Bienn. Symp. North. Wild Sheep
and Goat Council 6: 77 - 83

LUNGWORM SURVEILLANCE IN BIGHORN SHEEP: POSSIBLE APPLICATIONS FOR POPULATION DENSITY ESTIMATES AND RANGE USE ASSESSMENT

DAVID E. WORLEY, Veterinary Research Lab., Montana State University, Bozeman, MT 59717

C. A. YDE, Montana Department of Fish, Wildlife and Parks, Libby, MT 59923

G. W. BROWN, Montana Department of Fish, Wildlife and Parks, Libby, MT 59923

JOHN J. McCARTHY, Montana Department of Fish, Wildlife and Parks, Augusta, MT 59410

Abstract: Population trends of certain wild ungulates (e.g., white-tailed deer) have been shown to be roughly proportional to the prevalence and intensity of the large stomach worm, Haemonchus contortus. Although comparable data on gastrointenstinal helminth levels in bighorn sheep seldom are available, information on lungworm (Protostrongylus spp.) infections frequently is accessible because of the assumed role of this nematode in the lungworm-pneumonia respiratory disease complex in Ovis canadensis. In addition to the direct application of lungworm prevalence data for herd health assessment, the possibility of utilizing Protostrongylus counts as an index for correlating herd densities and chronological fluctuations in population numbers warrants consideration as a possible management tool. In order to test this hypothesis, estimates of the size of bighorn herds on summer or winter ranges were examined in relation to fecal output of protostrongylid larvae and/or an appraisal of lung lesions and worm counts postmortem in 3 Montana herds ranging in size from less than 100 sheep to more than 800 animals. A retrospective assessment of the relevance of this technique for estimating population densities and evaluating range use relationships in bighorn herds suggested that fecal larval counts paralleled herd growth for a time in expanding populations, but failed to show consistent correlations as bighorn populations continued to grow. Postmortem worm counts showed a tentative relationship to degree of lung involvement, but were useful primarily to supplement fecal analysis data and relate respiratory tract lesions to specific types and numbers of adult parasites.

The role of disease in regulation of wild ungulate populations is recognized as a significant factor in certain instances, e.g. the lungworm-pneumonia complex in bighorn sheep (Buechner, 1960; Forrester, 1971). The well documented history of recurring respiratory disease problems in Rocky Mountain bighorn sheep and the consistent occurrence of protostrongylid lungworms in affected herds has led to the assumption that this parasite is involved either directly or as a predisposing agent in triggering outbreaks of respiratory disease (Uhazy and Holmes, 1971;

Lange, 1974; Schmidt et al., 1979). As a consequence, surveillance of lungworm incidence has become a common practice to monitor rates of infection and assess the risks that appear to be associated with high Protostrongylus levels.

Additional applications of lungworm prevalence data may emerge as indices reflecting fluctuations in herd densities and in effect could serve as an early warning system for identifying bighorn populations approaching critical levels, particularly in rapidly expanding herds. Previous efforts to relate parasite intensity to ungulate herd density have been described by Eve and Kellogg (1977) and Demerais et al. (1983), who demonstrated that correlations may exist between abomasal nematode counts (Haemonchus sp.) and the density of white-tailed deer herds in southeastern United States. Based on analysis of lungworm infection data from several Canadian bighorn herds, Holmes and Samuel (1974) postulated that Protostrongylus levels might reflect the condition status of mountain sheep populations because of implicit parasite involvement in the lungworm-pneumonia disease complex. In the present paper, the relationship between lungworm levels and population densities was evaluated to see if lungworm larval shedding rates and/or relative worm populations and lung lesions might serve as an analytical tool for estimating population densities and/or range status in 3 western Montana bighorn herds.

METHODS

Rate of excretion of lungworm larvae in bighorn feces was estimated with the Baermann technique (Thorne, 1983). Fecal samples collected on bedgrounds or around feeding sites at monthly or quarterly intervals were stored in paper bags at approximately 4°C until they were processed in the lab. Quantitative counts of larval output were based upon the number of first stage larvae isolated from 2-10 g. pellet groups after suspension in tap water for 12-18 hours at room temperature. Larval counts were expressed as larvae per gram of feces (LPG). These data were used to derive a lungworm index which was calculated by multiplying the percentage of infected sheep by the mean larval output for the group at each sample interval.

