

EVALUATION OF LUNGWORM, NUTRITION, AND PREDATION AS FACTORS LIMITING RECOVERY OF THE STILLWATER BIGHORN SHEEP HERD, MONTANA

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Abstract: The Stillwater bighorn sheep herd is currently at a low of approximately 30 animals. From November 1991 to August 1993, lungworm levels (*Protostrongylus* spp.), nutrition, and predation were evaluated on the winter range in relation to the recovery of the Stillwater bighorn herd. A total of 259 fecal pellet groups was collected and analyzed for lungworm larvae. Although during both years, the prevalence of lungworm larvae increased in the spring to 60% or more, the average level of infection suggested that lungworm does not play a significant role in limiting the herd. Fenbendazole medicated salt, as administered in the last four years, appeared to have been effective in controlling protostrongylid lungworm numbers. Fecal pellets were analyzed for nitrogen content as an index of nutrition. Results suggest that nutrition is not a limiting factor to the Stillwater herd. Mountain lion (*Felis concolor*) predation may play a role in limiting sheep overwinter survival. Bacterial pneumonia resulted in approximately 50% of the known mortalities in the winter of 1992-1993; however, since November of 1991, approximately 56% of the mortalities have been from unknown causes. Although protostrongylid lungworm and nutrition do not appear to be limiting factors in the recovery of the Stillwater herd, additional monitoring of these factors, as well as the study of predation, should continue. Future studies should be conducted to identify mortality factors for the Stillwater bighorn sheep herd on the summer range.

The number of bighorn sheep in North America has declined drastically since the turn of the century (Buechner 1960). These declines have often been attributed to the lungworm-pneumonia disease complex (Honest and Frost 1942, Buechner 1960, Forrester and Senger 1964, Forrester 1971). The lungworm-pneumonia complex is indeed very "complex", and is often associated with other physiological stress factors, such as bacterial and viral infection, poor nutrition, inclement weather, multiple parasitism, overcrowding, predation, and human caused disturbances (Forrester 1971, Hudson and Stelfox 1976, Hibler et al. 1982, Foreyt and Jessup 1982, Onderka and Wishart 1984, Belden et al. 1990, Foreyt 1990). Some authors have suggested that due to the complex nature of pneumonia and to the incomplete understanding of most predisposing factors or stresses, the lungworm-pneumonia complex be renamed "stress-related pneumonia" (Spraker et al. 1984, Festa-Bianchet 1988). Therefore, until

the many factors involved in the pneumonia complex are better understood, it is necessary to examine any possible predisposing or stress factors that may be present in bighorn sheep populations.

Festa-Bianchet and Samson (1984) concluded that parasites may be both a cause and result of stress. In many cases of pneumonia, *Protostrongylus* spp. clearly are a predisposing or stress factor for bighorns (Couey 1950, Buechner 1960, Worley et al. 1976, Wishart et al. 1980, Silflow and Foreyt 1988), especially in the case of summer lamb mortality due to transplacentally derived lungworm infections (Hibler et al. 1976, Schmidt et al. 1979, Spraker et al. 1984). Most bighorn sheep are infected with lungworm (Forrester and Senger 1964). Both prevalence (the proportion of hosts infected) and the intensity of infection (indicated by the first-stage larval output per gram of feces (LPG)), are used to measure the parasite pressure on bighorns (Forrester and Senger

1964, Gregory and Blackburn 1991). Lungworm levels may be affected by other factors, such as herd density and nutrition (Schwantje 1986, Festa-Bianchet 1988).

Nutrition may be important in relation to pneumonia-induced mortality (Honest and Frost 1942, Forrester and Senger 1964, Foreyt and Jessup 1982, Samson et al. 1987). Although current information suggests that nutrition is not necessarily a causal factor in relation to pneumonia (Jessup 1981, Foreyt and Jessup 1982, Bailey 1986, Ryder et al. 1992), the pneumonia complex is multi-factorial, and poor nutritive condition may be one predisposing or stress factor (Samson et al. 1987, Dunbar 1992). Additionally, nutrition has been shown to influence other important population parameters of bighorn sheep (Honest and Frost 1942, Hebert et al. 1984). Fecal nitrogen has been shown to be an effective measure of bighorn nutrition and population condition (Hebert et al. 1984, Irwin et al. 1993).

