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USE OF IVERMECTIN TO INCREASE LAMB SURVIVAL IN A HERD OF ROCKY MOUNTAIN BIGHORN SHEEP

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ABSTRACT

Population growth of a Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) herd is believed to be limited due to lungworm (*Muellerius capillaris*) induced mortality of lambs. Thirty-five of 93 ewes were treated with ivermectin during a preliminary study to decrease lungworm loads in ewes and to increase lamb survival. Treatments were administered orally (ivermectin mixed with a bait) or by subcutaneous injection. Oral treatment of free-ranging sheep was done by spraying the drug dose onto alfalfa hay. Oral treatments, at doses similar to those recommended for injection, were efficacious against *Muellerius*. Effects of treatment on marked ewes were analyzed by ewe group (comparisons among the east end (EE), west end (WE), and Grace Coolidge (GC) ewe groups) and by treatment group (injection, oral, or no treatment). No differences in larval counts among the ewe groups were found. No differences were found in the proportion of ewes lambing for either ewe groups or treatment groups, or in lamb survival among the treatment groups. There were also no differences in lamb survival among 2 ewe groups (partial treatment), but lamb survival in the third ewe group (untreated) was significantly lower ($P < 0.05$). Although treatment results from this preliminary study are not conclusive , ivermectin appeared to be efficacious against *Muellerius*, to reduce lungworm levels in bighorn sheep ewes, and to increase lamb survival. Advantages of using ivermectin over Cambendazole and Fenbendazole to treat bighorn sheep for lungworms are discussed.

INTRODUCTION

Habitat has been considered to be the most important criterion in selecting areas for reintroductions of Rocky Mountain bighorn sheep, with most reintroductions having been relatively successful (Geist

1974). However, factors other than habitat may also contribute to the success or failure of reintroduction programs. One such factor is the effect lungworms may have on survival and maintenance of a herd, particularly the survival of lambs.

Audubon's bighorn sheep (O. c. canadensis) were indigenous to the Badlands and Black Hills areas of South Dakota prior to European settlement in the 1800's but were extinct by 1916 (Buechner 1960). A herd of approximately 22 Rocky Mountain bighorn sheep from Wyoming were introduced into the Black Hills in Custer State Park (CSP), South Dakota (Fig. 1) in 1965 and subsequently increased to a level estimated between 100-150 animals in 1975 (Trefethen 1975). Although this introduction established a resident herd, now estimated to be approximately 90 animals, population growth between 1975-1985 has been virtually zero. Since natural mortality in yearlings and adults is believed to be minimal (Geist 1971), changes in the structure of the population are directly related to reproductive success and, especially, lamb survival. At best, recruitment of lambs in CSP bighorn sheep is thought to be only enough to maintain the herd at its present level.

Disease related mortality is responsible for a decline in the growth or size of many bighorn sheep herds. Epidemics attributed to the lungworm-pneumonia complex can be particularly severe on the lamb cohort (Forrester 1971, Hibler et al. 1972). Lungworms have been shown to predispose bighorn sheep to bacterial pneumonias, primarily caused by Pasteurella spp., which can be highly pathogenic (Forrester 1971, Post 1971, Hibler et al. 1972). Of particular importance is the effect of lungworm infection on the reproductive potential of bighorn sheep. Lungworms can adversely affect lamb survival both directly through heavy infections and indirectly by predisposing the lamb to secondary bacterial infections (Forrester et al. 1966, Woodard et al. 1974). Hibler et al. (1974) reported 95-98% lamb mortality within 3 months of birth in one herd of bighorn sheep they studied, with pneumonia cited as the major cause of mortality. With such deleterious lamb losses and resultant low recruitment, it is easy to visualize how lungworms could be detrimental to population growth of a bighorn sheep herd, regardless of how suitable habitat conditions may be.