Supplementary data on lungworm infection intensity and species occurrence was based on postmortem examination of respiratory tracts from hunter-killed sheep, road kills, and individuals taken for research purposes. After the respiratory tract was removed intact, the pleural surfaces of the lung were examined for plaques, nodules, bullae or other lesions characteristic of infection with the parenchymal lungworm, Protostrongylus stilesi. The trachea, bronchi and major bronchioles were opened longitudinally with scissors and the epithelial surfaces were examined grossly for P. rushi adults. The entire tract then was chopped into approximately 1 x 2 inch pieces which were agitated in warm saline solution on a reciprocating shaker for 30-45 minutes in an attempt to recover larval or adult forms embedded in lung parenchyma. Worms recovered by this procedure were counted and identified to species where feasible, using the criteria of Honess and Winter (1956) and Thorne et al. (1983). Several bighorn foetuses also were examined to determine whether prenatal lungworm infections occurred in lambs born to infected ewes. Respiratory tracts from foetal lambs were removed intact, chopped into

small pieces, and digested in pepsin-hydrochloric acid solution for 14-16 hours at 37°C to assay for the presence of larval or adult lungworms. The resulting tissue digests were washed on a fine mesh screen to collect Protostrongylus specimens recovered from infected tissue. A total of 806 fecal examinations and 40 necropsies performed on the Ural-Tweed, Thompson River and Sun River bighorn herds were analyzed retrospectively as the basis for this report. Previous data on lungworm prevalence and intensity in these herds are in Worley et al. (1976).

Estimates of herd size used for comparative purposes in this study were based on annual census data calculated from aerial and/or ground surveys made each year in mid- to late winter to include all age classes prior to lambing. A correction factor was employed in certain instances to compensate for the inability to verify total numbers in the Ural-Tweed and Thompson River herds where heavily forested habitat made accurate counts difficult. This was based on the assumption that only about 75% of the sheep present in the area were actually observed during each count. Hence, each estimate of total numbers was arbitrarily increased by 25%. A repetitive Lincoln-Index method utilizing marked animals was used during the early years of the Thompson River study to derive population estimates.

RESULTS

Ural-Tweed Herd

Prevalence and intensity of Protostrongylus infections were monitored via fecal analysis in this northwestern Montana herd at 5 intervals during the 11-year period from 1976 to 1987 (Table 1). The lungworm index doubled in the early years of the study during a period of static herd size ranging between 25 and 40 animals. Growth of the herd over the next 7-8 years roughly paralleled the rise in lungworm infection levels. During the next three years, herd size continued to increase, while the lungworm index decreased to negligible levels.

During this 11-year period the proportion of larval counts that exceeded 100 LPG paralleled the lungworm index curve closely, i.e. the fewest counts >100 occurred at the beginning and end of the period when counts were lowest and peaked in 1985-86 when lungworm prevalence and intensity were highest. A 212% increase in herd size was accompanied by a 19% increase in mean Protostrongylus counts, based on 505 sheep sampled during the 1976-87 interval. Total range area available to this herd was relatively constant at approximately 9477 hectares and did not vary seasonally.

Incidental findings derived from postmorten examinations on 6 sheep of either sex ranging in age from 1 1/2 to 6 years revealed extensive lung lesions suggestive of clinical lungworm-pneumonia syndrome in only 1 animal. The parenchymal lungworm (P. stilesi) occurred in a single sheep, whereas P. rushi was present in low to moderate numbers (1-44 worms) in 5 sheep. Concurrent infections with both lungworm species were seen in only 1 animal. The single sheep with clinically significant lung lesions was examined during the third year of the study prior to the rapid expansion of the herd.

Table 1. Relationship of lungworm larval counts to estimated size of Ural-Tween bighorn herd (1976-87).

