Bienn. Symp. North. Wild Sheep and Goat Counc. 10:26-34.

AN ANALYSIS OF POTENTIAL FACTORS RESPONSIBLE FOR THE DECLINE IN BIGHORNS IN THE TOM MINER BASIN

KRISTIN LEGG, Biology Department, Montana State University, Bozeman, MT 59717
LYNN R. IRBY, Biology Department, Montana State University, Bozeman, MT 59717
TOM LEMPKE, Montana Department of Fish, Wildlife, and Parks, Livingston, MT 59047

Abstract: The Tom Miner Basin bighorn sheep (*Ovis canadensis canadensis*) population is part of the upper Yellowstone metapopulation and declined from more than 100 sheep in the late 1970s to around 20 sheep in the 1990s. We identified 9 possible factors that may have contributed this decline: 1) competition for forage with livestock; 2) interactions between sheep and resident elk (*Cervus elaphus*); 3) interactions between sheep and colonizing mountain goats (*Oreamnos americanus*); 4) predation; 5) unfavorable weather; 6) hunting or poaching; 7) disease outbreaks; 8) inbreeding suppression; and 9) intraspecific competition. Using a variety of data and fragmented information, we systematically examined evidence supporting each factor. We eliminated most possibilities and were left with predation and weather as the most likely causes with disease as a distant third.

Determining why populations decline is, unfortunately, a major activity of biologists who work with Rocky Mountain bighorn sheep. In some cases, the proximal reasons are obvious (Buechner 1960, Onderka and Wishart 1984, Meagher 1982) and arguments center on ultimate or distal causation. In other cases, no good proximal reason is apparent (Roy 1992, Irby unpubl.). In most unexplained declines, neither potential causal factors nor herd status were monitored closely enough to unambiguously determine which factors were important. However, there are often fragmentary data sets are available which could be used to eliminate many factors and allow biologists to focus their efforts on the remaining factors. We have attempted to integrate all available information to assess the likelihood of the potential explanations for an unexplained decline in one herd unit in the Upper Yellowstone River Valley of Montana. We hope this approach will encourage other biologists dealing with bighorn population dynamics to take advantage of bits of information they have available and the process of deduction to narrow the range of possibilities when dealing with population declines.

The Tom Miner bighorn population is part of the Upper Yellowstone bighorn metapopulation (Fiedler and Jain 1992, Harrison 1993). Sheep in this metapopulation were historically distributed throughout the Gallatin and Abasaroka Mountains of southern Montana in a series of semi-independent herds. Genetic flow was probably maintained by movements of sheep among subpopulations while individual subpopulations likely increased or decreased in response to local environmental conditions and stochastic events. When Europeans settled the area in the mid 19th century, humans eliminated most subpopulations through hunting, disease transmitted by livestock, and/or habitat changes precipitated by settlement (Buechner 1960). Regulation of hunting, changing land use patterns, and better management of livestock allowed survivors to increase and recolonize some ranges (Keating 1982). Monitoring programs in the area showed general increases in occupied range and numbers during the 1960s and 1970s (Keating 1982, Montana Fish, Wildlife, and Parks, unpubl., Meagher, unpubl.). In the 1980s, a *Chlamydia* outbreak in Yellowstone National Park (Meagher 1982) severely reduced one or more herds in Yellowstone National Park; transplants and immigration increased the range of sheep in the Absaroka Mountains and possibly in parts of the Gallatin Range (Swenson, unpubl., Meagher unpubl.); the herds associated with Cinnabar Mountain and the northern Gallatin Range apparently declined; and herds in the Tom Miner area declined sharply (Irby unpubl., Swenson and Alt unpubl.). By the 1990s, herds in Yellowstone National Park showed some signs of recovery, but counts of sheep in the Tom Miner Basin continued to decline.

In 1994, the Northern Yellowstone Cooperative Wildlife Working Group, consisting of biologists representing the Montana Department of Fish, Wildlife, and Parks, the Gallatin National Forest, and Yellowstone National Park, asked us to assess the status of bighorn sheep in the Tom Miner Basin area. Through their support, funding from the Welder Wildlife Foundation and the Foundation for North American Wild Sheep, and the cooperation of private and public land managers in the Tom Miner Basin area, we monitored the population, located and organized all existing information related to the Tom Miner population, filled gaps in information where possible, and attempted to assess the probability that of each of 9 factors could be responsible for the suspected decline. The factors we identified were: 1) competition for forage with livestock; 2) interactions between sheep and resident elk; 3) interactions between sheep and colonizing mountain goats; 4) predation; 5) unfavorable weather; 6) hunting or poaching; 7) disease outbreaks; 8) inbreeding suppression; and 9) intraspecific competition. All of these factors have been proposed as explanations for bighorn declines in one or more herds (Oldemeyer et al. 1971, McCollough et al 1980, Skiba and Schmidt 1982, Heimer et al 1986, Harrison and Hebert 1988, Haas 1989, Varley 1994).

