



Distribution and seasonal prevalence of the bovine lungworm (*Dictyocaulus viviparus*) in selected areas in western Montana  
by John Brandon Winters

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Zoology  
Montana State University  
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Abstract:

A survey was conducted to determine the distribution and seasonal prevalence of bovine lungworm infections in beef herds of three western Montana counties. The purebred beef herd at the Montana Agricultural Experiment Station served as a pilot herd to indicate the seasonal dynamics of lungworm infections in herds in the area studied.

Infected cattle were detected on 27 of 35 ranches (77.1%) in Gallatin, Park and Ravalli counties. Of 16 ranches sampled in Gallatin Co., 12 (75%) yielded infected animals, whereas lungworm infections occurred on four of seven (57.1%) ranches in Park Co. and 11 of 12 (91.7%) ranches in Ravalli Co.

Based on 2,125 Baermann examinations of fecal samples collected from October, 1967 to August, 1969, 7.8% of all cattle were infected with *D. viviparus*. Incidences of 7.5%, 4.3% and 7.9% were obtained from all age groups in Gallatin, Park and Ravalli counties, respectively. Infection rates according to age showed that 6.6% of calves (less than 12 months old), 11.5% of yearlings (1 to 2 years) and 3.3% of cows (more than 2 years) harbored lungworms.

The mean number of larvae per gram of feces (l.p.g.) for all infected cattle was 0.37. Mean counts according to age for all infected animals were 0.39 l.p.g. in calves, 0.36 l.p.g. in yearlings and 0.42 l.p.g. in cows.

A seasonal occurrence of lungworm infections in calves was demonstrated in the three counties and in the pilot herd. With the exception of Ravalli Co. where inadequate late summer and early autumn sampling data were obtained, a "lungworm season" in calves extending from August to November was established. In yearlings in Ravalli Co., peaks of infection generally occurred in early summer, whereas in Gallatin and Park counties, many yearlings harbored lungworms into midautumn.

Recovery of *D. viviparus* larvae from pasture which was grazed by infected calves the previous fall apparently constituted the first documented record of overwinter survival of lungworm larvae in North America.

The significance of yearlings as carrier animals of bovine lungworms was demonstrated. The highest prevalence (11.5%) was found in this age group.

DISTRIBUTION AND SEASONAL PREVALENCE OF THE BOVINE LUNGWORM  
(DICTYOCAULUS VIVIPARUS) IN SELECTED AREAS IN WESTERN MONTANA

by

JOHN BRANDON WINTERS

A thesis submitted to the Graduate Faculty in partial  
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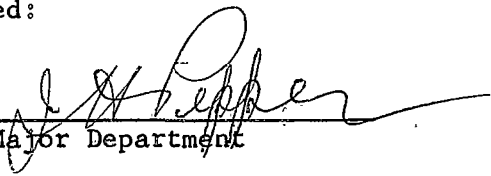
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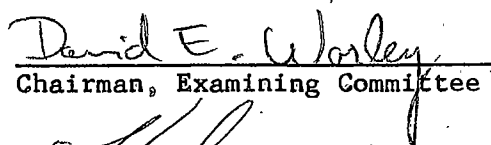
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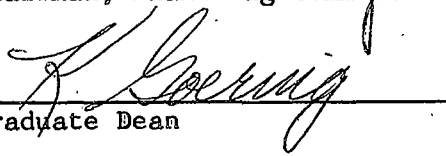
in

Zoology

Approved:

  
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MONTANA STATE UNIVERSITY  
Bozeman, Montana

December, 1969

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## ABSTRACT

A survey was conducted to determine the distribution and seasonal prevalence of bovine lungworm infections in beef herds of three western Montana counties. The purebred beef herd at the Montana Agricultural Experiment Station served as a pilot herd to indicate the seasonal dynamics of lungworm infections in herds in the area studied.

Infected cattle were detected on 27 of 35 ranches (77.1%) in Gallatin, Park and Ravalli counties. Of 16 ranches sampled in Gallatin Co., 12 (75%) yielded infected animals, whereas lungworm infections occurred on four of seven (57.1%) ranches in Park Co. and 11 of 12 (91.7%) ranches in Ravalli Co.

Based on 2,125 Baermann examinations of fecal samples collected from October, 1967 to August, 1969, 7.8% of all cattle were infected with D. viviparus. Incidences of 7.5%, 4.3% and 7.9% were obtained from all age groups in Gallatin, Park and Ravalli counties, respectively. Infection rates according to age showed that 6.6% of calves (less than 12 months old), 11.5% of yearlings (1 to 2 years) and 3.3% of cows (more than 2 years) harbored lungworms.

The mean number of larvae per gram of feces (l.p.g.) for all infected cattle was 0.37. Mean counts according to age for all infected animals were 0.39 l.p.g. in calves, 0.36 l.p.g. in yearlings and 0.42 l.p.g. in cows.

A seasonal occurrence of lungworm infections in calves was demonstrated in the three counties and in the pilot herd. With the exception of Ravalli Co. where inadequate late summer and early autumn sampling data were obtained, a "lungworm season" in calves extending from August to November was established. In yearlings in Ravalli Co., peaks of infection generally occurred in early summer, whereas in Gallatin and Park counties, many yearlings harbored lungworms into midautumn.

Recovery of D. viviparus larvae from pasture which was grazed by infected calves the previous fall apparently constituted the first documented record of overwinter survival of lungworm larvae in North America.

The significance of yearlings as carrier animals of bovine lungworms was demonstrated. The highest prevalence (11.5%) was found in this age group.

## INTRODUCTION

The bovine lungworm, Dictyocaulus viviparus (Bloch, 1782) (Nematoda; Trichostrongyloidea), is responsible for the disease known as verminous or parasitic bronchitis in cattle. It has a cosmopolitan distribution in cattle, and also has been reported in elk, moose, white-tailed and Columbian black-tailed deer (Enigk and Hildebrandt, 1964).

D. viviparus is considered to be one of the most injurious helminth parasites of cattle (Schwartz, 1942). Parasitic bronchitis is of great economic significance in many parts of the world. Failure to gain weight normally is a frequent sequela of this disease. Another important consequence is a decline in milk production in infected animals (Petrelius, 1951; Campbell and Wetherill, 1957). Mortality, especially in foreign countries, has been attributed to lungworm infections. The majority of severe outbreaks of dictyocaulosis have been confined to the British Isles where climatic and pasture conditions favor development and transmission of lungworm larvae. Jarrett et al. (1954) confirmed the disease-producing capabilities of D. viviparus and stated that during certain months parasitic bronchitis is the most important killing disease of British cattle. Epizootics of parasitic bronchitis have been reported in North America by Witter and Rountree (1953), Rountree et al. (1954) and Campbell and Wetherill (1957). Smith (1967) stated that D. viviparus was a significant factor in the death of 300 to 400-pound calves in Texas. In Russia, Penkov (1945)

encountered 50% mortality in cattle on farms in his district, whereas Dmitriev (1964) reported 213 deaths from another section. Lungworms were responsible for heavy mortality in Indian cattle (Malaki, 1961). An epizootic in Brazil resulted in 14% mortality in a herd of 1,200 animals (Rocha et al., 1967). Wertejuk (1965) noted that in 1963 in Poland 1,171 cattle died from severe D. viviparus infections.