The Muellerius lungworm is found to be ubiquitous among adult sheep in CSP (Pybus and Shave 1984, McCabe et al. 1985) and is suspected to be the major cause of lamb mortality. With 100% infection of the herd at high levels (as high as 15,000 larvae/gram feces [lgf, herein] in one ewe) in CSP bighorn sheep (McCabe et al. 1985), the possibility that most lambs in CSP are infected at birth is also very high. A significant reduction in lungworm burdens of pregnant ewes should reduce the possibility of fetal infection, resulting in a greater proportion of uninfected lambs being born. Absence of lungworms at birth would increase a lamb's chance of survival and ultimately increase recruitment to the population. Schmidt et al. (1979) reported that lamb survival

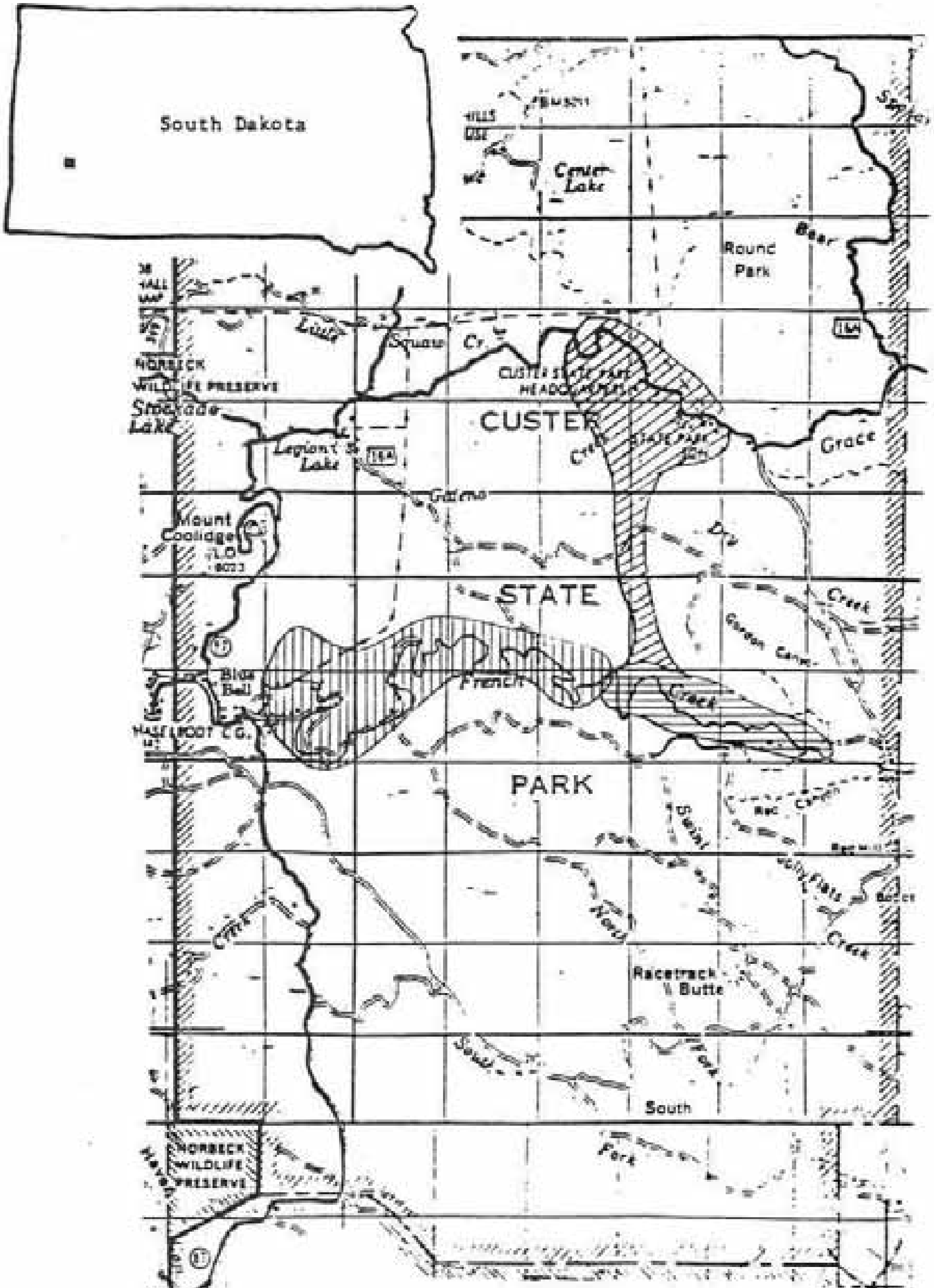

Figure 1. Location of French Creek Canyon and ewe groups in Custer State Park, South Dakota. Ewe groups: [diagonal hatching] Grace Coolidge, [horizontal hatching] East End, [vertical hatching] West End.

treated with anthelmintic drugs, indicating a causal relationship between bighorn lamb mortality and lungworm infection in ewes.

