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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.

West Nile Virus

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%			$\leq$ 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 $\geq$ 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