Predation may constitute an additional source of mortality, and may be related to the condition of the sheep (Buechner 1960, Hibler et al. 1982, Harrison and Hebert 1988). In some cases, predation may disproportionately affect one segment of a herd. Rams, during or just after the rut may be more susceptible to predation than other classes (Geist 1971, Harrison and Hebert 1988). Williams (1992) found that bighorns were an important prey item for mountain lions; however, Geist (1971) stated that lamb mortality due to predation was unlikely due to the precipitous terrain in which lambing occurs.

The Stillwater bighorn sheep herd, one of the last 12 native herds in Montana (Thorne et al. 1985), was reported to have peaked in the late 1940s and early 1950s at more than 100 animals (Buechner 1960, Pallister 1974). However, the Stillwater herd has recently been in decline since the early 1980s, with lamb recruitment averaging 20% from 1982-1988, and no recruitment at all in 1987 (Farmer 1992). Compared to the estimate of 50% recruitment needed for population growth, it is obvious that the Stillwater herd may have a problem maintaining a minimum viable population (Lawson and Johnson 1982). Stillwater lambs born in the summer are not arriving on the winter range and from 1989 to 1992, known summer lamb mortality was at least 50% (Farmer 1990, 1993). The Stillwater bighorn sheep herd currently consists of an estimated 30 sheep.

The Stillwater herd has been periodically tested for lungworm. In 1964, it had one of the highest average levels of infection of herds surveyed in Montana at 900 LPG and 100% prevalence (Forrester and Senger 1964). Stewart (1975) recorded *Protostrongylus* spp. levels at an average of 5.5 LPG in 91% of Stillwater sheep samples. However, in the mid to late 1980s, average LPG levels again increased to approximately 100 LPG in more than 80% of samples tested. One lamb was known to have died in 1988 from lungworm-pneumonia (Farmer 1988).

Efforts were made in 1989 to treat the Stillwater herd with fenbendazole medicated alfalfa pellets. Although several researchers have reported medicated pellets as palatable to sheep (Huschle and Worley 1986, Foreyt et al. 1990), the Stillwater herd apparently did not find them so (Worley unpublished). An older captive ewe who was accustomed to pelletized feed was even released into the Stillwater herd, hoping she might induce other sheep to eat the medicated feed (Farmer 1990). Later, salt blocks and loose medicated salt were placed on the winter range, with no response (Worley and Seese, unpublished). However, with the use of apple pulp as an attractant, sheep were finally observed consuming 0.5% fenbendazole medicated salt on the winter range early in the summer of 1990. Salt was also placed on the summer range (Farmer 1991). Initial findings the following winter suggested that fenbendazole consumption had been adequate, with average lungworm LPG values below 1. Additionally, a young ewe who died from a fall in spring of 1991 had very low lungworm levels (Farmer 1991). The Stillwater sheep have had continued access to medicated salt on the winter range every year since 1990.

Beginning in 1986, periodic measurements of Stillwater sheep fecal nitrogen values were made to assess the nutritional status of the herd. Although sampling was not done regularly and sample sizes were at times small, nitrogen values were generally within the range described by Hebert et al. (1984). Irwin et al. (1993) suggested that fecal nitrogen values below 1.3% may be indicative of nutritional deficiencies. For winter range samples from 1986 - 1991, (n=18), 17% of Stillwater fecal samples contained less than 1.3% fecal nitrogen (Farmer 1992).

The Stillwater area has resident populations of bobcats, coyotes, black bears, mountain lions, and eagles. Prior to the late 1980s, predation

was not considered a problem for the Stillwater bighorn herd. However, populations of both coyotes and mountain lions appeared to be increasing. Although this increase was not quantitatively documented, reports of both species in the area increased. The first documented predation loss was in 1990; a mountain lion killed the captive ewe introduced earlier that year (Farmer 1991). Predation may affect bighorns directly through mortality or indirectly by harassment or displacement of animals (Farmer 1986).

