THE PREVALENCE OF CANINE HEARTWORM (*DIROFILARIA IMMITIS*) INFECTION IN NORTH-CENTRAL OKLAHOMA

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PREFACE

In this study I have attempted to determine the current prevalence of canine heartworm infection in north-central Oklahoma, and to compare the results with those from previous studies. My primary objective was to determine if there has been an actual increase in the infection rate in the area.

I wish to extend my thanks to my major adviser, Dr. Helen E. Jordan, for her expert guidance, and unwavering patience and friendship during the course of this research project. Her encouragement and friendship throughout my association with Oklahoma State University has been invaluable.

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CHAPTER I

INTRODUCTION

Canine heartworm disease is caused by Dirofilaria immitis, a nematode transmitted by mosquitoes. The infection may lead to a number of clinical maladies and even death. Although D. immitis has been reported in many mammals including human beings, the most common natural host is the domestic dog, Canis familiaris. Otto and Jackson (1975), in a review of canine heartworm, reported that the parasite was first described by Leidy (1856), who worked in Pennsylvania. This description was based on specimens from two dogs believed to be from Georgia. They further report that in 1911 Railliet and Henry erected the genus Dirofilaria and named the species D. immitis.

Treatment for heartworm infection is very involved and risky for the dog. Prevention of the infection is a better tactic than is taking corrective measures after infections occur. Preventive measures include administration of chemicals to the dog on a regular basis to kill the developing larvae of the worm. The current recommendation by the American Veterinary Medical Association for dogs is preventive treatment

for dogs in endemic areas. Unfortunately, in regions where heartworm has not been recognized or is considered by local veterinarians to have an insignificant prevalence, many dogs needing preventive measures will go untreated.

Prevention of heartworm infection can be accomplished only if the introduction of the parasite into a region and its prevalence have been determined and brought to the attention of veterinarians concerned with its management. Endemic heartworm infection in north-central Oklahoma was not recognized until the mid-1960s, as reported by Pennington (1972). By the mid-1970s some veterinarians were claiming prevalence rates of 25 percent and higher.

The purposes of the present study were to establish the current prevalence of D. immitis in north-central Oklahoma, to provide a basis for comparing future increases or decreases in prevalence, and to classify heartworm infections according to age, breed, sex, weight, and length of coat of dogs found to be naturally infected.

CHAPTER II

LITERATURE REVIEW

Early Studies

Early studies on canine heartworm prevalence have been limited and in some cases compromised due to failure to differentiate the microfilariae of Dirofilaria immitis from those of Dipetalonema reconditum. As early as 1939, two distinct species of microfilariae were suspected when Mundhenk and Greene (1939) found microfilariae in 76 percent of 200 animal shelter dogs in Alabama, but only 1 percent of the dogs harbored adult heartworms at necropsy. Almost twenty years later, Newton and Wright (1956) correctly identified the two distinct species of microfilariae which occurred in the circulating blood of dogs. Their studies demonstrated major morphological differences between Dirofilaria immitis and Dipetalonema reconditum, the former transmitted by mosquitoes with adult worms living in the heart and the latter transmitted by fleas and being a smaller filarial worm living in the subcutaneous tissues and producing little or no pathologic change.

Diagnostic Procedures

Diagnosis of dirofilariasis in the dog generally is based on detection of circulating microfilariae in the peripheral blood or on radiographic signs of specific pulmonary vasculature or cardiac changes. To enhance chances of detection of microfilariae, concentration techniques, such as a modified Knott's method as reviewed by Jackson and Otto (1975) or a filter technique as discussed by Wylie (1970) and compared by Noyes (1978) may be used. Even so, a large proportion of infected dogs may not be detected.

Differentiation must be made between microfilariae of heartworm (Dirofilaria immitis), Dipetalonema reconditum or other microfilariae. Methods of differentiating the microfilariae were reviewed by Redington et al. (1978) at the Heartworm Symposium in 1977. In a direct saline mount of fresh blood, microfilariae of heartworm are generally numerous and undulate in one place. In contrast, microfilariae of D. reconditum are generally few and tend to exhibit progressive movement. Using a modified Knott's method, heartworm microfilariae generally appear straight with a straight tail and tapered head while those of D. reconditum are curved and have a blunt head and a curved or button-hook tail. Using a modified Knott's method, body size of D. immitis microfilariae

averages 313 microns long, ranging from 307-322, and 6.7-7.1 microns wide. Microfilariae of D. reconditum average 270 microns long, ranging from 269-283, and 4.3-4.8 microns wide, according to Lindsey (1962).

Life Cycle

Canine heartworms are completely dependent on mosquitoes for transmission. Ludlam, et al. (1970) reported that as many as 60 different species of mosquitoes are known to be vectors of the parasite. Otto and Jackson (1975), in a review of the development and growth of the heartworm, report that the active microfilariae, which are present in the blood of an infected dog, are ingested when the female mosquito takes a blood meal. Once inside the mosquito, the microfilariae migrate to the malpighian tubules. After further development, the infective larval stage moves toward the mouth of the mosquito. Escaping from the mouth parts of the mosquito as it feeds on the dog, the infective larva passes into the puncture wound and travels through the mucous membrane to continue development in or beneath the muscle membrane or the subserosa of veins where it grows rapidly and molts twice before arriving in the right ventricle of the dog's heart. The worms may remain in the heart and vessels for months to years.

General Distribution

Dirofilaria immitis is enzootic in most tropical and subtropical zones of the world. The parasite is recognized as being widespread, particularly in the Far East, southern Europe, northern Africa and North America, as well as in the Pacific and Caribbean Islands, according to Otto and Jackson (1975).

During the 1950s, canine heartworm in North America was recognized as a serious problem only within 50-75 miles of the eastern seacoast. According to a review by Otto (1974), the range extended south from New Jersey along the Atlantic Coast states to Florida and along the Gulf Coast states to Texas. Surveys conducted before mid-1950 were generally confined to the Southeast where high prevalence rates of the organism were found in central and coastal cities in Florida, Louisiana and Georgia. The consensus was that the parasite was enzootic to those areas. Only isolated cases were reported elsewhere and were considered to be too few in number to be significant.

Studies conducted in the late 1960s and early 1970s raised the possibility that the parasite distribution was spreading northward and inland. A significant, but low rate of prevalence of D. immitis infection was reported in Massachusetts, Connecticut, and Rhode Island. Mallack et al. (1971) reported a high

prevalence rate for the infection in Maryland, but results were clouded by the fact that all the dogs found to be parasitized were American and Walker foxhounds from three hunt clubs located in swampy tidal areas of the Patuxent River.

Rothstein (1961) reported after a survey of military sentry dogs in the United States that 12.2 percent of 1,026 dogs had microfilariae of D. immitis, with the highest prevalence (38%) located in the southeastern states.

By 1980, the nationwide prevalence pattern of D. immitis infection showed a definite increase. In addition to the coastal regions where the infection was already well established, heartworm had moved inland along the Mississippi River and its tributaries into the Midwest of the United States and across the border into Canada.

Slocombe and McMillan (1981) reported at the 1980 Heartworm Symposium on the results of a mail-out survey to Canadian veterinarians on their findings of dogs checked for microfilariae. Replies showed little change in distribution during the last decade. The disease was diagnosed throughout Canada except Newfoundland, Prince Edward Island and New Brunswick. Most cases were reported in Ontario. Two foci of infection existed, one in Manitoba and the other in southwestern Ontario. The

majority of the heartworm cases were found in companion dogs older than three years that were kept outdoors in either rural or suburban areas.

The insidious nature of canine heartworm disease is of major concern. The reporting of the increased prevalence of the disease in areas such as Michigan, Minnesota, and Illinois, which are neither coastal nor tropical areas, has given rise to several theories for the apparent movement inland and northward of this tropical and subtropical infection.

Various reasons which have been used to explain why heartworm was endemic primarily to the warmer climates were reviewed by Otto (1975). Reasons included the suggestion that a temperature of 70°F (21°C) or above for a period of 10-14 days was necessary for the microfilariae to reach the larval stage in the mosquito. Reasons for the movement of the infection into new areas include that the disease was being transmitted from southern to northern climes by way of canine travel, then established in the local dog population. Another hypothesis was that a decline in pesticide use because of environmental hazards had resulted in an increased mosquito population and subsequent canine infections. The suggestion has been offered by Otto that genetic adaptation or mutation in the mosquito has occurred which allowed incubation of

microfilariae at lower temperatures. The parasite seems to have adapted to colder climates, as evidenced by two recent studies. Hendrix et al. (1981) reported on the temperature effects on the development of D. immitis in Aedes vexans, the mosquito host found in large numbers in Minnesota. Using two cages, one placed outdoors and the other in a controlled environmental chamber, it was demonstrated that a sustained temperature above 70°F for 10-14 days was not necessary for development of larvae to the infective stage, although development was slowed as the temperatures dropped. Larvae were even found to have survived within infected, but dead, mosquitoes that were held in a freezing solution. When the dead frozen mosquitoes were thawed and dissected, live third-stage larvae were found in the mouth parts. The supposition was that if a mosquito adapts to a specific climate sufficiently well to feed and to survive, then transmission of the larval heartworm may be possible at a much lower temperature than previously believed possible.