Since this species of Dictyocaulus occurs throughout the world, numerous references on distribution exist in the literature. The bovine lungworm, which is enzootic to most areas of the United Kingdom, has also been observed in parts of South America, Scandinavia, Turkey, Japan, Fiji, New Zealand, the majority of European countries and many other regions of the world.

There have been no specific surveys on the distribution and incidence of D. viviparus in North America. In fact, the bovine lungworm has been virtually ignored in several statewide or regional surveys for helminths of cattle. Becklund (1961) examined viscera from 20 Florida calves for gastrointestinal parasites but apparently did not check the lungs. Surveys conducted by Bell (1957) in North Carolina and by Porter (1942a) in southeastern United States included only gastrointestinal nematodes. In studies of bovine parasitism conducted in Wisconsin (Cox and Todd, 1962) and in Illinois (Szanto et al., 1964), fecal samples collected from selected farms were not examined for lungworms.

According to Swanson et al. (1959) and Becklund (1964), D. viviparus is found in most regions of North America and in Hawaii. Choquette (1954) stated that parasitic bronchitis is widely distributed in Canada. Severe lungworm infections were reported by Campbell and Wetherill (1957) in cattle in Ontario. Graesser (1957) reported that D. viviparus in Alberta cattle has increased markedly in the past 5 years. Lafortune (1954) observed a mild outbreak of verminous bronchitis in a dairy herd in Quebec. At necropsy, one of 60 calves was found infected with lungworms in Hawaii (Alicata, 1960). On the mainland of the United States, numerous records of lungworm infections in cattle exist in the literature. Bailey (1955) stated that bovine lungworms are quite prevalent in southeastern United States where the climate is conducive to larval development on pasture (Rubin, 1956). Schwartz (1942) noted that lungworms were deleterious to southern cattle.

In Florida, D. viviparus has been commonly observed (Porter et al., 1941; Swanson et al., 1956). Swanson et al. (1959) concluded that parasitic bronchitis was an acute problem in Florida. Bovine lungworms have been frequently encountered in Georgia (Cooperrider, 1952; Andrews et al., 1953; Becklund, 1962). Studies by Porter (1942b), Ward (1946) and Smith (1967) revealed the presence of D. viviparus in cattle in Alabama, Mississippi and Texas, respectively. Reports from Maine have listed lungworm infections in cattle (Witter and Rountree, 1953; Rountree et al., 1954).

Verminous bronchitis is indigenous to several areas in Wyoming (Honest and Tucker, 1962). According to Lytle (1931), dictyocaulosis was quite common in calves in Oregon and the Pacific Northwest; he also indicated that the disease was increasing in these areas. Rubin (1956) considered the Pacific Coast states and the southeast to be the two prominent sites where lungworm disease occurs in the United States.

The southwest is believed to be relatively free of lungworm infections. Becklund and Allen (1958) examined 80 bovine fecal samples and 10 sets of lungs from New Mexico and Arizona cattle, but detected no lungworm larvae. Dewhirst et al. (1958) found no D. viviparus in cattle in Arizona.

The earliest documented infection of D. viviparus in Montana cattle occurred in 1931 and was listed in the 1930-1932 annual report of the Montana State Veterinary Surgeon. This case involved two calves from the northwestern part of the state. Included in Livestock Sanitary Board records from 1942-1964 were two case reports of dictyocaulosis in cattle in western Montana in 1949 and 1953 and several reports of cattle lungworm infections in southeastern Montana in 1962. Since 1962, Veterinary Research Laboratory (VRL) records contain numerous reports of occurrences of lungworms in southwestern Montana. These data were obtained from Baermann examinations of fecal samples and from necropsies of animals submitted to the VRL. A survey of endoparasitism in Montana cattle by Jacobson and Worley (1969) revealed the presence of D. viviparus in all areas of the state except the north central section.

The cyclical occurrence of dictyocaulosis in cattle is well established. Patent infections, particularly in calves, occur during certain months or seasons. The seasonal incidence in a herd varies geographically, i.e., it is contingent upon climatic and environmental conditions. Many British researchers have investigated this phenomenon thoroughly. Among them were Jarrett et al. (1954) who described epizootics in August and September resulting from light initial infections contracted by calves in the spring. Workers in Russia (Krastin, 1944; Orlov, 1946; Boev and Ivershina, 1954; Gadzhiev, 1954), Germany (Frick, 1964), Poland (Świetlikowski, 1959; 1965; Wertejuk, 1963), Czechoslovakia (Hovorka and Podhájecký, 1965), Sweden (Petrelius, 1951), Denmark (Henriksen, 1967) and Canada (Choquette, 1954) have also studied the seasonal dynamics of parasitic bronchitis in bovine herds. The only North American investigation on the cyclical incidence of verminous bronchitis in cattle was Choquette's 1954 study in Quebec.

Overwinter survival of D. viviparus larvae on pasture has been the source of considerable controversy for many years. Conflicting accounts from many parts of the world have been published on this aspect of lungworm bionomics. Even in Great Britain, where climatic extremes do not approach those found in western North America, varying views have been expressed concerning the longevity of bovine lungworm larvae on pasture.

As early as 1920, Daubney stated that the preparasitic stages of D. viviparus could easily withstand the winters in the British Isles. Many British researchers have published data in concurrence with

Daubney's statement (Taylor, 1951; Jarrett et al., 1954; 1955; 1957; Bell, 1955; Cunningham et al., 1956; Rose, 1956; Allan and Baxter, 1957). Conversely, in other studies carried out in the United Kingdom, Soliman (1952), Stableforth (1953), Michel and Rose (1954), and Michel and Shand (1955) disputed Daubney's assertion.

Świetlikowski (1956; 1959; 1965) confirmed that lungworm larvae were able to survive Polish winters. Elsewhere in Europe, Enigk and Düwel (1962) and Gräfner et al. (1965) observed that D. viviparus larvae were capable of tolerating winters in northcentral Germany, whereas Wetzel (1948; 1952) found no evidence of larval survival throughout the winters in eastern Germany. Similarly in the Soviet Union, two workers (Orlov, 1946; Morozov, 1958) claimed that larval persistence over the winter was not possible, while Danilin (1959) attributed lungworm infections in the spring to larvae which had remained alive during the previous winter. In Belgium, Vercruyse (1952) stated that infective larvae of D. viviparus were unable to overwinter on pasture. Although no conclusive information is available on the overwintering of lungworm larvae in Canada, Choquette (1954) maintained that if larvae were unable to withstand winter conditions in western Europe, they could hardly survive the more stringent Canadian winters.

