THE DISTRIBUTION AND FACTORS INFLUENCING THE ESTABLISHMENT OF *FASCIOLA HEPATICA* LINNAEUS 1758, IN NATIVE OKLAHOMA CATTLE

By

HENRY KIPKEMEI CHERUIYOT

Bachelor of Science
University of Nairobi
Kenya, East Africa
1970

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1975

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1978

THE DISTRIBUTION AND FACTORS INFLUENCING THE ESTABLISHMENT OF *FASCIOLA HEPATICA* LINNAEUS 1758, IN NATIVE OKLAHOMA CATTLE

Thesis Approved:

Helen E. Jordan
Thesis Adviser

John T. Homer

Robert D. Morrison

[illegible]

Duncan W. MacLean

David E. Howell

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

The author would like to acknowledge the invaluable aid rendered to him by his major adviser, Dr. Helen E. Jordan, in the design of this research as well as the search for funds. Despite a tremendous demand on her time, Dr. Jordan was a never-ending source of stimulating ideas, which made this seemingly tedious exercise a fascinating study. Her critical comments in editing this manuscript resulted in a concise and readable report.

Special thanks are also expressed to Dr. A. A. Kocan, Dr. D. W. MacVean, Dr. J. T. Homer, all of the Department of Parasitology and Public Health, to Dr. D. E. Howell of the Entomology Department, and Dr. R. D. Morrison of the Statistics Department. They kept abreast with the development of this research and gave much constructive advice in the course of the investigation.

Dr. A. L. Malle of the Pathology Department helped in the initial identification of veterinary practitioners in the state of Oklahoma. Ms. Amy VanDevender was invaluable in the spot identification of field collected snails. The author would also like to recognize the personal contribution of Dr. J. G. Williams, whose experience in packinghouses and interest in field trips made initial data gathering very stimulating.

Many other people have contributed tremendously to this endeavor and a list of them all would be too long. However, special thanks are given to the various county extension directors for contacting certain farmers in their areas for this research.

A special word of thanks must go to my wife, Ruth. She showed personal interest by accompanying me in field trips, helping to collect specimens, and making great contributions in encouraging me. My three children, Chepngeno, Chemutai, and Chepkirui, who also accompanied me in field trips, have been particularly patient. This thesis is dedicated to them all.

The author would finally like to thank the African-American Institute, the sponsor, for extensions to complete this research, for provision of a generous financial allowance, and for their total contribution to my education at this university. The Oklahoma Agricultural Experiment Station, Project No. 970, supplied funds for some apparatus and for a portion of the trips.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Fasciola hepatica, the common liver fluke of cattle, sheep, and other mammals, inhabit the bile ducts and gall bladder as adults. The migratory phases of the immature parasite occur in the peritoneal cavity, the parenchyma of the liver, and occasionally in other parts of the body, especially the lungs. The migratory behavior of this parasite has been reviewed extensively by Dawes and Hughes (1964). Lesions produced in the liver may cause an acute form of the disease. A chronic disease may develop later from adult flukes in the bile ducts. Both forms of the disease result in economic loss, particularly from liver condemnation.

The economic importance of liver flukes is not confined to liver condemnation alone. The parasites, if present in sufficient numbers, may be detrimental to the growth of cattle, quality and quantity of milk and beef, and even the efficiency of feed utilization (Black and Froyd, 1972; Brunsdon, 1967; Cawdery and Conway, 1971; Dawes, 1963; Hammond, 1965; Olsen, 1944; Pullan and Whitten, 1972).

Livers condemned due to fascioliasis would be some of the clues for the existence of the parasite for a given area. Liver condemnation alone does not imply that fascioliasis is endemic in the state where the animals are slaughtered because there is extensive cattle movement in the United States. Evidence of indigenous fascioliasis would exist if the condemned livers were from cattle that had been raised only within that locality under question, and particularly if the calves that were raised in the same pasture were also infected.

In Oklahoma, except for the extreme southeastern portion, fascioliasis was considered to have been in cattle shipped in from other states. This assumption, for the most part, was based on the prevailing opinion that the environment for Oklahoma was unsuitable for its establishment. This assumption, however, was found to be incorrect when *Fasciola hepatica* was reported in a herd of indigenous cattle from Ada, Oklahoma (Connally et al., 1974).

Although the intermediate hosts of *F. hepatica* in the United States have been known since 1891 (Francis, 1891), epidemiological records and documentation of the distribution of *F. hepatica* in the United States is meager and for Oklahoma it does not even exist, except for the liver condemnation records, a credit to the United States Federal Meat Inspection. The extent to which this parasite has spread throughout Oklahoma and the suitable conditions necessary for its establishment and perpetuation in the state is unknown.

The objective of this investigation, therefore, is: (1) to determine the geographic distribution of the factors existing in Oklahoma that are suitable for *Fasciola hepatica* establishment and perpetuation according to published requirements; (2) to determine the geographic locations of naturally infected herds in Oklahoma; (3) to characterize field conditions ("*Fasciola* risk" farms) suitable for the liver fluke's establishment and perpetuation in the state based on known infected indigenous herds; (4) to test hypothesis of "*Fasciola* risk" farms; and (5) to check if the commonly encountered aquatic snails from farms where fascioliasis is endemic are infected with the parasite.

CHAPTER II

MATERIALS AND METHODS

Part I. Retrospective Study on the Potential for Establishment of *Fasciola hepatica*

Determinants of *F. hepatica* Establishment and Perpetuation

The determinants necessary for establishment and perpetuation of *F. hepatica* were obtained from examination of world literature. Effort was especially made to determine the range of both the definitive and the intermediate hosts, the bionomics of the parasite and those of the intermediate hosts, and the nature of the suitable environmental conditions for development of both the parasite and its intermediate hosts. Requirements enhancing the infection of the intermediate hosts or definitive hosts were similarly determined.

Occurrence of the Determinants of *F. hepatica* in Oklahoma

The identified determinants for *F. hepatica* in the state of Oklahoma were obtained from the literature survey, maps, and consultation.

The distribution and density of one definitive host, cattle, for *F. hepatica* were obtained from estimated census maps and state data (State Department of Agriculture, Division of Statistics). Presence of other definitive hosts, especially the reservoir hosts of F. hepatica, was noted through personal observation and interviews with local hunters.

The presence and distribution of snail intermediate hosts occurring in Oklahoma that are known to be suitable hosts for F. hepatica were obtained from the literature and by examination of snails collected by previous investigators and kept in the Museum of Zoology of the Oklahoma State University.

The historical records of this parasite occurring in the state of Oklahoma prior to the current study were established by obtaining data from written communication with United States Federal Meat Inspectors and from published case reports.

Physical descriptive information such as relief, rivers, lakes, excavation, irrigation, and physical isotherms and contours for Oklahoma was obtained through consultation with the Geography Department of Oklahoma State University (O.S.U.) and from published maps.

Rainfall and temperature conditions and variabilities in Oklahoma were obtained through personal communication with both the Geography and Agronomy Departments of O.S.U. and from O.S.U. Extension publications.

The nature of the different soils occurring in Oklahoma and their variation in pH, including the distribution of vegetation types such as prairies, deserts, forests, or a combination of them throughout the state, was obtained from physical maps of Oklahoma, from an O.S.U. Extension publication entitled "The Soils of Oklahoma," and from consultation with personnel of the Agronomy and Geography Departments of O.S.U.

An inference about the potentiality of Oklahoma for F. hepatica was then made by comparing the documented information on the parasite and similar environmental factors occurring in Oklahoma.

Part II. Geographic Distribution of *Fasciola hepatica* in Oklahoma

Characterization of Farms With Known Indigenous *F. hepatica*

The distribution of farms from which *F. hepatica* has been diagnosed and identified was determined through telephone communication with practicing veterinarians and through local records of identified owners at a packinghouse whose cattle had liver fluke.

Selection of Farms

Identification From Practicing Veterinarians. A list of practicing veterinarians in the state of Oklahoma was obtained from the O.S.U. College of Veterinary Medicine. All veterinarians in general or large animal practice in Oklahoma were interviewed by telephone. They were asked if they knew about the existence of *F. hepatica* anywhere in the state, either by personal experience in their clinic, packinghouse, or by communication from other individuals. When a veterinarian said he had some knowledge about the occurrence of this parasite, specific questions were asked to determine if the known bovine cases of fascioliasis were indigenous, shipped in, or the source of cattle was unknown. The veterinarian was specifically asked to provide the following information about the bovine fascioliasis case:

1. Age of cattle from which he diagnosed *F. hepatica*;
2. A complete history of the cattle and the entire herd on that farm, such as pasture management, introduction of new cattle (frequently or occasionally) from out of state, and whether

past cattle or the entire herd were raised from replacement calves;

3. Topographic characteristics of the pasture as to whether the pasture had boggy areas or was situated on a slope or hillside;
4. Total number of cases he has identified on that farm and breeds or sex of animal frequently infected.

This information was recorded and used in planning field visits.

If the cases were identified as indigenous, arrangements were made with the veterinarian for future visits and field surveys of the farms with indigenous fascioliasis. All the responses of the veterinarians were recorded and areas with cases of fascioliases were marked on a map of Oklahoma. A list of addresses and telephone numbers was made, according to these veterinarians, of the farmers whose cattle have had *F. hepatica*.

Identification From Packinghouses. In order to increase the number of fluke-suspected farms, names and addresses of farms that had sent cattle infected with liver fluke to a nearby packinghouse (Wilson Packing Plant in Oklahoma City) for slaughter in the summer of 1976 were obtained from Dr. W. D. Munsen, the resident federal government veterinarian, and from Dr. J. G. Williams, who worked there in the summer of 1976.

Field Survey of Selected Farms

The veterinarians who had knowledge of the existence of *F. hepatica* in the state were once more contacted by telephone. They were asked to communicate with the farmers from whom they obtained the cases of fascioliasis and inform them of the arrangement being made to survey their farms. To confirm the final visit dates and times, these farmers were then called and asked the directions to their farms. When the farm was located, the farmer was then interviewed, field observations were made, and specimens (feces and snails) were collected. The form used to record all data from the field survey is given in Appendix C.

The farm owners identified from packinghouses were telephoned and informed of the likely fluke problem in their herd. A request was then made to visit their farms for the purpose of surveying the possible occurrence of *F. hepatica* in the remaining animals.

Interview. Information was obtained from the farmer about the history of animals including breeds, recent (six months to six years) introduction of cattle or sheep into the farms, the number of recently introduced animals and their origin, pasture management such as rotation or if additional pastures were occasionally rented from other farms, occurrence of deaths in his animals and the causes, feed supplement, type of medication and when, and the name of his veterinarian.

Topography. Existence of slopes, flood plains or boggy areas, and drainage ditches were noted and the estimated fraction of pasture containing these features was determined. These data were plotted on a rough sketch of the farm and bog, marsh or areas with ponds were photographed.

Water. The presence of ponds, dams, streams, water troughs, ditches, excavation, irrigation, or obstructions that could lead to temporary retention of rain or flood water were also noted. The source of water, whether surface, well or city water, was determined through direct observation or through an interview with the owner.

Soil. Soil samples of the farm were obtained and classified by visual examination as either sandy, clay or the intermediate form (loam).

Vegetation. The vegetation in that portion of the pasture determined as bog or flood plain was classified as either short or tall grass. Additionally, observations were made and noted as to whether or not the grass was under weeds, trees, or exposed. The type of grass was also noted as either thick mat or with straight blades. Vegetation in water or likely to be covered by water for extended periods of time during the wet season was recorded.

Wildlife. The existence of lagomorphs such as rabbits and rodents on the farm was determined by finding their fecal droppings or by asking the farmer how often he saw them.

Collection of Fresh Cattle Feces. Fresh cattle manure was easily collected by walking among the herd. If the cattle were lying down at this time, they tended to rise and move away. The behavioral responses observed in resting cattle that were disturbed were defecation and urination. Feces from identifiable cattle were also obtained at feeding or milking time. The presence of the farmer or his supervisor was indispensable in the differentiation of the indigenous from the introduced cattle; when a cow defecated, the farmer was asked if the cow was raised on his farm or if it was purchased. When all animals in a pasture were known to have been born and raised on the premises, feces were collected by simply walking through the pasture and picking freshly deposited feces. Freshly deposited feces were identified by a moist surface that was uncrusted, glittered, and gave off water vapor when placed in a transparent bag. If the origin of the cattle in the farm was unknown, no feces collection was made.

The collection procedure consisted of turning a Ziploc* plastic bag inside out with the palm of the hand open. A handful of the feces was then scooped out and the hand withdrawn. The bag was then sealed and labeled with farm, pasture, date, and when possible the age and/or breed of cattle as given by the farmer during the interview. All specimens collected from one pasture were put together in a larger bag and similarly labeled. The number of fecal specimens collected varied with availability of fresh feces but 25 percent of cattle feces was attempted.

Snail Collection. The aquatic environments in the pasture were located and it was determined if they had water or were potentially capable of holding water. They were then inspected for the snail intermediate hosts of *F. hepatica* by walking around them. Representative specimens of 11 varieties of shell configuration types of snails that occurred on the surface of the mud, under the leaves, or on the edge of the water were hand picked. Empty shells of snails in the areas were also collected. Snails that might occur in the mud of ponds and streams were collected by using a mud scraper or a dip net attached to a long handle. The mud that was scooped from the water was strained and the remaining debris in the screen or net was examined for snails. Snails of the same grossly apparent morphological configuration were separated on site and placed in a labeled specimen jar containing the pond water, or all of the debris from the screen was collected and examination for snails was done immediately

---

*Ziploc Storage Bags, manufactured by The Dow Chemical Company, Indianapolis, Indiana.

on arrival in the laboratory. Snails collected from different ponds and pastures were separated from each other even when they were of the same species. Snail collection was not confined to these Fasciola-suspected farms alone. A search for snails was made on the region of the farms studied by inspection under bridges, roadside water, lakes, parks, college ponds, or monumental fountains of the nearby recreational areas. Snails with sinistral configuration according to Eddy and Hobson (1961) and tentatively identified by Amy VanDevender were suspected as belonging to the family Physidae, while those with dextral were labeled Lymnaea. Ten live and ten empty shells of snails resembling Lymnaea on the basis of shell configuration were mailed to the National Museum of Zoology, Mollusk Division, Washington, D.C., and to the Museum of Zoology, Mollusk Division, University of Michigan, for positive identification.

Laboratory Studies

Snail Examination for Cercariae. The snails from the field were kept in water originating from the same snail source in the laboratory for at least one day. The water was then changed, at least once every other day, with tap water that previously had been conditioned by letting it stand for one week, according to instructions supplied by the North Carolina Biological Supply Company, Burlington, North Carolina. About ten snails were kept together in each fingerbowl that was filled two-thirds with water according to suggestions by the North Carolina Biological Supply Company. All snails were fed fresh lettuce purchased locally and cut into small pieces. Fragments of blackboard chalk were added to snail water for their calcium source. Dead snails were removed immediately when found. All snails were exposed to a 75 watt lamp placed about two feet from the dishes throughout the holding period. Each dish of snails was scanned daily for cercariae that had been shed. The shed cercariae were observed under a stereoscopic microscope to determine if they would encyst on the dish. Snails passing cercariae were separated from the others in order to determine the fraction of snails infected.

Examination of Feces for *F. hepatica* Eggs. The method described for the ante-morterm diagnosis of *F. hepatica* throughout this investigation was a modification of Dennis et al. (1954), Dinnik and Dinnik (1963a), Willmont and Pester (1952). The modification is as follows:

1. Dennis et al. (1954) method: The use of detergent was completely avoided and instead of using centrifuge tubes for sedimentation, large 1 liter jars or 500 ml beakers were used. Examination of sediment for *F. hepatica* eggs was accomplished under the dissecting microscope instead of the compound microscope.
2. Dinnik and Dinnik (1963a) method: The only modification here was the elimination of ice cold water for sedimentation of eggs in the fecal suspension and substitution of cold tap water.
3. Willmont and Pester (1952) method: Selective sieves although present were not used; only one standard sieve of 100 meshes/inch was used throughout. There was also no bolting silk which these authors described.

After the final decantation of the fecal suspension, as outlined by these authors, the following specific procedure was followed throughout. The sediment was swirled a few times in the beaker and strained through a wire mesh (32-90 meshes per inch) into another beaker. The beaker previously used to prepare the fecal suspension was rinsed with a little water and washings were poured into the mesh. The fecal debris in the mesh was then thoroughly rinsed with running water in a spray from until the beaker was filled. The beaker and its contents were allowed to remain undisturbed for another five minutes after which the aqueous layer was decanted. The egg-laden sediment was then emptied into a glass dish and scanned under 40x power of the dissecting microscope. A dissecting needle was used to slowly move any debris which obscured the field. The entire dish was scanned for fluke eggs. The presence or absence of fluke eggs was recorded.

Characterization of "*Fasciola* Risk" Farms and Hypothesis Testing

The characterized farms surveyed with known indigenous *F. hepatica* were analyzed to determine the essential and enhancing factors necessary for the biology of the liver fluke in them. From this analysis a profile was outlined for the type of farm that would be at risk if *F. hepatica* were to be introduced. This farm profile was defined as a "*Fasciola* risk" farm. By this definition a hypothesis was stated that if infected cattle were introduced into a "*Fasciola* risk" farm, liver fluke would be established and perpetuated. This, in essence, would provide for the spread of *F. hepatica* in the state.

According to the distribution of cattle, vegetation, climate, and topographic variations including knowledge gained from literature analysis of this study and responses from practicing veterinarians and packinghouses, the state of Oklahoma was divided into five regions approximating west, north, east, south, and central. From each of the sections, counties that were known to have farms with liver flukes were deleted from this portion of the study to avoid duplication. Then about half of the remaining counties in each of the five regions were randomly selected using a table of random numbers. For each selected county a locale near a town at approximately the center of the county was selected and visited by car.

Roads in the proximity of towns in the selected counties were followed in an attempt to locate farms that by visual inspection had the suitable conditions for establishment of _F. hepatica_ according to the criteria establsihed for "_Fasciola_ risk" farms. When a suitable farm was located, a visit was made to the farmer. Since this was an unexpected visit, precaution was taken by providing an introduction with identification and an explanation of the purpose of the visit. The procedures were followed until at least one farm had been located where detailed studies could be made. With the exception of one county (Payne), where the college was located and in which nine farms were visited, a maximum of four farms were visited in each county when it was possible. The number of the counties visited in each section were listed. Additionally, county extension agents of the selected counties were asked by written communication to provide names and addresses of cattle owners near the selected towns who had farms with the criteria of a "_Fasciola_ risk" farm.

The methods of field survey inside these test farms were as described for the farms with known indigenous _F. hepatica_.

CHAPTER III

RESULTS

Part I. Retrospective Study on the Potential for Establishment and Perpetuation of *Fasciola hepatica* in Oklahoma

Determinants of *F. hepatica*

From the examination of the literature for the requirements in the biology of *F. hepatica*, determinants considered to be pertinent for its establishment and perpetuation were the following: susceptible definitive hosts (Table I)* required available intermediate hosts (Table II), specific *F. hepatica* determinants for its establishment in nature (Table III), specific environmental factors for the intermediate hosts (Table IV), and specific environmental factors for extramammalian stages of *F. hepatica* (Table V).