STUDY AREA

The Tom Miner Basin (Fig. 1) is located in the Upper Yellowstone River Valley 26 km north of Gardiner, Montana and borders the northwest corner of Yellowstone National Park. Winter ranges are scattered over 150 km^2 in and adjacent to the Basin. Elevations range from 1500 to >3000 m. Winter ranges in the Basin are typically grass-covered southwest-facing slopes at elevations >2000 m. For comparison, winter ranges used by adjacent sub-populations (Point of Rocks, Cinnabar Mountain, and Mount Everts) are at lower elevations (1500-2000 m), drier, and in grass or sage-steppe communities. Summer ranges for all herds are ridge tops and alpine meadows >2000 m in elevation.

Land ownership in the study area was a mix of

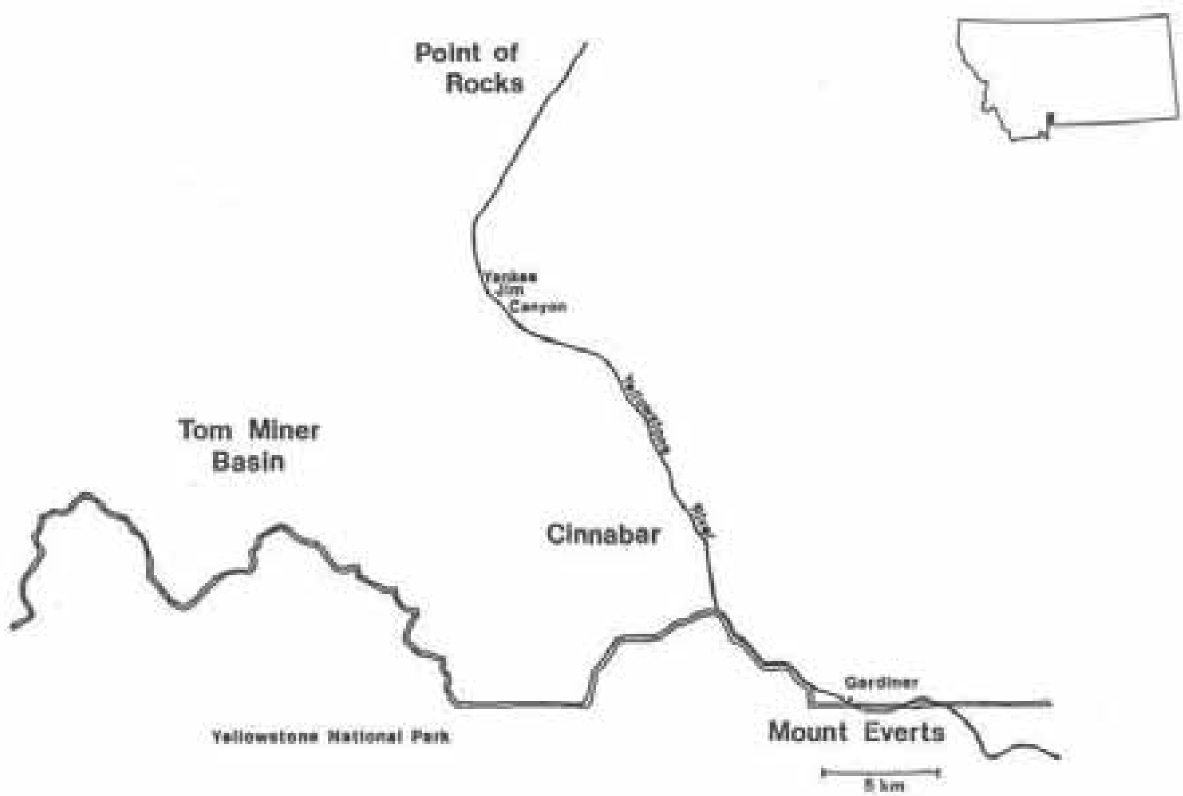

Figure 1. The locations of the Tom Miner Basin, Point of Rocks, Cinnabar and Mount Everts winter ranges in the upper Yellowstone River Valley.

private, state, and federal (primarily Yellowstone National Park [YNP] and Gallatin National Forest [GNF]). Wintering areas in the Tom Miner Basin are mostly on Forest Service land, but public access in the Basin is limited to a few trailheads with no direct vehicular access. The Point of Rocks winter range is on private land, but a county road crosses the range. The Cinnabar Mountain winter range includes private and Forest Service lands and easy vehicular access via a county road. Wintering areas used by the Mount Everts herd are in Yellowstone National Park. Public access is allowed but strictly controlled.

METHODS

We have used a diverse set of data for this analysis. Population trend information for sheep, other native ungulates, and livestock was obtained from MDFWP surveys, the Cooperative Agency sheep counts, YNP (Meagher, unpubl.), GNF files, surveys by personnel from Montana State University (Keating 1982, Irby unpubl.), and fieldwork conducted during this study (Legg 1996). Information on population linkages, and the subsequent likelihood of isolation leading to inbreeding, was obtained from Keating (1982), Irby et al. (1986), Meagher (unpubl.), and Legg (1996). Information on hunting was obtained from MDFWP files. The influence of predation was assessed from studies by Murphy (unpubl.) and observations during fieldwork in 1994-96. Data on vegetation status and relative abundance of ungulates at specific sites were obtained from an unpublished report prepared by Grunnigen (USFS, unpubl., 1975) and fieldwork we conducted in 1995-96 (Legg 1996).

