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PARASITE LOADS AND THEIR RELATIONSHIP TO HERD HEALTH IN THE HIGHLANDS BIGHORN SHEEP HERD IN SOUTHWESTERN MONTANA

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Abstract: A study was conducted in 1992-93 to determine the parasite load of an established bighorn sheep herd located in the Highlands and East Pioneer mountain ranges in southwestern Montana, in order to estimate the potential impact of parasitism on the health of the herd. Post-mortem examination of 52 hunter-killed animals enabled determinations to be made of the numbers and types of helminths and Protozoa present at necropsy. These data were used to evaluate relative levels of infection and year-to-year fluctuations in parasitism. Forty-five fecal samples from these sheep, as well as 35 samples from a group of sheep captured for relocating, also were screened via the Baermann and modified Lane flotation techniques for additional evidence of the occurrence of parasites of the respiratory and gastrointestinal tracts in a bighorn population considered to be relatively healthy. Seventeen species of parasites belonging to eight genera were identified during the course of the study, including ten nematode, two cestode and five protozoan species. Coccidia (*Eimeria ahsata, E. faurei, E. intricata, E. ovina and E. ovinoidalis*) occurred commonly as mixed infections of low intensity. Average counts of protostrongylid lungworm larvae were 10.7 ± 153.3 LPG in 1993 (n=19). The group of 35 sheep captured for transplanting in 1992 had an average lungworm output of 21.8 ± 74.1 LPG. There were no significant differences between any of these lungworm larval shedding rates because of the high standard deviations. One species of adult cestode, *Wyominia tetoni*, was recovered from the livers of nine sheep. The lungs from 50 animals harbored mean *Protostrongylus* populations of 3.4 ± 4.6 in 1992 and 3.1 ± 5.1 in 1993. In addition, mixed gastrointestinal nematode populations consisting of *Ostertagia trifurcata, O. ostertagi, Nematodirus abnormalis, N. davtiani, Chabertia ovina* and *Trichuris* spp. were present in low numbers during both years, with all infections consisting of fewer than twenty adult worms per animal. The abomasal nematode *Marshallagia marshalli* was the only gastrointestinal parasite that occurred at levels suggestive of possible clinical parasitism, with averages of 236 and 114 worms per sheep in 1992 and 1993, respectively.

The original Highlands bighorn sheep herd, located in the Highlands and East Pioneer mountain ranges of southwestern Montana, disappeared in the early 1900's (Couey and Schallenberger 1971). In the late 1960's, an effort was made to re-establish this herd through two transplants of bighorn sheep from the Sun River herd. The first reintroduction, consisting of 27 animals, took place in 1967. This was followed by a second transplant of 31 sheep in 1969 (Couey and Schallenberger 1971, Janson 1974). Both groups were released into the Camp Creek drainage of the Highlands mountain range.

Even though this re-established herd has been in existence for over 25 years, limited information is available about its current size, parasite load and general health status. Further, no information is available on whether the parasite load is stable or increasing in this population. Information on parasites could be very important, as Thorne et al. (1982) believe that large populations of bighorn sheep are more likely to contract disease and/or parasites than small populations. It has also been documented that many bighorn die-offs occur in populations that appear to be thriving or have reached or exceeded the carrying capacity of their range. In addition, this herd may eventually be affected by the possibility of the BLM issuing a permit to allow four sections of public land, in and around bighorn winter range and rutting grounds in the western portion of the traditional range utilized by the herd, to be grazed by domestic sheep. This would allow for the possible transmission of disease and parasites from these domestic sheep to the bighorns. This action has been delayed until an ongoing study of the Highlands bighorn sheep herd's feeding and migration habits has been completed.

