Bienn. Symp. North. Wild Sheep
and Goat Counc.7:118-124.

SAFETY AND EFFICACY OF FENBENDAZOLE AGAINST *PROTOSTRONGYLUS* SPP. INFECTIONS IN ROCKY MOUNTAIN BIGHORN SHEEP (*OVIS CANADENSIS CANADENSIS*)

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Abstract: Fenbendazole, at a precalculated dosage of about 10 mg/kg of body weight, was fed in pelleted feed each day for 3 consecutive days to over 200 wild Rocky Mountain bighorn sheep in Washington (n=65), Idaho (n=75), and Oregon (n=75) during winter, 1985-1986. A second study in Washington (n=60 sheep) was conducted in 1986-1987. Before treatment, lungworm larvae were detected in feces from 84, 93, and 97% of the sheep from Washington, Idaho, and Oregon, respectively. Mean pretreatment numbers of *Protostrongylus* spp. larvae/g of feces (lpg) were 5.9 (WA), 13.2 (ID), and 24.4 (OR). Posttreatment samples had 0.1, 0, and 6.8 lpg, respectively, indicating high efficacy. Larvae were detected in 3% (WA), 0% (ID), and 67% (OR) of the animals after treatment. Numbers of other parasites were also reduced, and the reproductive rate (ewe:lamb ratios) improved after treatment. At Washington State University, 6 pregnant and 6 non-pregnant captive bighorns were fed fenbendazole at 30 or 50 mg/kg BW (3 or 5 times the field dosage) each day for 6 consecutive days and no toxic effects were observed. Six healthy lambs were born to the pregnant ewes indicating the safety of the drug in pregnant bighorn ewes.

Lungworms of the genus *Protostrongylus* are prevalent in bighorn sheep populations (Forrester and Senger 1964, Forrester 1971, Uhazy et al. 1973, Hibler et al. 1982). The lungworm-pneumonia complex is an important mortality factor for Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in North America (Buechner 1960, Forrester 1971). Mortality results from bacterial invasion of lungs damaged by lungworm infections (Hibler et al. 1982, Spraker and Hibler 1982). The pneumonia preceding death generally results from a combination of lungworms, bacteria (*Corynebacterium* or *Pasteurella* spp.), and viruses (parainfluenza 3 virus, respiratory syncytial virus). Mortality is frequent in lambs because transplacental infection by lungworm larvae occurs, and the maturing lungworms overwhelm the young lambs, predisposing them to pneumonia before they are 3 months old. In populations where lungworm infection produces high mortality, the loss of the breeding stock may exceed the recruitment of lambs, resulting in population extirpation (Forrester 1971, Hibler et al. 1982). By eliminating or significantly reducing numbers of lungworms in bighorn

sheep, recruitment rates may be increased because mortality due to the lungworm complex may be reduced significantly.

This trial was to determine the safety and effectiveness of fenbendazole in feed against Protostrongylus spp. in naturally infected bighorn sheep. In the Pacific Northwest, bighorns can be fed the drug in feed primarily in winter when ewes are pregnant; therefore, determining safety of the drug in pregnant bighorn sheep was also a primary objective.

We thank personnel from the Idaho and Oregon Departments of Fish and Game, the Washington Department of Wildlife, and veterinary students from Washington State University for assisting with this project. S. Zender and J. Andrews made the safety study possible by allowing use of the sheep at Washington State University. Funding was provided by the Western Region USDA Interregional Project 4, Minor Use Animal Drug Clearance Program.

METHODS

Field Study

Wild Rocky Mountain bighorn sheep were studied in Washington, Idaho, and Oregon in winter 1985-1986, and in Washington in winter 1986-1987. The Hall Mountain herd of about 80 sheep was in northeast Washington (Pend Oreille County). These sheep had moderate lungworm infections, had been fed pelleted feed and hay in winter for several years, and were acclimated to people and feeding practices. I (WJF) had monitored lungworm numbers in these sheep for several years. They have never been hunted. Sheep were treated in winter 1985-1986 and 1986-1987. In Idaho, the Panther Creek herd in the Salmon River Drainage consisted of about 140 sheep, and historically had a moderately heavy infection of lungworms. Rams were hunted in fall. Sheep were treated after the hunting season (winter 1985-1986) to allow a 8-10 month drug withdrawal period. The Lostine herd of about 100 bighorns was in northeast Oregon (Wallowa County). These sheep were also given supplemental feed in winter for several years. I (WJF) had monitored lungworm levels in these sheep for about 5 years. Rams were hunted on a limited basis in fall. Sheep were treated after the hunting season (winter 1985-1986) to allow an 8-10 month drug withdrawal period. Treated sheep were observed daily throughout the experiment to determine any deleterious effects associated with treatment. Animals were not killed for tissue evaluation or drug residue analysis because of their value.