The objectives of this study were to examine three factors possibly limiting the recovery of the Stillwater herd: 1) measure the prevalence, intensity and seasonal patterns of *Protostrongylus* spp. infection and determine the effectiveness of a free-choice medicated salt program in a free-ranging bighorn herd; 2) measure fecal nitrogen as an index to herd nutrition and condition; and 3) attempt to learn the cause of known mortalities in order to estimate the extent of predation on the herd.

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STUDY AREA

The study area is located at the Stillwater Mining Co. facility near Nye, Stillwater County, Montana, approximately 80 miles (130 km) southwest of Billings. The Stillwater herd's primary winter range is approximately a 3 square mile (5 square km) parcel contained within the

permit area for the Stillwater Mine. The elevation of the primary winter range is approximately 5,000 feet (1600 m) above sea level, with most bedding areas located about 600 feet (200 m) higher on a rocky outcrop referred to as the "reef". The secondary winter range on the West Fork of the Stillwater and summer ranges west of the Stillwater drainage were also included in this study.

METHODS

Attempts were made to collect feces at 2-3 week intervals on the primary winter range where the main habituated segment of the herd is located. Additionally, collections were made on the West Fork winter range during the winter of 1991-1992. All known bedding and activity areas were searched, and all fresh pellets known to be from sheep were collected. Also, samples from individually recognizable sheep were obtained from direct observation. Although larvae of *Protostrongylus* spp. are known to remain viable in samples that are several months old (Buechner 1960, Hibler et al. 1982), no samples were collected that were estimated to be more than a few weeks old. In the field, pellets were classified according to age and sex of the donor when possible. The samples were placed inside reclosable plastic bags and were placed in a refrigerator as soon as possible.

The Baermann technique (Forrester 1971, Hibler et al. 1982) was used to extract larvae from seven gram samples of feces. Samples were left in small funnels (10 cm diameter) for 24 hours. Approximately 10 ml of fluid containing first-stage *Protostrongylus* spp. larvae were withdrawn into petri dishes for examination. Larvae were counted under a 25 x dissecting microscope; results were expressed as first-stage larvae per gram of feces (LPG). These data were also used to calculate prevalence of *Protostrongylus* spp. Fecal analysis data are not reliable in assessing parasitism in individual animals due to large variation in larval shedding rates; however, it is useful in consideration of levels of parasitism in the herd as a whole (Forrester and Senger 1964).

Nitrogen analysis was performed by the Montana State University Chemistry Station Laboratory on monthly composite samples. Thirty pellets, 2 each from 15 pellet groups, were randomly subsampled from the pellet groups