Additional findings not included in Tables I through V are the longetivity of the parasite (*F. hepatica*) as a source of contamination (Leiper, 1938; Ross, 1968; Van Cleave, 1934), the effects of environment on the extramammalian stages of the parasite (the miracidia, the cercariae, and the metacercariae) (Krull, 1934; Rees, 1931, 1948; Ross, 1970a,b; Ross and Todd, 1968; Rowan, 1956), and intramolluscan stages

---

*All tables are presented in Appendix A.

(Krull, 1941). For the fluke eggs to develop, three conditions must exist: (1) that the eggs be freed from feces, (2) that the freed eggs must be surrounded by at least a film of water, and (3) that the temperature of the micro-environment must be above 9.5°C but less than 30°C (Rowcliffe and Ollerenshaw, 1960; Christernsen et al., 1976).

When miracidia hatch, they are short-lived and, in the absence of water, cannot infect snails (Harris and Charleston, 1971; Michel and Ollerenshaw, 1963). Hatching of eggs or activity of miracidia require well-oxygenated water with low pH (4.2 to 6.9) (Rowcliffe and Ollerenshaw, 1960). The rate of asexual mulitplication of the larval stages within the snail host is either retarded or halted altogether at very low temperature (Dinnik and Dinnik, 1963b).

The emergence and activity of the cercariae also are dependent on water. Conditions for the emergence of cercariae of F. hepatica have been shown to be similar to those of other trematodes (Barbosa and Oliver, 1958; Gumble et al., 1957; Kuntz, 1947; Rees, 1931, 1948; Schreidber and Schubert, 1949). Since fresh water was demonstrated to be more important for the emergence of F. hepatica cercariae from their snail intermediate hosts (Kendall and McCullough, 1951) (Table V), onset of wet conditions after a dry period will therefore stimulate the release of cercariae (Kendall and McCullough, 1951; Walton, 1918). In aestivating snails, larvae of F. hepatica could survive at least ten months of dry weather dormancy on the part of the snail (Kendall, 1950, 1965). Kendall, however, observed that the stage of development of the parasite in aestivating snails was not as advanced. The majority of snails die under dry conditions (Pilsbry, 1896; Strandine, 1941; Thomas, 1883) and developing stages are likewise killed.

Direct sunlight and high temperature (110°F) are detrimental to the metacercariae (Kendall, 1965). Survival of metacercariae can be measured in months in the winter but in weeks during the height of the summer (Michel and Ollerenshaw, 1963). Using tracer sheep, Olsen (1945, 1947) noted that after prolonged drought, in which temperature was relatively higher than normal, pastures were relatively free of metacercariae. Marek (quoted by Olsen, 1947) reported that when grass growing in a moist area was subsequently made into hay during rainy weather, the metacercariae encysting in it survived and were able to infect rabbits eight months after storage. Metacercariae of F. hepatica, however, failed to survive in silage when kept for 35 to 57 days (Wikerhauser and Brglez, 1961, quoted by Kendall, 1965).

With respect to the snail intermediate hosts, it has been reported that slightly unsuitable snails can transmit this parasite under certain circumstances (Kendall, 1965). This author reported that the younger snails of the unsuitable intermediate hosts can be experimentally infected. In the suitable snail hosts of F. hepatica, however, the snails must grow and attain a certain size (0.25 inch) before they can be infected with miracidia of F. hepatica (Ewers, 1964; Kendall, 1965; Krull, 1934; Ollerenshaw, 1959; Thomas, 1893).

Lymneid snails are more amphibious than truly aquatic snails (Thomas, 1883; Walton, 1918), but the young and newly hatched snails seem to remain under the surface of water (Van Cleave, 1935). Since they are amphibious, the intermediate hosts of F. hepatica are more often found in temporary water and wet muddy places which occasionally become dry for part of the year (Armour, 1975; Boray, 1964; Kendall, 1949; Olsen, 1944; Pilsbry, 1896; Strandine, 1941; Swales, 1935; Thomas, 1883; Walton, 1918). Additionally, these snails can withstand dry conditions for prolonged periods of time (Baker, 1911; Pilsbry, 1896; Van Cleave, 1934).

Environmental conditions, that is, the pH, oxygen tension, salinity, and pollution, in addition to its presence or absence, are important factors influencing the occurrence and numbers of snails in a locale. No snails are found in brackish water where salinity exceeds 940 parts per million (Boray, 1964). Turbidity (concentration of silica in water) is also important (Goodrich, 1940). Slight pollution of water with some farmyard manure is sufficient to bring about extinction of some lymneid snails (Goodrich, 1940). The importance of aeration to snails is known. Lymnaea and Planorbis could be kept submerged in water for long periods in well-aerated water, but die in a few hours in water that had previously been boiled and protected from contact with air (Willem, 1896, quoted by Noland and Reichel, 1943).

The effect of altitude on survival of intermediate host snails has not been conclusively investigated, but fascioliasis in the western part of Britain is enzootic only on lands below 1000 feet (Edwards, 1968; Michel and Ollerenshaw, 1963; and Ollerenshaw, 1959, 1966). However, snail intermediate hosts of F. hepatica have been found in the United States at altitudes from near sea level to 5600 feet where temperatures get as low as -40°C for long periods (Shaw and Simms, 1929). From the literature it was unclear whether the effect of altitude was restrictive for the snails or for the parasite itself.

Topographically, the stream gradient has an important influence on the distribution of snails because it governs the flow of water (Boray, 1964). This author noted also that water lying between banks with steep slopes or flowing with a speed exceeding 15 cm/sec was unlikely to carry any snails. Irrigation, excavation or dams usually change the population density and distribution of snails (Armour, 1975; Boray, 1964; Branson, 1959; Mehl, 1932, quoted by Olsen, 1944; Wright, 1971). Besides flowing water, Lymneae are known to prefer low lying flat areas (Alicata, 1938; Boray, 1964; Francis, 1891; Olsen, 1944; Swales, 1935; Van Volkenberg, 1929).

Occurrence of the Determinants of F. Hepatica in Oklahoma

The necessary factors of the biology for F. hepatica were found to exist in some regions of Oklahoma.

The parasite has been introduced into Oklahoma as evidenced by the documentation of infected native cattle (Connally et al., 1974) and from condemned livers at slaughterhouses in Oklahoma and neighboring states (Table VI and Figures 1 and 2).* The other pertinent factors for this parasite that was determined to occur in Oklahoma were a suitable definitive host (Table VII, Figures 3 and 4), intermediate hosts (Table VIII and Figure 5), and external factors for the establishment and perpetuation of F. hepatica (Table IX and Figures 6, 7, and 8).

Besides the factors listed in Table IX and Figures 6, 7, and 8, additional information was found to exist in Oklahoma that, according to the literature survey in the retrospective study, influences the establishment of F. hepatica as follows.

---

*All figures are presented in Appendix B.

Topography and Water

Beginning from the southeastern corner of Oklahoma in the northwest direction the land rises steadily from an altitude of under 300 feet above sea level, most of it being bottom lands, and reaches about 1000 feet in the central region around Payne, Tulsa, Pawnee, and Logan Counties (see Figure 8). The land then rises a little more steeply around Woods, Woodward, Dewey, and Washita Counties, which average 1500 feet in their eastern boundaries to over 3500 feet in the eastern side of Beaver and Texas Counties. From here the land forms a plateau, which is characterized by plains sometimes with very irregular ground surface, and reaches a peak of about 5000 feet at the eastern corner of Cimarron County (Gray and Galloway, 1969). A cross section, A-B, of Oklahoma from Cimarron County to Idabel may be represented by Figure 8 and the enclosed map.

Climate

In Oklahoma, there is a steady drop in rainfall from about 50 inches per year in the southeast and eastern Oklahoma to under 18 inches annually in the Panhandle area (see Figure 6). Snow is a rather infrequent occurrence in southeast Oklahoma, but in the Panhandle has been recorded in all months except July and August (Gray and Galloway, 1969).

Temperature varies less than rainfall in Oklahoma. The temperature conditions follow an east-west gradient, being lower in the Panhandle area (west). The mean annual temperature range is from 63.8°F at Idabel in the extreme southeast to 53.6°F at Boise City in the western part of the Panhandle. Average July temperatures are 78°F in the Panhandle to

82°F in the southeast half of the state. January averages are 32°F in the northwest to 44°F in the extreme southeast.

Due to the lack of rainfall and temperature extremes, the western portion of the state including the Panhandle is more arid. However, even in other areas of the state in the summer, ponds are either dry or low due to high temperature and persistent winds. In terms of both minimum temperature and rainfall, eastern Oklahoma is more suitable for *F. hepatica* and its intermediate hosts.

Soils and pH

Soils that develop under oak-pine forests in the east with a sandier upper portion are acid and light in color when ploughed. The prairie soils that develop on a more clay parent material under tall grass have a dark color, sometimes up to a foot or more. The prairies west of the 99th meridian, except for the sandy soils, have not been bleached of lime and have lime zones at some depths in the profile so that soils range from neutral to alkaline at the surfaces. Generally, soils in eastern Oklahoma range from moderate to strongly acidic while those in the western portion are more basic (Gray and Galloway, 1969).

Vegetation

The western Panhandle is characterized by steppe grass growing dispersely on the ground. For the most part, the area is characteristic of arid or semi-arid lands accommodating desert plants (especially in Cimarron County) such as cacti. As one moves eastward, the vegetation gradually changes to mixed prairies between the Panhandle and the central region. Central Oklahoma is generally characterized by tall grass of the savannah type, while the eastern region is characterized by forest (see Figure 7).

Summary for the Suitability of Oklahoma for *F. hepatica*

From the study of the potential suitability of Oklahoma for *F. hepatica*, Oklahoma has the necessary conditions for the establishment and perpetuation of this parasite, namely: definitive hosts (higher in the east than the west), intermediate hosts (distributed throughout the state), and areas of suitable environmental conditions. Suitable environmental conditions are that temperatures for part of the year are above 9.5°C and below 35°C. The clay-type soils, pH of 5.4 to 7.3, and fresh clear surface water with vegetation found in eastern Oklahoma is far more suitable for *F. hepatica* than the arid western portion of the state.

Part II. Geographical Distribution of *Fasciola hepatica* in Oklahoma

The five regions visited during the investigation are summarized in Figure 9 and all counties visited are presented in Figure 10.

Characterization of Farms With Indigenous *F. hepatica*

Selection of Farms

The telephone responses from practicing veterinarians, which constituted one source of data for identifying farms with *F. hepatica*, are recorded in Table X. Counties having farms that were identified from packinghouse data are listed in Table XI. All counties in Oklahoma identified as having farms with F. hepatica from both data sources (veterinarians and slaughterhouses) are shown in Figure 11. F. hepatica farms were identified in more counties from central Oklahoma than in other regions in the slaughterhouse data, but in the data obtained from practicing veterinarians, the southern region of the state had the most counties with definitive F. hepatica infections (see Table XII).

Field Survey

The field characteristics, animal history, soil types, surface water, and mollusks for each farm containing indigenous F. hepatica are given in Table XIII. Landscapes of typical farms visited are shown in Figures 12, 13, and 14.

There were 22 farms that were identified by packinghouses or by veterinarians as having indigenous F. hepatica in their cattle. Only ten of these farms were visited during the survey. Six farms were located in the central portion, three in the southern portion, and one in the eastern portion of the state. Three of the farms visited had calves that were infected with F. hepatica. Two farms had cattle and calves which had no history of having been moved to other pastures. The majority of cattle studied on these farms were Hereford (five farms), Holstein (two farms), Angus (one farm), and mixed breeds (two farms).

The majority of the snails that were found in ponds of the pastures visited on the identified farms were those with sinistral configuration, tentatively identified as belonging to the family Physidae and of the family Planorbidae, dominated by the genus Helisoma. These two families of Gastropoda were present almost in every pond in every county. Live snails of the family Lymneidae were collected on the campus of the Northeastern Oklahoma State University. These *Lymnaea* species were present on a part of the spring near flowing water rather than in the pond itself a few yards away. Other evidence of *Lymnaea* were empty shells collected near Purcell (McClain County), Wewoka (Seminole County), and Lamont (Grant County), and along the Cimarron River between Perkins and Interstate Highway 35 (Payne County). These collected live snails are being maintained in the Department of Veterinary Parasitology of the Oklahoma State University. This department is also storing the empty shells. Illustrations of some of the snails collected are presented in Figure 16.

Laboratory Studies

Several cercariae were observed to emerge from the *Physa* and *Helisoma* species kept in the laboratory for a day in previously conditioned tap water. The majority of these cercariae were the furcocercous type with variable morphological shapes, lengths, and structures. These cercariae were not of interest in this study and were discarded. The other type of cercariae were amphistome-like. However, unlike amphistome cercariae, most of them did not encyst on the glass container. After vigorous swimming, they slowed down; some lost their tails and finally died and degenerated. None of the cercariae was suspected as being *Fasciola* based on the fact that they did not encyst.

The prevalence of *F. hepatica* in cattle fecal specimens collected from farms visited as a result of telephone interviews and packinghouse records for June and July of 1976 are summarized in Table XIV. *F. hepatica* was identified in 6 of the 34 calves under two years of age (Table XV). The 6 calves with *F. hepatica* were female. *F. hepatica* was found in 67 of 247 cattle examined over two years of age. The majority of the cattle with F. hepatica were Hereford and Semmental in which 30 percent of the cattle examined were infected. Of the Angus, Holstein, and mixed breed cattle that were examined, 5, 28, and 40 percent, respectively, had F. hepatica (Table XIV). All the positive cattle (calves and adults) were considered to have indigenous F. hepatica infections based on the herd history. Nine of the ten farms that were examined had naturally infected native cattle. As shown in Table XV, 5 percent of the female calves, 14 percent of the bulls, and 29 percent of the adult females were infected.

An interesting coincidence was noticed in the course of the laboratory study. Two kinds of trematode eggs were observed: one was lemon-shaped with golden color shell characteristics of F. hepatica eggs, and the other, while resembling those of F. hepatica completely in shape and other morphological features, lacked the golden pigmentation, i.e., was colorless and smaller. The two kinds of eggs (see Figure 17) occurred together; one was F. hepatica and the other was earlier misdiagnosed as infertile F. hepatica eggs. However, the type which was different from the typical F. hepatica was later identified as Paramphistomum. The cattle found infected with this trematode from farms with indigenous F. hepatica infections are recorded in Table XIV.

Characterization of "Fasciola Risk" Farms and Hypothesis Testing

"Fasciola Risk" Farm

According to the results of the survey of indigenous liver fluke farms, a "Fasciola risk" farm was defined as one having the following characteristics:

1. Cattle, particularly if some individuals were maintained for several years or more and/or calves were born and raised on the premises (amphibious snails increase the risk).
2. Boggy areas or flood plain in parts of the pasture where cattle were maintained.
3. Surface water that remains for extended periods of time, particularly lakes and "wet weather" springs.
4. Vegetation in the boggy areas which can easily get submerged under water, particularly short grass.

Field Survey

The five regional divisions that were used in the survey to test the hypothesis are given in Figure 9. A total of 35 counties were visited in these five regions, but field surveys were carried out only in 27 counties. Eight of the counties were not surveyed because farms in them were either inaccessible from the roads taken or there were no owners on the premises at the time of the visit.

The snails collected from these hypothesis test farms were similar to those collected from farms previously suspected of *F. hepatica* infections. No live lymneid snail was collected but empty shells of snails that were identified as *Lymnaea* were collected at Lamont and Wewoka in Grant and Seminole counties, respectively. No *Lymnaea* were collected in the two farms from which *F. hepatica* was identified.

The results of field data collected from farms visited to test the "*Fasciola* risk" farm hypothesis (i.e., farms having *F. hepatica* present) are presented in Table XVII.

A total of 15 calves under two years were examined for *Fasciola hepatica* and 772 adult cattle (females and bulls) were examined in 42 farms from the 27 counties surveyed. Only 2 farms had cattle harboring *F. hepatica*: one in central Oklahoma and the other in eastern Oklahoma. Cattle in the 42 hypothesis farms had variable histories. Six farms that were negative for *F. hepatica* had no new animals added into the herd and, as far as the farmers were concerned, several generations of cattle had been raised from replacement calves in the pasture. Thirty-five farms had cattle from other states, but only two of these had *F. hepatica* in them. One farm had all the cattle brought in from Texas, but their calves were free of infection. The farms having *F. hepatica* in native cattle had a history of cattle introduced from regions known to have liver fluke.

Laboratory Study

Fecal specimens collected from the calves examined did not have *F. hepatica* eggs in them. However, from the 772 fecal specimens from adult cattle, 4 had *F. hepatica* eggs. Two of these specimens came from Holstein cattle at Perkins in Payne County near the Cimarron River. The other two came from Angus cattle near Warwick in Lincoln County. The two farms were near each other (six miles apart) at the boundary of the two counties. Laboratory results of fecal specimens from these farms are given in Table XVIII.

Snail examination revealed that these snails were naturally infected with trematode larvae. None of the cercariae emerging from these snails were considered *Fasciola hepatica* because they did not encyst.

CHAPTER IV

DISCUSSION

Part I. The Potential for the Establishment of *Fasciola hepatica* in Oklahoma

The literature survey for factors necessary for the establishment and perpetuation of *Fasciola hepatica* compares favorably with factors occurring in Oklahoma. Additionally for Oklahoma, regions that seem to have the best environmental conditions for both the parasite (*F. hepatica*) and its intermediate hosts (snails of the genus *Lymnaea*) are the same regions that have the highest host density (see cattle density in Figure 3). Since the cattle population in Oklahoma has increased from 1973 to 1976 (see Figure 4), this means that animal density (number per unit acre) has also increased. Van Volkenberg (1934) reported that high host density alone enhances establishment of parasites. Eastern Oklahoma seems to have the factors that can be considered favorable for *F. hepatica*, and indeed was found to agree approximately with the findings of this study. Support for the evidence of suitability of Oklahoma for *F. hepatica* can be discerned from the fact that the parasite was found in native cattle that had no history of having been moved out of the premises. This alone implies that the intermediate host was present and that the environmental conditions must have been suitable for the establishment of these indigenous *F. hepatica* infections.

Part II. Geographical Distribution of *Fasciola hepatica* in Oklahoma

Characterization of Farms With Indigenous *F. Hepatica*

The farms from which *F. hepatica* has been diagnosed were obtained from two sources: practicing veterinarians in the counties and from one Oklahoma City packinghouse (Wilson Packing Plant). The number of veterinarians who possessed the knowledge of this parasite in the state was an extremely small number compared to those who had not seen any cases of *F. hepatica*. This may be one of the indications of how rare this parasite is in the state or that it is not diagnosed because it is not suspected. The problem about the present recording system for liver fluke at packinghouses is that the source of the condemned animal is not known (Pullan, 1972; Williams, 1976). The packinghouse list of farms from which some cattle had *F. hepatica* in Oklahoma was very small. However, considering that the list was drawn only for a period of time less than one month (June 28 through July 22, 1976), the number of farms with *F. hepatica* would be proportionally larger if the list was made for an entire year. Additionally, if the list of farms that sent the liver fluke infected cattle to slaughter was made from all the 18 Oklahoma City packinghouses, the number of farms with indigenous infections can be even larger and possible distribution even greater than shown in this study. Distribution of *F. hepatica* herds could be made by utilizing packinghouses if they recorded the sources of each slaughtered animal. Statistical determination of the density of *F. hepatica* in the state may well depend on accurate collection of data from these packinghouses for native Oklahoma cattle. Collected data could be used not only to show how many cattle are infected, within statistical limits, but the dollar loss to the farmers and the nation resulting from the liver condemnation.