Feed And Drug Composition

Supplemental feed consisted of a pelleted ration (alfalfa 69%, barley 31%). Feeding began in December, 1985, and continued for about 30 days before drug administration. During the 30 days, average daily consumption was determined. Numbers of sheep eating the pellets were counted each day and the average feed consumed per head per day was calculated. The amount of drug (fenbendazole) mixed in feed and pelleted at the Washington State University Feed Plant, was calculated to approximate a daily intake of 10 mg/kg of body weight. The

medicated feed was used for 3 consecutive days in January or early February. Traditionally, sheep ate the pellets within 1 hour. We observed the sheep as they ate to determine the number of sheep, the identity of as many sheep as possible, and the amount of feed consumed.

Sheep

I had monitored parasite levels of these populations for several years and determined that 85-100% of the sheep in all 3 herds were infected with lungworms (Protostrongylus spp.). Many sheep in 2 of the 3 populations (WA and OR) were ear-tagged over the last few years for identification. Other sheep had specific horn growths, color patterns, or physical deformities that identified them.

Twelve sheep used for the safety study were captured at Hall Mountain in a corral trap on December 19, 1985, and transported to Washington State University. Animals were marked with ear tags, and released into a 2-ha (5-acre) enclosure developed specifically for bighorn sheep. Treatment was accomplished in January 1986.

Parasitology

During the pretreatment feeding period, fresh fecal samples were collected from observed sheep and placed in whirl-pak bags that were numbered with sheep tag numbers. Samples from non-tagged sheep were collected randomly. About 30 pretreatment fecal samples were collected from each population on the day of treatment. Approximately 20 pellets were collected from each sheep and 10 g of feces were evaluated for lungworm larvae with the Baermann technique (Beane and Hobbs 1983). Numbers of Protostrongylus larvae per g of feces were recorded. Fecal flotation (sugar solution, sp. gr.=1.27) was used to determine the identities and numbers of other parasites.

About 4 weeks after treatment, 30 fecal samples were collected from tagged and untagged sheep in each population. Feces were analyzed to determine numbers of Protostrongylus larvae and other parasites per g.

Percent efficacy was measured by mean number of larvae in the pretreatment samples, minus mean numbers of larvae in the posttreatment samples, divided by mean number of larvae in the pretreatment samples, times 100.

Penned Sheep Safety Study

Twelve sheep (6 mature ewes, 3 immature ewes, 1 ram lamb and 2 ewe lambs) from the Hall Mountain population were maintained at Washington State University to determine the safety of fenbendazole. Six sheep (Group 1) were treated daily with fenbendazole in feed for 6 consecutive days at 30 mg/kg of body weight (BW) which was 3x the proposed field dose of 10 mg/kg. Six sheep (Group 2) were treated daily for 6 days with fenbendazole in feed at 50 mg/kg BW, 5x the proposed field dose. Sheep were assigned randomly to treatment groups with 1 lamb in Group 1 and 2 lambs in Group 2. Sheep were observed at least twice daily to determine if any adverse signs were associated with drug treatment. Since treatment was after the breeding season,

mature ewes (2 1/2 years-old and older) were assumed to be pregnant. Sheep were maintained at WSU for 30 days before treatment and for 6 months after treatment. Observations on lambs born to treated ewes were recorded.

Feed Analysis

Replicate feed samples were analyzed for fenbendazole content by Scientific Associates, Inc., St. Louis, MO 63123.

RESULTS

Feed assay results were 111-115% of theoretical, indicating excellent mixing of drug. No toxicity of the drug was observed in any herd of sheep.

