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A 20-YEAR HEALTH EVALUATION STUDY OF A HEALTHY BIGHORN SHEEP POPULATION IN NORTHEASTERN WASHINGTON

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Abstract: Between 1976 and 1996 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) at Hall Mountain in northeastern Washington were captured and specific biological samples were collected for health evaluation of the herd. Samples from 230 bighorn sheep were collected during the study and evaluated for respiratory viruses, *Pasteurella* spp., internal and external parasites, antibodies to respiratory viruses, *Anaplasma* spp. and *Brucella* spp. Respiratory viruses were not detected during the study, although antibodies against parainfluenza virus 3, bovine virus diarrhea virus and respiratory syncytial virus were detected sporadically, and four reactors to *Brucella ovis* were detected. *Pasteurella hemolytica* was detected in all sheep sampled when samples were collected from the pharyngeal area, but was rare when sampled from nasal sinuses. All *P. haemolytica* isolates were biotype T (also called *Pasteurella trehelosi*), and were primarily serotypes T3, T4, T3,4, and T3,4,10. Internal parasite numbers were low based on fecal evaluation, *Psoroptes* spp. mites were not detected on any sheep, and ticks were uncommon. Respiratory disease was not observed clinically during the 20-year study, and animals appeared clinically healthy. During the study period, 85 bighorn sheep were translocated to other areas in Washington and Oregon, several bighorn sheep migrated into Canada and formed a new herd, and 14 mortalities were confirmed. Bighorn sheep in the Hall Mountain population have not had known contact with domestic sheep or other livestock, are fed at a feed station in winter, and are dewormed during most winters with fenbendazole or ivermectin in feed supplements. We believe the results of this long-term study represent herd health parameters characteristic of a proactively managed herd of healthy bighorn sheep.

Bighorn sheep (*Ovis canadensis*) are susceptible to numerous diseases that can affect their well-being and survival. Monitoring populations of bighorn sheep for specific health parameters can provide a basis for determining the health status of the population in terms of predicting population survival and growth, and suitability for transplant stock. Between 1976 and 1995, we monitored a healthy herd of bighorn sheep on Hall Mountain (48050'N, 117015'W) in northeastern Washington for specific disease parameters. To our knowledge, this herd of bighorn sheep has never had signs of infectious diseases and has not experienced excessive mortalities. The purpose of these studies was to document the presence and prevalence of specific disease agents in a herd of bighorn sheep through the use of physical observations and established laboratory techniques.

We thank the hundreds of enthusiastic veterinary students who have participated in this study over the 20 years. We also thank the numerous personnel from the Washington Department of Fish and Wildlife, United States Forest Service, and wildlife groups who assisted in the study.

History of the Hall Mountain Bighorn Sheep Herd

In 1972, 18 Rocky Mountain bighorn sheep *(Ovis canadensis canadensis)*, including five rams and 13 ewes, were transplanted to Hall Mountain in northeastern Washington from Waterton Lakes National Park, Alberta, Canada (Johnson 1983). The only addition to the herd since the original transplant has been two adult ewes from Wildhorse Island on Flathead Lake in Montana in 1981. A winter feeding station was established at Hall Mountain from which the sheep are fed alfalfa hay and alfalfa grain pellets. Mineralized block salt is available at all times, and anthelmintic medicated feed blocks or pellets are provided during most winters. The bighorn sheep at Hall Mountain have never been hunted, and are generally accustomed to the presence of humans. The Hall Mountain herd is a tourist attraction, and hundreds of people visit the sheep feeding station each winter. Currently the herd contains approximately 35 animals (Table 1).

Between 1977 and 1993 a total of 85 sheep were translocated from Hall Mountain to other areas in southeastern Washington and northeastern Oregon to initiate new herds or supplement existing herds. Some

sheep have migrated into British Columbia and have initiated a new herd near Salmo Pass, which currently numbers approximately 25 sheep. Although there is some interchange of sheep between the Hall Mountain and Salmo Pass herd, the interchange is minimal. A total of 14 known mortalities have been recorded in the Hall Mountain herd during the 20 year period. The deaths have been attributed to cougar predation, illegal hunting, capture myopathy and unknown causes. Population numbers, lamb-ewe ratios, and translocated sheep are listed in Table 1.