Ernst and Slocombe (1983) reported similar results in their study using naturally infected dogs from Ontario and Georgia. They concluded that larvae of D. immitis could tolerate the same temperature extremes as the mosquitoes.

Heartworm Surveys

California

Weinman and Garcia (1980) conducted a survey of the prevalence of heartworms in coyotes in California. Their findings showed 44.8 percent of mature coyotes examined were positive for the nematode. They concluded that the coyote could serve as an important reservoir host in the area due to the high prevalence rate of the worm and the large coyote population with its close proximity to human habitation and an abundance of outdoor dogs. They also reviewed previous reports for the area which included a 1970 survey of 515 animal shelter dogs and 800 beagles kenneled out-of-doors with no positive animals found in either group. They further reported that records from the School of Veterinary Medicine at Davis revealed only twelve confirmed cases of heartworm in the area during the period 1957 to 1968. A 1976 report they examined showed a local prevalence rate of 11-12 percent in adult outdoor dogs. They commented that it was not clear how much of the sharp rise in prevalence rates seen in the area was really due to increased transmission and how much reflected increased surveillance by practitioners.

Leftwich and Carey (1981) reported that tests done in 1980 on 500 animal shelter dogs and on 1,462 dogs in

area veterinary clinics in Solano and Napa counties in California showed a prevalence rate of D. immitis of 2.4 percent and 4.9 percent, respectively.

Corselli and Platzer (1982) reported that examination of blood samples from 560 dogs attending heartworm clinics in southern California and southwest Arizona showed 17 (3%) positive for microfilariae of D. immitis. It was concluded that heartworm was enzootic in these areas.

Colorado

Pyle et al. (1978) found five (1.7%) of 300 dogs examined at a clinic in northeastern Colorado to be infected with heartworms. All dogs tested were at least six months of age. The five infected dogs were all large outdoor varieties and four had reportedly resided in an endemic area outside of Colorado.

Sears et al. (1980) reported that a heartworm survey conducted in west-central Colorado suggested that D. immitis was being transmitted locally. Blood samples were taken from dogs at nine veterinary clinics and two dog pounds in the Grand Junction, Colorado, area. Owners of dogs sampled at veterinary clinics were asked to complete a questionnaire to determine age, sex, breed, residence, and travel history. The survey was conducted during a six-month period in 1970. Of the 801

dogs examined for heartworms, 27 (9%) were found to be positive. Of the positive dogs, 50 percent had never been out of Mesa County, Colorado, which is a semi-arid, high altitude, region. However, a large agricultural industry in the area necessitates major irrigation practices which provide agreeable conditions for a breeding mosquito population.

Connecticut

Tritch et al. (1973) conducted a survey of D. immitis infection in dogs in southwestern Connecticut. Using the modified Knott's method, they found a prevalence of 3.2 percent infection.

Florida

Gotthelf (1978) conducted a survey from January to August of 1978 in Florida and found 7 percent infection with microfilariae in approximately 400 dogs from the Humane Society of Broward County, and a 5 percent positive infection rate in 300 dogs tested at local veterinary medical hospitals. He commented that the wide variation found in prevalence rates of the parasite in various areas across the country accentuated the need to identify enzootic areas.

Georgia

Thrasher et al. (1968) reported that blood specimens from 136 male and 137 female privately-owned dogs were examined by a modified Knott's technique in Atlanta, Georgia. An overall prevalence of 5.4 percent was found. Blood specimens from 40 pound dogs were examined and 12.5 percent were found to be infected with heartworm.

Lewis and Losonsky (1978) reported that 689 cases of *D. immitis* infection were recorded at the University of Georgia during January, 1967, to June, 1974. Of the dogs found positive, 68 percent were males. Dogs 2 to 7 years old accounted for 64 percent of the positive animals and only 3 percent were less than one year old. Dogs of mixed breeding were more commonly infected than purebreds.

Illinois

McKinney (1962) conducted a survey in Champaign County, Illinois. He reported that 1.4 percent of the dogs examined were infected with *D. immitis* microfilariae.

Marquardt and Fabian (1966) conducted a blood sample survey of dogs living in 45 Illinois counties during a two-and-a-half year period ending in late 1965.

Dogs from 28 counties were infected with D. immitis with the prevalence ranging from 10.4 percent in the north to 34.6 percent in the south.

Ward et al. (1974) examined blood samples from 100 dogs owned by personnel at Chanute Air Force Base in Illinois. All the dogs were at least one year of age. Three dogs were found to have microfilariae. All three were short-haired dogs and maintained out-of-doors and all were thought to have contracted the infection elsewhere in the United States.

Noyes (1981) reported that heartworm was found throughout the state of Illinois with increased numbers of veterinarians (69% in 1971 and 89% in 1979) reporting infections. However, total numbers of animals reported to be infected decreased (7.2% in 1971 and 0.9% in 1979). Noyes commented that he felt the decrease was probably due to preventive measures. Noyes made his comparisons with records from the Illinois State Veterinary Medical Association which began a management and survey program in 1971. The program consisted of annual recommendations for heartworm management and a questionnaire to be completed and returned by practitioners in of the association.

Indiana

Prevalence of D. immitis infection in stray and

abandoned dogs was studied by Kazacos (1978) from January, 1975, to September, 1976, in Tippecanoe County, Indiana, which is located 60 miles northwest of Indianapolis in Indiana. The dogs were from one to nine years of age, with an average age of two years. Dogs under one year of age were excluded from the study. Of 112 dogs examined, 67.9 percent were male and 32.1 percent were female. On removal of the heart and lungs from each dog, the right ventricle, right atrium and pulmonary arteries were examined for D. immitis. One or more adult heartworms were found in 15.2 percent of the animals. More male dogs (15.8%) than female (13.9%) were found to be infected. An average number of 12.2 worms was recovered from each infected animal.

Kazacos indicated that heartworm was less prevalent in north-central Indiana than in the southern or northwestern areas in Indiana. He reached this conclusion based on a statewide questionnaire survey of practicing veterinarians in five geographic sectors who reported an average infection rate of 17.6 percent in 1976 for the entire state.

Iowa

Alls and Greve (1974) conducted examinations of blood samples from 385 dogs native to Iowa using a modified Knott's test and a modified filter membrane

technique July, 1971, to March, 1972. Their results showed 6.5 percent (25 dogs) positive for heartworm. Significant differences were not found in infection rates in dogs of different sexes, breeds and coat lengths.

Christensen (1977) conducted blood examinations for microfilariae in August and September of 1975 in the area of Ames, Iowa. The negative dogs were examined again in May, 1976. Four of the 47 dogs examined in 1975 and 3 of the 43 dogs examined in 1976 were found to be infected. Six of the seven infected dogs were housed outside.

Kansas

Graham (1974) reported that prevalence of D. immitis in 288 dogs examined during the summer of 1972 in Leavenworth County, Kansas, was 16.7 percent or 48 positive dogs. Heartworm infections were concentrated along the eastern border of the county, and 45 of the infected dogs were located within four miles of the Missouri River. No host sex preference was seen. Dogs maintained inside homes or screened kennels were found to have significantly fewer infections than dogs continuously kept outisde. No heartworm microfilariae were found in dogs less than two years old, but in dogs 3 to 5 years old the prevalence reached its highest

level of 27.3 percent. In dogs 11 to 16-years-old, the prevalence was less than half that of the younger dogs.

Maryland

Roberts (1985) reported that during 1980-1981 patent D. immitis infections were found in 10.9 percent and 5.0 percent of dogs at two animal shelters in the Baltimore-Washington, D.C., areas. More male than female and more old than young dogs were infected.

Michigan

Stone (1957) reported that during the 1950s, D. immitis was seldom found in dogs in the Midwest. One case was reported in Michigan, but the dog had been born in Savannah, Georgia, and had visited the South on two occasions. Stone stated he felt more complete autopsies would probably reveal a greater incidence of heartworm in the Midwest than was recognized at that time.

Worley (1964) conducted a survey of 123 stray adult dogs impounded in southeastern Michigan. Of the dogs examined, 5.7 percent harbored D. immitis.

Prouty (1972) conducted a survey of heartworm infections in three southeastern Michigan towns during January to July, 1971. The prevalence in 1,977 dogs was 22 percent in Belleville and 6 percent in Detroit and

Farmington. There was a higher incidence in male dogs than in females. In all locations, the infections were more prevalent in dogs kept outdoors than in those housed indoors at night.

