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OVERVIEW AND PRELIMINARY ANALYSIS OF A BIGHORN SHEEP DIEOFF, HELLS CANYON 1995-96.

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Abstract: In November 1995, a bighorn sheep pneumonia epidemic started in northern Hells Canyon, Washington. In an effort to prevent spread of the disease, all 72 live sheep in the area of the initial outbreak were captured and transferred to a captive holding facility. However, the epidemic continued, and by February had apparently spread approximately 40 miles to the south. An estimated 327 bighorn sheep died, including 50-75% of the bighorn sheep in 4 Oregon and Washington herds most affected by the disease. Bighorn sheep across the Snake River in Idaho showed signs of respiratory disease, but no dieoff occurred. Bighorn sheep across the Imnaha River in Oregon were apparently unaffected. After surviving 16 days in captivity, bighorns removed from the wild began to die from bacterial pneumonia despite intensive treatment with antibiotics. Ultimately, 8 of 72 bighorns survived in captivity. Bacterial, viral, and parasitological samples were collected from 97 free-ranging bighorn sheep. Three feral goats and 6 domestic sheep were also sampled. *Pasteurella* associated pneumonia was the cause of bighorn mortality, but the factors that triggered the outbreak were not determined. Treatments included placing medicated protein blocks and feed near sick sheep. The most effective treatment appeared to be net-gunning sheep from a helicopter, treating with antibiotics, and releasing them at the capture site.

INTRODUCTION

This paper chronicles a Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) pneumonia epidemic that occurred in and near Hells Canyon of the Snake River in Washington and Oregon, November 1995 - March 1996. The epidemic resulted in mortality of approximately 327 bighorn sheep including 50 - 75% of the bighorn sheep in 4 of 10 herds in and around Hells Canyon. We report on the spread of the epidemic, summarize preliminary virology, bacteriology, and parasitology data and include information on efforts to treat free-ranging bighorn sheep affected by the disease outbreak.

STUDY AREA

Hells Canyon of the Snake River is located in Oregon, Idaho, and Washington (Fig. 1). Elevations range from approximately 243 m (800 ft) near Lewiston, Idaho to above 2743m (9000ft) in the Seven Devils Mountains, Idaho and Wallowa Mountains, Oregon. Much of the area is public land managed by the U.S. Forest Service. Livestock grazing, primarily cattle (*Bos taurus*), but also some domestic sheep (*Ovis aries*) and domestic goat (*Capra hircus*), occurs on public and private lands.

Canyon topography is steep and sharply dissected. Perennial bunchgrass plant communities dominate the landscape interspersed with deciduous shrub and tree dominated riparian stringers and shrub-fields. Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) stands occur on northerly aspects (Johnson and Simon 1987, Mancuso and Moseley 1994). Climate is characterized by light precipitation, low relative humidity, and wide ranges in temperature. Summers are hot and winters mild. Annual precipitation averages less than 25 cm (10 in.) in the canyon with the heaviest precipitation occurring in the winter months and in May and June (Johnson and Simon 1987).

History of bighorn sheep in Hells Canyon

Bighorn sheep (*Ovis canadensis*) were once abundant in Hells Canyon, but, as elsewhere in the west, populations declined precipitously with the arrival of settlers in the late 1800s, and bighorns were completely extirpated from the Hells Canyon area by the 1940s. The first reintroduction of bighorn sheep to Hells Canyon occurred in 1971. Since then, 357 sheep have been released at approximately 12 locations. Relocated sheep originated in and near Banff and Jasper National Parks, Alberta; the Middle Fork Salmon River, Idaho; Wildhorse Island and Thompson Falls, Montana; Tarryall and Cottonwood Creek, Colorado and Whiskey Basin, Wyoming. The most recent reintroduction occurred in February 1995 with the release of 38 bighorns from Cardinal River, Alberta into the Lower Hells Canyon, Oregon herd (Fig. 1).

