LAMB SURVIVAL IN RELATION TO MATERNAL LUNGWORM LOAD IN ROCKY MOUNTAIN BIGHORN SHEEP

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ABSTRACT

The relationship between the output of lungworm larvae in the feces of bighorn ewes and reproductive success was investigated in the Sheep River herd in southwestern Alberta from 1981 to 1983. This herd had a history of high lamb production, but variable lamb survival.

In 1981, the lamb:ewe ratio at birth was 95:100, lamb survival was 90% to November, and mean lungworm larval output for ewes during the March-April period was low. In 1982 and 1983 lamb:ewe ratios at birth were also high, but an estimated 32% and 28% respectively of lambs born each year disappeared before October; average larval output of ewes was higher. Ewes whose lambs survived had significantly fewer larvae in feces than ewes whose lambs died before October. In 1982, lambs that started coughing in July, were never seen playing and behaved in a lethargic manner. Most disappearances seemed to occur between late July and early September. Lambs in 1983 appeared healthier, were rarely coughing, some play was observed and disappearances spanned the entire summer.

Lamb mortality was possibly caused by transplacental transmission of the parasite. A few larvae were recovered from three fetuses collected in 1983. Alternatively, high larval output and lamb death could have been consequences of poor maternal body condition. Since the number of larvae in the feces of all ewes in 1981 were not significantly lower than those of successful ewes in either year of summer lamb mortality, an hypothesis is proposed to explain lamb mortality as a result of the behavior of individual ewes, not a consequence of a factor affecting the entire herd.

INTRODUCTION

Almost all bighorn sheep (Ovis canadensis canadensis) in Alberta are infected with lungworms (Protostrongyulus spp.) (Uhazy et al. 1973; this study). Eggs produced by adult worms hatch into first stage (L1) larvae that leave the host via the feces. L1 output follows a yearly cycle, peaking in late winter and early spring. At this time, fecal samples collected from different sheep usually show a very wide range of larvae per gram of dry feces (LPG) (Uhazy et al. 1973).

Bighorn fetuses can become infected transplacentally in the latter stages of pregnancy. Transplacental infection has been associated with catastrophic lamb die-offs (Hibler et al. 1972, 1974; Woodard et al. 1974; Spraker 1979; Spraker and Hibler 1982). Lamb mortality caused by pneumonia results as a complication of the onset of reproduction among worms acquired transplacentally (Spraker 1979). Infected lambs are characterized by lethargic behavior, rough hair coat and violent coughing. Death usually occurs between late July and September (Woodard et al. 1974; Spraker and Hibler 1982).

Both transplacental infection (Gates and Samuel 1977) and summer lamb mortality (Horejsi 1976) have been reported in Alberta, but a direct link between them has not been established. Summer lamb mortality as high as that reported from Colorado (Hibler et al. 1974) has not been observed in Alberta.

Following an all-age die-off in the Sheep River Wildlife Sanctuary in 1978 (Wishart et al. 1980), a study of the local sheep herd was initiated to determine the relationship between a sheep's area use behavior, lungworm infection and reproductive performance. Here we report on the correlation between maternal lungworm larval output and lamb survival to autumn.

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MATERIALS AND METHODS

The study area is located within the Sheep River drainage in southwestern Alberta. Detailed descriptions can be found in Wishart (1958) and Horejsi (1976). The ewe's winter range has been a Wildlife Sanctuary since 1973, and is semi-protected. The lambing grounds and the summer range are located in the front ranges of the Rockies to the west of the winter range. Hunting for trophy rams and non-trophy sheep (ewes and lambs) on a permit basis is allowed outside the Wildlife Sanctuary.

Sheep were captured using projectile syringe darts loaded with ketamine and xylazine (Festa-Bianchet and Jorgenson 1985) or xylazine only, or in a corral trap baited with salt. Captured sheep were tagged with colored plastic tags and numbered metal tags. A swollen udder was considered to be an indication that a ewe was pregnant or lactating. Following lambing, survival of individual lambs was monitored through their association with tagged ewes. Exact dates of lamb death were not known, as intervals between ewe sightings varied from a few days to over a month. When a lactating ewe was never seen with a lamb but was sighted within 2-3 weeks following the peak of lambing, it was assumed that the ewe had produced a lamb that had died at or shortly after birth. These events were considered neonatal mortality.

