



Parasite loads and their relationship to herd health in the Highlands bighorn sheep herd in southwestern Montana

by Kerrie L Hoar

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Biological Sciences

Montana State University

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Abstract:

A two year study was conducted to determine the parasite load of a bighorn sheep herd located in the Highlands and East Pioneer Mountain ranges in southwest Montana. This study involved the post-mortem examination of 52 bighorn sheep followed by microscopic examination of recovered parasites for identification purposes. Forty-five fecal samples from these sheep, as well as 35 samples from a group of bighorn sheep captured for transplanting, were tested via the Baermann and the modified Lane fecal flotation techniques.

Sixteen species of parasite belonging to eight genera were collected and identified during the course of this study-including ten nematode, one cestode, and five protozoan species. A modified Lane fecal flotation test, performed on 27 fecal samples, revealed the presence of five species of Eimerian Protozoa-*E. ahsata*, *E. faurei*, *E. intricata*, *E. ovina*, and *E. ovinoidalis*. The Baermann technique revealed an average LPG (the number of *Protostrongylus* spp. Larvae Per Gram of fecal material) level for this herd to be 10.7 ± 27.6 in 1992 ($n = 26$) and 116.6 ± 153.3 in 1993 ($n = 19$). The group of 35 bighorns that were captured for transplanting in December, 1992, had an average LPG level of 21.8 ± 74.1 . Statistical analysis showed no significant difference between any of these LPG levels.

One species of cestode, *Wyominia tetoni*, was recovered from the livers of nine bighorn sheep. The lungs from 50 sheep were examined and were found to harbor a mean *Protostrongylus* spp. infection level of 3.4 ± 4.6 in 1992 and 3.1 ± 5.1 in 1993. In addition, *Ostertagia trifurcata*, *O. ostertagi*, *Nematodirus abnormalis*, *N. davtiani*, *Chabertia ovina*, and *Trichuris* spp. were recovered in low numbers both years-with all infections being less than twenty adult worms per animal. *Marshallagia marshalli*, recovered from 38 of the 44 abomasa examined, was the only species that occurred in significant levels in this herd with averages of 235.5200 and 114.4737 in 1992 and 1993, respectively. However, high standard deviations make these averages unreliable as a health index.

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IN SOUTHWESTERN MONTANA

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Date December 6, 1995

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ABSTRACT

A two year study was conducted to determine the parasite load of a bighorn sheep herd located in the Highlands and East Pioneer Mountain ranges in southwest Montana. This study involved the post-mortem examination of 52 bighorn sheep followed by microscopic examination of recovered parasites for identification purposes. Forty-five fecal samples from these sheep, as well as 35 samples from a group of bighorn sheep captured for transplanting, were tested via the Baermann and the modified Lane fecal flotation techniques.

Sixteen species of parasite belonging to eight genera were collected and identified during the course of this study—including ten nematode, one cestode, and five protozoan species. A modified Lane fecal flotation test, performed on 27 fecal samples, revealed the presence of five species of *Eimerian* Protozoa—*E. ahsata*, *E. faurei*, *E. intricata*, *E. ovina*, and *E. ovinoidalis*. The Baermann technique revealed an average LPG (the number of *Protostrongylus* spp. Larvae Per Gram of fecal material) level for this herd to be 10.7 ± 27.6 in 1992 ($n = 26$) and 116.6 ± 153.3 in 1993 ($n = 19$). The group of 35 bighorns that were captured for transplanting in December, 1992, had an average LPG level of 21.8 ± 74.1 . Statistical analysis showed no significant difference between any of these LPG levels.

One species of cestode, *Wyominia tetoni*, was recovered from the livers of nine bighorn sheep. The lungs from 50 sheep were examined and were found to harbor a mean *Protostrongylus* spp. infection level of 3.4 ± 4.6 in 1992 and 3.1 ± 5.1 in 1993. In addition, *Ostertagia trifurcata*, *O. ostertagi*, *Nematodirus abnormalis*, *N. davtiani*, *Chabertia ovina*, and *Trichuris* spp. were recovered in low numbers both years—with all infections being less than twenty adult worms per animal. *Marshallagia marshalli*, recovered from 38 of the 44 abomasa examined, was the only species that occurred in significant levels in this herd with averages of 235.5200 and 114.4737 in 1992 and 1993, respectively. However, high standard deviations make these averages unreliable as a health index.

Introduction

At the beginning of the 19th century, there were between 1,500,000 and 2,000,000 bighorn sheep (*Ovis canadensis*) in North America (Buechner, 1960). By the end of the 19th century, bighorn sheep populations had been driven to the brink of extinction due to market hunting, degradation of and competition for habitat by domestic species, human intrusion into terrain favored by bighorns and epizootics. Today, there are less than 100,000 bighorn sheep left in North America, (see Fig. 1) (Buechner, 1960; Jessup, 1981). In the mid 1900's, strict hunting regulations were imposed on bighorn sheep hunters in an attempt to prevent the extinction of this species. Restrictions were also put on the grazing of domestic livestock to prevent habitat degradation and competition for resources between bighorn sheep and domestic livestock. Once these measures were in place, attempts were made to reintroduce bighorn sheep into areas where they had disappeared. The first bighorn sheep transplant in Montana took place in 1942 when 11 sheep from the Sun River herd were relocated to the Gates of the Mountains near Helena. Today, approximately one half of Montana's huntable populations of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) have been established or augmented by transplants (Janson, 1974).

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 transplant, consisting of 27 sheep, took place in 1967. This was

followed by a second transplant of 31 sheep in 1969 (Couey and Schallenberger, 1971; Janson, 1974). Both groups of bighorn sheep were released into the Camp Creek drainage of the Highlands mountain range. The success of these two transplants has been phenomenal, growing from a group of 58 animals occupying a single drainage to today's herd which exceeds 350 animals¹ and extends over two mountain ranges. The majority of the Highlands' mature rams exceed 180 points (by Boone and Crockett scoring methods) by the age of $6\frac{1}{2}$ (Frisina, 1992; Frisina and Atcheson, 1993).

In the past several years, the Highlands herd has developed a reputation among bighorn sheep hunters for its large rams. Since 1989, hunters have taken at least 19 trophy-size rams (196+ points) from this herd (Frisina, 1992). Each year Montana offers one bighorn sheep permit to the highest bidder to raise money needed to fund bighorn sheep management projects and research. The 1992 recipient purchased the tag for \$88,000 and killed a $195\frac{4}{8}$ (green score) ram from the Highlands bighorn sheep herd. In addition, recipients of previous auctioned tags have hunted and successfully taken trophy rams from this herd (King, 1992). On April 21, 1992, the carcass of a $7\frac{1}{2}$ year old ram was found in this area which ranks as the largest bighorn ram in the United States and the fifth largest in the world with a score of $203\frac{5}{8}$ points. (This ram might have scored 208-210 points if it had not laid in the field for several months prior to scoring.) (Frisina, 1992; Frisina and Atcheson, 1993; Weigand, 1994).

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) believes that large populations of bighorn sheep are more likely

¹In 1994, a major epizootic killed more than half of this herd. To date, it is not known exactly how many sheep survived.

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 this study, hunter-killed bighorn sheep were examined in order to determine the numbers and types of parasites present in the Highlands bighorn sheep herd. 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 Seese, 1988 and 1992).

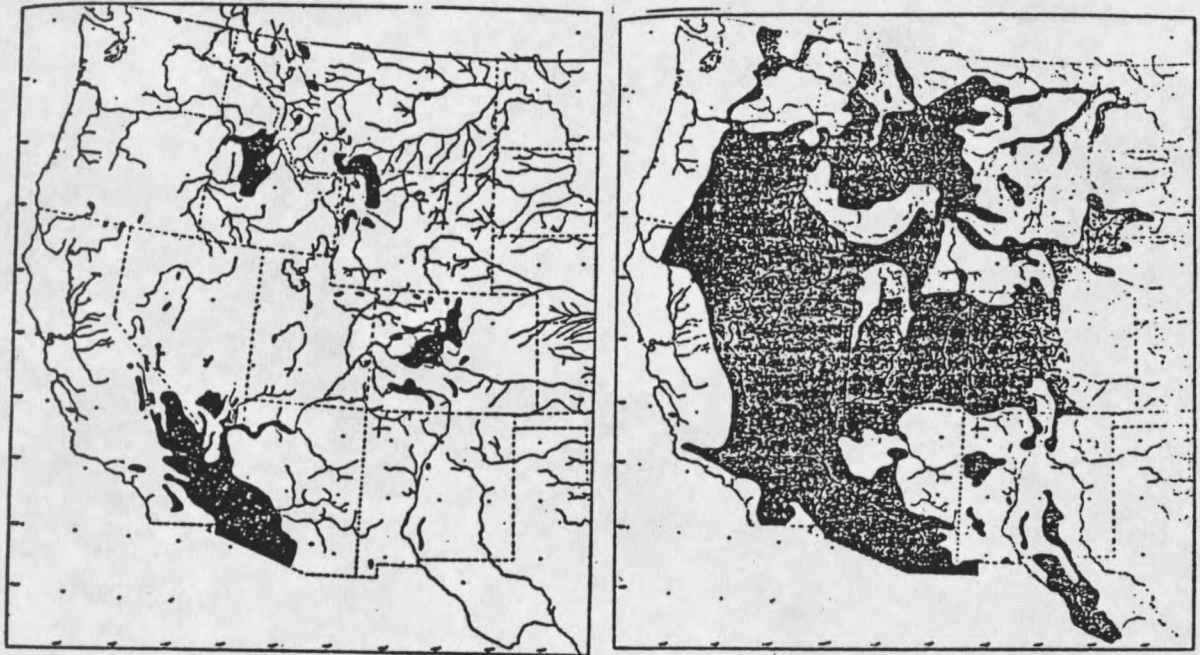


Figure 1: Probable distribution of bighorn sheep in the United States before (left) and after (right) the arrival of the white man (Buechner, 1960; Forrester, 1971).

Study Objectives

The objectives of this study were to:

1. Identify lung and gastrointestinal parasites present in the Highlands bighorn sheep herd.
2. Estimate the average level of lung and gastrointestinal parasite infections present in the Highlands bighorn sheep herd—both within individual sheep and within the herd.
3. Identify potential trends in the level of parasite infection in the Highlands bighorn sheep herd.
4. Determine if there is a correlation between sex, age, and/or level of precipitation and level of parasite infection in the Highlands bighorn sheep herd.
5. Identify potential relationships between bighorn sheep population size and level of parasite infection in the Highlands bighorn sheep herd.

Study Area

The Highlands bighorn sheep herd is located primarily within Montana Hunting District 340 (HD 340), (see Fig. 2) The boundaries of the study area were determined by the 1992-93 legal descriptions of HD 340 for bighorn sheep hunting issued by the Montana Department of Fish, Wildlife and Parks (MDFWP). The MDFWP bulletin states that HD 340 encompasses "those portions of Beaverhead, Madison, Jefferson and Silver Bow Counties lying within the following-described boundary: Beginning at Dillon, then northerly along Route 41 to Route 2, then northwesterly along said route to Interstate 90, then westerly along said interstate to Interstate 15, then southerly along Interstate 15 to Route 43, then westerly along said route to the Quartz Hill Road, then southerly along said road to Vipond Park and the Canyon Creek-Trapper Creek Road, then southerly and easterly along said road to Interstate 15 at Melrose, then southerly along said interstate to Dillon, the point of beginning" (MDFWP, 1992).

HD 340 encompasses 235km² with elevation ranging from 1593m along the Big Hole River to 3108m 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.

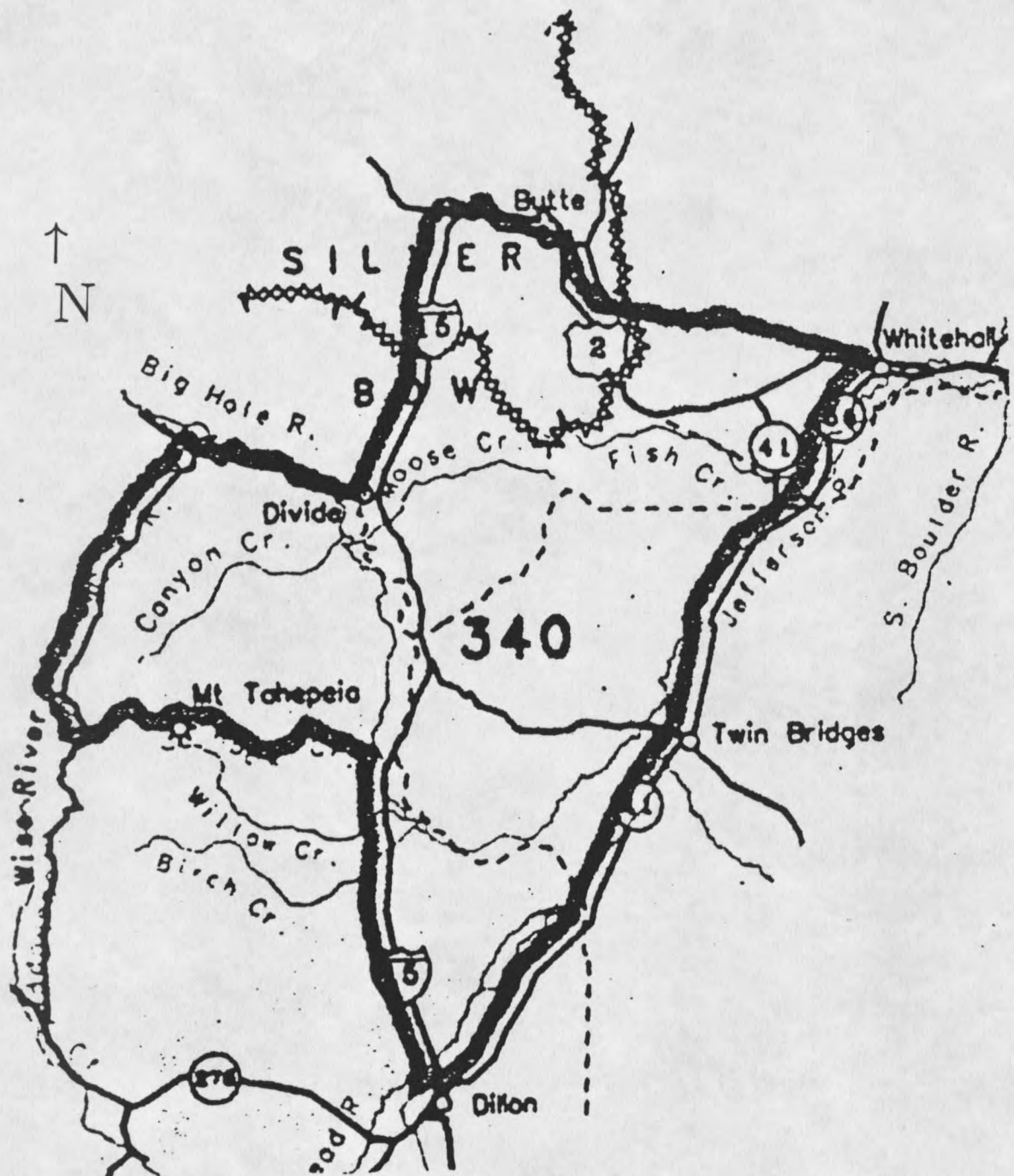


Figure 2: Map of HD340 taken from (MDFWP, 1995b).