During the present study, hunter-killed bighorn sheep were examined in order to determine the numbers and types of parasites present in the Highlands population. The greatest advantage in using hunter-killed sheep in a study of this type is that a large sample can be obtained in a short time from widely distributed areas without arousing public animosity (Hunter and

Pillmore 1954). These data were also used to determine if there is a relationship between population size and parasite loads. The latter is based on a procedure for using parasite levels to estimate range utilization, herd densities, and other health-related factors in free-ranging ungulate populations. This concept has been used to correlate parasite intensity with the health status of white-tailed deer herds in the southwestern United States (Demarais et al 1983, Eve and Kellogg 1977), and is used routinely to infer a relationship between the size of deer herds and available forage (Doster 1985). The concept of using parasite levels, especially lungworm (*Protostrongylus spp.*) and stomach worm (*Marshallagia*) burdens in bighorn sheep as indicators of the balance between herd size and available range has been proposed (Worley and Seesee 1988, 1992).

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OBJECTIVES

The objectives of this study were to 1) Identify lung and gastrointestinal parasites present in the Highlands bighorn herd; 2) Estimate the average level of lung and gastrointestinal parasite infections present in the herd; 3) Identify potential trends in the level of parasite infection in Highlands sheep herd; 4) Determine if there is a correlation between sex, age, and/or level of precipitation and level of parasite infection in the herd; 5) Identify potential relationships between bighorn sheep population size and level of parasite infection in the study herd.

STUDY AREA

The Highlands bighorn sheep herd is located primarily within Montana Hunting District 340. This district encompasses 235 km^2 with elevation ranging from 1593 m along the Big Hole River to 3108 m on Table Mountain in the Highlands range (Weigand 1994). Land ownership is a combination of private, Bureau of Land Management (BLM), Forest Service, and state-owned parcels.

METHODS

Parasite sampling of hunter-killed sheep in HD 340 was accomplished in the following manner. Lists of permit holders for the 1992 and the 1993 hunting seasons were obtained from the Montana Department of Fish, Wildlife and Parks (MDFWP). The MDFWP Regional Supervisor for Region 3 sent a letter requesting the cooperation of each permit holder in the collection of an incisor, lungs, liver, and gastrointestinal tract of each hunter-killed sheep for use in this study and that of another Montana State University graduate student. A copy of this letter, along with a collecting kit, was sent to each person on both the 1992 and the 1993 permit holder lists approximately one to two weeks prior to the beginning of the bighorn hunting season (which begins on September 1 and ends on November 29). Each collecting kit consisted of one coin envelope for the storage of the incisor, one (1992) or two (1993) large garbage bags for the storage of requested organs, one pair of disposable gloves, and one tag for identification of hunter and other pertinent information such as date and location of kill and sex and age of sheep. Manila identification tags were used in 1992, but, upon receipt of specimens, it was discovered that moisture had obscured much of the information on some of the tags. For this reason Tyvek tags were used in 1993 and any information included was written on the tag with a permanent marker prior to the inclusion of the tag in the collecting kit. This measure allowed for the collection of sex and age information on a greater number of sheep in 1993.

Each bighorn carcass that was received underwent a thorough post-mortem examination. The fecal samples obtained during post-mortem examinations were analyzed in the lab with the use of the Baermann and the modified Lane fecal flotation procedures. Rumen contents were removed and frozen for examination in another project. Liver specimens were collected and frozen and are now being tested in a DNA analysis study. Any parasites recovered from these hunter-killed sheep were then counted and, when possible, their genus, species, and sex determined. These data were then used to determine the intensity and types of parasite infections present in the resident Highlands sheep.

The age of each bighorn was determined in one of three ways. First, some of the sheep were aged in the field through mandibular tooth replacement and wear and through annular horn rings by an MSU graduate student or a MDFWP employee when the animal was collected from the hunter. Second, records of all hunter-killed bighorn rams are kept by the MDFWP. These records include the age of the ram, as well as other information such as date and location of kill. Since the name of the hunter was known for some of the ram specimens, the MDFWP records were consulted to verify the age of those specimens. Finally, the original letter sent to each hunter requested the collec-

tion of an incisor. The incisors that were received were sent to Matson's Laboratory, Milltown, Montana, for age determination utilizing the cementum age analysis technique. These age data were later analyzed in determining the presence or absence of an age/parasite load correlation for the Highlands bighorn sheep herd.