The results did not conclusively show any discernible pattern of *F. hepatica* distribution in the state. However, there is an apparent pattern of *F. hepatica* distribution in the state, since the responses from veterinarians and packinghouse records tend to show some concentration of *F. hepatica* cases in central and eastern Oklahoma (see Figure 11).

Several factors may have made it impossible to obtain a true picture of the infection in the farms investigated. Some of the farms, although judged to be "*Fasciola* risk" because of boggy areas, flood plain, and high cattle density, were not accessible from highways, particularly the fenced interstate highways. On several occasions no investigation was made at all, because either the land owners were repeatedly absent from the premises or some of them refused permission to check their cattle. Those who did refuse believed their cattle would be quarantined if found infected and they could not be convinced that such was not the case. Eight potential "*Fasciola* risk" farms were not examined (two in Cherokee County, one in Adair County, two in Canadian County, two in Logan County, and one in Grant County) for this reason.

Although county extension agents were asked to help reduce suspicion when visiting a farm for the first time, several of them misunderstood the letter and contacted farmers whose farms did not have the field characteristics conducive to endemic fascioliasis. A case in point is a farmer selected in Woodward County for this investigation. He had the highest cow-acres ratio than any farm investigated and this was the only reason the extension agent chose it. When this farm was finally located and visited, it contained only 22 cattle raised in a 4.9 acre bermuda plot, with no boggy areas or ponds except a well water supply.

Some difficulties were encountered when collecting feces in the field. When cattle were scattered over a wide area, feces were hard to find, especially in pastures with tall grass. Additionally, cattle feeding on lush green grass often had diarrhea and feces were not easy to pick. A few different species of snakes were present in several pastures and one farmer in Tillman County had killed 21 snakes in the morning just before the investigation. Care in collecting feces in dry river beds, therefore, slowed down the collection.

There were some problems with snail collection. Some of these problems are associated with lack of rainfall or water in their habitats. It had been dry most of the time during this investigation. A typical consequence of this may be seen on the F. hepatica problem farm near Purcell, Oklahoma. The water level was very low and boggy areas were completely dry on each visit. Efforts to collect snails were unsuccessful. However, during the third visit, which was specifically aimed at digging out snails from moist parts of the boggy waterways, empty shells identifiable as Lymnaea were collected as well as other snails with dextral configuration which were tentatively identified as belonging to the family Succinidae. Other unidentified empty shells were also collected. Future investigators of fascioliasis should make their visits coincide with times of heavy rainfall in order to collect live snails. One needs to spend considerable time looking for and collecting numerous snails, especially in boggy areas. One problem with collection of snails during this survey was the lack of experience on the part of the investigator. It was only toward the end of the survey that boggy areas were found to harbor empty shells of snails identifiable as *Lymnaea*.

Forecasting fascioliasis in Oklahoma is not feasible at the present time because enough data have not been collected, but a "*Fasciola* risk" farm can be described. Since clinical syndromes of fascioliasis are less in cattle than in sheep, association of the disease with climate may depend on frequently diagnosing flukes from apparently healthy animals. However, in those farms in the state already known to suffer effects of fascioliasis, the suitability of the systems devised by Armour (1975), Gettinby et al. (1974), Ollerenshaw and Rowlands (1959), and Ross (1970) may be studied to see if they can be used to monitor the fascioliasis problem and to design possible control measures, particularly drainage.

Other limitations to this investigation are the time and cost. A complete investigation should consist of examining the entire herd and several such herds per county. To examine and obtain 70 fecal samples from a herd of 100, one needs not less than two days per farm and since some places were quite distant from campus, samples would spoil, especially if live specimens were retained too long in the trip. Additionally, strong financial support would enable employment of an assistant and would meet transportation, supply, and secretarial costs.

The laboratory results showed that another fluke of the genus *Paramphistomum* occurred simultaneously with *Fasciola hepatica* in cattle. This observation can be very useful in further identifying a "*Fasciola* risk" farm. Since the two flukes utilize similar snails as intermediate hosts (*Stagnicola* [*Lymnaea*] *bulimoides techella* and *Pseudosuccinea* [*Lymnaea*] *columella*, Olsen, 1974), the discovery of a *Paramphistomum* fluke in a herd of cattle may suggest the suitable determinant factors for *Fasciola* *hepatica*, and can be used to alert the farmer of the danger of introducing *F. hepatica* infected cattle onto a farm.

CHAPTER V

CONCLUSIONS

This study has presented some evidence that those factors considered necessary for the establishment of Fasciola hepatica occur in Oklahoma. These factors are suitable definitive hosts, intermediate hosts, and environmental conditions suitable for both the extramammalian stages of the parasite and its intermediate hosts. Since F. hepatica has been diagnosed from naturally infected herds in this state, the conditions for its establishment in that herd must have been suitable in the first place. In Oklahoma, the prevalence of F. hepatica infection is confined to the central and eastern half of the state, according to the findings of this study. It was also shown that the eastern portion has more suitable conditions for the establishment and perpetuation of F. hepatica than western Oklahoma.

Based on the findings of the field survey during this investigation, the profile of a "Fasciola risk" farm in Oklahoma includes:

1. Presence of definitive hosts (cattle) in sufficiently high density whose records indicate frequent or occasional introduction from out of state.
2. Existence of boggy areas in the pasture where water collects for several months or more during the year.
3. Ground surface in boggy areas which is covered with short grass (grass that can be easily submerged when flooding occurs).

It is suggested that cattle infected with _F_. _hepatica_ should not be introduced into a "_Fasciola_ risk" farm.

LITERATURE CITED

Alicata, J. E. 1938. Observations on the life history of Fasciola gigantica, the common liver fluke of cattle in Hawaii, and the intermediate host, Fossaria ollula. Hawaii Agri. Exper. Station, 22 pp.

______, and L. E. Swanson. 1937. Fasciola gigantica, a liver fluke of cattle in Hawaii, and the snail, Fossaria ollula, its important intermediate host. J. Parasitol. 23(1):106-107.

Armour, J. 1975. The epidemiology and control of bovine fascioliasis. Vet. Rec. 96(9):198-201.

Baker, F. C. 1909. Mollusks from Kansas and Oklahoma. Nautilus 23: 91-94.

______. 1911. The Lymnaeidae of North and Middle America, recent and fossil. Chicago Acad. Ser. Pub. 3(1-XVI):1-539.

Barbosa, F. S., and L. Oliver. 1958. Studies on the snail vectors of Bilharziasis mansoni in northeastern Brazil. Bull. WHO 18:895-908.

Beresford, O. D. 1976. A case of fascioliasis in man. Vet. Rec. 98(1): 15.

Berg, C. O. 1953. Sciomyzid larvae (Diptera) that feed on snails. J. parasitol. 39:630-636.

______. 1964. Snail control in trematode diseases: The possible value of Sciomyzid larvae snail-killing Diptera. In Advances in Parasitology 2:259-309. B. Dawes (ed.), Academic Press, New York.

Black, N. M., and G. Froyd. 1972. The possible influence of liver fluke infestation on milk quality. Vet. Rec. 90(3):71-72.

Boray, J. C. 1963. The ecology of Fasciola hepatica with particular reference to its intermediate host in Australia. Proc. 17th Int. Vet. Congress 1:709-715.

______. 1964. Studies on the ecology of Lymnaea tomentosa, the intermediate host of Fasciola hepatica I. History, geographical distribution, and environment. Austral. J. Zool. 12(2):217-230.

Branson, B. A. 1959a. Notes on Oklahoma snails (Gastropoda), with new records. Southwestern Naturalist 3-4:224-226.

______. 1959b. Oklahoma gastropoda: Range extensions, a faunal addition, and a nomenclature change. Okla. Acad. Sci. Proc. 37:30-32.

______. 1959c. The recent gastropoda of Oklahoma. Part I. Historical review, general comments and higher taxonomic categories. Okla. Acad. Sci. Proc. 39:21-37.

______. 1961. The recent gastropoda of Oklahoma. Part II. Distribution, ecology and taxonomy of fresh-water gastropods. O.S.U. publication. Arts and Science Studies, Biological Studies Series 58(6):17.

______, and W. R. Heard. 1959. Snails from the upper peninsula of Alaska with feeding habits of Brooks Lake fishes. Nautilus 73(1): 14-16.

______, and I. E. Wallen. 1958. Some further records of snail distribution by counties in Oklahoma. Okla. Acad. Sci. Proc. 36:34-37.

Bruce, R. G., and J. Armour. 1973. A further study of the epidemiology of ovine fascioliasis in Scotland and its control using molluscicide. Vet. Rec. 92:518-526.

Brunsdon, R. V. 1967. Liver fluke--Fasciola hepatica in sheep and cattle in New Zealand and its control. New Zealand Vet. J. 15(1-2): 9-23.

Cain, S. A. F. Segadas-Vianna, and F. Bunt. 1950. Mollusks of Sodon Lake, Oakland County, Michigan. II. The winter occurrence of certain species. Ecology 31(4):546-553.

Cawdery, M. J. H., and M. A. Moran. 1971. A method for estimating the level of infection of fascioliasis to which sheep are exposed. Brit. Vet. J. 127(3):118-124.

______, and A. Conway. 1971. Production effects of the liver fluke, Fasciola hepatica, on beef cattle. Vet. Rec. 89(24):641-643.

Cawston, F. G. 1946. South African aquatic snails. Nautilus 60:35.

Christernsen, N. O., P. Nansen, and F. Frandsen. 1976. The influence of temperature on the infectivity of Fasciola hepatica miracidia to Lymnaea truncaluta. J. Parasitol. 62(5):698-701.

Colton, H. S. 1912. Lymnaea columella and self-fertilization. Proc. Acad. Nat. Sci. Phila. 64:173-183.

______, and M. Pennypacker. 1934. The results of twenty years of self-fertilization in the pond snail Lymnaea columella Say. Amer. Nat. 68:129-136.

Connally, D. D., H. E. Jordan, and A. A. Kocan. 1974. A case report of indigenous bovine fascioliasis in Oklahoma. Okla. Vet. Med. Assoc. 26:87-89.

Dawes, B. 1963. Hyperlasia of the bile duct in fascioliasis and its relation to the problem of nutrition. Parasitol. 53:123-133.

______, and D. L. Hughes. 1964. Fascioliasis: The invasive stages of Fasciola hepatica in mammalian hosts. In Advances in Parasitology, 2:97-168. B. Dawes (ed.), Academic Press, New York.

Dennis, W. R., W. M. Stone, and L. E. Swanson. 1954. A new laboratory and field diagnostic test for fluke ova in feces. J. Am. Vet. Med. Assoc. 124:47-50.

Dexter, R. W. 1953. The mollusks inhabiting some temporary pools and ponds in Illinois and Ohio. Nautilus 67:26-33.

Dikmans, G. 1930. Fasciola hepatica in bile ducts of rabbits in Louisiana. J. Parasitol. 16(3):162.

Dinnik, J. A., and N. N. Dinnik. 1963a. A method for the simultaneous diagnosis of schistosomiasis, fascioliasis and paramphistomiasis in cattle. Bull. Epizoot. Dis. Africa 11(1):29-36.

______, and ______. 1963b. Effect of seasonal variations of temperature on the development of Fasciola gigantica in the snail host in the Kenya Highlands. Bull. Epizoot. Dis. Africa 11(2):197-207.

Eddy, S., and A. C. Hodson. 1961. Taxonomic keys to the common animals of the northcentral states exclusive of the parasitic worms, insects and birds. 3rd ed. Burgess Pub. Co., Minneapolis, 162 pp.

Edwards, C. M. 1968. Liver fluke in sheep. Field trials in Wales on control by planning in advance. Vet. Rec. 82:718-728.

Ewers, W. H. 1964. The influence of the density of snails on the incidence of larval trematodes. Parasitol. 54(3):579-583.

Eyerdam, W. J. 1937. A concentrated population of Lymnaea palustris nuttalliana. Nautilus 51:72.

______. 1941. Lymnaea auricularia Linnaeus in western Washington and Kamchatka. Nautilus 55:18-19.

Ferriss, J. H. 1906. Mollusks of Oklahoma. Nautilus 20:16-17.

Ford, B. R., and B. Z. Lang. 1967. Fasciola hepatica in hibernating Citellus tridecemlineatus (Mitchell). J. Parasitol. 53:1073.

Francis, M. 1891. Liver flukes: The common fluke (Distomum hepaticum), a new species (Distomum texanicum). Texas Agr. Exper. Sta. Bull. 18: 127-136.

Fretter, V., and J. Peake. 1975. Functional anatomy and physiology. In Pulmonates. Vol. 1. Academic Press, New York.

Gettinby, G., M. J. H. Cawdery, and J. N. R. Grainger. 1974. Forecasting the incidence of fascioliasis from climatic data. Int. J. Biometeor. 18:319-323.

Goodrich, C. 1940. Civilization and aquatic mollusks. Nautilus 54:6-10.

______. 1944. Pulmonates of the Coosa River. Nautilus 58:11-15.

Gordon, H. M., I. G. Pearson, B. J. Thomson, and J. C. Boray. 1959. Copper pentachlorphenate as a molluscicide for the control of fascioliasis. Austral. Vet. J. 35(11):465-473.

Gray, F., and H. M. Galloway. 1969. Soils of Oklahoma. O.S.U. Okla. Agri. Exper. Station miscellaneous publication, 1959; revised 1969, 56 pp.

Greger, D. K. 1915. The gastropoda of Payne County, Oklahoma. Nautilus 29(8):88-90.

Gregg, W. O. 1923. Introduced species of Lymnaea in southern California. Nautilus 37:34.

Grigorian, G. A. 1959. Experimental data on the duration of conservation of Fasciola gigantica. Veterinariia 36(12):35-37.

Gumble, A., Y. Otori, L. S. Ritchie, and G. W. Hunter. 1957. The effect of light, temperature and pH on the emergence of Schistosoma japonicum cercariae from Oncomelania nosophora. Trans. Am. Micr. Soc. 76(1): 87-92.

Hammond, J. A. 1965. Observations on fascioliasis in Tanganyika. Bull. Epizoot. Dis. Africa 13(1):55-65.

Harris, R. E., and W. A. G. Charleston. 1971. Control of fascioliasis--some theoretical and practical considerations. New Zealand Vet. J. 19(4):65-72.

Henderson, J. 1923. The post-glacial dispersion of mollusca in the southern Rocky Mountains. Nautilus 37:77-81.

Hoffman, W. A. 1931. Ova of Fasciola hepatica in human feces. J. Parasitol. 18:53-54.

Hughes, D. L., E. Harness, and T. G. Doy. 1976. The establishment and duration of Fasciola hepatica infections in two strains of rats and the development of acquired resistance. Res. Vet. Sci. 20:207-211.

Ingalls, J. W., S. W. Hunter, D. B. McMullen, and P. M. Bauman. 1949. The molluscan intermediate host and schistosomiasis. I. Observations on the conditions governing the hatching of the eggs Schistosoma japonicum. J. Parasitol. 35(2):147-151.

Kendall, S. B. 1949. Bionomics of Lymnaea truncatula and the parthenitae of Fasciola hepatica under drought conditions. J. Helminth 23(1-2): 57-68.

Kendall, S. B. 1950. Snail hosts of Fasciola hepatica in Britain. J. Helminth. 24(1-2):63-74.

______. 1965. Relationships between the species of Fasciola and their molluscan hosts. In Advances in Parasitology 3:59-98. B. Dawes (ed.), Academic Press, New York.

______. 1975. Treatment of fascioliasis in cattle. Vet. Rec. 96:411.

______, and F. S. McCullough. 1951. The emergence of the cercariae of Fasciola hepatica from the snail Lymnaea truncatula. J. Helminth. 25(1-2):77-92.

Krull, W. H. 1933a. The snail Pseudosuccinea columella (Say) as a potentially important intermediate host in extending the range of Fasciola hepatica Linn. J. Wash. Acad. Sci. 23(8):389-391.

______. 1933b. New snail and rabbit hosts for Fasciola hepatica Linn. J. Parasitol. 20(1):49-52.

______. 1933c. Infections of the white-footed mouse Peromyscus leucopus noveboracensis, with Fasciola hepatica Linn. J. Parasitol. 20(2):99.

______. 1934. Notes on the hatchability and infectivity of refrigerated eggs of Fasciola hepatica Linn. Proc. Iowa Aca. Sci. 41:309-311.

______. 1941. The number of cercariae of Fasciola hepatica developing in snails infected with a single miracidium. Proc. Helm. Soc. Washington 8(2):55-58.

Kuntz, R. E. 1947. Effect of light and temperature on emergence of Schistosoma mansoni cercariae. Trans. Am. Micr. Soc. 66:37-49.

Leiper, J. W. G. 1938. The longevity of Fasciola hepatica. J. Helminth. 16(3):173-176.

Lynch, J. J. 1965. The ecology of Lymnaea tomentosa (Pfeiffer 1855) in South Australia. Austral. J. Zool. 13:461-473.

McKay, A. C. 1925. Fasciola hepatica in rabbits. J. Austral. Vet. Assoc. 1:66.

Michel, J. F., and C. B. Ollerenshaw. 1963. Fascioliasis in Animal Health Production and Pasture. A. N. Worden (ed.), Longmans, London.

Montgomerie, R. F. 1931. On the longevity of Fasciola hepatica in experimentally infected rabbits. J. Helminth 9(4):209-212.

Moxham, J. W., R. H. Ansell, and P. Gallagher. 1969. Liver fluke disease appears to be spreading. New Zealand J. Agri. 119(2):34-37.

Noland, L. E., and E. Reichel. 1943. Life cycle of Lymnaea stagnalis completed at room temperature without access to air. Nautilus 57: 8-13.

Norton, R. A., and L. S. Monroe. 1961. Infection by Fasciola hepatica acquired in California. Gastroenterol. 41(1):46-48.

Ogambo-Ongoma, A. H. 1969. The incidence of Fasciola hepatica Linnaeus, 1758, in Kenya cattle. Bull. Epizoot. Dis. Africa 17(4):429-431.

______. 1972a. The effect of clearing on the population of Lymnaea natalensis. Bull. Epizoot. Dis. Africa 20(1):25-30.

______. 1972b. Fascioliasis survey in Uganda. Bull. Epizoot. Dis. Africa 20(1):35-41.

Oklahoma Agricultural Statistics. 1974. Issued in 1975. Compiled by Okla. Crop and Livestock Reporting Service, Oklahoma City. A cooperative function of the Okla. Dept. of Agri. and USDA.

Oklahoma Agricultural Statistics. 1976. Issued in 1977. Compiled by Okla. Crop and Livestock Reporting Service, Oklahoma City. A cooperative function of the Okla. Dept. of Agri. and USDA.

Ollerenshaw, C. B. 1959. The ecology of the liver fluke (Fasciola hepatica). Vet. Rec. 71(2):957-963.

______. 1966. The approach to forecasting the incidence of fascioliasis over England and Wales, 1958-1962. Agri. Meteorol. 3:35-53.

