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INFLUENCE OF RAINFALL ON LUNGWORM INFECTIONS IN BIGHORN SHEEP*

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Abstract: From 1959 through 1968, lungs from 124 Rocky Mountain bighorn sheep (*Ovis c. canadensis*) from the Sun River herd in western Montana were examined for lungworm infections. All lungs were infected with *Protostrongylus stilesi* and 104 (84%) contained concurrent infections of *P. stilesi* and *P. rushi*. Significant correlations were observed between levels of lungworm infection and total rainfall during April, May, and June of each year. An explanation of this in terms of terrestrial snail (intermediate host) populations and a suggestion for the possible use of these data in developing a predictive model for forecasting lungworm levels for use in bighorn sheep management are given.

INTRODUCTION

Lungworms of the genus *Protostrongylus* are associated with the bighorn sheep pneumonia complex, a disease which may have contributed to the general decline in numbers of bighorn sheep since the nineteenth century.[1] In 1964, Forrester and Senger[2] presented data on lungs from 143 Rocky Mountain bighorn sheep (*Ovis c. canadensis*) from 10 herds in western Montana from 1958 through 1963. In that study, the year to year changes in infection levels were attributed to variations in rainfall during the preceding year. The present report presents the results of a ten-year study from 1959 to 1968 of the variations in intensity of lungworm infections in one herd of bighorn sheep in western Montana and the correlation between these infection levels and rainfall.

MATERIALS AND METHODS

From October to December of each year (1959, 1961-1963, and 1965-1968), lungs were obtained from hunter-killed bighorn sheep from the Sun River herd in Teton and Lewis and Clark Counties in western Montana. All were from rams over three years of age. Lungs were frozen until examined. Quantitative analyses of each lung for infections by *Protostrongylus stilesi* and *P. rushi* followed techniques described previously.[2] Some information on 44 of the lungs was discussed elsewhere.[2]

Climatological data were obtained from published records[10] for the Gibson Dam Station, located within the range of the Sun River herd. Using the Statistical Analysis System library of computer programs designed and implemented by A. J. Barr and J. H. Goodnight,[9] correlation coefficients, regression equations, and associated tests of significance were computed.

RESULTS AND DISCUSSION

All of the 124 lungs collected over the ten-year period were infected with *P. stilesi* and 104 (84%) contained concurrent infections of *P. stilesi* and *P. rushi.*

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No lungs contained only *P. rushi.* Details of these infections are presented in Fig. 1 and Table 1.

Correlation coefficients for levels of infection of *P. stilesi* and *P. rushi* with total rainfall during the period of April, May, and June were high (0.91, significant at $\alpha = .01$, and 0.71, significant at $\alpha = .05$, respectively). Regression lines showed high infection levels in years of high rainfall during April, May, and June. With the exception of the year 1965, the year following a significant flood, the fit was especially good for the *P. stilesi* data. Due to the absence of rainfall data in the range nine to 14 inches, it did not seem desirable to fit curvilinear regressions.

Correlations were computed for infection levels with individual monthly rainfall data from January through August, but none approached statistical significance except those for April, May, and June. None of the correlations of *P. stilesi* infection levels with rainfall data for each of the three months separately were as large as the correlation with total rainfall during the three-month period. The same was true for *P. rushi* correlations except for the month of May, where the correlation (0.78) was essentially the same as for total rainfall in the three-month period.

Multiple linear regressions of infection levels on April, May, and June rainfall data showed essentially equal