Bighorn sheep have persisted at all the reintroduction sites. Over 700 bighorn sheep occurred in and near Hells Canyon by the winter of 1994-95 (Table 1). However, at least 5 population dieoffs have been reported since reintroductions were initiated: in 1971-72, 1983-84, 1986-87, 1988, and 1991. Three of these dieoffs (1972, 1983-84, and 1991) occurred in the Upper Hells Canyon, Idaho and Upper Hells Canyon, Oregon herds. The 1986-87 dieoff occurred in the Lostine herd (Coggins 1988) and the 1988 dieoff occurred in the Mountain View herd (Foreyt et al. 1990) (Fig. 1). The epidemics in the upper Hells Canyon and Lostine herds were thought to be related to contact with domestic sheep, but no definitive cause could be identified for previous dieoffs.

Dieoff chronology

This epidemic occurred in the winter of 1995-1996 at the northern end of Hells Canyon in Washington and Oregon. On 3 November 1995, Washington Department of Fish and Wildlife (WDFW) personnel observed a feral domestic goat with bighorn sheep in the Tenmile Creek area along the Snake River south of Asotin, Washington at the lower end of Hells Canyon. During the same period, local residents observed bighorn sheep coughing. On 18 and 19 November, 2 dead rams were discovered in 2 separate locations 15-20 miles upstream of Tenmile Creek. One of the rams was retrieved and taken to the Washington State University Animal Disease Diagnostic Laboratory, where pneumonia was determined to be the cause of death. More dead sheep were observed between Tenmile Creek and the Grande Ronde River (Fig. 1) over the next several days. On 28 and 29 November, 18 dead sheep were observed in a WDFW aerial survey and a bighorn ram, bighorn ewe, and the feral goat were collected together. The goat and bighorn ram appeared healthy, but the ewe showed signs of pneumonia including coughing and lack of mobility. By early December 1995, a total of 35 dead bighorn sheep were observed north of the Grande Ronde River. Ram, ewe, and lamb mortality were high near Tenmile Creek where the outbreak apparently started. Ram mortality dominated as the epidemic progressed to the south.

In an attempt to contain the spread of the disease, the 72 bighorn sheep remaining north of the Grande Ronde River were aerially net-gunned and placed in captivity at the Idaho Department of Fish and Game (IDFG) Wildlife Health Lab at Caldwell, Idaho. Fifty-eight were captured on 2 and 3 December, the remaining 14 were captured on 12 December. On 7 December, a lethargic bighorn ram was observed south of the Grande Ronde River during an aerial survey and on 18 December, 4 bighorns south of the Grande Ronde River in Washington were observed coughing (Table 2). On 21 December, 3 dead rams were found in Washington. One of these, the sick ram observed on 7 December, had been dead approximately 10 days. Bighorn sheep in Washington were again observed coughing during an aerial survey conducted on 5 January, as were sheep across the Snake River in Idaho, where 1 dead ram was located and collected. On 16 January, another dead ram was found in Washington. On 20 January, a coughing ram was collected upstream in Oregon and a dead ewe was retrieved in Idaho. On 30 January, 2½ months after the original outbreak, the first dead bighorns (2 ewes) were observed in Oregon, approximately 40 miles from the original outbreak (Fig. 1). Bighorns continued to die at a high rate through mid-March and some adult mortality continued through June. Low lamb survival was also apparent through July (Table 2). Mortality in the Wenaha and Mountain View herds was not confirmed until summer and fall of 1996.

Between mid-November 1995 and July 1996, approximately 120 dead bighorns were observed (including those that died in captivity) and 207 more were estimated to have died in the Hells Canyon area (Table 1). Initial mortality was highest in the Black Butte, Washington herd and the lower Hells Canyon, Oregon herds. Later mortality occurred in the Mountain View and Wenaha herds. Losses in other herds were light (Table 1).

