Proc. Fifth Bienn. Symp. North.
Wild Sheep and Goat Council 1986

HARVESTING MOUNTAIN GOATS: STRATEGIES, ASSUMPTIONS, AND NEEDS FOR MANAGEMENT AND RESEARCH

James A. Bailey, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado 80523.

Abstract: Mountain goats (*Oreamnos americanus*) are harvested (1) conservatively to avoid risk of population decline, (2) to maximize and sustain the harvest, or (3) to control herd size and distribution. Strategies for achieving these goals include control of roads, limiting and distributing the harvest, causing a density dependent increase in productivity as a response to harvest, estimating and harvesting each annual herd increment, harvesting mostly males, and monitoring population responses. Most strategies depend upon assumptions regarding the dynamics and ecologies of goat populations, and there is little empirical evidence for most assumptions, especially for local herds. Further, the accuracy and precision of monitoring are often unknown. There are opportunities for experimental management and research on goat populations. These studies will be most productive if specific hypotheses are tested by manipulating herd size or composition, or the herd environment, and if there are long-term commitments to the studies and to measuring several population parameters including reproduction and behavior.

This is an analytical review of the problems encountered in managing the harvest of mountain goats. Options and strategies, knowledge-base and assumptions, and needs for management and research are considered. My perspective derives from the literature and from experience with a herd of goats that was transplanted into Colorado in 1950. I am indebted to many students who have studied this herd, including B. Johnson, L. Adams, M. Masteller, K. Risenhoover, E. Rominger, D. Fieth, M. Opincarne, and J. Stone, all with support from the International Order of Rocky Mountain Goats. M. Masteller and R. Johnson made helpful comments on the manuscript.

HARVEST OPTIONS

Goals for harvesting mountain goats may be (1) to harvest conservatively and avoid the risk of a significant reduction of the base population; (2) to achieve a maximum-sustainable level of harvest; or (3) to reduce the numbers of mountain goats and/or limit geographic spread of a herd. In addition, harvest may be used to alter a population for research purposes.

A conservative harvest strategy may be justified because mountain goats have been easily overharvested (Foster 1977, MacGregor 1977). In particular, local populations that are newly accessible due to road expansion may be decimated quickly, as described by Chadwick (1983). In these locations, goats may be predictably present and available to hunters, and females may be shot at least as frequently as males.

Further, funds and methods for monitoring populations, especially local subpopulations, may be inadequate to detect population declines in time to effectively modify the intensity of harvest. These problems justify a conservative harvest strategy.

Agencies may strive for maximum sustainable harvest from a goat herd in order to maximize recreational opportunities, meat production, or income to support management activities.

Control of a goat population may be necessary when introduced ungulates are not consistent with the goal of naturalness in a national park (Houston 1968). In addition, mountain goats have been perceived as reservoirs of diseases that threaten other ungulates (Williams and Hibler 1982), and as serious competition for bighorn sheep (Ovis canadensis).

STRATEGIES, KNOWLEDGE AND ASSUMPTIONS

Conservative Harvest

Strategies for achieving a conservative harvest of mountain goats include limiting access with road control or closure, limiting the legal harvest, and control of illegal harvest. Road control or closure may be the most effective conservative strategy, especially for small herds, since (1) effects of any level of harvest on populations have seldom been measured; (2) adult females are often harvested; and (3) poaching may be difficult to control.

When goats are harvested conservatively, it is assumed that population monitoring will detect any serious population decline. Most monitoring of goat herds involves trend counts. These counts may have two limitations. First, each annual count may include several subpopulations. Trends for each subpopulation can be obscured in the total count. Second, counts are rarely replicated within years. Without knowledge of within-years variation of trend counts, short-term trends in population size cannot be detected (Harris 1986).