Precipitation data were collected via modem using the U.S. Department of Agriculture, Soil Conservation Service's Centralized Forecast System (CFS) Operational Database located at the West National Technical Center in Portland, Oregon. Some of the major data types contained in the CFS include snow course measurements, SNOTEL-telemetered sensor values, National Weather Service (NWS), and NOAA climate station data. These data types provide such data as snow water equivalent (i.e., water content of snow pack), current and historical precipitation, and current and historical air temperatures. The SNOTEL computer polls remote telemetry sites, files site data (e.g., snow water equivalent, air temperature, precipitation, and soil temperature), and produces special reports of site conditions. In addition to the precipitation data that are collected at each SNOTEL site, the CFS also includes monthly precipitation data that are collected by the National Weather Service (NWS) and loaded into the Operational Database (ODB). All data in the CFS are formatted into a water year period which runs from October to the following September (SCS, 1988). Specific site information such as location, elevation, etc., as well as data which were down-loaded from the CFS computer are included in Table 1.

Post-Mortem Examination Procedure

The post-mortem protocol used was similar to that described by Thorne et al. (1982) and Worley and Seesee (1988). Each specimen was first rinsed and then separated into its major parts (lungs, liver, abomasum, small intestine and large intestine), after which each organ or tissue was examined for any abnormalities and/or parasites.

Liver

The liver was examined for the presence of tapeworms and/or liver flukes. Initially, the liver was examined externally for any nodules or lesions that may have been caused by a parasite. Any such deformities were removed and preserved in glycerin-specimen vials in glycerin-alcohol. At a later date, these tapeworms were examined with a dissecting microscope to determine their identity.

Lungs

The lungs were examined in detail for the presence of lungworms (*Protostrongylus* spp.). First, they were examined externally for any nodules or lesions which could have been caused by parasites. Any such abnormalities were excised and preserved in glycerin-alcohol for further examination. The lungs were then thoroughly washed over an 80-mesh screen and all of the major air passages were opened with scissors. Again, the lungs were washed thoroughly to remove any lungworms that may have been present in the air passages. These washings were then examined in an illuminated tray with an attached magnifying glass. All suspicious material was transferred to a petri dish for examination with a dissecting microscope to confirm their identity. All nematodes were stored in glycerin-alcohol until they could be examined in detail.

The washed lungs were then cut into one to two inch square sections, placed in a one-gallon container of tap water, and placed on a mechanical shaker for approximately 45 minutes to dislodge any nematodes which were located in the lung parenchyma. The lung sections and washings then were thoroughly rinsed over an 80-mesh screen. The lung tissue was discarded, and the washings were examined in an illuminated tray with a magnifying glass attachment. All suspicious material was removed to a water-filled petri dish for examination with a dissecting microscope to confirm their identity. All nematodes were stored in glycerin-alcohol until they could be cleaned in glycerin and examined microscopically. Utilizing Honess and Winter (1956), Thorne et al. (1982), and Boev (1984), the species and sex of each nematode was determined whenever the parasite material required for identification was intact.

Gastrointestinal Tract

The gastrointestinal tract was separated into abomasum, small intestine and large intestine. The contents were removed from the rumen and frozen, after which the rumen was discarded. All fat and excess tissues were removed from each section and examined carefully to detect the presence of any larval tapeworm cysts. Cysts recovered were then crushed in a water-filled petri dish to release the larva for examination with a dissecting microscope. A fecal sample was taken routinely from the rectum or large intestine and analyzed using the Baermann and modified Lane fecal flotation techniques described below.

An enterotome was used to incise, wash, and scrape each section of the intestinal tract simultaneously over screens (Bizzell and Ciordia 1962, Davis 1944). The ingesta were thoroughly rinsed over these screens to rinse away much of the excess soluble debris. The screen sizes used were: 60-mesh for the abomasal contents, and 24-mesh for the large intestinal contents. All washed ingesta were placed in jars and mixed with tap water. A small amount of 10% forma-

lin was then added to each jar to preserve the ingesta prior to microscopic examination. For identification, worms were placed in a drop of glycerin on a microscope slide with a coverslip and examined with a light microscope.