Sampling period	% infected	Av. Protostrongylus count (L.P.G.)	% counts >100 L.P.G.	Herd Size
1976-77	80 (40/50)	5.3	0	25-40
1978	85.3 (204/239)	9.5	1.2	25-40
1985 - early 86	96.2 (75/78)	49.1	7.6	60-70
1986	78.5 (62/79)	26.1	7.5	80-90
1987	76.2 (45/59)	6.3	0	100
CHANGE:	-4%	+19%		+212%

Thompson River Herd

This herd occupies approximately 28,560 hectares of forest range adjoining the Thompson River in northwestern Montana. Prevalence and intensity of lungworm infections were monitored via fecal examinations at 4 intervals during the nine-year period between 1973 and 1982 (Table 2). Quantitative Baermann examinations based on 301 fecal samples indicated that lungworm larval shedding levels at the beginning of the study in 1973 increased about 427% by 1981. During the same period, total sheep numbers increased by 82%. The resident sheep population has continued to increase at about a 20% annual rate since 1982, with very limited postmortem data suggested that no major change in Protostrongylus infection levels has occurred concurrently.

Detailed postmortem analysis of 14 sheep between 1973-80 indicated consistently low adult lungworm populations throughout this period. Of 5 adult ewes, 3 rams and 1 yearling ewe examined at necropsy, 3 sheep were infected with P. stilesi, 2 with P. rushi, and 4 were negative for adult lungworms. Total worm burdens were less than 5 in all instances. Lungs of 2 sheep with P. stilesi and 1 with P. rushi had lesions consisting of raised plaques or nodular foci under the pleura. None of 5 near-term (March-May) foetuses from pregnant ewes with active lungworm infections showed evidence of prenatal Protostrongylus infections. No gross lesions were seen in respiratory tracts of these lambs.

Sun River Herd

Chronological changes in lungworm infection levels in Sun River sheep were monitored over a 13-year period in which major fluctuations occurred in the size of the herd (Table 3). The range occupied by these

Table 2. Relationship of lungworm larval counts to estimated size of Thompson River bighorn herd (1973-82).

Sampling period	% infected	Av. Protostrongylus count (L.P.G.)	% counts >100 L.P.G.	Herd Size
1973	73 (33/45)	26.6	8.8	241
1974	88 (136/155)	25.7	7.7	241
1981	62 (37/60)	140.4	5.0	438
1982	93 (38/41)	29.7	4.8	481
CHANGE:	+27%	+12%		+100

Table 3. Herd size in relation to lungworm levels in the Sun River bighorn population (1971-84).

Year	Herd Size	No. sheep infected / Total no. examined	Adult lungworms/sheep: P. stilesi	Adult lungworms/sheep: P. rushi	Lungworm larvae*
1971	589	4/4	0	13	<1
1973	880	4/5	4	3	<1
1976	1000	1/1	0	8	7
1984	600	5/9	only fragments recovered; total no. indeterminate	184	9

* Expressed as larvae/g of feces

sheep consists of approximately 80,862 hectares of reefs, cliffs and ridges interfacing with foothills grassland along the east front of the Rocky Mountain chain. Historically, this area has supported the largest bighorn herd in the region.

Baseline necropsy observations in 1971 indicated that the predominant lungworm species in a small sample of the herd was P. rushi, with pleural adhesions and fibrinous pleuritis present in some animals. Additional postmortem observations in 1973 demonstrated that P. stilesi was present in 3 of 5 adult ewes selected at random from a herd then numbering about 880. Two of the 3 sheep also had concurrent infections with P. rushi. Emphysematous areas in the diaphragmatic lobes of the lung

and/or areas of patchy congestion were evident in 4 of 5 adult sheep examined.

Continued growth of the population during the next 6-8 years culminated in a herd of 1000-1200 sheep. Limited postmortem data during this period did not indicate that a parasite buildup was occurring. However, an extensive die-off apparently correlated with severe respiratory problems began in early 1984, following similar outbreaks in British Columbia and Alberta (Onderka and Wishart, 1984). Examination of 9 adult ewes and rams showing varying degrees of respiratory disease revealed a marked increase in Protostrongylus numbers in some animals, usually accompanied by signs of bronchopenumonia. Extensive areas of congestion were common in the diaphragmatic lobes, along with raised plaques under the pleura. Populations of 200-500 adult lungworms were observed in some sheep. A mortality rate of approximately 40% reduced the herd to about 600 animals within 3-6 months.