MATERIALS AND METHODS

Bighorn sheep at Hall Mountain have been captured by different methods. Initially, sheep were captured in groups with a drop net after baiting the area under the net with alfalfa hay. A permanent corral trap was constructed in 1983 to capture the sheep on a yearly basis. Sheep were attracted into the trap with alfalfa hay and alfalfa pellets, and when a sufficient number were inside the trap, the door was pulled closed. Sheep were then forced through an small chute where they were restrained physically. To facilitate handling, some large rams were given 100-200 mg of xylazine using a jab stick, while other rams were hazed into a drive net and then restrained physically. Some very large rams were released without being sampled due to human and animal safety concerns. Following sample collection, tranquilized rams were given yohimbine as the reversal drug. Less than ten sheep also were captured by hazing them into a drive net, or by immobilizing them with xylazine administered from a tranquilizing rifle or pistol. After sheep were restrained physically, the following medications were given: ivermectin (Ivomec, MSDAGVET, Rahway, New Jersery) at 0.2 mg/kg body weight, 5 cc of long acting penicillin (Flo-Cillin, Fort Dodge Laboratories, Inc., Syracuse, New York), selenium and vitamin E (BO-SE, Shering-Plough Animal Health, Kenilworth, New Jersey) at 1 cc per/25 kg body weight, and 2.5 cc of a 7-way clostridium vaccine (Fermicon 7/Somnugen, Bochringer Ingelheim Animal Health, Inc., St. Louis, Missouri).

Between 1976 and 1996, biological samples for evaluation were collected from 230 bighorn sheep (Tables 2-4). While the sheep were physically or chemically restrained, approximately 5 grams of feces was collected from the rectum, and 10 mls of blood was obtained from the jugular vein using an 18 gauge needle and 10 cc syringe, and then transferred to a Vacutainer blood collection tube. Nasal swab samples (Viral Culturette, Becton Dickinson Microbiology Systems, Cockeysville, Maryland) were collected for virus isolation, and nasal or pharyngeal swab samples (Transette, Spectrum Laboratories, Inc., Houston Texas) with charcoal Amies modified media, were collected for bacterial isolation. Cotton tipped swab samples were collected from each ear for detection of mites, and skin and hair were examined grossly for lice and ticks. Sex and age were determined on each sheep while they were restrained. Most sheep have been given large plastic ear tags for identification, and in the last two years of the study, sheep have been implanted with a microchip (AVID, Norco, California) in the cartilage at the base of one ear, and a second microchip in the subcutaneous tissues of the neck.

The blood tubes were placed in a cooler containing ice for transport to the laboratory. After centrifugation, the serum was withdrawn, placed in 2 ml plastic vials and frozen at -20C until it was evaluated for antibodies to parainfluenza 3 virus (PI3), infectious rhinotracheitis virus (IBR), bovine virus diarrhea virus (BVD) and respiratory syncytial virus (RSV). All serological analyses were done at the Washington Animal Disease Diagnostic Laboratory (WADDL), Pullman, Washington, by standard laboratory tests. All swab samples collected prior to 1991 were transported to the laboratory in ice; however, since 1991, swab samples for bacteria isolations have been placed in phosphate buffered glycerol (Foreyt and Lagerquist, 1994) and transported to the laboratory on dry ice. Within 24 hours of collection, swab samples for bacterial isolation were streaked onto sheep blood agar plates for isolation of *Pasteurella* spp. Suspected colonies of *Pasteurella* spp. were identified based on morphological characteristics (Carter, 1990). Biotyping and serotyping of isolates were done by methods described by Foreyt and Lagerquist (1994). Swab samples for virus isolation were inoculated onto ovine embryonic tracheal cells (American Type Culture Collection No. CCL 44) and bovine turbinate cells (American Type Culture Collection No. CRL 1390) for two passages at 10-day intervals and were examined daily for cytopathic effect (Castro, 1992). Additional specimens were tested for respiratory syncytial virus by use of solid phase-enzyme immunoassay (Abbott RSV EIA, Abbott Laboratories, South Pasadena, California). Ear swabs were transported in glass blood collection tubes and examined in the laboratory for mites using a dissecting microscope with 20 to 40X magnification. Ticks and lice were placed in glass tubes and identified later in the laboratory using a dissecting microscope with 20 to 40X magnification. Fecal samples were evaluated for parasite eggs and oocysts by the sugar flotation tech-nique (specific gravity of 1.27) as described by Foreyt (1997). Feces also were evaluated for lungworm larvae using the standard Baermann

technique (Beane and Hobbs, 1983). Numbers of eggs, oocysts, and larvae per gram of feces were determined.

RESULTS

The herd composition and numbers of bighorn sheep in the Hall Mountain herd are listed in Table 1. A total of 230 bighorn sheep were captured for sample collection between 1976 and 1996, with most captures occuring in December of each year (Table 2-4). One sheep died during capture, and four sheep died within 24 hours of capture, probably from capture myopathy. Between 1976 and 1993, 85 bighorn sheep were removed from the herd as transplant stock to other areas in southeastern Washington and northeastern Oregon.

