieth centuries due to unregulated hunting. The first survey of known mountain goats ranges indicated approximately 2,785 animals in 1955. Populations have increased only slightly over the 5 decades since, despite efforts to restore populations through transplants into native ranges and unoccupied suitable habitat. Mountain goat populations are believed to have reached a peak of 3,090 animals in 1990, and have declined steadily since. Currently mountain goat populations are at the lowest levels on record, with an estimated 2,590 animals remaining in Idaho. Several recent declines occurred suddenly, over <3 years, and resulted in near extirpation of some herds. Causes of recent declines are not well understood. The best-monitored mountain goat population in Idaho, the Palisades herd, demonstrated early and rapid population growth followed a population crash and near extirpation. Mountain goats are a game animal in Idaho. Harvest is strictly controlled by permit only, and only when populations exceed a threshold size of >50 adult animals as revealed by population survey data. Harvest is limited to <5% of the adults in each herd. Approximately 50-90 permits have been provided annually during the period 1982-present. Hunters are limited to harvest of 1 mountain goat in their lifetime. Hunters may harvest a mountain goat of either sex. Analysis of annual hunter harvest data indicate that hunter success rates are uniformly high (~80%), and that hunter success rates, male:female ratios among harvested animals, and mean age of harvested animals are all poor indicators of population trends.

Key words: mountain goat, *Oreamnos*, management, hunting.

Mountain goats occur only in northwestern North America. The largest populations occur in British Columbia and Alaska; populations in Idaho represent the southernmost limits of natural distribution although recent transplants have extended the range of this species into southern Utah and Colorado (Shacklton 1997).

DISTRIBUTION AND STATUS IN IDAHO

Information on the prehistoric distribution of mountain goats in Idaho is limited, but mountain goats are believed to have been distributed throughout northern and central Idaho (Fig. 1). Mountain goat bones have been recovered from 2 separate layers of the Bernard Creek rock shelter, an archaeological site within in the Hells Canyon Natural Recreation Area of Idaho (Randolph and Dahlstrom 1977). The bones were skeletal and fragmented, suggesting that the animals represented were consumed on site; radio-carbon dating placed their age at 300 to 1,000 years old (Reagan and Womack 1981). A corresponding, but somewhat older (500-1,500 years old) site was reported on the Oregon side of Hells Canyon on Camp Creek (Leonhardy and Thompson 1991). Corless (1990), writing about the Weiser branch of the Shoshone Tribe, reported that they hunted mountain goats in the Seven Devils Mountains above Hells Canyon.

There are few written records of mountain goats in Idaho prior to 1950. Narratives describing mountain goat range in Idaho are scarce, and narratives are confusing because female bighorn sheep were often called goats or ibex. Hallock (1879, quoted in Lyman 1998) wrote "The White Goat is confined to the loftiest peaks of the Rocky Mountains: it is not known south of Colorado, and is probably rare south of the Washington Territory". Owen Wister wrote in *The White Goat and His Ways* (1904) "In Alaska and British Columbia we find the goat, and in northwest Montana, and in Idaho, but only in spots …"; more specifically, he says that mountain goats may be found as far south as the 'Saw Tooth Mountains' in Idaho.

Other early records of mountain goats in Idaho include the Stanley Lake basin (Stanley Lake, Alturus Lake, and Boulder Peak), Loon Creek, and mountains along the Salmon River (Davis 1939) and "the high peaks [Cabinet and Selkirk Mountains?] of northern Idaho" (Rust 1946).

In May 1949, Stuart Brandborg began a year of intensive field work to document aspects of mountain goat ecology near the mouth of the Middle Fork of the Salmon River under the auspices of the Idaho Cooperative Wildlife Research Unit. Brandborg's initial work was expanded by the Idaho Department of Fish and Game in September 1950, when he was directed to conduct census and distribution studies of mountain goats in the entire Salmon River drainage and Selkirk Mountain range. This project, which relied primarily on ground surveys, was continued through 1952 (Brandborg 1955). The statewide population estimate of 2,785 mountain goats distributed among 88 peaks and drainages was the first comprehensive estimate of mountain goat numbers in Idaho.

Although Brandborg's 1955 estimate of 2,785 mountain goats in Idaho was based on 'liberal' estimates (Kuck 1977*a*), it is very comparable to subsequent information (Fig. 2). Kuck (1977*a*) believed that there were 2,200 to 2,500 mountain goats in Idaho in 1977, and statewide population assessments by wildlife managers with the Idaho Department of Fish and Game estimated 2,415 in 1981 (Idaho Department of Fish and Game 1980) and 2,765 in 1985 (Kuck and Pehrson 1985), 3,060 in 1990 (Hayden *et al.* 1990). Populations appear to have remained nearly constant through 2000, when the statewide population was estimated at 2,825 (Idaho Department of Fish and Game, file data). However, mountain goat populations may have declined between 2000 and 2004; biologist's estimates following spring aerial surveys in 2004 totaled less than 2,590 mountain goats (Idaho Department of Fish and Game, file data).

Despite the relative consistency in estimated population size, there have been dramatic regional fluctuations in mountain goat populations between 1955 and 2004. Brandborg (1955) estimated that 195 mountain goats occupied the Selkirk Range of the Idaho Panhandle adjacent to northeastern Washington, and an additional 25 mountain goats were reported in the Cabinet Mountain adjacent to western Montana. By 1977 these herds had dwindled to approximately 40 animals (Kuck 1977*a*), and despite closure of hunting in 1971 and over three decades of protection, only about 50 mountain goats were present in 2003 (Toweill 2003). Declines are now believed to have been, at least in part, due to over-harvest.

In central Idaho, mountain goat herds declined slowly but steadily from 1960-1975, years when annual harvest of mountain goat regularly exceeded 100 animals. The decline was most pronounced among both populations and occupied habitat south of the Snake River, in Big Creek and the Middle Fork of the Salmon River. Following surveys in 1982, wildlife managers reported that 'satellite' herds appeared to be missing (Oldenburg 1983).

In contrast with central and northern Idaho, in mountain goat herds increased in southern portions of their distribution between 1955 and 1982 in Idaho's Pahsimeroi, Lemhi, Medicine Lodge and Snake River ranges.

Declines in mountain goat populations in northern and central Idaho after 1960 were largely offset by herds established by transplants into suitable but unoccupied habitats. A small herds was established at Echo Bay on Lake Pend Oreille in 1960-1968 (stable at 40-50 animals from 1981-present), a herd was established in the Seven Devils Mountains near Hells Canyon in 1962-1964 (estimated to include 100 animals in 1981, and 200 in 2004), and a third herd was established north of Palisades Reservoir on the South Fork of the Snake River in 1969-1970. This herd, near Idaho's eastern border, grew rapidly and was estimated at 220 mountain goats in 1990, but declined from an estimated 195 animals in 2000 to only 42 in 2003. To the north, another mountain goat herd in the Red Conglomerates and Pilot Peak area along the border with Montana also declined dramatically from an estimated 155 animals in 2000 to 22 animals in 2004. Cause of these declines is not known.

MOUNTAIN GOAT MANAGEMENT

Mountain goat management goals identified in the statewide species management plan (Hayden et al. 1990) include management of mountain goat herds using both conservative hunter harvest strategies and transplants, refining knowledge of mountain goat population dynamics, maintaining or increasing recreational opportunities (consumptive and nonconsumptive) associated with mountain goat herds, and increasing knowledge of mountain goat diseases and parasites and their impacts on populations.

Harvest and Population Dynamics

Accurate data on mountain goat herd status is difficult to obtain. Many of the herds in central Idaho occur within designated Wilderness, and others occur along Rocky Mountain borders with adjoining states. Idaho has little true alpine habitat, and most mountain goat herds occur in subalpine habitats near the tree line at elevations of 7,000-10,000 feet. Counts are typically conducted from helicopter, using trained observers, but are confounded by small, patchy habitats used by mountain goats, poor visibility due to the presence of trees and rough, broken terrain, mountain goat behavioral avoidance of helicopters (animals may flee into timber, hide under tree canopies, or even enter caves), and unstable air currents. Independent verification of data by ground observers is rarely possible, so that detection rates are usually unknown. Due to cost (and often unstable weather), replicated data is rarely obtained; in fact, most mountain goat herds in Idaho are surveyed only once every 5 years. Further, despite data indicating that areas used by mountain goats vary both seasonally and annually in Idaho (Kuck 1977*b*), most observers focus primarily on historically favored habitats during annual surveys. As a result of these concerns, data presented on mountain goat populations discussed in this paper are based on actual count data, rounded to the nearest 10 animals, and thus represent a minimum estimate of mountain goat numbers.

In an effort to improve population estimation, Pauley and Crenshaw (paper in review) marked mountain goats in Idaho's Hells Canyon area using paintballs from hand-held paintball guns fired from a helicopter. Subsequent surveys of variously marked and unmarked animals allowed calculation of estimated population size using a Petersen estimator. Of particular note was the estimated sightability of mountain goats in this area, which ranged from 0.37 to 0.46. Other published estimates of mountain goat sightability by helicopter-based observers are 0.46 in coastal Alaska (Smith and Bovee 1984), 0.46 to 0.77 in west-central British Columbia (Cichowski et al. 1994), and 0.67 in the timbered Robson Valley of east-central British Columbia (Poole et al. 2000). Despite the low and variable probability of seeing mountain goats, the mark-recapture estimate shows promise for obtaining greatly improved population estimates.

Mountain goat populations are very susceptible to over-harvest and disturbance (for review, *see* Cote and Festa-Bianchet 2003). Idaho applies a very conservative approach to mountain goat harvest. Only one mountain goat may be harvested by an individual in Idaho, and all harvest is restricted to permits valid only in a limited area. In 2004, Idaho will issue a total of 40 mountain goat permits among 15 individual hunting areas statewide; i.e., maximum allowable harvest is less than 2% of the minimum number of mountain goats in the state, with an actual annual harvest that is likely less than 1% of the adult population.

Hunts are limited to discrete herds that include more than 50 adult mountain goats, and permits in those areas are limited to less than 4% of the adult population (1 permit/25 adult animals). Hunters may harvest any mountain goat, but are strongly encouraged to harvest adult male animals; nannies with kids are protected. Successful hunters must report their kill within 10 days for collection of biological data and hunt information; unsuccessful hunters must return their unused permit within 10 days of the close of the season. Hunters currently harvest an average of 40-50 mountain goats annually (Fig. 3).

Efforts to educate hunters to accurately identify and harvest only male mountain goats have had little success. Female typically have represented 30-40 percent of the harvest annually over the past 25 years (Fig. 4).

Hunter success rates are high. In 1975, 235 hunters harvested 93 mountain goats for a success rate of 40%; in contrast, harvest success has averaged >80% since 1980. Analyses indicate no identifiable association between population trend and either annual hunter success nor percent of the harvest comprised of females (Fig. 5).

Conservative management has provided a constant to slightly increase trend in average age of mountain goats harvested in Idaho. Average age of harvested mountain goats has increased from 5.2 to 6.2 years since 1990 (Fig. 6).

Among unsuccessful hunters, approximately half failed to hunt after receiving their permit. Kuck (1977*a*) reported that 32 (12%) of 267 mountain goat permit holders in 1975 failed to hunt, as compared with 3 (8%) of 39 permit holders I contacted in 2003 (file data).

Idaho's conservative approach to mountain goat management resulted in large part from studies conducted between 1969 and 1975 on Idaho's Pahsimeroi Range by Kuck (1977*b*). Following 3 years of baseline data collection, Kuck manipulated harvest rates in an attempt to relate harvest to annual production of kids. Although Kuck reported that annual production of kids appeared to be a function of shrub forage availability and nanny health, survival and recruitment kids was not related to harvest; i.e., population recruitment was not compensatory relative to harvest. Kuck reported that surviving animals redistributed themselves in the most favorable terrain following removal of dominant adults via hunting. Thus, mountain goat densities and foraging pressure on the favored cliffs remained constant, while less preferred cliffs, even though more productive in terms of vegetation, were abandoned. Kuck hypothesized that hunting could therefore decrease production, and that hunting mortality was likely additive to natural mortality. He believed that behavioral dominance within mountain goat populations was a constant force directing forage exploitation in the most desirable habitats, so that removal of dominant animals had little impact on forage availability, animal condition, or production of kids. Kuck concluded that selection for physical characteristics of habitat rather than forage was the key determinant of mountain goat population size, and that hunting mortality was additive to natural mortality (Kuck 1977*b*). If hunting is indeed additive, harvest levels should be reduced to focus harvest insofar as possible on post-breeding adults. This approach to harvest, implemented in Idaho since 1976, has been supported by more recent research on hunted and unhunted mountain goat herds (Gonzalez-Voyer et al. 2000), whose work suggested that harvest should be limited to 1-2% of adult males annually. However, this approach has failed to result in increases in mountain goat populations; most herds are presently static or declining slowly.

Swenson (1985) reported on data obtained over an 18-year period in Montana's Absoroka Mountains, and suggested that mountain goat populations that relied primarily on grasses (rather than shrubs, as in Idaho's Pahsimeroi Range) had a potential to exhibit compensatory response to hunting pressure in past because the forage base was more resilient than in habitats where mountain goats rely on longer-lived shrubs (Swenson 1985).

Some mountain goat herds, particularly those resulting from introductions to suitable but unoccupied habitat, have grown rapidly and are able to withstand higher levels of harvest during the expansion phase following introduction. Adams and Bailey (1982) reported that a herd introduced to the Sawatch Range of Colorado produced an annual harvestable surplus of about 7%, and reported that kid production declined as the population increased. In Idaho, Hayden (1989) documented a rate of growth of 22% in the Palisades herd between 1971 and 1983. In this herd, twinning was common (29% of adult females observed during 1982-1983), and 86% of mature females were observed with at least one kid. Observed survival of kids was 88% and yearling survival 95% during this study. After modeling this herd, Hayden recommended annual removal of 10-15% of adults during the initial growth phase to stabilize herd size, and to reduce potential for the herd to exceed carrying capacity of available range. He noted that many introduced mountain goat populations peak within 2 decades following introduction, and then stabilize at a level well below the peak numbers seen in the expansion phase. The Palisades herd apparently peaked at about 220 mountain goats in 1990, and between 2000 and 2004 it declined 78%, from a minimum of 195 animals to a minimum of 42.

These contrasting scenarios--endemic herds on stable to declining habitat in a 'post-decline' phase as defined by Caughley (1970) and introduced herds moving through phases of initial expansion, stabilization, decline, and post-decline phases—present a challenge to wildlife managers. Data suggest that harvest levels must be very conservative when applied to herds within stable environments unless those herds are clearly within the initial phases of population establishment as described by Caughley (1970). Data further suggest that, since harvest is likely additive to natural mortality within such situations and since no inversity response to food availability can be expected, the only way to provide additional harvest is to change the habitat within which populations occur.

To benefit long-established mountain goat populations, habitat change must significantly improve the forage base and, at the same time, alter behavioral habitat use patterns. For example, recent retreat of glaciers and semi-permanent icefields should expose soil and result in an increased forage base. In Idaho, where glaciers and semi-permanent icefields are rare, another opportunity to accomplish this goal is natural wildfire on alpine and subalpine ranges. Allowing natural wildfire to burn within mountain goat habitats would reduce tree encroachment on subalpine and alpine meadows, and would likely reinvigorate decadent shrubs essential in mountain goat diets, thereby increasing productivity in mountain goats herds. It appears that extensive wildfires in central Idaho Wilderness in 2000 have indeed resulted in an increase in mountain goat herds, but the evidence is confounded by associated changes in mountain goat visibility and detection by observers.

Evidence for initial rapid population increases following introduction of mountain goats into suitable unoccupied habitat provides wildlife managers opportunity to expand mountain goat range and associated hunting opportunity where habitat exists to support introduced mountain goats. However, such populations must be regularly monitored to keep expanding herds below levels at which they begin to damage available vegetation, resulting in a decline in numbers prior to herd stabilization.

Supplementing established herds of mountain goats in an effort to stimulate production has been attempted in Idaho, but available data are not encouraging. After only 3 mountain goats were observed in Idaho's Selkirk Range in 1971 and again in 1981, 28 mountain goats were introduced to this area. However, this introduction resulted in minimal herd response; only 34 mountain goats were present in 2001. It appears that survival of introduced animals is high, but that little recruitment has occurred. It was believed that food availability, if limited by mountain goats prior to their observed decline, should have increased due to the extremely low numbers of mountain goats present in this area over the decade of low use, but apparently either food availability was not a limiting factor or recovery did not occur.

Recreational Opportunities

Recreational opportunities associated with mountain goat management include hunting and wildlife viewing. Demand for hunting opportunity is high, with 400-500 applications received for the 40-50 mountain goat permits available annually since 2000.

Opportunities to view and photograph mountain goats in Idaho are limited for those unwilling or unable to climb into the steep and often remote country occupied. One of the premier viewing sites in Idaho is located at Farragut State Park on the south end of Lake Pend Oreille (Pope 2003). Sixteen mountain goats were introduced to Bernard Peak, 1960-1965 (Naylor 1988); the current herd numbers about 40 animals. These mountain goats are usually highly visible, and have become very habituated to people viewing them from the lakeshore or from boats below the primary cliffs utilized by the animals. Other sites include Priest Lake, the Mallard-Larkins Pioneer Area, Hells Canyon Dam, the Middle Fork Salmon River Canyon, the Main Fork Salmon River (above Corn Creek), and Upper Trail Creek (Pope 2003). These sites are very popular with the public, and interpretive materials have been provided at Farragut State Park.

However, much winter recreation has high potential to adversely impact mountain goat populations. Mountain goats are more susceptible to disturbance by helicopters than most open-terrain ungulates; Cote (1996) reported that mountain goats exhibited overt responses to 58% of helicopter flights within 1.2 mile (2 km), and Gordon and Reynolds

(2000) reported that mountain goats exhibited moderate to extreme response to helicopters during 75% of all sightings from the helicopter. Winter disturbance is especially problematic, since mountain goats that are already stressed by cold and by limited food supplies due to snow cover in all but the steepest environments may exhibit panic, increased metabolic rates and energy expenditure, and reduced time spent feeding (Gordon and Reynolds 2000). Repeated disturbance by helicopters, snow machines, or even logging or road building (Chadwick 1983) may result in abandonment of favored habitats—steep cliffs that readily shed snow cover, allowing goats access to forage in an environment where they are normally secure from predators—potentially reducing probability of winter survival through mechanisms of increased energetic demand associated with feeding and increased exposure to potential predators.

Increased winter activity in the vicinity of mountain goat habitat, especially heli-skiing and over-snow travel by snowmobiles, has potential to severely reduced the amount of habitat that may be used by mountain goats.

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Fig. 1. Mountain goat distribution in Idaho (Groves et al. 1997).

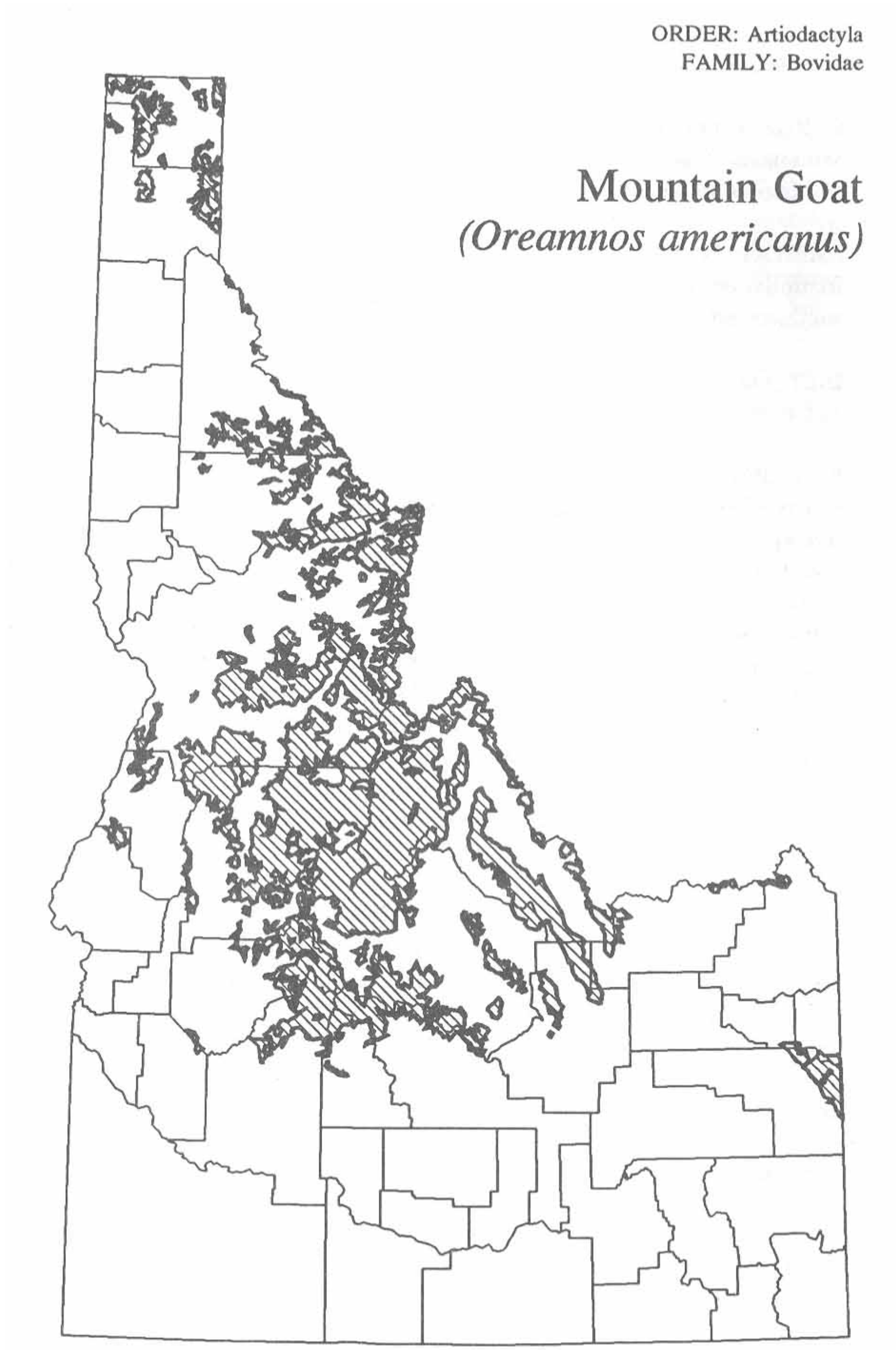


Fig. 2. Population estimates for mountain goats in Idaho, 1955-2004.