During the 1994 and 1995 summer field seasons, we remeasured 39 fecal pellet transects and 5 vegetation condition and trend transects measured in 1975 in Tom Miner Basin (Grunnigen, USFS, unpubl. 1975). We followed the U.S. Forest Service techniques applied in 1975 as closely as possible to insure compatibility between the 1975 and 1994-95 ungulate fecal counts, vegetation coverage estimates, and plant species composition descriptions. The transects were completed during July through August in all years and were located in areas of high winter sheep use in 1975. The transects were perpendicular to the contours of the open slopes in the southwest end of Tom Miner Basin. We counted all new pellet groups from bighorn sheep, elk, cattle, and other wild ungulates in each transect. New pellets were determined by color, sheen, and texture. Each transect consisted of 10 81-m^2 circles. In 1994-95, we measured additional fecal pellet transects in the Tom Miner Basin to cover areas with a wider-range of cattle grazing pressure and open grasslands considered adequate for sheep winter range but where bighorns were not known to winter. These transects followed the same sampling technique as Grunnigen used in 1975 but were spaced at 73-m intervals in elevation from the bottom to top of each site. The number of transects per site varied from 2 to 4 depending upon the meadow's size. The distance to escape terrain was recorded at each transect site (<100 m or >100 m) from escape terrain to determine the strength of association between and use of areas by sheep, elk, and cattle.

We repeated the 5 vegetation and condition and trend transects measured by Grunnigen in 1975 to assess changes in vegetation occurring in Tom Miner Basin over the past 20 years. Grunnigen (USFS, unpubl., 1975) used pace-line transects as described in 1975 USFS range evaluation manual to analyze range condition. He located transects in areas that "appeared typical of the unit as a whole." His transects paralleled ridge lines and the dominant ground cover in a 2-cm loop was recorded at 50 points per transect. The ground cover types included bare soil, erosion pavement, rock, litter, moss, and individual plant species in 3 desirability classes (desirable, intermediate, or least desirable) (F. Grunnigen, USFS, unpubl. 1975). The overall vegetation quality was rated on a scale from very poor to excellent.

The probability that a decline in sheep numbers occurred was assessed by assembling all population survey data and examining their consistency. The probabilities of each factor contributing to the decline was assessed via statistical tests where possible or via comparisons of population trends in subpopulations that had similar or greater exposure to the same factor at the same time.

RESULTS

Documenting the decline. -- MDFWP surveys of the Tom Miner area from 1979 - 1996 show a high of 115 sheep and a low of 15 (Fig. 2). Using years where we could separate counts into Tom Miner Basin winter ranges and the Point of Rocks winter range, a major decline evidently occurred between 1983 and 1984 in wintering areas within the Basin (Grizzly Creek, Sawtooth, Miner Campground, Bighorn Peak, Sheep Mountain). Counts did not delineate the Point of Rocks area as a separate unit until 1984. Extensive ground surveys in 1994-96 in the Tom Miner area did not reveal groups of sheep that were likely to have been missed in winter surveys. Based on these information sources, we conclude that the population in the Basin declined from a minimum of 115 (based on extensive fixed wing counts) in the 1970s to <20 in the mid 1990s (based on intensive helicopter surveys).