Serology results are listed in Table 2. Antibodies to the viruses PI3, BVD, and RSV were detected sporadically during the study. Prevalence did not vary over the experimental period. Antibodies were not detected for the viruses IBR and BT. Antibodies to *Brucella ovis* were detected in 5 of 82 (6%) sheep samples, and antibodies to *Anaplasma* were detected in 10 of 17 (59%) of the sheep tested. Viruses were not detected in 64 of the sheep sampled.

A summary of *Pasteurella haemolytica* recovered from pharyngeal swabs between 1991 and 1996 is in Table 3. *Pasteurella haemolytica* biotype T (= *Pasteurella trehelosi*) were recovered from all sheep sampled (Table 3). The most common serotypes recovered were T3,4 (33% of the samples), T 3,4,10 (19%), T untypeable (16%) and T4 (11%) (Table 3). Eight additional serotypes (21%) are listed in Table 3. *Pasteurella multocida* was recovered from pharyngeal swabs from four sheep.

Parasite eggs, larvae, and oocysts are listed in Table 4. *Protostrongylus* larvae were detected in 124 of 220 samples (56%), mean intensity of 6 larvae per gram of feces. Coccidia (*Eimeria* spp.), *Nematodirus* sp. and *Trichuris* sp. were recovered from 92%, 86%, and 66%, respectively, of the sheep evaluated. Other parasite eggs detected included pinworm, *Skrabinema ovis*, in 1 of 192 sheep, tapeworm, Moniezia sp. in 3 of 192 sheep, strongyles in 6 of 198 sheep, and *Capillaria* sp. in 5 of 198 sheep. Dorsal spined larvae compatible with *Parelaphostrongylus* sp. were detected in 4 of 220 fecal samples.

Although ticks were not specifically searched for on all sheep, ticks were recovered from 14 of the sheep captured. *Dermacentor albipictus*, adults and nymphs, was the only tick recovered. Ear swabs for mites (*Psoroptes* sp.) and ear ticks *Otobius megnini* were negative for 103 sheep. Gross observations on all sheep captured did not reveal lesions compatible with mange. One louse, *Linognathus* sp., was recovered from one sheep.

Table 1. Summary of annual bighorn sheep population at Hall Mountain.

Year	Estimated population	Best count	Lamb/ewe ratio	Translocated
1996	35	10R17E5L[a]	29/100	
1995	35	10R15E5L	33/100	
1994	35	13R14E6L	43/100	
1993	45	13R18E9L	50/100	4R4E3L
1992	40	12R14E5L	43/100	
1991	40	12R12E6L	50/100	2R3E1L
1990	45	19R20E11L	55/100	3L
1989	40	13R15E9L	60/100	
1988	30	10R12E5L	42/100	
1987	30	12R10E6L	60/100	1R2L
1986	35	13R11E9L	82/100	1R
1985	65	21R29E12L	41/100	3R15E8L
1984	65	17R27E17L	63/100	
1983	55	13R22E13L	59/100	1R3E7L
1982	70	21R34E15L	44/100	3R8E4L
1981	60	10R24E14L	58/100	
1980	45	4R15E9L	60/100	
1979	35	27 total	8 lambs	
1978	30	6R10E5L	50/100	
1977	25	NR[b]		
1976	36	5R7E2L	29/100	2R5E2L
1975	30	22 total	5 lambs	
1974	25	19 total	7 lambs	
1973	NR			
1972	18	5R13E	NR	First released

[a] R = ram, E = ewe, L = Lamb
[b] Not recorded

DISCUSSION

Results from this survey establish health parameter data for this herd of healthy bighorn sheep. Based on all observations, animals numbers and composition, and health data collected, it appears the Hall Mountain herd of bighorn sheep has remained healthy since the initial transplant in 1972. No

Table 2. Summary of serology results from Hall Mountain bighorn sheep (1976-1996).