Fecal samples were collected at capture and whenever identifiable sheep were observed to defecate. Samples were air-dried and analyzed for lungworm larvae with a modified Baerman technique (Samuel and Gray 1982). Larval output was measured as larvae per gram of dry feces (LPG). Between-ewe comparisons were made using feces collected when larval numbers peaked (March-April). When more than one sample was collected from the same ewe over this period, the average LPG was used for calculations, so that only one value was used for each individual. The LPG values used were averages of two or more samples in 68% of the cases. Comparisons were made using the Mann-Whitney statistic U, unless otherwise specified. All results reported are relative to marked ewes only. These increased from 40 to 90% of the total ewe herd during this study. Ewes whose lambs survived to October 1st are referred to as successful ewes. Those whose lambs disappeared before this date are referred to as unsuccessful ewes.

RESULTS

Lamb production was high in all three years of the study (Table 1). Although survival to the fall appeared to be greater in 1981, the difference was not statistically significant ($x^2 = 3.49$, $0.1 > P > 0.05$ comparing 1981 to 1982 and 1983). In both 1982 and 1983, lambs disappeared throughout the summer. Neonatal mortality was low, accounting for only 5% of the lamb crop over the two years.

Table 1. Lamb production and survival of the Sheep River herd, 1981-83. All tagged ewes two years of age and older are included.

Year	Lamb:Ewe ratio Birth	(N)[a] October	% lamb survival to October (N)[b]
1981	0.95 (22)	0.86 (22)	90.5 (21)
1982	0.93 (41)	0.63 (41)	68.4 (38)
1983	0.86 (50)	0.62 (47)	72.5 (40)

a. Number of ewes in sample
b. Number of lambs in sample

Table 2 summarizes fecal L1 output for all ewes two years of age and older. Differences in LPG were significant only between 1981 and 1982. In 1983, however, the distribution of LPG values was different, so that variance was greater than in 1982 (F-test = 1.943. $P < 0.05$). In both 1982 and 1983, successful ewes had lower LPG values than unsuccessful ones (Table 3). When larval output of successful ewes was examined, no significant differences were found among the three years (Table 4).

Table 2. *Protostrongylus* spp. L1 output per gram of dry feces for ewes of the Sheep River herd in March-April of 1981-83. Output in years followed by different letters was significantly different (P 0.01, Mann-Whitney U test).

Year	$\bar{X}$	N	(Range)
1981a	417	14	(0-1085)
1982b	776	33	(7-1989)
1983ab	680	51	(6-2811)

Table 3. A comparison of *Protostrongylus* spp. L1 output per gram of dry feces (LPG) in March-April of ewes whose lambs did and did not survive to October 1st in 1982 and 1983.

	Lamb alive			Lamb dead			
Year	$\bar{X}$	N	(Range)	$\bar{X}$	N	(Range)	p [a]
1982	642	19	(7 - 1718)	967	10	(139 - 1989)	0.025
1983	455	29	(6 - 1542)	1130	10	(160 - 2610)	<0.01

a. Mann-Whitney U test.

Table 4. Summary of statistical comparison of L1 output in March-April of all ewes in 1981, successful and unsuccessful ewes in 1982 and 1983, using the Mann-Whitney U test. (s = successful; us = unsuccessful).

	1981	1982s	1982us	1983s
1982s	>0.05			
1982us	<0.01	<0.025		
1983s	>0.5	>0.1	<0.01	
1983us	<0.01	<0.025	>0.1	<0.01

Lamb behavior was not quantified, but some obvious differences were evident between years. In 1981, lambs behaved 'normally': play was common, lambs appeared healthy and no coughing was observed. In 1982, no play was observed, lambs often displayed lethargic behavior with a tendency for laying down, and many had scruffy, rough hair coats from July onward. Several instances of coughing were observed beginning in mid-July. Coughing was similar to that described in sheep in areas affected by all-age die-offs (Feuerstein et al. 1980; Wishart et al. 1980: Personal observations), and lamb die-offs (Woodard et al. 1974). Lambs sometimes stood for 2-5 minutes with their mouth open, apparently experiencing difficulties in breathing, a symptom noticed also by Woodard et al. (1974). Coughing bouts among lambs were observed up to late October. Since lambs were identifiable only through their association with tagged ewes, it was not possible to know their identity when they were not close to their mothers. As a result, it was not known whether or not those that exhibited coughing and other symptoms most often were the ones that disappeared. In 1983, some play was observed and coughing was very rare. As in 1981, the subjective impression was that lambs appeared 'normal'.