Methods

Convenience sampling of hunter-killed sheep in HD 340 was accomplished in the following manner. Lists of HD 340 bighorn sheep 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 wrote 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, (see Appendix B). 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 sheep 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. The specimens that were obtained in 1992 were usually returned in an additional garbage bag (probably to prevent leakage); therefore, the 1993 collecting kits contained an additional garbage bag. Manila identification tags were used in 1992, but, upon receipt of specimens, it was discovered that moisture had obscured much of the information on many of the tags. For this reason, the tags used in 1993 were Tyvek and any known information (e.g., hunter name) 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 sheep carcass that was received underwent an extensive 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 by Weigand (1994) for inclusion in his food habits study on the Highlands bighorn sheep herd. 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 Highlands bighorn sheep herd.

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 collection of an incisor. The incisors that were received were sent to Matson's Laboratory in Milltown, Montana, for age determination utilizing the cementum age analysis technique. A copy of the report made by Gary Matson for all teeth received by him is included in Appendix B. These age data were later analyzed in determining the presence or absence of an age/parasite load correlation for the Highlands bighorn sheep herd. Those animals for which no age data could

be determined were not included in this analysis. In one case in which the age was determined through both the annular horn ring and the tooth cementum age analysis techniques, the age differed by one year; therefore, the data from this sheep was not included in the age/parasite load correlation.

The sex of each bighorn was determined in one of five ways. First, Montana issues bighorn sheep permits for HD 340 in two categories—"either sex" and "adult ewe". Since the name of the hunter was known for some of the sheep specimens, the MDFWP permit lists were used to determine which type of tag was issued to that individual. Those hunters who received "adult ewe" tags are assumed to have taken a female. Second, the sex of some of the bighorn sheep was determined in the field by an MSU graduate student or a MDFWP employee when the animal was collected from the hunter. Third, some of the hunters indicated the sex of their bighorn on the identification tag included in their collecting kit. Fourth, the MDFWP records of hunter-killed bighorn rams was again consulted for those specimens for which the name of the hunter was known. Finally, many of the specimens contained reproductive organs that allowed the sex of that bighorn to be determined. These sex data were later analyzed in determining the presence of a sex/parasite load correlation for the Highlands bighorn sheep herd. Those animals for which no sex could be determined were designated Unknown, U, and were not included in this analysis.

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 the data which were down-loaded from the CFS computer are included in Table 1.

Post-Mortem Examination Procedure

The post-mortem protocol followed was similar to that described by Thorne et al. (1982) and Worley and Seese (1988). Each specimen that I received was first rinsed and then separated into its respective parts—lungs, liver, abomasum, small intestine and large intestine, and then each individual section was examined thoroughly for any abnormalities and/or parasites. The results of each individual post-mortem examination can be found in Appendix A. A summary of the overall herd results for each year are tabulated in the next section in Tables 2 and 3.

Liver

The liver was examined for the presence of tapeworms and/or liver flukes. First, 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-

1992 and 1993 Divide Precipitation

Month	1992		1993	
	Ppt. (°F)	Dev. (°F)	Ppt. (°F)	Dev. (°F)
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

Table 1: Precipitation data collected at the NOAA weather station at Divide, Montana, for 1992 and 1993. This weather station is located near Divide, Montana, in Silver Bow county at an elevation of 1649 m. Abbreviation: Ppt. = Precipitation, Dev. = Deviation from average precipitation recorded for the Divide NOAA station.

alcohol (5% glycerin in 70% ethyl-alcohol) for further examination. A two-to-three inch square section was then removed from the posterior end of the right or left lobe of the liver. This liver section was frozen for use in a DNA analysis study which is currently being conducted by another MSU graduate student. The gallbladder and bile duct were then opened and examined for the presence of parasites. Finally, the liver tissue was sectioned with a post-mortem knife at 1 inch intervals and examined grossly for any parasites.

All cestodes were removed from the liver tissue (taking care to keep the worm intact with its scolex whenever possible), rinsed in tap water, and preserved in labeled

specimen vials filled with glycerin-alcohol. At a later date, these tapeworms were placed in a petri dish filled with tap water and examined under a dissecting microscope to determine genus or species utilizing Thorne et al. (1982).

Lungs

The lungs were examined 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 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 removed to a water-filled petri dish for examination with a dissecting microscope to confirm their identity. All nematodes were then placed in labeled, glycerin-alcohol filled specimen vials for preservation until they could be examined in detail at a later date.

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 might be located in the lung parenchyma. The lung sections and washings 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 then placed in glycerin-alcohol filled specimen vials for preservation until they could be identified specifically at a later

date.

Later, preserved nematodes were placed on a microscope slide with a drop of glycerin to preserve the mount, then covered with a coverslip. The specimens were then examined under a light microscope. Utilizing Honess and Winter (1956), Thorne et al. (1982), and Boev (1984), the genus, species, and sex of each nematode was determined whenever the sections of the parasite required for identification were intact.

Gastrointestinal Tract

The gastrointestinal tract was divided into abomasum, small intestine and large intestine. The contents were removed from the rumen and frozen. The rumen was then 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 and examined for identification using a dissecting microscope. Whenever possible, a fecal sample was taken from the rectum or large intestine and refrigerated in a plastic specimen cup to be analyzed at a later date 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 as follows: 60-mesh for the abomasal contents, 80-mesh for the small intestinal 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% formalin was then added to each labeled jar to preserve the ingesta for later study.

Later, the ingesta were again washed over the same screens used in the initial wash to remove any remaining soluble debris and then examined in an illuminated tray using a magnifying glass attachment. All suspicious material was then removed to water-filled petri dishes to confirm their identity. All nematodes were then placed in labeled specimen jars filled with glycerin-alcohol for identification at a later date. For identification, these worms were placed in a drop of glycerin on a microscope slide with a coverslip and examined with a light microscope. Utilizing Ransom (1911), Yorke and Maplestone (1962), Skrjabin et al. (1970), Levine (1980), and Thorne et al. (1982), each specimen was identified as to genus, or species, and sex whenever the required sections of the parasite were intact.

Baermann Technique

The Baermann fecal analysis procedure was first described in 1917 as a method to extract hookworm larvae from soil (Baermann, 1917). A modified Baermann technique was developed in 1922 and is now used widely to recover nematode larvae from feces (Beane and Hobbs, 1983; Dinaburg, 1942). In this study, the Baermann technique was used to determine the number and concentration of lungworm larvae (*Protostrongylus* spp.) present in a particular fecal sample.

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. In a few instances, no fecal sample was available for examination (e.g., those bighorns for

which the large intestine was not collected).

The Baermann apparatus consisted of a plastic funnel into which a wire screen was placed. A piece of rubber tubing was slipped over the stem of the funnel and closed with a clamp. Fecal material collected during post mortem examination was weighed into 5g² samples, wrapped in two layers of cheesecloth, and placed on the screen. The funnel was then filled with enough warm tap water to immerse the test material. The funnels were left in place for approximately 24 hours to allow time for any larvae present in the sample to migrate out of the feces into the water. These larvae would sink to the bottom of the tubing and were withdrawn into a gridded Petri dish and examined with a dissecting microscope to determine the number of first-stage larvae present (Thorne et al., 1982). First-stage larvae (L_1) are the non-infective stage of the parasite that is passed from the gastrointestinal tract of its host. It is most easily identified by its characteristic tail inflection (Lange, 1974). The weight of the sample and the total larvae count were then used to determine the Larvae Per Gram of fecal material (LPG) for each individual fecal sample.

Modified Lane Fecal Flotation Technique

The modified Lane fecal flotation procedure was developed by Dewhirst and Hansen in 1961, and is used routinely to recover many nematode and trematode ova and protozoan oocysts (and some larvae) (Dewhirst and Hansen, 1961). In this study, the modified Lane fecal flotation technique was used to determine the presence

²In 1992, I began using 10g fecal samples. After a literature search was conducted, I replaced this practice with one which utilized 5g samples as used in Dinaburg (1942) and Beane and Hobbs (1983). The use of 5g samples is just as efficient, but less time-consuming during the counting of larvae.

In addition, fecal samples taken from bighorn sheep captured for the purpose of being transplanted to another range consisted of only 2-5 pellets; therefore, the samples weighed less than 5g.

of gastrointestinal nematode ova and coccidian oocysts in a particular fecal sample.

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 enough time for ova to rise and adhere to the underside of the coverslip. The coverslip was then lifted carefully 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 (p404)). The common t-test (based on the assumption that $\sigma_x^2 = \sigma_y^2 = \sigma^2$) 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 $\sigma_x^2 \neq \sigma_y^2$ and 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 (e.g., $\sigma_{\bar{X}} \approx \frac{s_x}{\sqrt{n}}$). 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 (p412)) 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 (p407)).

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 (p719)). This test is based on the assumption that the probability distributions of $\bar{Y}$ corresponding to the different treatments (e.g., age groups) are each normal with the same variance. Therefore, differences in treatment effects (e.g., LPG levels of age groups) are associated with differences between the treatment (e.g., age group) means, μ_j .

Results

Post Mortem Examination

In 1992, 42 bighorn sheep hunting permits were issued for Hunting District 340 (12 'either sex' and 30 'adult ewe' tags). During the 1992 hunting season, 37 bighorn sheep were actually taken in HD 340. Of these 37 sheep, all or part of the requested organs from 28 animals were received for post mortem study. In addition, three bighorn sheep were found dead in the field (field mortalities) by MDFWP employees, and samples were collected from them and examined for inclusion in this study. In 1993, 16 'either sex' and 30 'adult ewe' tags were issued for HD 340. Of these, all or part of the requested organs from 21 animals were received for post mortem study.

Incisors from 17 bighorn sheep were received during this study (7 in 1992 and 10 in 1993). These teeth were sent to Matson's for age analysis, the results of which are included in Appendix B.

Parasites recovered from the Highlands bighorn sheep herd include *Wyominia tetoni*, *Protostrongylus rushi*, *Protostrongylus stilesi*, *Marshallagia marshalli*, *Ostertagia ostertagi*, *Ostertagia trifurcata*, *Nematodirus abnormis*, *Nematodirus davtianii*, *Chabertia ovina*, *Trichuris* spp., and cysts of *Taenia hydatigena*. Only *M. marshalli* occurred in significant levels in the 52 sheep examined in this study. The average annual infection levels of all other parasites were less than 20 worms per sheep.

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 type—that of *Wyominia tetoni*. *Wyominia tetoni* 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 levels³. T-tests also showed that no correlation existed between tapeworm infection level and sex of sheep in either year⁴. 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 examination of any bighorn sheep specimens. Liver lesions were recovered from two sheep specimens in 1992 and were analyzed at the Department of Livestock Diagnostic Laboratory at Marsh Laboratory in Bozeman, Montana. Both lesions consisted of abundant fibrous connective tissue. One of the specimens also contained dark pigment, a reaction consistent with the presence of liver flukes.

³A 95% Confidence Interval (CI) was calculated using a t-test with $n_{92}=30$ and $n_{93}=21$ and $t_{20}=2.045$ and $t_{20}=2.086$. The resulting intervals ($-0.18 \leq \mu_{92} \leq 0.78$ and $-0.24 \leq \mu_{93} \leq 0.72$) overlapped, indicating that no significant difference existed between these two means.

⁴A 95% CI was calculated for 1992 using a t-test with $n_{ram}=9$ and $n_{ewe}=17$ and $t_8=2.306$ and $t_{16}=2.120$. The resulting intervals ($-0.39 \leq \mu_{ram} \leq 0.61$ and $-0.40 \leq \mu_{ewe} \leq 0.99$) overlapped, indicating that no significant difference existed between these two means. A 95% CI was also calculated for 1993 using a t-test with $n_{ram}=10$ and $n_{ewe}=11$ and $t_9=2.262$ and $t_{10}=2.228$. The resulting intervals ($-0.58 \leq \mu_{ram} \leq 1.38$ and $-0.31 \leq \mu_{ewe} \leq 0.49$) overlapped.