Year	# bighorns sampled	# males/ # females	Adults/ lambs[a]	PI3[c,e]	RSV[b,d]	BVD[b,e]	IBR[b,f]	OPP[b,g]	Brucella[b]	Bluetongue[b]	Anaplasma
1996	18	10/8	13/3	4/17	2/12	0/17	0/17	0/17	1/17	ND	ND
1995	14	4/10	7/7	2/14	0/14	0/14	0/14	0/8	2/14	ND	3/8
1994	11	2/9	9/2	2/11	0/11	0/11	0/11	ND	1/11	ND	ND
1993	4	3/1	4/0	1/4	1/4	ND[h]	ND	0/4	1/4	ND	ND
1992	15	4/11	10/5	3/15	0/15	0/15	0/15	ND	0/15	0/15	ND
1991	9	5/4	2/7	4/9	0/9	0/9	0/9	ND	ND	ND	ND
1990	18	8/10	15/3	0/18	0/18	ND	ND	0/18	ND	0/18	ND
1989	9	6/3	8/1	0/9	0/9	0/9	0/9	0/9	ND	ND	7/9
1988	9	5/4	7/2	0/9	0/9	0/9	0/9	ND	ND	ND	ND
1987	18	10/8	15/3	0/18	0/18	0/18	0/18	ND	ND	ND	ND
1986	15	5/10	10/5	0/15	0/15	0/15	0/15	ND	ND	ND	ND
1985	15	4/11	11/4	0/15	0/15	0/15	0/15	ND	ND	ND	ND
1983	20	6/14	15/5	0/20	0/20	0/20	0/20	0/20	ND	0/20	ND
1982	34	10/24	24/10	ND	ND	ND	ND	ND	ND	ND	ND
1977	11	NR[i]	NR	3/11	ND	4/11	0/11	0/11	0/11	ND	ND
1976	10	NR	NR	5/10	ND	0/10	0/10	ND	0/10	0/10	ND
TOTAL	230	82/227	152/57	24/195	3/169	4/173	0/173	0/85	5/82	0/63	10/17

[a] Lambs are animals born that year; all others are included as adults
[b] Number of animals positive/number of animals sampled. A titer >5 considered positive
[c] Parainfluenza 3 virus
[d] Respiratory syncytial virus
[e] Bovine virus diarrhea
[f] Infectious bovine rhinotracheitis virus
[g] Ovine progressive pneumonia virus
[h] Not done
[i] Not recorded

viruses have been isolated from this herd, although a low antibody prevalence against three of the respiratory viruses, PI3 (12%), BVD(2%), and RSV (<1%) indicate that exposure to the viruses has occurred.

The significance of the high prevalence of *Anaplasma* sp. in this herd of bighorn sheep is unknown. Although anaplasmosis in wildlife generally produces only a mild disease (Thorne et al. 1982), experimental infections of two captive bighorn sheep with *A. ovis* have resulted in severe clinical disease, indicated that free ranging bighorn sheep may be adversely affected if exposed to the organism in nature (Tibbits et al. 1992). Recovered animals can become latent carriers, and may serve as natural reservoirs for anaplasmosis.

Five of 82 (6%) of the sheep had a *Brucella ovis* titer of >1:10. It is not known at this time if these titers indicate actual exposure or infection, or are cross reacting with other organisms. Although reproduction does not appear affected in the Hall Mountain herd, *Brucella* serology, isolation attempts for *Brucella* sp. from tissues, and observations of lamb numbers should be continued in the future to determine whether *B. ovis* is present within the herd, or whether these four reactors are false positive reactions.

Prior to 1991, only nasal swabs were collected for detection of *Pasteurella* spp., and *Pasteurella* spp.were not isolated. Since 1991, pharyngeal swabs have been collected from each animal and *P. haemolytica* has been isolated from every animal sampled. *Pasteurella haemolytica* biotype T is commonly isolated from healthy bighorn sheep; whereas biotype A isolates are uncommon in healthy bighorn sheep and are more frequently isolated from moribund or dead bighorns (Foreyt 1994, Silflow et al. 1994).

The relatively high prevalence of coccidia, *Nematodirus* sp., *Trichuris* sp., and *Protostrongylus* sp., which has been consistent throughout the study, appears to have no detrimental impact upon individual animals and therefore the herd as a whole. Fenbendazole or ivermectin medicated feed blocks or pellets have been available at the feeding station during most winters, and have been consumed by most of the sheep present. All animals which are captured are given an injection of ivermectin, which is effective against most gastrointestinal and external parasites, but not protozoan parasites, including coccidia. The goal of deworming sheep through use of anthelmintics on a yearly basis in this herd is to prevent an increase in parasites that could result in clinical effects of infection.

Table 3. Summary of Pasteurella haemolytica recovery from pharyngeal swabs collected from Hall Mountain bighorn sheep (1991-1996).