Three pregnant ewes with high L1 output were collected in 1983. The fetal lungs, liver and several placental cotyledons were dissected and analyzed for lungworm larvae. A few larvae were found (Table 5). Numbers were much lower than those found by Hibler et al. (1974) and Spraker in transplacentally infected fetuses and young lambs. Twelve fecal samples were collected from lambs between late June and August in 1981 and 1982. Some Protostrongylus sp. L1's were found in all (mean = 187 LPG, range 2-881), with no difference between years.

Table 5. First-stage (L1) and third-stage (L3) Protostrongylus spp. larvae recovered from bighorn sheep fetuses collected in 1983.

Date	Ewe LPG	Lungs L1	Liver L1	Liver L3	Cotyledons L1 [b]	Cotyledons (N) [a]
03/31	1641	n/a	0	4	0.0	(10)
04/08	2075	1	2	0	1.2	(9)
04/10	2992	0	0	1	0.0	(10)

a. No. of cotyledons examined.
b. Larvae/cotyledon

DISCUSSION

Spraker and Hibler (1982) discussed three types of pneumonia die-offs of bighorn sheep: all-age, transplacentally induced, and summer lamb mortality following all-age die-offs. The pattern of lamb behavior and mortality observed at Sheep River in 1982 and 1983 is reminiscent of transplacentally induced lamb die-offs. However, there were some differences between this mortality and the lamb die-offs reported in the literature. First, very few larvae were recovered from the three fetuses collected. Second, mortality at Sheep River was not as severe as that documented in other lamb die-offs (Hibler et al. 1974; Woodard et al. 1974). It is possible that rather than a strictly parasitological phenomenon, the summer lamb mortality at Sheep River may have been the result of a combination of heavy lungworm infection and poor condition of the ewe. The total size of the herd increased from 60-70 sheep in the mid 1950's (Wishart 1958) to about 110 in the early 1970's (Horejsi 1976), to over 140 at present. High population density may result in stress, either social or nutritional. Heavy parasite loads may be both a consequence and a contributing cause of stress. Stelfox (1976) found a correlation between range overutilization, low lamb survival and lungworm larval output. If the entire herd was under stress, however, one may expect conception rates to drop, but this did not happen. Lambing rates remained high in the three years of this study, and summer lamb mortality never accounted for more than 32% of the lamb crop. This suggests that, perhaps, rather than an overall stress situation affecting the entire herd, the cause of high lungworm larval output and lamb mortality should be sought within the behavior of individual ewes.

The larval output of successful ewes in 1983 was very similar to that of ewes in 1981 (Tables 2 and 3), a year of negligible summer lamb mortality. The larval output of unsuccessful ewes in 1983, however, was much higher than that of ewes in 1981. Similarly, although output in 1982 was significantly higher than in 1981, this significance disappears if only successful ewes are compared (Table 4). The basic questions to be addressed, therefore, is not what caused an increase in L1 output of the Sheep River herd, but what did some ewes do (or not do) that caused them to experience high L1 output. Major differences in individual behavior have been documented in the course of this study, particularly in the amount of use of the winter and summer ranges from July to mid-October. During this period, forage in the alpine summer range is of higher quality than that available on the winter range (Johnston et al. 1968; Hebert 1973), thus ewes that spend more time on the summer range may be in better body condition than those that remain on the winter range. Wishart et al. (1980) also postulated that summer use of the winter range may lead to heavy lungworm infection, because of a presumably greater availability of infected snails (Boag and Wishart 1982). It is therefore reasonable to suspect that area-use behavior may affect a ewe's larval output and be important to its reproductive success.

At this point, it is important to know what exactly determines how many larvae a ewe will expel with its feces. Forrester and Senger (1964) did not find a correlation between larval output and the area of lungworm lesions in the lungs of mature rams. Uhazy et al. (1973) believed that L1 output was related to the number of adult lungworms in a sheep's lungs. Conclusive data on this relationship, however, are yet to be gathered. An alternative hypothesis (D. Onderka, personal communication), that output is at least partly related to the reproductive performance of adult worms, has not been falsified. If this hypothesis was true, the same number of worms in different sheep may result in widely different numbers of L1's in the feces. It could be speculated that a healthy, vigorous ewe may be able to mount a better immune response and decrease the reproductive performance of its lungworms, while a ewe with inadequate body reserves may not be able to do likewise. The latter ewe may then have higher L1 counts. Because of its poor condition, and perhaps also because of transplacental infection, this same ewe may not be able to raise a healthy lamb that will survive to the winter. An inadequate milk supply may also force the lamb to feed more intensively on vegetation (Horejsi 1976). This behavior should increase the likelihood of being infected by lungworms. Transplacental transmission <u>per se</u>, at the low levels detected in lungworms fetuses from Sheep River, may <u>not</u> be sufficient to cause a lamb's death without the complicating factor of a stressed (nutritionally or otherwise) mother. Therefore, even if low levels of transplacental infection occurred for all lambs, only those born to less vigorous ewes will be likely to die.

