measurements meaningless. Therefore, this prediction equation was considered inadequate as an index to antler size.

For antlers with measurements common to all antler types, the prediction equation (3b) had an R^2 of 0.9677. This equation contained three linear variables and the non-linear effect of each variable: length of main beam, smallest diameter one inch above burr, and average diameter one inch above burr. The non-linear effect of the length of main beam showed the highest F value in the prediction equation. Although equation 3b contained three independent variables, there were actually only two linear measurements: length of the main beam and diameter one inch above burr. Both of these measurements could be taken with very few exceptions. In the regression analysis of this equation, a single measurement, the non-linear effect of length of main beam, gave an R^2 of 0.9182. This high value pointed to the possibility of using a single antler measurement as an index to antler development. In equation 3b, the addition of one other variable, the non-linear effect of smallest diameter one inch above burr, increased the value of R^2 to 0.9543, a considerable increase. Further addition to the prediction equation of the non-linear effect of average diameter one inch above burr gave an R^2 of 0.9677, a small increase.

Using foregoing criteria for judging the "best" prediction equation to determine total volume of deer antler, the equation that was considered applicable to virtually all antler types (3b) appeared to rank first. Should a single antler measurement be used to evaluate antler development, the length of main beam or average diameter one inch above burr appeared to be about equally effective.

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THE INCIDENCE AND DEGREE OF INFECTION OF *PNEUMOSTRONGYLUS TENUIS* IN THE WHITE-TAILED DEER OF WESTERN VIRGINIA[1]

By

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[1] This investigation was conducted as part of a Master of Science graduate program.

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ABSTRACT

The incidence and degree of infection by *P. tenuis* was studied in western Virginia deer herds *(Odocoileus virginianus).*

The objectives of the research 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.

Specimens were collected from Shenandoah, Augusta, Bath, Rockbridge, Botetourt, Giles, and Craig counties. Deer heads were obtained from hunters at check stations.

Three-hundred and nine deer heads, 230 does and 79 bucks, were examined for *P. tenuis* and 73% were infected. The majority of the worms (68%) were found on the dorsal surface of the brain. The 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 appeared to be an equal likelihood of infection by *P. tenuis* in deer of either sex less than 1½ years of age. There was no difference between sexes in the severity of infections in deer less than 1½ years old. Deer of either sex older than 3½ years also had an equal likelihood of infection by *P. tenuis,* but females between 1½ and 3½ years were more likely to be infected than males. Females older than 1½ years of age had significantly more worms per infection than males of the same age. There was no relationship between weight and incidence of infection in deer less than 1½ years or older than 3½ years. However, a relationship did exist between the weight of the 1½ to 3½ years age group and the incidence of infection, in that the heavier deer were more likely to be infected. Deer less than 1½ years of age had a lower incidence of infection than older deer and fewer worms per infection than older deer.

There was a significant difference in the incidence of infection between surveyed counties; however, there was no statistically significant difference between counties in 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 host populations seldom adversely affected by the parasites.

INTRODUCTION AND LITERATURE REVIEW

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: Strongylides) 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 sought-after big game animal in the state.

The objectives of the research 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.

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.

Anderson (1963) described the life cycle of *P. tenuis.* Anderson further elucidates the life cycle and pathogenicity in his later reports (1964 and 1965). The following species of land snails are suitable intermediate hosts: (1) *Discus cronkhitei,* (2) *Zonitoides arboreus,*

(3) *Deroceras gracile*, (4) *Stenotrema fraternum*, (5) *Triodopsis albolabris*, (6) *Anguispira alternata* (Anderson, 1963).

Dougherty (1945) first described *P. tenuis* from a male specimen found within the bronchiole of a deer in New York. Kennedy et al. (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. Symptoms associated with massive *P. tenuis* infections are neuroparalysis and blindness (Burg, et al., 1953; DeGiusti, 1955; Schwangart, 1940). 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, et al. (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, and he 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).

METHODS

Sample Selection and Location

Specimens were collected at check stations in seven southwestern Virginia counties: Augusta, Bath, Botetourt, Craig, Giles, Rockbridge, and Shenandoah. (Figure 1.)

The counties sampled were selected on the basis of location, anticipated high deer kill, and assured manpower at big game check stations. Deer heads, lung specimens, and fecal material were collected at the checking stations.

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 degrees F. in January and a high of 74 degrees 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 Byran, 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).

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.

Successful hunters, when checking their deer at selected stations, were asked to 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.