Bighorn sheep transferred to captivity survived for at least 16 days, although many exhibited signs of pneumonia (weakness and coughing) at capture. The bighorns were originally separated into 4 pens, with sheep captured together penned together. On 14 December they were put together in a single pen. On 19 December they started dying from pneumonia and within 3.5 months, despite subsequent separation into

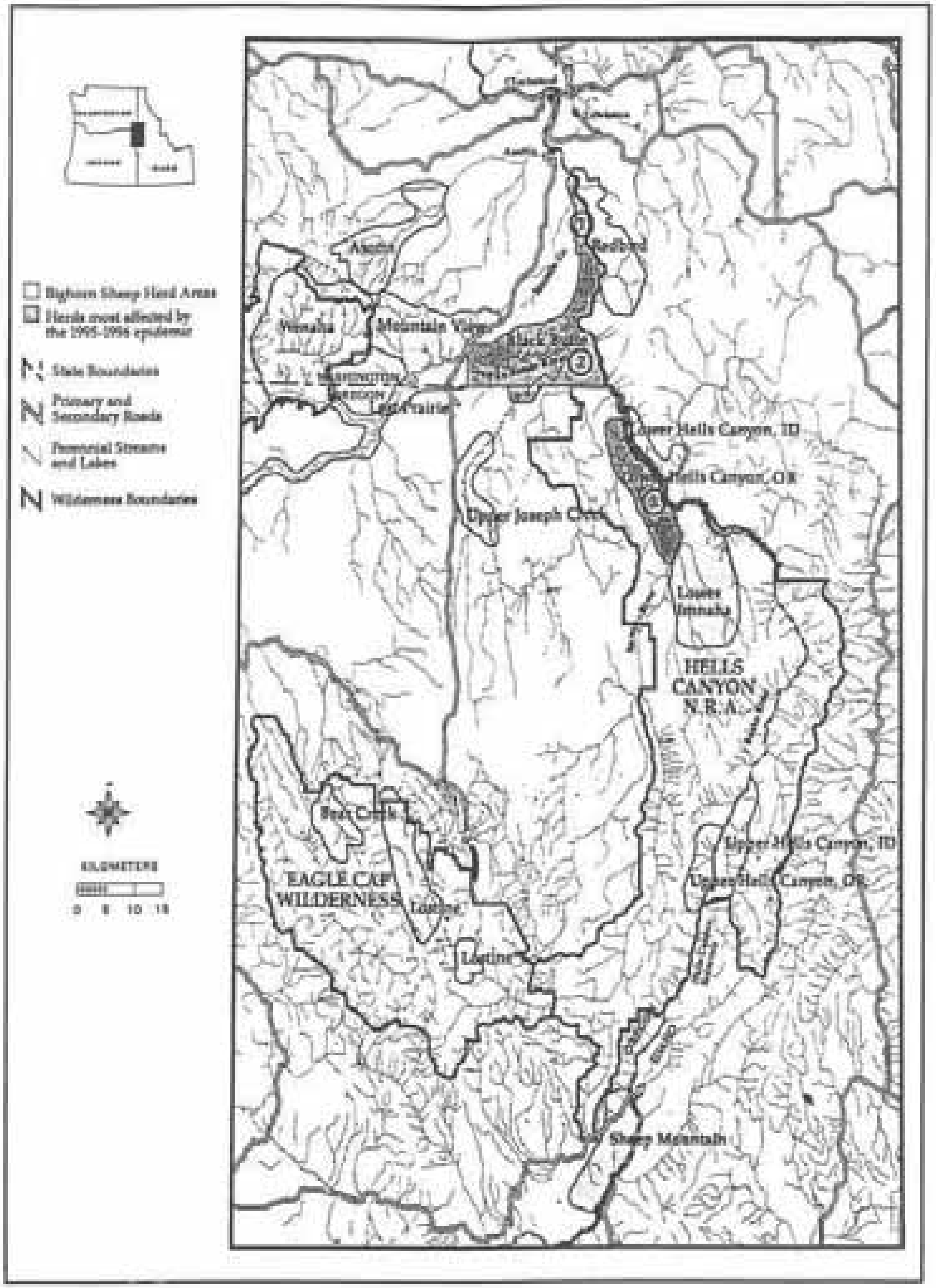

Figure 1. Bighorn sheep herds in and around Hells Canyon and the progression of the 1995-96 epidemic. Dead bighorn sheep were observed at location 1 in mid- November, location 2 by mid-December, and location 3 by mid- to late January. Dead bighorn sheep were also observed in the Lost Prairie/Wenaha, Mountain View, Upper Joseph Cr. and Redbird herds.