______, and W. T. Rowlands. 1959. A method of forecasting the incidence of fascioliasis in Anglesey. Vet. Rec. 71:591-598.

Olsen, O. W. 1944. Bionomics of the lymnaeid snail, Stagnicola bulimoides techella, the intermediate host of the liver fluke in southern Texas. J. Agri. Res., U.S. Dept. of Agri. 69(10):389-403.

______. 1945. Ecology of the metacercariae of Fasciola hepatica in southern Texas and its relationship to liver fluke control in cattle. J. Parasitol. 31(Supp.):20.

______. 1947. Longevity of metacercariae of Fasciola hepatica on pastures in the upper coastal region of Texas and its relationship to liver fluke control. J. Parasitol. 33:36-42.

______. 1948. Wild rabbits as reservoir hosts of the common liver fluke, Fasciola hepatica, in southern Texas. J. Parasitol. 34(2):119-123.

______. 1974. Animal parasites: Their life cycles and ecology. 3rd ed. University Park Press, Baltimore, 562 pp.

Peters, B. G. 1938. Habitats of Limmaea truncatula in England and Wales during dry seasons. J. Helminth. 16(4):213-260.

Pillers, A. W. N. 1926. Fasciola hepatica in the wild rabbit in England. Ann. Trop. Med. and Parasitol. 20(2):219.

Pilsbry, H. A. 1896. Lymnaea bulimoides Lea resisting drought. Nautilus 10(8):96.

Pilsbry, H. A., and J. H. Ferriss. 1906. Mollusca of the southwestern states. II. Proc. Acad. Nat. Sci. Phila. 58:123-176.

Price, E. W. 1953. The fluke situation in American ruminants. J. Parasitol. 39:119-134.

Pullan, N. B., and L. K. Whitten. 1972. Liver fluke, Fasciola hepatica, in New Zealand. Part I. A spreading parasite in sheep and cattle. New Zealand Vet. J. 20:69-72.

Rajčevic, M. 1929. Wie lange bleiben die Cerkarien der Leberegal (Distom. hepaticum) am gentrockneten alten Heu lebend und infektionsfahig? (Ein Beitrag zur Aetiologie der Distomatosis.) Deutsche Tierarztl. Wchnschr. 37(34):535-537. (Cited by Price, 1953. The fluke situation in American ruminants. J. Parasitol. 39:119-134.)

Rees, F. G. 1931. Some observations and experiments on the biology of larval trematodes. Parasitol. 23(4):428-440.

______. 1948. A study of the effect of light, temperature and salinity on the emergence of Cercariae purpurae Lebour from Nucella lapillus (L). Parasitol. 38(4):228-242.

Reinhard, E. G. 1957. Landmarks of parasitology. I. The discovery of the life cycle of the liver fluke. Exper. Parasitol. 6(2):208-232.

Richards, A. 1917. Note on the relation of snail fauna to floods. Nautilus 31(2):64-68.

Rodeck, H. G. 1933. Unusual concentration of Lymnaea. Nautilus 48(3): 106-107.

Ross, J. G. 1968. The life span of Fasciola hepatica in cattle. Vet. Rec. 82(21):587-589.

______. 1970a. The Stormont "wet day" forecasting system for fascioliasis. Brit. Vet. J. 126(8):401-408.

______. 1970b. The epidemiology of fascioliasis in northern Ireland. Vet. Rec. 87(13):370-375.

______, and M. J. Morphy. 1970. A combined investigation of the epidemiology of Fasciola hepatica infection in lambs and the ecology of Lymnaea truncatula. Vet. Rec. 87:278-282.

______, and J. R. Todd. 1968. Epidemiological studies of fascioliasis. Vet. Rec. 82(24):695-699.

Rowan, W. B. 1956. The mode of hatching of the egg of Fasciola hepatica. Exper, Parasitol. 5(2):118-137.

Rowcliffe, S. A., and C. B. Ollerenshaw. 1959. Observations on the Bionomics of the egg of Fasciola hepatica. Ann Trop. Med. and Parasitol. 54(2):172-181.

Schreiber, F. G., and M. Schubert. 1949. Results of exposure of the snail Australorbis glabratus to varying numbers of miracidia of Schistosoma mansoni. J. Parasitol. 35(6):590-592.

Shaw, J. N. 1931. Some notes on liver-fluke investigations. J. Am. Vet. Assoc. 78:19-26.

______, and B. T. Simms. 1929. Galba bulimoides Lea, an intermediate host of Fasciola hepatica in Oregon. Science 69:357.

Shoup, C. S. 1943. Distribution of fresh-water gastropods in relation to total alkalinity of streams. Nautilus 56(4):130-134.

Strandine, E. J. 1941. Effect of soil moisture and algae on the survival of a pond snail during periods of relative dryness. Nautilus 54(4):128-130.

Swales, W. E. 1935. The life cycle of Fascioloides magna (Bassi, 1875), the large liver fluke of ruminants in Canada, with observations on the bionomics of the larval stages and the intermediate hosts, pathology of fascioliasis magna, and control measures. Canad. J. Res. 12:177-215.

Taylor, A. W. 1961. Liver fluke infection in man. Lancet 2:1334-1336.

Thomas, A. P. W. 1883. The life history of the liver-fluke (Fasciola hepatica). Quart. J. Micr. Sci. 23:99-133.

Van Cleave, H. J. 1934. Length of life span as a factor in regulating populations. Ecology 15:17-23.

______. 1935. The seasonal life history of an amphibious snail, Fossaria modicella, living on sandstone cliffs. Ecology 16:101-108.

Van Eeden, J. A., and D. S. Brown. 1966. Colonization of fresh waters in the republic of South Africa by Lymnaea columella Say (Mollusca: gastropoda). Nature 210(2):1172-1173.

Van Someren, V. D. 1947. A sedimentation method for the detection and counting of fasciola eggs in faeces. J. Comp. Path. and Therap. (57(3):240-244.

Van Volkenberg, H. L. 1929. Report of the parasitologist. Rep. Porto Rico Agri. Exper. Station (1928):36-38.

______. 1934. Parasites and parasitic diseases of cattle in Puerto Rico. Bull. Puerto Rico Agri. Exper. Station No. 36, 26 pp.

Vaughan, T. W. 1893. Notes on a collection of mollusks from northwestern Louisiana and Harrison County, Texas. Amer. Nat. 27:944-961.

Wallen, I. E. 1951. Additions to "a check list of the land snails of Oklahoma." Okla. Acad. Sci. Proc. 32-27-30.

______, and P. Dunlap. 1953. Further additions to the snail fauna of Oklahoma. Okla. Acad. Sci. Proc. 34-76-80.

Walton, C. L. 1918. Liver rot of sheep, and bionomics of *Limnaea truncatula* in the Aberystwyth area. Parasitol. 10:232-266.

Warren, K. S. 1974. Helminthic diseases endemic in the United States. Am. J. Trop. Med. & Hygn. 23(4):723-730.

Wikerhauser, T., and J. Brglez. 1961. O vitalnosti metacerkarija *F. hepatica* iz silaze. (On the viability of *F. hepatica* metacercariae in ensiled fodder.) Vet. Arhiv. Zagreb. 31(11-12):315-318.

Williams, J. G. 1976. Uses for epidemiological data from slaughter of cattle in the Oklahoma City area. Okla. Vet. Med. Assoc. 28:104-105.

Willmott, S. M., and F. R. N. Pester. 1952. Variations in fecal egg-counts in paramphistome infections as determined by a new technique. J. Helminth 26(2-3):147-156.

Wright, C. A. 1971. Flukes and snails. Science of Biology Series, No. 4. Allen and Unwin, London.

APPENDIX A

TABLES

TABLE I

DEFINITIVE HOST DETERMINANTS OF *F. HEPATICA*

Specific Host Determinant	Significance	Reference
Cattle	Essential--Prevalent	Widely known
Sheep	Essential--Prevalent	Thomas (1883)
Lagomorphs	Nonessential--Potential reservoir	Dikmans (1930) McKay (1925) Krull (1933a,b) Montgomerie (1931) Olsen (1948) Pillers (1926)
Rodents	Not known but good host in laboratory	Ford and Lang (1967) Krull (1933c) Hughes et al. (1976)
Goats	Occasionally	Van Volkenberg (1934)
Pigs and Horses	Few cases observed	Van Volkenberg (1934)
Men	Few cases observed	Beresford (1976) Hoffman (1931) Norton and Monroe (1961) (quoted by Warren (1974)) Van Volkenberg (1934) Taylor (1961)

TABLE II

INTERMEDIATE HOST DETERMINANTS OF *F. HEPATICA*

Specific Host Determinant	Significance	Reference
Lymnaea truncatula	Widely distributed in Europe and parts of Asia, Essential	Kendall (1965) Reinhard (1957) Thomas (1883)
Lymnaea tomentosa	Widely distributed in Australia and New Zealand, Essential	Boray (1964)
Lymnaea cubensis	Worldwide, Essential	Boray (1964) Price (1953)
Galba (Lymnaea) bulimoides	North America, Essential	Shaw and Simms (1929)
Galba (Lymnaea) bulimoides techella (Stagnicola b. techella)	North America, Essential	Shaw and Simms (1929)
Fossaria (Lymnaea) cubensis	North America, Essential	Van Volkenberg (1929)
Fossaria (Lymnaea) ferruginea	North America, Essential	Shaw (1931)
Lymnaea transkii	North America, Essential	Krull (1933b)
Pseudosuccinea (Lymnaea) columella	North America, Essential	Krull (1933a) Baker (1909)
Lymnaea mwaurensis	Kenya, Rare	Kendall (1965)

TABLE III

F. HEPATICA DETERMINANTS FOR ESTABLISHMENT IN NATURE

Parasite Determinant	Significance	Reference
Infected Definitive Hosts Movement	Essential for the spread of the parasite	Moxhan et al. (1969) Ogambo-Ongoma (1969) Ollerenshaw and Rowlands (1959) Pullan and Whitten (1972)
Definitive Hosts Overstocking	Enhancing but not essential	Van Volkenberg (1934)
Introduction of Snails*	Essential for the spread of the parasite as follows: (1) Floods (2) Migrating birds and other animals (3) Actions of men	Cawdery and Moran (1971) Eyerdam (1937, 1941) Gregg (1923) Harris and Charleston (1971) Kendall (1949) Mehl (1932, cited by Olsen, 1944) Rodeck (1933) Van Eeden and Brown (1966)

*Snails on their own do not migrate far.

TABLE IV

ENVIRONMENTAL DETERMINANTS REQUIRED FOR INTERMEDIATE HOSTS

Environmental Determinant	Significance	Reference
Temperature	Minimum 10°C Maximum 35°C	Boray (1963) Kendall (1965)
Water	Fresh, clear, with vegetation; moisture very essential	Alicata (1938) Alicata and Swanson (1937) Boray (1964) Cawston (1946) Eyerdam (1937, 1941) Goodrich (1940, 1944) Kendall (1949) Lynch (1965) Noland and Reichel (1943) Ollerenshaw (1959) Pilsbry (1896) Strandine (1941) Thomas (1883)
Soil Types	Moist clay or muddy alluvial soils are essential	Alicata (1938) Boray (1964) Olsen (1944) Swales (1935) Van Volkenberg (1929)
pH	5.4 to 7.3	Boray (1964) Brunsdon (1967) Rowcliffe and Ollerenshaw (1960) Shoup (1943) Walton (1918)

TABLE IV (CONTINUED)

Environmental Determinant	Significance	Reference
Altitude	Below 1000 feet or altitudes in the United States, even up to 5000 feet	Edwards (1968) Michel and Ollerenshaw (1963) Ollerenshaw (1966) Shaw and Simms (1929)
Topography	Affects speed of water, standing water, or flooding	Armour (1975) Alicata (1938) Boray (1964) Branson (1959) Francis (1891) Olsen (1944) Swales (1935) Van Volkenberg (1929) Wright (1971)
Vegetation	Acts as food for snails and conservation moisture	Branson and Heard (1959) Cain et al. (1950) Dexter (1953) Ogambo-Ongoma (1972a,b) Strandine (1941) Walton (1918)

TABLE V

ENVIRONMENTAL DETERMINANTS REQUIRED FOR F. HEPATICA

Environmental Determinant	Significance	Reference
Temperature	Minimum 9.5°C Maximum 30°C These two ranges of temperature affect both the eggs and intramolluscan development of *F. hepatica*	Kendall (1965) Krull (1934) Michel and Ollerenshaw (1963) Olsen (1945, 1947) Rowcliffe and Ollerenshaw (1959) Thomas (1883)
Water	Fresh and clear for emergence of cercariae	Harris and Charleston (1971) Jepps (1933) Kendall and McCullough (1951) Rowcliffe and Ollerenshaw (1959) Walton (1918)
pH	4.2 to 6.9	Rowcliffe and Ollerenshaw (1959)

TABLE VI

LIVERS CONDEMNED IN OKLAHOMA AND NEIGHBORING STATES
IN 1973, 1975 AND 1976

State	Year	Animals Killed		Animals Condemned		Percent Condemned	
		Cattle	Calves	Cattle	Calves	Cattle	Calves
Arkansas	1973[2]	105,595		1,408		1.33	
	1975	135,519	00	1,827	00	2.09	0.0
	1976	170,652	4	3,571	00	0.0	0.0
Colorado	1973[2]	2,218,278		97,722		4.41	
	1975	153,284	208	75,498	15	0.0	0.0
	1976	2,276,267	4,822	123,529	00	0.0	0.0
Kansas	1973[2]	2,251,216		48,069		2.14	
	1975	1,403,479	31	3,899	00	2.78	0.0
	1976	2,788,964	5	100,804	00	3.61	0.0
Louisiana[1]	1973[2]	111,317		4,854		4.36	
	1975	158,033	2,939	16,849	405	10.66	13.78
	1976	147,127	17,262	17,762	1,478	12.07	8.56
Missouri	1973[2]	739,979		4,695		0.63	
	1975	798,622	16,023	5,742	00	0.72	0.0
	1976	892,555	13,254	8,175	2	0.92	0.0
New Mexico	1973[2]	352,228		7,134		2.03	
	1975	431,964	21	15,927	00	3.69	0.0
	1976	512,487	26	25,052	00	4.89	0.0

TABLE VI (Continued)

State	Year	Animals Killed		Animals Condemned		Percent Condemned	
		Cattle	Calves	Cattle	Calves	Cattle	Calves
Oklahoma	1973[2]	419,451		7,812		1.86	
	1975	384,963	2,901	13,175	15	3.4	0.52
	1976	602,584	1,182	26,091	29	4.33	2.45
Texas	1973[2]	2,968,792		144,819		4.88	
	1975	2,734,807	50,487	183,545	685	6.71	1.36
	1976	4,759,369	123,828	383,545	2,243	8.05	19.74
United States	1973[2]	30,747,614		1,147,721		3.73	
	1975	24,935,320	2,793,990	1,188,978	26,376	4.84	0.94
	1976	28,644,301	5,222,713	1,945,155	36,131	5.05	0.69

Source: USDA, Animal and Plant Health Inspection Service, Washington, D.C.

[1]States outside Oklahoma border but from which cattle are often shipped for slaughter in Oklahoma.

[2]Cattle and calves were not separated in the 1973 federal meat inspection records, and the figures shown for that year are the sum total of cattle and calves killed or condemned.

TABLE VII

DEFINITIVE HOSTS OF *F. HEPATICA* IN OKLAHOMA

Host Determinant	Distribution	Reference
Cattle	Oklahoma is third largest producer; has statewide distribution; about 5.6 million head in January, 1977	Oklahoma Agricultural Statistics, 1974 and 1977
Sheep	Statewide, but very few; only 72,000 head in January, 1977	Oklahoma Agricultural Statistics, 1977
Lagomorphs	Distribution not determined but are frequently seen	
Rodents	Similar for lagomorphs	

TABLE VIII

LYMNEID SNAILS COLLECTED IN OKLAHOMA

Species	Distribution of Determinant	Reference
Lymnaea (*Pseudosuccinea*) *columella*	Oklahoma and Leflore Counties, Winding Stair Mountain	Pilsbry and Ferriss (1906)
	Major, McCurtain, Muskogee, Pontotoc, and Woodward Counties	Wallen (1951)
	Payne County	Wallen and Dunlap (1953)
	Ottawa and Pittsburg Counties	Branson and Wallen (1958)
	Latimer County	Branson (1959b)
Lymnaea Fossaria humilis (Say)		
(a) As *Fossaria parva*	Adair, Beckham, Cherokee, Hughes, Leflore, Osage, Ottawa, Payne, Pittsburg, and Sequoyah Counties	Branson and Wallen (1958)
	Murray County	Branson (1959a)
	Texas and Woodward Counties	Wallen and Dunlap (1953)
(b) As *Fossaria dalli*	Beckham, Haskell, Nowata, and Osage Counties	Branson and Wallen (1958)
	Payne County	Wallen (1951)
(c) As *Fossaria modicella*	Adair, Beckham, Roger Mills, and Sequoyah Counties	Branson and Wallen (1958)

TABLE VIII (Continued)

Species	Distribution of Determinant	Reference
(c) As Fossaria modicella (continued)	Beaver, Cimarron, Delaware, Grant, Greer, Lincoln, Muskogee, Noble, and Payne Counties	Wallen and Dunlap (1953)
(d) As Fossaria obrussa	Adair County	Branson and Wallen (1958)
Lymnaea (Stagnicola) paulstris	Boiling Springs and Woodward State Parks	Wallen and Dunlap (1953)
Lymnaea (Stagnicola) bulimoides	Beaver, Caddo, Cleveland, Cotton, Garfield, Grady, Greer, Kiowa, McCurtain, Noble, Texas, Tillman, Woods, and Woodward Counties	Wallen and Dunlap (1953)
	Beckham, Choctaw, Ellis, Haskell, Leflore, Payne, and Roger Mills Counties	Branson and Wallen (1958)
	Craig, Murray, and Pawnee Counties	Branson (1959a)
	Oklahoma County	Ferriss (1906)
	Kay and Comanche Counties	Baker (1911)
	Woodward County	Vaughan (1893)
	Possibly every county	Branson (1961)
Lymnaea (Fossaria) cubensis	Payne County	Greger (1915)

TABLE IX

EXTERNAL FACTORS ENHANCING FASCIOLIASIS IN OKLAHOMA

Specific Determinant	Significance	Reference
Surface Water and Rainfall	Abundant in the eastern part of Oklahoma	Gray and Galloway (1969)
Temperature	Minimum of 32°F and 44°F at Boise City and Idabel, respectively. Maximum of of 78°F and 82°F at Boise City and Idabel, respectively	Gray and Galloway (1969)
pH	Moderate to strongly acidic (5.1 to 6.0) in eastern Oklahoma and moderately alkaline in the Panhandle	Gray and Galloway (1969)
Soil Type	The prairies and forested regions of Oklahoma has more clay than the more arid Panhandle area	Gray and Galloway (1969)
Vegetation	The western Panhandle is arid, central Oklahoma is prairie, and eastern Oklahoma is forest	Gray and Galloway (1969)
Topography	The Panhandle is more elevated than southeast Oklahoma (see Figure 8)	Gray and Galloway (1969)
Cattle movement and shipped-in infected cattle	This is practiced widely in Oklahoma	Dr. W. D. Munson (1977) personal communication Dr. J. A. Countryman (1976) personal communication

TABLE X

TELEPHONE INTERVIEW RESPONSES FROM VETERINARIANS

Types of Responses	Number of Counties	Number of Veterinarians
Type 1 Have seen or diagnosed the flukes in their clinics and knew fluke problem farms and that it probably involved indigenous cattle	10	18
Type 2 Have seen flukes at the autopsy (either at their clinics or packinghouses) but did not know the source of the cases	30	11
Type 3 Have seen flukes in their clinics, packinghouses, or at autopsy and were certain that the cases were animals that had been shipped in from other states	5	9
Type 4 Have neither seen flukes nor considered them a problem or hazard to Oklahoma	27	177
Total	113[1]	215

[1]Two or more of these responses identified the same case in each county.