Objectives of this preliminary study were to evaluate the effectiveness of a relatively new nematocide, ivermectin, in reducing lungworm levels of *Muellerius* in adult Rocky Mountain bighorn sheep and to compare the lamb survival of a treated ewe group with that of an untreated group. This study is part of a larger research effort to investigate causes which have limited growth of the CSP bighorn sheep herd over the past 10 years and to provide recommendations for increasing herd size.

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METHODS AND MATERIALS

STUDY AREA

Research was conducted in Custer State Park, South Dakota, which is located in the southeast corner of the Black Hills approximately 65 km southwest of Rapid City. Bighorn sheep ewes primarily inhabit French Creek Canyon, located in the central portion of the Park (Fig. 1). French Creek Canyon is approximately 19 km long and ranges from 140 to 270 m in depth. Elevations within CSP bighorn sheep range vary between 1160 to 1580 m. French Creek Canyon is characterized by steep, rugged walls with adjacent rolling meadows and Ponderosa pine (*Pinus ponderosa*) forests.

LAMBING SUCCESS AND SURVIVAL

Lamb:ewe ratios were calculated from ewe group counts made over 10 day intervals during the summer and fall of 1985 to determine an overall index of lambing success and lamb survival. The number of lambs and the number of ewes for each group observed were used. The number of each age class counted over the 10 day interval was summed and expressed as lamb:100 ewe ratios.

FECAL SAMPLES

Fecal samples were collected whenever fresh pellet groups were found. These included samples from marked, unmarked, and unidentified individuals. An effort was made to observe marked sheep long enough to collect a fresh, identifiable sample. Fecal samples were frozen and delivered to H. Shave at the Veterinary Diagnostic Laboratory, South Dakota State University, for analysis. Larval counts were determined using a modified procedure of the Baermann technique (Baermann 1917) where a Buchner funnel was not used.

Mean larval counts were calculated for each month from June through September 1985, for each age group (lambs and ewes), and for each ewe group. Means were compared using analysis of variance.

TREATMENT

CSP bighorn sheep ewes have segregated into 3 distinct groups, the Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups (Fig. 1). All GC sheep captured in January 1985 were injected with ivermectin. Injections were made subcutaneously in the front shoulder region at a rate of 200 μg/kg body weight as recommended by the manufacturers. At this rate, dosages for ewes and lambs were calculated to be 200 μg and 100 μg ivermectin, respectively (McCabe et al. 1985). Ivermectin is known to have a safety margin of up to 20x normal dosage in domestic sheep, therefore accurate estimates of dosages were not critical (Campbell and Benz 1984).

In early March 1985, individuals in the EE group were treated orally with ivermectin. All sheep of each age class (ewe or lamb) present at the EE feeding site were counted and a total volume of ivermectin was calculated at rates of 300 μg ivermectin/ewe, and 200 μg ivermectin/lamb. This volume was poured into a hand spray bottle and sprayed onto approximately 20 kg of alfalfa hay which had previously been spread out. Treatment was repeated again after 2 days to insure that as many sheep as possible from this ewe group received an adequate dosage. The WE ewe group was used as the control. Comparisons were made among the 3 treatment groups (oral, injection, no treatment) and among the 3 ewe groups (GC, EE, WE groups) for proportion lambing and lamb survival using chi-square tests of independence. Only marked ewes were used in these comparisons. Also, comparisons of lamb:ewe ratios for lamb survival among the ewe groups, including marked and unmarked ewes, were made using a chi-square test of independence.

In December 1985, EE ewes were again treated orally with ivermectin. Fecal samples from this group were collected and analyzed for lungworm levels in order to monitor any significant changes in levels and assess whether ivermectin was efficacious against Muellerius when administered orally at the dosages prescribed above. Comparison of larval counts were made using analysis of variance.

RESULTS AND DISCUSSION

LARVAL COUNTS

Comparisons Among Months

A total of 310 fecal samples were collected between 1 June and 30 September 1985. Of the 310 samples, 262 were from ewes and 48 from lambs. Lungworm counts for ewes were highest in June with a mean of 887 lgf (n = 57). Counts decreased by about half this number in July (491, n = 74) and were even lower in August (201, n = 100) and September (228, n = 31). The distribution of these counts are comparable to previous years (1983 and 1984) when counts decreased over the summer (McCabe et al. 1985).