If, on the other hand, L1 counts were directly correlated with the intensity of lungworm infection, two possible explanations for the lamb deaths could be proposed. Lungworm infection in itself could be a cause of stress, impairing the ewe's ability to successfully raise a lamb. Alternatively, heavy lungworm infection in the ewe may increase the likelihood and intensity of transplacental infection of the fetus. The very few larvae recovered from fetuses of ewes with high L1 output, however, do not support this hypothesis.

LITERATURE CITED

Boag, D. A., and W. D. Wishart. 1982. Distribution and abundance of terrestrial gastropods on a winter range of bighorn sheep in southwestern Alberta. Can. J. Zool. 60:2633-2640.

Festa-Bianchet, M., and J. T. Jorgenson. 1985. Use of xylazine and ketamine to immobilize bighorn sheep in Alberta. J. Wildl. Manage. 49: in press.

Feuertein, V., R. L. Schmidt. C. P. Hibler, and W. H. Rutherford. 1980. Bighorn sheep mortality in the Taylor River - Almont Triangle area, 1978-79: a case study. Colo. Div. Wildl. Spec. Rep. No. 48.

Forrester, D. J., and C. M. Senger. 1964. A survey of lungworm infection in bighorn sheep in Montana. J. Wildl. Manage. 28: 481-491.

Gates, C. C., and W. M. Samuel. 1977. Prenatal infection of the Rocky Mountain bighorn sheep (Ovis. c. canadensis) of Alberta with the lungworm Protostrongylus spp. J. Wildl. Dis. 13: 248-250.

Hebert, D. M. 1973. Altitudinal migration as a factor in the nutrition of bighorn sheep. Ph.D. thesis, U. of British Columbia, Vancouver.

Hibler, C. P., R. E. Lange, and C. J. Metzger. 1972. Transplacental transmission of Protostrongylus spp. in in bighorn sheep. J. Wildl. Dis. 8: 389.

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

Horejsi, B. L. 1976. Suckling and feeding behavior in relation to lamb survival in bighorn sheep (Ovis canadensis canadensis Shaw). Ph.D. thesis, U. of Calgary, Calgary.

Johnston, A., L. M. Bezeau, and S. Smoliak. 1968. Chemical composition and in vitro digestibility of alpine tundra plants. J. Wildl. Manage. 32: 773-777.

Samuel, W. M., and J. B. Gray. 1982. Evaluation of the Baerman technique for recovery of lungworm (Nematoda: Protostrongylidae) larvae from wild ruminants. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 3: 25-33.

Spraker, T. R. 1979. The pathogenesis of pulmonary protostrongylosis in bighorn lambs. Ph.D. thesis, Colorado State U., Fort Collins.

Spraker, T. R., and C. P. Hibler. 1982. An overview of the clinical signs, gross and histological lesions of the pneumonia complex of bighorn sheep. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 3: 163-172.

Stelfox, J. C. 1976. Range ecology of Rocky Mountain sheep in Canadian National Prks. Can. Wildl. Serv. Rep. Series No. 39.

Uhazy, L. S., J. C. Holmes and J. G. Stelfox. 1973. Lungworms in the Rocky Mountain bighorn sheep of western Canada. Can. J. Zool. 5: 817-824.

Wishart, W. D. 1958. The bighorn sheep of the Sheep River Valley. M.Sc. thesis, U. of Alberta, Edmonton.

Wishart, W. D., J. T. Jorgenson, and M. Hilton. 1980. A minor die-off of bighorns from pneumonia in southern Alberta (1978). Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 2: 229-245.

Woodard, T. N., R. J. Gutierrez, and W. H. Rutherford. 1974. Bighorn lamb production, survival, and mortality in south-central Colorado. J. Wildl. Manage. 38: 771-774.