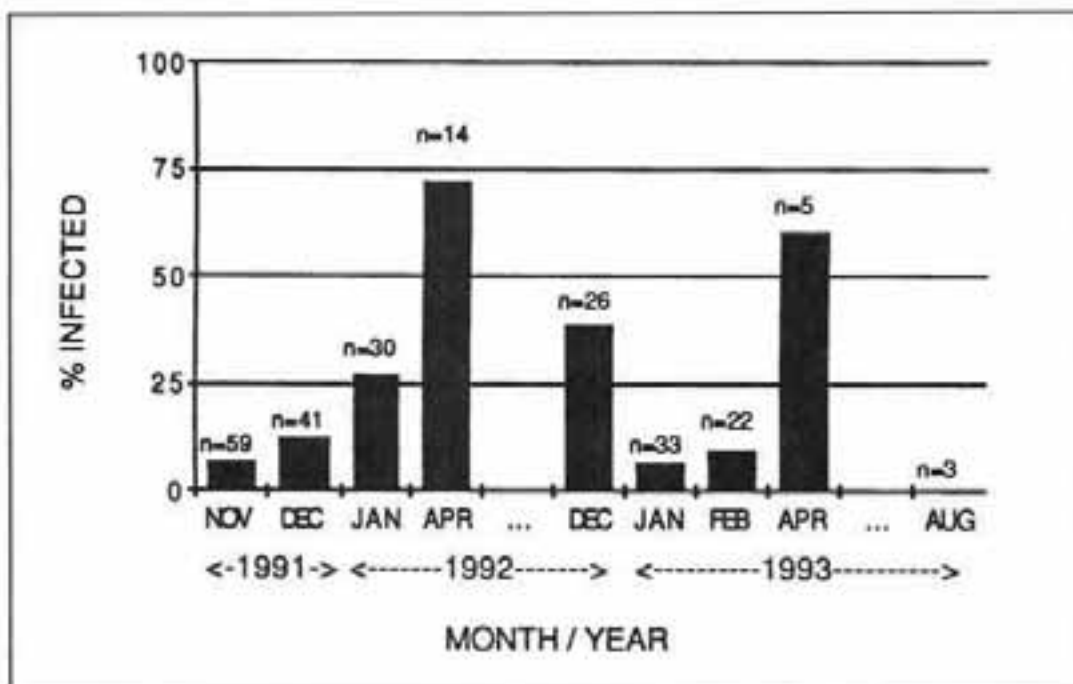


Figure 1. Prevalence of *Protostrongylus* spp. in the Stillwater bighorn sheep herd: November 1991 to August 1993. (** Sample sizes represent total number of samples examined.)

collected for lungworm analysis. The Kjeldahl method was used, and total fecal nitrogen values are given on a percent dry weight basis.

Mortality data were collected when a collared sheep died, during fecal pellet collection ground surveys, and by Stillwater Mine personnel. Ground surveys included all areas of known sheep activity on the winter range. Surveys of the winter range were also conducted a few times during the summer, as several sheep visit the winter range during the summer, presumably to obtain salt. Fresh carcasses were examined at the MDFWP laboratory in Bozeman, Montana State University, and the state of Montana Department of Livestock Diagnostic Laboratory.

Statistical analysis was done on MSUSTAT, version 5.10, developed by Richard E. Lund, Montana State University, Bozeman, MT 59717-0002. Loglinear fit for p-way tables (LOGLIN) analysis was performed to test for a relationship between age and prevalence of *Protostrongylus* spp. Chi-square analysis was used to evaluate all other lungworm data. Statistical significance was determined at $p < 0.05$.

RESULTS

Lungworm

Sheep of all age and sex classes were observed using the medicated salt. The number of sheep observed using salt at any one time and the frequency of salt use suggested that most, if not all, Stillwater sheep were using salt. No sheep were observed coughing.

The prevalence of *Protostrongylus* spp. generally increased over the sampling period for each year. As shown in Figure 1, the trends were similar between years, except for the value for December 1992. Each of the 3 samples from August 1993 were negative. The increases in prevalence in both years became statistically significant in late winter and early spring ($p < 0.05$) (Table 1). No difference was found between the prevalence of lungworm in males and females for either winter. There was no difference between the prevalence of lungworm in sheep less than 2 years old and adults. All 26 samples from males and females from the West Fork segment of the herd were negative for lungworm larvae.

The average LPG values of the positive

samples for the Stillwater herd were all below 4 LPG (Figure 2). The maximum LPG values recorded were 11 and 13 LPG in December 1992, from a 2 year old ram and a 6 year old ram, respectively. No difference was found in the LPG distributions between age or sex categories.

Fecal Nitrogen

There did not appear to be any difference in the fecal nitrogen values among years, and there was an increase in spring in both years (Figure 3). Fecal nitrogen values from the West Fork were the same as those of the main herd for adjacent sampling periods. No values were less than 1.5% fecal nitrogen.

Mortality

The causes of mortality in the Stillwater herd are summarized in Table 2. Mountain lion predation and bacterial pneumonia each accounted for 22% of the mortality; the remaining causes were unknown. The mortality study only included sheep on winter range, and therefore

Table 1. Differences between months for prevalence of *Protostrongylus* spp. in the Stillwater bighorn sheep herd: November 1991 to August 1993.

Month	P-value
Nov 91 to Dec 91	0.352
Dec 91 to Jan 92	0.119
Nov & Dec 91 to Jan 92	0.012*
Jan 92 to Apr 92	0.005*
Nov & Dec 91 to Apr 92	0.000*
Apr 92 to Dec 92	0.046*
Dec 92 to Jan 93	0.002*
Jan 93 to Feb 93	0.672
Feb 93 to Apr 93	0.008*
Dec 92 to Apr 93	0.371
Apr 93 to Aug 93	0.090

* indicates statistical significance at $p < 0.05$

does not include summer lamb mortality (except for two lambs found dead on the winter range during summer). The cause of death of these lambs was not determined.