TABLE XI

FASCIOLIASIS CASES IDENTIFIED AT WILSON PACKINGHOUSE[1] BETWEEN JUNE 28 AND JULY 22, 1976

County	Number of Farms	Number of Infected Cattle
Cleveland	1	1
Garfield	1	1
Grady	3	3
Hughes	1	3
Lincoln[2]	1	4
Logan	1	1
Okfuskee[2]	1	1
Oklahoma	1	1
Pittsburg	2	4
Pottawatomie[2]	1	1
Seminole[2]	3	3
Stephens	1	1
Total	17	24

[1]These data were collected from the Wilson Packinghouse in Oklahoma City.

[2]Counties that were visited from the above list.

TABLE XII

DISTRIBUTION OF IDENTIFIED *F. HEPATICA* BY REGIONS

Region	Veterinarians Interviewed	Known Cases	Number of Suspected[1] Cases	Number of Cases With Unknown Source	Total Cases
North	59	1	5	2	6
West	21	2	4	1	3
South	39	6	7	4	10
East	38	4	5	0	4
Central	58	5	4	4	10
Total	215	18	23	11	33

[1]The source includes an imported case of *F. hepatica* or cases seen in slaughter-house.

TABLE XIII

FIELD DATA OF FARMS IDENTIFIED FROM VETERINARIANS AND PACKINGHOUSES

County	Number of Farms Visited	Pasture Information
		T M S V A[1]
Atoka	1	3 2 1 3 3
Carter	1	3 2 1 3 3
Craig	1	2 2 2 2 2
Lincoln[2]	1	2 3 1 3 1
McClain	1	3 3 2 3 2
McCurtain	1	4 2 3 3 2
Okfuskee[2]	1	2 2 2 3 1
Pontotoc	1	2 2 2 3 1
Pottawatomie[2]	1	2 2 2 2 1
Seminole[2]	1	3 3 1 2 1

[1]Explanation of letters is given on following page.

[2]Farms identified from packinghouses.

The key to letters used in Table XIII and Figure 12 follows:

T (Topography) See Figure 12.

T_1 = very poor drainage throughout the pasture with boggy areas covering most of the pasture

T_2 = poor drainage for about 75 percent of pasture

T_3 = poor drainage for about 50 percent of pasture

T_4 = good drainage for more than 75 percent of pasture

M (Mollusks)

M_1 = no ponds or mollusks

M_2 = aquatic snails present except by snails of the family Lymneidae

M_3 = aquatic snails include those of dextral configuration resembling Lymnaea.

S (Soil Types)

S_1 = plainly sandy soils or sandy soil covering pasture

S_2 = loamy soils

S_3 = clay soils, can temporarily hold water on surface

V (Vegetation in Pasture)

V_1 = cattle do not depend on pasture for most of the year

V_2 = vegetation consists of tall grass throughout pasture

V_3 = grass is short and overgrazed

A (Animal History)

A_1 = no new animals have been added to pasture; complete herd is from replacement calves

A_2 = some cattle were introduced more than three years previously and are still in herd

A_3 = some cattle were introduced less than two years previously or bulls are only animals being changed

A_4 = never kept permanent animals

TABLE XIV

RESULTS OF FECAL EXAMINATIONS FOR <u>FASCIOLA HEPATICA</u> ON FARMS IDENTIFIED FROM VETERINARIANS AND PACKINGHOUSE

	Adult Cattle					Calves				
County[1]	Total Number Present	Number of Feces Examined	Feces Positive P[2]	Feces Positive F[2]	Percent Positive F[2]	Total Number Present	Number of Feces Examined	Feces Positive P[2]	Feces Positive F[2]	Percent Positive F[2]
Central Region										
Lincoln (PH)[4]	130	24	0	0	0	∞[3]	0	0	0	0
McClain (V)[4]	467	17	0	10	60	15	10	0	0	0
Okfuskee (PH)	65	24	3	2	9	∞	0	0	0	0
Pontotoc (V)	28	24	8	17	71	∞	0	0	0	0
Pottawatomie (PH)	25	14	0	0	0	∞	0	0	0	0
Seminole (PH)	70	26	15	3	11	∞	0	0	0	0
Southeastern Region										
Atoka (V)	65	14	5	4	30	∞	5	0	3	60
Carter (V)	1300	39	5	12	30	∞	0	0	0	0
McCurtain (V)	1000	22	8	1	5	67	17	0	1	6
Northeastern Region										
Craig (V)	1400	43	12	18	42	∞	2	2	2	100
Total	4550	247	56	67	27	82	34	2	6	18

[1]One farm was visited in each county listed.

[2]P indicates <u>Paramphistomum</u> and F indicates <u>Fasciola hepatica</u>

[3]Number of calves not known.

[4]PH indicates data supplied by packinghouse and V indicates data supplied by veterinarian.

TABLE XV

FREQUENCY OF *F. HEPATICA* ACCORDING TO AGE AND SEX
FROM FARMS KNOWN TO HAVE NATURALLY
INFECTED CATTLE

Age	Sex					
	Males			Females		
	Number Tested	Number Positive	Percent Positive	Number Tested	Number Positive	Percent Positive
≤ 2 years	2	0	0	32	6	5
> 2 years	14	2	14	233	67	29

TABLE XVI

FREQUENCY OF *F. HEPATICA* ACCORDING TO BREEDS FROM FARMS KNOWN TO HAVE NATURALLY INFECTED CATTLE

Frequency	Holstein	Angus	Hereford	Semmental	Mixed	Total
Cattle Tested						
Number Tested	39	38	83	39	48	247
Number Positive	11	2	25	12	19	69
Percent Positive	28	5	30	30	40	25
Farms Surveyed						
Number Tested	2	2	3	1	2	10
Number Positive	2	1	3	1	2	9
Percent Positive	100	50	100	100	100	90

TABLE XVII

FIELD DATA OF FARMS PREVIOUSLY UNSUSPECTED OF FASCIOLIASIS

County[1]	Number of Farms Visited	Pasture Information
		T M S V A
Adair	1	1 2 1 2 3
Beaver	1	3 3 1 3 3
Beckham	1	2 2 2 3 3
Canadian	1	3 2 1 3 4
Canadian	1	2 2 2 2 1
Cherokee	1	1 2 2 3 1
Cimarron	1	1 2 1 2 1
Cotton	1	4 2 1 2 1
Creek	1	1 2 2 2 1
Creek	1	1 2 1 3 1
Creek	1	3 2 1 3 2
Custer	1	2 1 1 2 2
Dewey	1	2 2 2 3 1
Grant	1	4 3 2 3 2
Grant	1	4 2 2 3 1
Harper	1	4 2 1 2 1
Jackson	1	2 2 2 2 1
Jefferson	1	1 2 1 3 1
Kay	1	1 3 1 2 2
Kingfisher	1	4 2 2 3 1
Kingfisher	1	3 2 2 3 1
Lincoln	1	2 2 2 2 1
Libcoln	1	1 2 2 2 1
Logan	1	1 3 2 2 1

TABLE XVII (Continued)

County[1]	Number of Farms Visited	Pasture Information
		T M S V A
Noble	1	1 3 1 2 1
Okfuskee	1	2 3 1 3 1
Oklahoma	1	2 2 1 2 1
Okmulgee	1	2 2 1 3 2
Osage	1	2 3 1 2 2
Pawnee	1	1 2 1 3 2
Payne	1	2 3 2 2 2
Payne	1	1 2 2 2 2
Payne	1	1 2 2 3 1
Payne	1	2 2 2 3 1
Payne	1	1 2 2 3 1
Payne	1	2 2 2 3 2
Payne	1	2 2 2 3 2
Payne	1	1 2 2 3 1
Payne	1	1 2 2 3 2
Tillman	1	1 2 2 3 2
Woodward	1	1 2 2 2 1
Woodward	1	4 1 2 2 1

[1]One ranch was visited for each county name listed (hence, designation 1 for number visited in column 2 above)

TABLE XVIII

RESULTS OF FECAL EXAMINATION FOR FASCIOLA HEPATICA
ON FARMS PREVIOUSLY UNSUSPECTED OF FASCIOLIASIS

County[1]	Adult Cattle: Total Number Present	Adult Cattle: Number of Feces Examined	Adult Cattle: Feces Positive P[2]	Adult Cattle: Feces Positive F[2]	Adult Cattle: Percent Positive for F[2]	Calves: Total Number Present	Calves: Number of Feces Examined	Calves: Feces Positive P[2]	Calves: Feces Positive F[2]	Calves: Percent Positive for F[2]
Adair	125	27	0	0	0	∞[3]	0	0	0	0
Beaver	65	19	0	0	0	∞	0	0	0	0
Beckham	172	26	0	0	0	∞	0	0	0	0
Canadian	3000	27	0	0	0	∞	0	0	0	0
Canadian	30	17	0	0	0	∞	0	0	0	0
Cherokee	45	17	0	0	0	∞	0	0	0	0
Cimarron	450	31	0	0	0	∞	0	0	0	0
Cotton	108	23	2	0	0	∞	4	0	0	0
Creek	250	22	0	0	0	∞	0	0	0	0
Creek	160	14	0	0	0	∞	0	0	0	0
Creek	119	25	0	0	0	∞	0	0	0	0
Custer	60	20	0	0	0	∞	0	0	0	0
Dewey	39	14	3	0	0	∞	0	0	0	0
Grant	55	11	0	0	0	∞	0	0	0	0
Grant	29	12	0	0	0	∞	0	0	0	0
Harper	120	26	0	0	0	∞	0	0	0	0

TABLE XVIII (Continued)

County[1]	Adult Cattle: Total Number Present	Adult Cattle: Number of Feces Examined	Adult Cattle: Feces Positive P[2]	Adult Cattle: Feces Positive F[2]	Adult Cattle: Percent Positive for F[2]	Calves: Total Number Present	Calves: Number of Feces Examined	Calves: Feces Positive P[2]	Calves: Feces Positive F[2]	Calves: Percent Positive for F[2]
Jackson	51	19	0	0	0	∞	0	0	0	0
Jefferson	69	21	0	0	0	∞	0	0	0	0
Kay	170	19	0	0	0	∞	0	0	0	0
Kingfisher	19	9	0	0	0	∞	0	0	0	0
Kingfisher	100	18	0	0	0	∞	0	0	0	0
Lincoln	47	17	0	0	0	∞	0	0	0	0
Lincoln	46	12	3	2	42	∞	0	0	0	0
Logan	110	22	0	0	0	∞	0	0	0	0
Noble	30	11	0	0	0	∞	0	0	0	0
Okfuskee	67	24	0	0	0	∞	0	0	0	0
Oklahoma	64	17	0	0	0	∞	0	0	0	0
Okmulgee	28	15	0	0	0	∞	0	0	0	0
Osage	90	21	0	0	0	∞	0	0	0	0
Pawnee	36	14	0	0	0	∞	0	0	0	0
Payne	85	21	2	2	10	∞	0	0	0	0
Payne	14	11	0	0	0	∞	0	0	0	0
Payne	72	13	0	0	0	∞	0	0	0	0
Payne	26	8	0	0	0	∞	0	0	0	0

TABLE XVIII (Continued)

County[1]	Adult Cattle: Total Number Present	Adult Cattle: Number of Feces Examined	Adult Cattle: Feces Positive P[2]	Adult Cattle: Feces Positive F[2]	Adult Cattle: Percent Positive for F[2]	Calves: Total Number Present	Calves: Number of Feces Examined	Calves: Feces Positive P[2]	Calves: Feces Positive F[2]	Calves: Percent Positive for F[2]
Payne	40	11	0	0	0	∞	2	0	0	0
Payne	70	17	0	0	0	∞	0	0	0	0
Payne	86	18	0	0	0	∞	0	0	0	0
Payne	65	19	0	0	0	∞	0	0	0	0
Payne	76	13	0	0	0	∞	0	0	0	0
Tillman	65	27	2	0	0	∞	2	0	0	0
Woodward	63	21	0	0	0	∞	0	0	0	0
Woodward	22	11	0	0	0	5	3	0	0	0

[1]One farm was visited in each county listed.

[2]P and F indicate the species *Paramphistomum* and *Fasciola*, respectively.

[3]Total number unknown.

APPENDIX B

FIGURES

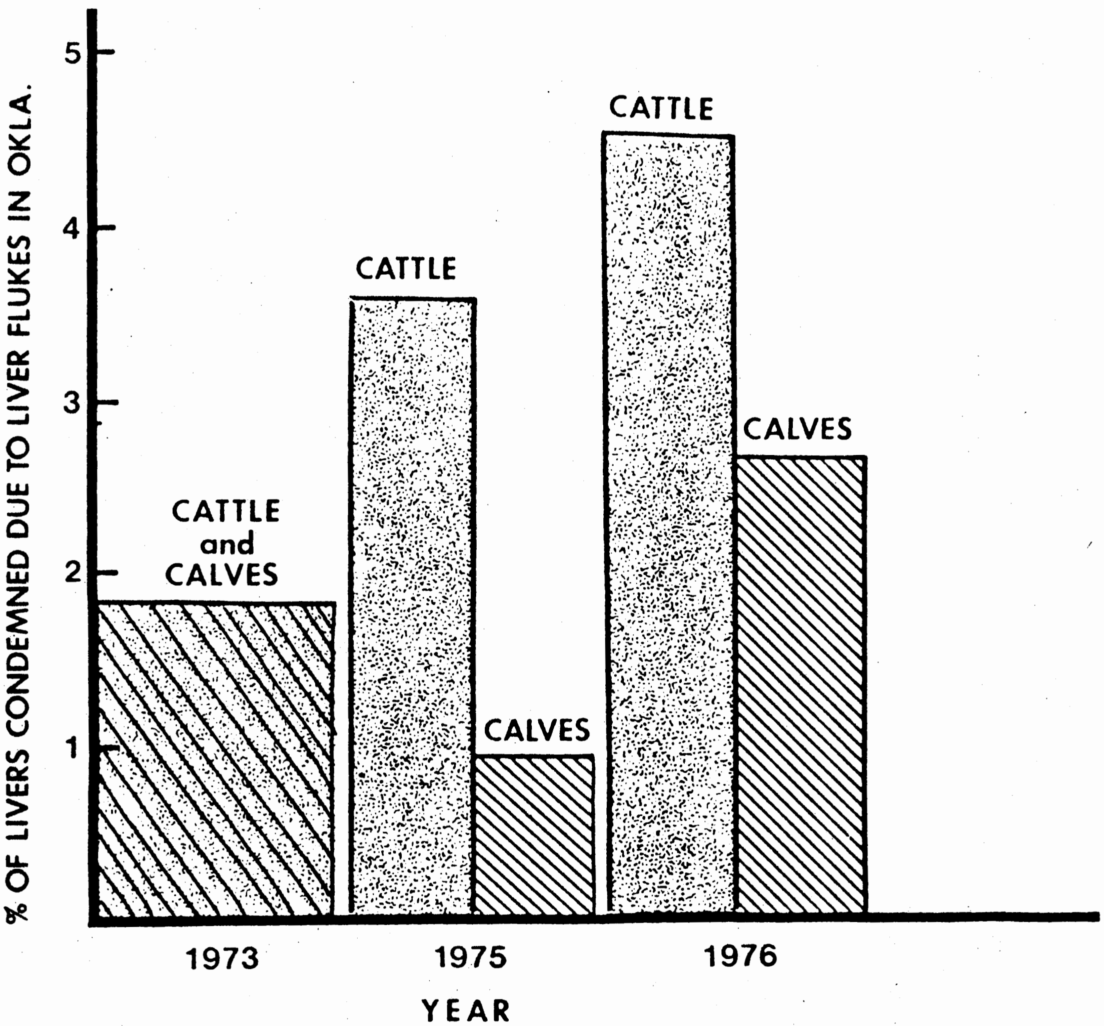


Figure 1. Prevalence of Fascioliasis From Federal Meat Inspection Records for Oklahoma (1973, 1975, and 1976)