Table 1. Estimated Hells Canyon bighorn sheep numbers, pre- and post-dieoff, 1995-96.

Herd name	Pre-dieoff	Post-dieoff	Mortality (%)
Black Butte, WA	220	55	75
Lower Hells Canyon, OR	80	25	69
Upper Joseph Creek, OR	30	20	33
Mt. View, WA	51	18	65
Wenaha/Lost Prairie OR/WA	120	60	50
Lower Imnaha, OR	130	130	0
Upper Hells Canyon, OR	20	20	0
Redbird, ID	60	57	5
Lower Hells Canyon, ID	25	24	4
Upper Hells Canyon, ID	5	5	0
TOTAL	741	414	44

Table 2. Hells Canyon bighorn sheep survey information collected during and after the 1995-96 epidemic.

Herd and date	Rams	Ewes	Lambs	Total (live)	Rams:100 ewes:lambs	% with symptoms of pneumonia	No. dead
Black Butte, Washington							
11/28/95	23	66	38	126	35:100:58	3	12
12/6/95	0	10	6	16	-	"some"	29
12/7/95	22	43	18	83	51:100:42	1	0
12/18/95	14	27	9	53	52:100:33	6	0
12/23/95	13	32	15	60	41:100:47	10	0
12/28/95	8	32	16	56	25:100:50	4	0
1/5/96	9	46	17	72	20:100:37	7	0
1/20/96	3	7	3	13	-	15	0
1/30/96	5	21	6	32	-	0	0
2/14/96	5	43	7	55	12:100:16	16	2
3/11/96	9	34	13	56	26:100:38	7	1
5/15/96	4	36	12	52	11:100:33	0	0
6/21/96	1	34	2	37	3:100:6	3	0
Lower Hells Canyon, Oregon							
12/18/95	7	41	18	66	17:100:44	0	0
1/5/96	8	35	13	56	23:100:37	0	0
1/20/96	3	9	3	27	-	4	0
1/30/96	4	12	4	20	-	15	2
2/12/96	3	27	4	34	11:100:15	9	9
2/15/96	6	18	5	29	33:100:28	17	12
2/28/96	2	13	4	19	-	16	3
3/11/96	4	18	4	26	22:100:22	12	0
6/20/96	4	16	2	22	25:100:13	0	0
Upper Joseph Creek, Oregon							
2/12/96	1	15	4	20	7:100:27	0	0
3/26/96	0	13	4	17	0:100:31	12	1
Mountain View, Washington							
3/96	7	28	6	41	25:100:21	0	0
5/15/96	1	20	11	32	5:100:55	0	1 lamb
6/21/96	1	11	0	12	9:100:9	0	0

Table 2. Continued.

Herd and date	Rams	Ewes	Lambs	Total (live)	Rams:100 ewes:lambs	% with symptoms of pneumonia	No. dead
Wenaha/Lost Prairie, OR/WA							
11/28/95	19	48	9	76	40:100:19	0	0
01/30/96	8	31	6	45	26:100:19	0	0
03/12/96	2	24	6	32	8:100:25	0	0
03/27/96	-	-	-	80	-	-	-
06/21/96	0	18	8	26	0:100:44	0	0
11/28/96	6	31	1	38	19:100:3	0	0
Imnaha, Oregon							
12/18/95	19	17	5	41	112:100:29	0	0
2/6/96	3	11	7	21	-	0	0
2/12/96	1	15	9	26	-	4	0
2/28/96	-	-	-	19	-	0	0
3/11/96	0	6	4	10	-	0	0
3/14/96	1	27	13	41	4:100:48	0	0
6/12-14/96	41	48	30	121	85:100:63	0	0
Redbird, Idaho							
12/1/95	11	25	10	46	44:100:40	0	0
12/18/95	8	15	6	29	-	0	0
12/23/95	14	16	4	36	-	8	0
12/28/96	11	21	10	42	52:100:48	5	0
1/5/96	7	26	11	44	27:100:42	11	1
1/20/96	2	3	0	5	-	0	1
1/30/96	6	24	10	40	25:100:42	6	0
2/14/96	6	23	9	38	-	0	0
2/28/96	6	19	6	31	-	0	0
3/20/96	9	24	13	48	38:100:54	2	0
6/20/96	13	23	11	47	57:100:48	0	0
8/21/96	6	40	5	51	15:100:13	0	0
Lower Hells Canyon, Idaho							
12/1/95	7	15	4	26	46:100:27	0	0
12/18/95	4	3	2	10	-	0	0
1/5/96	5	4	2	11	-	0	0
1/20/96	6	0	1	7	-	0	0
2/15/96	3	8	1	12	-	0	0
2/28/96	4	10	2	16	-	0	0
3/20/96	6	12	1	19	50:100:8	0	0
6/20/96	2	1	3	6	-	0	0