Overwinter survival of bovine lungworm larvae has not been verified in the United States. Porter (1942b) found that larvae were capable of remaining infective for 1 week, but not for 6 to 7 weeks, in Alabama. In Florida, larvae were shown to retain their infectivity less than 5

months (Porter et al., 1941). Honess and Tucker (1962) reported that D. viviparus could not tolerate the winter season in Wyoming. The latter claim was not based on an infectivity study, i.e., grazing susceptible calves in the spring on pastures vacated of parasitized animals since the previous fall.

Another facet of parasitic bronchitis which has been accorded worldwide attention is the significance of carrier animals in the propagation of the disease. A carrier is generally defined as an animal which harbors lungworms throughout the winter and ultimately serves as a source of infection to vulnerable calves the following spring. Adult lungworms, which persist in the lungs of cattle over the winter period, or inhibited fifth-stage larvae, which mature only when the resistance mechanism of the host is depressed, may perpetuate the disease from year to year. Taylor and Michel (1952) elucidated the phenomenon of retarded development in D. viviparus by observing fifth-stage worms in the lungs of adult cattle which had not been exposed to a source of infection for several weeks. The role of carriers in the epizootiology of lungworm infections has been investigated in the British Isles (Stableforth, 1953; Taylor and Michel, 1953; Jarrett et al., 1954; 1955; 1957; Michel, 1955; Michel and Shand, 1955; Rose, 1956). Other studies on the significance of carrier animals have been conducted in Russia (Krastin, 1944), Germany (Wetzel, 1948; Enigk and Düwel, 1962), Poland (Świetlikowski, 1965), Belgium (Pouplard, 1968) and Scotland

(Cunningham et al., 1956). Choquette (1954) suggested that carriers may be responsible for contaminating the pastures with infective larvae in Canada.

Owing to a paucity of data on lungworm infections in Montana cattle, the present study was initiated to determine the distribution and incidence of D. viviparus in cattle from three counties in western Montana. A second objective involved determining a seasonal lungworm cycle in bovine herds using the herd at the Montana Agricultural Experiment Station as an indicator. Another objective was to assess the importance of overwinter larval survival on pasture in propagating the infection.

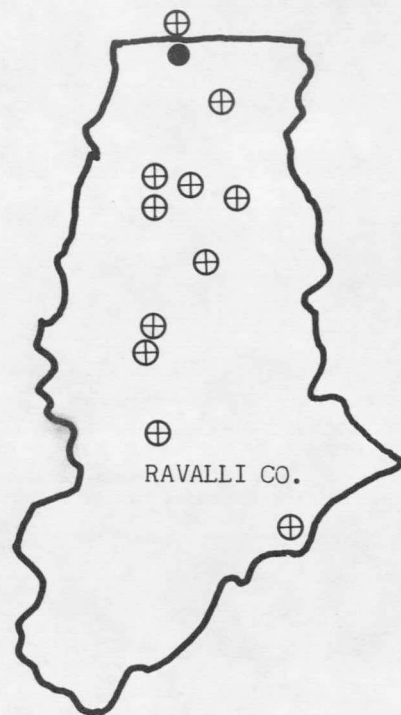
## MATERIALS AND METHODS

This survey was designed to determine the distribution and seasonal prevalence of D. viviparus in three western Montana counties where large numbers of cattle are produced. A map showing the geographic location of these counties is presented in Figure 1.

From October, 1967 to August, 1969, 2,125 fecal samples were collected from 35 ranches in Gallatin, Park and Ravalli counties and from the herd at the Montana Agricultural Experiment Station. The majority of samples were procured from cattle on pasture by picking up the freshly deposited feces from calves (less than 12 months of age), yearlings (1 to 2 years old) or adults (more than 2 years). In a few instances rectal sampling was employed. In cases where all animals were of a particular age or when calf and cow samples were distinguishable, fecal pats dropped within the last 24 hours were collected.

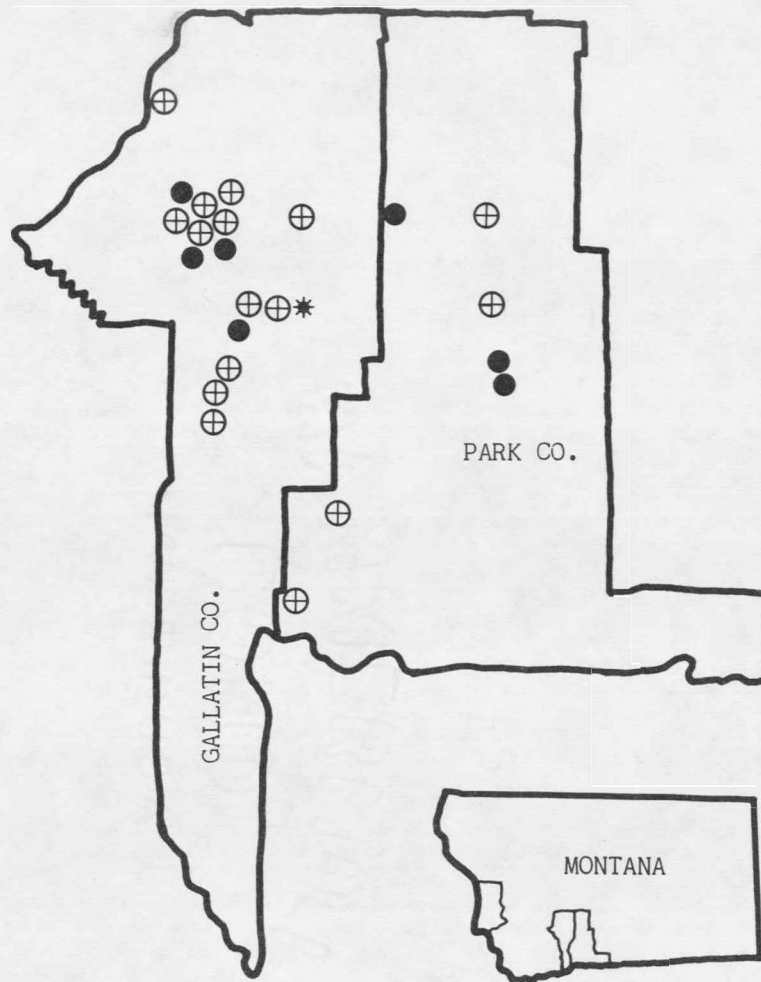
Initially, sampling was conducted during randomly selected months, but after the "lungworm season" was established, intensive collecting was confined to a 2 to 3-month period in the autumn. Sporadic sampling during other seasons was employed to confirm the seasonal incidence in calves and yearlings and to detect lungworm infections in adults.

Fecal samples from eight to 12 calves, yearlings and adult cattle normally were obtained from ranches in Gallatin and Park counties at each collection period. In Ravalli Co., the prevalence and seasonal



RAVALLI CO.

- ⊕ Designates ranch with infected cattle.
- Designates ranch with no infected cattle.
- \* Designates herd at the Montana Agricultural Experiment Station.



GALLATIN CO.

PARK CO.