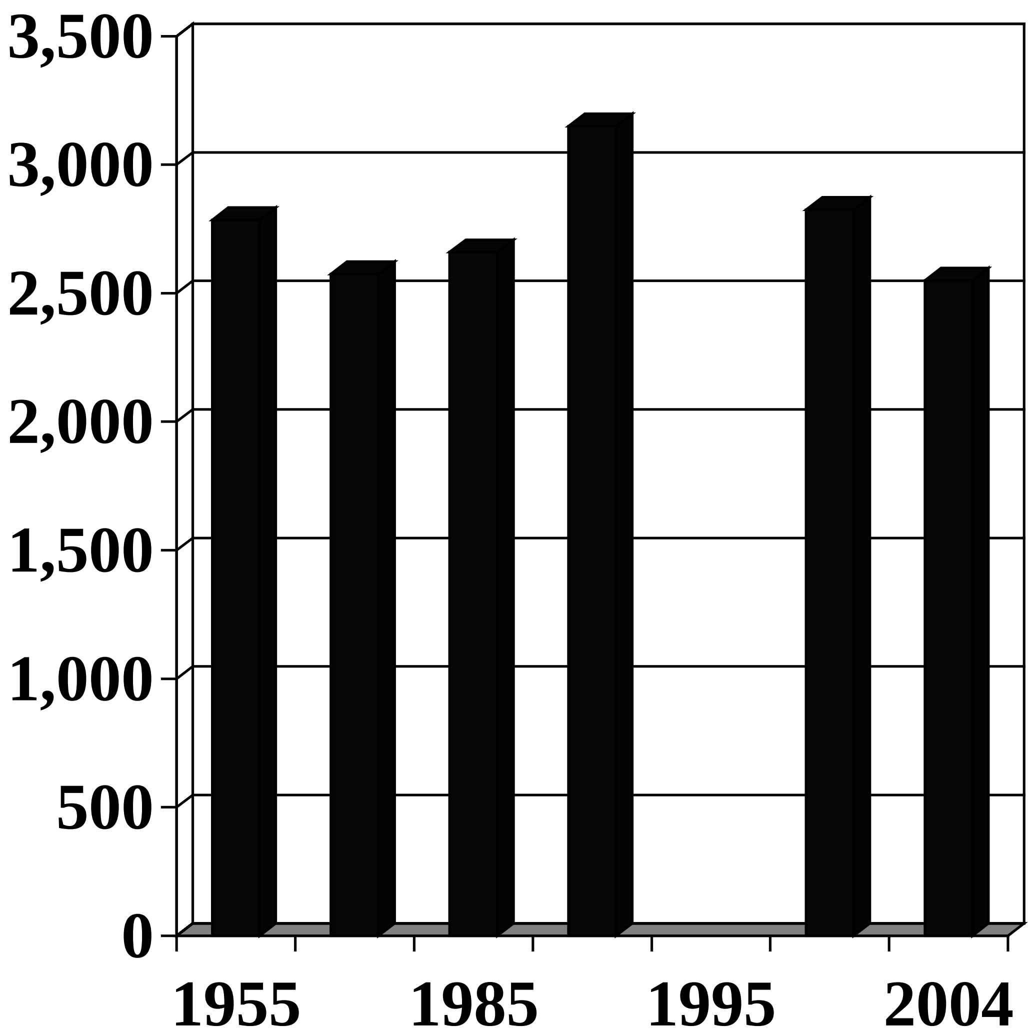


Fig. 3. Historic harvest estimates for mountain goats in Idaho, 1935-2003.

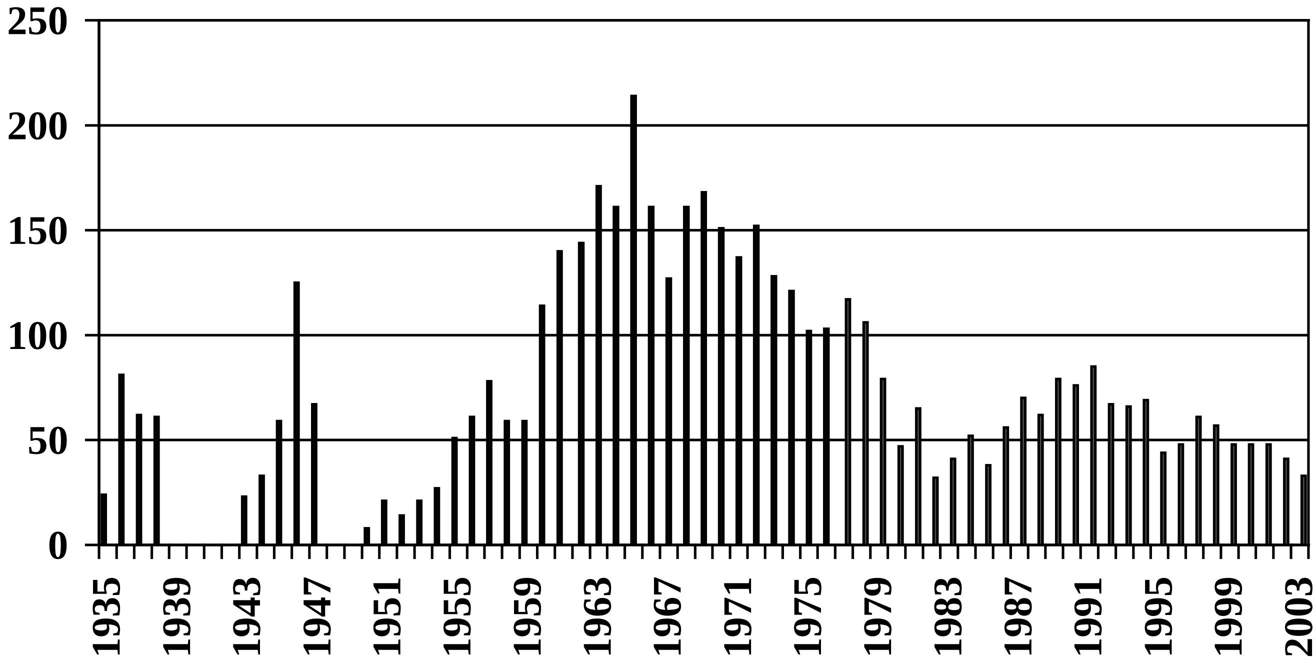


Fig. 4. Percentage of the annual mountain goat harvest comprised of males.

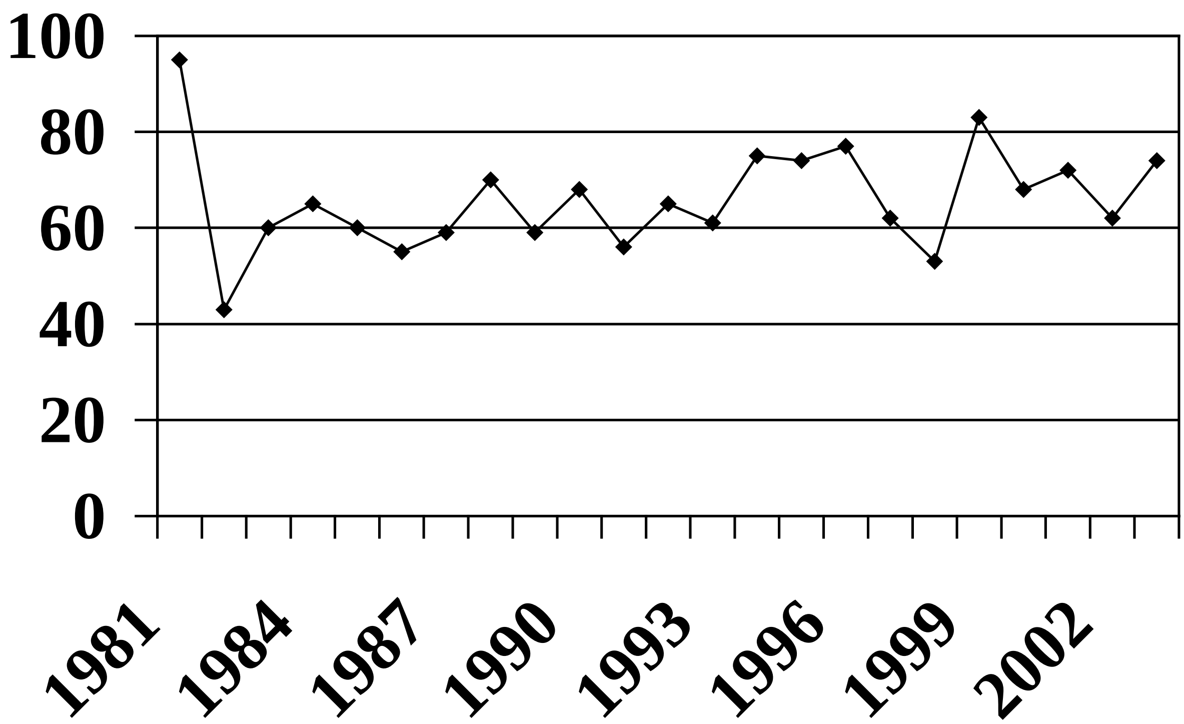


Fig. 5. Number of mountain goat harvest permits issued annually (solid line) and actual hunter harvests (dashed line).

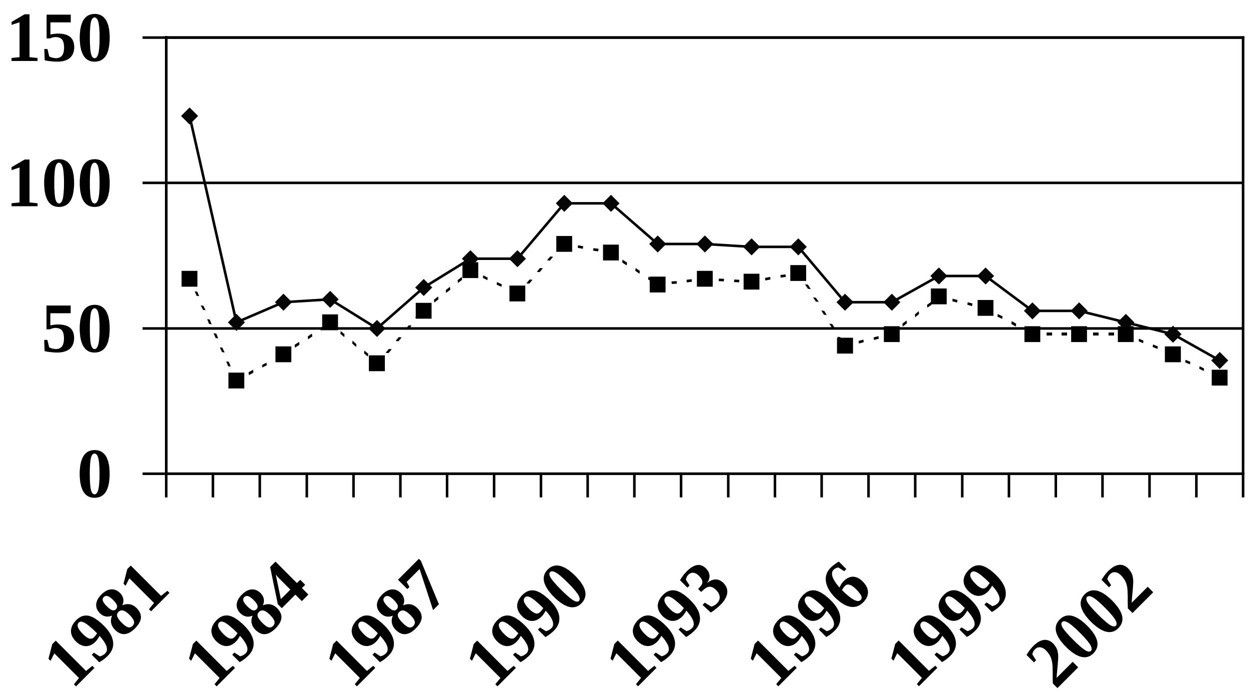
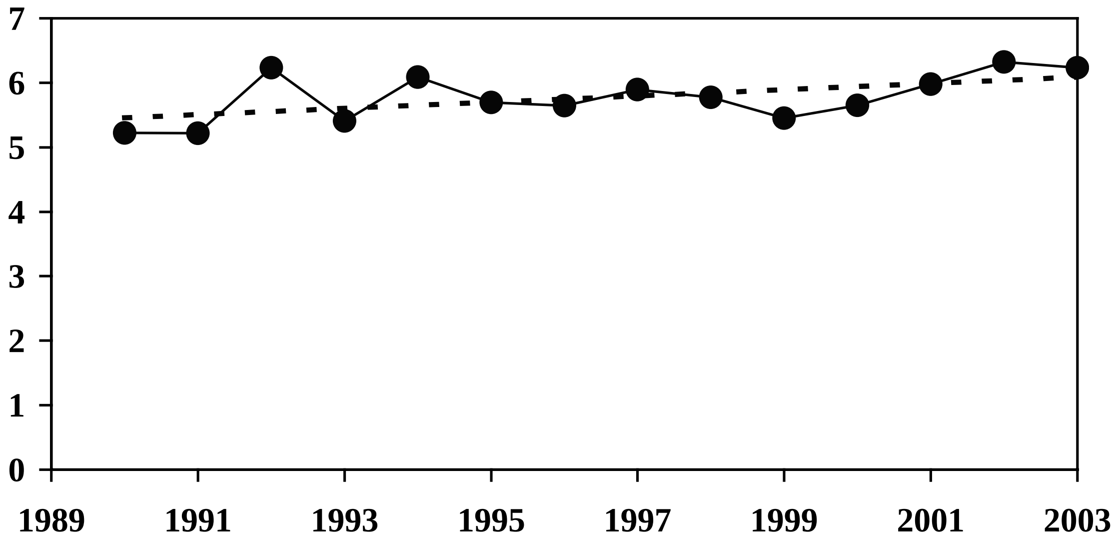


Fig. 6. Average age of mountain goats harvested in Idaho, 1990-2003.



Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:131-136

NWSGC POSITION STATEMENT ON HELICOPTER-SUPPORTED RECREATION AND MOUNTAIN GOATS

Kevin Hurley, NWSGC Executive Director

July 9, 2004

Introduction:

Less is known about mountain goats than other North American ungulates, due primarily to their relative scarcity and the inaccessible terrain they inhabit (Smith 1982, Festa-Bianchet et al. 1994, Wilson and Shackleton 2001). Disturbance of ungulates by helicopters can result in a variety of negative effects, including habitat abandonment significant enough to affect population status and herd viability, dramatic changes in seasonal habitat use, increased vulnerability to predation, alarm responses, decreased bouts of foraging and resting, increased animal movement and energy expenditure, and reduced productivity (Pendergast and Bindernagel 1976, MacArthur et al. 1979, Foster and Rahs 1981, Foster and Rahs 1983, Hook 1986, Joslin 1986, Pedevillano and Wright 1987, Dailey and Hobbs 1989, Côté 1996, Frid 1999, Denton 2000, Duchense et al. 2000, Gordon and Reynolds 2000, Phillips and Alldredge 2000, Dyer et al. 2001, Frid 2003, Gordon 2003, Keim and Jerde 2004).

Population and/or fitness-enhancing behaviors such as feeding, parental care, and mating may be detrimentally impacted in response to repeated helicopter disturbance, even when overt reactions to disturbance are not visible (Bunnell and Harestad 1989, Gill and Sutherland 2000, Frid and Dill 2002). Significant effects on reproduction, survival, and population persistence may occur. Increased vigilance resulting from disturbance may reduce the physiological fitness of disturbed animals by increasing stress, increasing locomotion costs (particularly during winters with severe snow conditions), and by reducing time spent in necessary behavior such as foraging or ruminating (Frid 2002). Physiological responses (e.g., elevated heart rates) to disturbance may not be directly reflected in overt behaviors, (Macarthur et al. 1982, Stemp et al. 1983, Harlow et al. 1986, Chabot 1991), but are nonetheless costly to individual animals, and ultimately, to populations.

Although the short-term behavioral responses of mountain goats to helicopter activity have been documented, longer-term habitat use and demographic consequences of disturbance remain poorly understood. Our recommendations are aimed at minimizing short-term behavioral disruptions that we believe are correlated with longer-term impacts. Research to date has not clearly identified thresholds of disturbance that trigger unacceptable responses; as a result, approach distances and other specific mitigation measures are precautionary recommendations.

Management recommendations:

<u>Exclusion zones/avoidance:</u>

Habitat segregation is typical of many ungulate species (Main et al. 1996), including mountain goats. During spring/summer/fall periods, adult male goats occupy habitats other than those occupied by nanny-juvenile ("nursery") groups (Geist 1964, Foster 1982, Risenhoover and Bailey 1982), with nursery groups typically occupying habitats more favorable for survival and reproduction (Fournier and Festa-Bianchet 1995). Adult female mountain goats have heightened sensitivity to disturbances during kidding and post-kidding periods (Penner 1988). Mountain goats are known to have a lower recruitment rate, compared to other ungulates (Bailey 1991, Festa-Bianchet et al. 1993). The health of mountain goat nursery groups provides obvious contributions to the reproductive success and survivorship of goat populations. Due to the sensitivity of adult female mountain goats to disturbance, and the importance of this age/sex class to the persistence of local goat populations, restrictions on late spring and early summer helicopter activities should focus on areas occupied or likely to be occupied by nursery groups. The very activities that serve to document use are, in themselves, disruptive to mountain goats. However, documentation of crucial winter habitat use by mountain goats is essential to identify and conserve those important winter ranges, particularly in coastal mountain ranges where deep snows are typical.

Recommendation:
Helicopter avoidance should focus on those areas identified as crucial winter range, and those areas occupied or highly suspected as used by nursery groups. Particular attention should be given to helicopter activities during identified pre-kidding, kidding, and post-kidding periods; such restrictions require identification and mapping of mountain goat habitats and identifying exclusion zones prior to the issuance of annual or multi-year heli-recreation special use permits.

Distance from occupied habitats:
Behavioral responses to helicopter activity have been documented at distances of up to 2 km for mountain goats and other ungulate species (Côté 1996, Frid 2003, Gordon 2003). Recent studies have shown that short-term behavioral responses of mountain goats increase as helicopters approach within approximately 1.5 km of mountain goats. It must be noted, however, that minimum distance needed is modified strongly by topography and the amount of cliff cover/escape terrain available; increased buffer distances may be needed in more rolling terrain with less cliff cover, or in very narrow canyons/valleys.

Recommendation:
Helicopter activity should not occur within 1.5 km of occupied/suspected nursery group or crucial winter range habitats during critical periods.

Timing of activities:
Winter is of particular concern for management of disturbance stimuli. Winter is a period of severe nutritional deprivation for mountain goats (Chadwick 1983, Fox et al.1989, Shackleton 1999). Periods of deep snow can reduce food availability and dramatically increase locomotion costs (Dailey and Hobbs 1989). In winter, mountain goats are known to be relatively immobile (i.e., movements not exceeding 50m/hour) (Keim 2003), to occupy small ($<4km^2$) and specific habitat areas (Keim 2003, Schoen and Kirkoff 1982, Smith 1982), and to have high rates (>0.66) of winter home range fidelity (Keim 2003. Schoen and Kirkoff 1982). Selection of small, isolated winter habitats by goats may become compromised if management of helicopter-recreation activity neglects to consider winter mountain goat habitats and the needs of wintering goats. It is imperative that management of activities such as helicopter-skiing address and acknowledge the potential effects on mountain goat populations, through development of enforceable mitigation strategies.

Recommendation:
Helicopter activity should not occur on or near occupied winter ranges between November 15-April 30 each year. Helicopter activity should not occur on or near occupied or suspected nursery group habitats between May 1-June 15 each year. Mountain goat winter and kidding distribution and habitat selection should be known and mapped prior to issuance of annual or multi-year heli-recreation special use permits.

Helicopter approach vectors:
The rate and horizontal distance of helicopter approach vectors affect the degree of overt disturbance to ungulates. The degree of overt disturbance also varies, according to the availability of escape terrain and topography (Frid 2003, Wilson and Shackleton 2000). Additional research should be directed at identifying and documenting best management practices for mitigating approach vectors.

Recommendation:

Vertical and horizontal approach vectors should be considered when developing mitigation strategies. Strategies should also consider local conditions including refuge availability, topography, and amount and distribution of cliff cover suitable as escape terrain.