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

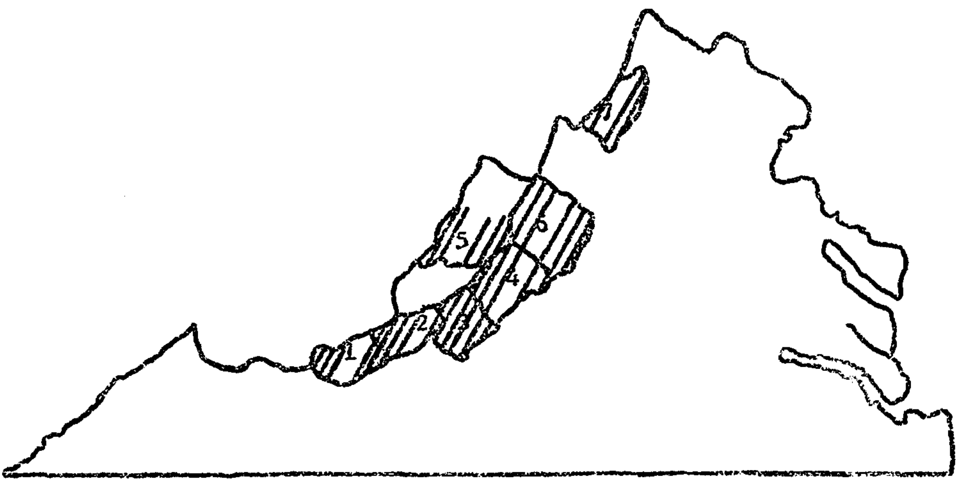


Figure 1. Location of 7 counties sampled for *Pneumostrongylus tenuis* in southwestern Virginia, 1963: (1) Craig; (2) Giles; (3) Botetourt; (4) Rockbridge; (5) Bath; (6) Augusta; (7) Shenandoah.

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 sagitally sectioned immediately after being removed from freezer storage.
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.
4. Suspicious hemorrhagic and discolored areas of the meninges were subjected to dissection to locate hidden parasites.
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 diagrammed and made part of the necropsy records.

Examination of Lung Specimens

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. 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 embedded in paraffin and sections 10 microns in thickness were cut with a microtome. Tissue ribbons were mounted on microscope slides with albumen fixative. Hematoxylin and eosin were used to stain slides. Thirty slides, with several ribbon sections on each, encompassing lung sections from 30 individual deer, were examined for parasite eggs and larvae with a Bausch and Lomb Dyna-Zoom microscope using 100x magnification. Notes were taken on slide observations: location, number and size of parasite eggs and larvae.

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 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 stations. 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 incomplete. Table 1 presents sex, age, and infection data for the 309 deer examined. The overall data revealed 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 1½ years of age were 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 1½ years and 1½ years and older. In the less than 1½ 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 1½ years old was 2.1 (s = ± 1.8), while the mean number of worms per infected buck was 2.4 (s = ± 1.8). The mean number of worms per infected doe 1½ years of age and over was 4.0 (s=±2.9), while the mean number of worms per infected buck was 2.9 (s=±2.1). In the total sample, 65% of the males carried a mean 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 1½ 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 appeared to be an equal likelihood of infection by *P. tenuis* in deer of either sex, at least in the deer less than 1½ years old.

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	½	16	29	2.4	1.8	0.33	1-8
F	½	24	40	2.1	1.8	0.29	1-10
M	1½	9	19	3.0	2.6	0.59	1-9
F	1½	19	54	4.4	2.8	0.38	1-13
M	2½	2	2	2.5	0.2	0.05	2-3
F	2½	7	27	5.0	3.8	0.73	1-10
M	3½	0	2	2.5	0.2	0.05	2-3
F	3½	4	21	3.9	1.6	0.34	1-10
F	4½	1	9	4.1	1.5	0.49	1-8
F	5½	2	9	3.4	2.3	0.76	1-8
F	6½	0	8	3.4	2.6	0.93	1-8
F	7½	0	3	3.3	2.3	1.34	2-6
F	8½	0	2	3.0	2.8	1.99	1-5
Total		84	225	x_n=3.4	s_n=2.6	s_x0.56	1-13

Table 2. Infection by sex and age for 309 deer heads, southwestern Virginia, 1963.

	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	45	34	64	166
Number infected	29	23	40	133
Per cent infected	64	68	63	80
Mean infection	2.4	2.9	2.1	4.0

A null hypothesis was tested that among animals older than 1½ 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 small sample size on male deer over 1½ years old (34), this test may have been invalid. However, the data are suggestive of a greater incidence of infection in females (80%) than in males (68%). (Figure 2.)