3 pens and intensive treatment with antibiotics, 64 of the 72 captive sheep died from *Pasteurella* associated pneumonia.

METHODS

Between 22 November and 2 April, samples were collected for disease and parasite evaluation from ninety-seven free-ranging bighorn sheep (Washington, n = 77; Oregon, n = 16; Idaho, n = 4), including the 72 Washington bighorn sheep net-gunned and subsequently placed in captivity. Samples were also obtained from 11 recently dead carcasses, 6 sick sheep that were euthanized, and 8 live sheep captured by helicopter net-gunning or darting from the ground.

Swab samples for bacterial isolation were also collected from 6 domestic sheep, all on private land in Washington. Five penned domestic sheep on a tributary to the Grand Ronde River were sampled on 3 December, and 1 domestic sheep penned along the

Snake River, north of the Grande Ronde River was sampled on 22 December. Bacterial samples were also obtained from 3 feral goats including the feral goat originally observed with the bighorn sheep in November 1995. Two feral female goats (remnants of a group of domestic goats ranging north of the Redbird bighorn sheep herd for about 30 years, S. McNeill, pers. commun.) were captured and sampled on 12 December.

Nasal and pharyngeal swab samples were collected for bacterial analysis from live animals and from carcasses. Swabs were analyzed at the University of Idaho Caine Veterinary Teaching Center (CVTC) and the Washington State University Animal Disease Diagnosis Lab (WADDL). Bacteria were classified by biogroup at CVTC and by serotype by WADDL using standard techniques (Frank and Wessman 1978, Kilian and Fredriksen 1981, Carter 1984). Cytotoxicity tests (Silflow et al. 1994) were conducted on selected bacteria samples at Washington State University. DNA analysis of selected isolates was conducted using restriction enzyme assay (Rudolph et al., in prep.). All bacterial data reported in this paper were collected in the field.

Blood serum from 72 bighorn sheep aerially net-gunned in Washington was tested for anaplasma antibodies. Samples from 20 randomly selected Washington bighorns were analyzed at the Idaho State Bureau of Animal Health Labs and samples from 2 bighorns captured and treated in Oregon were analyzed at WADDL. Serologic tests were conducted for bluetongue, bovine respiratory sinsitial virus (BRSV) *Brucella ovis*, bovine viral diarrhea (BVD), epizootic hemorrhagic disease (EHD), *Leptospira* spp., infectious bovine rhinotracheitis (IBR), vibriosis, and parainfluenza -3 (PI-3) antibodies using standard techniques.

Nasal swabs (Viral Culturette, Becton Dickinson Microbiology Systems, Cockeysville, MD) were collected from 26 of the 72 net-gunned sheep for viral evaluation (Cottral 1978) at CVTC.

Most bighorn sheep were inspected for external parasites, including *Psoroptes ovis* (scabies) and ticks. Fecal samples were collected and examined for intestinal parasites, including *Eimeria* spp. (coccidia), *Nemotodirus* spp., *Moniezia* spp., and *Trichuris* spp. using a sugar fecal flotation technique (Foreyt 1994). Presence of lungworm larvae (*Protostrongylus stilesi* and *P. rushi*) was evaluated with a modified Baermann technique (Beane and Hobbs 1983).