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 later identified as either *Protostrongylus rushi*, which lives in the air passages, or *Protostrongylus stilesi*, which lives in the lung tissue. A third species, *P. frosti*, has been observed in bighorn sheep in Wyoming, but was not observed in the bighorn sheep of the Highlands herd (Honest and Winter, 1956). The average infection rate per sheep was 3.4 ± 4.6 ($n = 30$) in 1992 and 3.1 ± 5.1 ($n = 17$) in 1993.

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 and 1991). A common t-test showed that no such correlation existed in this herd ⁵. Statistical tests also revealed that lungworm infection levels in 1993 had not changed significantly from those in 1992 ⁶. 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 by a veterinary pathologist in the Department of Livestock Diagnostic Laboratory at Marsh Laboratory in Bozeman, Montana. The diagnosis was made after a thorough examination of lung nodule sections recovered during post mortem examination. These nodules

⁵A 95% CI was calculated for 1992 using a t-test with $n_{ram}=9$ and $n_{ewe}=17$ and $t_8=2.306$ and $t_{16}=2.120$. The resulting intervals ($-3.12 \leq \mu_{ram} \leq 12.67$ and $2.12 \leq \mu_{ewe} \leq 8.03$) overlapped, indicating that no significant difference existed between these two means. A 95% CI was also calculated for 1993 using a t-test with $n_{ram}=8$ and $n_{ewe}=9$ and $t_7=2.365$ and $t_8=2.306$. The resulting intervals ($-6.52 \leq \mu_{ram} \leq 12.52$ and $-4.01 \leq \mu_{ewe} \leq 10.24$) overlapped.

⁶A 95% CI was calculated using a t-test with $n_{92}=30$ and $n_{93}=17$ and $t_{29}=2.045$ and $t_{16}=2.120$. The resulting intervals ($0.04 \leq \mu_{92} \leq 6.77$ and $-2.07 \leq \mu_{93} \leq 8.19$) overlapped, indicating that no significant difference existed between these two means.

contained "innumerable nematode 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, and this animal 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 between 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 received in 1992. Of these, 19 contained parasites. *Marshallagia marshalli* were recovered from 18 of these abomasa,

while specimens of *Ostertagia trifurcata* and *Ostertagia ostertagi* were found in only five. In 1993, all 19 abomasal specimens that were examined contained parasites. One abomasum contained the scolex of the bighorn sheep tapeworm *Wyominia tetoni*. The liver, where such cestodes are normally found, was not available for examination. However, it was assumed that this tapeworm specimen had been displaced from the liver to the abomasum of this sheep. In addition to *W. tetoni*, nematodes of the species *M. marshalli*, *O. trifurcata*, and *O. ostertagi* were also found in 1993.

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 significant⁷. In addition, statistical testing was conducted to determine if *M. marshalli* infection levels were sex related. Testing was conducted for both 1992 and 1993 and resulted in no significant difference between *Marshallagia* burdens in rams versus ewes in either year⁸. Statistical tests indicated that infection levels of *Ostertagia* spp. did not differ significantly between the two years of this study⁹. In addition, t-tests showed that infection levels were not correlated with host sex¹⁰.

⁷A Z-test was conducted with $n_{92}=25$ and $n_{93}=19$, using an α risk of 0.05 ($Z(0.05)=1.96$). The resulting statistic, $Z_{obs}=1.96$, indicated that the difference between years was marginally significant.

⁸A 95% CI was calculated for 1992 using a t-test with $n_{ram}=6$ and $n_{ewe}=16$ and $t_5=2.571$ and $t_{15}=2.131$. The resulting intervals ($-36.07 \leq \mu_{ram} \leq 694.73$ and $-118.24 \leq \mu_{ewe} \leq 577.49$) overlapped, indicating no that significant difference existed between these two means. A 95% CI was also calculated for 1993 using a t-test with $n_{ram}=9$ and $n_{ewe}=10$ and $t_8=2.306$ and $t_9=2.262$. The resulting intervals ($-61.60 \leq \mu_{ram} \leq 309.8196$ and $-3.41 \leq \mu_{ewe} \leq 215.01$) overlapped.

⁹A Z-test was conducted with $n_{92}=25$ and $n_{93}=19$, using an α risk of 0.05 ($Z(0.05)=1.96$). The test statistic, $Z_{obs}=1.63$, indicated that no significant difference existed between these two means.

¹⁰A 95% CI was calculated for 1992 using a t-test with $n_{ram}=6$ and $n_{ewe}=16$ and $t_5=2.571$ and $t_{15}=2.131$. The resulting intervals ($-15.77 \leq \mu_{ram} \leq 27.77$ and $-5.11 \leq \mu_{ewe} \leq 13.11$) overlapped, indicating that no significant difference existed between these two means. A 95% CI was also calculated for 1993 using a t-test with $n_{ram}=9$ and $n_{ewe}=10$ and $t_8=2.306$ and $t_9=2.262$. The

Small Intestine. The small intestines from 27 sheep were received in 1992. Of these, 12 specimens 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. The liver of this particular sheep did contain the scolex of two such tapeworms. Therefore, it was assumed that the segments that were recovered in the small intestine were shed from these liver specimens. In addition, *Marshallagia marshalli* were also recovered from the small intestine of two sheep specimens. Since this parasite is normally found in the abomasum, it was assumed that these specimens were displaced to the small intestine after the sheep had died. (One of these sheep contained *M. marshalli* in both the abomasum and the small intestine, while the other sheep contained *M. marshalli* in the small intestine only.) 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*, while the female parasites were simply classified as *Nematodirus* spp.

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 the tapeworm *W. tetoni*. As before, it was assumed that these segments were shed from specimens located in the liver, or from the *Wyominia* specimen that was recovered from the abomasum. Male and female *Nematodirus* specimens of the species *N. abnormalis* and *N. davtiani* were also recovered from the small intestine. Other studies (Becklund and Senger (1967), Thorne et al. (1982), and Worley and Seesee (1992)) of bighorn parasites have reported gastrointestinal tapeworms of the species *Moniezia benedeni*, *Moniezia expansa*, and *Thysanosoma actinioides*, but no specimens of these species were recovered during this study.

resulting intervals ($-3.94 \leq \mu_{ram} \leq 8.16$ and $0 \leq \mu_{ewe} \leq 0$) overlapped.

A Z-test was used to detect any difference in *Nematodirus* spp. infection levels between years. No significant difference was found ¹¹. Furthermore, statistical tests showed no correlation between infection level and host sex for this parasite ¹².

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 received in 1993. Of these, only six LI units contained parasites. One unit examined in 1992 contained one male specimen of the large-mouth bowel worm *Chabertia ovina*, while another (examined in 1993) contained one female specimen of this species. In both years, one large intestine was found to contain one female whipworm (*Trichuris* spp.). In addition, two large intestinal sections examined in 1993 contained *Wyominia tetoni* specimens. One such specimen consisted only of one segment, while the other intestine yielded a scolex in addition to a segment. The livers of both sheep were infected with this parasite; therefore, it was again assumed that the specimens recovered from the large intestine had originally come from the liver. 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 ¹³. No correlation between infection level and host sex

¹¹A Z-test was conducted with $n_{92}=27$ and $n_{93}=20$, using an α risk of 0.05 ($Z(0.05)=1.96$). The test statistic, $Z_{obs}=0.79$, indicated that no significant difference existed between these two means.

¹²A 95% CI was calculated for 1992 using a t-test with $n_{ram}=7$ and $n_{ewe}=17$ and $t_6=2.447$ and $t_{16}=2.120$. The resulting intervals ($-5.42 \leq \mu_{ram} \leq 12.57$ and $-4.12 \leq \mu_{ewe} \leq 10.59$) overlapped, indicating no that significant difference existed between these two means. A 95% CI was also calculated for 1993 using a t-test with $n_{ram}=10$ and $n_{ewe}=10$ and $t_9=2.262$. The resulting intervals ($-3.63 \leq \mu_{ram} \leq 8.03$ and $-3.42 \leq \mu_{ewe} \leq 6.22$) overlapped.

¹³A 95% CI was calculated for *Trichuris* spp. and *C. ovina* using a t-test with $n_{92}=26$ and $n_{93}=20$ and $t_{25}=2.060$ and $t_{19}=2.093$ for both species. The resulting intervals ($-0.12 \leq \mu_{92} \leq 0.19$ and $-0.16 \leq \mu_{93} \leq 0.26$) overlapped, indicating no that significant difference existed between these two means. A 95% CI was also calculated for *T. hydatigena* using a t-test with $n_{92}=26$ and $n_{93}=20$ and $t_{25}=2.060$ and $t_{19}=2.093$. The resulting intervals ($0 \leq \mu_{92} \leq 0$ and $-0.18 \leq \mu_{93} \leq 0.38$) overlapped.

could be detected for any of the three species ¹⁴.

Baermann Technique

Fecal samples were collected from 26 sheep in 1992 and from 19 sheep in 1993. Nineteen of the samples tested in 1992 contained one or more *L*₁ larvae of the genus *Protostrongylus*. All samples tested in 1993 contained larvae. Based on the resulting data, an average LPG of 10.7 ± 27.6 was calculated for each individual sheep received during the 1992 hunting season. In 1993, this number increased to 116.6 ± 153.3 .

On December 23, 1992, 35 sheep were captured as prospective candidates to be transplanted to the Sleeping Giant region near Helena, Montana. Thirty-two of these sheep were then transported to the Sleeping Giant region and released. (One adult ewe escaped and two large adult rams were released at the capture site.) At the time of capture, a fecal sample was removed from the rectum of each bighorn at the same time that several other tests were being conducted (e.g. nasal swab, blood sample, placement of radio-collar, etc.). The fecal samples consisted of only 2-5 pellets; therefore, all samples weighed less than 5g. (Exact weights are listed in Appendix A.) Each of the 35 fecal samples received was analyzed using the Baermann technique for the presence of first-stage larvae of the genus *Protostrongylus*. Of the 35

¹⁴A 95% CI was calculated for 1992 for both *Trichuris* spp. and *Chabertia* spp. using a t-test with $n_{ram}=6$ and $n_{ewe}=17$ and $t_5=2.571$ and $t_{16}=2.120$. The resulting intervals ($0 \leq \mu_{ram} \leq 0$ and $-0.19 \leq \mu_{ewe} \leq 0.30$) overlapped, indicating no that significant difference existed between these two means. Since no *T. hydatigena* cysts were found in 1992, it is reasonable to conclude that no correlation between infection level and host sex existed for this species in 1992. A 95% CI was also calculated for 1993 for *Trichuris* spp. using a t-test with $n_{ram}=10$ and $n_{ewe}=10$ and $t_9=2.262$. The resulting intervals ($0 \leq \mu_{ram} \leq 0$ and $-0.34 \leq \mu_{ewe} \leq 0.54$) overlapped. The t-test for *Chabertia* spp. yielded that same intervals as for *Trichuris* spp. with the sexes switched (i.e., $-0.34 \leq \mu_{ram} \leq 0.54$ and vice versa). A 95% CI was then calculated for 1993 for *T. hydatigena* using a t-test with $n_{ram}=10$ and $n_{ewe}=10$ and $t_9=2.262$. The resulting intervals ($-0.39 \leq \mu_{ram} \leq 0.79$ and $0 \leq \mu_{ewe} \leq 0$) overlapped.

sheep sampled, 34 were found to be infected with varying intensities of the parasite. The average LPG value for these 35 sheep was 21.8, with a standard deviation of 43.4.

A total of 80 fecal samples were analyzed and used to determine average LPG levels for this herd. (See Table 5.) Following Worley et al. (1976) to categorize lungworm infection levels, the Highlands bighorn sheep herd appears to be harboring low to moderate lungworm infections, with the exception of a few outliers. In addition, it appears that these lungworm levels are not increasing in the Highlands herd. This conclusion was reached through the analysis of the three sets of fecal samples collected during this study (i.e., 1992, 1992 Transplant, and 1993) ¹⁵.

Incidence of infection increased from 31% during the 1992 hunting season (September 1 through November 29) to 97% during the 1992 transplant (December 23). Statistical analysis showed this to be a significant increase ¹⁶. On the other hand, the increase from 97% during the 1992 transplant to 100% during the 1993 hunting season was not statistically significant ¹⁷.

Wishart et al. (1980) noted that annual differences in the numbers of lungworms in feces appears to be related to precipitation from the previous spring and summer. Forrester and Littell (1976) further noted that a high correlation existed be-

¹⁵The 95% Confidence Intervals that were calculated earlier were compared to see if any overlap existed. The 1992 and 1992 Transplant 95% CI's ($-11.13 \leq \mu_{92} \leq 32.50$ and $-19.84 \leq \mu_{92T} \leq 86.80$) overlapped, and the 1992 Transplant and 1993 95% CI's ($-19.84 \leq \mu_{92T} \leq 86.80$ and $-28.29 \leq \mu_{93} \leq 261.43$) overlap, indicating that no significant difference existed between these two sets of means.

¹⁶A Z-test was conducted with $n_{92}=26$ and $n_{92T}=35$, using an α risk of 0.05 ($Z(0.05)=1.96$). The test statistic, $Z_{obs}=5.51$, indicated that a significant difference existed between these two proportions.