Habituation/Sensitization:
Animals may not be able to habituate to disturbance stress when disturbance is irregular and unpredictable (Bergerud 1978, Risenhoover and Bailey 1982, Penner 1988). Frid (2003) found that the proportion of Dall's sheep fleeing did not decrease with the number of cumulative weeks of disturbance. Habituation to disturbance stimuli often is partial or negligible, and habituation to strong disturbance stimuli may only partially occur (Bleich et al. 1994, Steidl and Anthony 2000, Frid 2003). Flight-initiation distance or vigilance might actually increase with repeated exposure to non-lethal stimulus if the stimulus is sufficiently adverse, resulting in sensitization to disturbance stimuli, the opposite of a habituation response (Frid and Dill 2002).

Recommendation:
It is inappropriate to assume that habituation of mountain goats to helicopter disturbance will occur over time. Reluctance to flee should not be perceived as habituation; numerous physiological responses occur, even in the absence of overt behavioral responses. All helicopter flights over or near crucial mountain goat habitat should be considered harmful to mountain goats populations, based on current knowledge. Additional research on the long-term behavioral effects of helicopters on mountain goats should be undertaken. Establishment of a cross-jurisdictional Research Steering Committee comprised of state and provincial government and non-government/academic experts is recommended. To enable such behavioral research to occur, spatially explicit control areas should be designated in which no helicopter-supported recreation term permits are issued.

Monitoring/Enforcement
Additional monitoring of the medium and long-term effects of helicopter activity on mountain goats is needed (Wilson and Shackleton 2000). Comprehensive, long-term land use and resource management plans, as well as project-specific activity plans, need to incorporate strategies and mitigation to protect and conserve critical mountain goat habitats, while still allowing commercial activities to occur, where appropriate. These plans need to thoroughly address helicopter-supported recreation effects on wildlife populations, both short and long term. These plans should identify research needed, cite pertinent existing research from other areas, and base helicopter-activity management on the best available scientific information. Enforcement of existing terms and conditions in special use permits should occur. If lacking, those terms and conditions, along with appropriate sanctions, should be developed for inclusion in activity/operating plans.

Recommendation:
Long-term monitoring is essential. If baseline data on mountain goat numbers, distribution, and seasonal habitat selection are lacking, steps should be taken to obtain those data. Monitoring should include both compliance with, and evaluation of the effectiveness of, mitigation strategies and exclusion zones. Long-term monitoring of mountain goat population performance is needed. Control areas to facilitate future behavioral research should be maintained, in which commercial helicopter activity is not permitted. Term permits should include enforceable provisions to address cases of non-compliance. Provisions should be included to modify permitted areas or conditions, based on new information, in an adaptive management approach. Permit fees should be adequate enough and used to conduct the monitoring and baseline data collection to manage these activities. Permitting of helicopter-supported recreation, especially in new areas, should not occur until managers have the ability, funding, and mechanism to collect adequate population demographic and habitat use data, to properly manage, mitigate, and monitor this activity.

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WESTERN ASSOCIATION OF FISH AND WILDLIFE AGENCIES

RESOLUTION

HELICOPTER-SUPPORTED COMMERCIAL RECREATION IN MOUNTAIN GOAT RANGE

WHEREAS, the Western Association of Fish and Wildlife Agencies sanctions and recognizes the Northern Wild Sheep and Goat Council as an international scientific and educational organization comprised of North American wild sheep and mountain goat biologists, managers, researchers, wildlife veterinarians, administrators, students, and advocates; and

WHEREAS, the Northern Wild Sheep and Goat Council has identified helicopter-supported commercial recreation (e.g., glacier overflights/takeoffs/landings, heli-skiing, heli-hiking, heli-trekking) in mountain goat habitat as an emerging issue in the management and conservation of mountain goats in the western U.S. and Canada; and

WHEREAS, the Northern Wild Sheep and Goat Council believes the sensitivity of mountain goats and their habitats call for a conservative approach until more comprehensive, science-based research can be completed; and

WHEREAS, the Northern Wild Sheep and Goat Council and its members have developed specific interim recommendations to minimize/mitigate adverse impacts from helicopter-supported commercial recreation; and

WHEREAS, the members of the Northern Wild Sheep and Goat Council stand ready to offer their professional advice and assistance with the management of airspace in and over mountain goat habitats, to maintain the integrity of those habitats.

NOW, THEREFORE, BE IT RESOLVED that the Western Association of Fish and Wildlife Agencies will assist and encourage the International Association of Fish and Wildlife Agencies to help elevate this issue to the attention of the leadership of wildlife, land-management, and airspace regulatory agencies in the United States and Canada.

BE IT FURTHER RESOLVED that the Western Association of Fish and Wildlife Agencies will support the pursuit of objective, rigorous, science-based evaluation of impacts to mountain goats from helicopter-supported commercial recreation, as outlined in the Northern Wild Sheep and Goat Council's position statement.

Adopted in Convention
Coronado, California
January 9, 2005

Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:137

MEASURING MOVEMENT RESPONSES OF WINTERING MOUNTAIN GOATS FROM AERIAL TELEMETRY OCCURRENCES

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CHRISTOPHER L. JERDE

Abstract: Many studies have commented on wildlife movements in response to helicopter and fixed-wing aircraft over-flights. However, research-oriented aerial telemetry has rarely been investigated as a disturbance variable. The potentially deleterious effects of displacing an animal are relatively unknown and are therefore rarely discussed or considered when proposing new telemetry research. We draw on the opportunity of 16 GPS collared mountain goats (*Oreamnos americanus*) that recorded location data over a 4-month winter period where regular telemetry flights were conducted. We evaluate two models using Akaike's Information Criteria to discriminate between distributions of step lengths during telemetry flights and at times other than during telemetry flights. In 7 of 16 individuals there was evidence for different distributions of step length during periods of disturbance. Two behavioral responses, short and long movements, occurred more often on days of aerial telemetry events than expected. The implications for studies that use aerial telemetry and GPS collar locations to track animal movement are discussed.

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and Goat Counc. 14:139

MOUNTAIN GOAT HABITAT SUPPLY MODELING AS A PARADIGM FOR EFFECTIVE FOREST STEWARDSHIP PLANNING

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Abstract: Mountain goats (*Oreamnos americanus*) in north-central BC show significant use of low-elevation forested habitats. Successive generations of goats use forested areas to access valley-bottom mineral licks from early spring to late fall, and for forage and cover during winter. In BC, mountain goat populations are considered sensitive enough to warrant special management under the Forest and Range Practices Act (FRPA). Despite legislated protection under the FRPA Identified Wildlife Management Strategy, many people consider that forest development can reduce or eliminate access to mineral licks, disturb goats on winter ranges, influence predator-prey dynamics, and create access to previously isolated goat populations.

Through a collaboration amongst industry, government, and First Nations stakeholders, we are developing a mountain goat habitat supply model (HSM) with the intent of: a) providing a useful operational planning tool at the Forest Stewardship Plan level, b) facilitating the direct assessment of forest impacts on goat habitat in relationship to timber values, and c) contributing to the development of adaptive management strategies that can also be applied to other geographical areas (e.g., regionally and provincially).

The results will serve industry planners and government resource managers, and are expected to provide measurable progress toward: a) developing standards for demonstrating due diligence and accountability in Forest Stewardship Plan submissions, b) developing innovative policies and improved standards for establishing adaptive management strategies that balance timber supply and mountain goat habitat needs, and c) providing forecasts of habitat supply useful for evaluating indicators of sustainable management as a basis for forest certification.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:140

OSPIKA MOUNTAIN GOAT ADAPTIVE MANAGEMENT TRIAL

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Abstract: Mountain goats (*Oreamnos americanus*) show strong fidelity to mineral licks. Traditional use by successive generations of goats has resulted in well-used trail systems through forested habitat between alpine summer ranges and valley bottom mineral licks. Industrial forest development has the potential to reduce or eliminate access to these mineral licks. Although a designated "regionally important" species under the British Columbia Identified Wildlife Management Strategy (IWMS), operational management options tend to be vague or non-existent due to a lack of technical information.

In 2001, the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) and Slocan Forest Products Ltd. Mackenzie Operations (SFP) initiated the Ospika Goat Project (OGP) a large-scale, multi-phase, collaborative study focused on the development and implementation of an effective policy to support integrated management of forests and mountain goat habitat in north-central British Columbia. Collaborators from government agencies and private industry are active in the project through participation in a Mountain Goat Management Team (MGMT). In order to develop effective operational management policies for the forest industry, an adaptive management approach is being taken to assess the impacts of forest harvesting on the use of low-elevation mineral licks by mountain goats (the "Adaptive Management Trial" component of the OGP).

The OGP Adaptive Management Trial aims to monitor the impact of 2 different forest harvesting strategies on the behaviour of mountain goats using low-elevation mineral licks and associated access trails in the Ospika River drainage. The study design involves monitoring the goat use of 4 mineral lick complexes and their associated forested trail systems before and after habitat alteration. Two sites are being subjected to timber removal, one employs the retention of a 100 m forested buffer along the primary mineral lick access trail while the area around the other access trail and lick will be clearcut with no forested buffer being retained. The 2 remaining sites, a control lick across the drainage and a lick in the vicinity of the treatment sites that will help assess possible post-treatment goat displacement, will be monitored but will remain untreated. Behavioural responses of goats to the treatments are being determined by monitoring the frequency, timing, and duration of lick visits by radio-collared goats before and after harvesting occurs. Goat visits are being assessed using remote radio-telemetry and camera stations set up at mineral licks and along their access trails.

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PARASITE FAUNA OF MOUNTAIN GOATS (*OREAMNOS AMERICANUS*) IN THE NORTHWEST TERRITORIES, BRITISH COLUMBIA, AND IDAHO.

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Abstract: For the first time, helminth and protozoan parasites are described from fecal samples of mountain goats (*Oreamnos americanus*) in the Northwest Territories (NT, Canada) (n=22; 62°18’ N; 128°58’ W), coastal British Columbia (BC, Canada) (n=18; 50°31’ N; 124°39’ W), and central BC (n=22; 56°30’ N; 123°55’ W). We also compared results with recent (1990-2003) and historical (1955) fecal-based surveys from mountain goats in Idaho (ID) (n=68 and 75, respectively). From fecal samples, we recovered eggs of the following gastrointestinal parasites: generic trichostrongyles (*Teladorsagia*/*Ostertagia* spp.); *Marshallagia* spp.; *Nematodirus* spp.; *Trichuris* sp.; *Moniezia* sp.; and the coccidians *Eimeria* spp. We also found protostrongylid larvae, including the lungworms *Protostrongylus rushi* and/or *P. stilesi*, and the muscleworm *Parelaphostrongylus odocoilei* (the last identified using molecular techniques). From carcasses of two mountain goats from coastal BC, we recovered adult specimens of *Teladorsagia circumcincta/T. boreoarcticus*, *Nematodirus maculosus*, and *P. rushi*, as well as larvae of *P. odocoilei*. From the carcass of an emaciated goat from central BC, we recovered a warble, *P. rushi*, larvae of *P. odocoilei* and high intensities of *Eimeria* spp., two species of *Marshallagia*, and *Teladorsagia circumcincta/T. boreoarcticus*.

Among the NT, central BC, coastal BC, and ID, the prevalence (percent of samples positive) and intensity (mean number of eggs or larvae per sample) of indirectly-transmitted parasites (protostrongylids and *Moniezia* sp.) were greatest in mountain goats from coastal BC. *Marshallagia* sp., common in mountain goats elsewhere, was rare in mountain goats from coastal BC. Our survey and a literature review support the hypothesis that, where range is shared, mountain goats and wild sheep may share some parasite species, but also have their own core parasite fauna (including a species of

Marshallagia that may be unique to mountain goats). In the NT and central BC, *Eimeria* spp. had greater abundance in fecal samples from mountain goats than season-matched samples from nearby thinhorn sheep populations. In combination with dental disease, chronic gastrointestinal parasitism may have contributed to emaciation and death of a goat from central BC.

Management recommendations include the recovery and identification of adult parasites from mountain goats, and/or combining more extensive fecal surveys with new methods for molecular identification of parasite eggs and larvae. These steps are crucial to understanding the parasite fauna and significance of parasitism in mountain goat populations, and the potential for parasite exchange with wild sheep.

INTRODUCTION

Knowledge of the parasite fauna of mountain goats (*Oreamnos americanus*) is currently limited to two fecal-based surveys (Brandborg, 1955; Pybus et al., 1984), and a few published reports, primarily from Alberta and South Dakota, based on adult parasites recovered from carcasses (Table 1; also see Hoberg et al., 2001). Such knowledge is necessary to assess the impact of parasitism on mountain goat populations, and to provide a sound basis for management decisions. Northern ungulates inhabit an environment threatened by habitat destruction and global climate change, and this could lead to shifts in the balance of host-parasite relationships (Hoberg et al., 2001). Such shifts, and their significance, cannot be detected or addressed without knowing the current parasite fauna of northern hosts, or established baselines for parasite shedding.

We examined parasites in fecal samples opportunistically collected from mountain goats in the Northwest Territories (NT), central British Columbia (BC), and coastal BC, from which parasites have not been described. As well, we compared our results with both current (1990-2003) and historical (1955) surveys of fecal parasites of mountain goats in Idaho. Fecal surveys are the least invasive and logistically simplest approach to describing internal parasites of wildlife. They are limited, however, because definitive species identification cannot be accomplished based on the shape and size (morphology) of eggs and larvae shed in feces. Therefore, where possible, we obtained adult parasites from carcasses to confirm identification (coastal and central BC), or used DNA analysis of parasites in fecal samples to determine species (larvae of *Parelaphostrongylus odocoilei*). For the remaining parasites, we reviewed the literature to establish likely species identifications for eggs and larvae shed in feces of mountain goats.

In part, our interest in the parasite fauna of mountain goats stems from concurrent investigations of the health status and parasite fauna of thinhorn sheep (*Ovis dalli*) in NT and BC (Jenkins et al., 2000; Kutz, 2001; Kutz et al., 2001; Jenkins and Schwantje, 2004; Kutz et al., 2005). Transmission of parasites between mountain goats and wild sheep has implications for management (especially if animals are translocated), and may have significance for the health of these populations. Mountain goats and thinhorn sheep likely share a similar parasite fauna: "Generally mountain goat and bighorn sheep (*Ovis canadensis*) have 1) similar numbers of helminth species, 2) many helminth species in common, and 3) are accidental hosts of a few others" (Samuel et al., 1977). To determine the potential for parasite exchange between mountain goats and wild sheep, we reviewed the available literature. As this suggested that many parasite species are shared, we compared prevalence and intensity of parasites shed in fecal samples from mountain goats and thinhorn sheep in two regions of range overlap (NT and central BC).

METHODS

Primarily in 2001-2002, fecal samples were collected from the ground or from captured mountain goats at locations in the Northwest Territories (NT) (62°18' N; 128°58' W), coastal British Columbia (BC) (50°31' N; 124°39' W), and central BC (56°30' N; 123°55' W) (Table 2, Figure 1). Samples from Idaho were collected between 1990 and 2003 from various locations, including Hell's Canyon, 7 Devils, Mt. Baldy, Rainey Creek, Black Mt., Palisade, Dry Diggins, Mt. Baird, and Big Elk Creek, and processed at other laboratories. Therefore, methods may differ from the following protocol.

All samples were kept frozen until processing. Sub-samples (5 grams per test) from each fecal sample were processed using a fecal flotation technique to quantify eggs and oocysts of gastro-intestinal parasites (Cox and Todd, 1962), and a modified beaker Baermann technique to quantify larvae of protostrongylid parasites (Forrester and Lankester, 1997). Dorsal-spined larvae and *Protostrongylus* spp. larvae were counted in 3 aliquots of 0.05 ml of the Baermann sediment on a slide under a compound microscope. If very few or no larvae were detected using the aliquot technique, the entire sediment was examined in a gridded Petri dish or on a slide, and all the larvae counted. The proportion of samples positive for each parasite (prevalence), and the average number of parasites shed per gram of feces (intensity), were calculated for each sampling location. Only prevalence was reported for the samples from Idaho.

Parasite larvae, eggs, and oocysts were identified as to type and, when possible, to genus or species. Nematodirine eggs from the Northwest Territories were cultured to third-stage larvae (Ministry of Agriculture, Fisheries, and Food, U.K., 1986). Dorsal-spined larvae were identified using molecular techniques (Jenkins et al., 2005). Adult parasites were recovered from the gastro-intestinal tracts and lungs of two adult female mountain goats from the Coastal Range of BC that died of causes unrelated to disease in November 2001 and September 2002. Adult parasites were identified using standard comparative morphology. As well, adult parasites were recovered and identified from an adult male mountain goat from the Ospika region (central BC) that died of emaciation, secondary to dental disease, in January 2004. Along with the rest of the samples from central BC, a fecal sample from this animal was collected and analyzed in March 2002 (at capture and collaring).

RESULTS

Possible identifications for eggs and larvae shed in feces were based on the known parasite fauna of mountain goats (Table 3). Dorsal-spined larvae (DSL) of *Parelaphostrongylus odocoilei* were recovered from mountain goats in the NT, central BC, and coastal BC, and may have been present, but not recorded, in the samples from Idaho. Prevalence of eggs and larvae in feces of mountain goats at the four locations, as well as values reported in a previous survey in Idaho and Montana, are presented in Table 4. The intensities of parasites shed in feces were compared among the mountain goat populations in the NT, central, and coastal BC in Table 5.

Tail morphology of third-stage larvae (L3) of *Nematodirus* spp. from fecal samples of mountain goats in NT differed from those described for *Nematodirus* spp. from domestic animals, but were not identified further. Adult parasites from mountain goat carcasses from coastal BC were identified as *Teladorsagia circumcincta/T. boreoarcticus* from the abomasum and small intestine, *Nematodirus maculosus* from the small intestine, and *Protostrongylus rushi* from the lungs. Dorsal spined larvae from the lungs of these two goats were identified as *Parelaphostrongylus odocoilei* using molecular techniques. From the carcass of an emaciated goat from central BC, we recovered *P. rushi*, low numbers of dorsal-spined larvae that were assumed to be *P. odocoilei*, a warble larvae, and high intensities of *Eimeria* spp., *Teladorsagia circumcincta/T. boreoarcticus*, and two species of *Marshallagia* (including one that may be unique to mountain goats). On fecal examination in March 2002, this goat had high intensities of eggs of *Marshallagia* spp. (10 eggs per gram of feces, EPG) and oocysts of *Eimeria* spp. (1200 oocysts per gram of feces, OPG) relative to the rest of the samples (means of 4 EPG and 330 OPG, respectively; see Table 5). On fecal examination in Jan. 2004 (at death), this animal still had high intensities of *Marshallagia* spp. (19 EPG) and *Eimeria* spp. (1200 OPG).

In samples from the NT, the prevalence and intensity of most parasites shed in feces were greater in Dall's sheep than mountain goats, except for eggs of generic trichostrongyles, which were present in 73% of samples from mountain goats, but absent in samples from Dall's sheep. As well, the intensity of *Eimeria* spp. was greater in fecal samples collected from mountain goats as compared to thinhorn sheep in the NT (3 X) and central BC (9 X). In samples collected in March 2002 from both mountain goats and Stone's sheep in central BC, no generic trichostrongyle eggs were observed, and DSL were present only in samples from mountain goats.

DISCUSSION

Comparing mountain goat populations

Our findings in mountain goats in the Northwest Territories (NT), central and coastal British Columbia (BC), and Idaho (ID), were consistent with the parasite fauna of mountain goats reported elsewhere (Tables 1 and 3), bearing in mind the limitations of fecal surveys. For example, eggs of generic trichostrongyles (*Teladorsagia*/*Ostertagia* spp.) were not recovered from samples collected in March in central BC. This likely reflects seasonal inhibition of egg output, as adult *Teladorsagia* spp. were present in the carcass of a goat from central BC examined in January. Season of collection strongly influences prevalence and intensity of parasite shedding in feces. Based on work in thinhorn sheep, shedding of eggs of trichostrongyles reaches a peak in late summer, when samples from mountain goats in the NT were collected. Conversely, prevalence and intensity of *Nematodirus* spp., *Marshallagia* spp., *Trichuris* sp., *Eimeria* spp., and the protostrongylids reach a peak in spring, when samples from mountain goats in BC were collected (Nielsen and Neiland, 1974; Jenkins and Schwantje, 2004). Prevalence results from Idaho cannot be interpreted in light of seasonal trends as the month of collection varied. The lower prevalence of some parasites in samples from mountain goats in Idaho in both the current and historical studies (Table 4) may reflect differences in season of collection, exposure to anthelmintics, or techniques among the different laboratories.

Observed differences in prevalence and intensity of parasites shed in feces must be interpreted carefully. Some may simply reflect small sample sizes combined with low prevalence of some parasites, for example, the tapeworm *Moniezia* sp. and the pinworm *Skrjabinema* sp. As well, there are limitations to identification of eggs and larvae in feces. For example, eggs of *Marshallagia* and *Nematodirus* spp. are somewhat similar in size and morphology, and may have been grouped together in the surveys in Idaho (Table 4). In addition, several protostrongylid species produce larvae similar in appearance; for example, both *Parelaphostrongylus odocoilei* and *Muellerius capillaris* produce dorsal-spined larvae (DSL), and this has led to some confusion (Table 4). Larvae of *P. stilesi* and *P. rushi* are also thought to be indistinguishable; however, the tails of the larvae in samples from mountain goats in NT and BC, which likely represent *P. rushi*, were shorter than those of larvae observed in samples from sympatric thinhorn sheep, which are likely those of *P. stilesi*. Molecular techniques show great promise to resolve species identity of morphologically similar parasites. For example, recent molecular work suggests that there may be more species of *Teladorsagia* in wild caprines and cervids than previously suspected (Hoberg et al., 1999).