MONTANA

Figure 1. Location of beef herds sampled in western Montana.

occurrence of bovine lungworms were studied on 12 ranches located throughout the county. Fecal samples were collected from approximately 15 animals on each ranch at 3-month intervals from weaning until the animals were about 18 months of age. They were obtained by personnel of the Western Montana Branch Station, packed in insulated shipping cartons and shipped via bus to the Veterinary Research Laboratory. All samples were assayed for D. viviparus larvae within 48 hours after collection.

Some ranchers in the three counties operated closed herds, whereas others purchased cattle periodically. The majority of the animals sampled were commercial grade Hereford or Angus cattle. Dairy cattle were not included in the survey.

The herd at the Montana Agricultural Experiment Station served as a pilot group of cattle in this investigation, i.e., results of periodic collections provided a general indication of the incidence and cyclical occurrence of lungworms in herds elsewhere in western Montana. This group of cattle was chosen because it was a native closed herd, and management and herd history were well established. Prior to the inception of the present study, lungworm incidence data collected in the autumn of 1966 were available for calves and cows. Subsequent samplings of calves and cows were conducted during the fall of 1967 and 1968. Calves were checked frequently during the summer months to determine when they initially acquired lungworm infections. To ascertain

the significance of adult cattle as carriers, sampling of cows was carried out from July, 1968 to August, 1969.

The standard Baermann apparatus (Baermann, 1917) was employed for detection of lungworm larvae in the feces. Approximately 75 g of feces were wrapped in a double layer of gauze and suspended in a 250-ml plastic funnel containing tepid water. An 80-mesh screen 6 cm in diameter was placed in the funnel 4 cm from the top to support the feces and to prevent large pieces of debris from filtering down. An 8-cm section of rubber tubing with a pinch clamp was attached at the base of the funnel. The samples remained set up for 18 to 24 hours to ensure that all larvae had migrated through the feces and settled to the bottom of the funnel. Approximately 20 ml of fluid were collected and examined with a dissecting microscope for first-stage D. viviparus larvae.

A larva per gram (l.p.g.) count was computed for each animal by dividing the total number of larvae observed by the weight of the feces. To facilitate interpretation of larval concentrations in feces, one of four degrees of fecal consistency (compact, moist, wet and very wet) was assigned to each sample.

Pasture sampling was employed to determine whether lungworm larvae were capable of overwintering. Collections were made in April and May, 1969 from a pasture that had been grazed by parasitized calves from the pilot herd the previous summer. Two to 12 oz of grass, litter, feces and soil were collected from 10 sites, eight of

which were confined to a small area adjacent to a water source. The other two samples were taken from the center of the pasture.

Three techniques were used for the detection of D. viviparus larvae on pasture: the methods of Baermann (1917), Michel and Parfitt (1955) and Donald (1967). The Baermann technique was employed most frequently since an accurate quantitative estimation of the level of pasture infestation was not considered essential. Samples were immersed in water in 2000-ml glass funnels equipped with a 40 or 60-mesh screen for 1 to 3 days. During this period repeated 20-ml portions were removed and examined for D. viviparus larvae. Larval identifications were confirmed using a compound microscope.

## RESULTS

Results of 2,125 Baermann examinations from October, 1967 to August, 1969 revealed that 7.8% of all cattle sampled during the study were infected with D. viviparus. Infection rates by age group showed 6.6%, 11.5% and 3.3% of calves, yearlings and cows, respectively, to be positive for lungworms (Table I). Of 35 ranches sampled in three western Montana counties, 77.1% contained infected cattle.

In Gallatin Co., lungworm larvae were detected in 7.5% of 560 fecal samples from all age groups (Fig. 2). Of 285 calves checked, 9.5% showed the presence of larvae. Incidence data from yearlings revealed that 13.2% of 91 were infected, whereas 1.6% of 184 cows were passing larvae. Data from a yearling operation 2 miles west of Bozeman (Gallatin Co.), where 32.7% of 264 animals sampled were infected, were excluded from Figure 2 because the yearlings had been purchased from various sites in Montana. The rate of infection in this group of yearlings also constituted the highest prevalence of lungworms encountered in a single herd in the present study; results of two midsummer samplings in 1968 showed that 70% and 64.3% of 10 and 28 animals were passing larvae. In August, 1969, 31.4% (60/191) of the entire yearling herd was found infected. Seventy-five percent (12/16) of the ranches sampled harbored infected cattle.

Lungworm larvae were found in the feces of 4.3% of 161 animals sampled in Park Co. Six and eight-tenths percent of 73 calves were positive. Of 50 yearling and 38 cow samples, 2% and 2.6% yielded

TABLE I. Percentage Incidence of Dictyocaulus viviparus in Three Age Groups of Cattle from Three Western Montana Counties.

Age Group	County				
	Gallatin	Park	Ravalli	Pilot Herd	All Animals
Calves	9.5 (27/285)	6.8 (5/73)	2.0 (10/494)	14.0 (26/186)	6.6 (68/1038)
Yearlings	13.2 (12/91)	2.0 (1/50)	13.0 (73/562)	1.9 (1/52)	11.5 (87/755)
Cows	1.6 (3/184)	2.6 (1/38)	*	6.4 (7/110)	3.3 (11/332)
All Animals	7.5 (42/560)	4.3 (7/161)	7.9 (83/1056)	9.8 (34/348)	7.8 (166/2125)

\*Indicates cows were not sampled.