¹⁷A Z-test was conducted with $n_{92T}=32$ and $n_{93}=19$, using an α risk of 0.05 ($Z(0.05)=1.96$). (The 3 sheep that either escaped or were released prior to transplanting were not included in the 1992T sample due to the fact that they re-entered the population and could have been included in the 1993 sample.) The test statistic, $Z_{obs}=0.75$, indicated that no significant difference existed between these two proportions.

tween lungworms and spring precipitation in April, May, and June in Alberta bighorn studies. This same phenomenon was also observed by Forrester and Senger (1964) and Festa-Bianchet (1991). To determine if such a phenomenon existed in the Highlands bighorn sheep herd, a Z-test was used to compare the 1992 and 1993 average LPG values to determine if there was a difference in larval output. A statistically significant difference was found ¹⁸. Next, the 1992 and 1993 average precipitation levels were tested to determine if there was a significant difference between these two years. These precipitation data were downloaded from the Soil Conservation Service's CFS database for the NOAA weather station located at Divide, Montana. Matched samples analysis for determining differences between two population means as specified in Neter et al. (1988 (p. 407)) showed that no significant difference in average precipitation levels existed ¹⁹. Since several Canadian researchers have seen a correlation between lungworm larvae levels and spring precipitation in April, May, and June, matched samples analysis was also conducted specifically for these three months. Again, no significant difference was found between 1992 and 1993 ²⁰. These results would indicate that the difference in larval output between years was not correlated with precipitation levels alone.

Correlations between bighorn sex and LPG have been noted by Festa-Bianchet (1988 and 1991), but no such correlation was found in the three fecal sample sets that were analyzed in this study ²¹. The LPG data from all individual fecal samples for

¹⁸ A Z-test was conducted with $n_{92}=26$ and $n_{93}=19$, using an α risk of 0.05 ($Z(0.05)=1.96$). The test statistic, $Z_{obs}=3.95$, indicated that a significant difference existed between these two means.

¹⁹ A matched samples statistical analysis was conducted with each d_i value representing the difference between the 1992 and the 1993 precipitation levels for a specific month. A single sample mean, $\bar{D}$ was calculated with $n=12$ and $t_{11}=2.201$. The resulting test statistic, $t_{obs}=1.25$, indicated that there was no significant difference between the 1992 and the 1993 monthly precipitation levels.

²⁰ A matched samples analysis was conducted with $n=3$ and $t_2=4.303$. The resulting test statistic, $t_{obs}=0.27$, indicated that there was no significant difference between years.

²¹ A Z-test was conducted for the 1992 samples with $n_{ram}=7$ and $n_{ewe}=16$, using an α risk of 0.05 ($Z(0.05)=1.96$). The test statistic, $Z_{obs}=0.86$, indicated that no significant difference existed between these two means. A Z-test was also conducted for the 1992 transplant samples with $n_{ram}=12$ and

which age data were available were then pooled for the purpose of testing for the presence of an age/LPG correlation. First, the 55 fecal samples were divided into one of five age groups—Lamb (L), 1, 2, 3, and 4+ year olds. (The 4+ classification was used because this was the age classification used by MDFWP during the 1992 transplant group collection.) Statistical analysis showed that no age/LPG correlation appeared to exist in 1992 or 1993 ²².

Modified Lane Fecal Flotation Technique

Twenty-five fecal samples were subjected to the modified Lane fecal flotation procedure in 1992. In 1993, only two of the nineteen fecal samples collected were subjected to this test. Ova from the genera *Nematodirus*, *Marshallagia*, and *Ostertagia*²³ were identified in the majority of these fecal samples. Oocysts were recovered from five species of *Eimeria* (*E. ahsata*, *E. faurei*, *E. intricata*, *E. ovina*, and *E. ovinoidalis*)—an enteric protozoa commonly found in bighorn sheep (Becklund and Senger, 1967; Thorne et al., 1982). Thorne et al. (1982) noted that *Eimerian* protozoa are highly host-specific, although most host species are susceptible to several species. In addition, he noted that a coccidian infection is usually caused by several species of *Eimeria* whose pathogenicity varies from non-pathogenic to highly pathogenic for that host species. This concept was confirmed in the Highlands herd where 11 of 14 infected animals harbored multi-species infections. Unfortunately, a quantitative

$n_{ewe}=23$ using an α risk of 0.05 ($Z(0.05)=1.96$). The resulting test statistic, $Z_{obs}=0.95$ indicated that no significant difference existed between these two means. Finally, a 95% CI was calculated for the 1993 samples using a t-test with $n_{ram}=9$ and $n_{ewe}=10$ and $t_8=2.306$ and $t_9=2.262$. The resulting intervals ($-103.14 \leq \mu_{ram} \leq 358.38$ and $-119.18 \leq \mu_{ewe} \leq 332.42$) overlapped, indicating that no significant difference existed between these two means.

²²An F-test as specified in Neter et al. (1988 (p.719)) was conducted with $n_L=11$, $n_1=14$, $n_2=9$, $n_3=4$ and $n_4=17$, using an α risk of 0.05 ($Z(4,50)=2.57$). The test statistic, $F_{obs}=1.32$, indicated that no significant difference existed between these means.

²³The ova of *Trichostrongylus*, *Cooperia*, and *Ostertagia* are indistinguishable. Since adult specimens of only *Ostertagia* were recovered, it was assumed that the ova were of this genus.

test was not conducted during this study, so average coccidian levels could not be determined. A complete table of results appears in Appendix A.

Herd Health vs. Parasite Level

Giordia and Baird (1971) proposed the obvious—that over-stocking pastures with cows results in overgrazing, concentrates infective larvae in a relatively small area, and thus increases the probability that larvae will be ingested by grazing cattle. When bighorns reach or exceed the carrying capacity of their range, a manager should see higher parasite levels and decreased forage or range quality, which will ultimately lead to unhealthy animals. Stelfox and McGillis (1970) found a direct correlation among forage production, ungulate stocking rates, endoparasite loads, and over-winter weight losses in bighorns in Canada.

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 southwestern United States, and is used routinely to infer a relationship between the size of deer herds and available forage by personnel of the Southeastern Cooperative Wildlife Disease Study (Demarais et al., 1983; Doster, 1985; Eve and Kellogg, 1977). While a parameter, 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, 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 Seese, 1988 and 1992).

Worley and Seesee (1992) state that there are two parameters that appear to be most useful for the purpose of determining parasite impact on herd health. These are 1) the total number of parasite species in a particular herd, and 2) the relative frequency of multiple infections. Multi-species infections occurred in 62% of bighorns examined in this study. In addition, 11 species of parasites (excluding protozoa) were seen. The level of infection was low for all species—with *M. marshalli* being the highest. According to Worley and Seesee (1992), this leads to the assumption that the Highlands herd was in moderate overall health in 1992-93. On the other hand, Weigand (1994) used forage amount and quality, reproductive success, and ram horn and body growth to determine that this herd was in excellent health. This information, combined with the low level of parasite infections, led to the conclusion that the Highlands bighorn sheep herd was in good condition in 1992-93. In 1994, however, a major epizootic killed more than half of this herd.

1992 Average Parasitic Infection Rates per Individual Bighorn Sheep						
Parasite	Bighorn Gender Group	Sample Size (n)	% Infected	Average Infection ($\bar{x}$)	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
<i>Protostrongylus</i> spp.	All	30	63	3.4	4.6	0 → 16
	Ram	9	78	4.8	5.3	0 → 15
	Ewe	17	65	3.5	4.6	0 → 16
<i>Wyominia</i> <i>tetoni</i>	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
<i>Marshallagia</i> <i>marshalli</i>	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
<i>Ostertagia</i> 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
<i>Nematodirus</i> 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
<i>Chabertia</i> <i>ovina</i>	All	26	4	0.04	0.2	0 → 1
	Ram	6	0	0	0	0
	Ewe	17	6	0.1	0.2	0 → 1
<i>Trichuris</i> 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
<i>Taenia</i> <i>hydatigena</i>	All	26	0	0	0	0
	Ram	6	0	0	0	0
	Ewe	17	0	0	0	0

Table 2: Summary of results obtained from post-mortem examination of 31 bighorn sheep received during the 1992 hunting season. 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.

1993 Average Parasitic Infection Rates per Individual Bighorn Sheep						
Parasite	Bighorn Gender Group	Sample Size (n)	% Infected	Average Infection ($\bar{x}$)	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
<i>Protostrongylus</i> 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
<i>Wyominia</i> <i>tetoni</i>	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
<i>Marshallagia</i> <i>marshalli</i>	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
<i>Ostertagi</i> 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
<i>Nematodirus</i> 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
<i>Chabertia</i> <i>ovina</i>	All	20	5	0.1	0.2	0 → 1
	Ram	10	10	0.1	0.3	0 → 1
	Ewe	10	0	0	0	0
<i>Trichuris</i> 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
<i>Taenia</i> <i>hydatigena</i>	All	20	10	0.1	0.3	0 → 1
	Ram	10	5	0.2	0.4	0 → 1
	Ewe	10	0	0	0	0

Table 3: Summary of results obtained from post mortem examination of 21 bighorn sheep received during the 1993 hunting season. Abbreviations: Average Infection = average parasitic infection per individual sheep; LPG = number of *Protostrongylus* Larvae Per Gram of fecal material.

1992 Transplant Sheep Baermann Technique Results Summary					
Bighorn Gender Group	Sample Size (n)	% Infected	Average Infection ($\bar{x}$)	Standard Deviation (s)	Range
All	35	97	21.8	74.1	0 → 241.2
Ram	12	100	34.6	70.2	0.3 → 241.2
Ewe	23	96	15.2	17.6	0 → 68.0

Table 4: Summary of results obtained from Baermann testing performed on fecal samples taken from a group of 35 bighorn sheep on December 23, 1992. These sheep were subsequently transplanted to the Sleeping Giant region near Helena, Montana. All results are given as number of *Protostrongylus* Larvae Per Gram of fecal material (LPG). Abbreviations: Average Infection = average LPG per individual sheep; All = All sheep (Male and Female).

Summary of Baermann Technique Results									
Sample Type	Sample Size	% Infected	LPG	Standard Deviation	Range	Infection Level			
						None 0	Low 1-5	Mod. 5-50	High > 50
1992	26	31	10.7	27.6	0-137.6	8	11	6	1
1992T	35	97	21.8	74.1	0-241.6	1	14	17	3
1993	19	100	116.6	153.3	0.4-534.6	0	3	6	10

Table 5: Summary of results of Baermann tests performed on fecal samples taken from 3 groups of bighorn sheep during the course of this study. Fecal samples were collected from hunter-killed sheep from both the 1992 and the 1993 hunting seasons, as well as from each member of a group of Highlands sheep captured and later transported to the Sleeping Giant region north of Helena, Montana. All results are given as number of *Protostrongylus* spp. Larvae Per Gram of fecal material (LPG).

Discussion

Post-Mortem Examination

The liver, lungs and gastrointestinal tract of all bighorn sheep received were thoroughly examined for the presence of parasites. Eleven species belonging to seven genera were collected and identified. All 11 species had been previously reported in bighorn sheep (Becklund and Senger, 1967; Worley and Seesee 1992).

Liver

Wyominia tetoni was the only species of parasite recovered from the livers of the Highlands bighorn sheep during this study. Unfortunately, virtually nothing is known about the life cycle of this cestode—including its transmission to or between hosts or its impact on its host. With this in mind, it could not be determined if the presence of one or two of these cestodes in the gall bladder or bile ducts of a bighorn sheep had any ill-effects on that individual. On the other hand, these tapeworms have an average length of 25 cm, are essentially the same diameter as the passageway that they occupy, and were found to be highly interwoven into the bile ducts of the specimens that were examined during this study. With this in mind, it is not unreasonable to assume that some obstruction of bile flow is experienced in infected sheep. The affect of this reduction of bile flow in occupied ducts is unknown, but could theoretically reduce the digestive efficiency of the host.

Lungs

The transmission of both *P. rushi* and *P. stilesi* is essentially the same in that it involves the ingestion of a snail intermediate host containing infective third stage larvae. Adult lungworms are located in the lungs of its host. These adults lay eggs which hatch in the lungs. The larvae migrate into the bronchioles where they are subsequently coughed up, swallowed, and passed with feces. These larvae then invade the foot of a terrestrial snail and develop into the infective third stage larvae that are ingested by bighorns. The location of adult *Protostrongylus* of the two species identified in the Highlands bighorn sheep herd differ, with *P. rushi* located in the air passages and *P. stilesi* located in the parenchyma (Thorne et al, 1982).

Average infection levels of 3.4 ± 4.6 and 3.1 ± 5.1 in 1992 and 1993, respectively, are lower than the average infection levels for Montana herds calculated by Worley et al. (1976). Without data on standard deviation, however, it could not be determined if this difference was statistically significant. (The statistical tests for equality of two population means, the Z-test and the t-test, require that the standard deviation be known in order to calculate the test statistic.) In addition, numbers of *P. rushi* and *P. stilesi* differed—with *P. stilesi* being much more prevalent (66 *P. stilesi* vs. 14 *P. rushi*). This factor should be taken into consideration since *P. stilesi* was regarded as the principal agent of verminous pneumonia in mountain sheep by Honess (1942), who concluded that *P. rushi* alone is relatively nonpathogenic (Worley et al., 1976). In addition, the larvae of *P. stilesi* have the ability to cross the placenta of pregnant ewes and infect the fetus. In such cases, lambs are born with a lungworm infection (Hibler et al. 1972 and 1974).

