THE INCIDENCE AND DEGREE OF INFECTION OF *PNEUMOSTRONGYLUS TENUIS* IN THE WHITE-TAILED DEER OF WESTERN VIRGINIA

by

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Last, but by no means least, I can say -- "This, with God's help, I have done."

INTRODUCTION

This paper reports on an epidemiological survey of the incidence and severity of infection of deer in seven southwestern Virginia counties by the brainworm, Pneumostrongylus tenuis (Dougherty, 1945). P. tenuis (Nematoda: Strongylidea) is placed in the family Protostrongylidae by Yamaguti (1961).

Approximately 40,000 deer are killed annually in Virginia by over 200,000 hunters. Thus, the White-tailed Deer is the most important sought-after big animal in the state.

P. tenuis has received increased attention recently in the literature and at scientific meetings. The Southeastern Cooperative Wildlife Disease Study has reported on extensive surveys of the incidence, degree of infection, and geographical distribution of P. tenuis made throughout the southeastern states during the past four years.

This nematode parasite is transmissible to certain domestic livestock and can be highly pathogenic when occurring in large numbers (Hayes, 1962). To maintain healthy deer herds we need to understand the biology and importance of the potentially pathogenic P. tenuis.

Pneumostrongylid infections in western Virginia deer may contribute to local periodic fluctuations in deer populations. Under certain circumstances, these nematodes are capable of producing mortality among White-tailed Deer (Hayes, 1962), Pers. Comm.

Epidemological data contained within this thesis may suggest further research on the possible intermediate hosts of P. tenuis in

the Virginia study area and other locations where high incidences of infection occur. Certain deer management practices are suggested for combating pneumostrongylosis when and where it may be a problem. Observations on pathology of pneumostrongylosis in deer are described and discussed in this thesis.

The Problem

A survey of seven western Virginia counties was made to ascertain the incidence and degree of infection of P. tenuis in the resident White-tailed Deer population. Deer heads, lung specimens, and fecal material were collected at state big game checking stations located within the study area on the western slopes of the Blue Ridge Mountains in Virginia.

Objectives

The objectives of this study were (1) to determine the distribution of pneumostrongylids in the White-tailed Deer in seven western Virginia counties and (2) to correlate incidence and degree of infection by pneumostrongylids with deer age, sex, geographic location, and physical condition.

Study Area

Sample Selection

The counties sampled were selected on the basis of location, estimated high deer kill, and assured manpower at big game check stations.

Location

Specimens were collected at check stations in seven southwestern Virginia counties which are as follows: West Augusta in Augusta County; Mountain Grove in Bath County; Patterson Creek in Botetourt County; New Castle in Craig County; Interior in Giles County; West Lexington in Rockbridge County; and Mt. Jackson in Shenandoah County (Figure 1).

Physical Description and Climate

The seven counties comprise an area of 3,885 square miles. Their approximate elevation varies from 1,500 to 4,000 feet above sea level. They have an average rainfall of 43 inches. The area has a low mean monthly temperature of 35° F. in January and a high of 74° F. in July.

The survey area is located in the Ridge and Valley Province of the Appalachian Highlands Physiographic Region. The main mountain ridges lie in a northeast-southwest direction and the secondary ridges are perpendicular to the main ridges. Quartzitic rocks form the western ridges of these mountains. The valleys consist of Cambrian and Ordovician limestones. Some areas in this region are considered the richest agricultural sections in the state (Raisz, 1962).

Agriculture and forestry are the predominant industries, with a slow trend toward light industry and residential development. The counties are largely forested and fall within the boundaries of the Jefferson and George Washington National Forests (Larson and Bryan,

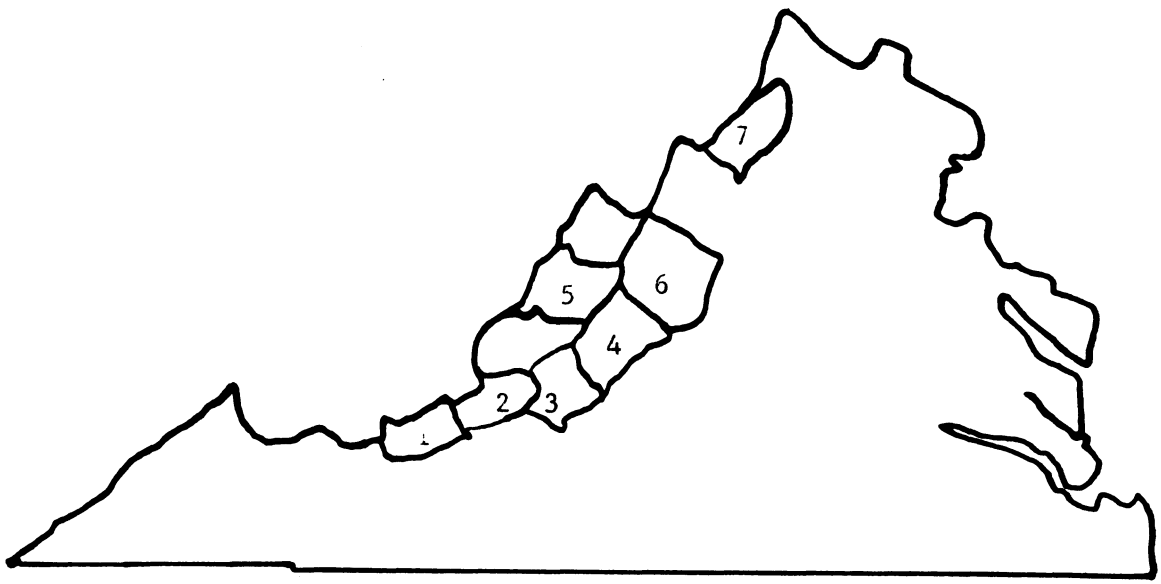


Fig. 1. Location of 7 counties sampled for Pneumostrongylus tenuis in southwestern Virginia, 1963: (1) Craig; (2) Giles; (3) Botetourt; (4) Rockbridge; (5) Bath; (6) Augusta; (7) Shenandoah.

1959). The forested areas are covered with the typical southeastern mountain hardwood forest types containing Scarlet Oak (Quercus coccinea), White Oak (Quercus alba), Black Oak (Quercus velutina), Virginia Pine (Pinus virginiana), Pitch Pine (Pinus rigida), Hickory (Carya, spp.), Black Gum (Nyssa sylvatica), Northern Red Oak (Quercus borealis), Yellow Poplar (Liriodendron tulipifera), and Chestnut Oak (Quercus montana) as dominants (Larson and Bryan, 1959).

LITERATURE REVIEW

The Southeastern Cooperative Wildlife Disease Study examined deer for pneumostrongylids through much of the southeast in an attempt to determine the incidence and degree of infection (1962). Preliminary results from this study indicated a need for the present investigation. Relatively little research has been done on the distribution of P. tenuis in Virginia, especially in the western portion of the state. The relation between intensity of infection and the host's physical condition is poorly understood.

Anderson (1964) described the life cycle of P. tenuis as follows: Adult worms occur in the subdural spaces. Undeveloped eggs are deposited on the dura mater of the cranium and also in the blood vessels associated with the meninges. Eggs on the meninges embryonate, hatch, and larvae enter the blood stream and are carried to the lungs where they break into alveoli. Larvae eventually make their way up the respiratory tract, are swallowed, and passed in droppings. Eggs deposited in the blood stream are carried to the lungs where they form minute emboliams that become fibrosed. These eggs develop in the usual way and larvae break out of cysts and pass into alveoli. First stage larvae passed in droppings penetrate the foot of snails and develop to the infective stage in about three weeks. Deer become infected when they ingest snails containing infective larvae. In fawns developing worms can be found in the central nervous system, especially in the spinal cord, 25 and 40 days

after exposure. After 40 days, worms apparently move onto the surface of the spinal cord and mature in the subdural spaces. There is a tendency for worms to accumulate in the cranium.

Anderson (1963) states the following species of land snails are suitable intermediate hosts: (1) Discus cronkhitei; (2) Zonitoides arboreus; (3) Deroceras grcile; (4) Stenotrema fraterum; (5) Triodopsis albolabris; (6) Anguispira alternata.