Parasitology

In all studies, sheep ate the medicated pellets readily, usually within one hour, indicating the palatability of fenbendazole. Based on pretreatment analysis of fecal samples, Protostrongylus larvae were detected in 84-100% of sheep in each population (Table 1). Mean numbers of larvae were 5.9-24.4 per gram of feces. After treatment, Protostrongylus larvae were detected in 0-67% of the sheep, with 0.68 larvae per gram of feces (Table 1), indicating a substantial reduction in larvae. Gastrointestinal parasites such as Nematodirus, Trichuris, and Moniezia, also were adversely affected by treatment (Table 1). Other parasites present in low numbers were trichostrongyles, Eimeria spp., and Skrjabinema sp.

Lamb-Ewe Ratios

In Washington, the lamb-ewe ratios for 5 years before treatment were 17-63:100. The year after initial treatment, the ratio was 73:100 (Table 2).

Table 2. Ewe-lamb ratios in The Hall Mountain, Washington, bighorn herd before and after treatment with fenbendazole in 1986.

Year	Lambs/100 ewes
1981-82	17
1982-83	36
1983-84	59
1984-85	63
1985-86 (Treatment)	41
1986-87	73

Safety Study in Captive Bighorn Sheep

During the 30-day acclimation period in the 2-ha pen, the sheep adjusted to the fences and to daily vehicle traffic nearby. No acclimation problems were apparent. Sheep in Group 1 that were fed fenbendazole at 30 mg/kg BW for 6 consecutive days, and sheep in Group 2 that were fed fenbendazole at 50 mg/kg BW for 6 consecutive days ate the feed readily. No adverse effects associated with treatment were observed. Between May 19, and June 3, 1985, 6 lambs were born to the 6 mature ewes and 5 of these were raised to weaning. The sixth lamb was removed from the ewe on the day of birth because of severe weather conditions, and it subsequently died of pneumonia at 5 days of age.

DISCUSSION

Based on the data, fenbendazole is safe when incorporated into feed and fed to wild bighorn sheep at approximately 10 mg/kg BW. Efficacy of fenbendazole against Protostrongylus spp. was excellent in 2 of the 4 studies, and moderate in the other 2. It is likely that some untreated animals mixed with treated animals during the post-treatment period. Data from these sheep would bias evaluations of treatment efficacies. Comparisons of pretreatment vs. posttreatment samples within tagged sheep indicated higher efficacies. In the Oregon study, about 9 weeks lapsed between pretreatment and posttreatment collections. Although this was not intended, snowstorms delayed collections. New untreated sheep may have moved in during this period, and some somatic larvae in treated sheep may have matured. Fenbendazole is effective against adult Protostrongylus, but may be less effective against somatic larvae (Schmidt et al. 1979). In dogs, fenbendazole prevents transplacental migration of larval Toxocara canis when fed during the time of larval migration (Burke and Roberson 1983). It is not known whether transplacental migration of Protostrongylus is prevented if fenbendazole is fed daily during the period when larval migration occurs between and ewe and fetus. It may be necessary to feed fenbendazole for a long duration to eliminate most transmission.

Ivermectin at a subcutaneous dosage of 0.2 mg/kg of body weight, and albendazole at an oral dosage of 10 mg/kg of body weight have also been effective in reducing Protostrongylus larvae in feces of infected bighorns (Foreyt and Johnson 1980, Miller et al. 1987), and may also have application in the overall health care of bighorn populations. Since the effects of parasites, especially lungworms, can be severe in bighorn populations, a field deworming program may benefit the health, reproductive status, and survival of a herd, as indicated in this study.

LITERATURE CITED

Beane, R. D. and N. T. Hobbs. 1983. The Baermann technique for estimating Protostrongylus infection in bighorn sheep: Effect of laboratory procedures. J. Wildl. Manage. 19:7-9.

Buechner, J. G. 1960. Bighorn sheep in the United States: its past, present, and future. Wildl. Monogr. 4. 174 pp.

Burke, T. M. and E. L. Roberson. 1983. Fenbendazole treatment of pregnant bitches to reduce parental and lactogenic infections of Toxocara canis and Ancylostoma caninum in pups. J. Am. Vet. Med. Assoc. 183:987-990.

Foreyt, W. J. and R. Johnson. 1980. Treatment for lungworms (Protostrongylus spp.) in Rocky Mountain bighorn sheep (Ovis c. canadensis) with albendazole. Proc. North. Wild Sheep and Goat Counc. 2:248-261.

Forrester, D. J. 1971. Bighorn sheep lungworm-pneumonia complex. Pp. 158-173 in J. W. Davis and R. C. Anderson (Eds.), Parasitic diseases of wild mammals. Iowa St. Univ. Press, Ames, IA. 364 pp.