Bacterial and viral isolations were obtained from the two sheep that died from pneumonia.

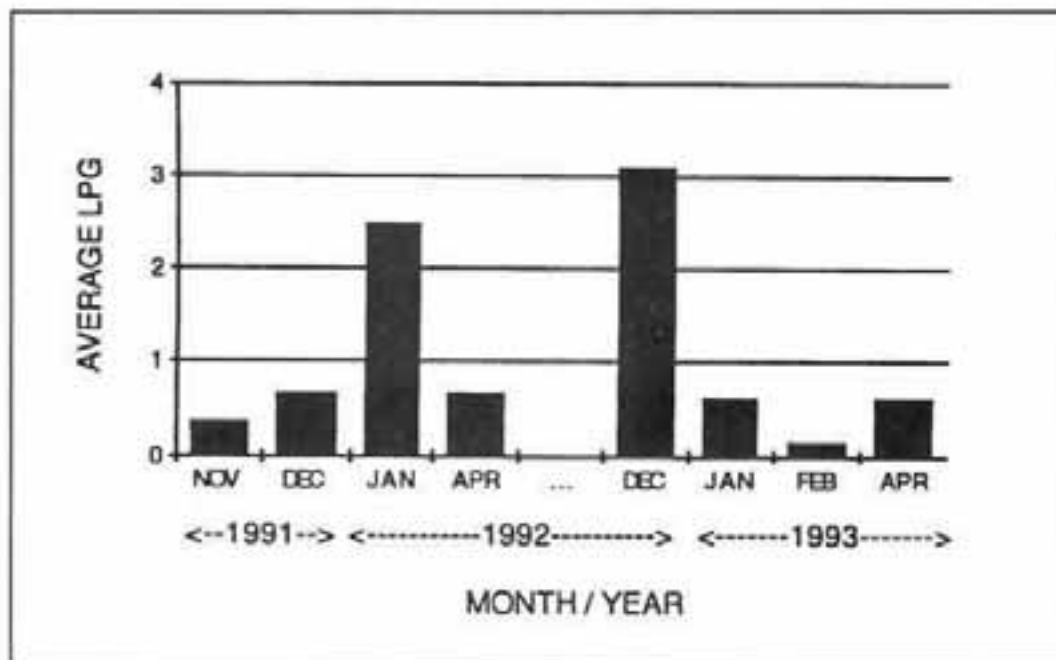


Figure 2. Average larvae per gram (LPG) of *Protostrongylus* spp. larvae in positive fecal samples from the Stillwater bighorn sheep herd: November 1991 to April 1993.