Dougherty (1945) first described P. tenuis from a male specimen found within the bronchiole of a deer in New York. Kennedy (1952) and Whitlock (1952), working with deer in New York, recovered nematodes from the tissues of the brain and spinal cord. Anderson (1956), in a Canadian survey, first found P. tenuis in the cranial cavities of deer. He later located adult worms in the dura of the brain and spinal cord and in the wall of the intercavernous sinus beneath the dura in the region of the pituitary fossa (1963). Anderson demonstrated that P. tenuis can occur in sites other than the cranium. Whitlock (1959) noted specimens in the eye of the moose. Alibasoglu (1961) believed the preferred infection site of P. tenuis to be at the base of the brain. Infection sites in Virginia deer examined by Dudak (unpublished) during the summer of 1963 were similar to those reported by Anderson (1963) and Alibasoglu (1961).

Symptoms and pathology are similar in all reported cases of pneumostrongylosis. (Burg,1953; DeGiusti, 1955; Schwangart, 1940), symptoms associated with massive P. tenuis infections are neuro-paralysis and blindness. Necropsy of animals with these symptoms usually reveals extensive hemorrhage within the brain.

Whitlock (1959) identified pneumostrongylids from sheep and moose in New York as Neurofilaria cornellensis. He earlier (1952) opined that the brain worm might be an abnormal parasite of sheep because of extensive damage it causes in the central nervous system. Alibasoglu (1961) examined two deer infected with P. tenuis that showed symptoms of opisthotonons, ataxia, and posterior paralysis prior to necropsy. The possibility that adult worms could cause serious intercranial bleeding by rupturing vessels, especially during oviposition, was raised by Burg (1953), who observed the fatal bleeding in a European Red Deer (Cervus elaphus) infected with a related lungworm (Elaphastrongylus cervi).

P. tenuis is apparently common in Ontario (Anderson, 1956); Michigan (DeGiusti, 1955); New York (Whitlock, 1959); and Pennsylvania (Alibasoglu, 1961).

Anderson (1962) observed that infections of different species of lungworms are common within a single host deer. Anderson cautioned that care must be used in identifying immature forms of P. tenuis, even when adults of a single species are found coexisting in the lungs. P. tenuis eggs, or immature nematodes, are carried to the lungs and can occur together with those of Protostrongylus coburni and Leptostrongylus alpenae, each of which have an indirect life cycle according to Cheatum (1951) and Goble (1943).

TECHNIQUES AND PROCEDURES

Procurement of Specimens

News releases promoting the study were submitted on October 7 and November 11, 1963 to daily and weekly newspapers serving the study area. The releases provided information about the study and appealed to deer hunters for cooperation in providing deer heads, lung tissue, and relative data.

Deer were hunted in the study area for six days, November 18-23, 1963. Collections were made on the first day of the season because approximately 90% of the total kill is taken that day. Hunters killed either sex on the first day and bucks only for the remainder of the season.

Biologists and students from the Department of Forestry and Wildlife at Virginia Polytechnic Institute and the Virginia Commission of Game and Inland Fisheries collected deer heads from hunters at check stations.

Successful hunters, when checking their deer at selected stations, were asked to voluntarily donate deer heads, lung tissue, and fecal material. The following information was obtained for deer whose heads were collected: date, age, sex, location of kill, hunter's name and address, big game tag number, body fat content, hind leg measurement, and county of kill.

Storage of Deer Heads

All deer heads were frozen and stored in freezer lockers near collection points. Heads were subsequently transported to the Virginia

Polytechnic Institute campus where they were stored until examined. All heads were frozen within 24 hours. A sample of 369 heads of both sexes was obtained.

Post-mortem Laboratory Examinations

The first 100 deer heads were examined by the necropsy method described in the Southeastern Cooperative Wildlife Disease Study report (Anonymous, 1962).

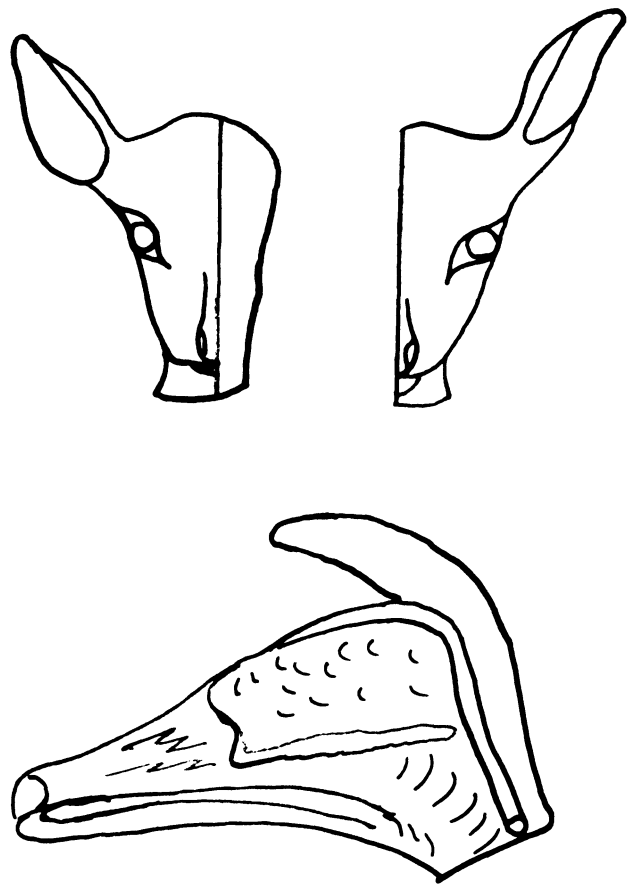
Modifications of this procedure were made to facilitate a more thorough and detailed examination. Consulting pathologists suggested the use of a band saw to make sagittal sections, as opposed to the cranial cut technique employed by the Southeastern Cooperative Wildlife Disease Study.

The sagittal sections exposed the brain for a satisfactory and detailed examination.

The following steps were taken in examination of the deer heads:

1. Deer heads were sagittally sectioned immediately after being removed from freezer storage (Figure 2).
2. Heads were allowed to thaw for 24 hours after being sectioned. The brain was carefully examined under a 3x illuminated viewer and extracted.
3. Meningeal folds were examined for larvae and adult worms with a binocular dissecting microscope at 30x and with the use of a Bausch and Lomb Nicholas illuminator.
4. Suspicious hemorrhagic and discolored areas of the meninges were subjected to dissection to locate hidden parasites.

Front - View



Side - View

Fig. 2. Two views of the sagittal head cut used in making necropsies.

5. The cranial cavity with arachnoidea and dura mater were scanned with the illuminated viewer at 3 magnifications.
6. Neural canals and sinuses of the cranium were dissected and examined.
7. Worms were extracted with forceps without difficulty as long as the brain tissues were moist. As drying occurred, however, a few drops of ethyl alcohol were administered to facilitate extraction. Worms were preserved in 70% alcohol solution with 10% glycerine.
8. Worm locations within the cranium were diagramed on 5-1/2" x 8" file cards (Figure 3).
9. Biological information on the tag attached to each deer head was transferred to another 5-1/2" x 8" file card. This data card also contained the necropsy report for that deer: number of worms, stage of development (adult or immature), sex hemorrhagic condition, exudate, meninges color and condition, and miscellaneous information (Figure 4).

Examination of Lung Specimens

1. Thirty lung specimens were obtained at check stations. Approximately 0.5 inch cubes were cut from the posterior lobes and fixed in Bouin's solution for sectioning. Lung specimens were taken only from animals whose heads were also collected.
2. Specimens were washed for several hours in running water and treated successively with 30, 50, and 70% ethyl alcohol over 48 hours after being in the fixative for six weeks. The lung tissues were then

Front Side

CHECK STATION DATA: SPECIMEN NO._____

Big game tag No.

Checking station

Hunters name and address

Date of kill

Site of kill

Weight

Was deer dressed before weighing? Yes No

Sex

Hind leg length

Fat content

Age

Back Side

NECROPSY REPORT

No. of worms: Weight of brain:

Male
Female
Adult
Immature

Location: See card No.