Some interesting facts were discovered when the post mortem examination

records were reviewed for each animal that was diagnosed with verminous pneumonia by the Montana Diagnostic Lab. One of these animals harbored 16 lungworms. Although this level of lungworm infection is quite low for bighorns in general, it is among the highest counts for the Highlands herd. This does not, however, indicate that an infection level of only 16 adult lungworms will cause pneumonia in this herd since three sheep with similar infection levels (15 to 17 lungworms) had healthy lungs with no nodules. On the other hand, one of those sheep diagnosed with verminous pneumonia had no adult lungworms, while the other two had only six. It was also discovered that only one pneumonic bighorn had more *P. stilesi* than *P. rushi* in its lungs. At first glance, it appears that *P. rushi* may not be 'relatively nonpathogenic' (at least in the Highlands herd) as indicated by Worley et al. (1976). Upon further study, however, it was discovered that infected bighorns that had pneumonic lung nodules harbored both species of lungworm. Since the species of lungworm located within these nodules was not determined, it is not known which species was the cause of infection. One could argue that these nodules housed *P. stilesi* simply due to their location with the lung parenchyma. In addition, it cannot be proven that the presence of lungworms and nodules in the lungs of these bighorn sheep was responsible for the infection. All of these discoveries, however, lead to the conclusion that the number and species of adult lungworms alone cannot be used to determine the health of an individual bighorn.

Gastrointestinal Tract

Statistical tests used to analyze data collected during the course of this study revealed no correlation between sex of host and GIT parasite infection level. In addition, no significant difference in infection levels could be detected between the two years of this

study. This would lead to the conclusion that GIT parasite levels remained relatively constant during 1992-93.

Abomasum. Of 44 bighorn abomasa examined, 38 contained *M. marshalli* and 9 contained *Ostertagi* spp. *Haemonchus contortus* has been recovered from the abomasum of bighorn sheep in other studies, but none were found in the Highlands herd (Becklund and Senger, 1967; Thorne et al., 1982). As noted earlier, *Marshallagia marshalli* was the most common parasite found in the Highlands bighorn sheep herd, with 86% of these animals being infected. Thorne et al. (1982) go so far as to say that "*Marshallagia marshalli* appears to be more prevalent in bighorn sheep than in any other wild ruminant of Wyoming and Montana" and "*M. marshalli* is common, almost ubiquitous, in bighorn sheep in Wyoming." The average infection levels of this parasite were the highest that I encountered during this study. In heavy infections, *Marshallagia* affects its host by damaging the abomasal mucosa, destroying gastric glands, and, thereby, reducing feeding efficiency and causing slow weight gain (Thorne et al., 1982; Worley and Seesee, 1992). Large horn size and body growth in rams and high lamb/ewe ratios found by Weigand (1994) in this herd would indicate that the level of *Marshallagia* encountered during this study was not heavy enough to cause clinical problems in this herd in 1992-93.

Small Intestine. Nothing of any apparent clinical significance was found in the small intestines received for examination. Low infection levels of *Nematodirus davtianii* and *N. abnormalis* were seen. In high levels of infection, *Nematodirus* can cause destruction and necrosis of the intestinal mucosa resulting in diarrhea and weight loss. This does not appear to be a concern in the Highlands herd.

Large Intestine. Only two specimens of *Trichuris* and of *Chabertia* were recovered from the 46 large intestines examined. Large intestinal parasites appear to play a very minor role in the ecology of the Highlands bighorn sheep herd.

Baermann Technique

Examination and analysis of 80 fecal samples revealed that host sex and age were not correlated with LPG levels in 1992 and 1993. It appears that precipitation levels had no effect on the increase in average larval output from 1992 to 1993. However, this conclusion could be misleading for several reasons. First, fecal samples were collected only in the fall and winter of 1992 and 1993, but Uhazy et al. (1973) and Festa-Bianchet and Samson (1984) report that larval fecal output appears to be at its highest in the early spring. Second, data were collected for only two years; therefore, no year-to-year trends could be determined. Third, many other factors (i.e., habitat, crowding, etc.) could have influenced lungworm larval output in these two years.

Incidence of infection increased from 31% in 1992 to 100% in 1993. Statistical analysis showed this to be a significant increase ($Z_{obs} = 4.6653$). In fact, when the incidence of infection for the 1992 hunting season (September 1 through November 29) was compared to the incidence of infection for the 1992 transplant group (December 23), a significant difference was found. These are a number of possible reasons why the proportion of sheep infected increased so drastically in less than one month. First, the highest concentration of bighorn sheep in HD 340 is in the Maiden Rock area. Naturally, in areas such as this where sheep are more concentrated in a smaller area, the incidence of parasitic infection would be higher than in other areas of HD 340. Possibly, the environment around Maiden Rock was more conducive to the survival of the snail intermediate host required for the transmission of this infection. Either

of these factors could have caused the higher incidence of infection seen in the 1992 transplant group, which was taken from the Maiden Rock area. The answer could be simply that comparing data from two different sampling schemes was not a good practice. Another possibility is that the 1992 hunter killed sample was not a true representation of the entire herd, and that the entire herd had a higher incidence of infection than was reflected by that sample. Whatever the reason, larval output does appear to have increased significantly during the course of this study and should, therefore, be closely monitored.

Numbers of adult lungworms and LPG values in individual bighorn sheep were not correlated. In several cases, high LPG values were detected through the use of the Baermann technique (e.g., # 264-93 $\rightarrow$ 206.2 LPG, # 404-93 $\rightarrow$ 534.6 LPG, and # 409-93 $\rightarrow$ 318.4 LPG) in individuals for which no adult lungworms could be found. One sheep (# 75-93) was found to have 16 adult lungworms, but had an LPG of 0.0. With this in mind, the performance of either lung dissection or Baermann technique alone as a means to determine the lungworm burden of individuals in this herd in future studies should be carefully considered.

Modified Lane Fecal Flotation Technique

Several species of coccidia were recovered from fecal samples during this study. Two of these species, *Eimeria ahsata* and *E. ovinoidalis*, are highly pathogenic in domestic sheep (Thorne et al., 1982). With this in mind, coccidian infection levels in the Highlands herd should be determined and monitored on a regular basis.

Herd Health vs. Parasite Level

Worley and Seesee (1992) state that there are two parameters that appear to be most useful for the purpose of determining parasite impact on herd health. These are 1) the total number of parasite species in a particular herd, and 2) the relative frequency of multiple infections. This 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.

Statistical Tests

Several factors may have affected the validity of the statistical tests conducted during this study. First, the rules and regulations of bighorn sheep hunting affect these statistical tests. In order to conduct a random sample, each sheep must have an equal probability of being included in the sample. Montana hunting regulations restrict hunters to taking only adult ewes and $\frac{3}{4}+$ curl rams from 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 the Maiden Rock area; therefore, any sheep located outside of this area (i.e., those sheep located east of Interstate 15) could not be 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 also 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 the Maiden Rock area. These factors must be taken into consideration when determining the validity of using hunter-killed sampling as a means to determine the health of a bighorn sheep herd.

It is possible to set up a sampling scheme that would combine Stratified Random Sampling and Simple Latin Square +1 as a means of collecting fecal samples for testing. This type of a scheme would ensure that such samples were random and well-distributed throughout the study area. Development and implementation of such a sampling scheme could be invaluable in assessing the lungworm burdens of bighorn sheep.

Disease Transmission

The epizootic that occurred in the Highlands in the fall of 1994 took place in an area in which domestic sheep were in contact with bighorns. Unfortunately, this is not the first time that such a tragedy has struck bighorn sheep herds in Montana. The

history of bighorn sheep in Montana—and throughout North America—is punctuated by many such die-offs (Buechner, 1960; Forrester, 1971; Goodson, 1982). According to Forrester (1971), “the lungworm-pneumonia complex is unquestionably the most significant disease in bighorn sheep in that it prevents prolonged over-population with consequent destruction to forage supplies.”

Bighorn lungworm-pneumonia complex involves a lungworm, a bacterium and/or virus, and stress. Infection by lungworms of the genus *Protostrongylus* appears to be endemic in bighorn sheep. These lungworms inhabit either the air passages or the parenchyma of the sheep's lungs. Such an infection is thought to reduce the integrity of the host's lungs, thereby increasing the animal's susceptibility to a secondary infection by a pneumonia-causing microorganism. The most common bacteria seen in this disease complex are *Pasteurella haemolytica* and *Pasteurella multocida*, but the genera *Corynebacterium*, *Streptococcus*, and *Staphylococcus* has also been implicated. The virus Parainfluenza 3 is also involved in some cases. Many healthy bighorn sheep herds have a high frequency of lungworm, as well as the presence of bacteria, without the presence of this disease complex. Therefore, some other factor must be involved. Thorne et al. (1982) state that “the fatal lungworm-pneumonia complex is usually preceded by stress in the form of one or more of the following conditions; inclement weather, overcrowding, poor range condition and under-nutrition, and harassment by predators and humans.” He goes on to state that there are probably other, as yet unrecognized, stresses that act upon bighorn sheep, and, possibly, *protostrongylid* lungworms alone can act as sufficient stress to initiate pneumonia. Thorne et al. (1982) are supported in their views by Buechner (1960), Forrester (1971), Foreyt (1980), and many other experts in the field. This becomes important when trying to discern the cause of verminous pneumonia in those sheep from which lung nodules were recovered during this study.

While the presence of bacteria in the lungs of sick bighorns is not questioned, the source of such an infection is very controversial. Currently, there are two major hypotheses which explain the process by which a bighorn might develop a bacterial pneumonia. The first idea involves the transmission of the organism from domestic livestock, namely sheep, to bighorn sheep which inhabit the same range. Investigations into several bighorn sheep die-offs have linked the presence of domestic sheep to the epidemic. In these cases, domestic sheep were either in direct contact with the bighorns shortly before the outbreak, or domestic sheep had recently been present in the range utilized by the bighorns. While the circumstantial evidence which implicated the domestic sheep (or cattle) could not be proven in most cases, the majority of investigators have come to a common conclusion: "bighorn sheep and domestic sheep should not occupy the same ranges or be managed in close proximity to each other, because of the potential adverse effect on the bighorn sheep" (Blaisdell, 1982; Foreyt and Jessup, 1982; Coggins, 1988; Onderka et al., 1988; Rawlings, 1988; Sandoval, 1988; Foreyt, 1989; Callan et al., 1991; Foreyt, 1990).

A second hypothesis is one in which pneumonia is induced by stress. It is widely accepted that the majority of bighorn sheep are infected with *Protostrongylus* spp. lungworms. In addition, this hypothesis holds that *Pasteurella* spp. infections are also endemic in bighorn populations. These infections are non-pathogenic until the introduction of a stressor lowers the host's immunity until pneumonia occurs. This phenomenon results in an all-age die-off (Buechner, 1960; Forrester, 1971; Spraker, 1977a; Foreyt, 1980; Festa-Bianchet, 1988; Fougere-Tower and Onderka, 1988).

The Highlands situation brings to light the ongoing controversy surrounding disease and/or parasite transmission between domestic livestock and wildlife. Disease and/or parasite transmission is indeed possible between domestic sheep and bighorn

sheep (Foreyt, 1989; Foreyt and Jessup, 1982; Foreyt, 1990; Foreyt et al., 1990). Foreyt's results are challenged by many who feel that they cannot be extrapolated to the wild. Blaisdell (1982), Foreyt and Jessup (1982), Coggins (1988), Onderka and Wishart (1988) and Sandoval (1988) have reported bighorn sheep die-offs that have been attributed to verminous pneumonia where the bacteria and/or virus was transmitted to bighorn sheep by clinically normal domestic sheep. Spraker (1977), Andryk and Irby (1986), Bailey (1986), Festa-Bianchet (1988) and Fougere-Tower and Onderka (1988) have shown that the etiologic agent in similar die-offs was unlikely to have been contracted from domestic sheep.

Results of a habitat and behavior study of the Highlands bighorn sheep herd revealed that contact does, indeed, occur between domestic sheep and bighorn sheep in this area. Even though the domestic sheep are confined to pastures, bighorns have been observed in these pastures amongst the domestic sheep (Weigand, 1994). In addition, the recovery of the parasite *Ostertagia ostertagi* from bighorns during this study may support the suspicion of parasites being transmitted from domestic stock to bighorns. While the bighorn sheep is not the normal host of this species, it is the most common parasite found in Montana cattle and is occasionally recovered from domestic sheep. In addition, 8 of the 16 species of parasite recovered from bighorn specimens have also been recovered from domestic cattle and/or sheep. The potential for disease/parasite transmission from domestic stock to bighorn sheep in HD 340 has been established. What remains is for a long-term monitoring system to be implemented to assess this situation.

Conclusions and Recommendations

The Highlands bighorn sheep herd was found to harbor ten nematode, one

cestode, and five protozoan species of parasite. Of these, only *Marshallagia marshalli* was found in significant levels. Since heavy infections of this parasite can cause decreased vigor in bighorns, its levels should be closely monitored.

Though 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 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 levels could prove to be beneficial for the future management of this herd (and other bighorn sheep herds).

Further research into the lifecycle and pathogenesis of *Wyominia tetoni* is needed to determine the effect of this parasite on its host. Namely, how does the presence of one or two of these cestodes affect bile flow and digestive efficiency in bighorn sheep?

Studies have shown that increased precipitation favors higher larval survival and transmission; therefore, the apparent higher incidence of infection in 1993 may be correlated with environmental conditions. It appears that level of precipitation alone does not affect larval output, but other environmental factors could be involved. In order to determine if such trends exist in the Highlands herd, long-term monitoring must be employed.