For lambs, fecal counts were lower in June (3 lgf, n = 6) and July (6, n = 13) than in August which had a mean of 20 lgf (n = 16). In September, counts dropped to 6 lgf (n = 13); these levels were comparable to June and July levels.

Although the means were not different ($P > 0.70$), the fluctation seen in lamb fecal counts might be expected since lambs which were born in early June would be producing larvae by mid- to late August whether they were infected as fetuses or not. The drop in counts during September would likely be due to loss of lambs with high counts. Lambs born infected with the parasite (high counts) would begin dying at this time leaving mostly lambs which had not been infected at birth but were becoming infected through grazing and were in the process of building levels (low counts).

Comparisons Among Ewe Groups

Mean lungworm levels for ewes among groups from June-September 1985 were 233 lgf (n = 36) for the GC group, 496 lgf (n = 102) for the EE group, and 444 lgf (n = 124) for the WE group. Although, there were no statistical differences in counts among groups ($P > 0.09$), the probability of no difference is relatively low.

Since approximately half of the EE group had been treated, a lower fecal count of lungworms was expected. Ivermectin has been shown to retain anthelmintic activity against Dictyocaulus viviparus, a cattle lungworm, for about 21 days (Armour et al. 1985). Since these ewes were treated in March, there was sufficient time for the ivermectin to be metabolized and lungworm levels to build back to pretreatment levels by late spring-early summer, thus the reason for no difference between the EE and WE groups. Levels for the GC group tentatively support lowered lungworm counts due to treatment.

Mean levels for lambs in the EE and WE ewe groups were 15 lgf (n = 23) and 7 lgf (n = 24), respectively. No differences were found between lamb larval counts from the EE and WE groups ($P > 0.76$).

Effectiveness of Oral Treatments on Larval Counts

Figure 2 depicts the levels of fecal larval counts for collection days at the EE feeding site. There was a great reduction in levels of fecal larval counts between pre- and post-treatment counts. High counts, which were persistent for at least 17 days after the last treatment (19 December), were probably due to the amount of time it took for the effects of treatment to be seen in larval counts. All December counts were higher than the 5 January count ($P < 0.01$), indicating that ivermectin was efficacious against Muellerius in bighorn sheep.

Similar results of oral treatment using ivermectin were found for Oestrus ovis, a parasite which occurs in domestic sheep and goats, European ibex (Capra ibex), and bighorn sheep (Roncalli 1984). When a group of Corriedale sheep were treated orally at a rate of 200 μg/kg body weight, ivermectin was found to be 100% effective against all 3 larval stages of the nematode. Apparently, ivermectin may be administered orally at rates similar to those recommeded for injection, with comparable results.

LAMBING SUCCESS AND SURVIVAL

Tables 1 and 2 list the number of ewes found in each category for treatment types and ewe groups. Four out of 9 ewes from the GC group were treated by injection with only 2 of the treated ewes producing lambs. One ewe from the EE group moved to the WE group after oral treatment in March. Thus, all 3 ewe groups contained both treated and untreated, marked ewes. However, location of ewes after treatment should have had no effect on treatment results.

No differences were found in the proportion of ewes lambing for either treatment groups or ewe groups (Table 1), or in lamb survival among treatment groups (Table 2). There was also no difference in lamb survival between the EE and GC ewe groups ($P > 0.40$); however, lamb survival in the WE group was significantly lower than either the EE or GC groups ($P < 0.01$, Table 2).

Lamb:ewe ratios in 1985 exhibited a bimodal distribution (Fig. 3) indicating some ewes had not conceived until their second estrus. Bimodality in 1985 follows the general trend seen in 1984. Sheep were not observed prior to 1 July 1983, thus the onset of lambing in 1983 is not known. If the peak of lambing for 1983 (Fig. 3) is assumed to be the second peak of lambing, it would correspond exactly to the second peak of lambing in 1984. What is most important from the curves in Fig. 3 is that troughs occur 30-40 days after peaks, the approximate amount of time lungworm loads could have fatal effects on lambs if transplacental transmission of larvae had occurred (Hibler et al. 1974). Also, lamb production and survival for the EE group (half of the ewes treated) was higher than that for the WE group (only 1 treated ewe present, Fig. 4). These results suggest that ivermectin treatment had a positive effect on lamb survival. Reasons explaining the 100% survival rate for the GC ewe group are unknown but may reflect both individual and annual variation associated with such a small sample size.