The relationship between severity of infection and sex was examined. The null hypothesis was tested that among deer less than 1½ years of age, there is no significant difference between male and female deer in the number of worms per infection.

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

The null hypothesis was tested that among deer 1½ years of age and older there are 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 (2df). The hypothesis was, therefore, rejected at the 95% confidence level.

It would appear that within the less than 1½ years 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.

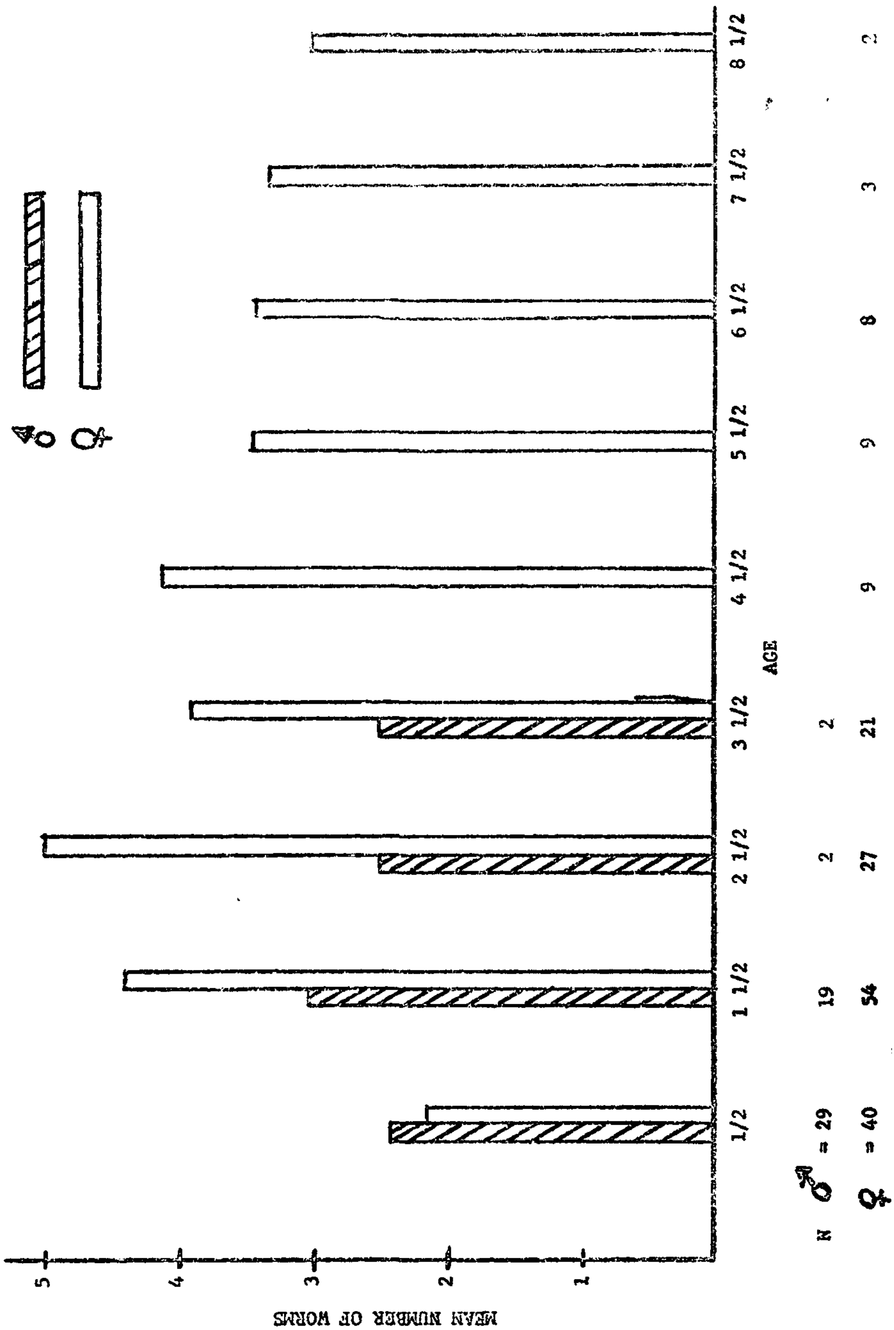
The Incidence and Degree of Infection by P. tenuis Relative to Host's Weight.

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.

Various age classes were equally likely to be represented in the different samples, with the exception of a bias from hunters 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.