This study lasted only two years; therefore, no valid hypotheses could be formulated regarding the presence (or absence) of potential trends in the parasite loads and the effect of weather conditions on these parasite loads 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 the *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 testing. Unfortunately, the death of the majority of the Highlands herd during the fall and winter of 1994-95 precludes this herd from further studies such as this. However, other herds are available for such long-term studies as are required to determine the true relationship between herd health and parasite loads in bighorn sheep. The Sun River herd, for example, is a hunted herd and has been a major source for the capture and removal of small transplant herds. The task of supplemental fecal sample collection could be easily accomplished. Continued health monitoring is the only way to determine if current management methods are, indeed, working on bighorn sheep herds.

THE REFERENCE MATTER

REFERENCES CITED

- T. A. Andryk and L. R. Irby. Population characteristics and habitat use by mountain sheep prior to a pneumonia dieoff. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 272-291, 1986.
- G. Baermann. Eine einfache methode zur auffindung von ankylostomum - (nematoden) - larven in erdproben. *Welteureden. Batavia. Geneesk. Lab. Feestbundel.*, pages 41-47, 1917.
- J. A. Bailey. The increase and dieoff of Waterton Canyon bighorn sheep: Biology, management and dismanagement. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 325-340, 1986.
- R. D. Beane and N. T. Hobbs. The Baermann technique for estimating *protostrongylus* infection in bighorn sheep: Effect of laboratory procedures. *Journal of Wildlife Diseases*, 19(1):7-9, 1983.
- W. W. Becklund and C. M. Senger. Parasites of *Ovis canadensis canadensis* in Montana, with a checklist of the internal and external parasites of the Rocky Mountain bighorn sheep in North America. *The Journal of Parasitology*, 53(1):157-165, 1967.
- W. E. Bizzell and H. Ciordia. An apparatus for collecting helminth parasites of ruminants. *Journal of Parasitology*, 48(3):490-491, 1962.
- J. A. Blaisdell. Lava beds wrap-up, what did we learn? In *Transactions of the Desert Bighorn Council*, pages 32-33, 1982.
- S. N. Boev. *Protostrongylids*. American Publishing Company, New Dehli, India, 1984.
- H. K. Buechner. The bighorn sheep in the United States, its past, present, and future. *Wildlife Monographs*, 4:174pp, May 1960.
- R. J. Callan, T. D. Bunch, G. W. Workman, and R. E. Mock. Development of pneumonia in desert bighorn sheep after exposure to a flock of exotic wild and domestic sheep. *Journal of the American Veterinary Medical Association*, 198(6):1052-1056, 1991.

- H. Ciordia and D. M. Baird. Internal parasitism of beef cattle on winter pastures: level of parasitism as affected by stocking rates. *American Journal of Veterinary Research*, 32(9):1353-1358, 1971.
- V. L. Coggins. The Lostine Rocky Mountain bighorn sheep die-off and domestic sheep. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 57-64, 1988.
- F. Couey and A. Schallenberger. *Game Management in Montana*, chapter Bighorn Sheep, pages 97-105. Montana Fish and Game Department, Helena, Montana, 1971. Edited by: E. W. Mussehl and F. W. Howell.
- L. R. Davis. Two new entertome devices. *American Journal of Veterinary Research*, 5:60-61, 1944.
- S. Demarais, H. A. Jacobson and D. C. Gynn. Abomasal parasites as a health index for white-tailed deer in Mississippi. *Journal of Wildlife Management*, 47(1):247-252, 1983.
- L. W. Dewhirst and M. F. Hansen. Methods to differentiate and estimate worm burdens in cattle. *Vet. Med.*, 56:84-89, 1961.
- A. G. Dinaburg. The efficiency of the Baermann apparatus in the recovery of *Haemonchus contortus*. *Journal of Parasitology*, 28:433-440, 1942.
- G. L. Doster. Deer herd health checks in 1985. *SCWDS Briefs: A Quarterly Newsletter from the Southeastern Cooperative Wildlife Disease Study*, 1(3):2, October 1985.
- J. H. Eve and F. E. Kellogg. Management implications of abomasal parasites in southeastern white-tailed deer. *Journal of Wildlife Management*, 41(2):169-177, 1977.
- M. Festa-Bianchet. A pneumonia epizootic in bighorn sheep, with comments on preventive management. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 66-76, 1988.
- M. Festa-Bianchet. Numbers of lungworm larvae in feces of bighorn sheep: Yearly changes, influence of host sex, and effects on host survival. *Canadian Journal of Zoology*, 69:547-554, 1991.
- M. Festa-Bianchet and J. Samson. Lamb survival in relation to maternal lungworm load in Rocky Mountain bighorn sheep. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 364-371, 1984.
- W. J. Foreyt. Treatment for lungworms (*Protostrongylus* spp.) in Rocky Mountain bighorn sheep (*ovis c. canadensis*) with albendazole. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 248-261, 1980.

W. J. Foreyt. Fatal *Pasteurella haemolytica* pneumonia in bighorn sheep after direct contact with clinically normal domestic sheep. *American Journal of Veterinary Research*, 50(3):341-344, 1989.

W. J. Foreyt. Pneumonia in bighorn sheep: Effects of *Pasteurella haemolytica* from domestic sheep and effects on survival and long-term reproduction. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 92-101, 1990.

W. J. Foreyt and D. A. Jessup. Fatal pneumonia of bighorn sheep following association with domestic sheep. *Journal of Wildlife Diseases*, 18(2):163-168, 1982.

W. J. Foreyt, T. Parker, and V. Coggins. Safety and efficacy of fenbendazole against *Protostrongylus* spp. infections in Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 118-124, 1990.

D. J. Forrester. *Bighorn Sheep Lungworm-Pneumonia Complex*, chapter 6 in *Parasitic Diseases of Wild Mammals*, pages 158-173. Iowa State University Press, Ames, Iowa, 1971.

D. J. Forrester and R. C. Littell. Influence of rainfall on lungworm infections in bighorn sheep. *Journal of Wildlife Diseases*, 12:48-51, 1976.

D. J. Forrester and C. M. Senger. A survey of lungworm infection in bighorn sheep of Montana. *Journal of Wildlife Management*, 28(3):481-491, 1964.

B. Fougere-Tower and D. K. Onderka. Aspects of the life cycle of *Protostrongylus stilesi* (nematoda, protostrongylidae) in bighorn sheep with emphasis on environmental influences on extretion of lungworm larvae in feces. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 91-97, 1988.

M. R. Frisina. Personal interview of November 2, 1992, with Michael R. Frisina-wildlife biologist with MDFWP, 1992.

M. R. Frisina and J. D. Atcheson. Highlands ram tops 'em all. *Montana Outdoors*, 24(2):36-37, 1993.

N. J. Goodson. Effects of domestic sheep grazing on bighorn sheep populations: A review. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 287-313, 1982.

C. P. Hibler, R. E. Lange, and C. J. Metzger. Transplacental transmission of *Protostrongylus* spp. in bighorn sheep. *Journal of Wildlife Diseases*, 9:384, 1972.

C. P. Hibler, C. J. Metzger, T. R. Spraker, and R. E. Lange. Further observations on *Protostrongylus* spp. infection by transplacental transmission in bighorn sheep. *Journal of Wildlife Diseases*, 10:39-41, 1974.

R. F. Honess. Coccidia infesting the Rocky Mountain bighorn sheep in Wyoming with a description of two new species. *Bull. Wyo. Agric. Exp. Sta.*, 244:1-28, 1942.

R. F. Honess and K. B. Winter. *Diseases of Wildlife in Wyoming*. Wyoming Game and Fish Department, Cheyenne, Wyoming, 1956.

G. N. Hunter and R. E. Pillmore. Hunting as a technique in studying lungworm infestations in bighorn sheep. In *Proceedings of the Nineteenth North American Wildlife Conference*, pages 117-131, 1954.

R. G. Janson. Bighorn sheep transplanting in Montana. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 96-98, 1974.

D. A. Jessup. Pneumonia in bighorn sheep: Effects on populations. *Cal-Neva Wildlife Transactions*, pages 71-78, 1981.

F. King. Personal interview of November 2, 1992, with Fred King-wildlife biologist with MDFWP, 1992.

R. Lange. Cause and nature of mortality in bighorn sheep. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 104-107, 1974.

N. D. Levine. *Nematode Parasites of Domestic Animals and of Man*. Burgess Publishing Company, Minneapolis, Minnesota, second edition, 1980.

Montana Department of Fish, Wildlife and Parks. Legal descriptions of the 1992 & 1993 big game hunting districts for the state of Montana. Helena, Montana, 1992.

Montana Department of Fish, Wildlife and Parks. Montana big game hunting regulations, 1995.

J. Neter, W. Wasserman, and G. A. Whitmore. *Applied Statistics*. Allyn and Bacon, Inc., Newton, Massachusetts, third edition, 1988.

D. K. Onderka, S. A. Rawluk, and W. D. Wishart. Susceptibility of Rocky Mountain bighorn sheep and domestic sheep to pneumonia induced by bighorn and domestic livestock strains of *Pasteurella haemolytica*. *Canadian Journal of Veterinary Research*, 52:439-444, 1988.

D. K. Onderka and W. D. Wishart. Experimental contact transmission of *Pasteurella haemolytica* from clinically normal domestic sheep causing pneumonia in Rocky Mountain bighorn sheep. *Journal of Wildlife Diseases*, 24(4):663-667, 1988.

B. H. Ransom. *The Nematodes Parasitic in the Alimentary Canal of Cattle, Sheep, and other Ruminants*. Government Printing Office, Washington, 1911.

A. V. Sandoval. Bighorn sheep die-off following association with domestic sheep: Case history. In *Transactions of the Desert Bighorn Council*, pages 36-37, 1988.

J. W. Scott. A new genus and new species of tapeworm from the bighorn sheep. *Anat. Rec.*, 81:65-66, 1941.

Soil Conservation Service (SCS). *Snow Survey and Water Supply Products Reference*. U.S. Department of Agriculture, Portland, 1988.

K. I. Skrjabin, N. P. Shikhobalova, and I. V. Orlov. Trichocephalidae and capillariidae of animals and man and the diseases caused by them. In K. I. Skrjabin, editor, *Essentials of Nematodology*, volume 6. Israel Program for Scientific Translation, Jerusalem, 1970. Translated from Russian.

T. R. Spraker. Fibrinous pneumonia of bighorn sheep. In *Transactions of the Desert Bighorn Council*, pages 17-18, 1977.

T. R. Spraker and C. P. Hibler. Summer lamb mortality of Rocky Mountain bighorn sheep. In *Transactions of the Desert Bighorn Council*, pages 11-12, 1977.

J. G. Stelfox and J. McGillis. Seasonal growth patterns of bighorns correlated with range conditions and endoparasite loads. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 35-38, 1970.

E. T. Thorne, N. Kingston, W. R. Jolley, and R. C. Bergstrom, editors. *Diseases of Wildlife in Wyoming*. Wyoming Game and Fish Department, Cheyenne, Wyoming, second edition, 1982.

L. S. Uhazy, J. C. Holmes, and J. G. Stelfox. Lungworms in the rocky mountain bighorn sheep of western Canada. *Canadian Journal of Zoology*, 51:817-824, 1973.

J. P. Weigand. Range use and interspecific competition of Rocky Mountain bighorn sheep in the Highland mountains, Montana. Master's thesis, Montana State University, Department of Biology, 1994.

W. D. Wishart, J. Jorgenson, and M. Hilton. A minor die-off of bighorns from pneumonia in southern Alberta. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 229-247, 1980.

D. E. Worley and et al. Lungworm infection in Montana bighorn sheep- a re-examination. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 83-88, 1976.

D. E. Worley and F. M. Seesee. Lungworm surveillance in bighorn sheep: Possible applications for population density estimates and range use assessment. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 77-83, 1988.

D. E. Worley and F. M. Seesee. Gastrointestinal parasites of bighorn sheep in western Montana and their relationship to herd health. In *Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council*, pages 202-212, 1992.

W. Yorke and P. A. Maplestone. *The Nematode Parasites of Vertebrates*. Hafner Publishing Company, New York, 1962.

APPENDICES

APPENDIX A

Post Mortem Examination Results

1992 Fecal Flotation Results						
Sheep Number	Age	Sex	T.C.O.	Nem.	Mar.	Eim.
237-92*	1	F	NA	NA	NA	NA
238-92 *		F	NA	NA	NA	NA
279-92 *	Lamb		NA	NA	NA	NA
489-92	6	M	NA	NA	NA	NA
516-92	3	F	0	3	6	0
517-92			3	1	11	0
558-92	10	F	0	0	9	0
676-92		M	NA	NA	NA	NA
677-92		M	0	3	2	0
678-92		F	0	0	0	0
679-92		F	5	1	0	3 → E. faurei 2 → E. ovina
722-92	4	F	NA	NA	NA	NA
753-92		F	0	7	10	0
754-92		F	1	2	15	0
755-92		M	1	9	13	1 → E. ahsata
18-93		F	0	1	0	20 → E. ahsata 2 → E. ovina
19-93			0	1	0	2 → E. ahsata 3 → E. faurei
56-93	1	F	0	5	4	7 → E. ahsata 5 → E. ovina 1 → E. ovinoidalis
57-93	2	F	0	1	6	2 → E. ahsata 14 → E. ovina 2 → E. ovinoidalis
58-93	2	F	0	0	0	0
74-93			NA	NA	NA	NA
75-93		M	0	2	1	89 → E. ahsata 11 → E. intricata 20 → E. ovina 42 → E. ovinoidalis
76-93		M	0	1	0	2 → E. ovinoidalis
77-93		F	12	3	7	35 → E. ahsata 5 → E. ovina 10 → E. ovinoidalis
78-93	1	F	0	0	1	0
79-93		M	1	1	0	1 → E. ovina → E. ovinoidalis
80-93	3	F	1	2	3	0
81-93	5	F	0	1	0	9 → E. ahsata 9 → E. ovina 8 → E. ovinoidalis
82-93		M	4	10	13	31 → E. ahsata
83-93	4	F	0	4	2	15 → E. ahsata 5 → E. faurei 13 → E. ovina
84-93		M	1	2	1	0

Table 6: Results of a qualitative Modified-Lane Fecal Flotation test performed on fecal samples taken from hunter-killed bighorn sheep during the 1992 hunting season. Three fecal samples (*) were taken from sheep that were found dead in the field. All bighorn ages are given in years. Abbreviations are as follows: T.C.O. = *Trichostrongylus* spp., *Cooperia* spp., or *Ostertagia* spp. (genus indistinguishable); Nem. = *Nematodirus* spp.; Mar. = *Marshallagia* spp.; Eim. = *Eimeria* spp.; and NA = fecal sample Not Available for testing.

