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Evaluation of Management Treatments Intended to Increase Lamb Recruitment in a Bighorn Sheep Herd

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ABSTRACT: We administered a suite of treatments to a herd of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) that was experiencing poor lamb recruitment and showing signs of respiratory disease. Despite 3 yr of treatment with various combinations of anthelmentics, antibiotics, vaccines, and hyperimmune serum products, recruitment was not improved.

Key words: *Bibersteinia trehalosi*, bighorn sheep, *Mannheimia* spp., *Pasteurellaceae*, pasteurellosis, *Ovis canadensis*, recruitment, respiratory disease.

Respiratory disease, typically observed as acute to chronic pneumonia, represents one of the most significant threats to the long-term viability of bighorn sheep (*Ovis canadensis*) populations throughout western North America. Pneumonia epizootics in bighorn herds occur with variable frequency and severity (Marsh, 1938; Cassirer and Sinclair, 2007; George et al., 2008; Wolfe et al., 2010; and references therein). Years of depressed recruitment often follow such epizootics, adding to population suppression and hindering recovery (e.g., George et al., 2008; Wolfe et al., 2010). Although lamb pneumonia appears primarily responsible for depressed recruitment, determining the cause of mortality is sometimes difficult because carcasses are not available for necropsy. Bacteria species in the family *Pasteurellaceae* are often isolated from pneumonic bighorn sheep and have been implicated in the associated pathology (Onderka et al., 1988; George et al., 2008; Wolfe et al., 2010; Miller and Wolfe, 2011). Few tools are available for wildlife managers to use in protecting or recovering bighorn sheep populations from respiratory disease (Cassirer et al., 2001; George et al., 2008, 2009; Wolfe et al., 2010). Here we describe a suite of treatments used in an attempt to increase lamb recruitment in a free-ranging bighorn sheep herd.

The Badger Creek bighorn sheep herd winters in the vicinity of Gribbles Park (38°38′34″N, 105°47′34″W), about 21 km northeast of Salida, Colorado, USA. The immediate area is characterized by mountainous terrain with open southern slopes and timbered northern slopes at an elevation of 2,680 m above sea level. Average annual precipitation is 38–50 cm. This herd was started with a translocation of 19 adult bighorns in 1990 from the Rampart Range herd (George et al., 2009) and reached an estimated peak size of about 62 animals in 2005 (K. J. Woodruff, unpubl. data). Annual lamb recruitment to winter (December–February) generally remained at ≥16 lambs prior to 2000 based on observation of animals on bait sites (K. J. Woodruff, unpubl. data). However, annual lamb recruitment has been depressed since at least 2004 with no more than seven lambs surviving (lambs: 100 females ≤15.2 [SE=5.3]; Table 1).

Each winter from the late 1990s through 2007, the Colorado Division of Wildlife (CDOW) fed bighorns in this herd both alfalfa hay and apple pulp daily for an average of 5 wk, the latter laced once or twice each winter with fenbendazole (about 3 g per ewe per treatment) with the intent of reducing lungworm (*Protostrongylus* spp.) burdens (Miller et al., 2000; K. J. Woodruff, unpubl. data). Historically there had been no known die-offs of significant numbers of bighorns in the area; however, managers indicated that the adult population began

TABLE 1. Winter treatments and maximum counts of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) lambs and ewes in the Badger Creek herd, Gribbles Park, Colorado, present on winter range from 2004–2010. Effect of treatment on lamb recruitment, if any, was expected to occur in the year following treatment. See text and footnotes for details of herd treatments.