Minnesota

Schlotthauer et al. (1981) reported that although heartworm infection was seen in a few dogs as early as 1937, an epizootic in Hennepin County, Minnesota, in 1956, indicated that heartworm infection was moving northward and westward. This area is located far beyond the tropical and subtropical climates once believed necessary for the incubation of the disease. Whereas most outbreaks in the 1960s were restricted to the greater metropolitan area of Minneapolis and St. Paul, other cases were sporadically reported in central Minnesota. In 1978, a survey of veterinarians revealed a 2.1 percent prevalence rate based primarily on blood tests. Over half of the state's 87 counties reported infections, and over a third of the infections were from the Minneapolis-St. Paul area.

Mississippi

Ward (1965) conducted a necropsy survey for D. immitis infection in over 6,000 dogs from locations

between Memphis, Tennessee, and New Orleans, Louisiana. Adult worms were found in 11 percent of the animals. Most of the infected dogs came from the southern part of the 400-mile-long area surveyed where microfilariae of D. immitis had been previously found in 44 percent of canine blood samples examined.

Keegan (1977) reported that in order to assess the prevalence of D. immitis, questionnaires were sent to veterinarians across Mississippi. A total of approximately 10,500 dogs had been seen during 1972 by 83 veterinarians. It was the opinion of 61 of the veterinarians that there had been a rise in recent years of the number of dogs infected.

Missouri

Pratt et al. (1981) reported that a statewide mail survey in Missouri revealed that heartworm microfilariae had been diagnosed in 447 of 11,823 dogs (3.8%). The dogs were examined between January and September, 1979. A questionnaire for 1978 indicated an 8.4 percent prevalence of D. immitis, based on examination of 36,463 dogs. Of 493 animal shelter dogs from central Missouri and Mississippi river communities, 23 (4.7%) were positive for D. immitis microfilariae. The individual prevalence rates were highest in the Mississippi river areas.

Pratt and Corwin (1984) reported that a mail-in 1981 questionnaire answered by 51 veterinarians in Missouri revealed 849 (3.8%) of 22,414 dogs were infected with heartworm. The prevalence rates for D. immitis in Missouri dogs seemed to be stable when compared with past surveys.

Nebraska

Pratt and Corwin (1984) reported that a 1981 mail-in survey of 38 Nebraska veterinarians showed 86 (3.3%) of 2,598 dogs examined were infected with heartworm. Pratt and Corwin commented that the finding of 3.3 percent infection was similar to that in Missouri, and stated they felt the similarity was due primarily to location of water bodies in both states.

New Jersey

Lillis (1964) conducted a survey of dogs and cats in New Jersey. The survey revealed that 51 of 550 dogs and 3 of 317 cats were infected with D. immitis.

A survey by Brown and Marshall (1976) showed 30 (7.3%) of 412 dogs of various ages and breeds examined in New Jersey harbored microfilariae of D. immitis. The highest prevalence rates were found among German shepherd dogs and dogs of mixed breeding. Dogs kept

outdoors had a higher prevalence of the infection than those kept indoors.

New York

In a 1973 survey of 100 stray dogs from the public pound in Buffalo, New York, Sengbusch et al. (1975) found two dogs infected with D. immitis. The dogs were examined for microfilariae in the blood and for adult worms in the heart and pulmonary blood vessels at necropsy. This was the first report of heartworm in domesticated dogs in New York state.

Todaro and Morris (1975) screened 1,000 local dogs from Syracuse, New York, in 1974 for the presence of microfilariae of D. immitis. The infection rate was found to be 1.1 percent. Data collected from Syracuse veterinarians concerning examinations of some 13,000 dogs yielded a similar average infection rate.

In a later survey, Todaro et al. (1977) screened blood samples from 25,822 dogs in Onondaga County, New York, during a 21-month period in 1974-1975. The average heartworm infection rate based on microfilariae findings was about 1 percent.

North Carolina

Butts (1979) reported that 135 (10.1%) of 1,332

dogs examined for D. immitis microfilariae in Mecklenburg County, North Carolina, in July and August, 1976, were infected. Dogs kept outdoors at night were more frequently infected (18.2%) than dogs kept indoors (3.4%).

Falls and Platt (1982) reported that microfilariae of D. immitis were detected by a modified Knott's technique in 11 of 41 dogs from North Carolina and 8 of 59 dogs from Virginia with an overall prevalence of 19 percent.

Ohio

Groves and Koutz (1964) found heartworm microfilariae in the blood of 7 of 340 dogs examined in Ohio. Adult heartworms were recovered from the heart or pulmonary artery of 3 of 7.

Streitel et al. (1977) found adult D. immitis in the hearts of 24 (4.9%) of 500 dogs from a humane shelter in Columbus, Ohio. The dogs examined were one year of age or older. The number of worms recovered ranged from 1 to 19 and averaged 3. Of the 24 infected dogs, 4 harbored only male worms and 8 only females. Microfilariae were found in the peripheral blood of only 12 of the 24 infected dogs.

Keller et al. (1978) reported the prevalence of heartworms in greater Cincinnati to be only 0.2 percent

in the 502 stray dogs examined from the Hamilton County Animal Shelter. Dogs lacking permanent canine teeth were excluded from the survey. Samples were taken from the cephalic vein of all but the very small dogs, in which the jugular vein was used to obtain samples. Blood from one group of 314 animals was examined using a microhematocrit method and none was found to contain microfilariae. The second group of 188 dogs was examined using both a microhematocrit and a modified Knott's test, and only one animal was found positive. The investigators noted that no previous surveys had been conducted in the area so no determination of changes in the prevalence rates of the disease could be made. They also noted that animal shelter dogs tended to be younger and probably had a lower prevalence than the general population. Keller reviewed records from the College of Veterinary Medicine at Ohio State University, and reported that necropsy examinations revealed that prevalence rates of dogs with adult heartworms for the past four years to be 0.4 percent in 1974, 0.7 percent in 1975, 0.4 percent in 1976, and 0.9 percent in 1977.

Rabalais et al. (1978) reported finding D. immitis microfilariae in 6 (3.8%) of 160 native dogs examined in three northeastern counties of Ohio in 1976. Examinations of 230 dogs from the same areas gave an infection rate of 3.0 percent. Dipetalonema

reconditum infections were not seen in the 1976 survey, but 3.8 percent of the dogs harbored this parasite in 1971.

Appleton et al. (1979) conducted a survey in 1977 of blood samples from 2,101 dogs from southwestesrn Ohio. The overall prevalence of D. immitis was 1.9 percent. The prevalence of 4.5 percent in 422 animal shelter dogs was significantly higher than in the 1.2 percent of 1,679 dogs from veterinary clinics. Significantly higher prevalence rates were found in male dogs, dogs with short hair, and those kept out-of-doors most of the time. There was no difference in prevalence rates between dogs which had been out of Ohio within the year of study and those kept within the state which indicated heartworm was endemic in the area.

In a follow-up survey from July to September, 1981, done by Keller and Montgomery (1982), 16 (4.3%) of 371 stray dogs were found to be positive for heartworm microfilariae. These results showed a definite increase in the prevalence of heartworm infections in the Cincinnati, Ohio, area since their previous survey in 1978 which had a prevalence of 0.2 percent.

Oklahoma

A microfilarial survey of dogs in north-central and central Oklahoma was conducted in June and July, 1969,

by Pennington et al. (1970). Samples of blood were collected from 100 dogs found in city animal shelters in Enid, Edmond, Guthrie, Ponca City, and Stillwater, Oklahoma, and examined using a modified Knott's technique. Dogs were not found to be infected with heartworms. The authors stated that D. immitis was known to occur in north-central Oklahoma because dogs with heartworm had been diagnosed and treated at the Oklahoma State University Veterinary Medical Clinic. They concluded from the survey that the prevalence of D. immitis was low in the general dog population of north-central Oklahoma.

A subsequent survey by Pennington (1972) two years later indicated the prevalence of D. immitis in dogs in north-central Oklahoma to be 1.3 percent.

Kocan and Laubach (1976) found that 13 (4.5%) of 286 dogs tested over a one-year period in the small animal clinic at Oklahoma State University were positive for D. immitis. Of 150 dogs examined by necropsy, 11 harbored adult D. immitis. Most infected dogs were said to have never left Oklahoma. Although the prevalence of the disease could not be scientifically determined due to incomplete records and mobility of the animal population, it was assumed that canine heartworm was, at that time, enzootic in Oklahoma.

Tennessee

Utroska and Lewis (1979) reported a 24.7 percent prevalence rate of D. immitis infection in the metropolitan area of Memphis, Tennessee. This area, with its considerable numbers of lakes, ponds, rivers, and standing water, combined with a moderate climate, provided a year-around breeding ground for mosquitoes. Most of the 231 dogs tested were strays and the remainder were hunting dogs. All of the dogs had their adult canine teeth. The percentage positive for heartworm in the pound dogs was 19 percent. The remaining 31 animals were hunting dogs. Of the four breeds examined, all of the beagles, Brittany spaniels and English setters were found to be infected, but no infection was found in the Labradors. Utroska stated in the report that the extremes in rate of infection among the four groups of dogs are not uncommon in his practice, but admitted that the small sampling left room for criticism.