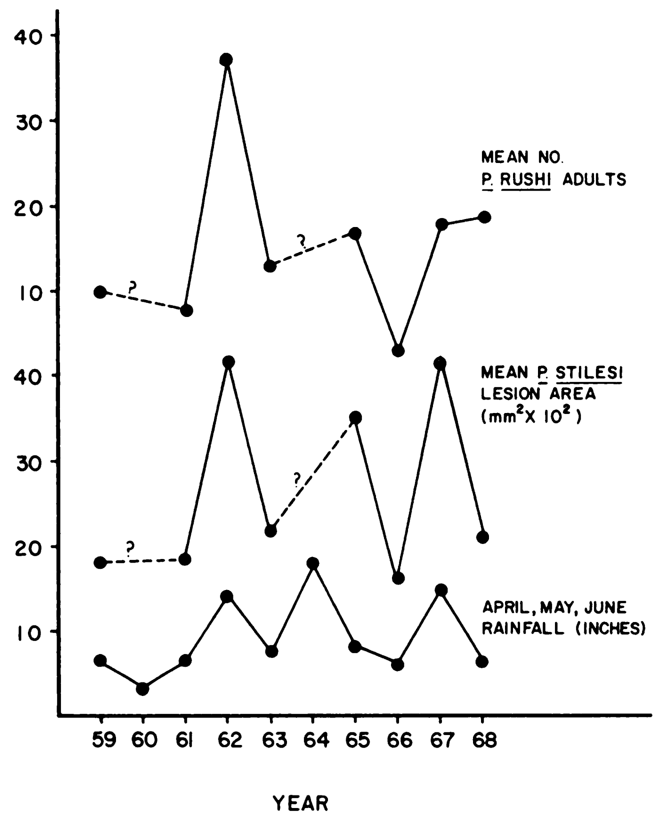

FIGURE 1. Comparison of mean total **P. stilesi** lesion areas, numbers of **P. rushi** adults and total rainfall during April, May, and June.

TABLE 1. Lungworm infections in lungs of bighorn rams from the Sun River herd (Montana) during 1959-1968.

Year	No. lungs examined	No. *P. rushi* adults		*P. stilesi* lesion area (mm^2)	
		Mean	(range)	Mean	(range)
1959	21	10	(0-89)	1,812	(57-4,247)
1960	0	—		—	
1961	16	8	(0-28)	1,868	(405-4,751)
1962	9	37	(0-162)	4,174	(1,406-7,681)
1963	17	13	(0-65)	2,202	(301-7,355)
1964	0	—		—	
1965	19	17	(0-77)	3,527	(1,054-8,700)
1966	6	3	(0-10)	1,630	(293-4,022)
1967	23	18	(0-65)	4,178	(1,740-8,037)
1968	13	19	(0-53)	2,124	(204-4,483)
All Years	124	16	(0-162)	2,689	(57-8,700)

contributions for the three months on *P. stilesi* infection levels. A greater contribution was found for May than for April or June on *P. rushi* infection levels, but this was regarded as a data artifact because of probable sources of error in obtaining the *P. rushi* data and the lack of biological interpretation of the finding.

The observed direct correlation between lungworm infection levels and rainfall during April, May, and June is probably related to activities and infection of intermediate host snail populations. Monson and Post[4] reported experimental transmission of *P. stilesi* to bighorn-mouflon sheep hybrids via the land snail *Vallonia pulchella*. Although this snail occurs on some bighorn areas of Colorado,[6] it is not widespread and has not been reported from other bighorn areas in the western states.[1] However, another closely related species (*Vallonia cyclophorella*) is common and has been found, along with several other species of land snails in the families Pupillidae and Valloniidae, to be infected naturally with protostrongylid lungworm larvae and/or to support development of such larvae under laboratory conditions.[1]

Pillmore[7,8] noticed changes from year to year in the infection of *V. pulchella* in Glen Eyrie, Colorado, and correlated increases in levels of infection with above-normal rainfall during April and May. A similar effect was suggested by Forrester and Senger[2] from observations made on infection levels in 143 lungs collected from 10 bighorn sheep herds in Montana during 1958 to 1963. The present observations support those earlier reports.

Migration of protostrongylid larvae from fecal material has been found to be maximal during periods of high humidity.[3] Forrester and Senger[2] pointed out that in Montana the spring months (April, May, and June) usually have considerable amounts of rainfall and moderate temperatures which provide ideal conditions for migration of larvae from bighorn fecal material, terrestrial snail activity with subsequent exposure of the snails to the larvae, and eventual infection of bighorn sheep via ingestion of infected snails. They also showed that during these same three months higher numbers of first stage lungworm larvae were found in bighorn feces than at other times of the year.

The findings reported herein may prove valuable in developing a predictive model for forecasting lungworm levels in bighorn sheep for management purposes similar to the method developed by Ollerenshaw[5] for forecasting the incidence of fascioliasis in domestic sheep. For example, it may be desirable to increase harvest levels of bighorn sheep in years of abnormally high amounts of rainfall during April, May, and June to insure the safe overwintering of a smaller but healthier herd of bighorn sheep rather than risk the chance of increased winterkills due to high lungworm infections and their contribution to the bighorn sheep pneumonia complex. Other interacting factors or combinations of factors in addition to rainfall (e.g. temperature, relative humidity, etc.) may prove useful in refining such a predictive model, increasing its value for management of bighorn sheep.

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