Winter	Herd treatments[a]	Lambs	Ewes	Lambs: 100 ewes
2004–2005	F,B	7	46	15.2 (SE=5.3)
2005–2006	F,B	5	35	14.3 (SE=5.9)
2006–2007	F,B	2	34	5.9 (SE=4.0)
2007–2008	F,T,D	0	25	0.0
2008–2009	F,T,D,M,R,H	2	23	8.7 (SE=5.9)
2009–2010	F,T,D,M,R	2	22	9.1 (SE=6.1)
2010–2011	N	0	16	0.0

[a] F = fed hay and apple pulp daily; B = oral fenbendazole once or twice per winter; T = tulathromycin (Draxxin®, Pfizer Animal Health, New York, New York, USA); D = doramectin (Dectomax®, Pfizer Animal Health); M = *Mannheimia haemolytica* serotype 1 vaccine (One Shot®, Pfizer Animal Health); R = multivalent respiratory virus vaccine (Triangle® 4 + type II BVD, Fort Dodge Animal Health, Fort Dodge, Iowa, USA); H = intranasal hyperimmune sera (RP-Bridge and M-Bridge, VDx, Inc., Newburg, Wisconsin, USA); N = no treatments.

decreasing around 2001, and reported finding at least five adult bighorn skulls in different locations between 2005 and 2009. No carcasses were recovered, so cause of death was not determined in any of these cases. In March 2008, local managers noted that some adults were coughing and had mucopurulent nasal discharge and that the 2007 cohort lambs were absent from the Badger Creek herd. We captured most of the known females in this herd (22 of 25) and two males under a drop net, collected blood for serology and oropharyngeal swabs for bacterial culture (University of Idaho, Caldwell, Idaho), and administered tulathromycin (Draxxin®, Pfizer Animal Health, New York, New York, USA, 200 mg subcutaneously) and doramectin (Dectomax®, Pfizer Animal Health, 10 mg subcutaneously) in an attempt to treat the observed respiratory disease and to improve lamb recruitment in the following year. In addition, all captured animals were uniquely marked with ear tags. The five animals that escaped capture (three females and two males) were later darted with tulathromycin. Cultures revealed presence of a *Bibersteinia trehalosi* (biogroup 4^{CDS}) strain known to be pathogenic in bighorns (Miller and Wolfe, 2011), other *Pasteurellaceae* strains, and *Mycoplasma* spp. Serology revealed exposure (17/24, 71%) or active infection (7/24, 29%) with parainfluenza three (PI3) virus. Based on bacterial culture results and similarity to patterns seen in other affected bighorn herds (Cassirer and Sinclair, 2007; George et al., 2009; Miller and Wolfe, 2011; L. L. Wolfe, unpubl. data), we attributed the recruitment problems to respiratory disease. Despite treatment, lamb recruitment through December remained low in 2008 (Table 1).

In February 2009 we captured 18 of the approximately 34 (50%) known animals in the herd by drop net for treatment (Table 1); this timing was based on when the animals would come consistently to bait. In addition to repeating treatments with tulathromycin and doramectin as above, we administered a *Mannheimia haemolytica* serotype 1 bacterin-toxoid (One Shot®, Pfizer Animal Health, 2 ml subcutaneously), a multivalent, killed respiratory virus vaccine (Triangle® 4 + type II BVD, Fort Dodge Animal Health, Fort Dodge, Iowa, USA, 2 ml intramuscularly), and two hyperimmune serum products (RP-Bridge and M-Bridge, VDx, Inc., Newburg, Wisconsin, USA, about 2 ml each, sprayed intranasally). Blood and oropharyngeal swabs were collected and screened as above. In addition, an enzyme-linked immunosorbent assay (ELISA; Confer et al., 2003) was used to measure serum antibody levels to both *M. haemolytica* leukotoxin and *M. haemolytica*

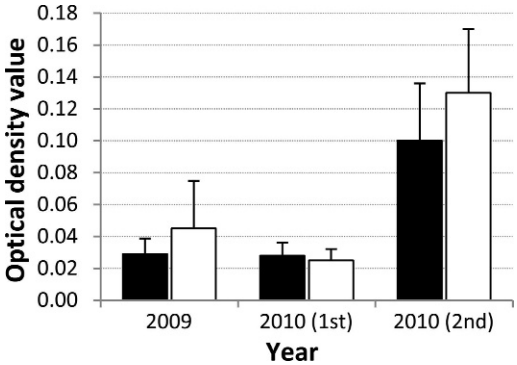

FIGURE 1. Enzyme-linked immunosorbent assay optical density values reflecting levels of serum antibodies to *Mannheimia haemolytica* leukotoxin (black bars) and whole cells (open bars) in samples collected from 10 Badger Creek bighorn sheep before vaccination in 2009, and for 8 bighorns sampled both before (1st) and after (2nd) vaccination in 2010. Bar heights are mean values; error bars represent +2 standard errors for each mean. See text and Table 1 for details of vaccination.