Hemorrhage:

Exudate:

Meninges Color and Condition:

Misc:

Fig. 3. Sample data card on which was recorded pertinent information for each deer head collected.

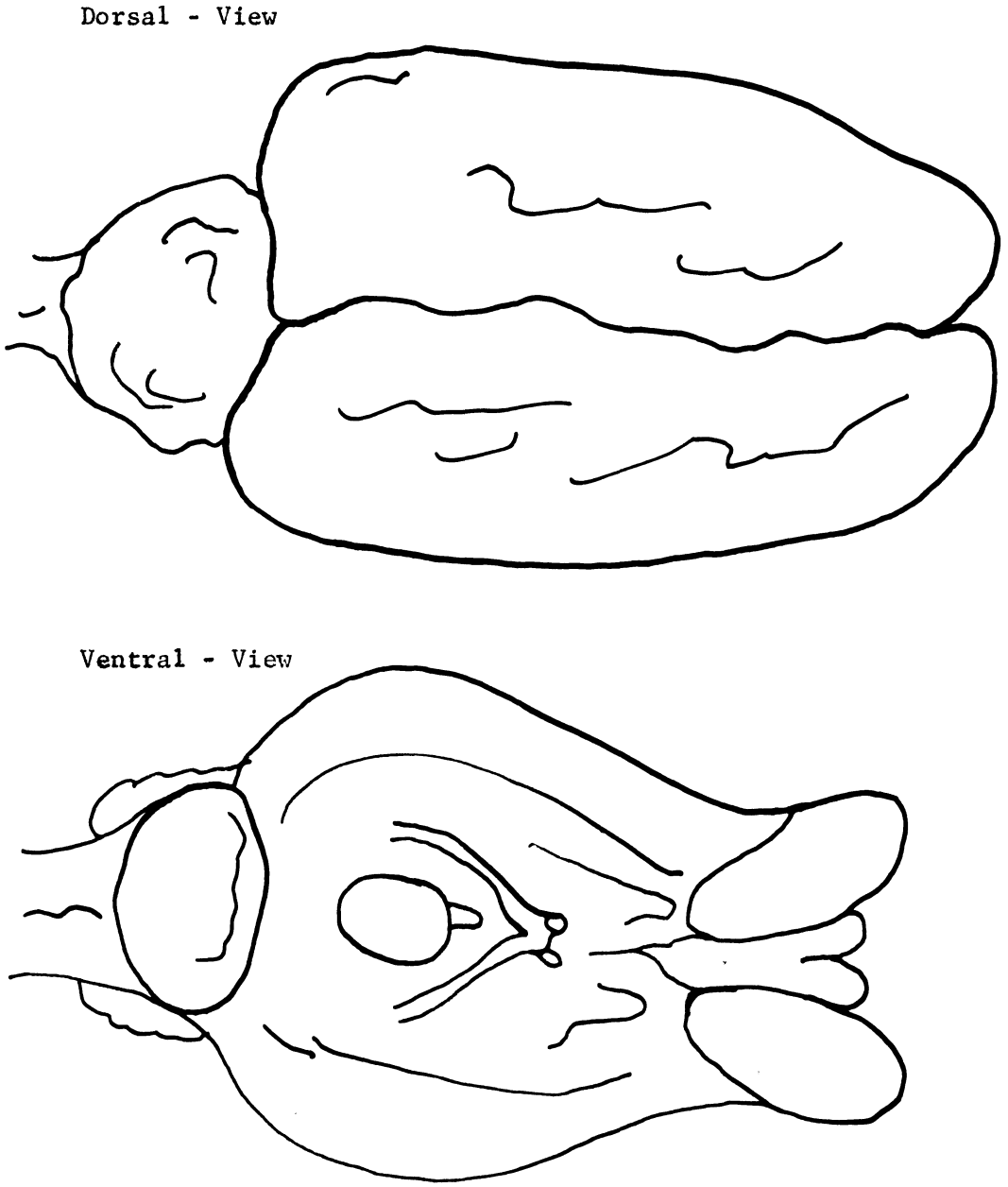


Fig. 4. Dorsal and ventral views of the deer brain.

embedded in paraffin and sections 10 microns in thickness were cut with a microtome. Tissue ribbons were mounted on microscope slides with albumen fixative. Nematoxylin and eosin were used to stain slides.

3. Thirty slides, with several ribbon sections on each, encompassing lung sections from 30 individual deer, were examined for parasite eggs and larvae with a Baush and Lomb Dyna Zoom microscope using 100x magnification.
4. Notes were taken on slide observations: location, number, and size of parasite eggs and larvae.

Mounting Nematodes for Study

Worms were taken from preservative jars and placed in lactophenol for clearing. Specimens were removed from lactophenol after 30 hours at room temperature and mounted in Hoyer's medium on 3" x 2" micro slides, the technique recommended by Grundmann (1955).

Fecal Examinations

Fecal specimens were obtained from deer carcasses incompletely field dressed. In such cases, an incision was made into the posterior portion of the large intestine and fecal pellets removed. Pellets were frozen two months before they were examined. Fecal specimens were thawed, soaked in distilled water for 48 hours, then mascerated with a spatula. The mascerated material was transferred to centrifuge tubes and centrifuged at 6,700 RPM for one minute. Four samples of sediment from each fecal specimen were removed with a syringe pipet and transferred to slides for examination under 100x magnification.

RESULTS

Three hundred and sixty-nine deer heads, 30 lung specimens, and 11 fecal specimens were collected at hunter check station. Of the heads collected, 79 from bucks and 230 from does were usable. Sixty heads were discarded because they were head shot, had putrefied, or the attached data tag was lost or not completed properly. Table 1 presents sex, age, and infection data for the 309 deer examined. The overall results showed a 73% infection rate with a mean of 3.4 worms per infection ($s = \pm 2.6$), and a range of 1-13 pneumostrongylids per infection.

The Incidence and Degree of Infection by Sex of the Host

It was not known if the sex of the host would have an influence on the infection rate or severity of infection by *P. tenuis*. Hunters shooting male deer older than 1-1/2 years of age were somewhat reluctant to part with the heads. Enough older male deer heads, however, were collected for a statistical analysis. Data were analyzed for age categories less than 1-1/2 years and 1-1/2 years and older. In the less than 1-1/2 year age group, 29 of 45 females were infected (64%), while 40 of 64 males (63%) were infected. The mean number of worms per infected doe less than 1-1/2 years old was 2.1 ($s = \pm 1.8$), while the mean number of worms per infected buck was 2.4 ($s = \pm 1.8$). The mean number of worms per infected doe 1-1/2 years of age and over was 4.0 ($s = \pm 2.9$), while the mean number of worms per infected buck was 2.9 ($s = \pm 2.1$). In the total sample, 65% of the males carried a mean

Table 1. Sex, age, and infection data for 309 deer heads examined for P. tenuis and collected from seven southwestern Virginia counties, 1963

Sex	Age in years	No. of deer uninfected	No. of deer infected	Mean worms per infection	Standard deviation for the mean (±) values	Standard error	Range
M	1/2	16	29	2.4	1.8	0.33	1-8
F	1/2	24	40	2.1	1.8	0.29	1-10
M	1-1/2	9	19	3.0	2.6	0.59	1-9
F	1-1/2	19	54	4.4	2.8	0.38	1-13
M	2-1/2	2	2	2.5	0.2	0.05	2-3
F	2-1/2	7	27	5.0	3.8	0.73	1-10
M	3-1/2	0	2	2.5	0.2	0.05	2-3
F	3-1/2	4	21	3.9	1.6	0.34	1-10
F	4-1/2	1	9	4.1	1.5	0.49	1-8
F	5-1/2	2	9	3.4	2.3	0.76	1-8
F	6-1/2	0	8	3.4	2.6	0.93	1-8
F	7-1/2	0	3	3.3	2.3	1.34	2-6
F	8-1/2	0	2	3.0	2.8	1.99	1-5
Total		84	225	$x_n = 3.4$	$s_n = 2.6$	$s_{\bar{x}} = 0.56$	1-13

infection of 2.7 (s = ± 2.1) worms; and 75% of the females carried a mean infection of 2.9 (s = ± 2.6) worms (Table 2).