An unharvested or conservatively harvested goat population should be at or near ecological carrying capacity (Caughley 1976, 1979). The conservative harvest strategy assumes there are no important detrimental effects of this high ecological density upon the goats or upon habitat resources for goats or other species. (Ecological density is the number of animals relative to the quantity and quality of habitat resources; Bailey 1984). For mountain goats, there is very little empirical basis for or against this assumption.

Maximum-sustainable Harvest

Several non-exclusive strategies are used in attempts to maximize harvests from goat populations. These are (1) by reducing a herd, attain a density-dependent response of increased reproduction, recruitment, survival, and therefore, harvestable surplus; (2) regardless of density-dependent or density-independent variation in herd dynamics, measure and harvest a number of goats equal to the annual increment; (3) harvest primarily male goats; and (4) apply these strategies optimally to each subpopulation in a herd.

Density Dependence: While density dependence has been demonstrated for some herds of some ungulate species (Caughley 1970, McCullough 1979, Houston 1982), we cannot presume that density dependence is more, less, or equally important, relative to density-independence, for mountain goats; and we should expect variation among goat herds in the relative importance of density dependence. In goats, density dependence may be demonstrated (1) by comparing small, newly transplanted herds vs. larger, established or native herds; (2) by observing a herd during population growth; and (3) by comparing a herd before vs. after a natural or contrived population decline. When transplanted herds are involved in these comparisons, the effect of herd density may be confounded with an effect of herd age since establishment. Regardless of density, an older herd may have modified its environment, especially its habitat resources, in ways that are detrimental to herd performance.

Three studies involving transplanted herds indicate that density dependence may occur in mountain goats. Young, small herds have had, on average, higher rates of kid production than have older and presumably larger herds (Bailey and Johnson 1977). As two introduced herds have increased, rates of kid production have declined (Adams and Bailey 1982, Swenson 1985). In addition, Smith (1984) found weak evidence (not statistically significant) of density dependent rates of population growth in Alaska herds. A study involving reduction of a long-established herd in Olympic National Park, is currently underway (Houston et al. 1983).

In contrast, Kuck (1977a) reported that reduction of Idaho's native Pahsimeroi Mountain goat herd resulted in a declining rate of kid production. Similarly, a drastically reduced herd of introduced goats in the Crazy Mountains, Montana, has never recovered despite discontinued hunting. This suggests there was little or no herd benefit from reduced density (J. Swenson, personal communication).

There has been large density independent variation in the productivities of mountain goat populations. Several studies have indicated negative impacts of deep and/or persistent winter snow upon rates of kid production (Adams and Bailey 1982, Swenson 1985, and references therein). These studies imply that nutrition and/or energy demands during gestation influence fetal or neonatal survival. Stevens (1983) suggested that summer forage conditions in Olympic National Park have determined rates of kid production measured a year later. This implies that summer nutrition influences pregnancy rates. While density independence is well documented in mountain goats, concurrent density dependence may be detected if the critical weather data are used in covariant analysis (Bailey 1984, 1986) and if several years' data are obtained (Adams and Bailey 1982, Swenson 1985).

Delayed density dependence has been detected in populations of several vertebrate species. Delayed density dependence can be caused by development of population or environmental characteristics at one level of density (or ecological density); and persistence of these characteristics after a change in density (or ecological density). Persisting characteristics that have been documented for some vertebrates, but not for mountain goats, are (Bailey 1984):

I. Persisting population characteristics

   A. age structure
   B. physical and physiological conditions of animals
   C. genetic constitution

II. Persisting environmental characteristics

   A. condition of habitat resources
   B. prevalence of predators
   C. prevalence of disease

Since density independence is to be expected in goat populations, and since responses of a population to a change in density may be delayed, a hypothesis of density dependence and a harvest strategy that assumes density dependence cannot be refuted without many years of data. Thus a management strategy based on this assumption should include a long-term commitment to the strategy and to relatively precise monitoring of the population and of weather.