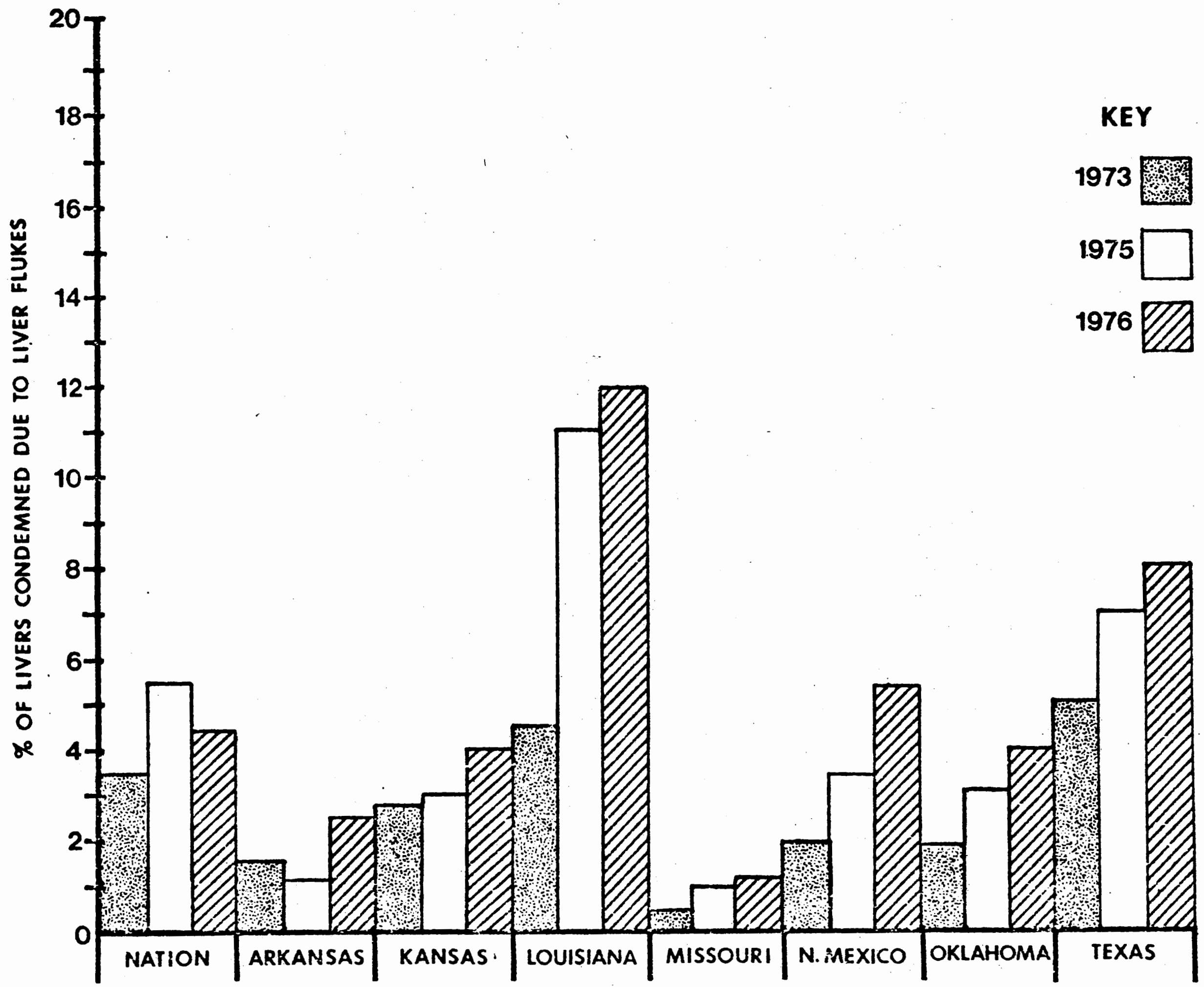
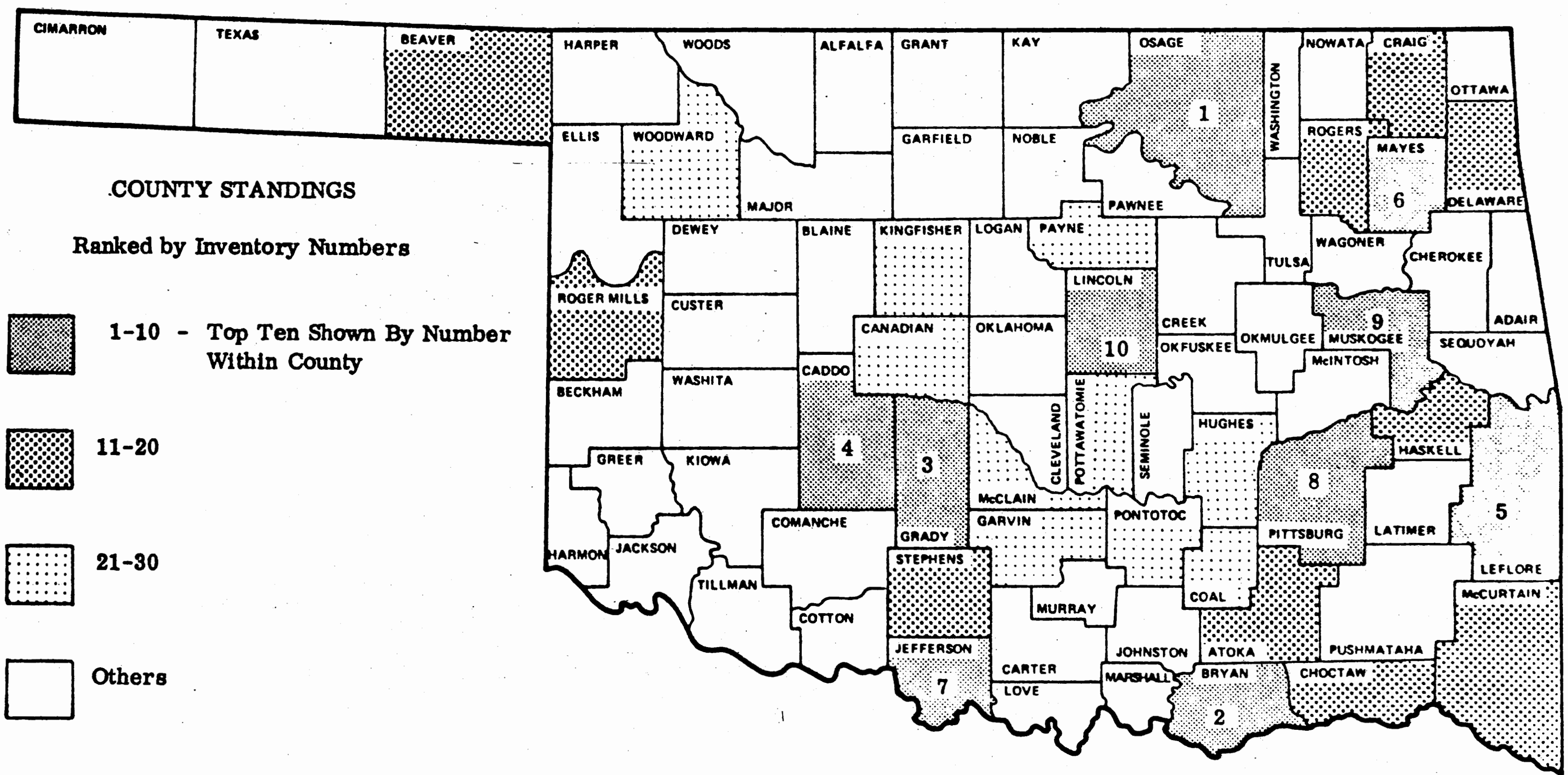


Figure 2. Prevalence of Fascioliasis From Federal Meat Inspection Records for Oklahoma and Neighboring States (1974, 1975, and 1976)

PLEASE NOTE:

Dissertation contains small
and indistinct print.
Filmed as received.

UNIVERSITY MICROFILMS.



Source: Oklahoma Agricultural Statistics, 1976

Figure 3. Beef Cattle Distribution in Oklahoma in January, 1977

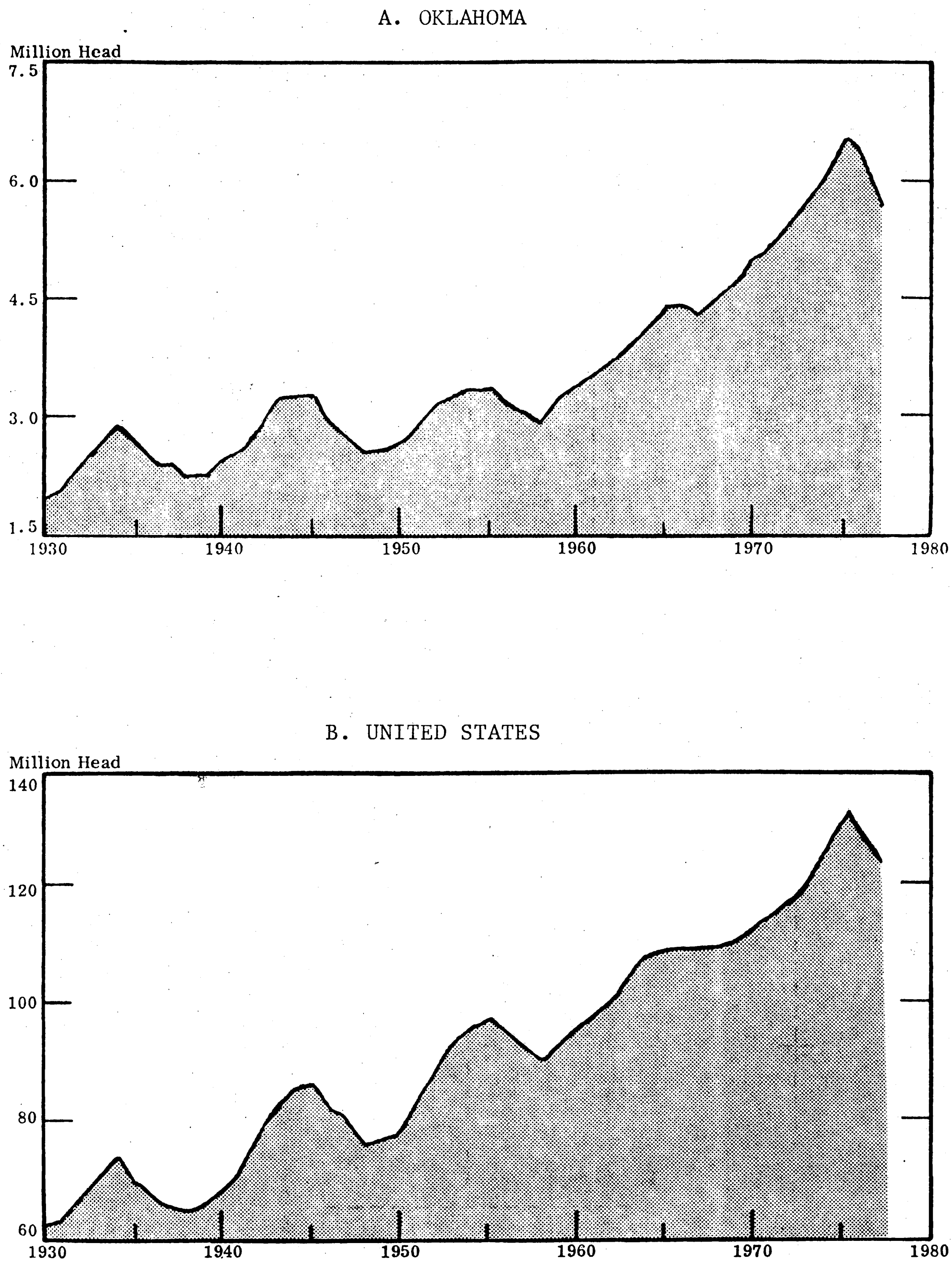


Figure 4. Cattle on Farms--January 1 Inventory, 1930-1977

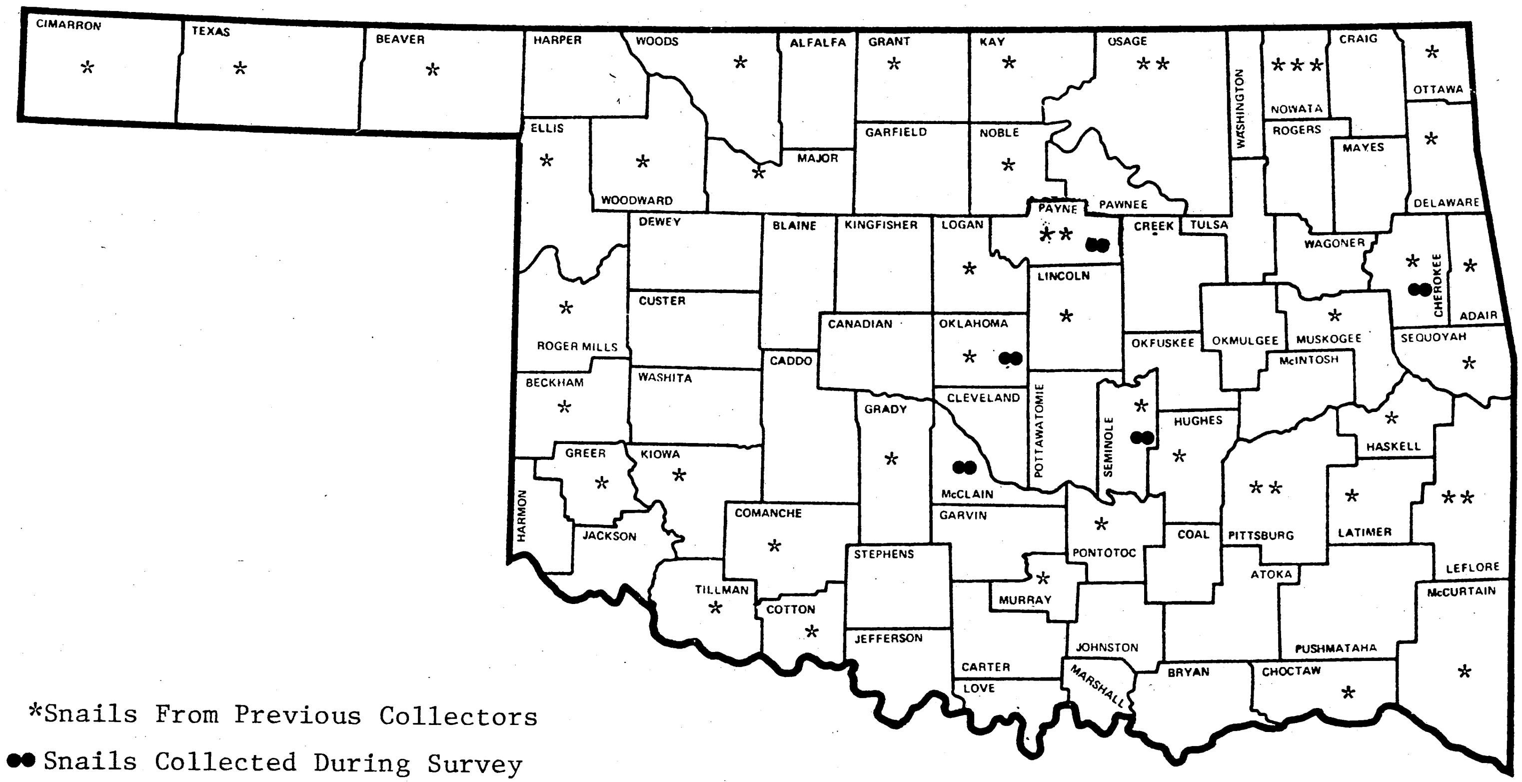
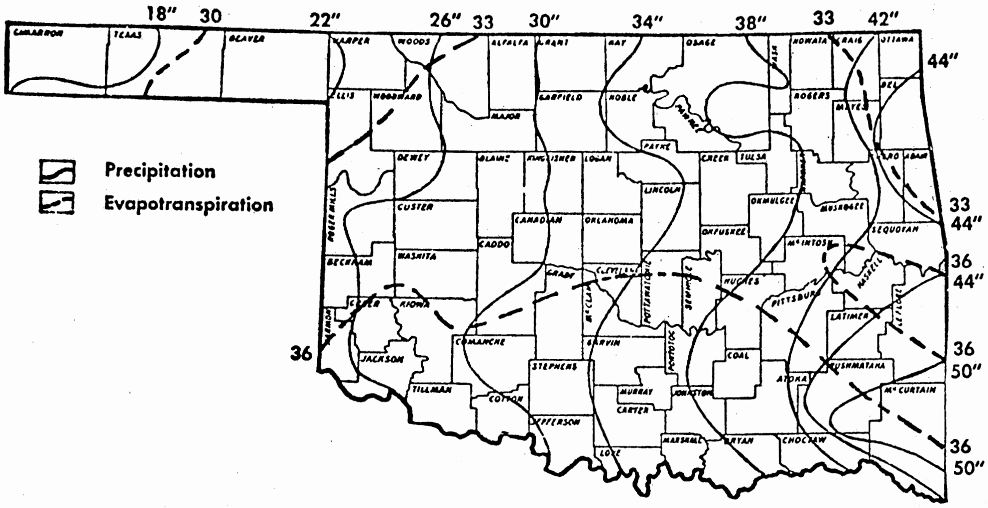
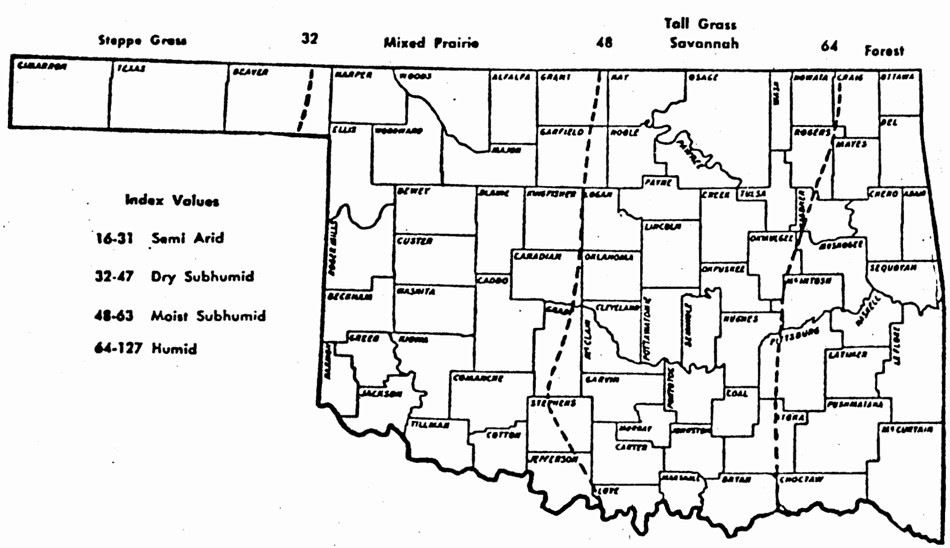


Figure 5. Distribution of Lymneid Snails in Oklahoma



Source: F. Gray and H. M. Galloway, Soils of Oklahoma, O.S.U., Okla. Agri. Exper. Station misc. pub. (1959).

Figure 6. Average Annual Rainfall Zones of Oklahoma



Source: Gray and Galloway, Soils of Oklahoma (1959).