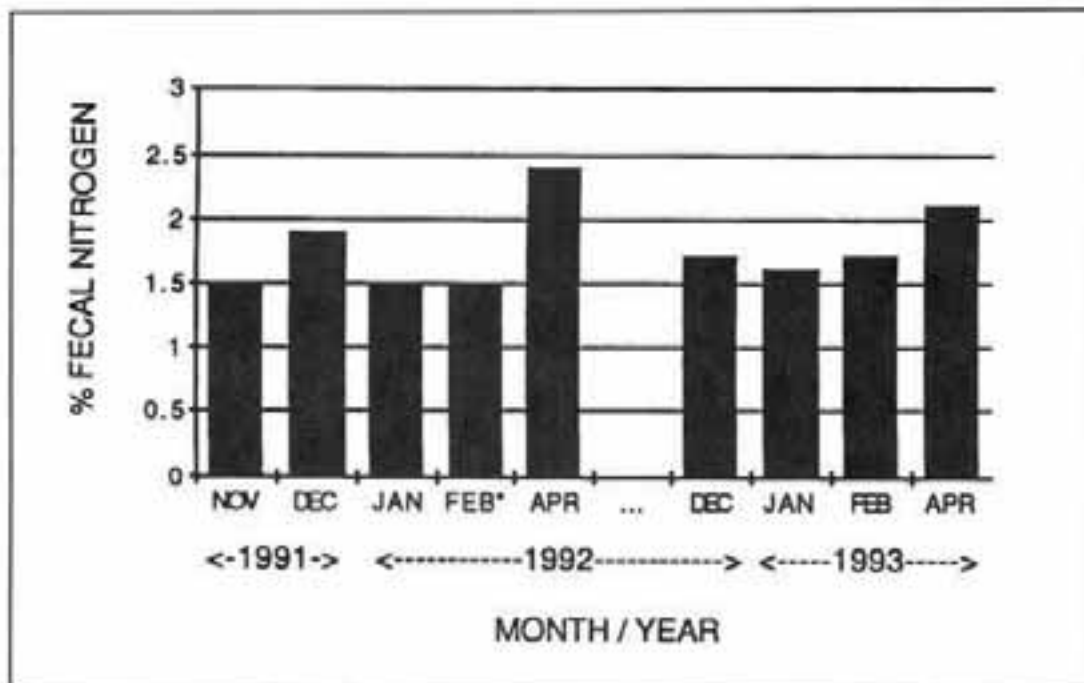


Figure 3. Percent fecal nitrogen for composite samples in the Stillwater bighorn sheep herd: November 1991-April 1993. (West Fork sample)

No *Pasteurella* spp. bacteria or viruses were isolated from an adult ram; however, *Moraxella* spp. was recovered. *P. hemolytica* and a noncytopathic Bovine Viral Diarrhea (BVD) virus were isolated from a female lamb. No other carcasses found were in a condition to obtain bacterial or viral information.

DISCUSSION

Lungworm

In evaluating the prevalence data for the Stillwater herd, sample size must be considered. However, in this case, sample sizes are inherently small since there are so few sheep in the herd. With small samples, prevalence may be skewed higher, and zero values may be underestimates of the population value (Gregory and Blackburn 1991). Nevertheless, in this study, an average of 26 samples were collected each month. In a population of an estimated 30 sheep, confidence in the results should actually be greater due to the probability of sampling a significant portion of the herd. The April and August samples were the smallest. Thus, if confidence in results is reduced

due to sample size, only April and August should be most affected. However, the overall effect of sample size was tested by performing the analysis on doubled sample sizes; no changes in significance ($p < 0.05$) resulted.

The prevalence of *Protostrongylus* spp. in the Stillwater herd has been effectively suppressed over the winter with fenbendazole medicated salt. However, in April of both years, dramatic increases occurred, bringing the prevalence in the Stillwater much closer to that of unmedicated herds. The results of this study differ from those in the Ural-Tweed herd (unmedicated), where prevalence was high in January and February. The December 1992 value differs from both the December 1991 and Ural-Tweed values, and may be suspect. However, both studies reported high prevalence occurring in April (Yde et al. 1988). As in this study, Yde et al. (1988) did not find differences in prevalence among age or sex classes. If there were any seasonal trends of differences, it is likely that fenbendazole may have masked them.

Although results from this study did not suggest a relationship between prevalence and intensity, it is interesting that unusually high values for both parameters occurred in December 1992. Logically,

Table 2. Causes of death for known mortalities in the Stillwater bighorn sheep herd: November 1991-August 1992.

Season/year	Sex and age class	Cause of death
Winter 91-92	unknown-? ♀ #25?	mountain lion predation
Winter 91-92	unknown	unknown
Spring 92	lamb of the year ♀	unknown--carcass intact
Spring 92	♀ #97	unknown--carcass intact
Summer 1992	lamb of the year	unknown
Winter 92-93	♀ #24	mountain lion predation
Winter 92-93	lamb ♀	bacterial <i>P. haemolytica</i>
Winter 92-93	♂ #96	bacterial pneumonia--no <i>Pasteurella</i>
Unknown	adult ♀	unknown--whole carcass not found

an increase in the number of sheep infected with and shedding lungworm larvae should result in an increase in the level of infection in individual sheep. However, the increase in average LPG for the month of December was probably skewed higher due to two ram samples. When those 2 samples were excluded from the data, the average LPG for December was less than 1 LPG. Nevertheless, the presence of those two rams did not significantly affect the prevalence value for December.

Overall, no seasonal trends were apparent in LPG values in the Stillwater herd. Several authors have reported spring increases in lungworm larval output (Forrester and Senger 1964, Festa-Bianchet and Samson 1984, Fougere-Tower and Onderka 1988). However, Arnett et al. (1993) suggested that larval output of adult sheep may decline from November to April. Spring increases in LPG would not be expected in the Stillwater herd since sheep crave and increase their use of salt in the spring (Lawson and Johnson 1982). Regardless of the expected trend, fenbendazole likely masked it. Any expected differences in LPG distributions in age or sex categories would also likely be negated by fenbendazole.