Despite the limitations of fecal surveys, differences in prevalence and intensity of parasite shedding among the four mountain goat populations (NT, ID, central and coastal BC) may reflect differences among climate, habitat, host density, and parasite sharing with sympatric ungulates. Both types of protostrongylid larvae (DSL and *Protostrongylus* spp.) and eggs of the tapeworm *Moniezia* sp. were present at higher prevalence and at least 10 times greater intensity in samples from coastal BC than any other location. While there may be a seasonal component to this difference, it is possible that climatic conditions of the coast are more favorable for the intermediate hosts required for transmission of these parasites (gastropods for protostrongylids and free-living oribatid mites for *Moniezia* sp).

Conversely, the warm, wet environment of coastal BC may not favor survival of free-living stages of *Marshallagia* spp., common in mountain goats elsewhere. Specimens of *Marshallagia* spp. were not recovered from mountain goat carcasses from coastal BC, and we recovered only one egg of *Marshallagia* spp. from feces of one mountain goat (of 18 examined) in coastal BC. This may reflect differences in climate or habitat; alternatively, as there is minimal range overlap between mountain goats and wild sheep in this region in coastal BC (Shackleton, 1999), perhaps *Marshallagia* spp. are maintained in mountain goat populations only when range is shared with wild sheep. *Marshallagia* spp. are the most prevalent gastrointestinal nematodes in wild sheep (Uhazy and Holmes 1971; Nielsen and Neiland 1974; Jenkins and Schwantje, 2004; Kutz et al., 2005).

Mountain goats may share range, and thereby some species of parasites, with sympatric ungulates. Eggs of *Strongyloides* sp., *Thysanosoma actinoides,* and *Thysaniezia giardii* (also known as *T. ovilla* according to Schmidt, 1986), were reported in 1 of 75 samples from mountain goats in Idaho and Montana (Brandborg, 1955), but were not found in samples from mountain goats at any location in the current study. It is possible that these parasites, which are more typically associated with domestic cattle and sheep, are present in goats from Idaho and Montana, some of which were translocated from other regions (Oldenburg, 1996). In addition, mountain goats in ID and MT may share range with bighorn sheep, which can harbor parasites of domestic sheep and cattle (Hoberg et al., 2001). Parasites of domestic animal origin may not be present in the mountain goat populations examined in NT and BC because the only sympatric ungulates are thinhorn sheep, woodland caribou, moose, and, in BC, elk or mule deer (Shackleton, 1999; Veitch et al., 2002).

Comparing mountain goats and thinhorn sheep

A literature search and our findings in mountain goats and thinhorn sheep in the NT and central BC were consistent with the hypothesis that many parasite species are common to both hosts (Table 3). For example, *Parelaphostrongylus odocoilei* was present in mountain goats as well as many populations of Dall's and Stone's sheep in the NT and BC (but not the Stone's sheep population at Williston Lake in central BC) (Jenkins et al., 2005). In Table 3, many species of gastrointestinal nematodes are common to both mountain goats and thinhorn sheep, including *Skrjabinema ovis*, *Nematodirus maculosus*, *N. davtiani*, *N. oiratianus interruptus*, *Marshallagia marshalli*, *Trichuris schumakovitschi*, as well as the protostrongylid lungworms *Protostrongylus stilesi* and *P. rushi*. For others, such as *Teladorsagia* spp. and *Moniezia* sp., specimens have not been identified to species level in one or both hosts, rendering comparisons impossible. In addition to shared parasite species, each host likely has its own core parasite fauna. For example, species of *Eimeria* appear to be relatively host specific (Table 3). As well, a species of *Marshallagia* that may be unique to mountain goats has been identified in Alberta, Alaska, Washington, Wyoming, and now, central British Columbia (Lichtenfels and Pilitt, 1989; Hoberg et al., 2001).

The relative significance and abundance of a parasite may differ between mountain goats and thinhorn sheep, even where range is shared. In the NT, generic trichostrongyle eggs (*Teladorsagia* and *Ostertagia* spp.) were present in samples collected from mountain goats, but not Dall's sheep. Based on recovery of adult parasites and ongoing fecal surveys, the trichostrongyles *Teladorsagia* and *Ostertagia* spp. are apparently uncommon in Dall's sheep in the Mackenzie Mountains, NT, even in the summer months of peak shedding (Kutz, 2001; Kutz et al., 2005). Such a disparity between mountain goats and sheep in the same geographic area is not unusual; Samuel et al. (1977) found that *Teladorsagia circumcincta* was the most prevalent and abundant parasite in mountain goats of west-central Alberta, while *Marshallagia marshalli*/*M. occidentalis* predominated in bighorn sheep from the same area. *Teladorsagia* and *Ostertagia* spp. may dominate the abomasal niche in mountain goat populations, while *M. marshalli*/*M. occidentalis* fill this niche in wild sheep.

Differences in prevalence and intensity of parasites between mountain goats and wild sheep may reflect variation in host density and behavior (such as gregariousness), habitat selection, and/or susceptibility. To minimize variation due to seasonal effects on parasite shedding, we compared prevalence and intensity of parasites in samples from mountain goats and thinhorn sheep collected in the same month. In the NT, relative to Dall's sheep, prevalence and intensity of shedding of most parasites were lower in samples from mountain goats. Mountain goat populations in the NT are small and discontinuous (Veitch et al., 2002), and this could decrease parasite transmission and overall levels of infection. However, in the NT and central BC, *Eimeria* spp. had greater abundance in fecal samples from mountain goats than those from thinhorn sheep. Coccidian parasites appear to be well-established in all mountain goat and thinhorn sheep populations that we examined, but further investigation is needed to determine the significance of these parasites.

Significance

This is the first time that baseline data on parasites have been collected from mountain goats in the Northwest Territories (NT) and central and coastal British Columbia (BC). The parasite fauna of mountain goats in the NT, BC, and Idaho (ID) was generally consistent with that of mountain goats throughout their range (Table 1), although there were population-level differences (especially the coastal BC population). As well, mountain goats and thinhorn sheep shed similar types of parasite eggs and larvae, and the literature suggests that exchange of some parasite species between mountain goats and wild sheep is likely when range is shared (Table 3). When contemplating translocation of either mountain goats or wild sheep, the possibility of introduction of parasites and other important pathogens to naïve populations should be considered.

The effects of parasitism in mountain goats are largely undescribed, but may have implications for wildlife health and management. Both thinhorn sheep and mountain goats are hosts for the muscleworm *Parelaphostrongylus odocoilei*, which may have played a role in the death of one naturally-infected mountain goat in Washington (Pybus et al., 1984). It has also proven pathogenic in naturally and experimentally infected thinhorn sheep (Kutz et al., 2001; Jenkins, 2005). Disease-related die-offs, such as those associated with the pneumonia complex in bighorn sheep, have not been reported in mountain goat or thinhorn sheep populations, despite the presence of several species of protostrongylid parasites known to cause lung damage.

The effects of gastrointestinal parasitism in wild ungulates range from subtle to severe, especially when combined with nutritional stress. In domestic livestock, high intensities of gastrointestinal parasitism can cause diarrhea, anorexia, weight loss, and even death. In wild sheep, high burdens of *Marshallagia* spp. have been linked to stomach ulceration and decreased body condition and fecundity (Uhazy and Holmes, 1971; Nielson and Neiland, 1974; Kutz, 2001). High intensities of *Marshallagia* spp., *Teladorsagia* spp., and *Eimeria* spp. in an emaciated mountain goat from central BC suggest that this animal had been compromised for some time (at least two years prior to death), and that parasitism may have contributed to, or been exacerbated by, the poor body condition.

This study represents a preliminary description and literature review of the internal parasite fauna of mountain goats. We did not include trematodes (flukes) or external parasites, although both have been recovered from mountain goats in Idaho (ticks in the recent study, trematode eggs in Brandborg, 1955). Definitive identification by recovery of adult parasites has yet to be accomplished in mountain goats in the NT and many other regions. If the opportunity arises, mountain goat carcasses should be examined in order to definitively characterize the parasite fauna. Alternatively, molecular identification of eggs and larvae from fecal surveys may soon allow definitive species identification and accurate descriptions of the geographic distribution and relative proportions of shedding of previously indistinguishable parasite species (Hoberg et al., 2001; Jenkins et al., 2005; Kutz et al., 2005). We first need to know what parasites and diseases are present in wildlife such as mountain goats before we can assess their significance and management implications. Such baseline information is necessary to anticipate and mitigate the effects of habitat disturbance and global climate change on the impact of parasites on wildlife health.

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Table 1: Prevalence, expressed as number of positive animals/number of animals examined (percent), of adult parasites recovered and identified from mountain goats in seven studies from the literature.

	Pybus et al., 1984 AB and WA (n=2)	Samuel et al., 1977, AB (n=53) & BC (n=3)	Boddicker et al., 1971, S DK (n=28)	Boddicker & Hugghins, 1969 S DK (n=1)	Kerr & Holmes, 1966 West-central AB (n=7 adults)	Brandborg, 1955 ID and MT (n=3)	Cowan, 1951 Banff and Jasper, AB (n=10)
MUSCLE							
Parelaphostrongylus odocoilei	2/2 (100)	NA	NA	NA	NA	NA	NA
LUNG							
Protostrongylus stilesi	1/2 (50)	26/41 (63) 0/3 (0)	26/26 (100)	1/1	1/7 (14)		2 (NA)
P. rushi	1/2 (50)	36/46 (78) 1/3 (33)	10/26 (38)				
ABOMASUM							
Teladorsagia circumcincta[1]	NA	29/30 (97) 2/3 (67)	24/25 (96)	1/1	7/7 (100)		10/10 (100)
Teladorsagia trifurcata[1]	NA	23/30 (77) 0/3 (0)	6/25 (24)		5/7 (71)		10/10 (100)
Teladorsagia davtiana[1]	NA	20/30 (67) 0/3 (0)			2/7 (29)		
Marshallagia "*O.*" *occidentalis* [2]	NA	24/30 (80) 3 (0)			5/7 (71)		10/10 (100)
Marshallagia marshalli [2]	NA	26/30 (87) 2/3 (67)			3/7 (43)		10/10 (100)
Ostertagia ostertagi	NA		11/25 (44)				
Trichostrongylus axei	NA		1/25 (4)				
SM. INTESTINE							
T. colubriformis	NA		1/25 (4)				
Nematodirus davtiani	NA	1/32 (3) 0/3 (0)					
N. helvetianus	NA	1/32 (3) 0/3 (0)	2/26 (8)				
N. maculosus [3]	NA	27/33 (82) 3/3 (100)	11/26 (42)		6/7 (86)		

Nematodirus spp.	NA	28/33 (85) 2/3 (67)		1/1			1 (NA)[4]
LG. INTESTINE							
Oesophagostomum venulosum	NA		24/26 (92)				
Trichuris spp.	NA	0.3/28 (1) *sic* 0/3 (0)	13/26 (50)		1/7 (14)		2 (NA)
T. oreamnos [5]	NA	0/28 (0) 2/3 (67)					
T. schumakovitschi	NA	2/28 (7) 0/3 (0)					
Skrjabinema ovis [6]	NA	1/28 (4) 0/3 (0)			2/7 (29)	1/3 (33) [7]	Present[8]
CESTODES							
Avitellina sp.	NA	6/31 (19) 0/3 (0)					
Moniezia benedeni	NA	6/31 (19) 0/3 (0)	1/26 (4)				1/6 (17)
Unidentified anoplocephalidae	NA	3/31 (10) 1/3 (33)					NA
Thysanosoma actinoides	NA	4/29 (14) 2/3 (67)	1/26 (4)		2/7 (29)	2/3 (67) [9]	2 (NA)
Taenia hydatigena	NA	5/39 (13) 0/3 (0)	15/26 (58)		1/7 (14)	2/3 (67) [10]	10/10 (100)

NA – not available, not reported, or not possible to conclude based on methods used by the investigators; [1] Some referred to as *Ostertagia* spp. in the original source, all now considered morphotypes of *Teladorsagia circumcincta* (Hoberg et al., 2001); [2] May represent species unique to mountain goat (Lichtenfels and Pilitt, 1989); [3] Species reported as *Nematodirus maculosus* may be a combination of *N. becklundi* (as described by Durette-Desset and Samuel, 1992, from goats in Alberta), and *N. maculosus*; [4] Identified as *Nematodirus filicollis*; [5] New species described by Knight, 1974; [6] *S. crami* and *S. oreamni* are synonyms for *S. ovis* (Schad, 1959); [7] Originally identified as *Skrjabinema crami*; [8] Originally identified as *Skrjabinema oreamni*; [9] May have been reported as "*Thysanosoma wyominia*" in one case; [10] Cysticerci, probably *T. hydatigena*

Table 2: Collection data for fecal samples from mountain goats in the current study, and thinhorn sheep from a concurrent study used for comparison. Numbers in the Map column correspond to Fig. 1.

Map	Location	Species	Date collected	n
1	Katherine Creek, Mackenzie Mts, Northwest Territories (NT)	Dall's sheep	August 2001	37
2	Ramhead Outfitting Zone, Mackenzie Mts, NT	Mountain goat	August 2001	22
3	Ospika R., Central British Columbia (BC)	Mountain goat	March 2002	22
4	Williston Lake, Central BC	Stone's sheep	March 2002	14
5	Coastal Mts, BC	Mountain goat	March 1995 (5) Nov. 2001 (13)	18
6	Idaho, various locations	Mountain goat	1990-2003	68

Table 3: Labels used in tables and possible species identifications for eggs and larvae recovered from fecal samples, based on: Shah and Levine, 1964; Todd and Ogara, 1968; Uhazy et al., 1971; Clark and Colwell, 1974; Nielsen and Neiland, 1974; Hoberg et al., 2001; Kutz, 2001; and Kutz et al., 2005.

Label	Species in mountain goat	Species in thinhorn sheep
SKRJAB	*Skrjabinema ovis* [1]	*Skrjabinema ovis* [1]
TRICHO	Generic trichostrongyle eggs: *Teladorsagia* spp. [2], *Ostertagia* spp. [3], *Trichostrongylus* sp.	Generic trichostrongyle eggs: *Teladorsagia* spp. [2], *Ostertagia gruehneri/O. arctica, Ostertagia ostertagi* [3]
NEM	*Nematodirus maculosus, N. becklundi, N. davtiani, N. filicollis, N. helvetianus, N. odocoilei, N. oiratianus interruptus*	*Nematodirus maculosus, N. davtiani, N. oiratianus, N. oiratianus interruptus, N. spathiger, N. archari, N. andersoni*
MARSH	*Marshallagia marshalli/M. occidentalis, Marshallagia sp.* [4]	*Marshallagia marshalli/M. occidentalis*
TRICHU	*Trichuris oreamnos, T. schumakovitschi*	*T. schumakovitschi*
MON	*Moniezia benedeni, M. expansa*	*Moniezia* sp.
PROTO	*Protostrongylus stilesi, P. rushi*	*Protostrongylus stilesi, P. rushi*
DSL	dorsal-spined larvae: *Parelaphostrongylus odocoilei*	dorsal-spined larvae: *Parelaphostrongylus odocoilei*
EIM	*Eimeria oreamni, E. montanaensis, E. ernesti*	*Eimeria dalli, E. crandallis, E. ahsata, E. parva,* and *E. ninakohlyakimovae*

[1] synonyms include *S. crami* and *S. oreamni* (Schad, 1959)
[2] *Teladorsagia* probably represents a group of cryptic species (Hoberg et al., 1999)
[3] *O. ostertagi* in Dall's sheep in Alaska is thought to originate from bison. May occur in mountain goats that have shared range with domestic animals or bighorn sheep.
[4] An undescribed species of *Marshallagia* possibly unique to mountain goats (Lichtenfels and Pilitt, 1989).

Table 4: Prevalence, expressed as number of positive samples/number of samples examined (percent), of parasites in fecal samples from mountain goats in the Northwest Territories (NT), central British Columbia (BC), coastal BC, and current and historical fecal surveys in Idaho (ID) and Montana (MT).

	Mackenzie Mts, NT August 2001	Ospika, Central BC March 2002	Coastal BC Mar 1995 (5) & Nov 2001 (13)	Idaho 1990-2003	ID and MT Brandborg, 1955 [2]
NEMATODE LARVAE					
Dorsal-spined	9/22 (41) [1]	14/22 (64) [1]	16/18 (89) [1]	NA*	5/75 (7) [3]
Protostrongylus sp.	11/22 (50)	12/22 (55)	14/18 (78)	7/68 (10)*	10/75 (13)
NEMATODE EGGS					
Marshallagia sp.	10/22 (45)	20/22 (91)	1/18 (6)	NA*	11/75 (15)
Nematodirus sp.	7/22 (32)	19/22 (86)	15/18 (83)	16/68 (24)*	0/75
Generic trichostrongyle	16/22 (73)	0	5/18 (28)	11/68 (16)*	1/75 (1) [4]
Trichuris sp.	2/22 (9)	6/22 (27)	2/18 (11)	12/68 (18)*	7/75 (9)
Skrjabinema sp.	0	0	1/18 (6)	NA*	0
TAPEWORM EGGS (*Moniezia* sp.)	1/22 (5)	0	8/18 (44)	4/68 (6)*	2/75 (3)
COCCIDIAN OOCYSTS (*Eimeria* sp.)	22/22 (100)	22/22 (100)	14/18 (78)	50/68 (74)*	NA

NA = not reported

* identified in other laboratories. Dorsal-spined larvae may not been distinguished from *Protostrongylus* sp. larvae, and *Marshallagia* sp. eggs may have been grouped with those of *Nematodirus* sp. (or the reverse in Brandborg, 1955). As well, tapeworm eggs were not identified as to genus and were assumed to be *Moniezia*-type (versus *Thysanosoma*, for example)

[1] *Parelaphostrongylus odocoilei*, based on molecular identification (Jenkins et al., 2005

[2] Identified parasites to species level; however, species generally cannot be determined from egg or larval morphology alone.

[3] Thought to be *Muellerius* sp., but may be *P. odocoilei*

[4] Thought to be larvae of *Trichostrongylus* sp.

Table 5: Mean and range of intensities (number of eggs, larvae, or oocysts per gram of feces) in fecal samples from mountain goats in NT, central, and coastal BC.

Parasite	Mackenzie Mts, NT August 2001	Ospika, Central BC March 2002	Coastal BC Mar 1995 & Nov 2001
SKRJAB	0	0	0.9
TRICHO	2.8 (0.2-10.4)	0	1.2 (0.2-3.3)
NEM	0.4 (0.2-0.6)	3.2 (0.2-20)	3 (0.2-11.8)
MARSH	0.5 (0.2-1.4)	4 (0.2-20)	0.59
TRICHU	0.2	1.2 (0.2-3.8)	0.4
MON	6.4	0	79.2 (0.5-215.9)
PROTO	1.5 (0.2-5.2)	0.9 (0.2-2.61)	25.6 (0.3-129)
DSL	1.6 (0.2-3.2)	6 (0.2-29)	54.4 (0.59-504.4)
EIM	145 (1.8-800)	330 (2.4-3000)	200 (30.8-937.5)

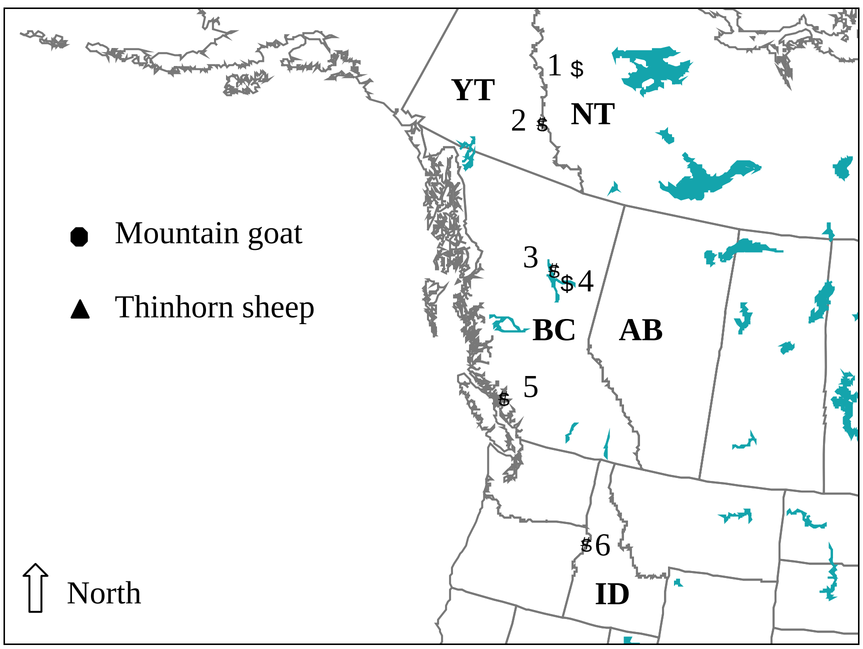

Figure 1: Locations where fecal samples were collected from mountain goats (2, 3, 5, and 6) and thinhorn sheep (1 and 4); numbers correspond to Map column in Table 2. Two carcasses of mountain goats were collected at site 5, and one at site 3. YT = Yukon Territory, NT = Northwest Territories, BC = British Columbia, AB = Alberta, ID = Idaho

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DOES BIOLOGICAL KNOWLEDGE MAKE ANY DIFFERENCE IN WILD SHEEP MANAGEMENT?