<u>Harvesting the Annual Increment</u>: If the annual increase of a goat population can be measured or estimated from other population data, and if harvest does not distort population sex-age composition, then a number of goats equal to the annual increment can be harvested annually without reducing the base population. In practice, the annual population increment has been estimated from population counts (or estimates) and sex-age classifications made annually or less often. More conservative harvests may be based upon the numbers of animals counted (the known-minimum population), without estimating the numbers of goats unseen. Using these counts or population estimates, the annual population increment has been estimated (1) from the kid:adult ratio, (2) from the yearling:adult ratio, (3) from indicated rates of population growth in recent years, based on annual counts or population estimates, and (4) from population modeling based on field data and "reasonable" estimates of mortality rates. In these four methods, each subsequent method uses more field data and requires fewer risky assumptions about herd population dynamics.

Several studies have shown that kid production varies greatly among years according to weather conditions (see above citations). During 11 years on our study area, kid:adult ratios have varied between 10 and 62 kids per 100 adults, 2+ years old (mean = 42, S = 13.7). Limited data indicate that overwinter survival of kids into the yearling class can also be highly variable. During 10 years on our study area, survival of kids has varied between 42 and 85% (mean = 59, S = 14.2); and over 11 years yearling:adult ratios have ranged from 5-45 per 100 adults (mean = 26, S = 10.2). Consequently, annual population surveys with post-survey designation of harvest objectives would be best for a strategy of harvesting each annual increment. However annual surveys can be expensive, particularly with helicopters (classification of yearlings from fixed-wing craft is questionable), and harvest permits are often issued before summer population surveys in order to meet social, rather than biological, objectives.

Based on one or more of the above four methods, most management agencies have chosen to estimate annual increments in goat herds conservatively and to harvest conservatively. Strategies intended to maintain sizes of native herds have been to harvest 4-5% of the population estimate (Hall 1977, Kuck 1977b); to harvest 10% of the known-minimum summer population (Ballard 1977); and to harvest 5% of the known-minimum number of at least 40 adults and yearlings (Kuck 1986). For young, introduced herds, which have been more productive than native herds, strategies have been to harvest an average of 7% of the population estimate (Adams and Bailey 1982); and to harvest 12-16% of the known-minimum population (Swenson 1985).

All these strategies are based on averages from past experience with individual herds. There is no guarantee they will be successful in the future or in other herds. Using average population increment, based on past experience, as a basis for harvest objectives will result in population growth in half the years, and population decline in half the years--even if herd dynamics do not change. Well-documented density independent variation in goat herds is unpredictable. Therefore, if herds and harvests are to be maintained, either a conservative harvest strategy is appropriate, or there must be monitoring of herd trend and probably of herd composition, as a basis for frequent adjustments in harvest strategy (Smith 1984).

Replacive Harvest: When harvest is replacive (substitutes for natural mortality), harvest will not reduce a population. This concept is related to the concept of density dependent mortality in which harvest reduces a herd, but survival rates are greater for the remaining smaller population. Intuition suggests that harvest is least likely to be replacive when the number of animals harvested is quite large and when prime-age, rather than older, animals are harvested. Kuck (1977a) concluded that harvest of more than 12-18% (my calculations) of the known-minimum population of goats at Pahsimeroi Mountain was additive mortality because the population declined. However, the population decline could also have been due to documented declining kid production and to harvest of nannies, with consequent loss of kid production. There appear to be no data to support or refute the assumption that goat harvests can be replacive mortality.

Harvesting Males: In polygynous, sexually-dimorphic species, harvest of greater numbers of males vs. females is often prescribed. Since males breed several females, there can be excess males, not necessary for maximum reproduction. In addition, where the sexes are not segregated in the critical season, removal of males may allow females more access to habitat resources, thus favoring survival and reproductive success of females in a density dependent manner. Neither of these two possibilities has been tested with mountain goats. By contrast, harvesting females rather than males will not only reduce numbers, but also the reproductive rate of a herd (unless harvest is replacive within the adult female segment).