1993 Fecal Flotation Results						
Sheep Number	Age	Sex	T.C.O.	Nem.	Mar.	Eim.
222-93	6	M	0	7	11	1 → <i>E. ahsata</i> 1 → <i>E. ovinoidalis</i>
223-93		M	0	0	0	0
264-93	5	F	NA	NA	NA	NA
265-93		F	NA	NA	NA	NA
298-93	4	M	NA	NA	NA	NA
299-93		M	NA	NA	NA	NA
319-93	4	F	NA	NA	NA	NA
320-93	5	M	NA	NA	NA	NA
339-93		F	NA	NA	NA	NA
340-93		F	NA	NA	NA	NA
404-93	2	F	NA	NA	NA	NA
405-93	3*/4**	F	NA	NA	NA	NA
407-93		M	NA	NA	NA	NA
408-93		M	NA	NA	NA	NA
409-93	5	M	NA	NA	NA	NA
410-93	6	M	NA	NA	NA	NA
411-93	1	F	NA	NA	NA	NA
412-93		F	NA	NA	NA	NA
413-93	6	M	NA	NA	NA	NA
414-93	8	F	NA	NA	NA	NA
415-93	2	F	NA	NA	NA	NA

Table 7: Results of a qualitative Modified-Lane Fecal Flotation test performed on fecal samples taken from hunter-killed bighorn sheep during the 1993 hunting season. All bighorn ages are given in years. Abbreviations are as follows: T.C.O. = *Trichostrongylus* spp., *Cooperia* spp., or *Ostertagia* spp. (genus indistinguishable); Nem. = *Nematodirus* spp.; Mar. = *Marshallagia* spp.; Eim. = *Eimeria* spp.; and NA = fecal sample Not Available for testing; * = Age determined by tooth cementum age analysis; ** = Age determined by annular horn rings.

1992 Baermann Technique Results				
Sheep Number	Age	Sex	Sample Size (g)	LPG
237-92 *	1	F	5.0	NA
238-92 *		F	3.3	0.0
279-92 *	Lamb		5.0	30.8
489-92	6	M	NA	NA
516-92	3	F	10.0	0.1
517-92			10.0	22.5
558-92	10	F	10.0	0.2
676-92		M	10.0	0.2
677-92		M	NA	NA
678-92		F	10.0	0.0
679-92		F	10.0	0.1
722-92	4	F	NA	NA
753-92		F	10.0	0.0
754-92		F	10.0	32.4
755-92		M	10.0	4.0
18-93		F	10.0	11.8
19-93			10.0	2.2
56-93	1	F	5.0	0.4
57-93	2	F	5.0	0.0
58-93	2	F	5.0	0.0
74-93			NA	NA
75-93		M	5.0	0.0
76-93		M	5.0	0.0
77-93		F	5.0	2.6
78-93	1	F	5.0	0.0
79-93		M	5.0	137.6
80-93	3	F	5.0	14.4
81-93	5	F	5.0	10.0
82-93		M	5.0	3.0
83-93	4	F	5.0	1.0
84-93		M	5.0	4.2

Table 8: Results of a Baermann test performed on fecal samples taken from hunter-killed bighorn sheep during the 1992 hunting season. Three fecal samples (*) were taken from sheep that were found dead in the field. All results are given as number of *Protostrongylus* spp. Larvae Per Gram of fecal material (LPG). All bighorn ages are given in years. Abbreviations; NA = fecal sample Not Available for testing.

1992 Transplant Baermann Technique Results				
Sheep Number	Age	Sex	Sample Size (g)	LPG
30249	$\frac{1}{2}$	F	2.0	23.5
30201	$\frac{1}{2}$	F	1.4	3.6
30217	$1\frac{1}{2}$	F	2.4	1.7
30236	$\frac{1}{2}$	F	3.0	3.7
30209	$2\frac{1}{2}$	F	2.2	44.1
30282	$\frac{1}{2}$	M	2.0	7.0
30276	$\frac{1}{2}$	F	2.5	11.2
30247	$4\frac{1}{2}+$	F	2.7	4.4
30212	$1\frac{1}{2}$	M	3.0	0.3
30213	$1\frac{1}{2}$	F	3.2	7.8
30243	$1\frac{1}{2}$	M	2.2	0.5
30250	$\frac{1}{2}$	M	2.0	2.0
30237	$1\frac{1}{2}$	M	3.2	33.8
30205	$1\frac{1}{2}$	F	3.4	33.5
30284	$1\frac{1}{2}$	F	1.4	6.4
30220 *	Adult	F	2.0	34.0
26439	$2\frac{1}{2}$	F	4.2	2.4
30226	$2\frac{1}{2}$	F	3.8	8.4
30229	$1\frac{1}{2}$	M	3.6	14.4
30215	$\frac{1}{2}$	F	1.1	16.4
64436	$1\frac{1}{2}$	F	4.7	40.9
30223	$\frac{1}{2}$	M	1.7	241.2
30239	$2\frac{1}{2}$	M	3.1	92.3
30219	$4\frac{1}{2}$	F	0.3	0.0
30225	$3\frac{1}{2}$	F	0.5	4.0
30240	$3\frac{1}{2}$	F	3.9	0.3
30203	$1\frac{1}{2}$	M	2.7	0.7
30233	$1\frac{1}{2}$	F	0.4	15.0
26444	$\frac{1}{2}$	F	7.5	68.0
26439	$2\frac{1}{2}$	F	2.5	5.6
26430 *	Adult	M	1.9	19.5
30235	$\frac{1}{2}$	M	2.0	2.5
26434	$4\frac{1}{2}+$	F	2.5	8.8
26442	$4\frac{1}{2}+$	F	3.4	3.8
26428 *	Adult	M	1.7	0.6

Table 9: Results of a Baermann test performed on fecal samples taken from a group of 35 bighorn sheep that were captured on December 23, 1992, and were transplanted to the Sleeping Giant region near Helena, Montana. Three sheep were not transported to the transplant site—two adult rams (*) were released and one adult female (*) escaped at the capture site. All results are given as number of *Protostrongylus* spp. Larvae Per Gram of fecal material (LPG). All bighorn ages are given in years. (Adults are those animals $\geq 4\frac{1}{2}$ years.)

1993 Baermann Technique Results				
Sheep Number	Age	Sex	Sample Size (g)	LPG
222-93	6	M	5.0	1.8
223-93	9	M	5.0	9.0
264-93	5	F	5.0	206.2
265-93		F	5.0	27.6
298-93	4	M	NA	NA
299-93		M	5.0	0.4
319-93	4	F	5.0	5.8
320-93	6*/5**	M	5.0	0.4
339-93		F	5.0	50.2
340-93		F	5.0	20.8
404-93	2	F	5.0	534.6
405-93	3*/4**	F	5.0	20.8
407-93	6	M	5.0	102.6
408-93	4	M	5.0	317.6
409-93	6*/5**	M	5.0	318.4
410-93	6	M	5.0	344.2
411-93	1	F	5.0	45.4
412-93		F	5.0	60.2
413-93	7*/6**	M	5.0	54.2
414-93	8	F	NA	NA
415-93	2	F	5.0	94.6

Table 10: Results of a Baermann test performed on fecal samples taken from hunter-killed bighorn sheep during the 1993 hunting season. All results are given as number of *Protostrongylus* spp. Larvae Per Gram of fecal material (LPG). All bighorn ages are given in years. In one case, the age, calculated by both annular horn rings (*) and by tooth cementum age analysis (**), did not coincide; therefore, both ages are tabulated here. Abbreviations: NA = fecal sample Not Available for testing.

1992 Post-Mortem Results (Lung and Liver)								
Sheep	Proto.							Wyom.
	rushi		stilesi		spp.			tet.
	M	F	M	F	M	F	U	U
237-92	0	0	1	0	2	8	0	0
238-92	2	0	1	0	0	4	0	0
279-92	0	0	0	0	0	0	0	0
489-92	0	0	0	0	1	2	5	0
516-92	1	3	1	1	0	0	0	1
517-92	0	0	0	0	0	0	1	0
558-92	0	5	1	0	0	0	0	0
676-92	0	0	0	0	0	0	0	0
677-92	0	0	0	1	0	0	0	0
678-92	2	0	2	0	0	0	0	0
679-92	1	0	0	0	0	0	0	0
722-92	NA	NA	NA	NA	NA	NA	NA	NA
753-92	2	13	1	0	0	0	0	2
754-92	0	0	0	0	0	0	0	2
755-92	0	7	2	0	0	0	0	0
18-93	0	0	0	0	0	0	0	0
19-93	0	0	0	0	0	0	0	1
56-93	1	0	0	0	0	0	0	0
57-93	0	1	0	0	0	0	0	0
58-93	0	0	0	0	0	0	0	0
74-93	0	0	0	0	0	0	0	2
75-93	3	9	3	0	0	0	0	0
76-93	0	0	0	0	0	0	0	0
77-93	0	0	0	0	0	0	0	0
78-93	0	0	0	0	0	0	0	0
79-93	1	0	1	0	0	0	0	1
80-93	0	1	0	3	0	0	1	0
81-93	0	0	0	1	0	0	0	0
82-93	0	0	0	0	0	1	0	0
83-93	0	0	0	0	0	0	0	0
84-93	2	2	3	0	0	0	0	0

Table 11: Results of a post-mortem test performed on lungs and livers taken from hunter-killed bighorn sheep during the 1992 hunting season. Results are tallied by parasite genus and species, parasite gender, and number of specimens found in each category. Abbreviations: / Proto. = *Protostrongylus*; Wyom. = *Wyominia*; tet. = *W. tetoni*; spp. = parasite Species unknown; NA = organ in which this genus and species of parasite is normally found Not Available for examination; M = Male parasite; F = Female parasite; U = parasite gender Unknown

1992 Post-Mortem Results (Intestinal Tract)														
Sheep	Marsh.			Nema.			Oster.			Chab.		Trich.		Taen.
	marsh.			abn.	dav.	spp.	tri.	ost.	t/o	ovina		spp.		hyd.
	M	F	U	M	M	F	M	M	F	M	F	M	F	U
237-92	1	2	0	0	0	2	0	0	0	0	0	0	0	0
238-92	1	0	2	0	0	0	0	0	0	0	0	0	0	0
279-92	0	0	0	0	0	0	0	0	0	0	0	0	0	0
489-92	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
516-92	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0
517-92	73	165	0	0	0	0	0	0	0	0	0	0	0	0
558-92	304	443	0	0	0	0	7	0	10	0	0	0	0	0
676-92	253	354	0	0	0	0	0	0	0	0	0	0	0	0
677-92	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
678-92	5	9	0	0	0	0	0	0	0	1	0	0	0	0
679-92	0	0	0	1	1	3	0	0	0	0	0	0	1	0
722-92	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
753-92	20	17	0	0	0	11	0	0	0	0	0	0	0	0
754-92	88	270	0	0	0	6	8	0	17	0	0	0	0	0
755-92	68	201	0	0	0	0	0	0	0	0	0	0	0	0
18-93	89	79	0	0	0	0	0	0	0	0	0	0	0	0
19-93	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56-93	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57-93	0	0	0	0	0	1	0	0	0	0	0	0	0	0
58-93	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74-93	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
75-93	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0
76-93	56	74	0	0	0	0	0	0	0	0	0	0	0	0
77-93	219	478	0	0	0	29	11	0	11	0	0	0	0	0
78-93	25	74	0	0	0	0	0	0	0	0	0	0	0	0
79-93	185	238	0	0	0	11	2	0	8	0	0	0	0	0
80-93	360	679	0	0	0	0	0	0	0	0	0	0	0	0
81-93	11	34	0	0	0	1	0	0	0	0	0	0	0	0
82-93	131	248	0	0	0	4	8	0	18	0	0	0	0	0
83-93	172	292	0	0	0	0	0	0	0	0	0	0	0	0
84-93	54	114	0	0	1	9	0	0	0	NA	NA	NA	NA	0

Table 12: Results of a post mortem test performed on intestinal tracts taken from hunter-killed bighorn sheep during the 1992 hunting season. Results are tallied by parasite genus and species, parasite gender, and number of specimens found in each category. Abbreviations: / Marsh. = *Marshallagia*; marsh. = *M. marshalli*; Nema. = *Nematodirus*; abn. = *N. abnormalis*; dav. = *N. davtianii*; Oster. = *Ostertagia*; tri. = *O. trifurcata*; ost. = *O. ostertagi*; t/o = *O. trifurcata* OR *O. ostertagi* (I was not able to differentiate females of these two species.); Chab. = *Chabertia*; Trich. = *Trichuris*; Taen. = *Taenia*; hyd. = *T. hydatigena*; spp. = parasite Species unknown; NA = organ in which this genus and species of parasite is normally found Not Available for examination; M = Male parasite; F = Female parasite; U = parasite gender Unknown