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Abstract: The unique success of wildlife restoration and management in the United States is tightly linked to the Roosevelt Doctrine, which states that the best management is based on the best science. This concept provides the underlying rationale for wild sheep and goat research. After 16 years of observing fragmented management thinking, I [WEH] articulated the concept of the working management hypothesis in 1988. I presumed that articulation and integration of current natural history/species biology into a management "prescription" would facilitate successful management by those without a specialty in wild sheep or goats. Prior to this effort, Alaskan Dall sheep (*Ovis dalli dalli*) management had proceeded on an *ad hoc* basis as politics and structural agency priorities trumped relevant sheep adaptations to environment on an ongoing basis. These problems persist. A typical case study is briefly reviewed in this paper. The putative goal for this symposium section is to refine the working management hypotheses for wild mountain sheep. Since the articulated working hypotheses have been largely ignored, three questions come to mind. "Is it possible to construct a working management hypothesis?" "If not, what is the point of biological research on sheep and goats?" and "Should we put any effort into a working management hypothesis for mountain goats?" These questions are offered for discussion.

Almost two decades ago I began to argue that increased management success should attend managing according to what I called a "working management hypothesis" (Heimer 1988). I proposed that this hypothesis consist of anticipated sheep population responses to management challenges based on what we known about wild sheep adaptations to environment. Subsequently, I learned from Toweill and Geist (1999) this is a hoary notion, perhaps first articulated as the Roosevelt Doctrine in the late 19th century. The Roosevelt Doctrine held that the best management would be based on the best scientific information. This assumption has been the basis for modern North American wildlife conservation for so long that it is considered intuitively obvious. By the last quarter of the 20th Century (my period involvement in agency management) it had been virtually forgotten as an articulated concept until resurrected by Geist under a slightly different rubric (Geist 1978). Geist's approach was couched in the modern concept of evolutionary inclusive fitness, and argued that management success must be based on management within the suite of adaptations naturally selected for by environment within any managed species.

Those few of us who embraced this antique but neo-radical notion were charged with developing a "retrograde" approach to contemporary wildlife research. In contrast with our more 'with it' fellows, we saw research less as an attempt to quantify observations and catalog the statistical probabilities of their recurrence than as a quest to define species adaptations to environment and relate them to management challenges and opportunities. In an effort to reintroduce wildlife management at this level in Alaska, I proposed and have argued for the working management hypothesis concept within this context (Heimer 1988, 2000*a*, 2000*b*).

A definition of "management' is basic to this discussion. During the "Roosevelt Doctrine era" (which I define as "modern"), "management" meant intervening in natural ecosystems to maintain or augment pre-defined human benefits while "conserving" the system. Of course, this sort of management could not leave the ecosystem in the unmanaged or "natural" condition. The trick was to produce the desired human benefits without wrecking the system. In what I call the "postmodern" era, I argue the definition of "management" has become intuitively subjective; and now popularly carries the connotation of simply observing and quantifying wildlife interactions while making rules to keep humans from significantly interfering with "the natural."

Within the framework of preserving and enhancing human benefits, I suggested an articulated working hypothesis defined by the compiled scientific, anecdotal, and adaptation-rationalized biology of the managed species should facilitate success for managers who were not species specialists. I reasoned having the best and most comprehensive information summarized in "digest format" and related to potential management scenarios seemed was necessary to revivify the Roosevelt Doctrine.

The notion that management, which I argue had evolved adaptively in the postmodern era, could (or should) be returned to this level of simplicity has not been generally embraced by the neo-traditionalist leadership of postmodern management agencies. Nevertheless, primarily through persistence and skullduggery on my part, and the open-mindedness of our colleagues in the sheep management community, working hypotheses for thinhorn (*Ovis dalli dalli*, and *stonei*), Rocky Mountain Bighorn (*Ovis canadensis*), California Bighorn (*Ovis canadensis caleforneinsis*), and Desert Bighorn (*Ovis canadensis nelsoni*) sheep have been articulated and published (see Heimer, Wishart, Toweill, and Lee, 2000). One goal for this present, goat-centered symposium is to produce a working management hypothesis for Rocky Mountain Goats (see Toweill et al., this proceedings).

In spite of having an articulated working hypothesis for Dall sheep in Alaska for almost two decades, the impact on Dall sheep management success has been slight. It is the purpose of this paper to cite a case study where the choice to manage apart from the published working hypothesis resulted in a notable departure from the Roosevelt Doctrine. The consequences of this choice sacrificed the managed populations and compromised human benefits. Dall sheep populations declined, and required a series of necessary corrective regulatory steps. The secondary purpose of this paper is to invite the symposium to share ideas on the efficacy of the working hypothesis concept.

THE CASE STUDY: [Draft contributed by KMG]

Overview: The study area is what Alaskans call Game Management Unit 11. It lies primarily on the western end of the Wrangell Mountains as they extend westward into Alaska from Kluane National Park in Canada for about 175 miles. Sheep habitat lies primarily on the south side of the Wrangell Mountains north of the Chitina River, but there are significant habitats on the northwestern slope of the Wrangell Mountains in Game Management Unit 11. The maximum population estimate for this area was approximately 4,000 Dall sheep in the early 1990s (Strickland *et al*. 1993). Sheep densities in this area are on the low side of the Alaskan average of roughly 1.1 sheep per square mile. Calculated sheep densities at maximum population sizes were in the neighborhood of 0.7 sheep per square mile (Heimer and Smith 1975) until population declines began in the early 1990s. By some accounts, populations may have declined to less than half of the observed maximums.

Harvest management until 1978 was under the traditional ¾-curl regulation inherited from territorial days in Alaska (Heimer and Watson 1990). The initial increase in legal horn size was driven partially by biology, but primarily by politics (Heimer 1982). Subsequently, harvest regulations have varied primarily as a result of political influences (Heimer 2000*c*). These latter-day harvest management choices generally set aside the biological protections which had been previously established. In the seemingly noble cause of providing customary and traditional subsistence harvest opportunities, harvest strategies typically designed to lower sheep population densities across wild sheep distributions were implemented. These included the harvest of "any sheep," and encouraged the harvest of ewes from declining populations beginning in 1989. In the early 1990s general population declines began throughout Alaska. Sheep populations in Unit 11 declined, as did hunter harvests. Eventually, corrective steps subsequently limiting the harvest to rams only, then to ¾-curl rams for residents (full curl for nonresidents has remained standard) have been incrementally implemented over the last several years at the insistence of the sheep harvesting public.

It seems likely the declines in hunter-harvested sheep were caused by decreases in overall sheep population numbers compounded by liberal harvest regimes (Heimer *et al*. 1994). The declines, presumably associated with weather, were complicated by unchecked growth in predator populations associated with changes in land classifications and politicization of predator management. While there is little that can be done about the weather, and perhaps only slightly more can be done about predation, the consequences of political management choices (e.g. necessarily "reinventing" ram-only seasons and ¾-curl bag limits for residents) could have been considerably mitigated if guided by the biology of Dall sheep in intact ecosystems.

Structural components: The working management hypothesis for thinhorn sheep has five structural components. These are: distribution, abundance, and population strategy; predation and harvest management; disease; parasites; and disturbance. The longer term management approach in the study area failed significantly with respect to the first two. The first has to do with distribution and abundance.

The sheep populations in GMU 11 should be understood to be particularly sensitive to weather events because of the geography of the area. Typically, precipitation moves inland (northward) from the Gulf of Alaska. Habitats on the windward (snow accumulating) southern slopes of Alaska's generally east-west oriented mountain ranges generally do not support Dall sheep because of excessive snow accumulation. Snow accumulations 'deeper than a Dall sheep's legs are long' seem to preclude occupation by sheep. Exceptions to the general distribution include the south-facing slopes of the Wrangell Mountains, which are on the leeward side of the coastal Chugach Mountains. Thus, these Wrangell Mountains of the study area, which are in a sort of "snow shadow." The Southern Wrangell Mountains (which contain most of the sheep discussed here), are among the lower density habitats in Alaska. Geography-influenced weather is most likely the cause.

The most hunter-vulnerable sheep populations on the south side of the study area are those closest to human habitations. These populations are exquisitely susceptible to coastal weather influences because they lie at the northern end of the Copper River "trench" as the river bends from "east-west" to "north-south." The Copper River valley constitutes a "weather channel" which runs directly (north and south) through the weather-protective Chugach Mountains (which make sheep habitation in the Southern Wrangells even possible). The humans who hunt these weather-labile sheep are located there primarily because of the salmon-rich Copper River (valley) which formerly supported a rail link transporting copper ore from the upper Chitina River to the port at Cordova. Consequently, the Southern Wrangell Mountains were perhaps the worst place in Alaska to offer extremely liberalized sheep harvest seasons.

The second place where the working hypothesis of thinhorn management could have helped the managers relates to predator and harvest management.

Given that the sheep in the study area are exquisitely weather labile, providing liberal and perhaps unsustainable "any sheep," "any ram," and "young ram" harvests for residents on both state and federal lands has to be perceived, at least in retrospect, as a major management misstep. Sheep populations were being decimated by weather as it was, yet harvest regulations typically designed to lower sheep population numbers were implemented. The, predator and harvest management, component of the thinhorn working hypothesis contains emphatic data-grounded recommendations against this sort of liberal harvest scheme (Heimer 2000b).

DISCUSSION:

The obvious question here is, "Why did this happen?" I have discussed the perils of the federal takeover of fish and wildlife management in Alaska previously (Heimer 2000*c*). In this case, the ultimate driver of hyper-permissive harvest management was federal usurpation of Alaska's inherent state's right to allocate the state's common-property wildlife resources. When the feds decided to allocate harvest privileges to "rural residents" (primarily Alaska Natives with the allocation justified by "federal trust responsibility" for "Indians"), they moved to exclude non-Natives and non-local residents. This, of course, didn't go down with the State, and a bizarre competition to provide the most lenient harvest regime developed. Nothing could have been farther from the precepts of the Roosevelt Doctrine.

As detailed above, first harvests (for "residents") were liberalized to the extreme with the new "any sheep" federal bag limit in 1990. At first, the federal regulations defined "residents" as local to specific villages and locations. Subsequently, the state defined "residents" as "all Alaskans" due to a court decision which said the State could not discriminate among its residents. This meant that the number of hunters for which the "any sheep" bag limit applied increased beyond anyone's imagination. Nevertheless, the liberal bag limit (with a 42-day season and voluntary reporting) persisted until 2001 when local residents, concerned that the beleaguered sheep population would be extirpated, petitioned the Alaska Board of Game for more restrictive seasons. At that point, the season was restricted to "any ram" to protect ewes for population restoration purposes. This change lasted two years, and in 2003 the resident bag limit was increased to ¾-curl. Unfortunately, even this bag limit restriction (for general Alaskan residents only—federal regulations still allow the harvest of "any sheep" for federally recognized subsistence users, and nonresidents were restricted to harvest of full curl rams only) is unlikely to maximally facilitate population recovery. Heimer and Watson (1986) showed it highly likely that maximal harvests of ¾-curl rams will compromise reproduction and survival. Their subsequent work (Heimer and Watson 1990) showed increases in harvests associated with limiting harvest to Class IV (full curl) rams. These findings are factored into the harvest and predator management section of the thinhorn working hypothesis.

I realize this discussion has a certain, "coulda-woulda-shoulda" tone. Nevertheless, I argue that the information necessary to the earlier decision makers who set sheep management in the Southwestern Wrangells on this tragic course was available at that time. It has certainly been available for the last six years, being published in 1999. Still, it has had no notable effect on management. Again, the question is "Why?"

I suggest we address this question by first asking, "Is it possible to articulate a functional working hypothesis?" I suggest the answer is "yes," and I argue that if we don't, there is no point in doing wildlife research. In the context of "modern" management as defined here, if research does not produce knowledge relevant to providing and sustaining human benefits while not wrecking the ecosystem, there is no justification for it. Alternately, if one ascribes to what I define as "postmodern management," there is no need for this effort either. The working management model is only relevant if "modern management" in accordance with the Roosevelt Doctrine is the goal.

Addendum: Discussion at the end of this presentation indicated it was the consensus of the symposium that a working hypothesis, while it may not be a prefect model, is definitely a worthwhile effort. To that end, this symposium produced a working hypothesis for mountain goats. NWSGC is indebted to Dale Toweill, Steve Gordon, Emily Jenkins, Terry Kreeger, and Doug McWhirter (as well as all the researchers and managers who contributed to their compendium) for this effort. However, unless the sheep and goat community continues to refine and reference this significant effort, it will have failed to live up to our collective vision. If I could tell you how to make this happen, I would. Sadly, I can't. The best I can offer is to keep plugging away at the project, and arguing for this approach to the Roosevelt Doctrine. It has always worked when applied in the past, and I see no reason it should not work now.

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HABITAT SELECTION, MOVEMENT AND RANGE FIDELITY OF STONE'S SHEEP

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Abstract: Stone's sheep (*Ovis dalli stonei*) are generally assumed to be limited by the availability of suitable winter-spring forage and escape terrain, but there is little quantification of those needs. Their affiliation with mountainous environments is well documented but the relative influence of distance to mineral licks, habitat type, slope, aspect, elevation, curvature, and predation risk from bears and wolves is less understood. We used these variables within resource selection functions (RSFs) to quantify selection of seasonal habitats by Stone's sheep in northern British Columbia. GPS locations of 33 female Stone's sheep fitted with GPS collars were collected from December 2001 to October 2003 in the Besa River drainage. Predation risk was determined using RSFs from GPS locations of 15 grizzly bears and 5 wolf packs over the same time period in the same area. Stone's sheep showed a strong selection for topographic variables and habitats across all seasons with seasonally different selection for licks and predation risk. Movement patterns and range fidelity changed seasonally in relation to use of licks and spring green-up. This research improved habitat capability models for Stone's sheep and provided baseline information on seasonal habitat selection to address potential consequences of oil and gas development in the Besa-Prophet Pre-tenure Planning Area of the Muskwa-Kechika Management Area.

Key words: Stone's sheep, *Ovis dalli stonei*, seasonal habitat selection, predators, mineral licks, movement, range fidelity

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THE NORTHERN RICHARDSON MOUNTAINS DALL'S SHEEP ECOLOGY STUDY

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Abstract: Dall's sheep are hunted for subsistence purposes by Gwich'in people within the northern Richardson Mountains, and are a valued species for sport hunting in North America. With Dall's sheep population fluctuations in the northern Richardson Mountains, a possible increase in harvest and human activities, and limited information regarding Dall's sheep-habitat relationships, diet and parasites in this region, this two year project will determine 1) seasonal range, movement rates, corridors, 2) seasonal patterns of habitat use, 3) diet and nutritional content of diet species, and 4) parasitic load. This project will focus on two study blocks, chosen for comparative purposes, within the northern Richardson Mountains of the Northwest and Yukon Territories. There will be GPS collars applied to 15 Dall's sheep (9 rams, 6 ewes). These collars will provide locations through ARGOS satellite transmission. Seasonal ranges, movement rates and corridors will be determined using collar locations and GIS. Seasonally, study sites will be selected to characterize the habitat by randomly selecting known sheep locations and non-sheep locations. Diet, nutrition of diet species, and parasitic load will be determined through forage and faecal analysis. This project is designed to obtain information that is required to understand population-habitat relationships and population fluctuations and to assist co-management boards with determining potential opportunities for future outfitting and development in the northern Richardson Mountains.

Key words: Dall's sheep, *Ovis dalli dalli*, hunting, seasonal habitat use, parasite loads

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TOP-DOWN AND BOTTOM-UP REGULATION OF BIGHORN SHEEP POPULATIONS IN NEW MEXICO, USA

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Abstract: Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) populations restricted to alpine ecosystems year-round, exhibit classic bottom-up population regulation related to density-dependence. Rocky Mountain bighorn sheep reintroduced into alpine ecosystems increase quickly, generally doubling every 3 years, and then stabilize. Growth curves of alpine bighorn populations in NM generally asymptote at densities of ~6 bighorn/km^2 of total range of ~23 bighorn/km^2 of winter range. Seasonal habitats are most constricted during winter and annual fluctuations in populations are correlated with winter severity. Annual mortality is skewed toward lamb and yearling cohorts. No mortality due to predation was documented during monitoring of 85 radiocollared bighorn, between 1993 and 2002. Desert bighorn sheep (*O. c. mexicana*) populations, in Chihuahuan desert ecosystems of New Mexico, are controlled by mountain lion (*Puma concolor*) predation in classic top-down population regulation. Reintroduced populations generally increase very slowly if at all. Populations generally do not exceed 0.5 bighorn/kmn^2. Despite long term lamb:ewe ratios in desert bighorn populations that are predicted to resulting moderate growth, most populations have declined or gone extinct due to high adult mortality attributed primarily to mountain lion predation. If lamb losses due to predation are added to the metric, resulting lamb:ewe rations should result in substantial population growth. Monitoring 172 radiocollared desert bighorn sheep, between 1992 and 2002, documented a minimum of 70 mortalities due to lion predation. Mean density of a free-ranging (not supplementally fed) bighorn population in a large (5.6 km^2) fenced facility in the Chihuahuan desert has been 40-times greater (19 $\pm$ 3.1 bighorn/km^2) than that documented in nearby wild desert bighorn populations (0.48 $\pm$ 0.1 bighorn/km^2). Lethal control of both mountain lions and coyotes (*Canis latrans*) is implemented at this facility. Lions are subsidized predators in desert ecosystems, and top-down control may be a function of this phenomenon. Evidence that both top-down and bottom-up regulatory mechanisms control populations of the same species within New Mexico is presented.

Key words: bighorn, *Ovis Canadensis, Puma concolor, Canis latrans*, lethal control, top-down, bottom-up population regulation

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PROTECTING BIGHORN SHEEP HABITAT – A WORTHY CAUSE?

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Abstract: In 1950, F. Couey estimated that 1200 bighorn occupied 16 different areas within the state of Montana . Primarily a result of regulated hunting, transplant of animals to suitable areas, and protection and proper management of habitat important to bighorn sheep, 43 well established populations now numbering 4,500 reside in nearly all suitable historic habitats, from the rugged mountainous regions of the west to the river breaks in the east. Although the predominance of the acres of occupied habitat is under public ownership, important areas are in private ownership and some public land areas are not accessible to bighorn sheep hunters or the general public due to private land closures or leased hunting rights. The strong desire by many to own a little, or large, piece of Montana is now a major factor influencing wildlife habitat and hunter and public recreational access. In 1987, Montana's state legislature passed landmark legislation, known as House Bill 526, which provided authority and approximately $3.3 million annually in funding for Montana Fish, Wildlife &Parks to acquire through fee title, lease, or conservation easement, important wildlife habitat that was seriously threatened. Since that time $32.7 million has been spent and over 258,526 acres of important wildlife habitat has been acquired. The administrative rules that were adopted by FWP are collectively known as Habitat Montana. These rules apply to all acquisitions of interest in land by FWP to secure wildlife habitat, including bighorn sheep auction license funding which Montana receives from the auction of one license each year. Since 1986, when the auction funds first became available, over 4,000 acres of important habitat for bighorn sheep has been acquired in four locations in Montana. The criteria for selection of projects and the procedures used by FWP to acquire wildlife habitat is described using the Whiskey Ridge Conservation Easement Proposal currently in process. Although securing important bighorn sheep habitat is a worthy goal in and of itself, benefits also accrue to the landowner who wants to maintain his/her ranching operation or pass the ranch on to heirs, the local economy, hunters, and the general public. Often, it's not the monetary exchange that is significant, but the social benefits one receives from accomplishing something that will insure bighorn sheep will be present in the area for many years to come.

Journals of early explorers indicate Rocky Mountain sheep were widely distributed in Montana in the early 1800s. Meriwether Lewis described them near the mouth of the Marias River in July, 1806 (Thwaites Ed., Lewis, Vol. 5.pp 229, July 29, 1806). About he same time (July 26, 1806), Clark, who was going down the Yellowstone River, describes observing 40 bighorns near Pompey's Tower. On August 3, 1806, Clark again describes: "at the junction of the Missouri and Yellowstone Rivers I saw a large gang of ewes, yearlings and lambs and one ram. Shot the ram. We now have one ram, a ewe, and a yearling in the collection." Joseph Whitehouse also stated the following in his journal during the same expedition: "the hunters came in at dark had killed 1 black taild. Deer 2 Ibex or mountain Sheep (rams) which had handsom large horns. we took care of the horns in order to take them back to the U. States. a pleasant evening (Moulton, G., 1986).

Although Lewis and Clark do not mention bighorn when they crossed the Rocky Mountains, there are other references to bighorn in the mountains about that time. Bradbury described Indian bows made from the male horns of an animal the French called "gros corne" (Thwaites, Early Western Travels, Vol 5, 1809-11), and Gabriel Franchers, in his voyage to the Northwest Coast of America described an animal with great curved horns like a domestic sheep (Thwaites, Vol 6, 1811-14).

Like most game animals, bighorn sheep decreased dramatically during settlement of the West. Contact with domestic sheep, range competition from livestock, disease, and subsistence hunting all contributed to the decline. Montana's bighorn hunting season was closed in 1915, and remained closed until 1953. Following major die-offs along the East Front of the Rockies in 1925, 1927, and 1932, bighorn sheep in Montana were considered rare or even endangered.