Although Stillwater LPG levels were clearly below any physiological stress threshold, it is unlikely that even with consistent winter range medication, *Protostrongylus* spp. would be completely eliminated from the herd. First, in order for fenbendazole to eliminate all adult lungworms in bighorns, multiple doses are required (Huschle and Worley 1986). Second, use of salt may be sporadic by and among individual sheep (Huschle and Worley 1986, Worley and Seese 1990). Third, fenbendazole is effective against adult lungworms, but may be less effective against somatic stored larvae (Schmidt et al. 1979, Foreyt

et al. 1990). Fourth, concentrations of bighorns on a small, repeatedly used winter range may result in more lungworm exposure (Wishart et al. 1980). Finally, the Stillwater area was reported to have a relatively dense population of intermediate host snails (Forrester and Senger 1964). Therefore, the results of this study suggest that the Stillwater herd is as lungworm-free as can be expected in any free-ranging medicated herd.

Fecal Nitrogen

Fecal nitrogen results indicated that the Stillwater herd is not suffering nutritional deficiencies. The values were within the range described by Hebert et al. (1984), and the sheep appeared to respond to spring "green-up" with the April increase in fecal nitrogen. No fecal nitrogen values were recorded below 1.3%, indicating that the nutritional status is satisfactory (Irwin et al. 1993). It appears that the management of the Stillwater herd has been successful in maintaining optimal nutritional condition.

Mortalities

Only two summer mortalities were recorded on the winter range; both were lambs. Generally, lack of radio-collared animals made carcass collection difficult. In many cases, cause of death was obscured by deterioration of the carcass. However, if the carcass was completely intact and appeared undisturbed (as indicated in Table 2), it is unlikely that predation was the cause of death.

One ewe mortality (♀ # 97) may have been influenced by humans and mine activity. This sheep did not associate with others in the herd and displacement from the primary winter ranges could have increased exposure to some mortality factors. She wintered in a talus/scrub juniper drainage at an

elevation of approximately 1000 to 2500 feet (330 - 830 m) above and approximately 2 miles (3.2 km) south-southwest of the primary winter range. Predation was unlikely as the carcass had not been disturbed or moved since death. Unfortunately, no further information could be obtained. No other mortalities could be attributed directly or indirectly to human disturbance. No sheep on the primary winter range appeared to be under nutritional stress.

As sheep move to winter ranges, their strong affinity for escape terrain may be lessened (Pallister 1974, Stewart 1975). Although mountain lion predation resulted in winter range mortality, limited studies with radio-collared lions did not indicate that summer range predation is significant in the Stillwater herd (Shawn Stewart, MDFWP, pers. comm.)

Pasteurella spp. are the most commonly reported pneumonia-related respiratory pathogens in bighorn sheep (Foreyt 1990) and were probably responsible for the death of 1 lamb. The absence of *Pasteurella* in 1 ram may be due to deterioration of the carcass.

MANAGEMENT IMPLICATIONS

The use of the fenbendazole medicated salt resulted in very low levels of *Protostrongylus* spp. And it does not appear that lungworm is a significant limiting factor to the recovery of the Stillwater herd. However, increases in prevalence in spring to levels near those of unmedicated herds may indicate residual low lungworm levels in sheep and on the range. Continued placement of medicated salt may prevent the herd from becoming re-infected at a level inducing physiological stress. Fenbendazole remains the drug of choice due to its demonstrated efficacy and low toxicity (Hibler et al. 1982, Foreyt et al. 1990). Fecal nitrogen values indicated that the Stillwater herd is not limited by nutritional constraints. Previous management actions were successful in maintaining adequate nutritional condition in this herd. Predation did not play a role in limiting Stillwater bighorn sheep overwinter survival. However, observed levels of predation were not excessive except when considering the small size of the herd. Continued monitoring of the Stillwater herd is needed to assess the role of bacterial pneumonia, as well as other factors related to a small remnant bighorn herd.

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