A null hypothesis of no difference in infection rates between sexes of deer less than 1-1/2 years old yielded a two-tailed Chi Square test value of 0.043 (1 df). The null hypothesis could not, therefore, be rejected when p = 0.10. There seems to be an equal likelihood of infection by P. tenuis in deer of either sex at least in the deer less than 1-1/2 years old.

A null hypothesis was tested that among animals older than 1-1/2 years there is no greater incidence of infection among females than males. A Chi Square test yielded a value of 3.3 (1 df); thus, the null hypothesis could be rejected when p = 0.10.

Due to the lack of data on male deer over 1-1/2 years old, this test may have been invalid. However, the data are suggestive of a greater incidence of infection in females (80%) than in males (68%).

The relationship between severity of infection and sex was examined. The null hypothesis was tested that among deer less than 1-1/2 years of age, there is no significant difference between male and female deer in the number of worms per infection (Table 3).

Infections were split into three rows of 1-3, 4-6, and more than 7 nematodes. A two-tailed test yielded a Chi Square value of 1.592 (2 df). The null hypothesis could not be rejected when p = 0.10.

Table 2. Infection data by sex for 309 White-tailed Deer heads examined for brainworms, southwestern Virginia, fall, 1963

	Total males	Total females	Males less than 1-1/2 years of age	Males older than 1-1/2 years of age	Females less than 1-1/2 years of age	Females older than 1-1/2 years of age
Number of specimens	79	230	45	34	64	166
Number infected	52	173	29	23	40	133
Per cent infected	65	75	64	68	63	80
Mean infection	2.7	2.9	2.4	2.9	2.1	4.0
Standard deviation of the mean (±)	2.1	2.6	1.8	2.1	1.8	2.9

Table 3. Sex, specimens uninfected and infected, and worms per infection for deer less than 1-1/2 and over 1-1/2 years of age from seven southwestern Virginia counties, 1963

Sex	Age in years	No. of specimens uninfected	No. of specimens infected	No. of nematodes per infection (1-3)	(4-6)	(7+)
M	-1-1/2	16	29	23	5	1
F	-1-1/2	24	40	35	4	1
M	1-1/2+	11	23	19	2	2
F	1-1/2+	33	133	63	40	30
Total		84	225	140	51	34

The null hypothesis was tested that among deer 1-1/2 years of age and older there is no significant differences between male and female deer in the number of worms per infection. The two-tailed Chi Square test was used again yielding a value of 7.229 (2 df). The hypothesis was, therefore, rejected at the 95% confidence level.

It would appear that within the less than 1-1/2 year age group sex of the host does not have a significant effect upon the severity of infection by P. tenuis. Among older deer, however, females have significantly more worms per infection than males (Table 3).

The Incidence and Degree of Infection by P. tenuis Relative to Host's Weight

The mean weight of field dressed male deer of all age groups from all counties was 74.8 pounds ($s = \pm 27.6$), while the mean weight for females was 80.4 pounds ($s = \pm 21.4$). The weight of an individual White-tailed Deer depends upon nutrition, age, health, and genetic stock. Before a possible relationship between weight and infection by P. tenuis could be tested, it was necessary to see if significant differences existed between weights of deer collected in the counties studied regardless of parasitic infection. The percentages for deer weights in categories of 30-60 pounds, 61-90 pounds, and 91-130 pounds as related to the total deer sample are as follows: Shenandoah - 21%, 58%, and 21% of 19 animals; Augusta - 16%, 43%, and 40% of 57 animals; Bath - 19%, 75%, and 6% of 16 animals; Rockbridge -

12%, 41%, and 47% of 34 animals; Botetourt - 35%, 65%, and 0% of 23 animals; Giles - 22%, 36%, and 42% of 36 animals; Craig - 32%, 32%, and 35% of 71 animals.

Various age classes were equally likely to be represented in the different samples, with the exception of a hunter bias of not donating antlered deer. Essentially all deer examined were in good physical condition as evidenced by fat deposits. The null hypothesis that no real difference existed between counties in their respective weights was tested. The Chi Square test for K independent samples was used with six rows (counties) and three columns based on weights of 30-60 pounds, 61-90 pounds, and 91-130 pounds. A two-tailed value of 32.703 (12 df) was obtained. The hypothesis was rejected at the 95% confidence level, suggesting that the deer weights from the counties sampled were not drawn from the same population (Table 4).

Since weights varied significantly between counties, all deer were arranged into three classes--less than 1-1/2 years, between 1-1/2 and 3-1/2, and 3-1/2 years and older. The mean weight of field dressed deer of the less than 1-1/2 year age group from all counties was 55.8 ($s = \pm 4.5$) pounds, while the mean number of worms per infected animal in this age group was 2.3 ($s = \pm 1.0$). The mean weight of field dressed deer in the age group between 2-1/2 to 3-1/2 and 3-1/2 and older, from all counties, was 84 ($s = \pm 3.6$) pounds and 93 ($s = \pm 9.7$) pounds respectively, while the mean number of worms per infected animal in these age groups was 4.1 ($s = \pm 3.0$) and 3.7 ($s = \pm 1.5$ respectively.

Table 4. Age and weight distribution of the sample of 256 deer examined for P. tenuis from seven southwestern Virginia counties, 1963*

Counties	Age and weight -1-1/2 years			Age and weight 1-1/2 - 3-1/2 years			Age and weight 3-1/2+ years	
	(30-60)	(61-90)	(91-130)	(30-60)	(61-90)	(91-130+)	(61-90)	(91-130+)
Shenandoah	3	3	1	1	6	3	2	0
Augusta	9	11			8	13	6	10
Bath	3	1			5	1	6	0
Rockbridge	4	8			5	10	1	6
Botetourt	7	1		1	10	0	4	0
Giles	8	5			8	9	0	6
Craig	23	8	1		10	21	3	5
Total	57	37	2	2	52	57	22	27

* No weight data on 53 of animals carried in total sample (Table 1).

Each age class was tested for no difference between weight and incidence of infection. The respective two-tailed Chi Square values were 2.226 (4 df), 19.412 (6 df), and 8.457 (5 df). The null hypothesis could not be rejected for the less than 1-1/2 years and the 3-1/2 years and older age classes, since there did not appear to be a statistically significant difference between weight and incidence of infection within the two age classes. A relationship appears to exist between the weight of the 1-1/2 to 3-1/2 year age group and incidence of infection in that the null hypothesis was rejected at the 99% confidence level. Thus, animals in all three age classes were not equally likely to be infected regardless of their weight (Table 5).

Even though it is not altogether possible to predict, on the basis of weight and age, that a deer will be infected by P. tenuis, it is possible that among the infected animals the brainworm numbers per infection could be related to the host's weight. A null hypothesis that no significant difference existed between severity of infection in deer of different weights within the same age group was tested. As before, the age groups tested were less than 1-1/2 years old, between 1-1/2 and 3-1/2 years old, and 3-1/2 years old and older (Table 5). The weights represented three columns of 30-60 pounds, 61-90 pounds, and 91-130 pounds; and worms per infection were represented in rows of 1-3, 4-6, and 7 and over. The two-tailed Chi Square value for K independent samples was 1.932 (2 df), 0.603 (2 df), and 2.121 (2 df) respectively for each of the age groups. The null

Table 5. Age, weight, and worms per infection for 184 deer examined in all age categories by weight groups for P. tenuis from seven southwestern Virginia counties, 1963*

Weight pounds	Age and worm infection -1-1/2 years (1-3)	(4-6)	(7+)	Per cent of total sample infected	Age and worm infection 1-1/2-3-1/2 years (1-3)	(4-6)	(7+)	Per cent of total sample infected	Age and worm infection 3-1/2+ years (1-3)	(4-6)	(7+)	Per cent of total sample infected
30-60	31	4	1	33.0	0	0	0	0.0	0	0	0	0.0
61-90	21	5	1	24.8	15	10	10	25.1	12	7	1	32.8
91-130	0	0	0	0.0	21	9	12	30.0	15	5	4	39.3
Total	52	9	2	57.8	36	19	22	55.3	17	12	5	72.1
	N = 63				N = 77				N = 44			

* Specimens lacking weight data are excluded from Table 5.

hypothesis could not be rejected when p = 0.10. The severity of infection does not seem to be related to the host's weight within age groups.