Baermann Technique

A modified Baermann procedure was used to determine the number and relative concentration of lungworm (*Protostrongylus* spp) larvae shed by each animal (Dinaburg 1942, Beane and Hobbs 1983). When possible, a fecal sample was removed from the rectum of each sheep during the post-mortem examination. If the rectum was not collected, the fecal sample was obtained from the most distal portion of the large intestine that was available.

Modified Lane Fecal Flotation Technique

The modified Lane fecal flotation procedure developed by Dewhirst and Hansen (1961) was used routinely to recover nematode ova and protozoan oocysts from ruminant feces. This apparatus consisted of a glass centrifuge tube into which fecal material was mixed with a small amount of a saturated salt solution. This mixture was stirred for 1 to 3 minutes to break up the fecal pellets. The mixture was then transferred through a small screen into a clean centrifuge tube. This tube was then filled with a saturated salt solution until a slight bulge or positive meniscus formed. A cover-glass was then placed on top of the tube, and the apparatus was left alone for approximately 10 minutes to allow ova to rise and adhere to the underside of the coverslip. The coverslip was then lifted from the tube and placed on a clean microscope slide and examined under a light microscope to determine the type and number of ova and oocysts present (Thorne et al. 1982).

Statistical Tests

For the purpose of conducting statistical tests on the data that were collected, some basic assumptions were made. One, the samples were assumed to be random samples, so that each individual bighorn sheep in the Highlands herd had an equal chance of being included in the sample. Second, it was assumed that each sample was independent and representative of the whole herd.

Statistical tests for equality of two population means were based on techniques for both normal populations with equal variances and large samples from arbitrary populations (Neter et al. 1988). The common t-test was used for comparing normal populations with equal variances. The Z-test was used for comparing large samples from arbitrary populations. This test is based on the assumption that the sample sizes are large enough so that the estimated standard deviations of the sample means are roughly equivalent to the respective parameters. An F-test for testing the equality of variance was used to determine which of these two tests, for the means, was appropriate. The method described by Neter et al. (1988) was used for analyzing the difference between two population proportions.

A statistical test for determining the difference between two population means using matched samples was employed for analyzing precipitation data. This method simplifies to the analysis of a single population mean using a common t-test (Neter et al., 1988).

The statistical test employed for determining the relationship between a dependent variable (e.g., LPG) and one or more independent variables (e.g., bighorn age) was based on a one-way analysis of variance (ANOVA) model, or F-test (Neter et al. 1988).

RESULTS

Helminth Parasites

Worm parasites recovered from the Highlands bighorn sheep herd included *Wyominia tetoni, Protostrongylus rushi, Protostrongylus stilesi, Marshallagia marshalli, Ostertagia ostertagi, Ostertagia trifurcata, Nematodirus abnormalis, Nematodirus davtiani, Chabertia ovina, Trichuris* spp., and cysts of *Taenia hydatigena*. Only *M. marshalli* occurred in significant numbers in the 52 sheep examined in this study. The average annual infection parasite intensities of all other parasites were less than 20 worms per sheep. Mean infection levels in 1992/93 are summarized in Tables 2 and 3.

Liver

Examination of the gall bladder and bile ducts of 51 sheep (30 in 1992 and 21 in 1993) led to the recovery of only one parasite: *Wyominia tetoni*. This cestode was first described by J.W. Scott in 1941 and has only one known host-*Ovis canadensis* (Scott 1941, Thorne et al. 1982). This parasite was recovered in very low numbers (1-2 per sheep) from 9 of the 51 livers examined. In addition, a common t-test showed that there was no significant difference between the 1992 and the 1993 infection levels. T-tests also showed that no correlation existed between tapeworm infection level and sex of sheep in either year. The identification of a trend in cestode levels required that at least three sets of data be compared, therefore, no such analysis was attempted.