Since mountain goats are polygynous, it is likely that larger harvests can be sustained if males are emphasized, producing a population sex ratio slanted toward females. However there is little sexual dimorphism in goats and in some studies females have been more easily and frequently observed than have males (Foster 1982, Risenhoover and Bailey 1982). Consequently, there is a tendency to harvest many adult females. On our study area, 45% of the harvest during 1967-1979 was females (Adams 1981). Throughout Colorado, despite a (non-mandatory) hunter orientation program, 59% of the 41 goats harvested in 1985 were females. It was suggested that poor weather during the 1985 hunting season diminished hunters' ability or interest in seeking male goats. Montana has recently published a hunter-education pamphlet, encouraging goat hunters to seek and identify males.

Subpopulations: There have been few long-term studies of goat populations with numerous marked animals. In a few studies, individual goats have shown strong fidelity to their winter ranges (Smith 1976, Kuck 1977a, Rideout 1977); but on our Colorado Study area, some nannies have used different winter ranges in consecutive years. In some populations, goats are consistently seen on isolated mountaintops or cliff-outcrops, and the extent of movement between these isolated habitats is poorly known, if at all (Smith 1982). It is suggested that some goat herds consist of somewhat discrete geographic subpopulations, particularly in winter. Ideally, harvest strategies would be formulated and applied to each subpopulation. But these subpopulations and the amounts of movement of goats between them are unknown for most administrative game management units. Further, census units for goats tend to be large, and data from more than one subpopulation are often combined. When hunting-season access varies among subpopulations, some can be overharvested while others are underharvested.

Population Recovery: Selection of a maximum-harvest strategy, rather than a conservative strategy, presents some risk that a population of goats will be overharvested and drastically reduced. This could result from inadequate population data, from erroneous assumptions regarding population processes, from unexpected levels of harvest on females, or from geographic concentration of the harvest. The impact of overharvest is lessened if goat populations can recover quickly once harvest is curtailed.

Mountain goats have a relatively low biotic potential. Although twinning is not uncommon, most nannies do not reproduce until 3 years old. Recovery of a decimated herd may also be delayed by the chance occurrence of detrimental (density-independent) weather, or by a delayed density-dependent response (see above). In apparently good habitats, reduced goat populations have been able to recover rather quickly (Smith 1984, Swenson 1985). But other herds have recovered slowly (Kuck 1977a, and the Crazy Mountain herd in Montana). Reasons for slow population recovery might include poor habitats, high predator-prey ratios, slow replacement of breeding-age nannies, or inbreeding depression of herd performance.

Population Control

Control of exotic species is a dominant and appropriate goal in national parks. We should maintain several large and relatively complete natural ecosystems in North America. Otherwise, as we alter more land, ever more intensively, we will have no basis for comparison. One day, we will not be able to know what we have done to the continent. Nor will we know all our options for managing our environment. Consequently, in national parks the scientific values of ecosystems, kept as natural as possible, are at least as important as the recreational values.

With exotic mountain goats, the difficulty of population control in and near national parks will depend upon access to the herds, and upon public acceptance of control as a goal. Public acceptance of control will vary directly with public awareness and understanding of the scientific values of natural ecosystems. This awareness and understanding is currently poor. Control of mountain goats in parks will also depend upon a willingness of state agencies to harvest goats intensively near park boundaries.

Mountain goats may compete with bighorn sheep, but this potential competition has many complex components (Adams et al. 1982) and has not been demonstrated. Goats carry diseases that can infect other ungulates but transmission has not been verified for at least some diseases and the role of goats as reservoirs is little known.