The Incidence and Degree of Infection by Age

The age of the deer could perhaps have an influence on the severity and incidence of infection. The number of infected deer less than 1-1/2 years old was 69 (63%) of 109 deer examined, while the number of infected deer older than 1-1/2 years was 156 (78%) of 200 deer examined.

The Null hypothesis was tested that there is no difference in the incidence of infection of deer less than 1-1/2 years old and those older than 1-1/2 years. The two-tailed Chi Square test value obtained was 9.255 (1 df) which fell outside the 99% confidence level. The hypothesis was rejected. The deer less than 1-1/2 years old have a lower incidence of infection than older deer (Table 3).

In the infected deer less than 1-1/2 years of age, 58 (84%) of 69 had less than 4 worms per infection; whereas among the older deer, 74 (47%) of 156 were infected with 4 or more worms (Table 3).

The null hypothesis was tested that there is no difference in severity of infection of deer less than 1-1/2 years old and those older than 1-1/2 years. The Chi Square value obtained was 21.457 (4 df) which fell outside the 99% confidence level. The hypothesis was, therefore, rejected. The deer less than 1-1/2 years old are less likely to be heavily infected by P. tenuis.

The Incidence and Degree of Infection by Counties

The incidence and degree of infection within the surveyed counties appeared to differ significantly (Table 6). The incidence of infection by counties was: Bath, 17/17 (100%) with a mean infection of 2.9 (s = ± 2.3); Giles, 44/52 (85%) with a mean infection of 3.3 (s = ± 2.8); Botetourt, 21/28 (78%) with a mean infection of 2.8 (s = ± 2.4); Craig, 60/79 (76%) with a mean infection of 4.0 (s = ± 3.2); Shenandoah, 14/21 (66%) with a mean infection of 2.9 (s = ± 2.0); Augusta 50/77 (65%) with a mean infection of 3.7 (s = ± 1.5); Rockbridge 19/35 (54%) with a mean infection of 3.7 (s = ± 2.5) (Table 6). The null hypothesis was tested that no significant difference existed in the incidence of infection between counties.

A Chi Square test for K independent samples yielded a value of 19.352 (6 df) which indicated a rejection of the null hypothesis. There was a significant difference in the incidence of infection between surveyed counties at the 99% confidence interval.

The severity of infection between counties did not appear to vary significantly. It might be expected that counties with high incidences of infection would have animals with a large number of worms per infection. The null hypothesis was tested that no real difference existed between counties in the number of worms per infected animal. The seven surveyed counties were represented in columns and the number of nematodes in rows of 1-3, 4-6, and 7 and over. The Chi Square value for K independent samples was 11.105 (12 df).

Table 6. Infected, uninfected, per cent infected, and mean number of worms per infection for 309 deer examined in seven southwestern Virginia counties, 1963

County	No. of deer examined	No. uninfected	No. infected	Per cent infected	Mean worms per infection	Standard deviation (±)
Shenandoah	21	7	14	66	2.9	2.0
Rockbridge	35	16	19	54	3.7	2.5
Botetourt	28	7	21	78	2.8	2.4
Craig	79	19	60	76	4.0	3.2
Giles	52	8	44	85	3.3	2.8
Bath	17	0	17	100	2.9	2.3
Augusta	77	27	50	65	3.7	1.5
Total	309	84	225	73	x_n = 3.4	s_n = 2.6

The null hypothesis could not be rejected when p = 0.10. There does not seem to be any significant difference between counties and the number of worms per infection. The smallest parasite populations per infection generally occurred in those counties with the highest incidence of infected deer (Table 6).

Gross Lesions

This study was essentially an epidemiological survey; therefore, the observations of pathology caused by P. tenuis were confined to brain and cranial examinations made in the laboratory. It would appear that infections in the deer herds of western Virginia are general and that the percentage of infected animals varies between 70% and 80%. The range of infection in the 225 infected deer was from 1-13 nematodes with a mean infection of 3.4 brainworms. The adult worms tended to appear round and hairlike to the naked eye. Their color varied from brown to a pale greenish-yellow and they appeared opaque to semi-transparent under transmitted light.

The male nematodes ranged in length from 4.9-6.6 cm and the females from 8.0-9.1 cm. The width of both sexes varied between 0.5 and 1.0 mm. The morphological features observed were similar to those described by Anderson (1963). A total of 775 worms were found in the subdural spaces, intertwined throughout the arachnoidea, affixed to the dura, and attached within and on the superior sagittal sinus and transverse sinus. Of the 775 pneumostrongylids found, 527 (68%) were located on the ventral surface of the brain, the remaining 248 (32%) were located on the dorsal surface of the brain. In one case a

nematode was attached to the ventral surface of the pia mater, located superior on the brain, without any apparent membrane damage observable.

Thirty-five infected animals, having a mean infection of 7 worms, displayed highly discolored and necrotic areas on the dura and arachnoidea. The damaged tissue varied in color from dark reddish-brown to a dull yellow. Yellow necrotic rings 1 mm in diameter could be observed in large numbers on the arachnoidea predominately in the parasitized areas. Many vessels in the dura were found to be distended and surrounded by hemorrhagic areas ranging from 0.5 cm to 3.0 cm in diameter. Excessive amounts of hemorrhaging was associated with between 7-13 worms per infection in 15 animals. In 13 infected animals, the origin of hemorrhaging was difficult to ascertain. Gun shot wounds in head and neck regions may have caused some of the cranial hemorrhages.

Results of Lung Tissue and Pellet Examinations

No evidence of worm larvae were found in the 12 fecal specimens examined.

Fifteen of 30 lung tissue specimens (50%) were found to contain in the alveolie either eggs, larva, or both. The 15 positive slides were correlated with head examination results for the respective deer, all of which had brainworm infections. Six negative slides were also found to have come from infected animals; however, the infections were low, numbering 1-3 worms.

DISCUSSION

This study is limited to epidemiological data collected in the fall of 1963. No serious attempt was made to relate infection by P. tenuis with the health of the host. At the time of collection, deer were not subjected to the physiological stresses which usually maximize the effects of parasitic infections.

Sex of the host did not significantly influence infection rates or severity of infection by P. tenuis in deer less than 1-1/2 years old. Both sexes of young deer had the same opportunity for infection and the same degree of parasititropy. Since young deer of either sex spend their first three or four weeks feeding and living with the doe in a forest glade or stream bottom, the opportunity for initial infection by P. tenuis is probably equally present. These weeks of glade and stream bottom feeding might possibly explain the higher percentage of infection (80%) in female deer 1-1/2 years of age and over. Males of this same age group had an infection rate of 68%.

Females older than 1-1/2 years had significantly more worms per infection than males of the same age. This difference again may possibly be due to the females spending more time on bottomlands. DeGiusti (1963) examined 836 heads and found the infection rate to be higher in females than in male deer, but no mention was made of how much higher.

Male deer, during the rutting season, eat substantially less food than females (Cowan, 1962). This reduction in ingested food could result in the lower incidence of infection and lesser mean number of worms per infection. The physiological differences attributed to sex hormones may also contribute to the lesser infection of males as opposed to females.

The incidence of infection was related to weight within certain age groups, and not in others. Deer between 1-1/2 and 3-1/2 years of age showed a significant relationship between weight and incidence of infection. The heavier animals in this age group had a higher incidence of infection. The heavier deer were obviously in excellent physical condition. Possibly, their higher infection rate resulted from a greater volume of food ingested.

No relationship between weight and incidence of infection was evident in deer less than 1-1/2 years and older than 3-1/2 years. Doe deer in these age groups may be less productive than those between 1-1/2 and 3-1/2 years of age. Perhaps the pregnant and lactating females ingest more succulent foods than older deer, thereby increasing their exposure to infection.