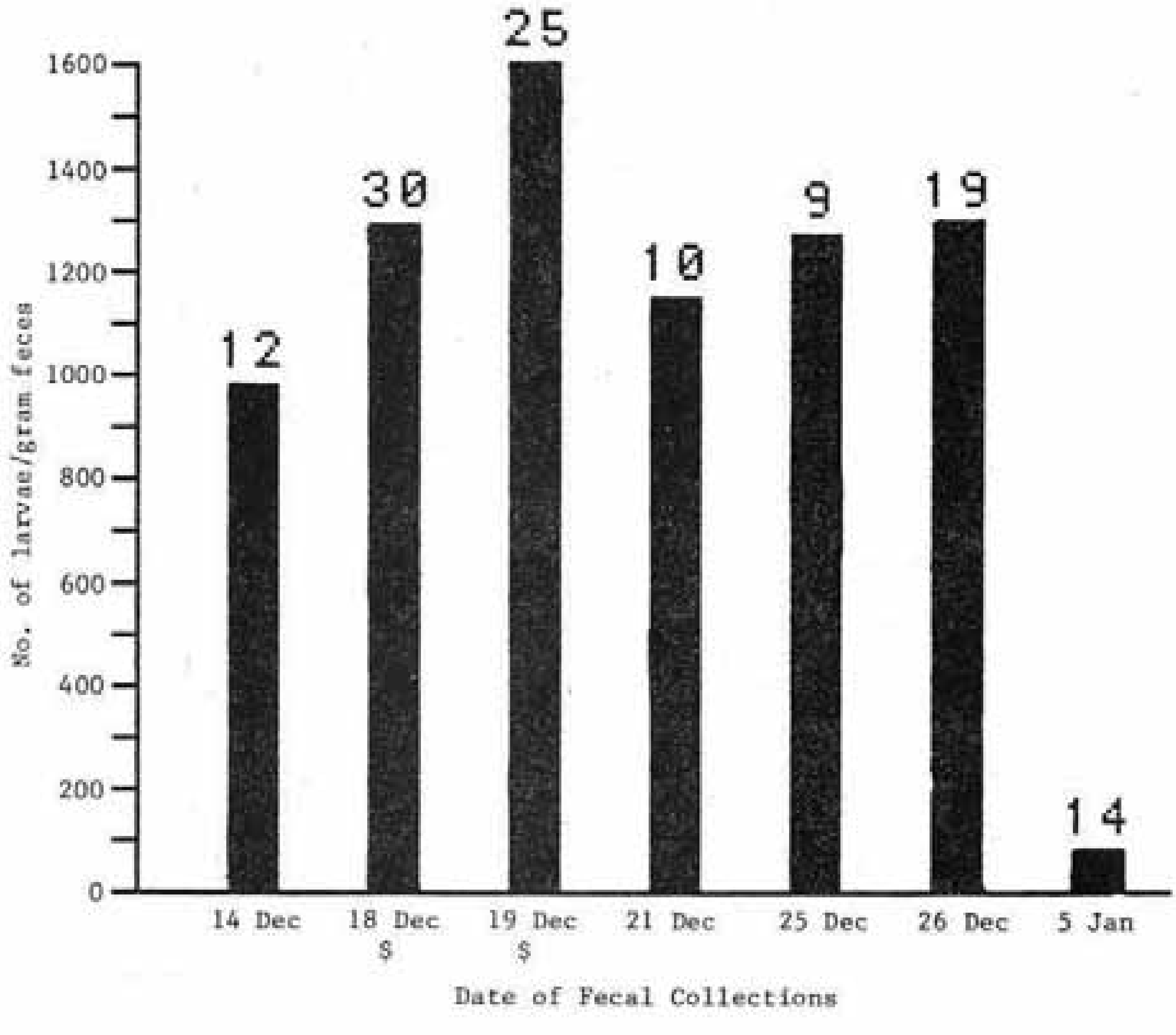

Figure 2. Mean lungworm levels for the east end ewe group treated with Ivermectin during December 1985 in Custer State Park, SD. Numbers on top of bars represent the number of pellet groups collected. ($) denotes day of treatment.

Table 1. Chi-square test of independence comparisons for proportion of ewes lambing among treatment groups and among Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups in Custer State Park, 1985. Critical value for all tests = 3.841 at the 0.05 level of significance.