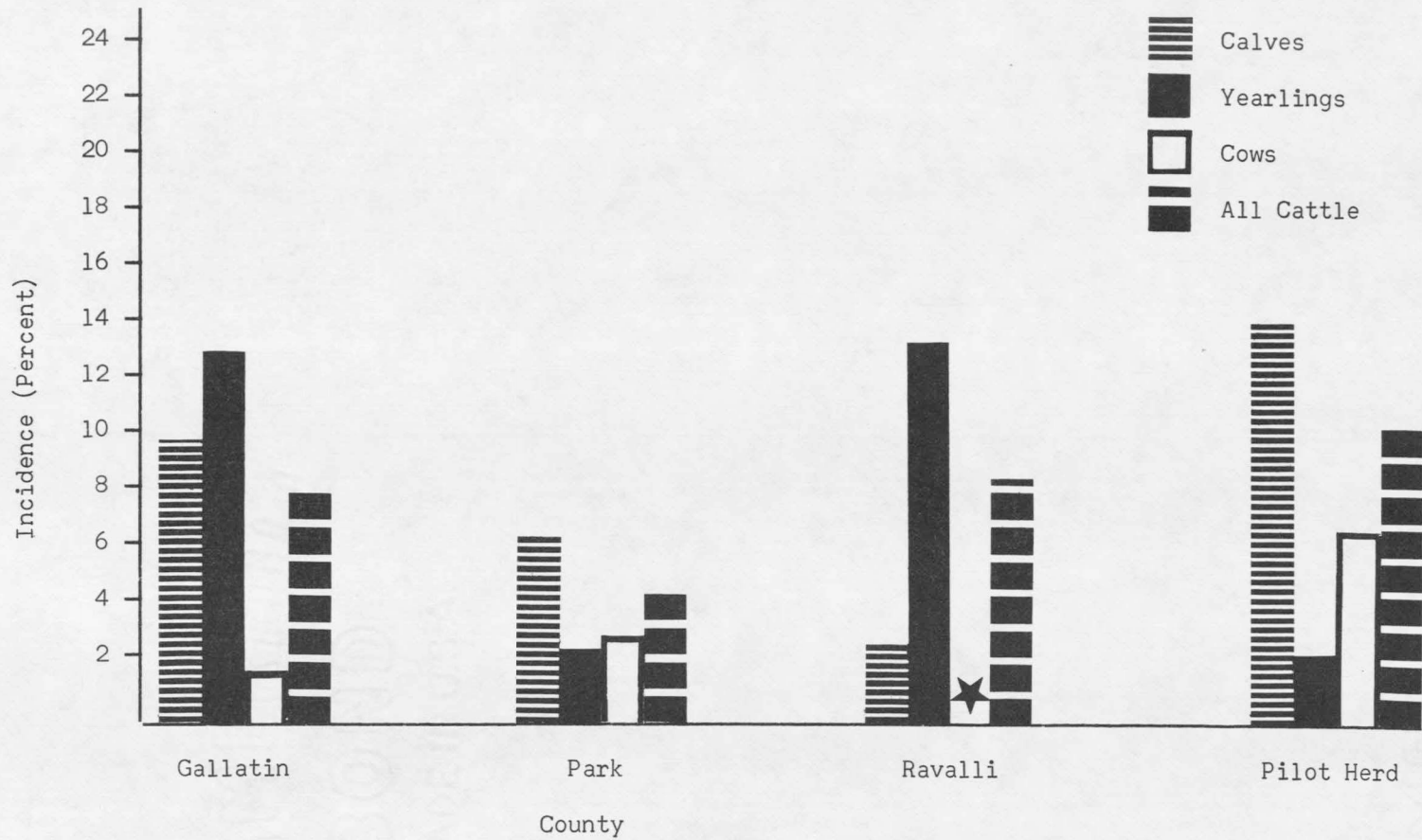


Figure 2. Incidence of D. viviparus in cattle from three counties in western Montana.

★ = cows not sampled

larvae respectively. Infected animals occurred on 57.1% (4/7) of the ranches sampled.

Seven and nine-tenths percent of 1,056 fecal samples examined in Ravalli Co. had D. viviparus. Two percent of 494 calves and 13% of 562 yearlings were infected. Infected cattle were detected on 11 of 12 (91.7%) ranches in Ravalli Co.

The overall rate of infection in the herd at the Montana Experiment Station was 9.8% (34/348). Fourteen percent of 186 calf fecal samples contained lungworm larvae, whereas 1.9% of 52 yearlings and 6.4% of 110 cows harbored lungworm infections.

The mean number of larvae recovered per gram of feces (l.p.g.) for all infected cattle encountered in this study was 0.37 (range 0.01 to 5.5). Table II lists the average and range of lungworm larval counts from each age group in the three counties and in the pilot herd. Calves from Gallatin Co. and the indicator herd exhibited similar average l.p.g. counts--0.39 and 0.44, while calves in Park and Ravalli counties voided averages of 0.79 l.p.g. and 0.06 l.p.g. Fecal samples obtained from yearlings in Gallatin Co. contained an average of 0.5 l.p.g. Counts from yearlings in Ravalli Co. averaged considerably lower, 0.17 l.p.g. Owing to the dearth of infected cows encountered in the survey, computation of a mean l.p.g. output in adults was limited to the pilot herd, where seven cows had larval counts ranging from 0.03 to 1.55 (avg. 0.48). Mean counts according to age for all cattle examined were 0.39 l.p.g. in calves, 0.36 l.p.g. in yearlings and 0.42 l.p.g. in cows, indicating

TABLE II. Lungworm Larval Counts<sup>+</sup> of Infected Cattle in Three Western Montana Counties.

Location	Age of Animals			All Cattle
	Calves	Yearlings	Cows	
Gallatin County	0.39 (0.01-2.07)	0.5 (0.01-5.5)	0.04 (0.01-0.10)	0.47
Park County	0.79 (0.03-1.74)	81.7**	1.07*	0.84
Ravalli County	0.06 (0.01-0.10)	0.17 (0.01-3.88)	---	0.16
Pilot Herd	0.44 (0.01-3.67)	0.04*	0.48 (0.03-1.55)	0.44
All Locations	0.39	0.36	0.42	0.37

<sup>+</sup>Expressed as mean number of larvae per gram of feces (l.p.g.), and range.

\*Indicates figure was based on one animal.

\*\*Indicates yearling was autopsied at ranch and larval output was not included in totals.

no appreciable difference in intensity of infections among the three age classes. More than 50% of the animals sampled from each age group were passing between 0.01 and 0.1 l.p.g. Larval counts in excess of 1.0 l.p.g. were observed infrequently. The highest larval output detected during the investigation was 5.5 l.p.g.

A pronounced seasonal trend in lungworm infections in calves was evident in the three counties and in the pilot herd. All infected calves in Gallatin and Park counties and in the indicator herd were detected from late summer to midautumn, whereas D. viviparus in calves in Ravalli Co. occurred from late November to late March. The cyclical occurrence of dictyocaulosis in calves from the indicator group of cattle is depicted in Figure 3. A prevalence of 14.5%, based on 55 calves sampled in late October, 1967 increased markedly to 50% (14/28) in mid-September, 1968.

A seasonal cycle occurred in yearlings only in Ravalli Co., where infections were acquired from late March to early August. In the other three localities, positive yearlings were observed sporadically throughout the year. Figure 4 outlines the percent of cattle infected at periodic collections in Ravalli Co., where one group of cattle was sampled at 3-month intervals from December, 1967 (9 months old) to October, 1968 (19 months of age). Another group was followed from January, 1969 (10 months old) to July, 1969 (16 months). In the first group, incidence of lungworms increased progressively until a peak (11%) was established in June. These animals spontaneously shed their infections by October.