Severity of infection was not related to body weight within age groups. The amount and source of ingested food may be contributing factors. The examined deer were well fed and apparently had an adequate food supply. Poor browse supplies tend to increase the amount of feeding (Van Volkenburg and Nicholson, 1943); thereby increasing exposure to helminths.

Deer less than 1-1/2 years old had a lower incidence of infection. The host reaction to P. tenuis may be more violent in young deer, resulting in a smaller residual nematode population. Deer less than 1-1/2 years of age also had fewer worms per infection than older deer. The volume of food ingested by young deer may be less; thereby reducing the incidence and severity of infection.

Bath, Giles, and Botetourt Counties had a greater incidence of infection than the other counties surveyed. Possibly these three counties offered a more favorable habitat for land snails, the parasite's intermediate host. A calcium deficiency in the diet could result in selective feeding on snails. This snail-deer relationship, if existent, would be expected to increase the severity of infection.

Counties with high infection rates did not have significantly more worms per infection than those with low infection rates. The counties with low infection rates, however, had more worms per infection than counties with high infection rates; but the difference was not statistically significant. Deer herds with a high number of uninfected and susceptible deer may carry more severe infections as opposed to herds where animals developed immunological mechanisms because of frequent exposure to the parasites.

Further research concerning the pathogenic effects of P. tenuis on the White-tailed Deer is needed prior to employment of control methods. Possible control methods would be difficult to administer

in the study area and are probably unwarranted. Employment of a technique intended to eradicate deer herds with high rates of infection would be an enormous undertaking, impractical, and not in the public interests.

Salt blocks containing a nematocide might be developed and placed in areas where the severity of infection in the deer herd assumes problem proportions, or when deer infections are a threat to domestic livestock. Additional study of the life cycle and intermediate host or hosts might indicate weak points where the life cycle could be attacked. At present, the economic feasibility of possible control methods is uncertain.

How important is the brainworm in controlling White-tailed Deer numbers? This question cannot be answered definitely with the information now available. The malnutrition-disease complex often dramatically influences the population dynamics of a species. P. tenuis may be a serious pathogen, but this research and that done elsewhere (Anderson, 1964; DeGiusti, 1963) indicate that the deer-P. tenuis relationship is a relatively stable and common association, with deer populations seldom adversely affected by the parasite.

SUMMARY AND CONCLUSIONS

(1) Heads from 369 deer were collected at hunter check stations in 7 western Virginia counties. Sixty specimens were discarded because they were head shot, had putrefied, or the attached data tag was lost or incomplete.

(2) A total of 309 deer heads were examined for P. tenuis. The sample consisted of 230 does and 79 bucks.

(3) There were 775 pneumostrongylids extracted from the infected specimens; 527 (68%) were located on the ventral surface of the brain, the remaining 248 (32%) were located on the dorsal surface of the brain.

(4) Of the 309 deer heads examined, 256 (73%) were infected. The mean number of worms per infection was 3.4 ($s = \pm 2.6$). Infections ranged between 1-13 pneumostrongylids.

(5) Excessive hemorrhaging was associated with infections in the 15 animals containing more than 7 nematodes.

(6) Of 30 lung-tissue specimens, 15 (50%) were found to contain eggs, larva, or both in the alveoli.

(7) Infections by P. tenuis in the deer herds of western Virginia is general, with 70% to 80% of the population infected.

(8) There appears to be an equal likelihood of infection by P. tenuis in deer of either sex less than 1-1/2 years of age. There is no difference between sexes in severity of infections in deer less than 1-1/2 years old.

(9) There is not an equal likelihood of infection by P. tenuis in deer of either sex older than 1-1/2 years. Females older than 1-1/2 years of age had significantly more worms per infection than males of the same age. Female deer 1-1/2 years of age and over had a 80% infection; males of this age category had a 68% infection rate.

(10) There is no relationship between weight and incidence of infection in deer less than 1-1/2 years old or older than 3-1/2 years.

(11) A relationship does exist between the weight of the 1-1/2 to 3-1/2 years age group and incidence of infection in that the heavier deer are more likely to be infected.

(12) The deer less than 1-1/2 years of age have a lower incidence of infection and also have fewer worms per infection than older deer.

(13) There was a significant difference in the incidence of infection between surveyed counties, the differences ranging between 100% in Bath County and 54% in Rockbridge County.

(14) There is no statistically significant difference between the severity of infection in the various counties.

(15) Further research concerning the pathogenic effects of P. tenuis on the White-tailed Deer is imperative prior to employment of any control methods.

(16) P. tenuis may be a serious pathogen, but this research indicates that the deer-P. tenuis relationship is a relatively stable and

common association, with deer populations seldom adversely affected by the parasite.

LITERATURE CITED

Anonymous. 1962. A field method for collecting meningo-worms (Odocoileostrongylus tenuis) from White-tailed Deer (Odocoileus virginianus). Southeastern Cooperative Disease Study, Department of Pathology and Parasitology, School of Veterinary Medicine, University of Georgia, Athens. 15 p. Mimeo.

Alibasoglu, M., D. C. Kradel, and H. W. Dunne. 1961. Cerebral nematodiasis in Pennsylvania deer (Odocoileus virginianus). Cornell Vet. 51:431-441.

Anderson, R. C. 1956. Elaphostrongylus odocoilei Hobmaier and Hobmaier, 1934, in the cranial case of Odocoileus virginianus borealis Miller. Can. J. Zool. 34:167-173.

_____. 1962. The helminth and arthropod parasites of the White-tailed Deer (Odocoileus virginianus): a general review. Trans. Roy. Can. Inst. 34:57-92.

_____. 1963. The incidence, development, and experimental transmission of Pneumostrongylus tenuis Dougherty (Metastrongyloidea: Protostrongylidae) of the meninges of the White-tailed Deer (Odocoileus virginianus borealis) in Ontario. Can. J. Zool. 41:775-792.

_____. 1964. Motor ataxia and paralysis in moose calves infected experimentally with Pneumostrongylus tenuis (Nematoda: Metastrongyloidea). In press.

Burg, W. B., E. A. Baudet, and J. H. Verwey. 1953. Lethal bleeding in the cranial cavity of deer (Cervus elaphus) caused by a nematode, belonging to the family Metastrongylidae. Proc. 15th Intern. Vet. Congr., Stockholm. 1:414-416.

Cheatum, E. L. 1951. Disease in relation to winter mortality of deer in New York. J. Wildl. Mgmt. 15:216-220.

Cowan, I. McT. 1962. Discussion In Cowan, R. L. 1962. Physiology of nutrition as related to deer. Proc. First Natl. White-tailed Deer Disease Symposium. Univ. of Georgia, Athens.:1-8.

Dougherty, E. C. 1944. The nematode lungworms (suborder Strongylina) of North American deer of the genus Odocoileus. Parasitology 36:199-208.

DeGiusti, D. L. 1955. The occurrence of a protostrongylid nematode in the meninges of Michigan deer. J. Parasitology 41:42. (Suppl.)

_____. 1963. Incidence and distribution of Elaphastrongylus odocoilei in Michigan deer herd. J. Parasitology 49:47. (Suppl.)

Gobel, F. C. 1943. Notes on the adults of Protostrongylus coburni in the lungs of White-tailed Deer. J. Parasitology 29:158.

Grundmann, A. W. 1955. Improved methods for preparing and mounting nematodes for study. Turtox News 33:152-153.

Kennedy, P. C., J. H. Whitlock, and S. J. Roberts. 1952. Neurofilariosis, a paralytic disease of sheep: I. Introduction, symptomatology, and pathology. Cornell. Vet. 42:118-124.

Larson, R. W. and M. B. Bryan. 1959. Virginia's Timber. Southeastern Forest Expt. Sta., Asheville, N. C. Forest Survey Release 54. 72 pp.

Raisz, E. J. 1962. Physiographic map of Virginia. The Geographic Press, Maplewood, New Jersey.

Schwangart, F. 1940. (Endemic paresis of red deer and tuberculosis in deer.) In German. Berlin. u. Munchen. Tierarztl. Wchnschr. 6:61-66.