Bighorn sheep transferred to captivity were treated with 5ml oxytetracycline (LA200), 5ml penicillin (Flocillin), and 2ml ivermectin (Ivomec) at capture. Ten bighorn sheep with signs of respiratory disease (9 in Oregon and 1 in Idaho) were treated with antibiotics and anthelmintics in the field 3 February - 27 March 1996. Seven of these (5 ewes, 2 young rams) were net-gunned from a helicopter, and 3 (1 ram and 2 ewes) were darted from the ground. All were released at the capture sites. Approximately 1 ton of medicated feed containing tetracycline, salt, trace minerals, and molasses was dropped from a helicopter near sick bighorns in Hells Canyon January - March. Three 23kg salt blocks containing selenium and 6-14kg protein blocks containing ivermectin were also distributed in Oregon.

RESULTS

Because of the differential mortality of adult rams, 77% of the bighorn sheep sampled were females, and of the 93 sheep where age was recorded, 66% were under 4.5 years of age and 46% were lambs and yearlings.

Bacteriology

Pasteurella bacteria were found in 93 of 97 bighorn sheep sampled. *Pasteurella* was not detected in 1 live sheep and 3 carcasses, possibly due to field contamination. *Pasteurella trehalosi* (also called *P. haemolytica* type T) was identified in 86 of 93 bighorn sheep with *Pasteurella* (92%). Four biogroups of *P. trehalosi* were identified. A single biogroup (2B) was isolated in 91% (69) of 75 bighorns where *P. trehalosi* was classified to biogroup. *P. haemolytica* and *P. multocida* were also isolated but were less common (48 and 20 bighorns, respectively).

Pasteurella trehalosi serotypes 4 (22 bighorns) and 3 (3 bighorns) were detected. The remaining *P. trehalosi* isolates agglutinated in several antisera including 3,4,10, and 15. *Pasteurella haemolytica* biotype A, serotypes 1 (2 bighorns), 2 (1 bighorn), 5 (2 bighorns), and 11 (1 bighorn), were detected. The remaining *P. haemolytica* isolates agglutinated in several antisera including 1,2,7,8,11, and 15. Most *Pasteurella* isolates agglutinated in more than 1 antisera or were untypable and may represent organisms unique to bighorn sheep (Dunbar et al. 1990). Direct cross-referencing between biogroups and serotypes was not possible. Isolates classified as a single biogroup by CVTC were sometimes divided into different serotypes by WADDL. Other bacteria isolated in the bighorn sheep samples included *Clostridium perfringens*, *C. sordelii*, and *Actinomyces pyogenes*.

Pasteurella haemolytica biotype A was isolated from the 6 domestic sheep and the 3 feral goats. *Pasteurella trehalosi* biogroup 2 (a biogroup found in 5 bighorn sheep) was isolated from the 2 Idaho feral goats and 3 of the domestic sheep. *Pasteurella multocida* was isolated from the Washington feral goat.

Cytotoxicity

Three of 24 bacteria samples tested were found to be cytotoxic. These were all *P. haemolytica* biotype A: 1 was from the bighorn ewe captured with the feral goat in Washington 29 November, 1 was from a bighorn ewe net-gunned south of the Grande Ronde River, Washington 2 December, and the third was from the single domestic sheep from the Snake River sampled 22 December.

DNA analysis

DNA analysis of selected **Pasteurella** isolates indicated that *P. haemolytica* and *P. multocida* bacteria were transferred between at least 4 bighorn sheep and 3 feral goats. The Washington goat observed at the start of the outbreak and a bighorn ewe collected with the goat shared genetically identical *P. haemolytica* and *P. multocida* bacteria. *Pasteurella haemolytica* biotype A in both Idaho goats matched *P. haemolytica* in bighorn sheep across the Snake River in Washington and bighorn sheep over 45 miles to the south and across the Snake River in Oregon. However, overall, DNA typing did not identify a single common *Pasteurella* organism in the affected bighorn sheep herds. To the contrary, in most cases *Pasteurella* bacteria isolated from the bighorn sheep exhibited a high degree of genetic variation (Rudolph et al. in prep.).