MANAGEMENT AND RESEARCH NEEDS

Management

If goats are to be managed intensively, there is a need for more and better local information on population size or trend, herd composition, and movements and distribution of herd segments. If funds are not available for obtaining this information, a conservative harvest strategy is justified. However, replication of ground-based trend counts, so that precision can be evaluated, may not be expensive. Marking and reobserving some goats will be of great value. Marked goats may provide the basis for a census, may permit evaluation of possible bias in herd composition data, may identify subpopulations in need of separate management, and may indicate differences between males and females in distribution and exposure to hunting.

There is a need to educate hunters on the importance of harvesting males rather than females, and on identifying males in the field. The hunter-education pamphlet used in Montana should be considered for use in other states and provinces. Hunter orientation classes, held in areas with high densities of goat hunters, are desirable.

Control of hunter access is needed in many areas. This may involve road location, road closure or opening, and timing of the harvest in relation to road conditions. Either reduced or improved access could be desirable. Reduced access may avoid overexploitation, legal and illegal, of local populations. Improved access could distribute a limited harvest over more subpopulations, or could allow hunters more time to find and harvest male goats. Hunting-unit boundaries might be modified according to road locations in order to achieve a good distribution of a limited harvest across subpopulations within a herd.

Lastly, biologists need an experimental approach to management (Bailey 1982). The efficacies of harvest strategies should be evaluated continually with population monitoring. Adequate testing of a strategy will require at least several years' commitment to the strategy and to monitoring the results.

Research

Research on census methods, trend counts, and classification counts of goat populations may be done by management biologists or by research biologists. Most management today is based upon trend and classification counts. There is very little consideration of either the accuracy or the precision of these two types of data. Studies of factors affecting accuracy and precision are needed.

Mark-reobservation methods show promise for censusing local populations (Smith and Bovee 1984). Since only a small proportion of a goat herd can usually be marked, confidence limits for the population estimate, based on a single sample of the marked-unmarked ratio, will be large. However, confidence limits can be narrowed by observing several samples of the marked-unmarked ratio, and basing confidence limits on the variance of the several independent population estimates. If male goats are less observable than are females (Risenhoover and Bailey 1982), the sexes should be marked in proportion to their occurrence in the herd, or a biased population estimate will result.

We know very little about factors affecting pregnancy rates, natality, neonatal survival and overwinter kid survival in mountain goats. Weather factors and population density have been shown to be involved in several herds. But variations in pregnancy rates, and in fetal and neonatal survival have always been submerged in the measured end product: the kid-adult ratio observed in summer or autumn. Further, how do weather or density affect reproduction and kid survival? Do they influence nutrition? energy costs? social intolerance? distribution according to social status? Does social status of a nanny affect her performance? or performance of her offspring? We have barely begun to observe these factors in untreated goat herds. We can learn much more if we experimentally modify a population or its environment.

In particular, we need to study density-dependence in mountain goats. This can best be accomplished with a long-term commitment to the study, and experimental modification of population size. Such a commitment should not be wasted by measuring only a few population parameters, perhaps imprecisely. Animals should be marked. Parameters of reproduction and survival should be measured. Movements, distribution and social factors should be observed. Forage conditions and weather factors should be measured. Can we assume, as we have been, that diseases need not be evaluated? Hypotheses regarding all these factors in relation to density are implied in the literature. They should be tested in planned experiments.

CONCLUSION

Our knowledge-base to support almost all harvest strategies for mountain goats is weak. For many herds, a conservative strategy, as promoted by Chadwick (1983), seems appropriate. There are abundant opportunities for basic and applied research in goat population dynamics. These studies will be most fruitful if herd size or composition, or the herd environment, are experimentally manipulated in planned tests of specific hypotheses.

LITERATURE CITED

Adams, L. G. 1981. Ecology and population dynamics of mountain goats, Sheep Mountain-Gladstone Ridge, Colorado. M.S. Thesis. Colo. State Univ., Ft. Collins. 189pp.

________ and J. A. Bailey. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 46:1003-1009.

________, K. L. Risenhoover, and J. A. Bailey. 1982. Ecological relationships of mountain goats and Rocky Mountain bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:9-22.