Van Volkenberg, H. L., and A. J. Nicholson. 1943. Parasitism and malnutrition of deer in Texas. J. Wildl. Mgmt. 7:220-223.

Whitlock, J. H. 1952. Neurofilariosis, a paralytic disease of sheep. II. Neurofilaria cornellensis n.g., n. sp. (Nematoda, Filarioidea), a new nematode parasite from the spinal cord of sheep. Cornell Vet. 42:125-132.

_____. 1959. Elaphostrongylus, the proper designation of Neurofilaria. Cornell Vet. 49:3-14.

Appendix Table I. Sex, age, weight, and number of worms per infection of 17 deer collected from Bath County, 1963, N = 17

Specimen number	Sex	Age	Weight	No. of worms
319	M	1-1/2	75	1
316	F	1-1/2	64	2
315	F	1/2	65	10
276	M	1-1/2	68	5
284	F	8-1/2	89	5
320	M	3-1/2	No data	2
38	F	3-1/2	65	4
34	M	1/2	31	1
33	F	1/2	32	1
29	F	3-1/2	84	3
23	F	1/2	55	1
22	F	1-1/2	83	4
8	M	3-1/2	80	3
47	F	3-1/2	77	1
43	F	2-1/2	93	3
30	F	2-1/2	86	1
18	F	7-1/2	64	2

Appendix Table II. Sex, age, weight, and number of worms per infection of 79 deer collected from Craig County, 1963, N = 37

Specimen number	Sex	Age	Weight	No. of worms
153	F	1/2	110	0
336	F	3-1/2	100	10
335	F	1/2	59	2
331	M	1/2	40	4
328	F	5-1/2	96	3
329	F	1/2	35	0
324	F	1/2	40	1
321	F	3-1/2	78	4
123	M	1-1/2	91	1
122	F	1/2	55	0
121	F	4-1/2	90	6
120	F	1/2	59	3
119	F	1-1/2	85	1
118	F	1/2	64	1
117	F	1/2	58	1
116	F	1/2	33	1
115	F	1-1/2	95	1
113	F	1-1/2	95	0
112	M	1/2	50	0
111	F	5-1/2	93	2

Appendix Table II. Sex, age, weight, and number of worms per infection of 79 deer collected from Craig County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
110	F	1-1/2	112	0
107	M	1/2	74	3
105	F	1/2	59	1
104	M	1/2	53	0
103	F	1-1/2	74	5
102	F	1-1/2	93	5
100	F	1/2	49	4
99	F	2-1/2	105	3
98	F	1/2	60	0
97	F	2-1/2	85	6
95	F	1/2	60	0
94	F	4-1/2	No data	3
91	F	1-1/2	89	2
87	F	6-1/2	110	3
114	M	1/2	75	1
108	F	1-1/2	85	4
109	F	2-1/2	95	10
223	F	6-1/2	No data	8
225	F	1-1/2	97	6
226	F	1/2	52	1
227	F	1-1/2	92	12

Appendix Table II. Sex, age, weight, and number of worms per infection of 79 deer collected from Craig County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
228	F	1/2	75	1
229	M	2-1/2	127	3
230	F	1-1/2	75	0
231	F	1-1/2	No data	1
232	M	1-1/2	122	3
233	M	1/2	72	1
234	F	3-1/2	102	6
235	M	1-1/2	85	0
236	F	6-1/2	No data	1
237	M	1/2	57	0
197	F	1/2	62	3
198	F	1-1/2	No data	2
199	F	1/2	No data	1
200	M	1/2	72	0
201	F	1-1/2	127	0
202	F	2-1/2	105	4
203	F	2-1/2	104	13
204	F	2-1/2	110	0
205	F	1/2	59	0
206	F	3-1/2	87	1
208	F	3-1/2	No data	10

Appendix Table II. Sex, age, weight, and number of worms per infection of 79 deer collected from Craig County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
209	F	2-1/2	103	8
210	M	1/2	56	1
211	F	1/2	57	0
212	M	1/2	55	0
213	F	1-1/2	102	0
214	F	1/2	57	1
215	F	1-1/2	No data	4
216	F	2-1/2	96	8
217	M	1/2	56	2
218	F	1/2	56	1
219	M	1/2	75	0
220	M	1-1/2	70	9
221	F	1-1/2	70	3
222	F	2-1/2	104	3
149	M	1-1/2	85	8
106	F	1-1/2	95	7
224	F	1-1/2	104	7

Appendix Table III. Sex, age, weight, and number of worms per infection of 21 deer collected from Shenandoah County, 1963, N = 21

Specimen number	Sex	Age	Weight	No. of worms
253	F	1-1/2	84	0
251	F	1-1/2	94	3
247	F	2-1/2	99	0
244	F	1/2	55	1
243	F	2-1/2	108	5
241	F	1/2	No data	0
240	F	1-1/2	60	3
41	M	1/2	63	4
40	M	1/2	68	1
39	F	1-1/2	78	3
35	F	1/2	56	1
32	M	1/2	60	0
28	F	1-1/2	80	2
26	F	3-1/2	81	2
25	F	1/2	97	1
21	M	1-1/2	No data	2
20	F	1/2	77	0
13	F	1-1/2	71	0
5	F	3-1/2	84	0
4	F	2-1/2	86	8
19	F	1-1/2	66	5

Appendix Table IV. Sex, age, weight, and number of worms per infection of 35 deer collected from Rockbridge County, 1963, N = 35

Specimen number	Sex	Age	Weight	No. of worms
274	M	1/2	65	0
275	M	1/2	55	0
277	M	2-1/2	125	2
278	M	1/2	63	5
279	M	1-1/2	88	0
280	F	1-1/2	99	2
281	F	2-1/2	91	0
282	M	1-1/2	95	1
283	F	3-1/2	91	3
285	F	1/2	50	3
286	M	1/2	64	2
287	F	1/2	76	6
288	F	6-1/2	112	1
289	M	1/2	72	3
290	F	3-1/2	116	0
291	F	1-1/2	73	0
292	F	3-1/2	110	4
293	F	2-1/2	109	4
294	F	3-1/2	94	7
295	F	3-1/2	110	0
296	F	1/2	60	10

Appendix Table IV. Sex, age, weight, and number of worms per infection of 35 deer collected from Rockbridge County, 1963, N = 35 (continued)

Specimen number	Sex	Age	Weight	No. of worms
297	M	1-1/2	99	0
298	F	1-1/2	104	5
299	F	1/2	73	0
300	M	1-1/2	110	0
301	F	1/2	63	1
302	M	1-1/2	83	0
303	M	1-1/2	103	0
304	F	8-1/2	85	1
305	M	1-1/2	100	0
307	M	1/2	55	0
308	F	1/2	72	5
309	F	1-1/2	84	0
310	F	4-1/2	No data	5
314	F	1-1/2	83	0

Appendix Table V. Sex, age, weight, and number of worms per infection of 28 deer collected from Botetourt County, 1963, N = 28

Specimen number	Sex	Age	Weight	No. of worms
83	F	1-1/2	86	0
82	F	2-1/2	80	7
81	F	1-1/2	90	4
79	F	1/2	56	0
78	M	1/2	56	3
77	M	1/2	66	1
76	F	1-1/2	66	0
75	F	1-1/2	60	3
73	M	1/2	58	1
71	M	1-1/2	85	0
72	M	1-1/2	66	0
70	M	1/2	44	2
69	F	5-1/2	78	1
68	F	1-1/2	62	4
67	F	1/2	42	0
66	M	1/2	38	2
207	F	1/2	60	5
80	F	3-1/2	71	3
74	F	1-1/2	No data	7
339	F	1-1/2	66	3
338	F	5-1/2	No data	4

Appendix Table V. Sex, age, weight, and number of worms per infection of 28 deer collected from Botetourt County, 1963, N = 28 (continued)

Specimen number	Sex	Age	Weight	No. of worms
337	F	3-1/2	66	4
334	F	1-1/2	61	5
333	F	1/2	No data	0
330	F	5-1/2	67	1
327	F	2-1/2	No data	4
326	F	1-1/2	No data	1
323	F	2-1/2	78	1