TREATMENT COMPARISONS

Treatment Type	No. ewes lambed	No. ewes not lambed	
oral	8	1	$x^2 = 2.359$
injection	2	2	$P > 0.20$
oral	8	1	$x^2 = 1.365$
control	13	6	$P > 0.35$
injection	2	2	$x^2 = 0.494$
control	13	6	$P > 0.45$

EWE GROUP COMPARISONS

Ewe Group	No. ewes lambed	No. ewes not lambed	
WE	8	3	$x^2 = 1.222$
EE	10	1	$P > 0.35$
WE	8	3	$x^2 = 0.642$
GC	5	4	$P > 0.40$
EE	10	1	$x^2 = 3.300$
CG	5	4	$P > 0.08$

Table 2. Chi-square test of independence comparisons for lamb survival among treatment groups and among Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups in Custer State Park bighorn sheep, 1985. Critical value for all tests = 3.841 at 0.05 level of significance.

TREATMENT COMPARISONS

Treatment type	No. lambs alive	No. lambs dead	
oral	6	2	$\chi^2 = 0.621$
injection	2	0	$P > 0.40$
oral	6	2	$\chi^2 = 0.404$
control	8	5	$P > 0.50$
injection	2	0	$\chi^2 = 0.200$
control	8	5	$P > 0.20$

EWE GROUP COMPARISONS

Ewe Group	No. lambs alive	No. lambs dead	
WE	2	6	$\chi^2 = 7.901$
EE	9	1	$P < 0.01$
WE	2	6	$\chi^2 = 6.964$
GC	5	0	$P < 0.01$
EE	9	1	$\chi^2 = 0.536$
GC	5	0	$P > 0.40$

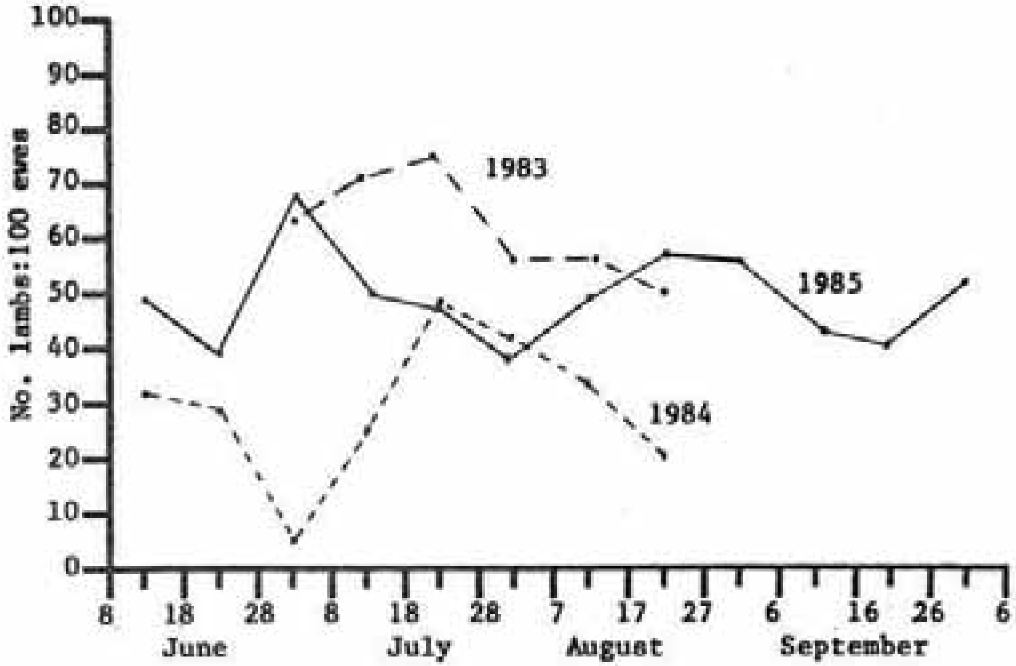

Figure 3. Lamb:ewe ratios in Custer State Park bighorn sheep for 1983, 1984, 1985.