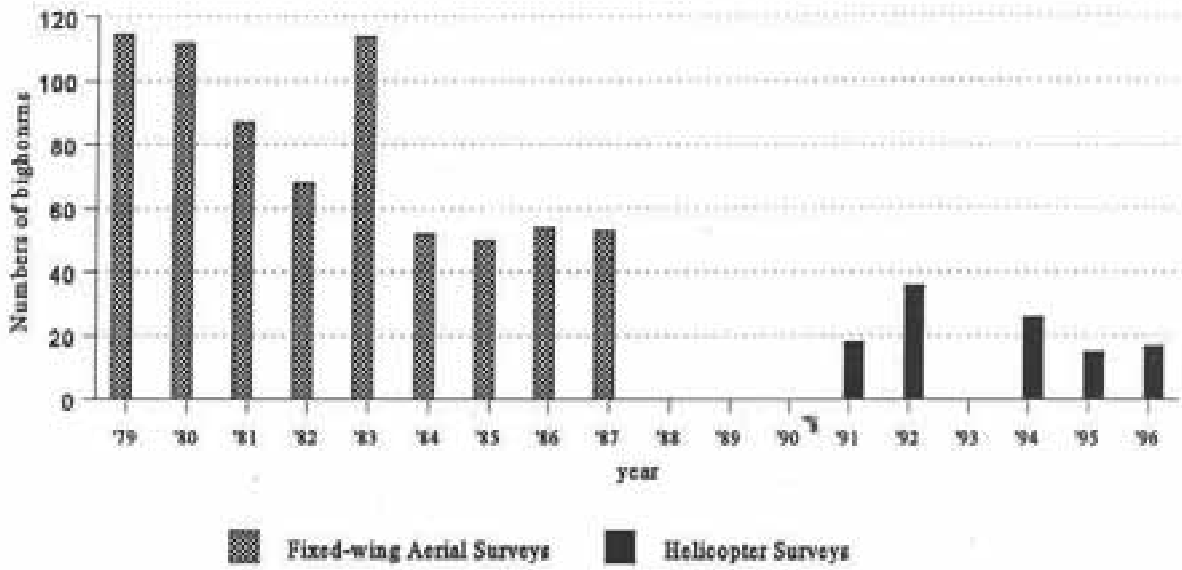

Figure 2. Maximum number of sheep counted in Tom Miner Basin in the years 1979-1996, the survey was not completed in 1988, 1989, 1990, and 1993. In 1979-1987 counts were from a fixed-wing aircraft (Irby) and in 1991-1996 surveys were from a helicopter (Lemke).

Potential factors in the decline

Competition for forage with livestock. -- Domestic sheep numbers in the Tom Miner Basin were high during the early 1900s through the 1950s (Keating 1982). No commercial herds were in the Basin at least since the mid 1970s. Cattle replaced sheep as the dominant livestock in the mid 20th century. Fecal counts on sites used by bighorns in the Basin suggested low use by cattle in 1975 and almost no use in 1994-95 (Table 1). Vegetation composition, vegetaion trend, and soil condition and trend at sites in the Basin indicated vegetation was in good condition in 1975 and had not changed by 1994 (Table 2).

Interactions with elk. -- Trend counts from MDFWP during 1990-1995 show variable elk numbers in the Tom Miner Basin (Fig. 3), but the Northern Yellowstone elk herd has been steadily increasing since the mid 70s expanding into ranges north of YNP (Singer 1991). Fecal counts at sites used by bighorns in 1975 indicated elk used 26 of the 39 sites, and elk used all sites in 1994 and 1995. Comparisons between elk and sheep fecal density at these sites in 1975 and 1995 indicated a 40% increase in elk pellets/ha and an 80% decline in sheep pellets/ha. Pellet counts at the complete array of sites measured in 1994 and 1995 indicated that elk and sheep distributions were based on habitat features. The increase in elk pellet density between 1975 and 1994 was not likely to have been directly related to the decrease in sheep pellet density. Elk pellets were associated with sites away from escape terrain that sheep evidently avoided (Table 3). Vegetation condition at sites used heavily by sheep, elk, or both species were classified as "fair to excellent," and we found no difference in the frequency of "good" to "excellent" quality vegetation classifications among those categories or between those categories and sites used lightly by all ungulates.

Interactions with mountain goats. -- Mountain goats were first reported in the Tom Miner Basin in 1990. By 1994, observations of goats were common, and in 1995, we sited a minimum of 13 goats in the basin. The goats were seldom seen within 500 m of sheep in summer and never sighted on sites used heavily by sheep in winter.

Predation. -- Potential predators of sheep in the Tom Miner Basin include grizzly bears (*Ursus arctos horribulus*), black bears (*Ursus arctos americanus*), mountain lions *(Felis concolor)*, coyotes (*Canis latrans*), and golden eagles (*Aquila chrysaitos*). Population trends of these species are unknown, but sight-

Table 1. Mean pellet groups per acre for cattle and bighorns in areas with bighorn use and areas of no bighorn use in 1975, 1994, and 1995.

	No Bighorn Use					Bighorn Use				
Year	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Cattle 1975	20	117.3	127.2	0.0	420.0	19	39.6	57.7	0.0	217.2
Bighorn 1975	20	0.0				19	155.2	165.3	4.9	509.6
Cattle 1994	26	46.0	111.6	0.0	408.7	13	6.7	22.8	0.0	82.6
Bighorn 1994	26	0.0				13	37.5	42.5	4.4	160.9
Cattle 1995	23	6.6	17.4	0.0	69.6	16	3.5	14.3	0.0	56.5
Bighorn 1995	23	0.0				16	39.7	69.5	4.4	287.0

Table 2. Vegetation and soil condition and trend measures in 1975 and 1994 from transects completed in Tom Miner Basin. Condition was rated on a scale of very poor to excellent (very poor, poor, fair, good, excellent) and trend was either up or down based on USFS description for range analysis.