Figure 7. Vegetation Distribution in Oklahoma

CROSS-SECTION A-B OF OKLAHOMA FROM BLACK MESA TO IDABEL

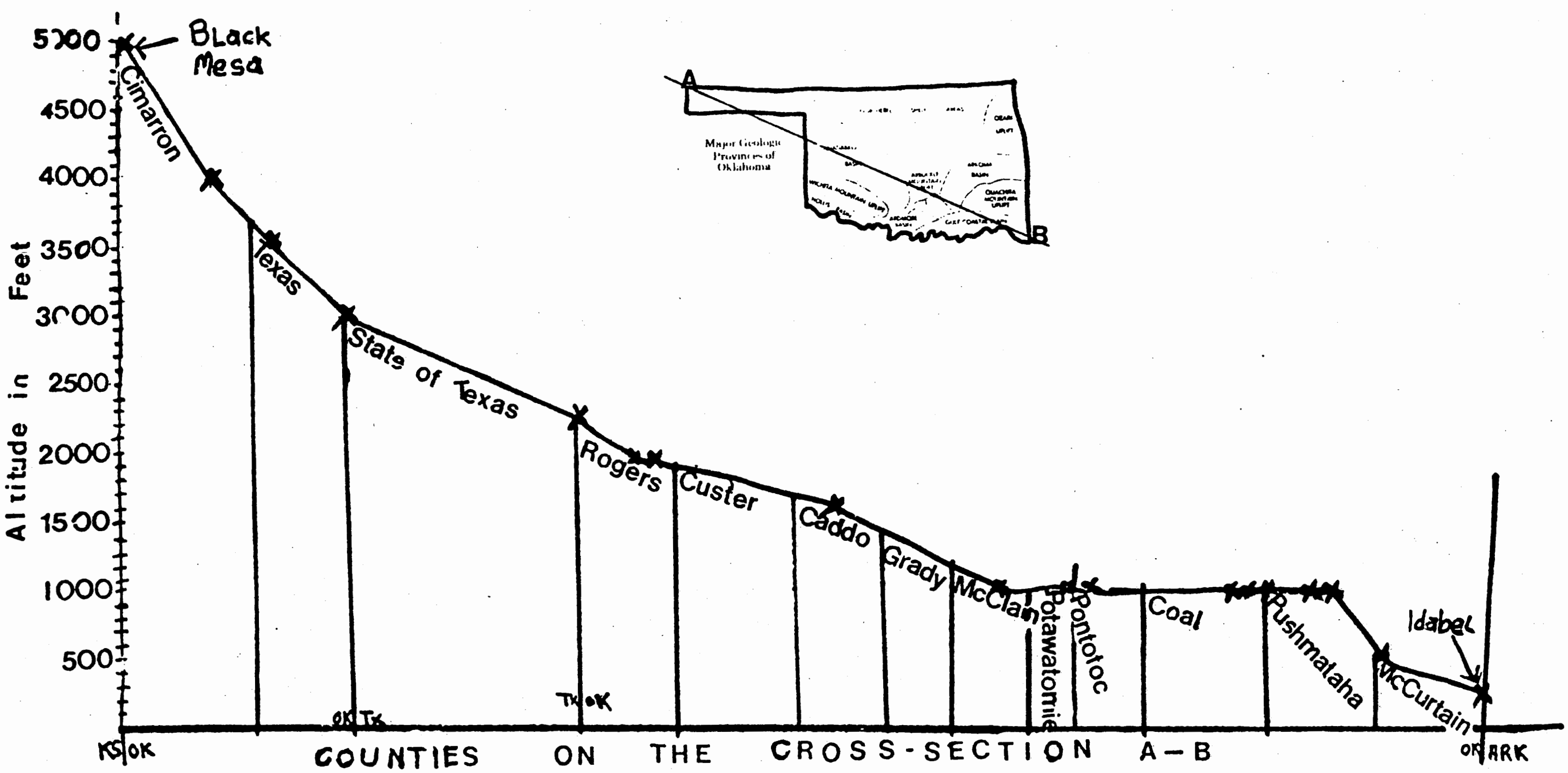


Figure 8. A Topographical Profile of Altitude in Oklahoma From Northwest to Southeast

Regions: 1--Northern
2--Western
3--Southern
4--Eastern
5--Central

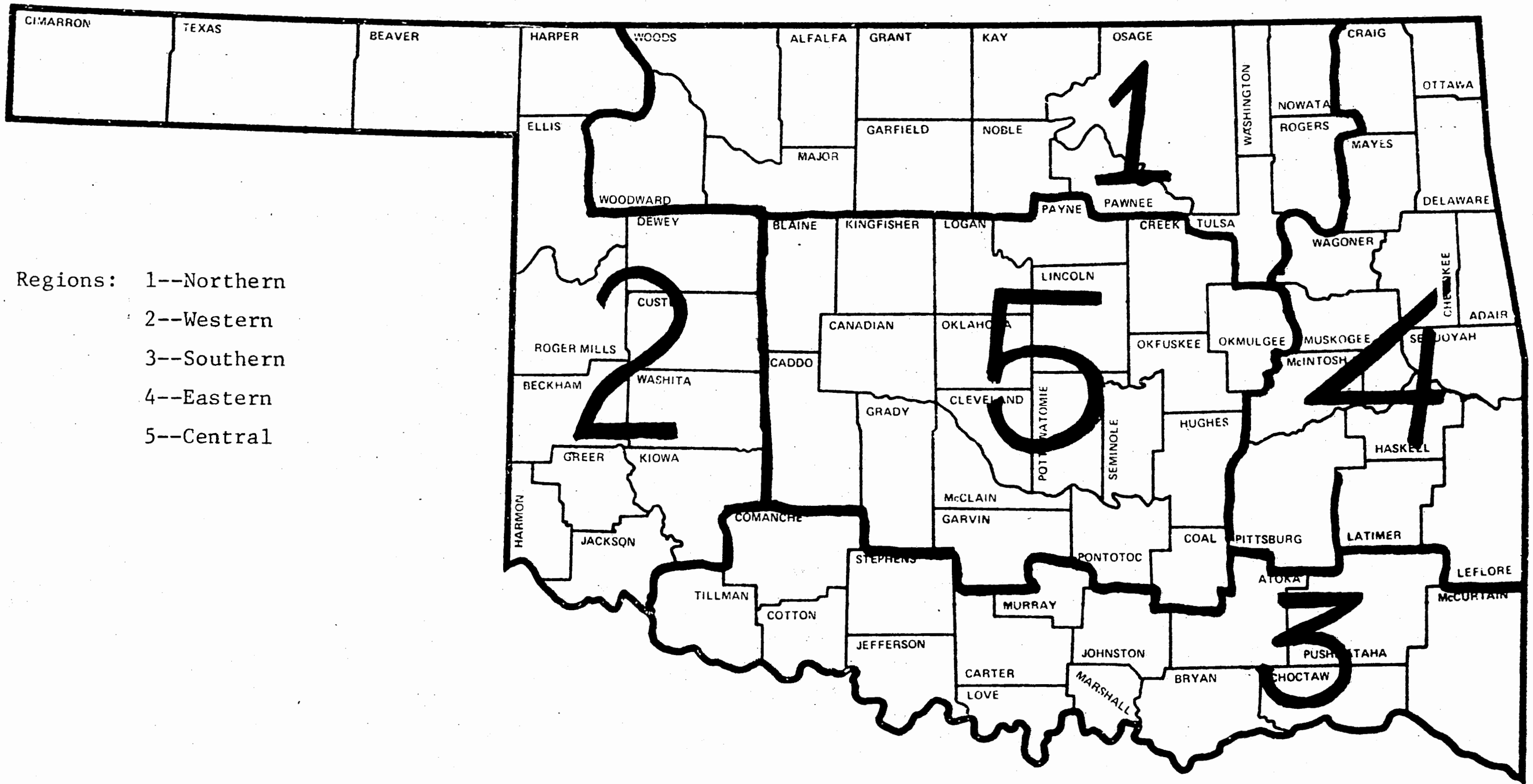


Figure 9. Regional Divisions of Oklahoma Used in Survey

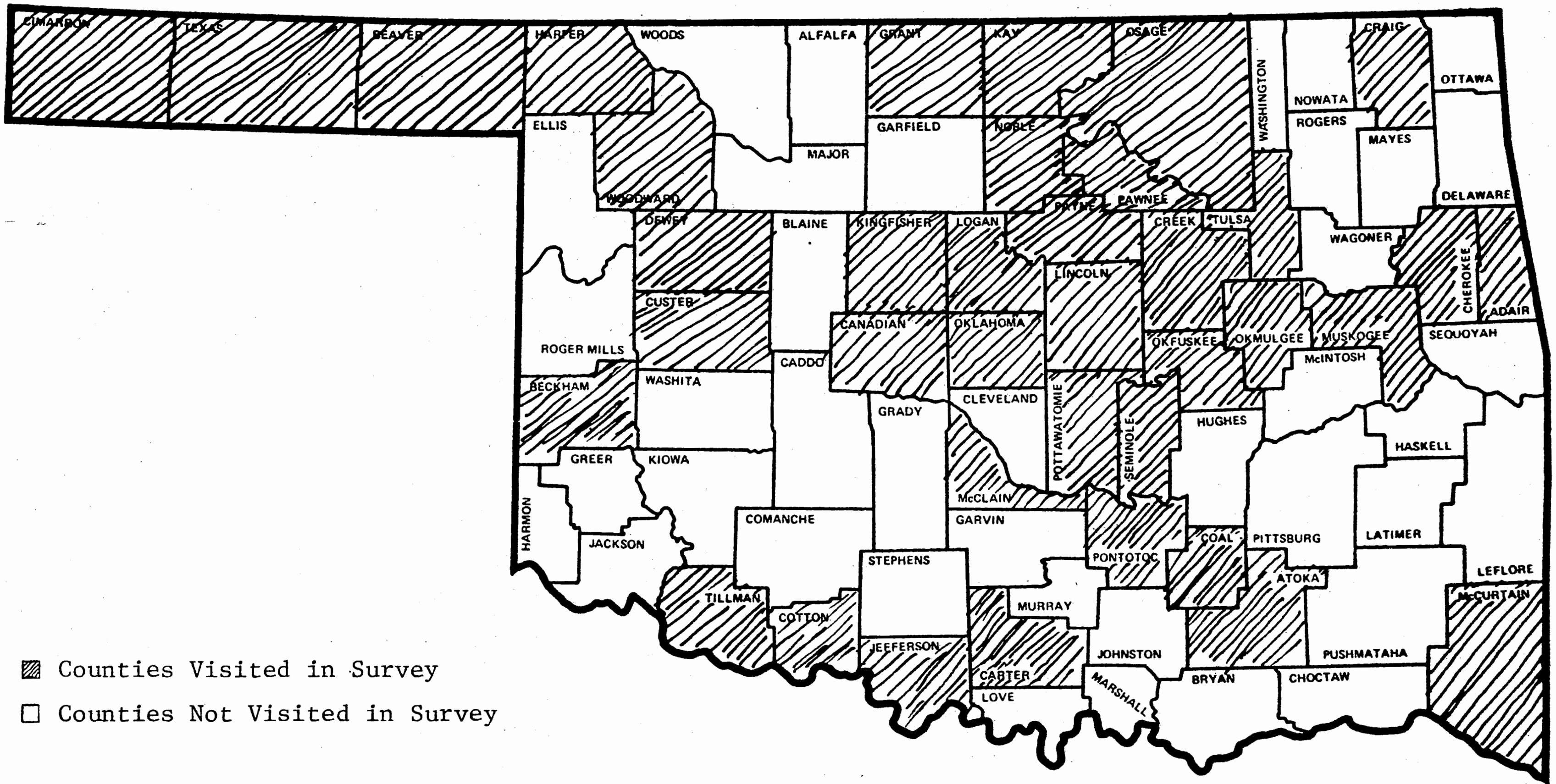


Figure 10. Counties Surveyed for *Fasciola hepatica* in Oklahoma

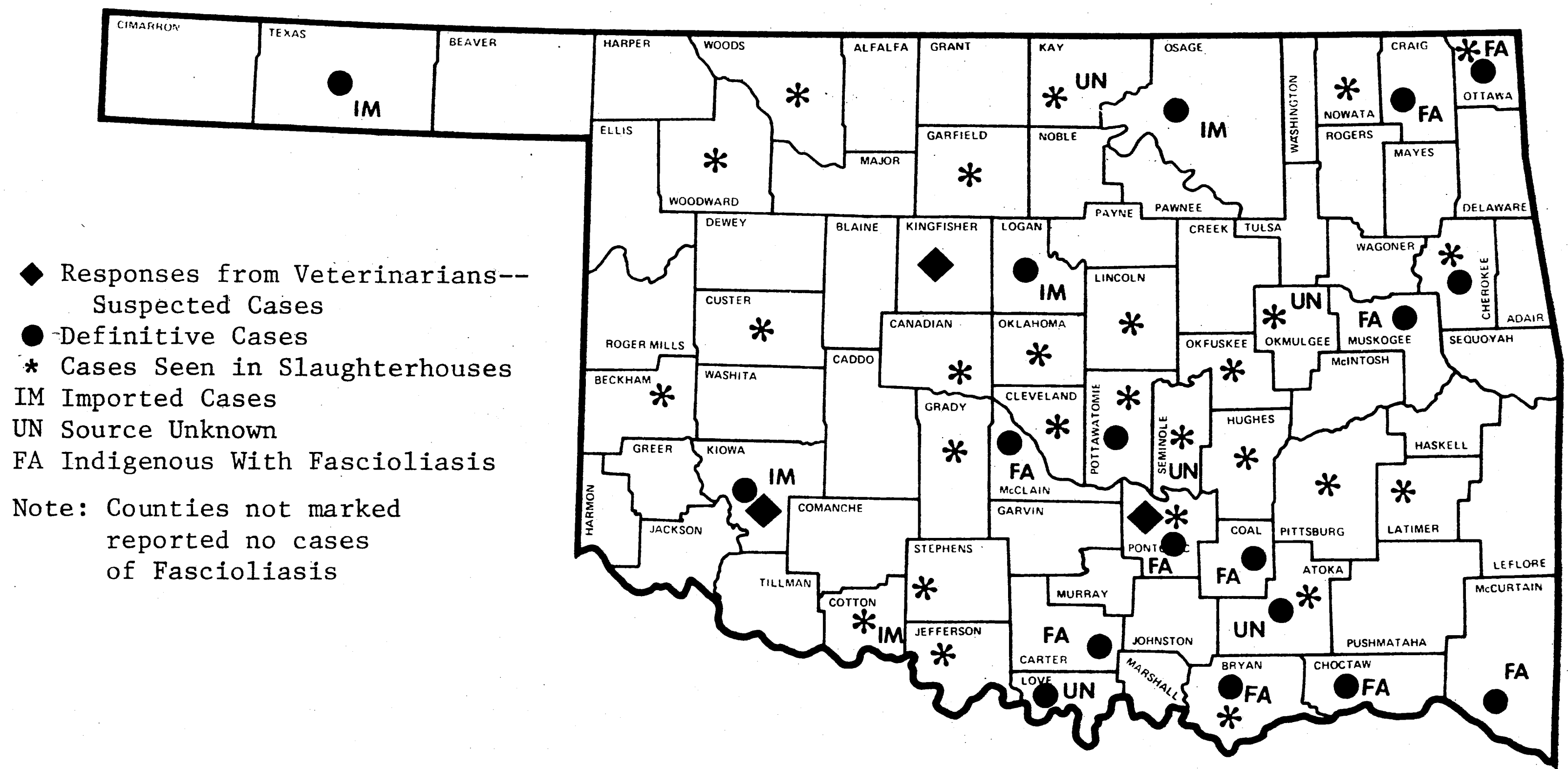


Figure 11. The Distribution of Fascioliasis Cases in Oklahoma Identified From Veterinarians and Packinghouses

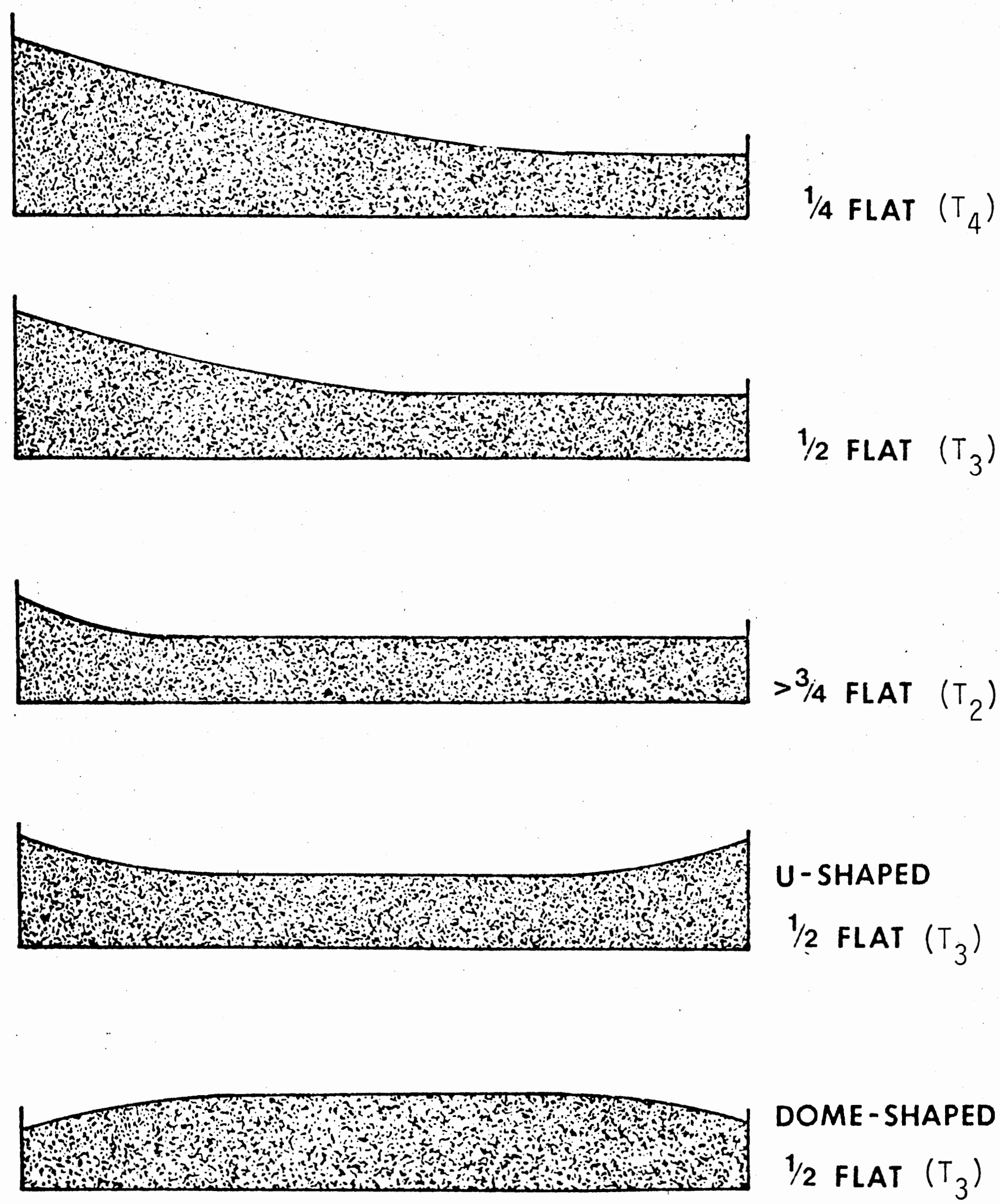
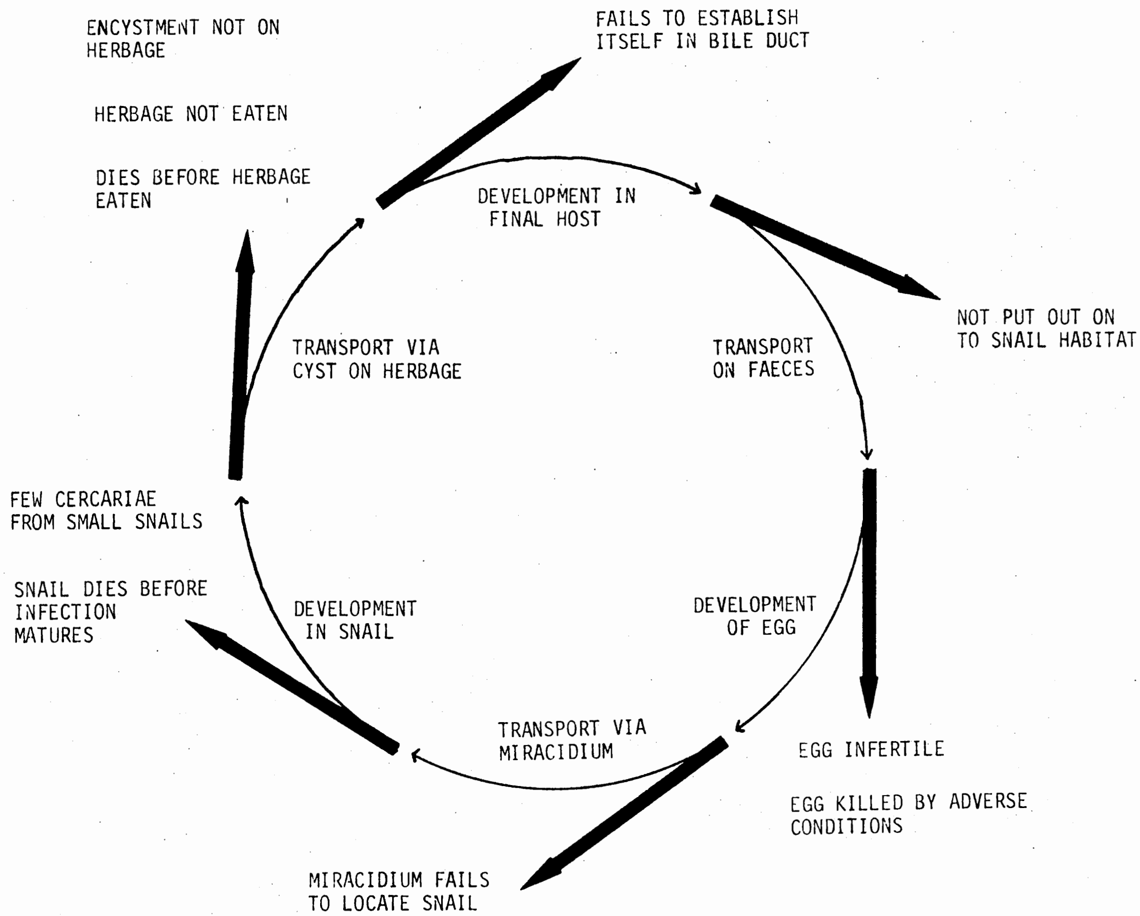