Since weights varied significantly between counties, all deer were arranged into three classes — less than 1½ years, between 1½ and 3½, and 3½ years and older. The mean weight of field-dressed deer of the less than 1½ 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 2½ to 3½ and 3½ and older, from all counties, was 84 ($s = \pm 3.6$) pounds and 93 ($s = \pm 9.7$) pounds, respectively. 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. 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 1½ years and the 3½ 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 appeared to exist between the weight of the 1½ to 3½ year age group and incidence of infection in that the null hypothesis was rejected at the 99% confidence level. Thus, animals in

Fig. 2. Intensity of Infection by Sex and Age of 225 Virginia Deer.



all three age classes were not equally likely to be infected regardless of their weight.

Even though it is not 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 (Figure 3). 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 1½ years old, between 1½ and 3½ years old, and 3½ years old and older. 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 seven 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 hypothesis could not be rejected when $p = 0.10$. The plotting of nematodes per infection against weight (Figure 3), however, shows an increase in the intensity of infection with weight (or age) that may be nonetheless real, if not statistically significant.

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 1½ years old was 69 (63%) of 109 deer examined, while the number of infected deer older than 1½ 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 1½ years old and those older than 1½ 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 1½ years old had a lower incidence of infection than older deer (Figure 2).

In the infected deer less than 1½ 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 (Figure 2).

The null hypothesis was tested that there is no difference in severity of infection between deer less than 1½ years old and those older than 1½ 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 1½ years old were less likely to be heavily infected by *P. tenuis.*

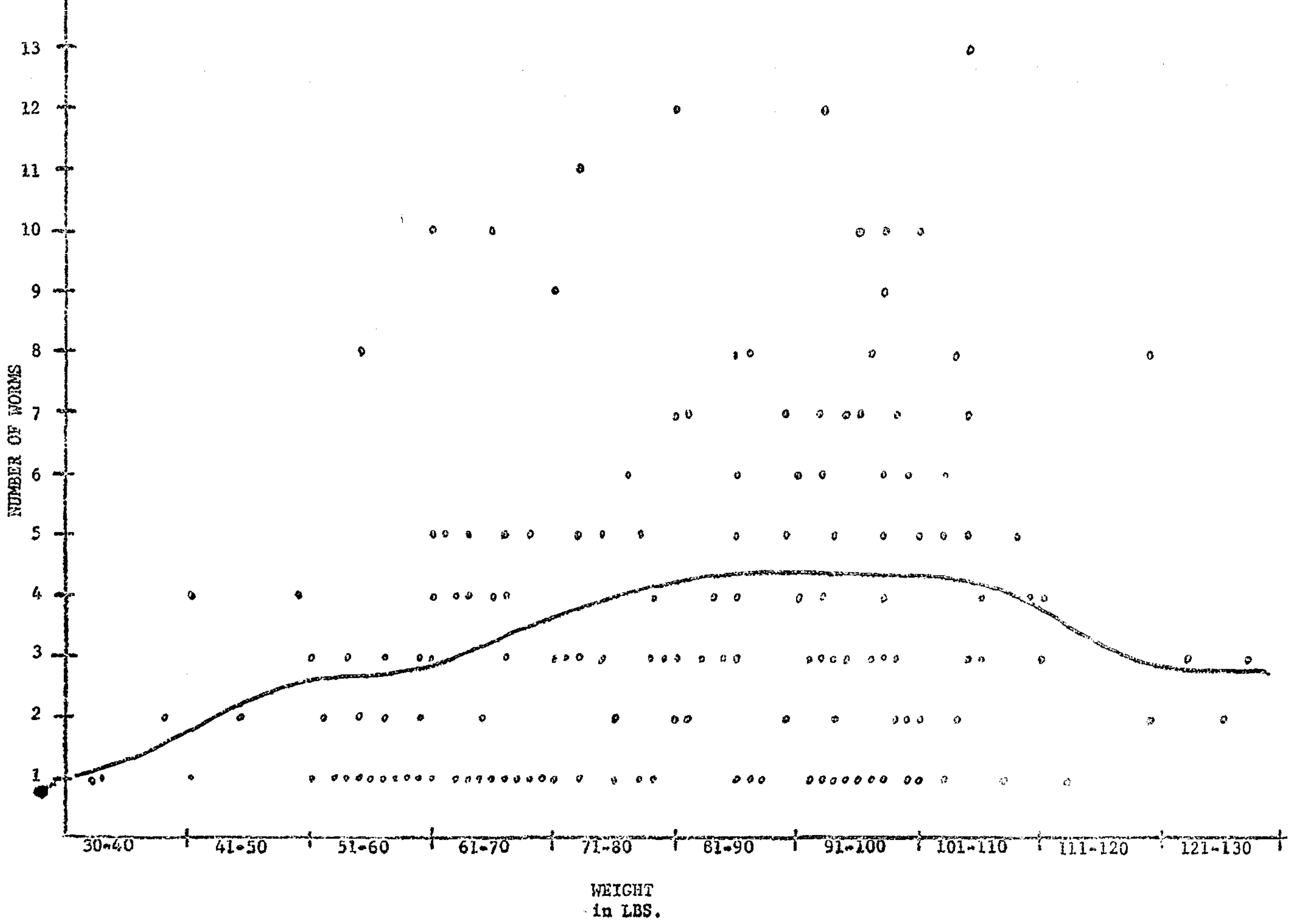
The Incidence and Degree of Infection by Counties