Transect	Vegetation Cond		Soil Condition		Vegetation Trend		Soil Trend	
	1975	1994	1975	1994	1975	1994	1975	1994
1	fair	fair	fair	fair	down	up	down	up
2	good	good	excel.	excel.	up	up	up	up
3	fair	good	excel.	excel.	up	up	up	up
4	fair	good	good	good	up	up	up	up
5	fair	good	excel.	excel.	up	up	down	up

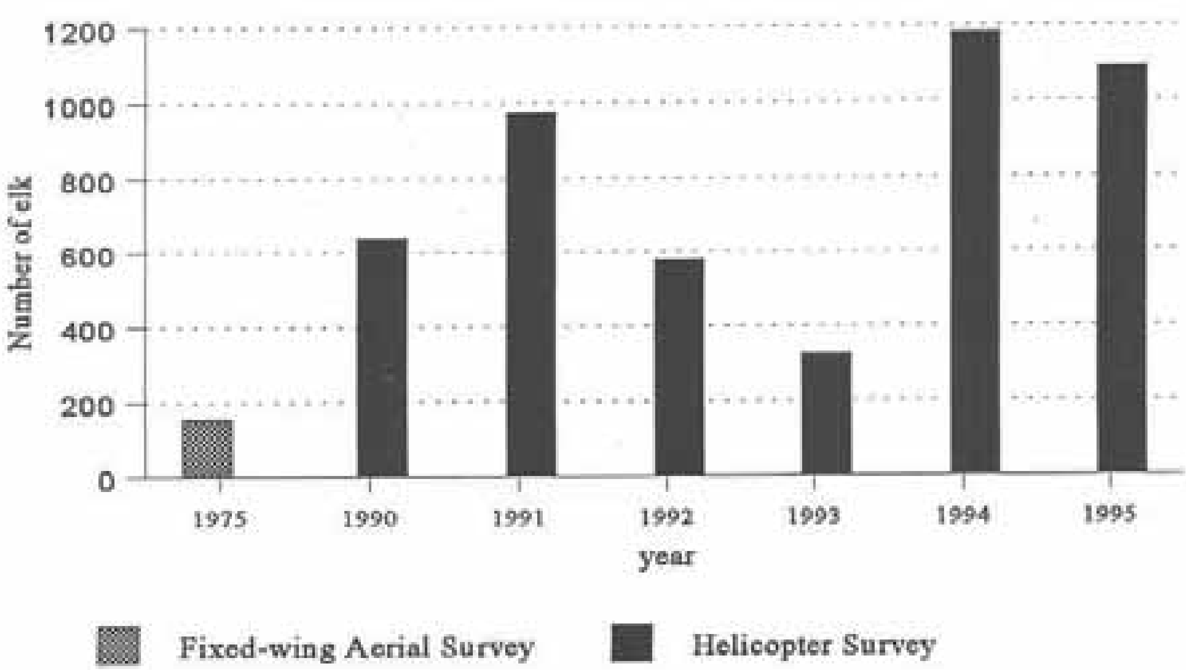

Figure 3. Number elk in Tom Miner Basin from the MDFWP count in 1975 (Constan) and annual winter surveys from 1990 to1995 (Lemke).

Table 3. Mean pellets per acre for bighorn, elk, and cattle at ≤100 meters and >100 meters to escape terrain in 1994/1995 combined.

Species	≤ 100 meters			> 100 meters		
	N	Mean	SD	N	Mean	SD
Bighorn	21	15.91	20.38	34	.52	1.04
Elk	21	34.21	34.44	34	52.56	43.85
Cattle	21	1.48	3.67	34	27.79	48.42

ings of grizzly bears have increased in the Basin over the past 20 years. Lions have increased over much of Montana in the same period (Aune 1991, Riley 1993). Coyotes are reported to have increased in many areas of Montana following reductions in predator control efforts in the 1970s and falling fur prices in the 1980s (Giddings pers. commun.). Verified instances of predation in the Basin are rare, but 3 radiocollared sheep and 2-3 unmarked sheep were reported as probable predator kills in the Basin in the early 1980s (Irby unpubl.) , and Murphy (in prep.) recorded 4 kills of sheep in his study of lions in northwestern YNP during 1990-94. During fieldwork in 1994-96, we observed 3 sheep mortalities: 1 ewe killed by a lion, 1 ram probably killed by a predator, and 1 ewe death due to an unknown cause.

Evidence against predation as a factor in the decline is limited to comparisons of population trends in other herds. Sheep associated with the Mount Everts winter range in YNP are probably exposed to as many or more predators than those in the Tom Miner Basin, but the precipitous drop in this population was due to disease, and the population has recovered despite predation. Cinnabar Mountain and Point of Rocks probably have similar predator complexes (although the presence of human activities may limit some predatory activity) but did not experience a sharp decline at the same time as the Tom Miner herd declined.

Weather. -- The high elevations of wintering areas in the Tom Miner Basin insure greater snow depth and longer snow coverage than in wintering areas at lower elevations in the metapopulation. However, during the 10 years prior to the decline, winter severity was severe in 6 years, average for 1 year, and mild in 3 years. During the decline in 1983-84, the winter was mild, and after the decline only 3 of 11 winters were classified as severe and 8 winters were classified as mild (Farnes, unpubl.). If lamb:ewe ratios are a valid index to impacts of weather on populations (i.e. assuming lambs are more vulnerable than adults to weather related stress), ratios recorded in the Tom Miner in summer and winter were not consistently lower than in other herds in the metapopulation in years bracketing the decline (Irby 1994). The potential for catastrophic death due to avalanches is higher in the Tom Miner Basin than in other lower winter ranges, but no evidence has surfaced of mass death despite our extensive searches during the summers of 1994 and 1995 and annual heavy traffic by hunters throughout sheep range in the Basin every September. The highest number of dead sheep recorded at 1 site was 3 in 1981, and the deaths were attributed to predation (Irby unpubl.).