Texas

Knippa (1977) reported that of 100 dogs over nine months old from Texas, 33 were found to harbor microfilariae of D. immitis and 14 had microfilariae of D. reconditum. The infection was more common

among medium and large-size dogs older than two years of age and in dark-coated, long-haired dogs than in others.

Pigott (1978) conducted a survey of 100 dogs at five veterinary clinics in Corpus Christi, Texas, using a modified Knott's technique. Of the dogs examined, 27 were found to be infected with D. immitis, 2 with D. immitis and Dipetalonema reconditum and one with D. reconditum only. Infections were more common in black or brown dogs, in older and larger dogs and in dogs that lived outdoors.

Stewart et al. (1979) reported necropsy results of 81 dogs from a suburban area in north Texas showed 18 (22%) were infected with D. immitis. Mean adult worm burdens and infection rates were higher in male dogs than female dogs. The infection rate and worm burdens increased with age. Dogs with short hair were more commonly infected than those with medium or long hair.

Virginia

Kimbell (1976) examined blood samples from 213 dogs in Virginia using a modified Knott's technique. Heartworm microfilariae were found in 39 (18%) of the dogs. Seven of the infected dogs had never been outside northern Virginia.

West Virginia

Njaka (1980) reported that of 100 dogs examined from the Kanawha Animal Shelter three were positive for D. immitis microfilariae and six dogs were positive for D. reconditum. Two pet dogs were examined also with one positive for microfilariae.

Summary of Heartworm Surveys

As recently as ten years ago, Otto and Jackson (1975) stated that based on available information and local surveys, heartworm infection was rare west of the Mississippi River and had not been reported in local dogs in the western mountains. Even at that time heartworm was still considered to be a problem primarily in the Atlantic and Gulf coastal areas with a few isolated inland enzootic areas. During the last decade, the rapid inland and northerly movement of the parasite has drawn the attention of veterinary practitioners and animal owners across the country. With increased attention to the parasite has come increased surveillance, including many new surveys concerning distribution and prevalence. Table I, page 29, summarizes the surveys reviewed here. This is by no means a complete listing of all surveys, but instead is designed to give a cross-section of the country in respect to heartworm prevalence and distribution.

TABLE I

SUMMARY OF CANINE HEARTWORM SURVEYS

Location and Publ. Date	Authority	Positive for Heartworm
California		
1980	Weinman and Garcia	12.0%
1981	Leftwich and Carey	
	Solano County	2.4%
	Napa County	4.3%
1982	Corselli and Platzer	3.0%
Colorado		
1978	Pyle et al.	1.7%
1980	Sears et al.	9.0%
Connecticut		
1973	Tritch et al.	3.2%
Florida		
1978	Gotthelf	7.0%
Georgia		
1968	Thrasher et al.	
	Animal Shelter Dogs	12.5%
	Owned Dogs	5.4%
Illinois		
1962	McKinney	1.4%
1966	Marquardt and Fabian	
	Northern Illinois	10.4%
	Southern Illinois	34.6%
1971	Noyes	7.2%
1974	Ward et al.	3.0%
1979	Noyes	.9%
Indiana		
1976	Kazacos	17.6%
1978	Kazacos	15.2%
Iowa		
1974	Alls and Greve	6.5%
1977	Christensen	8.5%
Kansas		
1974	Graham	16.7%

TABLE I (Continued)

SUMMARY OF CANINE HEARTWORM SURVEYS

Location and Publ. Date	Authority	Positive for Heartworm
Maryland		
1985	Roberts	10.9%
Michigan		
1964	Worley	5.7%
1972	Prouty	
	Detroit	6.0%
	Belleville	22.0%
	Farmington	6.0%
Minnesota		
1978	Schlotthauer et al.	2.1%
Mississippi		
1965	Ward	11.0%
Missouri		
1981	Pratt et al.	3.8%
1984	Pratt and Corwin	3.8%
Nebraska		
1984	Pratt and Corwin	3.3%
New Jersey		
1964	Lillis	9.3%
1976	Brown and Marshall	7.3%
New York		
1975	Sengbusch et al.	2.0%
1975	Todaro and Morris	1.1%
1977	Todaro et al.	1.0%
North Carolina		
1979	Butts	10.1%
1982	Falls and Platt	26.8%
Ohio		
1964	Groves and Koutz	2.0%
1977	Streitel et al.	4.9%
1978	Keller et al.	.2%

TABLE I (Continued)

SUMMARY OF CANINE HEARTWORM SURVEYS

Location and Publ. Date	Authority	Positive for Heartworm
1978	Rabalais et al.	3.8%
1979	Appleton et al.	1.9%
1982	Keller and Montgomery	4.3%
Oklahoma		
1970	Pennington et al.	0.0%
1972	Pennington	1.3%
1976	Kocan and Laubach	4.5%
Tennessee		
1979	Utroska and Lewis	24.7%
Texas		
1977	Knippa	33.0%
1978	Pigott	27.0%
1979	Stewart et al.	22.0%
Virginia		
1976	Kimbell	18.0%
1982	Falls and Pratt	13.6%
West Virginia		
1980	Njaka	3.0%

CHAPTER III

MATERIALS AND METHODS

Animal Sources and Information

A survey on the prevalence of canine heartworm was conducted from June, 1983, through May, 1984. The three towns from which dogs were obtained are located in north-central Oklahoma and shown in Figure 1, page 33. Dogs to be euthanatized at city animal shelters in Stillwater, Ponca City, and Enid, Oklahoma, and privately owned animals from Ponca City were used in the survey as shown on Table II, page 34. A blood examination for microfilariae was performed on 104 of the dogs; the remaining 179 were examined both for microfilariae by blood test and for the presence of adult heartworms by necropsy. Only dogs from the Ponca City animal shelter and the Stillwater animal shelter were necropsied and examined for the presence of adult heartworms. Dogs were six months of age or older as determined by emergence and wear of teeth. Dogs were not sampled if the adult teeth were not yet fully emerged. Date of sampling, location, approximate age, estimation of weight, length of hair-coat, sex, and

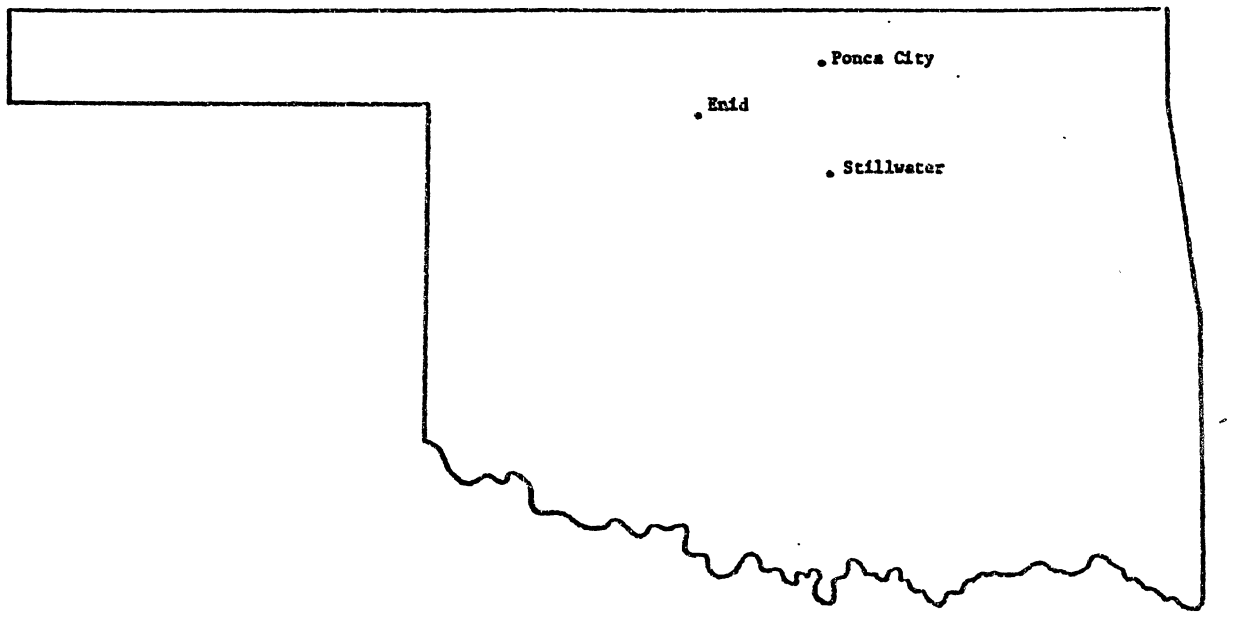

Figure 1. Location of towns in north-central Oklahoma where dogs were obtained to be examined for Dirofilaria immitis

TABLE II

NUMBERS OF DOGS FROM THREE LOCATIONS IN NORTH-CENTRAL OKLAHOMA EXAMINED FOR *DIROFILARIA IMMITIS* BY MODIFIED KNOTT'S TECHNIQUE AND/OR NECROPSY

Origin of Dogs	TYPE OF EXAMINATION Modified Knott's Only	Modified Knott's and Necropsy	Total
Ponca City Animal Shelter	42	100	142
Stillwater Animal Shelter	9	79	88
Enid Animal Shelter	22	0	22
Ponca City Owned	31	0	31
TOTALS	104	179	283

breed were recorded in an effort to ascertain if infections could be related to one or more of these factors. Hair length was recorded as short if less than 1 inch (<2.5 cm), medium if 1-2 inches (2.5-5.0 cm) or long if more than 2 inches (>5.0 cm).