Following Montana's acceptance of the Federal Aid to Wildlife Restoration Program, the State Fish and Game Department initiated a Bighorn Sheep Investigations project. The results of that effort were published in 1950, and author and biologist Faye Couey stated that 1200 bighorn occupied 16 different areas within the state at that time (Couey, 1950). Couey's recommendations included 1) establishing a "ranch" to hold captured bighorn for disease studies and future transplant stock; 2) treating bighorn with salt blocks containing Phenothiazine to treat them for intestinal nematodes; 3) limited permit hunting of rams; 4) trapping and transplanting bighorn to new areas to expand distribution; 5) predator control; and, 6) signs to educate hunters on the characteristics of bighorn to prevent accidental shootings.

Although the "ranch" was never established, and the salt block treatments proved to be unsuccessful, the hunting season was opened in 1953 and trapping and transplanting, although tried to a limited extent before, was began in earnest. From 1941 to the present, nearly 2,000 bighorns have been transplanted within Montana. Most, about 1800, were transplanted after 1960.

Today, there are 45 well established populations numbering 4,500 which occupy most of the historic habitat in Montana, especially on public land. Most transplants now occur in areas that have previously suffered a significant die-off. Additionally, more and more bighorn have been captured and transferred to other western states for transplant. Since 1990, 137 Montana bighorn have been transplanted in the states of Idaho, Oregon, Washington, and Utah.

Changing Times

But, another change is occurring across the landscape, impacting bighorn habitat and the public's access to view and utilize that resource.

Although 78.6 percent of the 3.7 million acres of habitat occupied by bighorn in Montana is under public ownership, over 802,000 acres still remain in private ownership and some public land areas remain un-accessible to bighorn sheep hunters or the general public due to private land closures. Once family owned farms and ranches primarily used for agricultural purposes, are now owned by nonresident landowners and large corporations with less dependence on agricultural production or they have been divided into smaller parcels for single family homes or vacation retreats.

The Center of the American West, University of Colorado at Boulder, recently initiated a "Ranchland Dynamics" project to obtain a clearer picture of the rates and patterns of changes in ownership and use of the West's ranchlands (Travis, W., et al, 2004). Of particular interest to this project is the widespread transfer of ranches out of traditional hands to a new generation of owners with different land management goals. They noted some ranchlands were being subdivided for residential use, while others were kept intact or enlarged when purchased by owners who often had more interest in the amenity values of the property rather than livestock production. In studying a ten county area in the Greater Yellowstone Area (GYE) of Wyoming and Montana, they have found that:

> "Universally, agricultural extension agents in each county reported major attrition among agricultural operators. Those ranch owners who inherited ranches burdened with debt or who borrowed money to buy and operate ranch properties during the period between 1975 and 2000 have had the greatest difficulty making a go of it. In the past fifteen years, as land values have increased in response to the demand for rural recreational and residential properties, full-time ranchers have been priced out of the land market. With the exception of a few rare individuals whose previous land investments have deepened their pockets, in today's Greater Yellowstone Area, traditional ranchers face a dilemma of being unable to expand their ranch operations in order to meet changing market conditions or to enable their children to join in the ranch enterprise."

These changes are significant in themselves, but when you consider the future and ask yourself ; What are the long-term consequences of the current high land values and lack of dependence on agricultural uses?, you begin to worry about the wildlife habitat values and how these might be protected for future generations. Increased emphasis on land protection and wildlife habitat enhancement efforts seems the only prudent avenue to take if we want to protect wildlife habitat values on private land in the future.

Montana's efforts to secure important wildlife habitat for future generations began with the acquisition of 1,004 acres of elk winter range on the east side of the Little Belt Mountains in the central part of the state near the Judith River in1940. Shortly thereafter, in 1947, the famed Sun River Game Range was purchased along the Rocky Mountain Front, primarily for elk winter range, but which also included some of the first bighorn sheep habitat secured by the state. Although several important big game winter ranges and key waterfowl areas were purchased early on, the effort really got going with the passage of House Bill 526 by the Montana Legislature in 1987.

Habitat Montana Program

House Bill 526 (87-1-241& 242 MCA) passed the legislature in 1987 and was reauthorized again in 1994. The legislation funding the program sunsets in March, 2006, so the 2005 Legislature will be considering legislation to reauthorize the program. House Bill 526 provided a "means for FWP to acquire wildlife habitat through leases, conservation easements, or fee title." It directed the FWP Commission to adopt a policy for the statewide program (Habitat Montana) to acquire diverse habitat, reasonably distributed across the state with emphasis on habitat that is seriously threatened. Funding for the program totals approximately $3.3 million per year from a portion of the fees paid for hunting licenses by nonresidents and residents. The majority of the funding (93%) comes from nonresident licenses.

The Habitat Montana Program (ARM 12.9.508-512) was adopted by the FWP Commission through the administrative rule process. The three main goals of the program are:

1) To Conserve Wildlife and Natural Communities
2) To Sustain Ecological Systems, and
3) Compatible Habitat Management

In adopting the policy, the commission directed all wildlife habitat acquisitions follow the procedures established under Habitat Montana regardless of funding source. Thus, the acquisition of sheep habitat utilizing the auction license funding follows the same procedures as that used to purchase a waterfowl area with duck stamp funds. To highlight the significance of this effort, Montana now has over 124 sites, totaling nearly 700,000 acres of important wildlife habitat protected (243,749 fee title; 117,545 lease; and 337,035 conservation easement).

The implementation procedures detailed in the plan involve identifying the staff responsible for different phases of an acquisition, establish criteria for property selection and prioritization, requires development of an environmental assessment and management plan for the property, sets procedures for public involvement and future monitoring requirements. Although the legislation provides authority to lease the land, or purchase an interest in the land through a conservation easement or by fee title, the legislation indicated conservation easements or lease are the preferred methods. As a result, the program emphasis has been on conservation easements and the acreage under conservation easement has dramatically increased over the last ten years (7,638 acres in 1992 versus 325,433 acres in 2002).

Since 1986, when the sheep license auction funds first became available, 4,585 acres of important habitat for bighorn sheep has been acquired in four locations in western Montana. In 1994, the 1,554 acre Cole property in the Thompson Falls area was purchased and eventually named the Mount Silcox WMA. Three separate transactions between 1995 and 2000 resulted in the purchase of 1,413 acres in the Lost Creek area near Anaconda. In 1998, 65.5 acres were added to the Kootenai Falls Wildlife Management Area. In addition to the acquisitions, a conservation easement on 1,552 acres was completed in 1998 on the Gillies Ranch near Rock Creek.

Whiskey Ridge Proposal:
Once the home of the Audubon sheep, *Ovis Canadensis auduboni*, (last one reported taken in 1916), portions of the Missouri River Breaks of northeastern Montana provide some of the best habitat for bighorn sheep in Montana today.

Between 1958 and 1961, 43 bighorns from the Sun River Herd were released near Two Calf Creek in north Fergus County. By 1971, the population had grown to 90 animals. The herd experienced high winter mortality during the winter of 1971-72 and for the next 8 years, the population was static at 20 to 30 animals. In 1980, 28 bighorns were released in the Chimney Bend area in north Fergus County. These sheep subsequently merged with the remnants of the Two Calf population and pioneered into the Missouri Breaks on both sides of the river. By 1986, a total of 63 sheep were counted during a fixed wing survey of this area. A total of 281 sheep were observed here in 1992. A 1995 survey recorded 462 animals, and by 1997, there were a minimum of 483 sheep in this area. In 2003, a complete survey of this area recorded in excess of 700, approximately ½ of that number on each side of the river. This herd now stands as Montana’s second largest next to the Sun River Herd (800 –900) in west central Montana.

In November, 2002, the local wildlife biologist recommended FWP consider purchasing a conservation easement on three ownerships along Whiskey Ridge some12 miles north of Winifred along the south side of the Missouri River. The properties encompass 4,360 acres of deeded ground with a ½ interest in another 320 acres. BLM acreage associated with the properties is 4,180 acres and State School Trust land is adds an additional 320 acres. Since two of the landowners wanted to sell out, and another wanted to retain ownership but buy out a sibling’s ½ interest, purchase of a conservation easement outright was only possible with the owner who wanted to buy out her sibling’s interest. FWP would have to come up with additional revenue to purchase the properties in fee title, even if the goal ultimately was to divest of the fee value and retain a conservation easement in the area.

In June of 2003, FWP sent a letter to the Montana Chapter of the Foundation For North American Wild Sheep and the national organization of FNAWS describing the project and asking if they wanted to form a partnership with FWP to secure the property. Basically, if FNAWS could raise enough revenue to purchase one of the properties and then subsequently donate or sell the conservation easement to FWP and sell the remaining fee value to another landowner, FWP might be able to obtain an easement on all three properties, the ultimate goal. In addition, if a local landowner with additional sheep habitat and interest in buying the underlying fee value of all the property could be found, perhaps additional sheep habitat in an adjacent area or another area of Montana could be protected.

So, began the long and sometimes circuitous route of moving forward with the proposal. The local FNAWS chapter took on the project with gusto. They contacted other chapters with a challenge and worked with individuals, corporations, and the national to raise enough funds to pursue a purchase agreement with one of the landowners. After much discussion, the decision was made to proceed with recommending to the FWP Commission that the department pursue acquisition and eventual retention of a conservation easement on the three properties along Whiskey Ridge. Following Commission approval last spring, additional negotiations occurred and, FWP sent out a solicitation for proposals from adjacent or other landowners in the state with sheep habitat that might wish to purchase the remaining fee value of the lands in exchange for a conservation easement on their properties. Additional inquiries have been made by individuals to purchase the fee value outright. At the time of submission of this publication, FWP and FNAWS are in the negotiation with the landowners.

If agreement can be reached with the landowners, the project still must go through the environmental assessment process, receive public comment, and ultimately be approved by both the FWP Commission and the State Land Board.

Conclusion:

As Dr. Harold Picton said in his February 2002 presentation to the Montana Chapter of the Wildlife Society annual meeting on “The Resurrection of Montana Wildlife Populations”, “The 19th century was disastrous for Montana wildlife. Fur trapping, hide hunting, and subsistence hunting by the early explorers and settlers depleted most of the wildlife to near extinction. Although protective laws were passed in the late 1800s and early 1900s, wildlife populations increased little. The surveys of the Montana Office of the State Game and Fish Warden, formed in 1901, painted a dismal picture. The only sizeable elk herds were in the Sun River-South Fork of the Flathead and Yellowstone Park areas (Avare, H. 1912)”. Picton also cited several reports which indicated the Sun River-Flathead elk herd was regarded as being in danger in 1913, and the head of the U.S. Biological Survey expressed fears that the Gallatin Herd of the Yellowstone Park area might go extinct.

The 20th century brought with it prosperity and a widespread interest in restoring the once great wildlife populations of the West. Today, we reap the benefits of that previous generation’s efforts. We are currently at the beginning of the 21st century. What will this century hold for wildlife and their habitat?

History shows that one cannot rely on the techniques of the past to perpetuate the wildlife populations of the future. All the protective laws and enforcement of the late 1800s did little to restore the wildlife to the West. The trapping and subsequent transplanting and reintroduction of wildlife to historic habitats brought back the wildlife where habitat was still present. Public land initiatives and establishment of the state game agencies, passage of the Pittman Robinson Wildlife Restoration Act and numerous other actions have helped significantly along the way.

We are now at a point when we need to focus on what is happening to the ownership and uses of the habitat that is key to bighorn and other wildlife survival. Without the habitat, we can transplant animals until the "cows come home" and no more animals will survive. Programs like Habitat Montana are pivotal to protecting wildlife habitat for the future. The partnerships we can form with organizations like FNAWS and sportsmen and women can result in projects like Whiskey Ridge coming to fruition. All we need to do is work together, just like the previous generation did in restoring the wildlife we currently enjoy.

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BRUCELLOSIS IN CAPTIVE ROCKY MOUNTAIN BIGHORN SHEEP (*OVIS CANADENSIS*) CAUSED BY NATURAL EXPOSURE TO *BRUCELLA ABORTUS* BIOVAR 4

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Abstract: Nine (4 female, 5 male) captive, adult Rocky Mountain bighorn sheep (*Ovis canadensis*) contracted brucellosis caused by *Brucella abortus* biovar 4 as a result of natural exposure to an aborted elk (*Cervus elaphus*) fetus. Clinical signs of infection were orchitis and epididymitis in males, and lymphadenitis and placentitis with abortion in females. Gross pathologic findings included enlargement of the testes and/or epididymides and yellow caseous abscesses and granulomas of the same. *Brucella abortus* biovar 4 was cultured in all sheep from a variety of tissues, including testes/epididymides, mammary gland, and lymph nodes. All sheep tested were positive on a variety of standard *Brucella* serologic tests. This is the first report of brucellosis caused by *B. abortus* in Rocky Mountain bighorn sheep. It also provides evidence that sheep develop many of the manifestations ascribed to this disease and that infection can occur from natural exposure to an aborted fetus from another species. Wildlife managers responsible for sheep populations sympatric with *Brucella*-infected elk or bison (*Bison bison*) should be cognizant of the possibility of this disease in sheep.

Key words: bighorn sheep, *Ovis Canadensis*, brucellosis, biovar 4, clinical infection, trans species infection

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EVOLUTIONARY GENETICS OF *PASTEURELLA* ISOLATED FROM WILD AND DOMESTIC SHEEP AND DOMESTIC GOATS.

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Abstract: Phylogenetic analysis of molecular sequences is commonly used to determine the source of infectious diseases, including diseases such as Hanta virus, HIV, and SARS. This approach has also been useful for determining the source of many bacterial infections, for example distinguishing Pasteurella bacteria from domestic sheep and cattle. We used phylogenetic analysis of two structural genes to classify Pasteurella samples collected from healthy Alaska Dall's sheep; from healthy and pnemonic bighorn sheep; from healthy and pneumonic and domestic sheep; and healthy domestic goats. Phylogenetic analysis successfully grouped bacteria isolated from bighorn, and Dall's sheep, and domestic sheep and goats. The significant correlation between host species and phylogeny of Pasteurella isolates suggests that there are host specific lineages of Pasteurella and/or that transfer of bacteria between species is relatively rare and short lived. The existence of host-specific lineages is not surprising but is significant in that it could help determine the host source of bacteria responsible for bighorn sheep pneumonia epizootics. The biogrouping classification scheme used to type Pasteurella bacteria was also generally supported by phylogenetic analysis. The phylogeny of the virulence-associated leukotoxin gene did not correspond to that of the structural genes, suggesting it evolves more rapidly, recombines, and may transfer among strains.

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BIGHORN SHEEP, HORIZONTAL VISIBILITY, AND GIS

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Abstract: Habitat evaluation models are commonly used in bighorn sheep (*Ovis canadensis*) reintroduction and restoration, and many of these models incorporate high horizontal visibility as necessary for suitable bighorn habitat. Other variables like cover type and canopy closure are easier to quantify and often are used as indices for horizontal visibility. Few studies have directly measured bighorn sheep preferences of horizontal visibility without using such indices. We measured horizontal visibility at a sample of locations used by sheep and paired locations 200 m away at 3 sites in western Montana, and we did not detect significant differences. This variable may be more important at coarser scales (2nd order) of selection than that which we measured (3rd order). We also used multiple regression and analysis of variance to assess the relationship between horizontal visibility and 3 explanatory variables easily quantified in a GIS (cover type, slope, and aspect). All 3 of our explanatory variables had significant relationships with horizontal visibility ($P \leq 0.001$). Simple indices such as cover type alone are insufficient to accurately predict horizontal visibility.

INTRODUCTION

Bighorn sheep suffered a dramatic population decline and reduction in geographic range during the latter part of the 19th century. Intensive restoration and translocation efforts begun during the 1950's have since returned their numbers from an estimated 20,000 in the contiguous U.S. in 1960 to nearly 50,000 in 1991 (Buechner 1960, Valdez and Krausman 1999). Sheep were extirpated from much of their native range, so these restoration efforts have focused on returning populations to unoccupied but suitable habitat. Bighorns rarely recolonize areas through dispersal due to strong site fidelity (Geist 1970, 1971), so management has been focused on artificial translocations and reintroductions (Hansen et al. 1980).

This management strategy places much emphasis on identifying suitable habitat where reintroduction efforts will be most successful. Many models have been developed to aid managers in identifying suitable bighorn habitat across their notably diverse North American range (Hansen 1980, Grunigen 1980, Holl 1982, Smith et al. 1991, McCarty 1993, Dunn 1996, Schirokauer 1996, Sweanor et al. 1996, Hughes 1997, Johnson and Swift 2000, Zeigenfuss et al. 2000, Dicus 2002). These modeling efforts continue today with changing approaches to defining and evaluating each feature of bighorn sheep habitat.

One such habitat feature, horizontal visibility (estimated as a percentage from 0-100), relates to the preference of bighorn sheep for open areas with little visual obstruction. Their predator avoidance strategy relies on an ability to detect danger at a distance, giving them ample time to retreat to safer terrain when needed (Geist 1971, Risenhoover and Bailey 1980).

We found few studies that directly measured bighorn sheep preference of horizontal visibility. Hayes et al. (1994) measured visibility at 70 locations used by a captive population of bighorn sheep, and compared these to measures of visibility at 30 randomly selected points within the same area. They did not find a significant difference in visibility between used and random sites. McCarty (1993) also sampled used and random points within a study area for visibility, and he did detect preference of more open areas. Etchberger et al. (1989) found significantly higher visibility values in areas used by sheep than those in a neighboring unused area.

Risenhoover and Bailey (1985) found habitat types preferred by sheep provided greater visibility than avoided habitat types. Their study was the more typical approach to horizontal visibility; this involved associating it with another habitat variable such as cover type or canopy closure. For example, field measures are used to estimate an average visibility for each cover type in a study area. Preference or avoidance of a cover type is then inferred to indicate preference or avoidance of the associated level of horizontal visibility. In this way, the biologists are not truly measuring the animal's preference for horizontal visibility, but are instead attributing different levels of preference between cover types to visibility. This is an indirect and potentially confounded assessment of how bighorn sheep respond to horizontal visibility.

Accurate measures of horizontal visibility come from site-specific work in the field, but indices are often used to incorporate this variable into habitat modeling (Hansen 1980, Holl 1982, Smith et al. 1991, Johnson and Swift 2000). This is also done by associating levels of visibility with different cover types or levels of canopy closure. Recently, the use of geographic information systems (GIS) and satellite imagery data has become popular in habitat modeling. However, horizontal visibility is a variable that escapes direct measurement through remotely-sensed data.

In this paper, we address 2 key questions concerning horizontal visibility and habitat modeling with regards to bighorn sheep habitat selection. First, we directly estimated the relationship between bighorn sheep habitat use and horizontal visibility by measuring visibility in the field at sites used by wild bighorn sheep and paired "available" sites. This avoided the problem of using selection of cover types to infer selection of horizontal visibility. However, we acknowledge that some index of horizontal visibility is required for future modeling in the GIS environment. Our second objective was to test what other habitat variables, if any, could be used to accurately predict horizontal visibility in a GIS framework.

METHODS

Do bighorn sheep prefer sites with higher horizontal visibility?

We captured 21 bighorn sheep among 3 herds in western Montana in March, 2001, using net-gunning from a helicopter (Krausman et al. 1985). We used radio-telemetry between March, 2001 and August, 2002, to collect locations of groups of radio-collared sheep among these 3 herds (Bearmouth, Garrison, and Skalkaho). We selected a systematic sample (every other location) of these locations for field measurements of horizontal visibility. For each of these selected "use" locations, we selected another location 200 m away in a random direction to measure visibility at "available" sites. To avoid disturbing sheep, we did not measure visibility at these sites on the same day in which sheep were located. The time period between locating sheep and returning to measure visibility ranged between 1 week and 12 months, which meant vegetative conditions during measurement were not always the same as when sheep were observed. We always measured visibility for both the use and the available sites during the same day, so we believe a valid estimate of the relative difference between them was maintained.

We used the staff-ball method to estimate horizontal visibility in the field (Collins and Becker 2001). Collins and Becker (2001) found this method to be more precise than both the cover-pole (Griffith and Youtie 1988) and checkerboard target (Nudds 1977, Smith and Flinders 1991), and we found it convenient in the field because it required only a single person. We cut 2 holes through a bright orange tennis-ball and mounted it on top of a gardening stake (staff); the staff was driven into the ground at the location of interest, and the bottom of the tennis ball was adjusted to 90 cm above the ground (Risenhoover and Bailey 1985). The observer walked a circle around the staff with a radius of roughly 20 m. While walking this circle, the observer stopped every eighth step and, with his or her eye-level also at 90 cm, looked for the "dimensionless point" where the ball and the right side of the staff intersected (Collins and Becker 2001). Collins and Becker (2001) suggested using the point of intersection between the ball and staff to yield a distinct yes or no result instead of subjective estimates or counts used with other methods. After completing the circle, the observer divided the number of times the point was visible by the total number of attempts, e.g. 12 visible/20 total = 60% horizontal visibility.

A biologically meaningful radius to measure visibility was difficult to select. A radius of 20 m was used in previous studies of horizontal visibility (McCarty and Bailey 1992) and fell in between other commonly used distances of 14 m (Risenhoover and Bailey 1980, Smith and Flinders 1991), 28 m (Johnson and Swift 2000) and 40 m (Risenhoover and Bailey 1985, Hayes et al. 1994). Twenty meters also corresponded to the diagonal radius of a 30 m by 30 m pixel which is the spatial scale of our GIS data.

We used a paired-samples T-test to detect differences between horizontal visibility at used and available sites. We analyzed data separately for each sex at each of 3 study sites (Bearmouth, Garrison, and Skalkaho). Bighorn sheep are known to have seasonal ranges, and make different tradeoffs in habitat selection to accommodate seasonal needs. For example, ewes may sacrifice forage quality for lamb security by retreating to rocky outcroppings in the spring. We suspected that horizontal visibility might have varied importance throughout the year so we divided ewe locations into 3 biologically meaningful seasons (winter, lambing, fall) for each herd and analyzed seasons separately. Roughly, the lambing season lasted from early May through late July, the fall season from early August through late November, and the winter season from early December through late April. The number of ram locations was insufficient to separate by season.