Drought could also influence population dynamics. Twelve of the last 20 years have had snow levels below normal, but below normal snow levels should favor sheep at high elevation by reducing snow cover on winter range. During the decline in 1983 to 1984 the annual precipitation was below normal in both years (NOAA 1983 and 1984) suggesting that drought could have affected summer ranges.

Human-induced mortality. -- The bighorn hunting season in the Tom Miner Basin is one of the few "open" sheep hunts in Montana with 50-125 valid licenses sold per year during the past 20 years. Quotas and hunting season length have been reduced in response to perceived declines in numbers of sheep, but legal mortality is unlikely to have produced the precipitous decline of the mid-80s. Legal sheep hunting in the Tom Miner Basin is restricted to adult males and is closely monitored. Annual harvest has varied from 3-9 animals (MDFWP unpubl., Irby et al. 1989) with no reported kills of females. Ram: ewe ratios have remained high before and after the years when the decline took place, and radiotelemetry studies in the 1980s suggest that most adult males escape harvest (Irby et al. 1989).

No illegal harvest of females has been reported in the Tom Miner Basin (MDFWP, Ann. Rep), and females are unlikely to attract much attention from poachers in a species in which large horns are the dominant incentives for illegal kills. Poachers are not likely to be caught (Vilkitis 1968, Pursley 1977), but the restricted access across private property and the steep, unroaded terrains in the Basin probably limit poaching during most of the year. Poaching during the hunting season would likely be reported by other hunters. Herds in the metapopulation that are much more accessible to poachers do not exhibit behavioral or population characteristics associated with heavy poaching (Irby et al. 1989).

Other human-induced mortality types (vehicle collisions, kills by pets, poison, etc.) are unlikely to be important in the Tom Miner Basin. Access is severely restricted by private property with no roads passing through sheep range, and human presence on sheep range is limited to light use by hikers and horseback riders.

Disease. -- Given the high number of dieoffs attributed to disease, this factor was our initial first choice. However, we have not located any information that implicates it. The *Chlamydia* outbreak in YNP (Meagher 1982) roughly corresponds to the decline in the Tom Miner Basin. However, no sheep were ever observed with the symptoms in the Tom Miner Basin or in the Cinnabar Mountain herd a population much more closely linked to YNP spatially and by interchange of individuals (Irby et al. 1989). Poor physical condition and coughing, symptoms associated with pneumonia-complex dieoffs, have been observed in the Cinnabar Mountain and Mount Everts herds, but never in the Tom Miner herd. During the 1977-96 period, no epizootics followed observations of coughing animals in any herd in the complex. Scabies and eczema (probably mechanically induced soremouth that appeared during a winter when snow depth forced sheep to feed extensively on sagebrush) have occasionally been observed in individuals from the Cinnabar herd, but no major dieoffs occurred. Contact with domestic sheep occurred historically in the Tom Miner Basin, but the only commercial herd maintained in the area was in range occupied by sheep in the Cinnabar herd during 1983-93. No acute dieoffs occurred. Low lamb: ewe ratios in many years in all herds could indicate disease in lambs, but we have never been able to sample tissue from lambs on summer range to verify this possibility.

Inbreeding suppression. -- We were unable to analyze tissue samples to determine relative heterozygosity in sheep from the Tom Miner Basin. Harvest data indicate that rams are relatively small, a possible indication of inbreeding (Stewart and Butts 1982, Fitzsimmon et al 1995) and that the population in the Basin is below the theoretical number required to minimize loss of genetic variability (Fitzsimmon et al 1995). At the time of the dieoff, however, the herd exceeded 100 individuals, and radiotelemetry studies (Irby et al. 1986, Legg 1996) show genetic linkages are likely between most subpopulations we have observed. Males from Cinnabar have been located in the Mount Everts and Tom Miner winter ranges. Ewes from Point of Rocks were observed on the Cinnabar winter range during the breeding season, and ewes from Cinnabar have visited the Mount Everts winter range. In the late 1970s, numbers in these herds probably exceeded 500 animals. Inbreeding conceivably could have affected recovery but probably was not a factor in the initial decline.

Intraspecific competition. -- If sheep in the Tom Miner Basin are restricted to small, favorable winter range sites, excessive use of these sites could reduce quality or quantity of vegetation. The limited winter range could lead to population declines that are due to direct or indirect effects of intraspecific competition. This possibility implies that vegetation composition on heavily used sites should change over time and productivity of the herd should decline. Data from 1975 and 1994-95 indicate no change or a slight improvement in range condition on sites heavily used by sheep in 1975 (Table 2). Lamb:ewe ratios varied markedly in surveys conducted in the Tom Miner Basin (Table 4), but data do not indicate a steady decline prior to the years when we assume the population crashed or any sign of a consistent recovery following the decline.