DISCUSSION

The ability to recognize fluctuations in lungworm infection levels and relate them to bighorn population trends appeared to have some application in both the Ural-Tweed and Thompson River studies, where a steady growth in both herds over an 8-9 year period was accompanied by a proportionate increase in lungworm indices. Increases in larval output and the proportion of infected Ural-Tweed sheep preceded an approximately 2-fold increase in herd size over a 7-year period (1978-85). In the Thompson River herd, fecal larval counts and herd numbers increased simultaneously over an 8-year period. In both herds, larval shedding rates decreased precipitously at this point while sheep numbers continued to increase. This suggests that herd immunity to lungworms may reach an effective level after adequate exposure occurs in a growing population to the point that it either actually reduces the prevalence of infection via a "self-cure" response (Stewart, 1955) or merely appears to do so by reducing fecundity of the existing lungworms. In either instance, it makes interpretation of lungworm larval counts more difficult and in general reduces the predictive value of fecal analysis data. Other biological criteria of value for judging overall herd health status, in conjunction with lungworm monitoring, include routine determinations of lamb/ewe ratios, field morbidity and mortality observations, and incidence of coughing and other signs of respiratory disease under field conditions.

Little or no opportunity existed during the present study to evaluate the feasibility of using lungworm larval discharge rates for anticipating overcrowding likely to trigger episodes of field mortality. Quantitative fecal analysis data collected at regular intervals appeared to be the preferred method for monitoring lungworm status of a herd. Postmortem findings can be a useful adjunct to relate lung lesions to specific numbers and types of Protostrongylus adults and to determine the extent of lung damage. However, the number of necropsy specimens required to estimate herdwide parasite loads accurately probably would be impractical to collect in most instances because of the large number of sheep required for examination to compensate for individual variability in worm numbers.

LITERATURE CITED

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. 4. 174 pp.

Demerais, S., H. A. Jacobson and D. C. Guynn. 1983. Abomasal parasites as a health index for white-tailed deer in Mississippi. J. Wildl. Manage. 47:247-252.

Eve, J. H. and F. E. Kellogg. 1977. Management implications of abomasal parasites in southeastern white-tailed deer. J. Wildl. Manage. 41:169-177.

Forrester, D. J. 1971. Bighorn sheep lungworm-pneumonia complex. Pp. 158-173 in Parasitic Diseases of Wild Mammals, J. W. Davis and R. C. Anderson, eds. Iowa State Univ. Press, Ames.

Holmes, J. C. and W. M. Samuel, 1974. Surveillance study of the parasites of bighorn sheep in the mountain national parks. Typewritten Report, Dept. of Zoology, University of Alberta, Edmonton, 22 pp.

Honess, R. F. and K. B. Winter. 1956. Diseases of Wildlife in Wyoming. Pp. 182-188. Wyoming Fish and Game Commission, Cheyenne.

Lange, R. 1974. Cause and nature of mortality in bighorn sheep. Pp. 104-107 in Constan, K. J. and J. L. Mitchell (Eds.), Proc. Bienn. Symp. North. Wild Sheep Counc., Great Falls, MT 146 pp.

Onderka, D. K. and W. D. Wishart. 1984. A major bighorn sheep die-off from pneumonia in southern Alberta. Pp. 356-363 in E. T. Thorne (Ed.), Proc. Bienn. Symp. North. Wild Sheep and Goat Counc., Yukon Wildlife Branch, Whitehorse. 513 pp.

Schmidt, R. L., C. P. Hibler, T. R. Spraker and W. H. Rutherford. 1979. An evaluation of drug treatment for lungworm in bighorn sheep. J. Wildl. Manage. 43:461-467.

Stewart, D. F. 1955. Self-cure in nematode infestations of sheep. Nature 176:1273-1274.

Thorne, E. T. (ed.). 1982. Diseases of Wildlife in Wyoming. Second Edition. Wyoming Game and Fish Dept., Cheyenne. 353 pp.

Uhazy, L. S. and J. C. Holmes. 1971. Helminths of the Rocky Mountain bighorn sheep in western Canada. Can. J. Zool. 49:507-512.

Worley, D. E., S. T. Stewart and T. Komberec. 1976. Lungworm infection in Montana bighorn sheep -- A Re-examination. Pp. 83-88 in E. T. Thorne (Ed.), Proc. Bienn. Symp. North. Wild Sheep Counc., Wyoming Game and Fish Dept., Cheyenne. 165 pp.