_____ and C. M. Senger. 1964. A survey of lungworm infection in bighorn sheep in Montana. J. Wildl. Manage. 28:481-491.

Hibler, C. P., T. R. Spraker and E. T. Thorne. 1982. Protostrongylosis in bighorn sheep. Pp. 208-213 in E. T. Thorne, N. Kingston, W. R. Jolley, and R.C. Bergstrom (Eds.), Diseases of Wildlife in Wyoming, 2nd Ed. Wyo. Game and Fish Dept., Cheyenne, WY. 353 pp.

Miller, M. W., N. T. Hobbs, W. H. Rutherford and L. L. W. Miller. 1987. Efficacy of injectable ivermectin for treating lungworm infections in mountain sheep. Wildl. Soc. Bull. 15:260-263.

Schmidt, R. L., C. P. Hibler, T. R. Spraker and W. H. Rutherford. 1979. An evaluation of drug treatment for lungworm in bighorn sheep. J. Wildl. Manage. 43:461-467.

Spraker, T. R. and C. P. Hibler. 1982. An overview of the clinical signs, gross and histological lesions of the pneumonia complex of bighorn sheep. Bienn. Symp. North. Wild. Sheep and Goat Counc. 3:163-172.

Uhazy, L. S., J. C. Holmes and J. G. Stelfox. 1973. Lungworms in the Rocky Mountain bighorn sheep of western Canada. Can. J. Zool. 51:817-824.

Table 1. Summary of eggs, larvae, and oocysts recovered pretreatment and posttreatment from bighorn sheep feces Washington (WA), Oregon (OR) and Idaho (ID).

Parasite	State	Year	Pretreatment No. obs. (% Pos.)	Pretreatment Larvae, eggs/g mean, S		Posttreatment No. obs. (% Pos)	Posttreatment Larvae, eggs/g mean, S		% Reduction of larvae
Protostrongylus	WA	1	67 (84)	5.9	8.2	37 (3)	0.1	0.7	98
	OR	1	69 (97)	24.4	24.1	36 (67)	6.8	13.0	72
	ID	1	61 (93)	13.2	18.4	20 (0)	0.0	0.0	100
	WA	2	31 (100)	6.9	7.0	25 (28)	4.2	10.9	39
Nematodirus	WA	1	67 (96)	42.9	44.9	37 (32)	4.1	8.1	90
	OR	1	69 (88)	36.4	33.4	36 (92)	18.5	16.8	49
	ID	1	61 (92)	8.6	6.5	20 (0)	0.0	0.0	100
	WA	2	31 (74)	25.5	28.1	25 (28)	15.4	44.0	40
Trichuris	WA	1	67 (55)	14.2	20.7	37 (35)	2.9	5.0	80
	OR	1	69 (25)	0.9	2.2	36 (14)	0.5	1.1	43
	ID	1	61 (26)	1.6	3.5	20 (10)	0.4	1.1	78
	WA	2	31 (74)	10.4	10.7	25 (28)	4.6	13.3	56
Strongyles*	WA	1	67 (0)	0.0	0.0	37 (8)	0.1	0.4	0
	OR	1	69 (6)	0.4	2.2	36 (3)	3.9	2.3	0
	ID	1	61 (5)	0.1	0.2	20 (0)	0.0	0.0	100
	WA	2	31 (0)	0.0	0.0	25 (0)	0.0	0.0	0
Moniezia	WA	1	67 (4)	0.3	1.5	37 (0)	0.0	0.0	100
	OR	1	69 (6)	4.3	18.4	36 (6)	8.3	29.5	0
	ID	1	61 (31)	16.9	30.8	20 (0)	0.0	0.0	100
	WA	2	31 (6)	0.6	2.7	25 (4)	0.1	0.6	79
Eimeria	WA	1	67 (96)	1034.8	2154.0	37 (89)	286.6	664.9	72
	OR	1	69 (97)	396.0	614.8	36 (100)	676.4	824.4	0
	ID	1	61 (49)	54.0	118.2	20 (40)	133.2	313.4	0
	WA	2	31 (100)	242.9	437.6	25 (96)	140.9	209.3	42

* Includes Haemonchus, Ostertagia, Oesophagostomum, and Trichostrongylus.