Year	# bighorns sampled	# males/ # female	Adults/ lambs*	Number positive	Type(s)	Mean # of isolates/bighorn
1996	16	10/6	13/3	16(100%)	T4 (n=2) T3 (n=4) T3,4 (n=7) T3,4,15 (n=1) T (Unt) (n=3)	3.1
1995	15	5/10	8/7	15(100%)	T4 (n=3) T3,4 (n=1) T3,4,10 (n=1) T3,4,10,15 (n=4) T4(10weak) (n=2) T4(3,10weak) (n=1) T3,4,10(15weak) (n=3) T(Unt) (n=1)	1.2
1994	11	2/9	9/2	11 (100%)	T4 (n=1) T3,4 (n=10) T(Unt) (n=1)	1.1
1993	4	3/1	4/0	4 (100%)	T4 (n=2) T3,4 (n=2)	1.0
1992	15	4/11	10/5	15 (100%)	T4 (n=2) T3,4 (n=2) T3,4,10 (n=9) T(Unt) (n=5)	1.2
1991	9	5/4	2/7	9 (100%)	T3,4 (n=4) T3,4,10 (n=5) T(Unt) (n=3)	1.3
TOTAL	70	29/41	46/24	70 (100%)	T4 (n=10) T3 (n=4) T3,4 (n=26) T3,4,10 (n=15) T3,4,10,15 (n=4) T(Unt) (n=13) T4(10weak) (n=2) T4(3,10weak) (n=1) T3,4,10(15weak) (n=3) T3,4,15 (n=1)	1.2

There have been no observed disease episodes among this herd of Rocky Mountain bighorn sheep at Hall Mountain since the initiation of the herd in 1972. Clinical disease has not been observed in existing herds that have received bighorns from Hall Mountain as transplant stock, or in recently initiated herds that originated from Hall Mountain. The continued good health of the current herd of bighorns at Hall Mountain would support their use as healthy transplant stock.

The number of animals at Hall Mountain has declined the past several years because some sheep have emigrated north into British Columbia, and a total of 85 sheep, especially mature ewes, have been removed from the herd as transplant stock. Therefore, additional removal of healthy sheep from the Hall Mountain herd, based on documented herd health history, is likely when the herd builds to an acceptably higher number of animals.

Table 4. Summary of fecal evaluation for parasites of Hall Mountain bighorn sheep (1976-1996).

Year	# bighorns sampled	# males/ # females	Adults/ lambs[a]	Protostrongylus[b]	Nematodirus[b]	Trichuris[b]	Coccidia[b]	Pinworm[b]
1996	16	10/6	13/3	9/16(7)	5/6(31)	4/6(14)	5/6(112)	0/6
1995	15	4/11	7/8	7/15(8)	12/13(78)	10/13(10)	13/13(642)	1/13(24)
1994[c]	11	2/9	9/2	9/11(7)	8/8(55)	7/8(28)	8/8(560)	0/11
1993	4	3/1	4/0	4/4(5)	4/4(40)	3/4(40)	4/4(193)	0/4
1992	15	4/11	10/5	0/15(0)	14/15(30)	12/15(17)	15/15(1008)	0/15
1991[d]	9	5/4	2/7	1/9(1)	2/2(13)	2/2(5)	2/2(19)	0/9
1990	18	8/10	15/3	5/18(8)	9/18(15)	12/18(26)	18/18(333)	0/18
1989	9	6/3	8/1	1/9(8)	3/9(29)	9/9(18)	9/9(1391)	0/9
1988	9	5/4	7/2	7/9(7)	8/9(86)	7/9(41)	7/9(NR)	0/9
1987	18	10/18	15/3	12/18(3)	18/18(53)	1/18(16)	18/18(NR)	0/18
1986	15	5/10	10/5	14/15(4)	12/15(57)	7/15(22)	15/15(2432)	0/15
1985	15	4/11	11/4	11/15(3)	14/15(70)	9/15(43)	14/15(1478)	0/15
1983	20	6/14	15/5	20/20(NR[e])	20/20(NR)	8/20(NR)	20/20(NR)	0/20
1982	34	10/24	24/10	20/34(NR)	33/34(NR)	27/34(NR)	31/34(NR)	0/34
1976	12	NR	NR	4/12(15)	8/12(18)	2/12(17)	4/12(NR)	0/12
TOTAL	220	82/126	150/58	124/220(6)	170/198(44)	130/198(23)	182/198(817)	1/198(24)

[a] Lambs are animals born that year; all others are included as adults
[b] Number of animals positive/number of animals sampled (mean number of larvae, eggs or oocysts per gram of feces of positive animals)
[c] Baermann technique for lungworm larvae conducted on all eleven samples; flotations conducted on eight samples
[d] Baermann technique for lungworm larvae conducted on all nine samples; flotations conducted on two samples
[e] Not recorded

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