Can we model horizontal visibility in a GIS?

We did a simple exercise in modeling horizontal visibility using several predictor variables. We compiled GIS data sets for each of the 3 study sites (Bearmouth, Garrison, and Skalkaho). We began with 2 vegetation layers commonly associated with horizontal visibility, cover type and canopy cover, with 30 m x 30 m resolution (Wildlife Spatial Analysis Lab, The University of Montana 2001). We reduced our cover type layer into 3 categories: xeric grass/shrub lands (Grass), open forests (OpenFor), and closed forests (ClosedFor). Two of the 3 study sites were burned during the fires of 2000, which was after the vegetation layers were created. We used fire severity GIS layers to add 3 more categories to our cover type layer: burned grass/shrub (GrasBurn), low-moderately burned forest (LowBFor), and severely burned forest (SevBFor) (Wildlife Spatial Analysis Lab, The University of Montana 2000). We were unable to correct the canopy cover layer for changes due to the fires, so the canopy cover data were omitted from the modeling process.

While vegetation certainly affects horizontal visibility, our field measurements were just as often affected by the topography of the area. Ridges and valleys often concealed the staff-ball target, even when the vegetation was open grassland. For this reason, we suspected that topographic variables like slope, aspect, or ruggedness might also contribute to some of the variation in horizontal visibility. Terrain ruggedness is often quantified by the density of contour lines on area maps (Beasom et al. 1983), and Ebert (1993) found it was highly correlated with slope values. Because of this correlation between ruggedness and slope, we used only slope and aspect layers created from the USGS National Elevation Data Set DEM, with a pixel size of 30 m x 30 m. We left slope as a continuous variable and categorized aspect into 1 of the 4 cardinal directions (N, S, E, W).

We pooled the use and availability locations for this analysis, and associated each location with a value for cover type, slope, and aspect from the GIS. To avoid sampling bias between sites, we randomly selected 100 points from each site for analysis. Before modeling, we visually assessed the relationships between predictor variables and horizontal visibility using simple boxplots and scatterplots. We then used multiple regression and analysis of variance to assess the relationship between each predictor variable and horizontal visibility. We began with a saturated model (all 3 predictor variables) and used the Type III Extra-Sums-of-Squares F test to assess variable significance. We used Student's T tests to evaluate parameter coefficients.

RESULTS

Do bighorn sheep prefer sites with higher horizontal visibility?

Visibility did not appear to be a significant variable at this scale of habitat selection ($P = 0.013 - 0.968$). We measured visibility at 644 locations (322 used, 322 available, Table 1). None of the tests for ewes at any site or season gave results indicating significant differences in visibility between used and available locations. When ewe data were pooled across seasons, results remained insignificant. Effect sizes were very small, but the magnitude of the difference did indicate generally higher visibility values at used sites during winter and fall. Ram data were pooled across all seasons, and 2 of the 3 sites revealed significantly higher visibility for used sites.

Can we model horizontal visibility in a GIS?

Simple boxplots and scatterplots did reveal some visual relationships between predictor variables and horizontal visibility. For example, changes in cover type had apparent effects on visibility values (Figure 1).

The Type III Extra-Sums-of-Squares F test revealed significant relationships between horizontal visibility and all 3 predictor variables: slope ($P = 0.001$), cover type ($P < 0.001$) and aspect ($P < 0.001$). Slope and visibility were negatively correlated, so higher slopes led to lower visibility (Table 2). Cover type and aspect are categorical variables, so coefficients presented in Table 2 are relative to an alias or reference category; grassland was the alias category for cover type and South the alias category for Aspect. All categories of cover type had lower values of horizontal visibility than grasslands, and West and North aspects had higher values of horizontal visibility than South aspects

DISCUSSION

We detected significant preference for areas of high visibility in the rams of 2 of our 3 study sites; it is questionable whether the magnitude of these differences (mean differences in % visibility of 20 and 10) are biologically significant. Selection was not observed for ewes for any season or site, though the magnitude of the differences indicated generally higher visibility at used sites during fall and winter. A biological explanation might suggest that ewes protecting lambs sacrifice good forage and high visibility for other habitat features like steep slopes and escape terrain, where rams, unhindered by young, choose areas with better forage and high visibility. However, the scale of our analysis could also explain the results.

We used a radius of 20 m to measure visibility, which is an important decision of scale. Sheep may perceive horizontal visibility at smaller or larger scales than this 20 m radius. Measurement at another radius might yield different results. Our comparisons were also limited to used sites and paired available sites 200 m away. This 200 m distance might not be adequate to detect habitat preferences. Perhaps the sheep are making selections at much larger scales, so the observer would have to go further than 200 m to get an appropriate comparison.

Risenhoover and Bailey (1985) found that visibility was an important habitat characteristic until a threshold was reached, beyond which other variables became more important. In terms of Johnson's (1980) different scales of selection, visibility might be an important variable of second order, or home range, selection. Third order selection occurs within the home range. For a bighorn sheep, much of this area might already exceed some threshold of horizontal visibility, and other fine-scale variables become more important. Because our methods were really measuring third-order selection (within the home range), we would be unable to detect any selection going on at a larger scale.

The average visibility values for sites used by ewes in each herd (56%, 59%, 61%) were all considerably lower than that required by Smith et al.'s (1991) bighorn habitat suitability model. Their model designated all areas with visibility less than 80% as unsuitable for bighorn sheep. Cut-offs of 62% (Johnson and Swift 2000) or 55% (Zeigenfuss et al. 2000) seem more reasonable given our data, and researchers and managers might be more liberal with this parameter in future bighorn habitat modeling. The lag-time between observed use of a site and the follow-up measurement of visibility in our data may bias our mean visibility values.

Several variables were correlated with horizontal visibility. Though our intent was to use all reasonable predictor variables in modeling, much unexplained variation remained. Our vegetation data were simplified into a few basic classes. More detailed and accurate distinctions between vegetation types may be possible as the quality of these remotely sensed data improves. Topography appeared to have important relationships with visibility, and more complex measures of topographic diversity might be incorporated into future modeling. Landscape configuration measures such as the diversity of aspects or slopes within a given radius might better estimate subtle topographic barriers to visibility. Divine et al. (2000) found that the resolution of digital elevation model (DEM) data had a significant effect on measures of terrain ruggedness. Thirty meter pixel sizes provided more precise measures of topographic variables such as slope than 100 m pixels. Future development of 10 m resolution DEM data in some areas may further improve our ability to quantify topography for visibility estimation.

We recommend researchers take into account the highly variable nature of horizontal visibility values before using simple indices like cover type to quantify it. Multiple regression modeling procedures such as ours may be useful in certain, site-specific cases to accurately predict horizontal visibility in a GIS framework.

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Table 1. Paired-samples T-tests compare horizontal visibility values for paired used and available locations for bighorn sheep at 3 study sites, 2001-2002. Means of used/available values, the sample size of paired values, and *P*-values are presented.

		Site					
		Bearmouth		**Garrison**		**Skalkaho**	
Sex	**Season**	**used/avail**	***P***	**used/avail**	***P***	**used/avail**	***P***
Ewe	Winter	56/51 n=24	0.364	68/64 n=39	0.289	66/63 n=45	0.509
	Lambing	53/54 n=13	0.913	48/44 n=38	0.437	56/60 n=29	0.562
	Fall	62/49 n=9	0.204	60/71 n=28	0.105	58/53 n=30	0.471
	Pooled	56/51 n=46	0.279	59/59 n=105	0.968	61/59 n=104	0.633
Ram	Pooled	69/49 n=25	0.028	67/67 n=31	0.935	65/52 n=39	0.013

Figure 1. Box plots of horizontal visibility values for each category of cover type at 3 study sites in western Montana, 2001-2002.

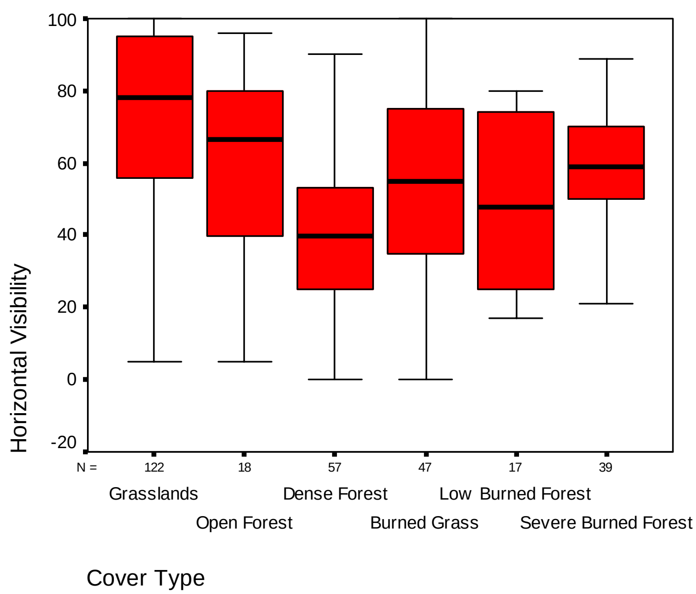

Table 2. Parameter estimates for multiple regression modeling of horizontal visibility data in bighorn sheep habitat in western Montana, 2001-2002. Coefficients and *P*-values for categories of Cover Type and Aspect are relative to their respective alias categories.

Parameter		β	Std. Error of β	t	*P*	95% Confidence Interval for β
Constant		80.927	4.584	17.655	0.000	(71.905, 89.948)
Slope		-.530	.164	-3.226	0.001	(-0.853, -0.207)
Cover Types[a]	OpenFor	-14.984	6.171	-2.428	0.016	(-27.129, -2.840)
	ClosedFor	-29.612	4.225	-7.009	0.000	(-37.927, -21.297)
	GrasBurn	-13.293	4.220	-3.150	0.002	(-21.599, -4.988)
	LowBFor	-23.752	6.192	-3.836	0.000	(-35.939, -11.565)
	SevBFor	-14.662	4.900	-2.992	0.003	(-24.306, -5.018)
Aspect[b]	West	12.838	3.667	3.501	0.001	(5.620, 20.055)
	North	4.928	5.090	.968	0.334	(-5.090, 14.947)
	East	-1.970	3.751	-.525	0.600	(-9.352, 5.413)

a Alias variable for Cover Type = Grassland
b Alias variable for Aspect = South

Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:191

A SIGHTABILITY MODEL FOR HELICOPTER SURVEYS OF BIGHORN SHEEP IN HELLS CANYON

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Abstract: We developed a model to correct for visibility bias of bighorns during helicopter surveys in Hells Canyon. Data on observation of radio-collared sheep collected during December and March 1999-2001 aerial surveys in 7 Hells Canyon bighorn herds was modeled using logistic regression. 204 of 235 groups (87%) containing radio-collared sheep were observed. Factors significantly contributing to group observability were the number of ewes in the group, presence of timber or shrub cover, and whether the sheep were moving. To develop a more robust model with wider applicability, we also modeled the combined Hells Canyon and Owyhee Canyonlands (Journal of Wildlife Management 59:832-840) data set. Preliminary analysis and likelihood ratio tests indicated that the data sets should not be combined and that the study areas should be modeled separately.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:192

EVALUATION OF WINTER TICK INFESTATION AND ASSOCIATED HAIR LOSS ON LOW-ELEVATION WINTERING STONE'S SHEEP IN NORTHERN BRITISH COLUMBIA

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Abstract: Stone's sheep (*Ovis dalli stonei)* wintering at low elevations along the Williston Reservoir in northern British Columbia were observed to exhibit hair loss in late winter similar to that seen in moose (*Alces alces*) affected by winter ticks (*Dermacentor albipictus*). We determined the relationship between hair loss and sheep wintering at high and low elevations. We conducted 69 examinations of 30 low-elevation (700 – 1,200 m) and 8 high-elevation (1,400 – 1,900 m) wintering Stone's sheep in March/April between 1999 – 2003, and fitted 27 sheep with VHF radio-collars. We classified the degree of winter tick-associated hair loss and breakage into one of 5 categories based on affected proportion of the torso: None (<1%), Very Low (1-5%), Low (6-15%), Moderate (16-30%), High (>30% of torso). Radio-collared sheep were monitored weekly - biweekly in fall (Oct/Nov) to determine range and habitat use during the peak tick larvae pick-up period.

No sheep that wintered at high elevation had winter ticks or exhibited any hair loss (n=14 exams), while 60% of low-elevation wintering sheep had some degree of tick-associated hair loss ranging from Very Low to High (n=55 exams), primarily on the neck, chest, and shoulders. Lambs were more affected by winter ticks than adult sheep. Of the 6 lambs examined in 2001, 83% exhibited Moderate to High hair loss compared to only 7% of adult sheep wintering at low elevation that same year (n=14) and 14% of sheep over all years (n=49). The degree of hair loss was directly related to the date that sheep descended to low-elevation ranges in the fall. The degree of hair loss did not appear to affect adult mortality or productivity because mortalities occurred in years when observed hair loss was low, and productivity throughout the study was normal. Starvation, likely related to late spring snow conditions, was the primary cause of death for 6 radio-collared females that died in spring 2002, and 2 females in spring 2003. Of the 12 and 14 sheep examined in March of these years respectively, only 15% had Low to Moderate hair loss (6-30%) and no sheep had High hair loss. Proportion of females producing lambs ranged from 85% - 100% annually throughout the study. Sheep that used low-elevation winter range came into greater contact with ticks than those that used high elevation winter range probably because Rocky Mountain elk (*Cervus elaphus nelsoni*) were present in higher densities on the low-elevation ranges and were likely the primary host for *D. albipictus*.

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and Goat Counc. 14:193-209

INFERRED NEGATIVE EFFECT OF "TROPHY HUNTING" IN ALBERTA: THE GREAT RAM MOUNTAIN/*NATURE* CONTROVERSY

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<u>Compiling Author's Note and Comment</u>: The wild sheep community is diverse. Specialties within this community range from focus at the molecular level of life increasing in complexity through the cellular level of disease mechanisms and the physiology of life leading to individually adaptive whole-animal behaviors we define as autecology. In animal groups, these individual responses to environment are first defined as "population biology," and ultimately, synecology. When modern humans interact with mountain sheep synecology, the integration of these diverse disciplines, with the goal of producing human benefits while conserving wild sheep, produces the overarching effort we call "management."

For optimal management, complete and rational integration of information the diversity represented within the wild sheep community is required. This almost never happens because few "basic researchers" understand the complex nature of management, and few "managers" appreciate the imputed significance of some "basic research." In the words of actor, Stroether Martin's prison-warden character in "Cool Hand Luke," "What we have here is a failure to communicate." Whether we are "basic researchers" or are *working in management at the political level, all of us exhibit the human tendency toward thinking our specialty is the touchstone of successful wild sheep conservation.*

The "Great Ram Mountain/NATURE controversy" illustrates this common human weakness compounded by sensationalized communication efforts. Dave Coltman and his co-authors applied molecular genetic analysis to the Ram Mountain (Alta.) data, and published an interpretation which others in the wild sheep community did not find particularly helpful. If the "Nature Science Update" (an electronic digest) hadn't emphasized Coltman et al's more extreme suppositions as fact, and if the "NATURE Publishing Group" has not made much of the hunting management- critical interpretations, Coltman et al.'s "Letter to NATURE" would have probably gone largely unnoticed. However NATURE's radical representation of hunting management criticisms in the tabloid press was interpreted as "anti-hunting," and was, thus, impossible for other researchers and managers to ignore.

The following collection of essays was produced by way of critique, commentary, and rebuttal. Their "target audiences" vary from the "deeply scientific" to the "popular." The Frisinas review the contributions hunter-funded conservation has made to wild sheep welfare and cite data which appear to refute the broad "hunting/genetic-harm" claims attributed to Coltman et al.. Rominger points to the unacknowledged variance between the Coltman et al. letter and previously published conclusions where the "et al." were senior authors. In these unacknowledged papers, density-driven nutritional scarcity was the common rationalization for observed declines in horn and body size on Ram Mountain. Geist discusses the history of "trophy selection" in Europe and suggests alternate (non-genetic) explanations for the changes in horn and body size reported from Ram Mountain. Geist's essay was submitted to NATURE a rebuttal. It was not accepted for publication. Finally, Heimer and Lee answer Coltman et al.'s allegation that managers have not considered genetic factors in regulation of wild sheep harvest management. They also place the arguments in the unique context of resource management politics in the USA.

If there is any value to recording this event, it is probably simply as a case study where academia and management collided. If there's a lesson in this history, it may be that "academics" no longer live in a sequestered world. Hence, it may be helpful for everyone in our community to understand what "managers" learned long ago from bitter experience: "Be circumspect in communications with the press because what 'comes out' isn't going to look very much like what you 'put in.'"

Perhaps more importantly, the wild sheep community, from the loftiest academic to the lowest manager, should realize that scientific data, their interpretation, and the inferences drawn from them have considerably less influence on the decisions that drive management in the "real world" than publicity in the tabloid press. That said, it is perhaps worth noting that, in spite of this spate of creative controversy in the wild sheep community, the world seems to have pretty much forgotten this ever happened…and it's only been three years. Nevertheless, this "scientific finding" is "out there," and it would be naïve to presume politically partisan publicists will not resurrect it for use as it suits *the anti-hunting agenda. I may be paranoid, but my experience at all levels of involvement in the wild sheep and management communities suggests a high probability it will pop up again…it's just a matter of when. [WEH]*

Abstract: More than 30 years ago, Bill Wishart, a charter member of the Northern Wild Sheep and Goat Council, initiated a long-term study of a small, isolated bighorn sheep (*Ovis canadensis canadensis*) population on Ram Mountain in Alberta. The primary rationale for this long-term study was field-testing prevailing wildlife management theories and practices. The first study documented the survival of lambs orphaned by fall ewe harvests. This study involved a complete trapping and marking program that began in 1971. Every sheep on the mountain has reportedly been captured and handled, perhaps twice, annually ever since. Many Ram Mountain studies have been published in the proceedings of this symposium. Throughout the years, the best possible records of matings and births have been gathered and maintained. In a 2003 paper by Coltman et al., these data on lineage were supplemented by population geneticists evaluating DNA similarities in cooperation with bighorn biologists. Resulting data were analyzed using a breeding value computer program from which a relationship between gene frequency and changes in body and horn size was inferred. Coltman et al. published these results and inferences drawn from them in a letter in the journal, NATURE. This letter statistically linked "trophy hunting" as practiced on Ram Mountain with decreases in horn and body sizes among rams. By way of suggestion these authors were credited with concluding, that "trophy hunting" was the cause of horn and body size decreases. Their letter to NATURE included an apparent indictment of "sport harvesting" in general, concluding traditional wild sheep harvest management has been particularly harmful. The letter and its suggestions subsequently became the basis for sensationalized non-technical articles by the *NATURE Publishing Group* in both newsprint and on the internet. Several rebuttals have been offered by the sheep management community. None has been as broadly distributed as the original "popularized" accounts of the original letter to NATURE. NATURE chose not to publish any of these rebuttals. This paper includes the available rebuttals.

[*Editor's note: This first essay represents a non-technical communication to the sheep hunting community. WEH*]

SPORT HUNTING: A MODEL OF BIGHORN SUCCESS

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The popular press is filled with bad news lately. Bighorn hunters, it is stated, are destroying the very rams they covet. Some argue that by killing large, older males, we are ruining the "gene pool" and favoring survival of small-horned bighorns. However, nobody seems to have informed North America's bighorns—they just seem to be getting bigger and bigger instead of going the way of 'tuskless' elephants. So, before you hang your head in shame, and your favorite sheep rifle over the mantle for good, consider some observable, documented facts.

Hit the Books

To get the truth, take a look at recorded bighorn trophies—the biggest of the big. While any legally taken, free-ranging bighorn should be considered a trophy, we chose to analyze the top 100 bighorns in the 11th edition of the Boone and Crockett (B&C) Record book. By analyzing these records, we can address the criticisms leveled against hunting by some scientists. If, as the scientists argue, hunting has been giving an advantage to smaller-horned sheep genes, bighorn trophies should have been getting smaller over time. The B&C records are a good data source because they take into account horn length and mass. Thus, the higher the score, the bigger and heavier the horns.

The B&C records show the number of rams with really big horns has dramatically increased over the past two decades. For example, there are only 19 rams reported in the B & C 11th edition with scores greater than 200 "points" (the way measurements are converted from inches into record scores). Nine of these rams (47%) were taken between 1883 and 1955 (over 72 years of harvesting). No "200 pointers" were reported from 1956 to 1986, but 10 (53%) were reported taken between 1987 and 1997 (a ten-year run). So, most (at least 53 percent) of the very biggest bighorn rams ever reported were taken within the last 10-year period of bighorn harvesting reported in the 11th edition of the B&C records.

Keep in mind that the 11th edition of the B&C book covers only trophies recorded through 1997, and 200 point bighorn rams continue to be harvested at what will prove a statistically increased rate compared with history as the records are continually updated. The new world's record bighorn (breaking a record which has been on the books since 1911) will be listed in the next edition of the B&C records. Also, an Alberta bighorn scoring 208 3/8, which will be yet another record for largest bighorn ever harvested, was taken in 2000. It is interesting to note that Alberta, the province where a tiny population of bighorns was studied to produce the "small horn gene selection" argument also produces these huge rams.