whole cells (Oklahoma State University, Stillwater, Oklahoma, USA). Analysis of samples identified *B. trehalosi* (biogroup 4^{CDS} and several biogroup 2 variants), *Mannheimia glucosida*, *Mycoplasma* spp., and antibodies to PI3 virus. At the time of capture, levels of antibodies to both leukotoxin and whole cells were relatively low as indicated by mean ELISA optical density (OD) values (Fig. 1; Sirochman, 2011). Adult survival appeared stable and lamb recruitment through December remained poor in 2009 (Table 1).

During January and February 2010 fewer bighorns came to bait at Badger Creek than in previous years. Managers believed that other individuals were alive but were avoiding the trap site. Because even the bighorns coming to bait became leery of the trap, only 10 were recaptured (via darting) and administered bacterin-toxoid, multivalent respiratory virus vaccine, tulathromycin, and doramectin (6 of 10 animals) as above (Table 1). Between 2 wk and 2 mo later, 8 of those 10 individuals were recaptured and all four treatments were again applied to each animal. Blood and oropharyngeal swabs were collected at each capture. Nine additional individuals were darted with doses of bacterin-toxoid that winter. Cultures still yielded *B. trehalosi* (biogroup 4 and biogroup 2 variants), several *Mannheimia* spp. strains, and *Mycoplasma* spp. Sera from bighorns captured in January and February 2010 (before receiving vaccine that year) had mean ELISA OD values that suggested concentrations of serum antibodies against *M. haemolytica* antigens were comparable to those measured in 2009 (differences in mean ± standard error OD values $\leq -0.02 \pm 0.015$; Fig. 1). However, mean OD values in sera from the eight recaptured individuals showed about a four-fold increase over mean values from samples collected earlier in the year (differences in mean±‴ standard error OD values $\geq 0.072 \pm 0.018$; Fig. 1), suggesting evidence of humoral immune responses to *M. haemolytica* antigens presumably stimulated by vaccination. No lambs from spring 2010 survived to December 2010 (Table 1).

Despite these aggressive herd health management efforts, the suite of treatments that we administered to the Badger Creek herd apparently did not improve lamb recruitment in any of the 3 yr in which these treatments were applied (Table 1). Overall, we do not know whether the treatments we applied were ineffective, or were insufficient or inappropriate with respect to remedying the cause of poor lamb recruitment in the Badger Creek herd. Weiser et al. (2009) noted that a single dose of antibiotics was unlikely to eliminate *Pasteurellaceae* from free-ranging bighorn sheep captured for translocation, and that antibiotic treatment with oxytetracycline actually appeared to increase the proportion of β-hemolytic isolates cultured after treatment. Miller et al. (1997) did not observe a change in *Pasteurellaceae* isolation rates as a result of vaccination with a *Pasteurellaceae* subcomponent vaccine despite stimulation of antibody responses. Cassirer et al. (2001) also were unable to improve

lamb survival by vaccinating female bighorns in late pregnancy with an experimental *B. (Pasteurella) trehalosi* and *M. haemolytica* vaccine, and a commercially available bovine *M. haemolytica* and *Protostrongylus multocida* combination vaccine (PRESPONSE7 H-M, Fort Dodge Laboratories, Inc.). Treatments may require repeated application to be effective, and this may not be feasible in a free-ranging population. Based on our experiences, it seems clear that developing alternative management strategies will be necessary to control or eliminate respiratory-disease–associated recruitment problems in bighorn sheep effectively.

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