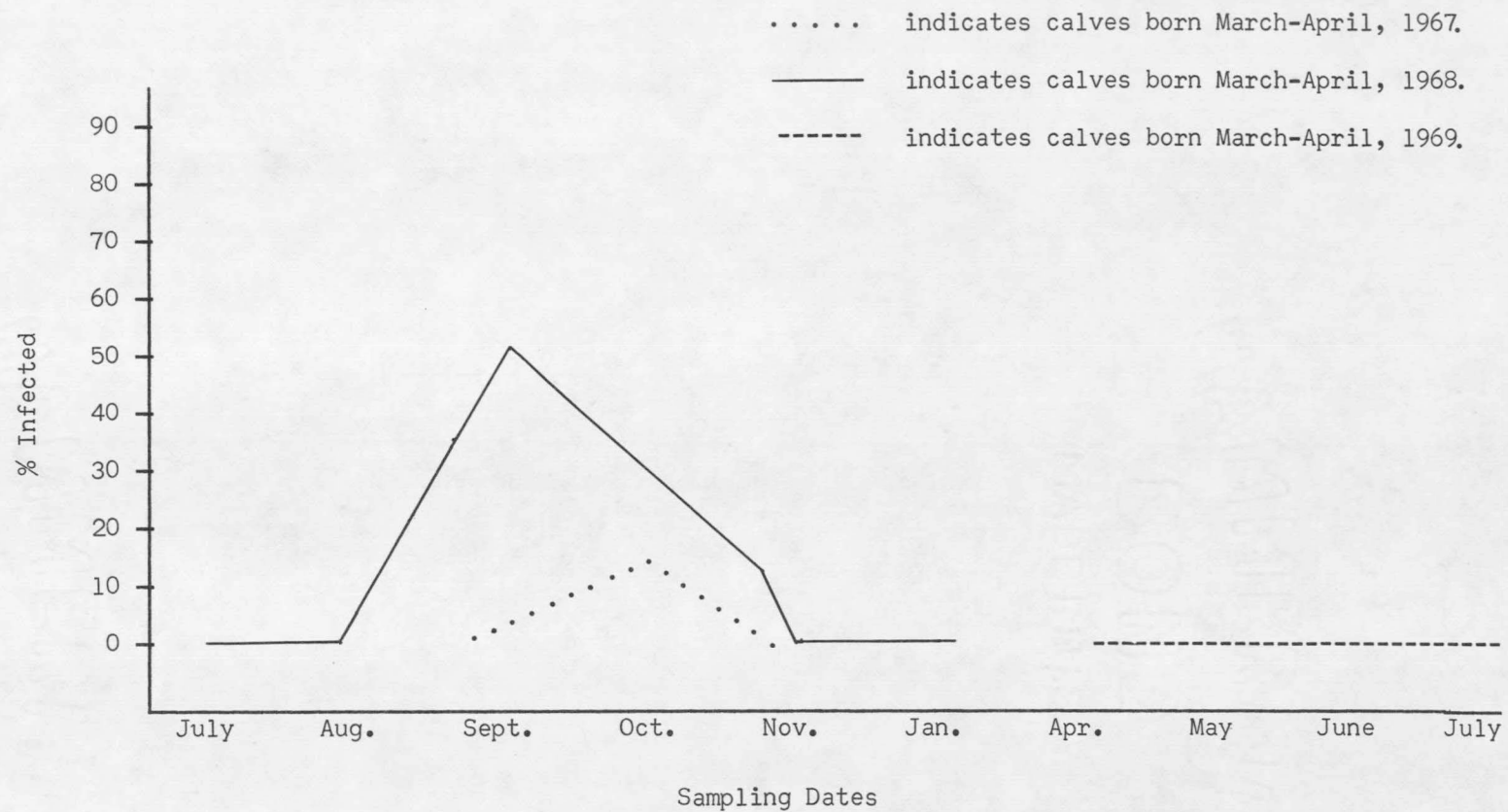


Figure 3. Seasonal occurrence of D. viviparus in calves in the Montana Agricultural Experiment Station herd.

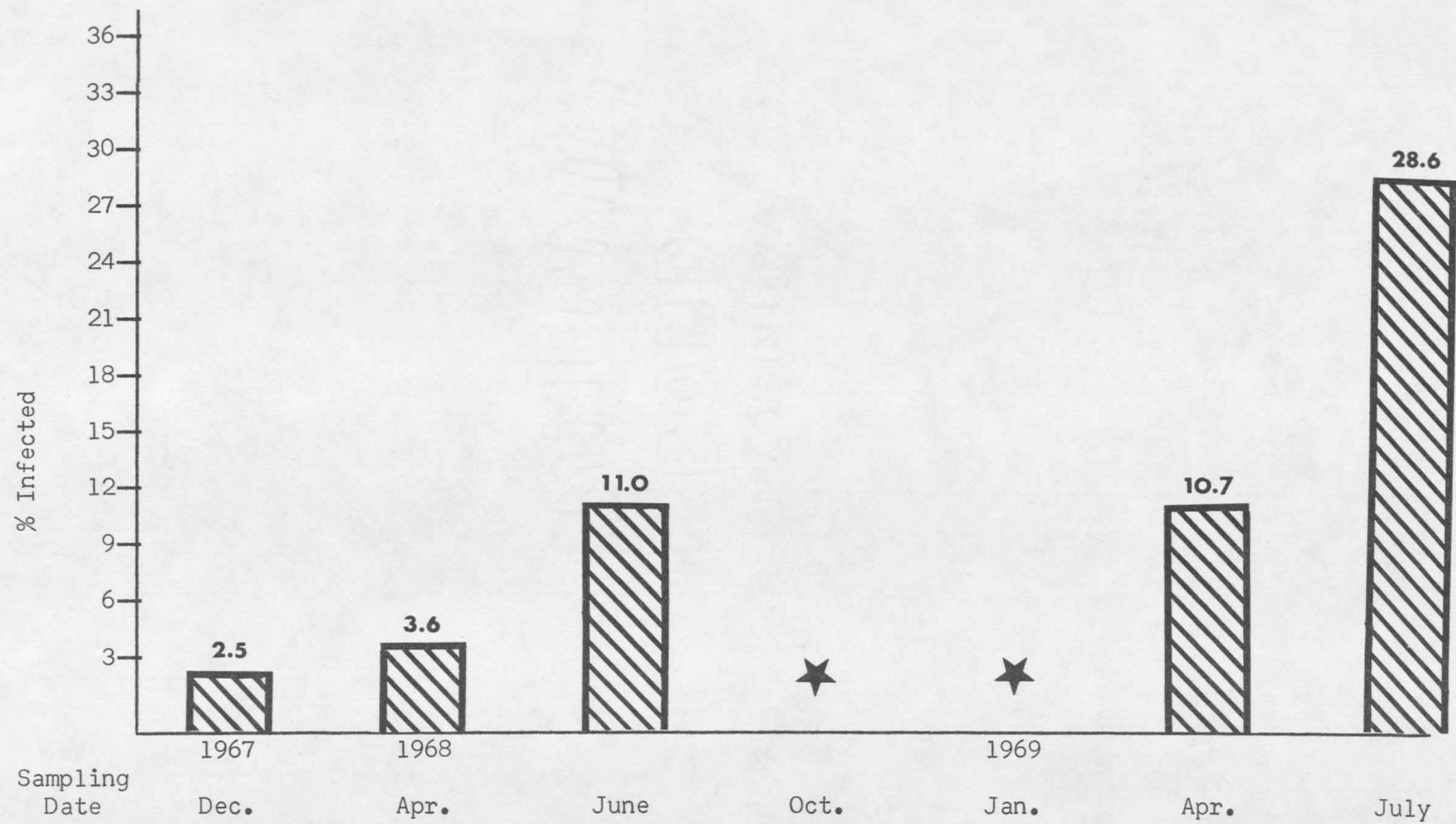


Figure 4. Seasonal occurrence of *D. viviparus* in cattle in Ravalli County.

★ = all cattle were negative

The latter group, negative in January, first had D. viviparus infections in April (incidence--10.7%) and maintained their infections through July (infection rate--28.6%).