Actual body weight was recorded when possible; otherwise, weights of animals were estimated. No distinction was made between neutered or intact dogs. Dogs were listed as a specific breed if they closely resembled that breed. They were listed as a cross-bred animal (e.g. hound X) if they were obviously of mixed lineage.

Collection and Examination of Samples

Blood

Blood specimens were collected from all animal shelter dogs just prior to time of euthanasia. Additional blood samples were collected from privately owned dogs in the Ponca City area.

Blood specimens were collected from dogs by drawing 3-4 ml of blood from the cephalic vein of the foreleg, using disposable 3 ml syringes and 20 or 22 gauge needles. One ml of each sample was placed in a 2 ml tube containing anticoagulant to be examined by a modified Knott's method for presence of microfilariae.

Two ml of each sample was placed in a clotting tube to be centrifuged for serum separation after clotting, and then examined serologically for presence of antibody to D. immitis as part of a related project. The blood samples were placed in an insulated chest to protect from excessive heat or cold as they were transported to the laboratory.

A direct wet mount of each blood sample was first examined for movement of microfilariae using a compound microscope, and scanning with a 100X magnification.

A modified Knott's technique as reviewed by Jackson and Otto (1975) also was conducted on all blood samples. One ml blood was added to 10 ml of 2 percent formalin in a 15 ml conical centrifuge tube and well mixed by inverting the tube several times. The sample was centrifuged at 1500 rpm for five minutes and the supernatant decanted and discarded. One drop of 1:1000 aqueous methylene blue was added to the sediment, mixed, and a drop of the mixture pipetted to a slide and covered with a 22x22 mm coverslip. The slides were examined microscopically (100X) for presence of microfilariae. Microfilariae were identified by length and width measurement and general morphology. Results were correlated with the results of the necropsy examinations.

Necropsy

Bodies of euthanatized dogs were returned to the laboratory where necropsy examinations were performed to determine if *D. immitis* adults were present. The heart, lungs, and adjacent blood vessels were removed and opened. The adult worms, if present, were removed, counted and categorized as to sex, fertility, and location in the host (Mullins, 1985).

Limitations of Study

It should be noted that this work is limited to the study of the prevalence of *Dirofilaria immitis* and excludes *Dipetalonema reconditum*, which is a distinctly different nematode found in dogs and transmitted by fleas but producing blood-inhabiting microfilariae similar in appearance to those of *D. immitis*.

CHAPTER IV

RESULTS

Results of examinations for heartworm showed an overall prevalence of the parasite in north-central Oklahoma dogs to be 8.8 percent.

As seen in Table III, page 40, dogs when examined by necropsy and/or a modified Knott's technique showed a marked difference in the percentage infection between Ponca City animal shelter dogs (3.5%) and Stillwater animal shelter dogs (18.2%). No dogs from the Enid animal shelter were found to harbor microfilariae. Owner-maintained dogs from the Ponca City area showed an infection rate of 12.9 percent. None of the dogs which were owner-maintained or from the Enid animal shelter were examined post-mortem. The group of dogs which were examined by necropsy (Table IV, page 41), showed a somewhat higher overall prevalence of infection than dogs examined for microfilariae only (Table V, page 42).

The greatest prevalence of heartworm infections was found among dogs older than three years of age, as seen in Table VI, page 43. Slightly more male dogs than female dogs were infected. Dogs with coat lengths less

than one inch (<2.5 cm) and those with coat lengths greater than two inches (>5.0 cm) had a slightly greater infection rate than those dogs with coats 1-2 inches (2.5-5.0 cm) long. Large dogs had a greater prevalence of infection than medium-size dogs which in turn showed greater infection rates than small dogs.

A complete listing, including age, sex, coat, weight, breed, and origin, of dogs found to be positive for heartworm infection is given in Table VII, page 44. Sixteen different breeds of dogs were represented among the 25 dogs found positive for heartworm. The greatest number of positive animals was found in the shepherd crossbreds.

Table VIII, page 45, lists the number of dogs examined in each category and the percent that number is of the 283 dogs examined. Likewise, the number of dogs found positive in each category and the percent that number is of the 25 dogs found positive is also listed to allow comparison of the percentages.

Complete data for all dogs examined, and results of examinations, as well as all information gathered on each animal has been included in the Appendix, that begins on page 59.

TABLE III

NUMBERS OF DOGS EXAMINED BY NECROPSY AND/OR MODIFIED KNOTT'S TECHNIQUE AND PERCENTAGES FOUND POSITIVE FOR *DIROFILARIA IMMITIS*

Origin Of Dogs	Number Examined	Number Positive	Percent Infected
Ponca City Animal Shelter	142	5	3.5%
Stillwater Animal Shelter	88	16	18.2%
Enid Animal Shelter	22	0	0.0%
Ponca City Owned Dogs	31	4	12.9%
TOTALS	283	25	*

*Overall prevalence of heartworm infection as indicated by necropsy and/or modified Knott's examination - 8.8%

TABLE IV

NUMBERS OF DOGS EXAMINED BY NECROPSY AND PERCENTAGES FOUND POSITIVE FOR *DIROFILARIA IMMITIS*

Origin Of Dogs	Number Examined	Number Positive	Percent Infected
Ponca City Animal Shelter	100	3	3.0%
Stillwater Animal Shelter	79	15	19.0%
TOTALS	179	18	*

*Overall prevalence of heartworm infection as indicated by necropsy - 10.1%

TABLE V

NUMBERS OF DOGS EXAMINED BY MODIFIED KNOTT'S TECHNIQUE AND PERCENTAGES FOUND POSITIVE FOR DIROFILARIA IMMITIS

Origin Of Dogs	Number Examined	Number Positive	Percent Infected
Ponca City Animal Shelter	42	2	4.8%
Stillwater Animal Shelter	9	1	11.1%
Enid Animal Shelter	22	0	0.0%
Ponca City Owned	31	4	12.9%
TOTALS	104	7	*

*Overall prevalence of heartworm infection as indicated by a modified Knott's examination - 6.7%

TABLE VI

AGE, SEX, COAT LENGTH, WEIGHT, AND BREED OF DOGS FROM NORTH-CENTRAL OKLAHOMA THAT WERE FOUND POSITIVE FOR *DIROFILARIA IMMITIS* BY NECROPSY AND/OR A MODIFIED KNOTT'S EXAMINATION

Age[a]	Sex[b]	Coat[c]	Weight[d] Lbs (Kg)	Breed	Origin
1	M	S	50 (23)	Hound X	Ponca City
1	M	L	55 (25)	Shepherd X	Stillwater
1	M	L	55 (25)	Shepherd X	Stillwater
1	F	M	20 (9)	Hound X	Ponca City
1	F	M	20 (9)	Terrier X	Stillwater
2	M	S	50 (23)	Pointer	Stillwater
2	M	L	20 (9)	English Cocker	Ponca Owned
2	M	L	20 (9)	English Cocker	Ponca Owned
3	M	M	12 (5)	Terrier X	Stillwater
3	M	M	65 (30)	St. Bernard	Ponca City
4	M	M	40 (18)	Shepherd X	Stillwater
4	M	M	75 (34)	Labrador	Stillwater
4	M	M	40 (18)	Brittany	Ponca Owned
4	M	L	50 (23)	Chow Chow	Stillwater
4	M	L	45 (20)	Shepherd X	Stillwater
5	F	S	40 (18)	Hound X	Stillwater
5	F	S	45 (20)	Doberman	Stillwater
5	F	L	15 (7)	Spitz	Stillwater
6	M	M	70 (32)	Wolfhound	Ponca City
6	F	M	70 (32)	Wolfhound	Ponca City
6	F	L	50 (23)	Border Collie	Stillwater
6	F	S	50 (23)	Hound X	Stillwater
8	M	S	40 (18)	German Shorthair	Stillwater
8	M	L	70 (32)	German Shepherd	Stillwater
12	F	S	45 (20)	Boxer	Ponca Owned