1993 Post-Mortem Results (Lung and Liver)								
Sheep	Proto.							Wyom.
	rushi		stilesi		spp.			tet.
	M	F	M	F	M	F	U	U
222-93	NA	NA	NA	NA	NA	NA	NA	0
223-93	0	1	0	0	0	0	0	0
264-93	0	0	0	0	0	0	0	0
265-93	0	2	4	1	0	0	0	0
298-93	0	0	0	0	0	0	0	1
299-93	0	0	0	0	0	0	0	0
319-93	1	2	1	0	0	0	0	0
320-93	0	1	0	0	0	0	0	0
339-93	0	0	0	0	0	0	0	0
340-93	1	0	0	0	0	0	1	0
404-93	NA	NA	NA	NA	NA	NA	NA	0
405-93	0	0	0	0	0	0	0	0
407-93	0	2	1	1	0	0	0	0
408-93	1	9	7	0	0	0	0	2
409-93	0	0	0	0	0	0	0	1
410-93	NA	NA	NA	NA	NA	NA	NA	1
411-93	NA	NA	NA	NA	NA	NA	NA	1
412-93	3	6	5	0	0	0	0	0
413-93	1	0	0	0	0	0	0	0
414-93	0	0	0	0	0	0	0	0
415-93	0	0	0	0	0	0	1	0

Table 13: Results of a post-mortem test performed on lungs and livers taken from hunter-killed bighorn sheep during the 1993 hunting season. Results are tallied by parasite genus and species, parasite gender, and number of specimens found in each category. Abbreviations: / Proto. = *Protostrongylus*; Wyom. = *Wyominia*; tet. = *W. tetoni*; spp. = parasite Species unknown; NA = organ in which this genus and species of parasite is normally found Not Available for examination; M = Male parasite; F = Female parasite; U = parasite gender Unknown

1993 Post-Mortem Results (Intestinal Tract)

Sheep	Marsh.			Nema.			Oster.			Chab.		Trich.		Taen.
	marsh.			abn.	dav.	spp.	tri.	ost.	t/o	ovina		spp.		hyd.
	M	F	U	M	M	F	M	M	F	M	F	M	F	U
222-93	39	0	0	0	1	8	0	0	0	0	0	0	0	0
223-93	1	4	0	0	0	1	0	0	0	0	0	0	0	0
264-93	37	48	0	0	1	1	0	0	0	0	0	0	0	0
265-93	90	122	0	0	0	0	0	0	0	0	0	0	1	0
298-93	3	11	0	0	0	0	0	0	4	0	0	0	0	1
299-93	50	121	0	0	0	0	1	0	2	0	0	0	0	0
319-93	11	17	0	0	0	0	0	0	0	0	0	0	0	0
320-93	NA	NA	NA	0	0	0	0	0	0	0	1	0	0	0
339-93	23	54	0	0	0	0	0	0	0	0	0	0	0	0
340-93	8	24	0	0	0	0	0	0	0	0	0	0	0	0
404-93	165	31	0	0	0	0	0	0	0	0	0	0	0	0
405-93	2	9	0	0	0	0	0	0	0	0	0	0	0	0
407-93	48	78	0	0	0	0	3	2	7	0	0	0	0	0
408-93	115	297	0	3	3	5	0	0	0	0	0	0	0	1
409-93	65	97	0	0	0	1	0	0	0	0	0	0	0	0
410-93	17	88	0	0	0	0	0	0	0	0	0	0	0	0
411-93	18	47	0	0	0	1	0	0	0	0	0	0	0	0
412-93	48	97	0	0	0	0	0	0	0	0	0	0	0	0
413-93	49	26	0	0	0	0	0	0	0	0	0	0	0	0
414-93	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
415-93	55	152	0	0	0	11	0	0	0	0	0	0	0	0

Table 14: Results of a post-mortem test performed on intestinal tracts taken from hunter-killed bighorn sheep during the 1993 hunting season. Results are tallied by parasite genus and species, parasite gender, and number of specimens found in each category. Abbreviations: / Marsh. = *Marshallagia*; marsh. = *M. marshalli*; Nema. = *Nematodirus*; abn. = *N. abnormalis*; dav. = *N. davtianii*; Oster. = *Ostertagia*; tri. = *O. trifurcata*; ost. = *O. ostertagi*; t/o = *O. trifurcata* OR *O. ostertagi* (I was not able to differentiate females of these two species.); Chab. = *Chabertia*; Trich. = *Trichuris*; Taen. = *Taenia*; hyd. = *T. hydatigena*; spp. = parasite Species unknown; NA = organ in which this genus and species of parasite is normally found Not Available for examination; M = Male parasite; F = Female parasite; U = parasite gender Unknown

APPENDIX B

Letters

GENERAL INFORMATION

WATSON'S LABORATORY CEMENTUM AGE ANALYSIS. General Information.

CERTAINTY CODES: A, B, C. A letter suffix is a reliability indicator or "certainty code" for a determined age. Some tooth section have a distinct annulus pattern and the result of age analysis is nearly certain. The result of the analysis of other tooth section is less certain because of indistinct or irregular annuli or because portions of the tooth root may have been missing.

A = result nearly certain. B = some error possible. C = error likely.

The judgement about whether a determined age could be in error is subjective. Criteria for certainty code assignment are as follows:

1. Distinctness of cementum band staining.
2. Regularity of cementum band pattern.
3. Relative amount and location of cementum and dentine.
4. Histological characteristics of cementum.

We have no evidence supporting any relationship between our certainty code and accuracy, but generally relate the most accurate result to the "A" certainty code.

Accuracy limits have been established as outlined below. For example, if I think that a 9-year-old mammal could be a year older or younger because of an unclear cementum pattern, it would be given a certainty code of "A" along with the determined age of 9 years. I think that a 6-year-old mammal could be a year younger or older, the certainty code of "B" would be given.

Determined Age	Certainty Code		
	A	B	C
1-7 years	+/- 0 years	+/- 1	+/- 2
8-15	+/- 1	+/- 2	+/- 3
16+	+/- 2	+/- 3	+/- 4+

THE REPORT GIVES AGE AT THE LAST BIRTHDAY, in the same style as human age is given. The dates below are the standardized "birthdays" we use for each species.

- 1 February - black bear, grizzly bear.
- 1 April - bobcat, lynx, gray fox, kit fox, red fox, river otter, mink, marten, fisher, badger, volverine.
- 1 May - pronghorn, arctic fox, coyote, wolf, striped skunk, raccoon.
- 1 June - deer, elk, moose, caribou, goat, sheep, bison.

EXPLANATION OF CODES USED IN "NOTES" SECTION: AH - abnormal histology; BR - broken root, cementum missing and no accurate age determination possible; CD - cementum damaged; IN - age determined by inspection, without sectioning; LI - lateral incisor (not standard I1); NE - no envelope with this I.D. number; NP - not processed; NS - not a standard tooth type for age analysis method, accuracy of result uncertain; NTR - no tooth received in envelope; PF - process failure; PR - processed.

JUVENILE AGE CLASS: Identified by "0" in the age column.

ABBREVIATIONS USED FOR SPECIES IDENTIFICATION:

BA badger	CA caribou	GB grizzly bear	MI mink	RO river otter
BB black bear	CO coyote	GO mountain goat	ML mountain lion	SH mountain sheep
BO bobcat	EL elk	MA marten	MO moose	WO wolf
BT black-tailed deer	FI fisher	NO mule deer	PR pronghorn antelope	WT white-tailed deer
	FO fox		RA raccoon	WV volverine

AGE DETERMINED BY CEMENTUM ANALYSIS

By: Gary Watson
 Watson's, Box 308, Milltown MT 59851
 Phone: (406) 258-6286

Tooth type: I1

Prepared for: Kriss Douglass
 Montana Dept Fish Wildlife & Parks
 Butte

Season of collection: fall

Species: Bighorn Sheep

Process code: h
 Filename: AH060694-225
 Date: 6 June 1994

Notes:

"B" RELIABILITY CEMENTUM AGES: THERE IS HISTOLOGICAL EVIDENCE TO SUPPORT THE REPORTED CEMENTUM AGE. IF ERROR IS PRESENT, IT WOULD BE LIKELY WITHIN THE RANGE GIVEN UNDER "NOTES".

"C" RELIABILITY CEMENTUM AGES: THERE IS LITTLE HISTOLOGICAL EVIDENCE TO SUPPORT THE REPORTED CEMENTUM AGE, WHICH MIGHT BE WITHIN THE RANGE GIVEN.

WATSON'S STANDARDIZED TOOTH TYPE FOR BIGHORN SHEEP CEMENTUM AGING IS I1. UNIDENTIFIED "LATERAL INCISORS" (I2, I3, C) WILL BE INCORRECTLY AGED BY 1-3 YEARS BECAUSE THEY ERUPT LATER IN LIFE.

THE HISTOLOGICAL CONDITION OF THE TEETH WAS EXCELLENT. IN THE TOOTH SECTIONS, THE INTACT PERIODONTAL MEMBRANE CONFIRMS THAT NO CEMENTUM IS MISSING FROM THE PERIPHERY OF THE ROOT. DIFFERENTIAL STAINING BETWEEN DARK CEMENTUM ANNULI AND LIGHT CEMENTUM IS FAIR (CEMENTUM ANNULI OF BIGHORN SHEEP ARE TYPICALLY INDISTINCT). FACTORS THAT CAUSE POOR HISTOLOGICAL CONDITION, CEMENTUM DAMAGE, OR POOR DIFFERENTIAL STAINING INCLUDE PHYSICAL ABRASION, PROLONGED EXPOSURE TO HIGH TEMPERATURES (AT OR ABOVE BOILING), AND EXPOSURE TO CHEMICAL AGENTS SUCH AS BLEACH.

DATA

Serial No	Agency ID	Age	CC	Notes	Serial No	Agency ID	Age	CC	Notes
1	558-92	10	A	10-11	10	319-93	4	B	4-5
2	516-92	3	A		11	328-93	5	B	4-5
3	722-92	4	B	4-5	12	404-93	2	B	2-3
4	78-93	1	B	1-2	13	405-93	3	B	3-3
5	80-93	3	A		14	409-93	5	A	
6	81-93	5	A		15	411-93	1	A	IN
7	83-93	4	B	4-5	16	413-93	6	B	6-7
8	264-93	5	B	4-5	17	414-93	8	B	7-9
9	298-93	4	A		18	415-93	2	A	

**Montana Department
of
Fish, Wildlife & Parks**



1400 So. 19th
Bozeman, MT 59715

August 25, 1992

Dear Bighorn Sheep Hunter (H.D. 340 Permit Holders):

A new project sponsored jointly by Montana State University and our Department is now in progress to provide information and specimens needed by biologists to manage the Highlands bighorn herd more effectively. The samples requested from hunters will aid in understanding food habits, seasonal movements, health status of the herd, and the effects of competition with livestock on range utilization and herd productivity.

If you bag a sheep (either ram or ewe), the following specimens are requested:

- INCISOR (1 of the four front teeth) - for aging (be sure to include the root)
- RUMEN (Paunch) - for food habits determination
- INTESTINAL TRACT - for determination of total parasite load
- LUNGS - to evaluate the possibility of a lungworm/pneumonia outbreak
- LIVER - to determine likelihood of cross transmission of liver flukes to bighorn sheep in an area where flukes are endemic in cattle and domestic sheep

The easiest method is to bag the complete gutpile in the green plastic bag. Plastic bags and disposable gloves are provided in the collecting kit. On the enclosed manila tag, please indicate the date of kill, estimated age, sex, location of kill, and your name. It can be used to wire the green bag closed. The small coin envelope is for the incisor tooth.

Specimens can be turned in to:

Mike Frisina, FWP Biologist, 1330 W. Gold, Butte (782-2060)
Kris Douglass, 221 N. Ophir, Butte (782-9060)
Jack Atcheson Taxidermy, 3210 Ottawa, Butte (782-0569)
Montana Dept. Fish, Wildlife & Parks, Wildlife Research Lab,
R-3 Headquarters, 1400 S. 19th, Bozeman (994-6357)
Kerrie A. Hoar, Forest Park Trailer Park #77, Bozeman (586-6966)
Joe Weigand, 119 Julia Martin Dr., MSU, Bozeman (586-1812)

For additional information, please contact:

Mike Frisina, Butte (782-2060)
Harold Picton, Bozeman (994-3251)
David Worley, Bozeman (994-4705)
Keith Aune, Bozeman (994-6357)

Thank you for your cooperation.

Sincerely,

Robert R. Martinka
Regional Supervisor

Enc.

**Montana Department
of
Fish, Wildlife & Parks**



1400 So. 19th
Bozeman, MT 59715

August 24, 1993

Dear Bighorn Sheep Hunter (H.D. 340 Permit Holders):

A new project sponsored jointly by Montana State University and our Department is now in progress to provide information and specimens needed by biologists to manage the Highlands bighorn herd more effectively. The samples requested from hunters will aid in understanding food habits, seasonal movements, health status of the herd, and the effects of competition with livestock on range utilization and herd productivity.

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 Keith Aune, Bozeman (994-6357)

Thank you for your cooperation.

Sincerely,

Richard E. Vincent
Acting Regional Supervisor

Enc.