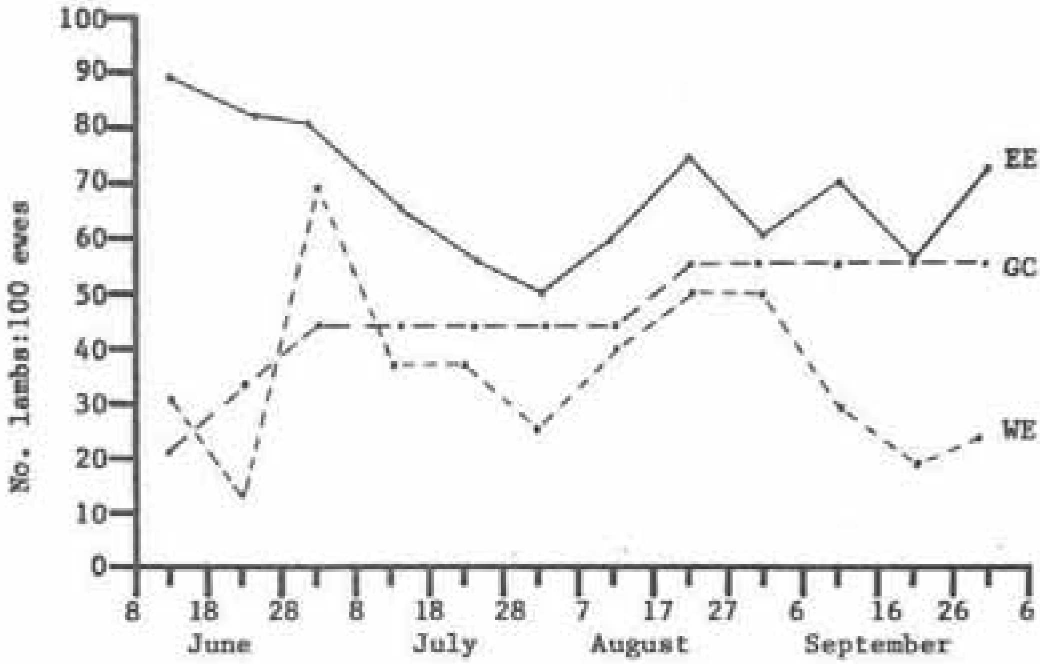

Figure 4. Lamb:ewe ratios in Custer State Park bighorn sheep for the Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups in 1985.

Similar results were found by Schmidt et al. (1974) for treatment against *Protostrongylus* spp. lungworms to increase lamb survival in a herd of bighorn sheep in Colorado, where several other nematocides were used. There were no differences in lamb survival among treatments, but a significant difference in lamb survival between treated and untreated ewes was found. Cambendazole had the greatest effect for increasing lamb survival, but was only efficacious against 3rd stage infective larvae. Fenbendazole had low efficacy against larvae, but was effective against the adult stage. These 2 drugs together were recommended for treatment against *Protostrongylus* to increase lamb survival and reduce the number of available larvae in the environment.

CONCLUSIONS

Lungworms appear to be a causative mortality factor in CSP bighorn lambs. Either method of ivermectin administration (injection or oral) at similar dosages will apparently yield similar results in reducing lungworm levels in bighorn sheep. The main advantages to using ivermectin over Cambendazole and Fenbendazole to treat bighorn sheep for lungworms are its specificity, wide therapeutic index, ease of application, and effectiveness against several life stages of lungworms.

The main disadvantage of ivermectin is its environmental instability. Water renders ivermectin inactive over a short period of time. Ivermectin also readily binds to soil, becoming inactive over time. Like Cambendazole and Fenbendazole, ivermectin should be administered orally only when sheep to be treated are present and ingestion of treated bait will be immediate.

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QUESTIONS AND ANSWERS

No Name: You're on to something very interesting, Larry. I don't know my literature real well, but I don't know of any other herd of bighorns in North America from which this genus of nematode (muellerius) has been reported in the lungs, so I guess we can assume it didn't come in with the transplant from Wyoming, or the worm would have found Tom Thorn a long time ago in which case the obvious question: Where do you think the parasite came from?

Layne: I don't know. Again the sheep were transplanted from Wyoming, and I have no doubt that at least one individual of these was infected, and if they were infected, they should have had Protostrongylus. Yet, Muellerius appears to be indigenous to the Black Hills region. There is another lungworm which was found in Alberta which is similar to Muellerius, but they haven't decided if its the same species, or why any Protostrongylus don't occur in the Park, maybe in tandem with Muellerius. Who know, there may be competition between the two, but again, there's no speculation of origin of Muellerius capillaris.

No Name: Since Muellerius capillaris is typically a domestic sheep and goat worm. Is there evidence there of transplacental transmission?

Layne: I mean, I don't know the literature on that one. It would be interesting to know.