[a]Age in years

[b]M=male and F=female

[c]S=short <1" (<2.5 cm), M=medium 1-2" (2.5-5.0 cm), L=long >2" (>5.0 cm)

[d]Weight in pounds and kilograms

TABLE VII

DIROFILARIA IMMITIS INFECTIONS IN DOGS FROM NORTH-CENTRAL OKLAHOMA AS CATEGORIZED BY ANIMAL AGE, SEX, COAT AND WEIGHT

Category	Number Examined	Number Positive	Percent Infected
AGE			
1 Year	106	5	4.7%
2 Years	95	3	3.2%
3 Years	24	2	8.3%
>3 Years	58	15	26.9%
SEX			
Male	162	16	9.9%
Female	121	9	7.9%
COAT LENGTH			
<1" (<2.5 cm)	82	8	9.8%
1-2" (2.5-5.0 cm)	103	7	6.8%
>2" (>5.0 cm)	98	10	10.2%
WEIGHT			
≤25 lbs (≤11 kg)	96	6	6.3%
26-49 lbs (12-22 kg)	133	12	9.0%
≥50 lbs (≥23 kg)	54	7	13.0%

TABLE VIII

NUMBERS AND PERCENTAGE OF DOGS EXAMINED COMPARED TO NUMBERS AND PERCENTAGES OF DOGS FOUND POSITIVE FOR DIROFILARIA IMMITIS IN NORTH-CENTRAL OKLAHOMA

Category	Number Examined	Percent of Total Examined (N=283)	Number Examined	Percent of Total Positives (N=25)
AGE				
1 Year	106	37%	5	20%
2 Years	95	34%	3	12%
3 Years	24	8%	2	8%
>3 Years	58	20%	15	60%
SEX				
Male	162	57%	16	64%
Female	121	43%	9	36%
COAT LENGTH				
<1" (<2.5 cm)	82	29%	7	32%
1-2" (2.5-5.0 cm)	103	36%	9	28%
>2" (>5.0 cm)	98	35%	9	40%
WEIGHT				
≤25 lbs (≤11 kg)	96	34%	6	24%
26-49 lbs (12-22 kg)	133	47%	7	48%
≥50 lbs (≥23 kg)	54	19%	12	28%

CHAPTER V

DISCUSSION AND CONCLUSION

Evidence from data collected June, 1983, to May, 1984, suggests that the prevalence of Dirofilaria immitis in north-central Oklahoma is increasing. Past surveys conducted in the north-central Oklahoma area include Pennington et al. (1970) who simply concluded that the prevalence of the infection was very low; Pennington (1972) who found the prevalence to be 1.3 percent; and Kocan and Laubach (1976) who found a prevalence rate of 4.5 percent.

A noticeable variation was observed in the prevalence rates found in the three different towns. Stillwater shelter dogs showed 18.2 percent infection, while Ponca City shelter dogs were only 3.5 percent infected. None of the animal shelter dogs from Enid were found to be infected. Several reasons for these differences may exist. Location of the three towns must be considered. There is a slight temperature variation ($<5^{o}F$) due to the north/south separation between Ponca City and Stillwater. Enid, to the west, is a more arid area. Also to be considered, in regard to the fact that

no dogs from Enid were found to be positive is the small number of dogs examined. Possibly this sample size of 22 dogs was not great enough to be truly representative. Outward appearance of other environmental factors such as vegetation, topography, and available water suggests only slight variation among the three towns. There is the possibility that mosquito species which are more suitable for transmitting the parasite are more abundant in the Stillwater area than in the Ponca City or Enid areas, perhaps for reasons including temperature, humidity, pest control practices, or vegetation. Certainly the vectors for heartworm are plentiful in Stillwater. Afolabi (1985) conducted a survey of Stillwater area mosquitoes to determine potential local vectors of heartworm. Of the 23 species captured, 13 harbored filariid larvae, with third-stage larva recovered from eight. Together, two of the mosquito species with infective larvae comprised 73 percent of the 39,280 mosquitoes captured. Similar surveys have not been conducted for the Enid and Ponca City areas.

Owner-maintained dogs from the Ponca City area showed a higher prevalence of infection than dogs from the Ponca City animal shelter. Four privately owned dogs from the Ponca City area were found to have heartworm microfilariae. Three of these infected animals were from one residence located near a creek

bottom where mosquitoes were abundant. The dogs were kenneled out-of-doors year around. The fourth dog had been maintained in Charleston, South Carolina, an area well known for a high prevalence of heartworm (Otto, 1975), for two years prior to this survey. The dog had been maintained out-of-doors year around while in South Carolina.

A factor which could account for the difference found in the prevalence among the three cities is that the infection is greater in areas to the southeast of Oklahoma and is simply moving in a northwesterly direction as it expands its area across Oklahoma. Another possible reason for the difference may be that Stillwater, location of Oklahoma State University, has a greater population exchange with other parts of the country, thereby bringing in new people with new dogs from all across the country, including endemic areas such as the Southeast and the Atlantic and Gulf coast areas.

The difference in infection rate found in the various age divisions may be due to increased exposure of the older dogs. Also, the long period of development of the heartworm within the dog tends to increase the age at which the dog is diagnosed as infected.

Only a small difference in infection rate was seen between sexes with a possible explanation being a

greater tendency for the male dogs to roam and cover more territory, thereby increasing their chances of exposure. Another reason for this difference, because the percentages are so close, could be pure chance.

Little variation was found among the dogs examined when grouped by length of coat, implying that the long, heavy coats of some dogs offered no significant protection.

Large dogs showed a greater prevalence of infection than did medium-size dogs which in turn had greater infection rates than small dogs. The probable explanation for the differences found is that the larger dogs spend a greater amount of time out-of-doors and tend to range over a greater territory than do the smaller dogs, which are often house pets, thereby increasing chances of exposure to heartworm-infected mosquitoes.

It appears from this survey that there has been a significant increase in heartworm infection in the area studied during the last several years. The present study revealed an infection rate of 8.8 percent. The last published study for this area showed a prevalence of 4.3 percent (Kocan and Laubach, 1976). Surveys by Pennington et al. (1970) and Pennington (1972) showed infection rates of 0.0 percent and 1.3 percent, respectively. Reasons to consider as an explanation for

the increase might include spread of the infection due to adaptation of the heartworm larvae or its mosquito vector to a wider range of environmental conditions. Also to be considered as reason for the rapid increase is the greater mobility of people and their dogs. It would be interesting to do further surveys of the area to compare increases and to include points farther to the south, west, and north to use for comparison.

CHAPTER VI

SUMMARY

Prevalence of Dirofilaria immitis in north-central Oklahoma has increased two-fold during the last decade to a present rate of 8.8 percent.

A survey of 283 dogs in north-central Oklahoma was conducted June, 1983, to May, 1984. Surveyed animals were examined by necropsy and/or a modified Knott's technique. Sources of dogs were animal shelters in three towns, Stillwater, Ponca City, and Enid, and private owners in Ponca City. Dogs examined by necropsy showed an infection rate of 10.1 percent. Dogs examined for microfilariae only had an infection rate of 6.7 percent. The combined results yielded an overall prevalence of 8.8 percent. Dogs older than three years of age had a greater rate of infection than younger dogs. Male dogs had a slightly higher infection rate than did females. Dogs from Stillwater had a greater prevalence of infection than dogs from Ponca City which, in turn, was greater than that of dogs from Enid.

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APPENDIXES

TABLE IX*

HEARTWORM DATA TABLE
STILLWATER ANIMAL
SHELTER DOGS

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
1	2	M	S	25 (11)	15	N	N	N
2	2	M	L	15 (7)	36	N	N	N
3	3	M	M	12 (5)	47	P	P	P
4	1	F	L	45 (20)	14	N	N	X
5	3	M	M	55 (25)	26	N	N	N
6	3	M	M	30 (14)	8	N	N	N
7	1	M	M	25 (11)	10	N	N	N
8	2	F	M	45 (20)	26	N	N	N
9	5	M	M	50 (23)	16	N	N	N
10	1	M	M	15 (7)	8	N	N	N
11	1	M	L	20 (9)	47	N	N	N
12	8	M	S	40 (18)	23	P	P	P
13	4	M	S	40 (18)	42	N	N	P
14	4	M	L	50 (23)	14	N	N	P
15	6	M	S	40 (18)	34	N	N	N
16	2	M	S	40 (18)	18	N	N	N
17	7	F	S	25 (11)	6	N	N	N
18	1	F	M	25 (11)	22	N	N	N
19	3	F	M	45 (20)	24	N	N	N
20	1	M	M	30 (14)	30	N	N	N
21	1	M	M	30 (14)	30	N	N	N
22	1	F	M	15 (7)	47	N	N	N
23	8	M	L	20 (9)	40	N	N	N
24	2	M	S	15 (7)	34	N	N	N
25	3	M	M	50 (23)	30	N	N	N
26	2	M	L	30 (14)	4	N	N	N
27	2	M	M	30 (14)	4	N	N	N
28	6	F	L	50 (23)	10	P	P	P
29	1	F	M	20 (9)	47	N	N	N
30	2	M	M	50 (23)	42	N	N	N
31	4	F	S	45 (20)	42	N	N	N
32	1	M	M	35 (16)	42	N	N	N
33	1	M	M	20 (9)	42	N	N	N
34	1	F	M	15 (7)	42	N	N	N
35	1	M	M	40 (18)	42	N	N	N
36	4	F	M	40 (18)	42	N	N	N

*See nomenclature list page 69 for explanation of terms used in table.