Three of the four cow infections found in Gallatin and Park counties were encountered from late September to October. The other positive cow sample was obtained in late July. In the herd at the Experiment Station, 21.4% of 28 cows were found passing lungworm larvae in early April, 1969. A third collection in late April revealed that 5% (1/20) still had patent infections. Subsequent samplings in May and June proved negative for lungworm larvae.

Pasture samples collected in April and May of 1969 yielded a total of 12 third-stage D. viviparus larvae. Larvae were recovered from litter, old fecal pats and the top few mm of soil. Based on recovery sites, larvae apparently overwintered in the "mat" layer formed at the grass-soil interface. Larvae averaged 358 microns (range 330 to 390 microns) in total length and in three larvae the mean anus to tail measurement was 35.7 microns (range 34 to 37 microns) (Table III). A sheath was discernible on the majority of the third-stage forms. Three larvae exhibited indistinct sheaths, whereas one had a double envelope. Movement was evident in several of the ensheathed larvae. Figure 5 shows a third-stage bovine lungworm larva which was recovered from pasture 9 months after grazing had ceased the previous fall.

TABLE III. Measurements of Third-Stage D. viviparus Larvae Recovered from Pasture Samples.

Total Length (Microns)	Anus to Tail (Microns)	Sheath
390	37	+
383	36	++
383	-	-
375	-	+
368	-	+
360	-	+
360	-	-
345	34	+
341	-	+
332	-	-
330	-	+
330	-	+

- Indicates sheath was absent.

+ Indicates sheath was present.

++ Indicates double sheath.

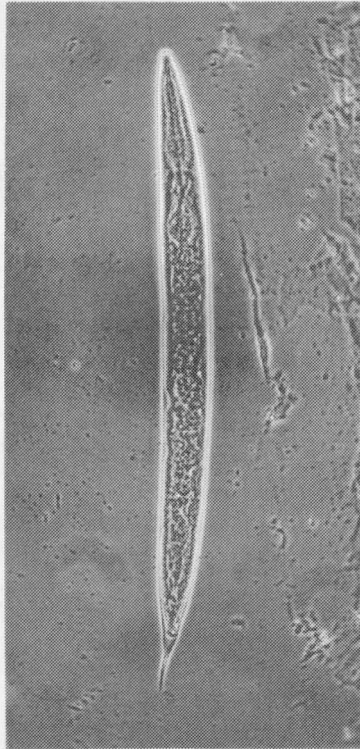


Figure 5. Third-stage D. viviparus larva recovered from pasture in spring of 1969, with sheath visible at posterior end.

Another aspect of the present study was a post-mortem evaluation of D. viviparus infections in cattle necropsied at the Montana Livestock Sanitary Board Diagnostic Laboratory. The average number of adult worms recovered from five animals was 90.4 (range 2 to 267). These five sets of lungs contained considerable blood-tinged frothy exudate. Also the most common gross changes associated with these infections were pneumonic areas often accompanied by localized areas of emphysema. Four of the animals originated from Gallatin Co., while one came from Cascade Co. in central Montana.

From miscellaneous Baermann examinations, known distribution of D. viviparus was extended into two new localities in southwestern Montana. Five percent (1/20) of autumn-born calves on a Madison Co. ranch were passing lungworm larvae in July, 1968. In the Big Hole Valley (Beaverhead Co.) one of nine (11%) cow fecal samples submitted contained larvae.

During a visit to a ranch in Park Co., an accompanying veterinarian autopsied a long-yearling steer (20 months old) which showed symptoms of brisket edema. Four hundred fifty-four D. viviparus adults were recovered from the lungs, and the larval concentration in the feces was 81.7 l.p.g. This was the heaviest D. viviparus infection encountered in the study.

Limited post-mortem observations indicated that mature cattle can contract lungworm infections. A 3-year-old bull in Gallatin Co. contained

approximately 150 lungworms, and a larval count of 0.5 l.p.g. was found in a 10-year-old bull from Park Co.

Fecal consistency data revealed that 60.8%, 16.7% and 19.2% of the samples from infected cattle were compact, moist and wet, respectively. Only 3.3% were classified as very wet. Therefore the majority of larval concentrations (l.p.g.) would reflect accurately the number of larvae contained in the feces.

## DISCUSSION

Relatively little data on the distribution of D. viviparus in the northwestern United States exists in the literature. Honess and Tucker (1962) stated that dictyocaulosis was indigenous to several areas in Wyoming. The bovine lungworm is enzootic to all areas of Montana except the north central region (Jacobson and Worley, 1969). The present study showed that 77.1% (27/35) of the ranches sampled in three western Montana counties contained infected cattle, indicating that lungworms in cattle are well established in the western part of the state.

Data on incidence of lungworms in western Montana can be related to Jacobson and Worley's study in which they noted infection rates of 5.8% (12/208) in calves and 8.4% (18/214) in yearlings. Calves examined in the present survey showed a similar incidence (6.6%), whereas D. viviparus was more prevalent in yearlings (11.5%). Alicata (1960) necropsied 60 calves in Hawaii and found one (1.6%) infected. Other figures on the incidence of lungworms in cattle of known ages apparently are not available in North America.

No data have been published concerning intensity of lungworm infections in North America. The majority of investigations on larval concentration (l.p.g.) have been conducted in Britain. Because of varying environmental factors and herd management practices, it was not justifiable to relate larval outputs in Montana cattle to the commonly-observed counts in excess of 100 l.p.g. in British cattle (Jarrett et al., 1954). Since Kassai and Holló (1962) reported that fecal larval counts

cannot be correlated with numbers of adult worms present in the lungs, the consistent low larval outputs obtained in the present study do not necessarily indicate light infections.

The seasonal nature of D. viviparus in cattle in western Montana was elucidated during the present study. A "lungworm season" in calves extending from August to November was established. Autumnal peaks of infection occurred in calves in Gallatin and Park counties and in the pilot herd. Calves in the indicator herd acquired larvae from mid-August to mid-September, 1968 and remained patent until late November.

The fall peaks of infection in Montana calves corresponded closely with peak periods of infection reported in foreign countries. Researchers in Russia (Gadzhiev, 1954), Germany (Frick, 1964) and Denmark (Henriksen, 1967) reported that peak lungworm infections occurred from June to August; this was slightly earlier than the maximum prevalence observed in the pilot herd. According to workers in Russia (Krastin, 1944; Dmitriev, 1964), Canada (Choquette, 1954), Scotland (Jarrett et al., 1954), Poland (Świetlikowski, 1959; 1965), Germany (Bohn, 1961) and Czechoslovakia (Hovorka and Podhájecký, 1965), peaks of infection extended from August to November. It can be concluded that the late summer to early autumn acquisition period of lungworm infections in Montana calves coincides with many other areas in the Northern Hemisphere. Although limited late summer and fall sampling data on calves in Ravalli Co. precluded a similar observation, these calves probably would have shown a similar pattern of seasonal occurrence with an autumnal peak.