This story gets even more interesting when we compare the top 100 bighorn rams of all time from the same B&C record book. It took 100 years to produce 47% of the top 100 trophies, and only two decades to produce 53% of the top 100. (The percentages here coincidentally match those for 200 point rams.) Keep in mind that, due to the timing of the 11th edition, the final three years of the 1990s are not included, and unusually large rams continue to be harvested and what appears to represent an increased rate.

These are real data; no complex computer modeling; no assumed factors; and no complicated statistical analyses. These simple data indicate a different phenomenon than those produced by what we consider excessive statistical massaging of marginal information. The information we present here represents hunters pursing Rocky Mountain bighorns across their entire range, not from one, unusual, small area.

What Makes for Big Horns in Bighorns?

It is obvious that genetics plays a role. If male, you are likely to end up with the hairline of your mother's father. Still, it is common to overlook how much genetic diversity there is within a specific animal population. Remember the forgotten 50 percent. Ewes contribute half of the genes determining individual sheep characteristics. It is also true that it isn't only the biggest rams that do the breeding. A recent study of Rocky Mountain bighorn sheep found that although a few larger-horned rams (age 8+ years) had a very high reproductive success, younger rams sired about 50 percent of the lambs. Mating success was not restricted to a few top-ranking rams each year. When all is said and done, the potential for horn size may be set by genes, as are other horn characteristic such as curl tightness and overall shape (probably influenced by both parents), but achieving that potential is limited by the environment occupied by the sheep population. A favorable weather cycle may have contributed to the recent bonanza in huge bighorns harvested, but could not have done so if the genetics for large horns had been previously compromised by harvest management.

A good way to understand potential is by analogy to a truck engine. You might have a dandy, beefy Dodge (a Ram, we hope) "Hemi," but if there's an engine speed "governor" that keeps the engine from driving your truck more than 50 miles per hour, you are not achieving the potential of the "Hemi." In the real world of wild sheep, habitat is the "governor" of horn size. It overrides genetic potential. Many years of research on North American deer indicate this is the way it is for antlered animals. In a nutshell, one can make a yearling buck deer (age 18 months) grow to any size from a "spike" to a "4-point," depending on the quality of nutrition provided. It probably works the same for bighorn sheep. [*Editor's note: See Geist's essay here for European experience in deer management.*]

The Montana Case

Montana graphically demonstrates how habitat quality determines horn size in bighorn sheep. Montana is colloquially known as "The Land of Giant Rams." The "Big Sky" has produced 42 of the top 100 rams listed in the B&C 11th edition. As mentioned earlier, many of these rams were taken by hunters during the 1980s and 1990s from herds created through a series of transplants over the past 30+ years. Many of the top 100 rams reported from Montana were taken from these transplanted herds, and the breeding stock for many of these transplants came from the Sun River population. The Sun River population is notable for its absence in the B&C records. Still, these "Sun River genetics," when introduced to new areas where population density is low and competition for food is minimal, produce the biggest of bighorn rams in the United States. Apparently other factors than genetics are at work here.

Sport Hunting: Sin or Savior?

To the sport hunter or general bighorn enthusiast, the "good old days" are now! Why? It is because the alliance between sportsmen/women, wildlife managers, and conservation organizations such as the Foundation for North American Wild Sheep (FANWS) are realizing the results of their investments and efforts on behalf of bighorn restoration and management.

A key time in the history of North American wildlife conservation was 1937, the year the Federal Wildlife Restoration Act (or Pittman-Robertson (P-R) Act) was passed by the US Congress. The P-R Act defined the mechanism by which hunters were able to focus tax dollars from sales of ammunition and firearms on restoration and management of wildlife in the USA. The law is very specific; the money must be used for meaningful wildlife restoration, conservation, and management to benefit purchasers of hunting licenses. These federal excise tax dollars match state hunting license dollars (3:1) to produce the dominant funding source for wildlife conservation efforts in the United States.

An important use of P-R funds, along with other hunter dollars generated by organizations such as FNAWS, is the restoration of bighorn herds through bighorn re-introductions and habitat conservation. Habitat acquisitions, conservation easements, and other creative strategies have resulted in many herds being re-established on historic ranges. Thus it is sport hunting which has provided the means for restoration of bighorn sheep and a steadily increasing number of unusually large bighorn rams. These facts were not presented in the newspapers from London to New York and across the internet as were the results of the scientists and their strained opinions.

<u>The moral of the story:</u>

Hunters, don’t hang your heads, and don’t be swayed by assumptions and theoretical conjecture disguised as truth by complex statistical analyses and computer models. The reality of things is that if we want to keep producing the biggest of the big, the proven way is more, not less, sport hunting of bighorn sheep. There is no need to apologize for that.

As so often happens, subjecting a small amount of data to statistical analysis led to a mathematical linkage of results with supposed causes that don’t stand up under other testing. The results in this case have been assumptions and opinions which have accomplished little on behalf of North America’s wild sheep. Hunting, however, has enabled the comeback of our beloved bighorns and continues to assure a future for the biggest of the big, as well as the average.

<u>Suggested Reading</u>:

Voodoo Science: The Road from Foolishness to Fraud by Robert Park. Available from “Amazon.com”

Records of North American Big Game, 11th Edition by Boone and Crockett Club. 1999. Available from Boone and Crockett Club, Missoula, Montana.

Restoring America's Wildlife by United States Fish and Wildlife Service 1987…Available through interlibrary loan.

[*Editor's note: This critique represents a call to academic accountability.*]

CRITIQUE OF THE COLTMAN ET AL. 2003 LETTER TO *NATURE*

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The conclusions of Coltman et al. (2003) in their recently published NATURE article contradict nearly 20 years of analyses published primarily by two co-authors of the manuscript (i.e. Jorgenson and Festa-Bianchet). After asserting, in a series of refereed scientific publications (e.g. Jorgenson et al. 1984, 1993, 1998, Festa-Bianchet et al. 1997, LeBlanc et al. 2001), that reductions in body mass and horn size of rams from the Ram Mountain population were the result of density-related decreases in forage availability, these authors have either chosen to ignore or recant their previous work. They have not acknowledged their apparent changes in perspective. Apparently these authors now conclude that, in fact, trophy hunting has induced the declines observed in ram body mass and horn size on Ram Mountain. In confusing contrast, a paper published in BEHAVIORAL ECOLOGY shortly after their NATURE article reports that 77.2% and 86.8% of the variance in body mass and annuli base circumference were explainable by a liner mixed effects model describing the effects of resource availability and age (Festa-Bianchet et al. 2004).

During the course of the Ram Mountain experiments bighorn sheep density in the Ram Mountain population was raised to a level as high as any ever reported in North America. The effect of density-dependence has been reported for many other ungulate species, and this sudden exclusion of the Ram Mountain bighorn population as represented in the NATURE article is enigmatic. Reports analyzing the results associated with high population densities, including the reduction of body mass and horn size, in multiple publications and presentations by the co-authors in the Coltman *et al*. (2003) manuscript simply don't match their present conclusions.

Consequently, an important question arises, "Are these authors now prepared to publish an *Errata/Corrigendum* for each of their previous publications that stated declines in body mass and horn length were a function of density-dependent factors?"

I suggest an analysis of horn-size of rams born to ewes transplanted from Ram Mountain into low-density sheep habitats would be an appropriate test of the prediction inferred from the NATURE article. If these rams do not exhibit continued diminution of horn and body sizes reported for rams remaining on Ram Mountain, the hypothesis that the reduction in horn size and mass were genetically-driven functions of hunting mismanagement rather than density-driven nutritional insufficiency must be rejected.

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[*Editor's note: The following "Letter to NATURE" was prepared and submitted to NATURE by Dr. Valerius Geist. It is in the format required by NATURE, and contains relevant lessons learned through trophy management for deer in Europe. NATURE chose not to publish this letter.*]

TROPHY MALES AS INDIVIDUALS OF LOW FITNESS (DRAFT)

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While wildlife trophies get a lot of attention in modern times in North America and Europe, such infatuation has a long and instructive history. Already in the Upper Paleolithic, cave painters invariably chose to paint large, complex antlers on male deer and long horns in ibex, bison, and wooly rhinos [1]. The trophy mania hit its high point in medieval central Europe when huge red deer antlers were used as gifts of state, when hunting records of nobility were recorded in exquisite detail and antlers were venerated objects of display in castles built to house trophy collections[2]. Such castles have survived into modern times, i.e. the castle of Moritzburg close to Dresden, Germany displays red deer of unequalled size[3]. These have, naturally, raised the question, "How might such antler growth be duplicated?" Moreover, in the late 19th and early 20th centuries, the vagaries of treatment of wildlife in central Europe led to declines in the trophy quality of antlers which lead to an early "Quality Deer Management" movement[4]. This movement reversed the decline within about a quarter century, and generated an intense interest in how to produce huge trophy antlers. We see, currently, in the United States the birth of a similar "Quality Deer Management" movement[5,6]. Some of the most interesting experimental deer management for trophies was carried out during the Third Reich on the Rominten Heath by Walther Frevert[7]. There is, consequently, a rich historical background on the biology of "trophy males," but this is currently poorly known.

The recent study by Coltman et al.[8] which demonstrated declines in horn and body size in bighorn rams with hunter selection for large-horned males, confirms the findings from the late 19th and early 20th centuries on European cervids[9,10,11]. The ongoing removal of males with superior antlers led to a severe shift in sex ratio in favor of females. This imbalance was primarily addressed by the culling males with inferior antlers, while sparing males with good antler growth. Wildlife eugenics, the culling of undesirables, was made popular by Ferdinand von Raesfeld's "Hege mit der Buchse"[12] (husbanding with the rifle) which subsequently was institutionalized in Germany's 1934 wildlife management legislation[13]. One thus suspects that, contrary to Coltman et al.'s fears, the declines in horn and body size in bighorn rams are not permanent, but can be reversed by similar means. Even if merely left to themselves, the selection pressures favoring horn size in bighorns[14] would return normal horn growth in time. Moreover, the rehabilitation of formerly strip-mined bighorn habitat in Alberta[15], as well as the reintroduction of bighorns to former ranges throughout the United States has not merely increased the wild sheep population of the continent by nearly 50 percent in a quarter century[16], but has also resulted in the growth of many rams with record-sized horns[17].

In central Europe, management for trophy deer also led to deliberate population reductions, habitat improvements, and the introduction of males with superior antlers from other regions[18]. The latter, however, was considered a failure[19]. The interest in improving trophy quality led to research into the nature of body and antler size variations in red deer, with the aim of reproducing antler sizes such has been seen in medieval times [20,21,22,23,24]. This illuminated the "biology" of trophy males in clinical detail and led to surprises. One can summarize the findings as follows: Deer varied in body size along a peadomorph-hypermorph axis, so that small-bodied deer retained juvenile proportions compared to large-bodied deer[25,26]. Body size was plastic, but slow to shift and it took some five generations for medium-sized deer to reach maximum body size[27]. This finding, rediscovered three decades later, was labeled the "maternal effect'[28,29,30]. Continuous access to highly digestible feed rich in protein calcium, and phosphate was a necessary condition for large antler and body size. However, trophy stags were exquisitely sensitive to shortages in food quality[31], which indicates that medieval foresters must have been very concerned about the possibilities that their treasured and pampered stags might move off somewhere else. It explains, in part, the brutality with which these foresters treated peasants who disturbed deer. While a high plane of nutrition was a necessary condition for exceptional antler growth, it was not a sufficient condition in itself. Optimal results were achieved by artificially preventing males from rutting[33]. Males that did not rut had no need to heal the severe rutting wounds suffered by rutting males[33], and were thus able to shift their body resources from repair and re-growth into increased body and antler growth. Moreover, the absence of wounding would lead to the desirable symmetrical antler growth.

However, stags that reached maximum antler development were severely handicapped by their unwieldy antlers in fighting and tended to lose out to normally-antlered males. Not infrequently trophy stags locked their complex antlers and died[34]. Large trophy antlers conveyed no apparent benefit to their bearers, quite the contrary. This suggests that in free-living populations, male deer with exceptionally large antlers may be non-breeders, and thus individuals of low fitness[35]. During eight years of field work with habituated mule deer in Waterton National Park, Alberta, Canada, I was fortunate to closely observe three bucks with exceptionally large antlers. All three became "shirkers" during the rutting season. They avoided other deer, bucks especially, and thus failed court and breed females. They merely fed and rested in seclusion. However, one of these bucks had a surprising history. He had been a normal rutting buck up to three years of age. During a fight with an old buck, he was flung upward and landed on his back in some wind-blown aspen trees. He quit rutting that year and for two more years. By then, he had grown to a very large body and antler size. The next rutting season he reversed and became a fully engaged, breeding master-buck. He continued as such for three rutting seasons. Hence, "shirking" is potentially reversible. Nevertheless, managing populations for trophy size remains highly questionable, as do the stated concerns of Coltman *et al*.

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[Editor's Note: Ray Lee and I also prepared a letter of rebuttal to NATURE. We focused on Coltman et al.'s allegation that insufficient attention has been given to protection of male social structure by modern managers and the political nature of wildlife management in the USA. When we learned Dr. Geist's letter had been rejected, we didn't bother to submit ours. It was too long anyway. I've left it in the draft NATURE format. WEH]

UNDESIRABLE CONSEQUENCES OF UNQUALIFIED SPECULATION ON THE NEGATIVE EFFECTS OF TROPHY RAM HUNTING

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Status-enhancing, but highly speculative, publications such as Coltman *et al*.[1], may compromise wild sheep conservation. Such research communications encourage emotionally driven anti-hunters to contravene biologically sound management programs, particularly in the United States. Coltman *et al*.'s[1] letter grossly exaggerated hazards to wild sheep populations resulting from managed human harvests. It's secondary references to "sport harvesting" as "one of the most pervasive and potentially intrusive human activities that affect game mammal populations globally[2], and the statement that "little attention has been paid to the potential evolutionary consequences, and hence the sustainability of harvest regimes[3,4]" are incorrect and damagingly expansive. The letter reported larger-horned, larger-bodied rams sire more lambs than smaller individuals; and made much of the fact that human harvesters prefer the largest rams available. These findings are not new. Reproductive success was quantitatively linked to dominance three decades ago[5]. Modern "sport harvesting" management of wild mountain sheep has typically limited harvest to 3-10% of available rams for more than 40 years. In Alaska, the most prolific and harvest-friendly wild sheep jurisdiction in the world, harvest strategies have been specifically designed to foster social order among rams for almost 20 years[6]. Alternate rutting strategies among thinhorn sheep resulting from differing ram mortality levels were identified and factored into sheep harvest management in Alaska beginning in 1984[7,8]. Coleman *et al*'s failure to acknowledge these facts was compounded by sensationalized reporting of these non-revolutionary findings by the "NATURE Science Update" and the NATURE Publishing Group[9,10]. Similar under-researched and over-sensationalized "scientific communications" are often used by animal rights groups and "anti-hunters" to orchestrate politically saleable, but biologically counter-productive 'corrections' in management programs through so called "citizen's initiatives" in the United States. These actions serve neither science, conservation, nor the managed species will in the longer run.

In 1971, Geist[5] published quantitative behavioral studies linking reproductive privilege in mountain sheep rams to dominance. Many investigators considered this behavioral generality absolute and papers showing sub-dominant rams make significant genetic contributions have been well-noted. Using the same data as Coltman *et al*.[1] four of those co-authors reported subdominant rams have sired approximately 50% of the lambs on ram mountain over time[11]. In that publication, our authors said,

> These result suggest that young or small rams achieve mating success through alternative mating tactics that are less dependant on body and weapon size, such as coursing and blocking.[11]

These findings do not appear to be congruent with the concern that "sport harvesting" management, as incorrectly represented by Coltman *et al*.[1] is a widespread cause of genetic deterioration in wild sheep. The earlier paper[11] interpreted the data as an adaptation to existing circumstances. We agree with that hypothesis.

Heimer[7] discussed at least three alternate rutting strategies among wild sheep rams. These strategies function adaptively to set back behavioral selection for large horns, effectively increasing genetic diversity among wild sheep populations in times of population stress. The most complex, the “alpha ram,” strategy was identified by Hogg[12,13]. When it is operative, ewes seek out unusually large dominant rams, while normal mature rams employ the more commonly observed coursing and blocking behaviors, attempting to sequester and mate with ewes as ewes seek the “alpha ram.” When “alpha rams” have been removed (either through “sport harvesting,” natural predation, or transplanting), the rutting strategy reverts to the more commonly understood “mature ram” or “normal” rutting strategy described in detail by Geist[5]. In cases where mature dominant rams were virtually absent, Heimer[7] described the development of an “immature ram” strategy, demonstrated to lower lamb production compared with the other strategies. The “immature ram” strategy may result from causes other than “sport harvesting.” A current example is the scarcity of mature rams on some Alaska Dall sheep ranges resulting from consecutive-year recruitment failures associated with unfavorable weather events acting in concert with high lamb-predation (by coyotes as demonstrated in Alaska [14]). Significant winter wolf predation on adult sheep is also a contributing factor[15].

Upon discovering the negative management consequences attending the “immature ram” strategy, managers in Alaska limited harvest to mature (Class IV) rams having complete full-curl horns, or a minimum age of 8 years, or with both horns broken by fighting[8]. Hence, the assertion that, “little attention has been paid to the potential evolutionary consequences, and hence the sustainability of harvest regimes” is demonstrably incorrect in the most sheep-rich and hunter-friendly jurisdiction in the world. The authors (and the *NATURE Publishing Group’s*) poorly researched indictment of “sport harvesting” and its management as unsustainable and having negative impacts on wild sheep genetics also betrays a distressing naivete with respect to the common management of bighorn ram harvests.

While regulations in some jurisdictions allow the harvest of “any ram” (designed to spare mature rams in harvested populations thus balancing ram age structures), the dominant practice is to limit harvests to biologically insignificant levels through the use of restricted entry permits. Even if every hunter were to succeed in taking a mature (or even a juvenile) ram, allowed harvests are predominantly limited to 3-10 percent of the available rams[16]. Only in exceptional circumstances, such as Ram Mountain, Alberta, is harvest allowed to exceed this level.

For decades, Ram Mountain has served as a “natural laboratory” and subjected to atypical population manipulations to test various hypotheses relating to mountain sheep management. Because of its isolation and unique population history, extension of Ram Mountain findings to the general case should be most judiciously applied. It wasn’t in Coltman *et al*.[1] or the resulting popularized versions reported by NATURE[8,9].

First, it wasn’t necessary to invoke genetic change to rationalize the observed decreases in horn and body size. These phenotypic effects are clearly explainable in non-genetic terms (see earlier essays presented here). Additionally, the injudicious expansion of findings from Ram Mountain to wild sheep in general, not to mention diverse animal taxa, does conservation of mountain sheep a disservice.

The erroneous tarring of “sport harvesting” as harmful may lead to serious negative impacts on wild sheep conservation. In the United States of America (USA), management agency funds are generated through a self-imposed “sport harvester’s tax,” and conservation funding is dependant on the perceived social status of the conserved species. That is, conservation programs for highly valued species are well funded by the “owner/sport harvester/conservationists; unique to wildlife management in the USA. Primarily due to this novel public-trust ownership of wildlife and the accompanying tradition of use by a broad diversity of citizens through unrestricted licensing/participation, restoration of high-status species in the USA is a success unparalleled in human history[17].

Surprisingly, wild sheep have not enjoyed historically high status with managing agencies so funding for wild sheep management has been traditionally minimal[18]. Hence, the managing agencies have not had great success in wild sheep restoration programs. Sheep “sport harvesters,” who place a high value on these species in spite of agency traditions, have seen to successes in restoration of wild sheep almost independently of public agency funding[18].

These “sport harvesters” or “trophy hunters” operate primarily through the Foundation for North American Wild Seep (FNAWS) by funding independent research and restoration projects as well as nascent agency programs. FNAWS has generated and spent funds approaching 30 million dollars over the last 27 year. Results have included a doubling of reported bighorn sheep numbers in North America[19]. Apparently unbeknownst to Coltman *et al.*[1], harvest from these restored populations is strictly regulated but nevertheless generates virtually all of the funding for wild sheep management and restoration in North America. Similar programs by other “trophy hunting” organizations such as the International Sheep Hunters Association (ISHA) support conservation of wild sheep worldwide.

In the USA, inaccurate or misleading indictment of sheep managers for alleged lack of concern regarding genetic (or overall population) health may have particularly deleterious effects. In the USA, many individual state constitutions allow citizens to enact legislation by popular vote without parliamentary discussion or amendment. This practice is becoming increasingly prevalent as animal rights groups seeking to outlaw, by emotional manipulation of the electorate, all animal uses they find philosophically objectionable. “Trophy hunting,” as negatively depicted by Coltman *et al.*[1], and the *NATURE Publishing Group* seems highly likely to become an attractive future issue for these interests.

The misapprehensions of Coltman *et al.*[1] regarding prevailing wild sheep management practices bespeak either inadequate scholarship or sympathy with a sociopolitical agenda that fosters a negative representation of “sport harvesters.” Alternately, in light of the sensational, non-technical coverage afforded this letter, we suggest editors at *NATURE* may have used naïve authors to advance a similar sociopolitical agenda in the popular press. The authors' suggestions that harvests be limited to full-curl rams and their implication that harvests be kept sufficiently low to protect behavioral genetic selection would have been quite helpful and timely 25 years ago. Today they aren't.

While we applaud the innovative use of quantitative genetics in confirmation of field observations, such uses of these techniques should be clearly reported as such. We encourage the authors to read more widely in the management literature before aspiring to alter management.

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