DISCUSSION

We systematically examined all evidence supporting 9 factors that could have lead to a decline in the Tom Miner Basin bighorn population. The factors we considered (1) competition for forage with livestock; 2) interactions between sheep and elk; 3) interactions between sheep and mountain goats; 4) predation; 5) unfavorable weather; 6) hunting or poaching; 7) disease outbreaks; 8) inbreeding suppression; and 9) intraspecific competition) are obvious choices based on the literature on bighorns. Although our data base was fragmentary, we could take advantage of fragmented data to assess each factor systematically. The obvious choices for blame soon became less obvious. Disease, the number one villain in sheep biology today, could not be eliminated, but we did not find strong evidence to support its role. Competition with livestock, another trendy explanation for problems with bighorns, does not seem important in this situation. Elk are routinely blamed for everything in the Northern Yellowstone area, but we could not establish a causal link between increases in elk and decreases in sheep. Mountain goat expansion from introductions in the Absaroka Range is also a worry to some biologists in the Yellowstone

Table 4. Lamb: Ewe ratios for the Mount Everts, Cinnabar Mountain, Tom Miner, and Point of Rocks winter ranges from 1984 to 1995 based on highest counts per class recorded during ground and helicopter surveys in November - April.

Year	Mount Everts			Cinnabar			Tom Miner			Point of Rocks		
	ewe	lamb	ratio	ewe	lamb	ratio	ewe	lamb	ratio	ewe	lamb	ratio
1984	40	8	20	21	5	24	10	8	80			
1985	15	5	33	44	18	41	26	7	27	15	5	33
1986	20	8	40	46	15	33	28	6	21	14	6	43
1987	10	5	50	47	9	19	37	18	49	3	2	67
1988	9	3	33	44	17	39	9	2	22	4	3	75
1989	14	1	7	30	4	13	18	0	0			
1990	18	4	22	34	2	6	14	2	14	11	3	27
1991	34	7	21	40	9	23	18	5	28	12	3	25
1992	17	2	12	16	3	11						
1993	32	9	28	31	5	16	16	4	25	4	0	0
1994	21	12	57	23	7	30	15	2	13	18	3	17
1995	35	7	20	20	6	30	13	1	23	12	3	25

area, but any impacts the goats may have are for the future. Overgrazing in local sites where sheep are forced to winter would be an intuitively appealing explanation, but available data just do not support this hypothesis.

New technology has revived our interest in genetics, and there is a tendency to blame many problems in small and fragmented homozygous populations on inbreeding (Stewart and Butts 1982, Berger 1990, Fitzsimmons et al. 1995). However, the metapopulation in the Upper Yellowstone probably has as good a chance of maintaining maximum heterozygosity as any bighorn herd in North America, and the decline in the Tom Miner population occurred when the metapopulation was close to historic high numbers. Large population size did not protect the herds comprising the metapopulation from declines.

Urbanization of the U.S. population and campaigns by animal rights groups have produced a surge in opposition to hunting, especially when hunting is directed toward relatively uncommon animals with excess trophy appeal (Horn 1992). Research suggests that controlled hunting could have negative impacts on bighorns (Heimer et al 1984, Fitzsimmons et al. 1995). Although biologists may be correctly identifying hunting impacts on some herds, the decline in the Tom Miner Basin does not fit the pattern expected from hunting impacts, legal or illegal (Irby et al 1989).

The two most likely explanations for the decline have been reduced to weather and predators with disease still lingering in the background. Sheep in the Tom Miner Basin must deal with extremely severe winter weather conditions. Their population buildup, which evidently occurred in the 1960s and early 1970s possibly coincident with reductions in domestic sheep in the area, occurred under more severe winter weather than their subsequent decline (Farnes, unpubl.) Drought patterns in the 1980s came about during and after their decline. Although, it is not obvious how reduced rainfall at an elevation that has too short a growing season to effectively utilize moisture in a dry year could impact forage quantity or quality, the impacts of drought on recovery should be investigated.

Predation is also a factor that deserves greater study. Murie's (1944) research on Dall sheep may have colored our view of the vulnerability of sheep to predators. Grizzly bears in Yellowstone have learned to kill elk effectively and potentially could take sheep. Bears could also influence kill rates of far more effective sheep predators, lions, by forcing them off kills and increasing the lion's overall predation rate (Murphy in press). Increases in lion kill rates and lion numbers (Aune 1991, Riley 1993) with rising elk numbers in the Tom Miner area could increase lion density and effectively raise the number of predators that intentionally or incidentally kill sheep. We observed several coyotes in sheep habitats in the Basin indicating reduced pressure on their populations due to reductions in predator control and fur harvest may have influenced them to use areas where they were once uncommon. Wolves generally prefer to hunt in less precipitous terrain than like the sheep range in the Tom Miner Basin (Murie 1944, Pletcher unpubl.), but one group of wolves released in YNP has frequented the upper drainages in Tom Miner Basin. The wolves were possibly drawn by the abundant elk and may become effective predators on sheep - at least in the short term when sheep have not been exposed to wolves for 50 years.