Appendix Table VI. Sex, age, weight, and number of worms per infection of 77 deer collected from Augusta County, 1963, N = 37

Specimen number	Sex	Age	Weight	No. of worms
238	F	4-1/2	No data	0
306	F	1-1/2	No data	3
273	F	1/2	No data	0
272	F	1/2	50	0
271	F	5-1/2	87	0
270	F	1-1/2	No data	5
269	M	1/2	65	0
268	F	3-1/2	93	1
267	F	1-1/2	No data	0
266	M	1/2	No data	0
265	F	1/2	No data	0
264	F	1-1/2	No data	5
263	M	2-1/2	100	0
262	F	5-1/2	No data	5
261	M	1-1/2	92	4
260	F	4-1/2	119	2
259	F	3-1/2	82	3
258	F	1/2	60	1
257	F	1-1/2	97	3
256	F	1/2	55	0
255	F	7-1/2	No data	2

Appendix Table VI. Sex, age, weight, and number of worms per infection of 77 deer collected from Augusta County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
252	F	4-1/2	97	4
249	M	1/2	No data	6
246	F	3-1/2	No data	4
245	F	6-1/2	96	1
242	F	1-1/2	80	12
46	F	3-1/2	90	0
45	F	1/2	60	0
42	F	1-1/2	70	1
174	F	6-1/2	102	5
175	F	1-1/2	103	2
176	F	5-1/2	111	0
177	F	1-1/2	No data	0
178	F	6-1/2	No data	7
179	M	1/2	72	0
180	M	1-1/2	98	3
181	F	1-1/2	76	0
182	M	1/2	65	1
183	M	1-1/2	70	1
184	F	1/2	63	3
185	F	1/2	53	1
187	M	2-1/2	No data	3

Appendix Table VI. Sex, age, weight, and number of worms per infection of 77 deer collected from Augusta County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
188	F	1-1/2	96	1
189	M	2-1/2	97	1
190	F	1/2	62	1
191	F	2-1/2	97	9
192	F	2-1/2	107	0
193	F	1-1/2	79	3
194	M	1/2	70	0
195	F	1/2	69	1
150	F	4-1/2	105	3
152	M	1-1/2	92	7
154	F	1/2	60	4
196	F	6-1/2	102	1
155	F	2-1/2	97	10
156	F	1/2	64	0
157	F	1/2	60	1
158	F	3-1/2	97	5
159	F	1-1/2	85	1
160	M	1-1/2	89	0
161	F	5-1/2	No data	2
162	M	1/2	64	0

Appendix Table VI. Sex, age, weight, and number of worms per infection of 77 deer collected from Augusta County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
164	F	1/2	73	0
163	M	1/2	67	0
166	F	1-1/2	114	0
168	F	5-1/2	85	5
169	F	1/2	52	0
170	F	4-1/2	85	8
165	F	1-1/2	72	11
171	M	1/2	64	0
172	F	1-1/2	No data	2
173	F	1-1/2	No data	7
317	M	1/2	No data	0
318	M	1-1/2	98	7
313	F	3-1/2	92	1
311	F	2-1/2	No data	7
312	F	4-1/2	77	5

Appendix Table VII. Sex, age, weight, and number of worms per infection for 52 deer collected in Giles County, 1963, N = 37

Specimen number	Sex	Age	Weight	No. of worms
332	M	1/2	72	1
85	F	1-1/2	89	7
84	F	1-1/2	89	0
124	M	2-1/2	127	0
101	F	3-1/2	107	1
92	F	2-1/2	110	3
90	F	1/2	No data	2
88	F	1-1/2	No data	1
86	F	1/2	54	2
65	F	1/2	67	1
64	F	1/2	No data	3
63	M	1-1/2	No data	8
61	F	1-1/2	No data	0
59	M	1/2	No data	4
58	M	2-1/2	No data	3
57	F	3-1/2	147	3
56	M	1/2	63	1
55	F	1/2	100	5
54	F	1/2	No data	1
53	F	1/2	No data	2
52	F	1/2	No data	6

Appendix Table VII. Sex, age, weight, and number of worms per infection for 52 deer collected in Giles County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
51	M	1/2	No data	3
49	F	2-1/2	No data	0
48	F	2-1/2	No data	1
137	F	1/2	67	1
138	F	1/2	51	2
139	F	1-1/2	69	0
140	F	2-1/2	78	4
141	F	1/2	No data	0
142	M	1/2	54	8
143	F	1/2	56	0
144	F	1-1/2	85	3
145	F	1-1/2	81	7
146	F	1/2	60	0
147	F	2-1/2	99	6
148	F	1/2	75	2
125	M	1/2	50	1
126	F	7-1/2	92	6
127	M	1-1/2	100	2
128	M	1-1/2	89	7
129	M	1/2	53	3
130	M	1-1/2	97	1

Appendix Table VII. Sex, age, weight, and number of worms per infection for 52 deer collected in Giles County, 1963, N = 37 (continued)

Specimen number	Sex	Age	Weight	No. of worms
131	M	1-1/2	94	1
132	F	4-1/2	100	1
133	F	1/2	54	1
134	M	1-1/2	81	2
135	F	3-1/2	98	2
93	F	5-1/2	119	8
62	F	1-1/2	No data	13
60	F	1-1/2	No data	1
50	F	1-1/2	92	3
44	M	1-1/2	99	1

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ABSTRACT

of

THE INCIDENCE AND DEGREE OF INFECTION OF PNEUMOSTRONGYLUS TENUIS IN THE WHITE-TAILED DEER OF WESTERN VIRGINIA

by

Daniel Dudak

Thesis submitted to the Graduate Faculty of the

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in candidacy for the degree of

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ABSTRACT

This investigation was concerned with the incidence and degree of infection by P. tenuis in western Virginia deer herds (Odocoileus virginianus). Relatively little research has been done on P. tenuis in Virginia, especially in the western portion of the state.

The objectives of this study were (1) to determine the distribution of pneumostrongylids in the White-tailed Deer in 7 western Virginia counties and (2) to correlate incidence and degree of infection by pneumostrongylids with deer age, sex, geographic location, and physical condition.

Specimens were collected from Shenandoah, Augusta, Bath, Rockbridge, Botetourt, Giles, and Craig Counties. Collections were made on the first day of the 1963 deer season. Biologists and students from the Department of Forestry and Wildlife at V. P. I. and the Virginia Commission of Game and Inland Fisheries collected deer heads from hunters at check stations. A sample of 369 heads of both sexes was obtained.

Three-hundred and nine deer heads, 230 does and 79 bucks, were examined for P. tenuis. Seventy-three per cent were infected. The majority of the worms (68%) were found on the dorsal surface of the brain. Overall range of infection was 1-13 worms. In addition, lung and fecal specimens were collected. Fifty per cent of the lung specimens were infected, but no larvae were found in the fecal material.

There appears to be an equal likelihood of infection by P. tenuis in deer of either sex less than 1-1/2 years of age. There is also no

difference between sexes in the severity of infections in deer less than 1-1/2 years old. Deer of either sex older than 3-1/2 years also have an equal likelihood of infection by P. tenuis, but females between 1-1/2 and 3-1/2 years are more likely to be infected than males. Females older than 1-1/2 years of age had significantly more worms per infection than males of the same age. There is no relationship between weight and incidence of infection in deer less than 1-1/2 years old or older than 3-1/2 years. However, a relationship does exist between the weight of the 1-1/2 to 3-1/2 years age group and the incidence of infection in that the heavier deer are more likely to be infected. The deer less than 1-1/2 years of age have a lower incidence of infection than older deer and have fewer worms per infection than older deer.

There was a significant difference in the incidence of infection between surveyed counties; however, there is no statistically significant difference between counties and the severity of infections.

Further research concerning pathogenic effects of P. tenuis on the White-tailed Deer is imperative prior to employment of any control methods. P. tenuis may be a serious pathogen, but this research indicates that the deer-P. tenuis relationship is a relatively stable and common association with deer populations seldom adversely affected by the parasites.