TABLE IX* (Continued)

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
37	2	F	M	50 (23)	31	N	N	N
38	8	M	L	70 (32)	22	P	P	P
39	2	F	L	20 (9)	39	N	N	N
40	1	M	M	50 (23)	22	N	N	N
41	1	M	M	50 (23)	42	N	N	N
42	2	M	L	20 (9)	36	N	N	N
43	2	F	M	35 (16)	8	N	N	N
44	1	M	S	20 (9)	47	N	N	N
45	2	M	S	65 (30)	18	N	N	N
46	1	F	L	20 (9)	42	N	N	N
47	2	M	M	15 (7)	15	N	N	N
48	2	F	M	30 (14)	12	N	N	N
49	1	F	S	15 (7)	47	N	N	N
50	2	F	L	50 (23)	33	N	N	N
51	6	M	S	5 (2)	13	N	N	N
52	1	M	S	7 (3)	13	N	N	N
53	5	F	S	40 (18)	26	P	P	P
54	2	F	M	35 (16)	26	N	N	N
55	2	M	S	50 (23)	35	N	N	P
56	4	M	S	50 (23)	26	N	N	N
57	1	F	L	25 (11)	47	N	N	N
58	8	M	L	65 (30)	16	N	N	N
59	1	M	M	20 (9)	47	N	N	N
60	1	F	M	20 (9)	47	N	N	P
61	2	F	L	40 (18)	42	N	N	N
62	1	F	L	35 (16)	4	N	N	N
63	2	F	L	15 (7)	36	N	N	N
64	1	F	M	20 (9)	42	N	N	N
65	1	M	M	85 (39)	22	N	N	N
66	1	M	S	40 (18)	20	N	N	N
67	2	M	L	15 (7)	36	N	N	N
68	6	F	S	50 (23)	26	N	N	P
69	1	F	L	20 (9)	29	N	N	N
70	1	F	M	40 (18)	10	N	N	N
71	1	M	L	55 (25)	42	N	N	P
72	1	F	L	35 (16)	22	N	N	N
73	1	M	L	55 (25)	42	N	N	P
74	4	M	M	75 (34)	30	N	N	P
75	2	F	M	50 (23)	3	N	N	N
76	5	F	L	15 (7)	44	N	N	P
72	1	F	L	35 (16)	22	N	N	N

*See nomenclature list page 69 for explanation of terms used in table.

TABLE IX* (Continued)

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
73	1	M	L	55 (25)	42	N	N	P
74	4	M	M	75 (34)	30	N	N	P
75	2	F	M	50 (23)	3	N	N	N
76	5	F	L	15 (7)	44	N	N	P
77	5	M	M	65 (30)	28	P	P	N
78	4	M	L	15 (7)	36	N	N	N
79	1	F	L	50 (23)	22	N	N	X
80	2	M	M	60 (27)	30	N	N	X
81	4	M	S	40 (18)	35	N	N	X
82	2	F	L	10 (5)	15	N	N	X
83	5	F	S	45 (20)	18	P	P	X
84	2	M	L	55 (25)	25	N	N	X
85	1	M	S	30 (14)	26	N	N	N
86	4	M	L	45 (20)	42	P	P	P
87	1	F	S	35 (16)	47	N	N	X
88	1	M	S	35 (16)	34	N	N	X

*See nomenclature list page 69 for explanation of terms used in table.

TABLE X*

HEARTWORM DATA TABLE
PONCA CITY ANIMAL
SHELTER DOGS

Dog Number	Age	Sex	Coat	Weight Lbs (Kg)	Breed	Direct	Knott's	Necropsy
1	5	M	L	15 (7)	36	N	N	N
2	2	M	M	15 (7)	47	N	N	N
3	3	F	S	40 (18)	38	N	N	N
4	1	M	L	20 (9)	47	N	N	N
5	1	M	S	15 (7)	47	N	N	N
6	3	F	M	50 (23)	42	N	N	N
7	2	F	L	30 (14)	42	N	N	N
8	1	F	L	35 (16)	42	N	N	N
9	6	F	M	35 (16)	12	N	N	N
10	4	M	L	15 (7)	47	N	N	N
11	4	F	M	15 (7)	12	N	N	N
12	2	F	L	35 (16)	42	N	N	N
13	2	M	M	50 (23)	30	N	N	N
14	8	M	S	10 (5)	47	N	N	N
15	2	F	L	20 (9)	47	N	N	N
16	1	M	S	40 (18)	26	N	N	N
17	2	F	L	40 (18)	42	N	N	N
18	1	M	S	25 (11)	26	N	N	N
19	1	F	M	45 (20)	26	N	N	N
20	2	M	S	20 (9)	47	N	N	N
21	1	F	S	25 (11)	34	N	N	X
22	1	F	S	25 (11)	18	N	N	X
23	1	F	S	30 (14)	26	N	N	X
24	1	F	S	30 (14)	18	N	N	X
25	3	M	S	15 (7)	26	N	N	X
26	3	M	L	15 (7)	15	N	N	X
27	1	F	M	25 (11)	12	N	N	X
28	2	M	S	35 (16)	26	N	N	X
29	1	F	L	20 (9)	47	N	N	X
30	4	F	M	20 (9)	4	N	N	X
31	1	M	M	40 (18)	22	N	N	X
32	3	M	M	15 (7)	47	N	N	X
33	2	M	S	20 (9)	47	N	N	X
34	2	M	L	50 (23)	16	N	N	N
35	2	M	L	40 (18)	47	N	N	N

*See nomenclature list page 69 for explanation of terms used in table.

TABLE X* (Continued)

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
36	1	M	S	35 (16)	26	N	N	N
37	1	M	M	40 (18)	26	N	N	N
38	1	F	S	30 (14)	18	N	N	N
39	1	F	S	30 (14)	26	N	N	N
40	2	M	S	40 (18)	26	N	N	N
41	1	F	S	35 (16)	26	N	N	N
42	2	F	L	30 (14)	42	N	N	N
43	2	M	L	50 (23)	24	N	N	X
44	3	F	L	25 (11)	32	N	N	X
45	1	M	M	20 (9)	41	N	N	X
46	3	F	S	40 (18)	48	N	N	X
47	2	M	M	40 (18)	8	N	N	X
48	2	F	L	25 (11)	41	N	N	X
49	1	M	S	35 (16)	26	N	N	N
50	3	M	L	50 (23)	4	N	N	N
51	1	F	L	30 (14)	42	N	N	N
52	2	F	M	30 (14)	26	N	N	N
53	1	F	S	30 (14)	26	N	N	N
54	1	F	S	30 (14)	26	N	N	N
55	1	M	S	25 (11)	42	N	N	N
56	3	F	M	30 (14)	12	N	N	X
57	2	M	L	80 (36)	47	N	N	X
58	2	F	M	15 (7)	7	N	N	N
59	2	M	M	30 (14)	42	N	N	N
60	1	M	L	55 (25)	15	N	N	X
61	2	F	L	40 (18)	14	N	N	X
62	2	M	L	45 (20)	16	N	N	N
63	3	M	L	65 (30)	46	N	N	P
64	2	M	L	50 (23)	16	N	N	N
65	1	M	S	40 (18)	35	N	N	N
66	1	F	L	25 (11)	32	N	N	N
67	2	F	L	50 (23)	22	N	N	N
68	2	M	L	80 (36)	46	N	N	N
69	5	M	S	45 (20)	11	N	N	X
70	1	F	S	15 (7)	26	N	N	X
71	2	M	M	30 (14)	42	N	N	X
72	5	M	L	50 (23)	42	N	N	X
73	1	F	M	37 (17)	4	N	N	N
74	2	F	M	35 (16)	10	N	N	N
75	2	F	S	36 (16)	26	N	N	N
76	4	M	M	45 (20)	16	N	N	N

*See nomenclature list page 69 for explanation of terms used in table.