Serology and virology

Positive titers to 10 pathogens were identified serologically indicating likely exposure (Table 3). However, PI-3 was the only virus detected (1 of 26 bighorns evaluated). PI-3 and RSV titers increased in captive animals indicating continued exposure (Hunter and Rudolph, unpubl. data).

Parasitology

Internal parasites detected are listed in Table 4. Ticks (*Dermacentor albipictus* and *Otobius megnini*) were also commonly observed, although the frequency was not recorded. Psoroptic scabies was common among the bighorn sheep sampled. *Psoroptes* mites were detected in 68% (50) of 74 sheep sampled and lesions were observed in 84% (58) of 69 sheep examined.

Treatments

Five of 7 bighorn sheep net-gunned from a helicopter and treated with antibiotics in the field were was not followed. Survival of bighorn sheep net-gunned, radio-collared, and treated was 83% (5 of 6) (Table 5). Overall survival rate in the herd where bighorn sheep were treated (Lower Hells Canyon, Oregon) was estimated at 31% (Table 1) and all 8 previously radio-collared bighorns not treated in this herd died during the epidemic.

Three bighorns darted from the ground with oxytetracycline died (Table 5), including 1 due to problems with darting. The effect of the medicated feed is unknown. Some bighorns apparently ate the feed, but protein and salt blocks appeared to be more palatable to bighorn sheep than medicated feed.

DISCUSSION

The cause of this dieoff appears to have been *Pasteurella* - associated pneumonia. However, analysis of the bacteriology, virology, and parasitology has not yet revealed a pattern that would indicate how the dieoff started. Typical stressors (Ward et al. 1990) such as winter weather, high lungworm levels, high levels of human disturbance, or overpopulation were not apparent factors in this dieoff. A wet fall had produced better than average forage conditions and

Table 3. Results of serologic tests for antibodies to pathogens in selected free-ranging Hells Canyon bighorn sheep sampled December 1995 - March 1996.

Pathogen*	n	No. positive	% positive	Range of positive titer values
Anaplasma	76	1	1	
Bluetongue	20	7	35	
BRSV	22	18	82	8 -16
Brucella ovis	21	1	5	
BVD	22	13	59	8 - 16
EHD	20	7	35	
IBR	22	13	59	8 - 32
PI-3	22	13	59	10 - 160
Vibriosis	20	8	40	+50 - +100

* BRSV = Bovine respiratory sinsitial virus, BVD = bovine viral diarrhea, EHD = epizootic hemorrhagic disease, IBR = infectious bovine rhinotracheitis, PI-3 = parainfluenza 3.

Table 4. Internal parasites recorded in Rocky Mountain bighorn sheep sampled in Hells Canyon, 22 November 1995 - 27 March 1996.

Parasite	Units[a]	n[b]	% presence	Mean intensity	Positive range
Coccidia	epg	51	39	102	6 - 410
Strongyles	epg	51	80	16	1 - 74
Nematodirus	epg	51	43	4	1 - 14
Moniezia	epg	51	10	93	4 - 278
Trichuris	epg	51	14	7	1 - 35
Protostrongylus	lpg	60	50	8	1 - 28

[a] epg = eggs per gram of feces, lpg = larvae per gram of feces.
[b] number of bighorn sheep tested.

Table 5. Hells Canyon bighorn sheep treated in the field, February and March 1996.