No evidence of liver flukes was seen during post-mortem examinations of any bighorn sheep specimens. Liver lesions recovered from two sheep speci-

mens in 1992 were analyzed at the Department of Livestock Diagnostic Laboratory in Bozeman, Montana. Lesions consisted of abundant fibrous connective tissue. One of the specimens also contained dark pigment, a reaction consistent with the presence of liver flukes. However, no adult or larval flukes were found.

Lungs

The lungs from 30 sheep were received in 1992. Of these, 19 contained parasites in either the air passages or lung tissue. In 1993, the lungs from 17 sheep were received, twelve of which contained parasites. All of the recovered lungworms were identified as either *Protostrongylus rushi*, which lives in the air passages, or *P. stilesi*, which inhabits lung tissue. The average infection rate per sheep was 3.4 ± 4.6 ($n = 30$) in 1992 and 3.1 ± 5.1 ($n = 17$) in 1993. Worm counts probably were not an accurate reflection of total worm burdens due to the difficulty in recovering intact specimens from lung tissue.

Infection levels of both rams and ewes were compared to determine if a correlation existed between sex and lungworm infection level as indicated by Festa-Bianchet (1988, 1991). A t-test showed that no such correlation existed in this herd. Statistical tests also revealed that lungworm infection levels in 1993 had not changed significantly from those in 1992. The identification of a trend in *Protostrongylus* spp. levels required that at least three sets of data be compared; therefore, no such analysis was attempted.

Three bighorns were diagnosed with verminous pneumonia at the Department of Livestock Diagnostic Laboratory in Bozeman, Montana. The diagnosis was made after a thorough examination of lung nodule sections recovered during post-mortem examination. These nodules contained "innumerable adult parasites and large numbers of ova" of the genus *Protostrongylus*. In addition, the pulmonary parenchyma immediately surrounding the nodules contained areas of necrosis and evidence of inflammatory cell response, both of which are consistent with verminous pneumonia. This same phenomenon was seen in lung nodules removed from one bighorn sheep in 1993 which was also diagnosed with verminous pneumonia.

Gastrointestinal Tract

The examination of portions of the gastrointestinal tract in 1992 and 1993 revealed the presence of 8 species of parasites. Statistical testing was conducted to determine if the average infection level of each of these parasites differed significantly during the two years of the study. In all cases no statistically significant difference existed in parasite levels between years. These data were to be further compared to the environmental conditions (e.g., precipitation amounts) during those two years to determine if parasite levels could be correlated to precipitation levels as suggested by Forrester and Littell (1976). Since parasite levels did not differ significantly between years, no comparison testing was conducted with the environmental data. In addition to <between year' comparisons, all parasite data were also tested to determine if a correlation existed between host sex and infection level. In all cases, no such correlation could be detected. The identification of a trend in gastrointestinal nematode levels required that at least three sets of data be compared; therefore, no such analysis was attempted.

Abomasum

The abomasa from 25 sheep were examined in 1992. Of these, 19 contained parasites. *Marshallagia marshalli* were recovered from 18 of these abomasa, while specimens of *Ostertagia trifurcata* and *O. ostertagi* occurred in five sheep. In 1993, all 19 abomasal specimens that were examined contained parasites. *Marshallagia marshalli* was the most common parasite found in bighorns during this study, with an average infection level per sheep of 235.5 ± 287.7 ($n = 25$) in 1992 and 114.5 ± 99.4 ($n = 19$) in 1993. In addition, *Marshallagia* was the only parasite found in significant numbers during this study. At first glance the 1992 average appears to be much higher than the 1993 average, but testing showed that the difference was only marginally significant. In addition, statistical testing was conducted to determine if *M. marshalli* infection levels were sex related. Testing conducted for both 1992 and 1993 indicated no significant difference between *Marshallagia* burdens in rams versus ewes in either year. Statistical tests indicated that infection levels of *Ostertagia* spp. did not differ significantly between the two years of this study. In addition, t-tests showed that infection levels were not correlated with host sex.