The incidence and intensity of infection within the surveyed counties appeared to differ significantly (Table 3). The incidence of infection by counties was: Bath, 17/17 (100%) with a mean infection of 2.9 ($s = \pm 2.3$); Giles, 44/52 (85%) with a mean infection of 3.3 ($s = \pm 2.8$); Botetourt, 21/28 (78%) with a mean infection of 2.8 ($s = \pm 2.4$); Craig, 60/79 (76%) with a mean infection of 4.0 ($s = \pm 3.2$); Shenandoah, 14/21 (66%) with a mean infection of 2.9 ($s = \pm 2.0$); Augusta, 50/77 (65%) with a mean infection of 3.7 ($s = \pm 1.5$); Rockbridge, 19/35 (54%) with a mean infection of 3.7 ($s = \pm 2.5$) (Table 3). 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 incidence 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). The null hypothesis could not be rejected when $p = 0.10$. There did not seem to be a significant difference between counties and the number of worms per infection. The smallest parasite populations per infection generally

Fig. 3. The Relationship Between Deer Weight and Intensity of Infection for 184 Deer.



occurred in those counties with the highest incidence of infected deer (Table 3).

Gross Lesions

The 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 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 was 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 ventural surface of the pia mater, located superior on the brain, without any observable membrane damage.

Table 3. Examination of 309 deer heads from seven southwestern Virginia Counties, 1963.

County	No. deer examined	No. infected	Per cent infected	Mean No. worms/infection
Shenandoah	21	14	66	2.9
Rockbridge	35	19	54	3.7
Botetourt	28	21	78	2.8
Craig	79	60	76	4.0
Giles	52	44	85	3.3
Bath	17	17	100	2.9
Augusta	77	50	65	3.7
Total	309	225	73	3.4

Thirty-five infected animals, with 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 infections of 7-13 worms in 15 animals. In 13 infected animals, the origin of hemorrhaging was difficult to ascertain.

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 alveoli 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 was 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 1½ 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 1½ years of age and over. Males of this same age group had an infection rate of 68%.

Females older than 1½ 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 related to sex 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 1½ and 3½ 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 1½ years and older than 3½ years. Doe deer in these age groups may be less productive than those between 1½ and 3½ 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 statistically related to body weight within age groups. The raw data, however, shows a significant increase in the intensity of infection with increasing host weight (Figure 3). The amount and source of ingested food may be contributing factors. The examined deer were fat 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 1½ 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 1½ 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 nutrition 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 deer from 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.

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 data tag was lost or incomplete.

(2) A total of 309 deer heads was 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) Infection by *P. tenuis* in the deer herds of western Virginia was general, with 70% to 80% of the population infected.

(8) There appeared to be an equal likelihood of infection by *P. tenuis* in deer of either sex less than 1½ years of age. There was no difference between sexes in severity of infections in deer less than 1½ years old.

(9) There was not an equal likelihood of infection by *P. tenuis* in deer of either sex older than 1½ years. Females older than 1½ years of age had significantly more worms per infection than males of the same age. Female deer 1½ years of age and over had an 80% infection rate while males of this age category displayed a 68% infection rate.

(10) There was no statistically significant relationship between weight and incidence of infection in deer less than 1½ years old or older than 3½ years.

(11) A relationship did exist between the weight of the 1½ to 3½ years age group and incidence of infection in that the heavier deer were more likely to be infected.

(12) The deer less than 1½ years of age had a lower incidence of infection and also 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% infected in Bath County and 54% in Rockbridge County.

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

(15) *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.

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EFFECTS OF VARIOUS OPENING DAYS ON DEER HARVEST AND HUNTING PRESSURE

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Establishment of deer hunting regulations is relatively uncomplicated throughout most of the southern United States at the present time. The choice is usually between bucks-only or any-deer harvests. Deer hunting regulations will undoubtedly become more complex as numbers of deer and hunters increase. More sophisticated variations in hunting regulations such as zoning and variation of opening day

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