Bailey, J. A. 1982. Implications of "Muddling Through" for wildlife management. Wildl. Soc. Bull. 10:363-369.

________. 1984. Principles of Wildlife Management. John Wiley and Sons, N.Y. 373pp.

________. 1986. Weather and Climate. In Inventory and Monitoring of Wildlife Habitat. U.S. Bur. Land Management. (in press)

________ and B. K. Johnson. 1977. Status of introduced mountain goats in the Sawatch Range of Colorado. Pp. 54-63 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

Ballard, W. 1977. Status and management of the mountain goat in Alaska. Pp. 15-23 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan thar in New Zealand. Ecology 51:53-72.

_______. 1976. Wildlife management and the dynamics of ungulate populations. Pp. 183-246 in T. H. Coker, ed., Applied Biology, Vol. 1. Academic Press, London.

_______. 1979. What is this thing called carrying capacity? Pp. 2-8 in M. S. Boyce and L. D. Hayden-Wing, eds., North American elk: ecology, behavior and management. Univ. Wyo. Press, Laramie. 294pp.

Chadwick, D. H. 1983. A Beast the Color of Winter. Sierra Club Books, San Francisco. 208pp.

Foster, B. R. 1977. Historical patterns of mountain goat harvest in British Columbia. Pp. 147-159 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

_______. 1982. Observability and habitat characteristics of the mountain goat (Oreamnos americanus) in west-central British Columbia. M.S. Thesis. Univ. British Columbia, Vancouver. 134pp.

Hall, W. K. 1977. Status and management of the Rocky Mountain goat, Oreamnos americanus, in the Province of Alberta. Pp. 8-14 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

Harris, R. B. 1986. Reliability of trend lines obtained from variable counts. J. Wildl. Manage. 50:165-171.

Houston, D. B. 1968. Ecosystems of national parks. Science 172:648-651.

_______. 1982. The Northern Yellowstone Elk. MacMillan Publ., NY. 474pp.

_______, B. Moorhead, E. Schreiner and R. Olson. 1983. Mountain goat ecology and management investigations, Olympic National Park. Nat. Park Service. 142pp.

Kuck, L. 1977a. The impact of hunting on Idaho's Pahsimeroi mountain goat herd. Pp. 114-125 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

_______. 1977b. Status and management of mountain goats in Idaho. Pp. 37-40 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

_______. 1986. Mountain goat hunting strategies in Idaho. Bienn. Symp. North. Wild Sheep and Goat Counc. 5: (this issue).

MacGregor, W. G. 1977. Status of mountain goats in British Columbia. Pp. 24-28 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

McCullough, D. R. 1979. The George Reserve Deer Herd. Univ. of Michigan Press. 271pp.

Rideout, C. B. 1977. Mountain goat home ranges in the Sapphire Mountains of Montana. Pp. 201-211 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp.

Risenhoover, K. L. and J. A. Bailey. 1982. Social dynamics of mountain goats in summer: implications for age ratios. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:364-373.

Smith, B. L. 1976. Ecology of Rocky Mountain goats in the Bitterroot Mountains, Montana. M.S. Thesis Univ. Montana, Missoula. 203pp.

Smith, C. A. 1984. Evaluation and management implications of long-term trends in coastal mountain goat populations in southeast Alaska. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:395-424.

_______ and K. J. Raedeke. 1982. Group size and movements of a dispersed, low density goat population, with comments on inbreeding and human impacts. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:54-67.

_______ and K. T. Bovee. 1984. A mark-recapture census and density estimate for a coastal mountain goat population. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:487-498.

Stevens, V. 1983. The dynamics of dispersal in an introduced mountain goat population. Ph.D. Thesis. Univ. Washington, Seattle. 202pp.

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

Williams, E. S. and C. P. Hibler. 1982. Survey of Colorado and Wyoming bighorn sheep and mountain goats for paratuberculosis. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:173-187.