Small Intestine

The small intestines from 27 sheep were examined in 1992. Of these, 12 tracts contained parasites. One small intestine contained 3 segments of the tapeworm *Wyominia tetoni*, a parasite normally found in the liver or gallbladder of bighorn sheep. In addition, *Marshallagia marshalli* was also recovered from the small intestine of two sheep. Roundworms of the genus *Nematodirus* were also recovered from the small intestine during the post-mortem examination. The male parasites were identified as *N. abnormalis* and *N. davtiani*.

Several of these parasite species were recovered from 9 of the 20 small intestine specimens that were received in 1993. One small intestine contained 2 segments of *W. tetoni*. Male and female *Nematodirus abnormalis* and *N. davtiani* were also recovered from the small intestine. Other studies of bighorn parasites (Becklund and Senger 1967, Thorne et al. 1982, and Worley and Seesee 1992) have reported tapeworms of the species *Moniezia benedeni, Moniezia expansa*, and *Thysanosoma actinioides*, but none were recovered during this study.

A Z-test was used to detect any difference in *Nematodirus* spp. infection levels between years. No significant difference was found. Furthermore, statistical tests showed no correlation between infection level and host sex for this parasite.

Large Intestine

The cecum, large intestine, and rectum were examined as a unit. All or part of the large intestinal <unit' of 26 sheep were received in 1992, while those of 20 sheep were examined in 1993. Of these, only six LI units contained parasites. One unit examined in 1992 contained one male specimen of the large-mouthed bowel worm *Chabertia ovina*, while another sheep examined in 1993 contained one female *C. ovina*. In both years a single large intestine was found to contain one female whipworm (*Trichuris* spp.). In addition, two large intestinal sections examined in 1993 contained *Wyominia tetoni* specimens. The mesenteries yielded larval cysts of the tapeworm *Taenia hydatigena* in two instances in 1993.

Statistical tests showed that infection levels for all three species did not differ significantly between years. Nor was any correlation detected between infection level and host sex.

DISCUSSION

The concept of utilizing parasite levels as an index of herd health in this study was based on a procedure for using parasite levels to estimate range utilization, herd densities, and other health-related factors in free-ranging ungulate populations. This concept has been used to correlate parasite intensity with the health status of white-tailed deer herds in the southeastern United States, and is used routinely to infer a relationship between the size of deer herds and available forage in this region (Demarais et al. 1983, Doster 1985, Eve and Kellogg 1977). While a para-meter such as the Abomasal Parasite Count (APC) developed by Eve and Kellogg (1977) is not available for a comparable analysis for bighorns, the concept of using parasite levels,

Table 1. Precipitation data collected at the NOAA weather station at Divide, Montana for 1992 and 1993.*

Month	1992		1993	
	Ppt. (in.)	Dev. (in.)	Ppt. (in.)	Dev. (in.)
October	2.4	0.81	1.5	-0.09
November	2.4	0.49	2.2	0.29
December	1.1	-0.97	2.4	0.33
January	1.0	-1.29	2.4	0.11
February	2.3	0.33	2.2	0.23
March	1.0	-1.78	1.8	-0.98
April	1.8	-0.68	4.4	1.92
May	1.2	-1.93	2.4	-0.73
June	6.9	3.84	4.2	0.36
July	1.9	0.21	3.1	1.41
August	0.4	-1.2	3.0	1.4
September	1.7	-0.27	1.1	-0.87
TOTAL	24.1	-2.44	30.7	4.16

*Located on the northern edge of the Highlands bighorn range at an elevation of 1649 m. Abbreviation: Ppt. = Precipitation, Dev. = Deviation from average precipitation recorded for the Divide NOAA station.

especially lungworm (*Protostrongylus*) and stomach worm (*Marshallagia*) burdens in bighorn sheep as indicators of the balance between herd size and available range has been proposed (Worley and Seesee 1988, 1992). They felt that there are two parameters that appear to be most useful for the purpose of determining parasite impact on herd health, i.e. 1) the total number of parasite species in a particular herd, and 2) the relative frequency of multiple infections. The current study has shown that the level of parasite infections is another important factor that should be considered when assessing herd health. Application of Worley and Seesee's health index alone led to the assumption that this herd was in moderate condition in 1992-93. Eleven species of parasites were seen and 62% of the bighorns examined had multi-species infections. However, several of these infections consisted of only a single parasite of two different species (e.g., one specimen each of *C. ovina* and *P. rushi*). The effect on the host of the two nematodes in this example was negligible, but their presence reduces the overall health index of this herd. For this reason, it seems reasonable to incorporate parasite infection level into such a health index.