LITERATURE CITED

Aune, K. E. 1991. Increasing lion populations and human-lion imteractions in Montana. Human-Mountain lion Iteractions Symposium and Workshop. Denver. 114pp.

Berger, J. 1990. Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conserv. Biol. 4:91-98.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monographs 4. 174pp.

Fiedler, P. L., and S.K. Jain, Ed. 1992. Conservation Biology: The theory and practice of nature conservation preservation and management. Chapman and Hall, New York, New York. 507pp.

Fitzsimmons, N. N., S. W. Buskirk, and M. H. Smith. 1995. Population history, genetic variability, and horn growth in bighorn sheep. Conserv. Biol. 9: 314-323.

Haas, C. C. 1989. Bighorn lamb mortality, predation, inbreeding, and population effects. Can. Journ. Zoo. 67: 699-705.

Harrison, S., and D. Hebert. 1988. Selective predation by cougars within the Junction Wildlife Management Area. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:292-306.

Harrison, S. 1993. Metapopulations and Conservation. Pages 111 - 128 *in* P.J. Edwards, R.M. May, and N.R. Webb, eds. Large - scale ecology and conservation biology. Blackwell Sci. Publ., Oxford. 387pp.

Heimer, W.E., S.M. Watson, and T. C. Smith III. 1986. Excess Ram Mortality in a heavily hunted dall sheep population. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:424-432.

Horn, W. R. 1992. Slings and arrows. Governor's Symp. On N. America's Hunting Heritage. Bozeman, MT. pp 108 - 115.

Irby, L. R. 1994. Utility of summer fixed wing aerial surveys in predicting lamb:ewe ratios observed on winter range. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:51-55.

______, J. E. Swenson, and S. T. Stewart. 1986. Management of bighorn sheep to optimize hunter opportunity, trophy production, and availability for nonconsumptive uses. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:113-127.

______, J. E. Swenson, and S. T. Stewart. 1989. Two views of the impacts of poaching on bighorn in the upper Yellowstone valley, Montana, USA. Biol. Conserv. 47:259-269.

Keating, K. A. 1982. Population ecology of Rocky Mountain bighorn sheep in the upper Yellowstone drainage, Montana/ Wyoming. M.S. Thesis, Montana State Univ., Bozeman. 79pp.

Legg, K. L. 1996. Movements and habitat use of bighorn sheep along the upper Yellowstone River valley, Montana. M.S. Thesis, Montana State Univ., Bozeman. 72pp.

McCollough, S. A., A. V. Cooperrider, and J. A. Bailey. 1980. Impacts of cattle grazing on bighorn sheep habitat at Trickle Mountain, Colorado. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:42-59.

Meagher, M. 1982. An outbreak of pinkeye in bighorn sheep, Yellowstone National Park: A preliminary report. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:198-201.

Murie, A. 1944. The wolves of Mount Mckinley. Washington, U.S. Print. Off. 238 pp.

NOAA. 1983-1984. Climatological data: Montana, annual summaries. National Oceanographic and Atmospheric Administration, Asheville, N.C.

Onderka, D. K., and W. D. Wishart. 1984. A major bighorn die-off from pneumonia in southern Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:356-363.

Oldemeyer, J.L., W.J. Barmore, and D.L. Gilbert. 1971. Winter ecology of bighorn sheep in Yellowstone National Park. Journ. Wild. Biol. 35:257-269.

Pursley, D. 1977. Illegal harvest of big game during closed season. Proc. Western Assoc. Game and Fish Comm. 57:61-71.

Riley, S. J. 1993. Cougars in Montana: A review of biology and management and a plan for the future. Montana Dept. Fish, Wildlife, and Parks, Helena. 28pp.

Roy, J. L. 1992. Ecology of reintroduced Rocky Mountain bighorn sheep following two transplants in the southern Madison Range, Montana. Masters Thesis, Montana State Univ., Bozeman. 102pp.

Singer, F. J. 1991. The ungulate prey base for wolves in Yellowstone National Park in The Greater Yellowstone Ecosystem: redefining Americas wilderness Heritage. R. B. Keiter and M. S. Boyce, Eds. Yale University Press. pp. 323-348.

Skiba, G. T., and J. L. Schmidt. 1982. Inbreeding in bighorn sheep: A case study. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:43-53.

Stewart, S. T., and and T. W. Butts. 1982. Horn growth as an index to levels of inbreeding in Bighorn sheep. Bien. Symp. North. Wild Sheep and Goat Counc. 3:68-82.

Varley, N. C. 1994. Summer - Fall habitat use and fall diets of mountain goats and bighorn sheep in the Absorka Range, Montana. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:131-138.

Vilkitis, J. R., and T. W. Butts. 1982. Characteristics of bigh game visitorsa nd extent of their activity in Idaho. Masters Thesis, Univ. Idaho, Moscow.