TABLE X* (Continued)

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
77	1	M	M	34 (15)	10	N	N	N
78	2	M	M	45 (20)	16	N	N	N
79	1	F	S	36 (16)	10	N	N	X
80	2	M	S	45 (20)	26	N	N	N
81	2	M	M	45 (20)	16	N	N	N
82	1	F	M	30 (14)	4	N	N	N
83	1	M	S	40 (18)	18	N	N	N
84	2	M	M	50 (23)	30	N	N	X
85	2	M	L	20 (9)	41	N	N	N
86	3	M	M	40 (18)	26	N	N	X
87	4	M	S	45 (20)	34	N	N	X
88	2	M	M	15 (7)	22	N	N	X
89	1	F	M	30 (14)	42	N	N	N
90	2	M	S	75 (34)	31	N	N	N
91	2	M	S	10 (5)	37	N	N	N
92	1	F	S	20 (9)	47	N	N	N
93	2	F	L	30 (14)	42	N	N	N
94	1	F	S	50 (23)	30	N	N	N
95	1	M	L	40 (18)	14	N	N	N
96	1	F	S	35 (16)	30	N	N	X
97	1	F	M	35 (16)	12	N	N	X
98	6	M	L	25 (11)	42	N	N	X
99	1	M	L	80 (36)	22	N	N	X
100	1	M	M	40 (18)	42	N	N	X
101	3	F	S	45 (20)	18	N	N	X
102	2	M	M	25 (11)	42	N	N	X
103	2	F	S	50 (23)	26	N	N	X
104	2	M	S	60 (27)	18	N	N	X
105	2	F	M	30 (14)	28	N	N	X
106	1	M	S	45 (20)	17	N	N	X
107	2	M	S	55 (25)	31	N	N	N
108	2	M	M	40 (18)	5	N	N	N
109	2	M	L	30 (14)	21	N	N	N
110	1	M	S	50 (23)	26	P	P	P
111	1	F	M	20 (9)	26	N	N	P
112	2	F	L	30 (14)	15	N	N	N
113	1	F	M	35 (16)	8	N	N	N
114	1	F	M	40 (18)	22	N	N	N
115	1	M	L	40 (18)	27	N	N	N
116	1	M	S	10 (5)	47	N	N	N
117	1	M	L	20 (9)	36	N	N	N

*See nomenclature list page 69 for explanation of terms used in table.

TABLE X* (Continued)

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
118	1	F	M	10 (5)	13	N	N	N
119	1	F	S	30 (14)	34	N	N	N
120	1	M	L	15 (7)	40	N	N	X
121	1	M	M	25 (11)	26	N	N	X
122	5	M	L	15 (7)	41	N	N	X
123	4	M	S	40 (18)	35	N	N	X
124	1	M	M	40 (18)	8	N	N	X
125	1	F	L	40 (18)	10	N	N	X
126	5	F	M	35 (16)	12	N	N	X
127	2	M	M	35 (16)	8	N	N	X
128	2	M	L	30 (14)	15	N	N	X
129	1	M	L	45 (20)	10	N	N	X
130	2	M	M	55 (25)	30	N	N	X
131	1	M	S	10 (5)	47	N	N	X
132	1	M	S	20 (9)	7	N	N	X
133	8	M	S	50 (23)	35	N	N	X
134	4	M	L	45 (20)	42	N	N	X
135	1	M	L	50 (23)	14	N	N	X
136	5	M	L	50 (23)	2	N	N	X
137	1	M	L	45 (20)	42	N	N	X
138	1	M	L	40 (18)	42	N	N	X
139	2	M	S	50 (23)	18	N	N	X
140	4	M	L	30 (14)	1	N	N	X
141	6	M	M	70 (32)	49	P	P	X
142	6	F	M	70 (32)	49	P	P	X

*See nomenclature list page 69 for explanation of terms used in table.

TABLE XI*

HEARTWORM DATA TABLE
ENID ANIMAL SHELTER
DOGS

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
1	2	M	L	40 (18)	42	N	N	X
2	2	F	M	45 (20)	30	N	N	X
3	1	M	L	45 (20)	28	N	N	X
4	3	F	S	50 (23)	18	N	N	X
5	2	M	L	50 (23)	14	N	N	X
6	2	F	L	30 (14)	24	N	N	X
7	5	M	L	50 (23)	45	N	N	X
8	4	F	M	60 (27)	22	N	N	X
9	2	M	M	45 (20)	8	N	N	X
10	1	M	M	45 (20)	30	N	N	X
11	2	M	L	45 (20)	42	N	N	X
12	2	F	M	40 (18)	16	N	N	X
13	1	M	L	20 (9)	47	N	N	X
14	1	F	M	25 (11)	26	N	N	X
15	1	M	M	50 (23)	42	N	N	X
16	5	F	M	50 (23)	22	N	N	X
17	2	M	S	50 (23)	9	N	N	X
18	2	F	M	40 (18)	5	N	N	X
19	2	M	M	40 (18)	26	N	N	X
20	2	M	M	30 (14)	26	N	N	X
21	2	F	L	25 (11)	42	N	N	X
22	3	M	L	20 (9)	44	N	N	X

*See nomenclature list page 69 for explanation of terms used in table.

TABLE XII*

HEARTWORM DATA TABLE
PONCA CITY OWNED
DOGS

Dog Number	Age	Sex	Coat	Weight Lbs(Kg)	Breed	Direct	Knott's	Necropsy
1	2	M	L	20 (9)	19	P	P	X
2	2	M	L	30 (14)	19	N	N	X
3	1	F	M	55 (25)	30	N	N	X
4	4	M	M	40 (18)	12	P	P	X
5	3	M	M	20 (9)	19	N	N	X
6	5	F	L	30 (14)	19	N	N	X
7	6	F	L	40 (18)	19	N	N	X
8	2	F	L	20 (9)	19	N	N	X
9	4	F	L	10 (5)	43	N	N	X
10	1	F	L	20 (9)	19	N	N	X
11	1	F	L	20 (9)	19	N	N	X
12	2	M	L	20 (9)	19	P	P	X
13	6	M	M	10 (5)	36	N	N	X
14	6	M	M	45 (20)	8	N	N	X
15	3	F	M	30 (14)	8	N	N	X
16	2	F	M	30 (14)	15	N	N	X
17	3	M	M	30 (14)	15	N	N	X
18	2	M	M	30 (14)	15	N	N	X
19	3	F	L	30 (14)	15	N	N	X
20	12	F	L	50 (23)	28	N	N	X
21	2	F	S	40 (18)	26	N	N	X
22	12	F	S	45 (20)	11	P	P	X
23	5	F	L	50 (23)	16	N	N	X
24	2	F	L	30 (14)	41	N	N	X
25	3	M	S	60 (27)	18	N	N	X
26	2	F	M	50 (23)	30	N	N	X
27	8	M	S	60 (27)	48	N	N	X
28	1	M	S	60 (27)	48	N	N	X
29	1	F	S	50 (23)	48	N	N	X
30	6	F	S	50 (23)	48	N	N	X
31	5	F	S	60 (27)	48	N	N	X

*See nomenclature list page 69 for explanation of terms used in table.

NOMENCLATURE USED IN TABLES

Dog Number	Research reference number
Age	Dog's age given in years
Sex	M = Male
	F = Female
Coat	S = Short, <1 inch (<2.5 centimeters)
	M = Medium, 1-2 inches (2.5-5 centimeters)
	L = Long, >2 inches (>5 centimeters)
Weight	Dog's weight given in pounds (kilograms)
Breed	1 Afghan
	2 Airedale
	3 Akita
	4 Australian Shepherd
	5 Basenji
	6 Bassett
	7 Beagle
	8 Blue Heeler
	9 Blue Tick
	10 Border Collie
	11 Boxer
	12 Brittany

NOMENCLATURE USED IN TABLES (Continued)

13 Chihuahua

14 Chow Chow

15 Cocker Spaniel

16 Collie

17 Dalmatian

18 Doberman

19 English Cocker

20 Fox Hound

21 Fox Terrier

22 German Shepherd

23 German Shorthair

24 Golden Retriever

25 Gordon Setter

26 Hound X

27 Husky

28 Irish Setter

29 Keeshond

30 Labrador

31 Mastiff

32 Norwegian Elkhound

33 Old English Sheepdog

34 Pit Bull

35 Pointer

36 Poodle

37 Rat Terrier

NOMENCLATURE USED IN TABLES (Continued)

38 Redbone Hound

39 Schnauzer

40 Scottie

41 Sheltie

42 Shepherd X

43 Shih tzu

44 Spitz

45 Springer

46 St. Bernard

47 Terrier X

48 Walker Hound

49 Wolfhound

NOMENCLATURE USED IN TABLES (Continued)

Direct — Direct blood examination for microfilariae

P = Positive

N = Negative

Knott's — Modified Knott's examination for microfilariae

P = Positive

N = Negative

Necropsy — Necropsy examination for heartworm

P = Positive

N = Negative

X = Not necropsied

VITA

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