Several factors may have affected the validity of the statistical tests conducted during this study. First, the rules and regulations of bighorn sheep hunting must have an equal probability of being included in the

Table 2. Worms Recovered at Necropsy of Highlands Bighorn Sheep - 1992 (n =27).

Parasite	Bighorn Gender Group	Sample Size (n)	% Infected	Average Infection (x)	Standard Deviation (s)	Range
LPG	All	26	73	10.7	27.6	0.0 - 137.6
	Ram	7	86	21.3	51.3	0.0 - 137.6
	Ewe	17	59	4.6	8.9	0.0 - 32.4
Protostrongylus spp.	All	30	63	3.4	4.8	0 - 16
	Ram	9	78	4.8	5.3	0 - 15
	Ewe	17	65	3.5	4.6	0 - 16
Wyominia tetoni	All	30	20	0.3	0.7	0 - 2
	Ram	9	11	0.1	0.3	0 - 1
	Ewe	17	18	0.3	0.7	0 - 2
Marshallagia marshalli	All	25	76	235.5	287.8	0 - 1039
	Ram	6	100	329.3	177.7	130 - 607
	Ewe	16	75	229.7	333.2	0 - 1039
Ostertagia spp.	All	25	20	4.0	8.6	0 - 26
	Ram	6	33	6.0	10.6	0 - 26
	Ewe	16	19	4.0	8.7	0 - 25
Nematodirus spp.	All	27	37	3.0	6.3	0 - 29
	Ram	7	43	3.6	5.0	0 - 11
	Ewe	17	41	3.3	7.3	0 - 29
Chabertia ovina	All	26	4	0.04	0.2	0 - 1
	Ram	6	0	0	0	0
	Ewe	17	6	0.1	0.2	0 - 1
Trichuris spp	All	26	4	0.04	0.2	0 - 1
	Ram	6	0	0	0	0
	Ewe	17	6	0.1	0.2	0 - 1
Taenia hydatigena	All	26	0	0	0	0
	Ram	6	0	0	0	0
	Ewe	17	0	0	0	0

Abbreviations: Average Infection = average parasitic infection per individual sheep; All = All sheep - Male, Female and Unknown gender; LPG = number of *Protostrongylus* Larvae Per Gram of fecal material.

sample. Montana hunting regulations restrict hunters to taking only adult ewes and 3/4+ curl rams in HD 340. This results in a sample that is not truly representative of the entire herd since lambs and small-horned rams had no chance of being included in any hunter-killed sample. The 1992 transplant, on the other hand, did sample rams and ewes from all age groups in the Highlands herd, but it was not a random sample. The sheep included in this transplant were taken from only one area; therefore, any sheep located outside of this area were not included. In addition, samples were received from only those hunters for whom it was convenient to collect and return the requested organs. This meant that those sheep that were far from a road, or shot during adverse weather conditions were probably not collected. This would have affected the distribution of the sheep included in each sample set. The sheep that were included in this study were most likely not uniformly distributed over the entire study area. Bighorns located close to a road had a higher chance of being taken by a hunter than those located in areas not so easily accessible. We know that the distribution of the sheep included in the 1992 transplant group was restricted to one specific site. These factors must be taken into consideration when determining the validity of using hunter-killed samplings as a means to determine the health of a bighorn sheep herd.

The Highlands bighorn sheep herd was found to harbor ten nematode, two cestode, and five protozoan species of parasites. Of these, only *Marshallagia marshalli* was found in significant numbers. Since heavy infections of this parasite can cause decreased vigor in bighorns (Thorne et al. 1982), its level should be closely monitored in surveillance studies designed to evaluate parasite effects in free-ranging sheep.