Date treated	Sex	Age (yrs)	Capture type	Oxytetracycline (LA-200)	Tylosin (Tylan)	Flocillin	Ivermectin	Survival
3 Feb	F	5.5	net-gun	5 cc	0	0	2.5 cc	no
15 Feb	F	1.5	net-gun	10 cc	0	5 cc	2.5 cc	yes
15 Feb	M	1.5	net-gun	8 cc	2 cc	5 cc	2.5 cc	yes
15 Feb	F	4.5+	net-gun	10 cc	2 cc	5 cc	2.5 cc	yes
19 Feb	F	2.5	dart	4 cc	0	0	0	no
11 Mar	F	4.5+	net-gun	10 cc	2 cc	5 cc	2.5 cc	yes
18 Mar	M	8	dart	8 cc	0	0	0	no
20 Mar	F	5.5	net-gun	11 cc	2 cc	0	2.5 cc	yes
20 Mar	M	0.5	net-gun	6 cc	1.5 cc	0	2.5 cc	unknown
27 Mar	F	4.5+	dart	8 cc	0	0	0	no

bighorn sheep were in excellent condition at the start of the dieoff. The only potentially predisposing factors detected were the prevalence of scabies and possibly the presence of PI-3. However, the role of these factors, was likely secondary to pasteurellosis. The PI-3 infection rate appeared to be low and scabies has apparently been present in Hells Canyon bighorn sheep since 1984 (Foreyt et. al 1990).

Circumstantial evidence would implicate the feral goat from Washington. The timing of the observation of the goat together with bighorn sheep in the area where the epidemic started just prior to the dieoff suggests cause and effect. It was demonstrated that *Pasteurella* spp. were transferred between bighorn sheep and feral goats in the wild. A bighorn ewe and feral goat shared genetically identical *Pasteurella* at the beginning of the outbreak, and only the bighorn showed signs of pneumonia, suggesting possible differential susceptibility to the same bacteria. One of the shared bacteria was cytotoxic in the bighorn and not in the goat. However, the direction of bacterial transfer (bighorn to goat or goat to bighorn) could not be determined, nor were these bacteria common among the bighorns sampled during the epidemic. Therefore, although domestic goats may pose a threat to bighorn sheep, their role in this dieoff could not be established.

Removal of sick bighorn sheep did not stop the epidemic, although it may have slowed the spread of disease. While handling large numbers of animals allowed collection of more disease-related data than would have otherwise been possible, it has not yet provided the information needed to determine the chain of events leading to the epidemic. Removing bighorns did not prevent the eventual spread of the disease nor did it prevent the loss of the captured bighorn sheep. Rather, the stress of captivity and handling may have increased mortality. Perhaps isolating the individuals or groups with clinical signs of illness from apparently healthy individuals might have increased bighorn survival, however there would still have been reluctance to return any of these bighorns to the wild because of the potential that they would be carrying a pathogenic *Pasteurella* transferred in captivity.

Over a 4-month period, the epidemic spread approximately 40 miles from the initial outbreak, despite a relatively patchy distribution of bighorn sheep in the area. The Snake, and possibly the Imnaha Rivers seemed to act as barriers to the spread of disease, even though bighorns are known to cross both rivers and genetically identical *Pasteurella* isolates were collected from both sides of the Snake River. Although bighorn sheep across the Snake River in Idaho exhibited signs of respiratory disease, including coughing, no large scale dieoff occurred. Perhaps reluctance of bighorn sheep to cross the rivers due to high water levels during the winter of 1995-96 protected the Idaho and Imnaha herds. A person hired to haze bighorn sheep away from the Imnaha River may have also helped reduce bighorn movements in and out of the Lower Imnaha herd.

Treatment of bighorn sheep in the wild appeared to be successful when sheep were net-gunned aerially. Sheep that were darted from the ground may have been too sick to respond to treatment or drug delivery may not have been successful. This corroborates experience in a previous dieoff in Oregon where treatment with antibiotics increased bighorn survival (Coggins 1988). The 16 day survival of bighorns net-gunned, treated, and transferred to captivity at the start of the epidemic also suggests treatment was effective, although apparently not adequate to offset problems encountered in captivity. Additional testing of drug treatments is warranted. Treatments were regarded positively by the public, but capturing and treating individual sheep was difficult and expensive.

Although relatively large numbers of bighorns were sampled during the course of this epidemic, to date we have been unable to trace the causative agent(s). We hope that further analysis will provide additional information and answer some of the questions raised during this experience.

LITERATURE CITED

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