The few foreign studies on a seasonal lungworm cycle in yearlings also compare favorably with the seasonal occurrence of dictyocaulosis in yearlings observed in this study. In Russia (Gadzhiev, 1954) and Poland (Świetlikowski, 1959), infections reached a peak in May and June. In the former case the yearlings lost their infections by September. In western Montana, yearlings consistently acquired lungworms from April to August and shed their infections by October. This was particularly evident in Ravalli Co., where on three ranches, two groups of yearlings had infections only in June, 1968 and July, 1969.

The seasonal pattern of D. viviparus in yearlings in the three counties apparently preceded the lungworm cycle in calves by a few months. The patent period in calves was confined to a more definite period (August through November) than infections in yearlings, since the latter can be exposed from April to September.

Two factors responsible for perpetuation of dictyocaulosis from year to year are overwinter survival of larvae and carrier animals. Larval persistence through the winter season is the more feasible explanation in western Montana for recurring pasture contamination in the spring and summer. The viable ensheathed lungworm larvae recovered in the spring of 1969 from an infested pasture had remained alive from mid-August, 1968 to mid-May, 1969, a period of 9 months. Larval acquisition by calves in August would require a 12-month larval survival, but this is not unlikely since Taylor (1951) in southern England, Jarrett et al. (1954;

1955) in western Scotland and Bell (1955) in Scotland reported that larvae were capable of surviving approximately a year on pasture.

Infectivity of larvae surviving on pasture in western Montana was not determined since calves from the pilot herd did not graze the pasture the succeeding fall from which ensheathed larvae had been recovered. Absence of infected cows grazing with the calves during late summer would provide some confirmation of larval infectivity. Snow cover continuing for a 3-month period during the winter of 1968-69 provided a favorable microclimate for larvae in the "mat" of organic material. The recovery of D. viviparus larvae from pasture in the present study apparently constitutes the first documented record of overwintering of lungworm larvae in North America.

Choquette (1954) speculated that increases in pasture infestations were contingent upon larval overwintering in Canada. Porter et al. (1941) in Florida, Porter (1942) in Alabama and Honess and Tucker (1962) in Wyoming did not ascribe lungworm infections in the spring to overwinter survival of larvae. Verification of larval infectivity must await further investigation.

Carriers, incriminated in many epizootics in foreign countries, apparently are relatively insignificant in initiating outbreaks in cow-calf operations in North America. Since only 1.6% (4/222) of cows examined from 23 ranches in Gallatin and Park counties were infected, they probably do not contribute markedly to infections in calves. Even though Rubin (1956) stated that "a lightly infected

animal" may be capable of infecting associated cattle, it is doubtful whether a cow excreting less than a few l.p.g. of feces could be responsible for infesting an entire pasture. Extensive studies in the British Isles (Jarrett et al., 1954; 1955; 1957; Michel and Shand, 1955; Cunningham et al., 1956) revealed that carrier animals are the major factor in producing epizootics in calves. Jarrett et al. (1955; 1957) and Cunningham et al. (1956) maintained that yearlings were the most important of the age groups in propagating parasitic bronchitis. Krastin (1944) in Russia and Pouplard (1968) in France also attributed pasture infestations in the spring to winter carriers.

In North America, Choquette (1954) theorized that carriers contributed to pasture infestations in the spring and Honess and Tucker (1962), working in Wyoming, demonstrated overwinter survival of adults in the lungs of cows. In western Montana, there is circumstantial evidence that yearlings serve as sources of infection for calves grazing with them. Since the four infected cows in Gallatin and Park counties were grazing with susceptible calves, they could be classified as potential sources of infection to the younger animals. Conversely, in the pilot herd, 21.4% (6/28) of cows found infected in April, 1969 would not contribute to infections in calves, since pasture rotation precluded exposure of calves to pastures contaminated by cows.

The present investigation revealed a prevalence of bovine lungworms in western Montana which was unrecognized previously. Although infection rates in herds were generally low, an incidence of more than 30% was

encountered on several ranches. No fulminating outbreaks were detected, but the aforementioned yearling operation west of Bozeman could be a potential site for an epizootic. On this ranch, overwintering of larvae could contribute to an increased level of pasture infestation each spring. Purchased yearlings, some harboring infections when released to graze these pastures, could also augment existing pasture contamination.

Since D. viviparus larvae possess limited migratory powers (both horizontal and vertical) (Michel and Rose, 1954) and cattle have an aversion to feces, translation of larvae from feces to pasture has been the source of considerable speculation. Robinson (1962) and Robinson et al. (1962) believed that if the association between a ubiquitous fungus of the genus Pilobolus and lungworm larvae were widespread, then this mold was a major factor in the epizootiology of parasitic bronchitis in England. The larvae migrate up the spongiophores of Pilobolus spp. and are propelled up to a distance of 10 feet by the discharge of the sporangia. This fungus is common on horse dung in Montana, but apparently occurs infrequently on bovine fecal pats (Montana Agricultural Experiment Station records). A more likely explanation, particularly applicable to the yearling operation 2 miles west of Bozeman, would be tracking of feces on the feet of animals. Diarrheic feces, resulting from ingestion of succulent vegetation, also could aid in dissemination of larvae throughout a pasture. Water sources, such as troughs and irrigation ditches, also could serve as sources of contamination for the cattle.

Morozov (1958) showed experimentally in Russia that coprophagous beetles passively transported larvae from feces to the soil. Observations by the author on the behavior of dung beetles and dung flies showed that both could aid in transporting the sluggish larvae to soil and pasture.

Infected cattle in western Montana did not originate from any particular type of ecosystem. They were found grazing well-irrigated lowland pastures (elev. under 3,500 ft.), intermountain valleys, high altitude forested rangeland (elev. above 6,000 ft.), sagebrush-dominated pastures (both at low and high elevations) and sparsely vegetated semi-arid land. It is believed that larvae can survive the winters of Montana under the snow and are resistant to desiccation during the relatively mild summers. Both carrier animals and overwinter survival of larvae probably contribute to spring and summer contamination, but the latter, because of the low prevalence of adult carriers, is more important in propagating dictyocaulosis.

The seasonal nature of this parasite which was established in calves in Gallatin and Park counties should aid future investigations on distribution and incidence of lungworm infections in Montana. Intensive sampling of calves during the "lungworm season" would undoubtedly reveal a higher incidence than noted in the present study.

Exposure to D. viviparus confers a strong immunity to infected cattle, but if they are not exposed as calves or the initial exposure is light, yearlings are apparently as susceptible as calves. In operations where

yearlings are permitted to graze with calves or where calves graze pastures previously occupied by yearlings, the importance of yearlings in the transmission of lungworm infections is apparent.

Based on this investigation, lungworms can be found on the majority of ranches in western Montana where beef cattle are raised and could become an increasing factor in morbidity in animals less than 2 years old. Because lungworms are widespread in Gallatin and Park counties, two of the leading beef producing areas in the state, they should warrant appropriate herd management, i.e., providing ample pasture for the cattle and instituting a periodic pasture rotational system. The cyclical nature of lungworm occurrences in calves and yearlings should facilitate fall treatment of clinically infected animals.

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