Although the concept of utilizing parasite loads in inferring herd health and range quality in bighorn sheep is feasible, more research is needed before it can be utilized with any reliability. More studies such as this one need to be conducted, and the data pooled, to

Table 3. Worms Recovered at Necropsy of Highlands Bighorn Sheep - 1993 (n = 20).

Parasite	Bighorn Gender Group	Sample Size (n)	% Infected	Average Infection (x)	Standard Deviation (s)	Range
LPG	All	19	100	116.6	153.4	0.4 - 534.6
	Ram	9	100	127.6	153.2	0.4 - 344.2
	Ewe	10	100	147.5	192.6	5.8 - 534.6
Protostrongylus spp.	All	17	59	3.1	5.1	0 - 17
	Ram	8	63	3.0	5.8	0 - 17
	Ewe	9	56	3.1	4.7	0 - 14
Wyominia tetoni	All	21	19	0.2	0.5	0 - 2
	Ram	10	30	0.4	0.7	0 - 2
	Ewe	11	9	0.1	0.3	0 - 1
Marshallagia marshalli	All	19	100	114.5	99.4	5 - 412
	Ram	9	100	124.1	123.3	5 - 412
	Ewe	10	100	105.8	77.9	11 - 212
Ostertagia spp.	All	19	16	1.0	2.9	0 - 12
	Ram	9	33	2.1	4.0	0 - 12
	Ewe	10	0	0	0	0
Nematodirus spp.	All	20	35	1.8	3.7	0 - 11
	Ram	10	40	2.2	4.2	0 - 11
	Ewe	10	30	4.2	3.4	0 - 11
Chabertia ovina	All	20	5	0.1	0.2	0 - 1
	Ram	10	10	0.1	0.3	0 - 1
	Ewe	10	0	0	0	0
Trichuris spp	All	20	5	0.1	0.2	0 - 1
	Ram	10	0	0	0	0
	Ewe	10	10	0.1	0.3	0 - 1
Taenia hydatigena	All	20	10	0.1	0.3	0 - 1
	Ram	10	5	0.2	0.4	0 - 1
	Ewe	10	0	0	0	0

Abbreviations: Average Infection = average parasitic infection per individual sheep; LPG = number of *Protostrongylus* Larvae Per Gram of fecal material.

determine baseline parameters on which to base herd health conclusions. In addition, level of parasite infection should be considered as an important parameter when making such conclusions about herd health.

Any future fecal analyses performed on this herd should include a quantitative Lane fecal flotation test. Since some of the coccidian species recovered during this study (namely, *E. ahsata* and *E. ovinoidalis*) are considered highly pathogenic in bighorns, analysis of infection level could prove to be beneficial for the future management of this herd.

MANAGEMENT CONSIDERATIONS

This study lasted only two years; therefore, no valid hypotheses could be formulated regarding the presence of potential trends in parasite loads and the effect of weather conditions on these infections in the Highlands bighorn sheep herd. Therefore, a long-term monitoring program should be devised for this herd.

As discussed earlier, this study showed that neither post-mortem examination nor fecal testing alone could accurately predict *Protostrongylus* infection levels in this herd. Festa-Bianchet (1991) stated that "larval counts are affected by infection intensity and body condition, do not predict pneumonia epizootics, and have limited reliability as an index of herd health." Lung dissections performed on sheep collected via hunter kills and/or field mortalities, combined with the testing of fecal material through the Baermann technique, is the best way to fully assess the lungworm burden of bighorn sheep. Therefore, hunter-killed sheep should continue to be collected for the purpose of monitoring parasite levels. In 1992, 75% of hunter-killed sheep were received for testing. In 1993, this return rate dropped to 53%. Even so, if return levels remain at this level, an adequate sample size could be obtained for valid statistical analysis. However, other herds also are available for such long-term studies as are required to determine the true relationship between

herd health and parasite loads in bighorn sheep. Routine health monitoring over a period of years is the best way to determine if current management methods are, indeed, working on bighorn sheep herds.

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