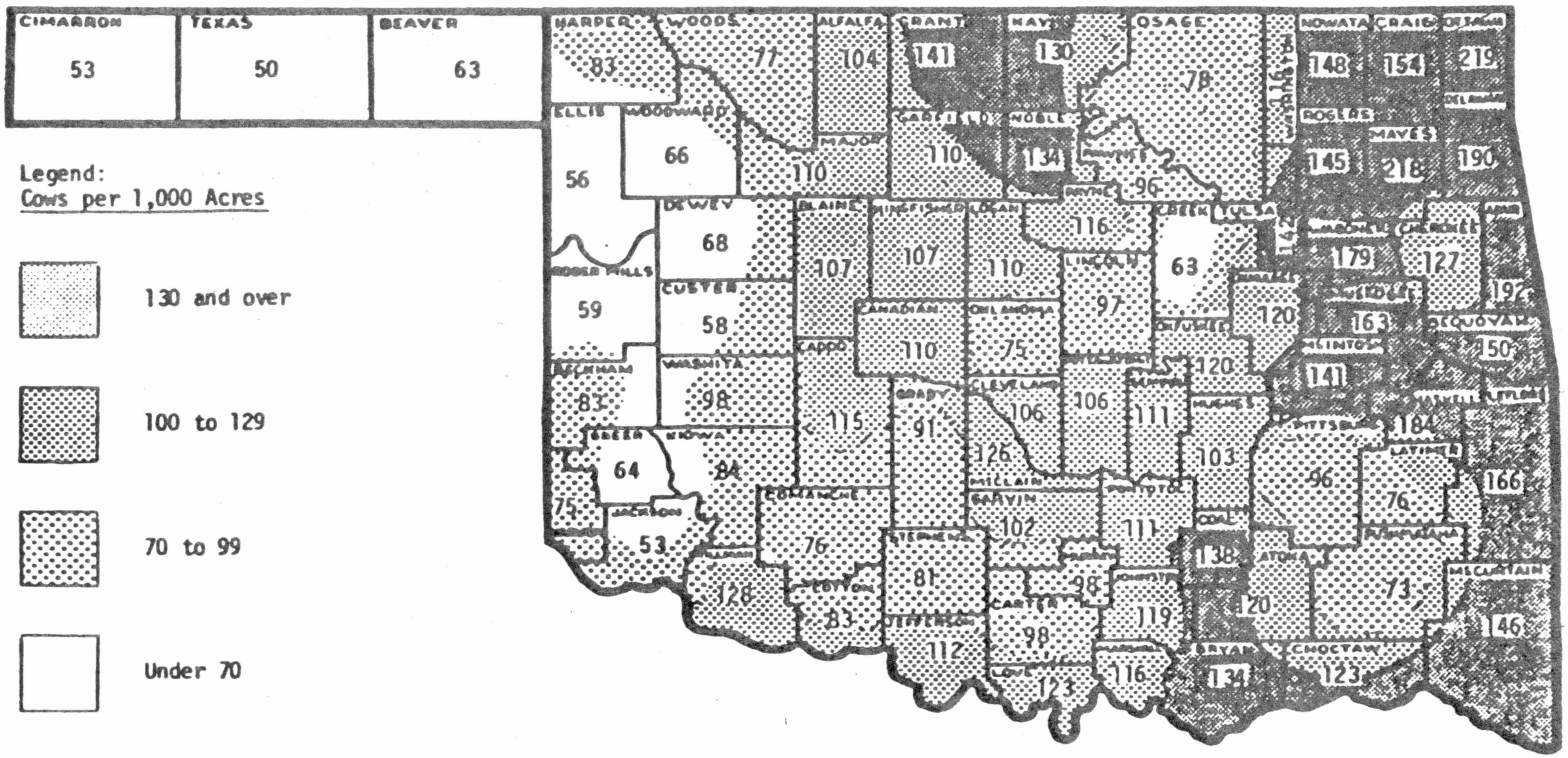
Figure 12. Sketches of Common Landscapes Observed in the *F. hepatica* Survey



Source: C. B. Ollerenshaw (1959), Ecology of the liver fluke (Fasciola hepatica), Vet. Rec. 71:957-963.

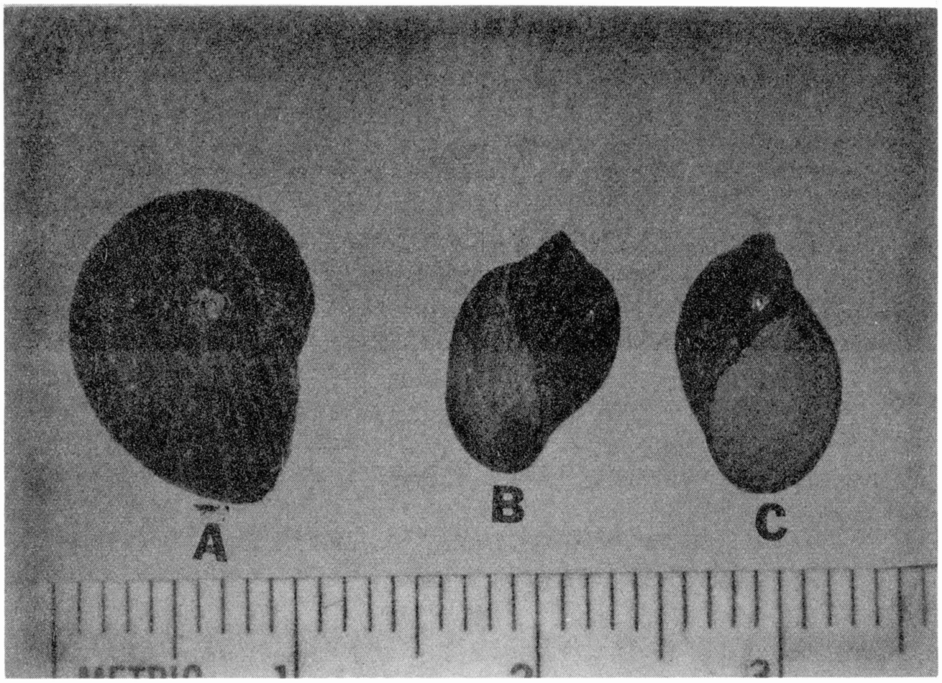
Figure 13. Weak Links in the Life Cycle of Fasciola Hepatica

OKLAHOMA: BEEF COWS PER 1,000 PASTURE AND RANGE GRASS ACRES--BY COUNTIES, JANUARY 1, 1974



Source: Oklahoma Agricultural Statistics, 1974

Figure 14. Beef Cattle Distribution in Oklahoma in January, 1974



A. Helisoma spp.

B. Physa spp.

C. Lymnea spp.

Figure 15. Some Snails Collected in the Field

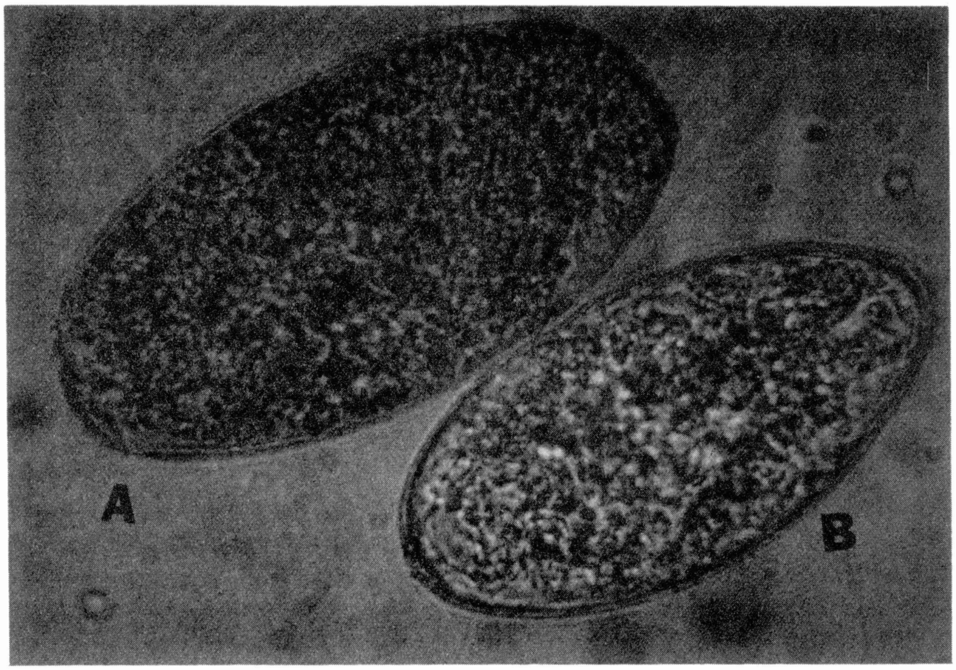


Figure 16. Typical Eggs of F. hepatica (A) and Paramphistomum (B)

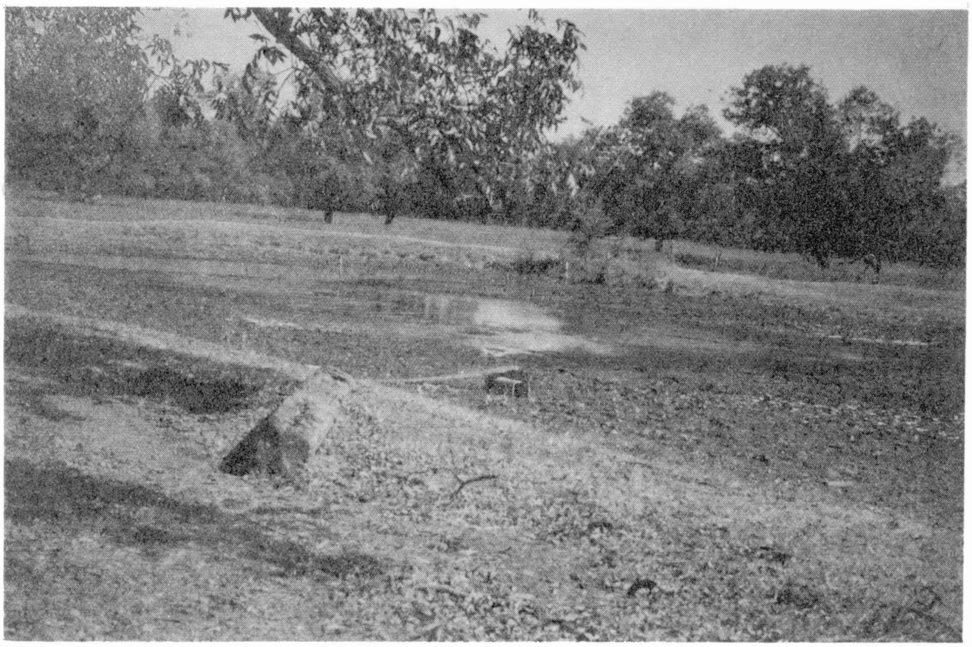


Figure 17. A Farm Near Ada, Oklahoma Where F. hepatica was Found (Pontotoc County)

Figure 18. A Farm Near Idabel, Oklahoma Where *F. hepatica* was Found (McCurtain County)

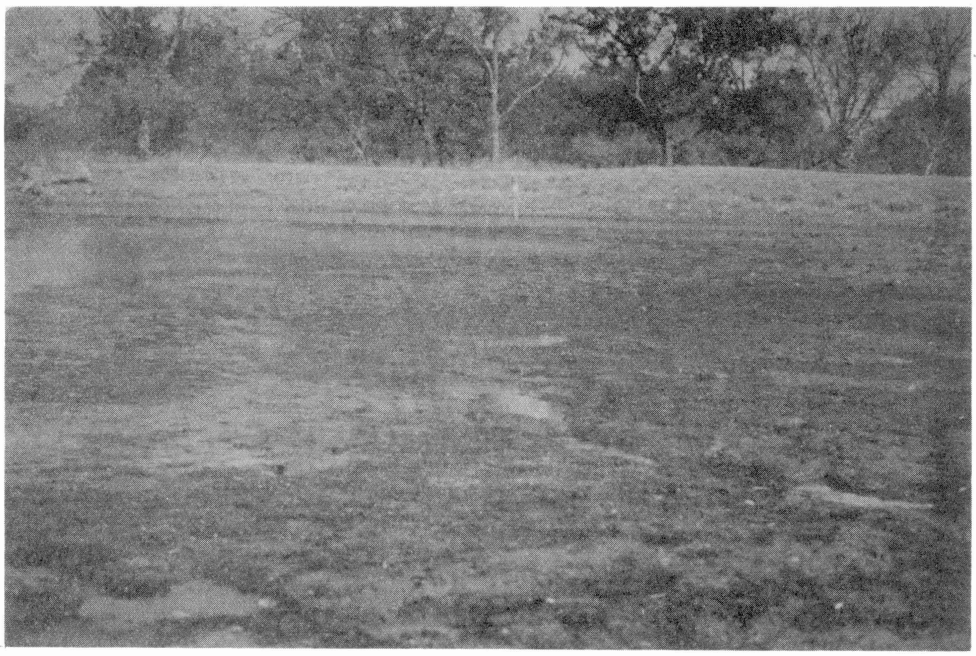


Figure 19. A Typical Marshy Ground Near Ada, Oklahoma Where F. hepatica was found (Pontotoc County)

APPENDIX C

DATA SHEET FOR FIELD AND LABORATORY SURVEY

FOR *FASCIOLA HEPATICA*

1. Geographic Location

   County:

   City:

   Farmer:

2. Field Observations

   a. Environment:

      (1) Size of farm in acres ______

      (2) Total number of animals in farm ______

      (3) Type of soil:

      (4) Vegetation:

      (5) Topography (drainage, flood plain, etc.):

      (6) Water source (conditions around including dirt, debris, snails, vegetation, etc.):

      (7) Evidence of drugs:

      (8) Type of feed:

      (9) Facilities (sheds, etc.):

      (10) Other animals on farm (e.g., sheep or goats):

(11) Evidence of wild animals (e.g., rabbits, rodents, etc.):

b. Physical Examination of Animals:

(1) Breeds:

(2) Sex:

(3) Age:

(4) General appearance:

(5) Appetite:

(6) Character of feces:

(7) History and division, movement, etc. of animals on farm:

(8) Other findings:

3. <u>Laboratory Examinations and Findings</u>

a. Total Fecal Collections ______

(1) Dairy cattle:

(2) Calves:

(3) Dry dairy cattle:

b. Feces (List of Parasite Type):

(1) Flotation test ($ZnSO_4$ solution):

(2) Sedimentation test:

c. Snails Collected:

(1) Type of snails:

(2) Evidence of cercariae, metacercariae:

(3) Other findings:

APPENDIX D

WEAK LINKS IN THE LIFE CYCLE OF

FASCIOLA HEPATICA

Successful transmissions of liver flukes or other parasitic disease is a result of numerous external factors, presence, and prevalence of both intermediate hosts as well as definitive hosts, and the presence of the parasite itself. The interaction of the parasite with the external environment is also very important in determining the successful establishment of the parasite. Considering flukes independently of their hosts, their life cycles, like those of many parasitic organisms, are a succession of lucky accidents. Passage of eggs of this parasite by its definitive host does not guarantee an external environment suitable for its extramammalian development, or does the presence of suitable snail hosts assure infection or that passive infection of definitive hosts by ingestion of the metacercariae will occur. The conditions enhancing these lucky accidents need to be understood to determine the weakest link in the life cycle of this parasite. These weakest links can be found by considering the total biology of the parasite including its complete ecological cycles, some of which are summarized by Figure 13, showing the several hazards that flukes undergo in their life cycles.

Despite so many odds, the liver fluke flourishes and spreads, sometimes at an alarming rate which, unless checked, will result in the infection of every conceivable susceptible host including man. This success may be due, at least partly, to an attribute of their life cycle. Flukes lay eggs, for example, estimated at 2,000 to 3,500 per day (Taylor, 1961) and their asexual reproduction within the snail enhances production of countless juveniles per fluke egg (Krull, 1934). Additionally, flukes are hermaphrodites and individuals are thus endowed with the capacity to lay viable eggs. The life span of liver flukes in their definitive hosts, particularly cattle, is considerable. According to Leiper (1938) and

Brunsdon (1967), liver fluke infection remains as long as the life of the host (goats, sheep). Although Kendall (1965) believed the life span to be 3 to 4 months and Ross (1968) reported it to be at least 26 months, this difference may be due either to worm burden (Ross, 1968) or to strain (breed), as shown by the work of Hughes et al. (1976). Field contamination, therefore, can continue for a long time. Fasciola hepatica eggs once deposited do not develop at the same rate (Rowcliffe and Ollerenshaw, 1959; Shaw, 1931; Thomas, 1883), so there is a continuous supply of miracidia. Additionally, the high reproductive rate of snails during favorable periods and the lack of complete destruction during adverse conditions together with the relatively large range of susceptible hosts ensure, to some extent, success of liver flukes. The long life of metacercariae is equally important, since they have been found alive and infective after long periods of time (Boray, 1963; Grigoryan, 1959, quoted by Hammond, 1965; Olsen, 1947; Rajcevic, 1929, quoted by Price, 1953). Kendall (1965) reported that metacercariae can be viable and infective to rabbits after eight months of storage. Ecological factors associated with hazards as well as successes that liver flukes undergo are summarized by Ollerenshaw (1959) in Figure 13.

In general, snail intermediate hosts are considered the easiest point to attack, partly because when present they can be easily seen. However, since they are easily spread and can survive adverse conditions, total destruction of snails may not be easy. Pulmonate snails (Fretter and Peake, 1975; Wright, 1971) and nearly all Lymneid snails (Colton and Pennypacker, 1934; Oken, 1817, Van Baer, 1835, Von Ihring, 1876, all quoted by Colton, 1912; Walton, 1918) are hermaphrodites and self-fertilization is the rule rather than the exception. A single fertile egg, therefore, can ensure a build-up of snails after some period of time following destruction of the parent snail population.

Contact of snails with the parasite can greatly be reduced using the approaches that have been suggested by various investigations, such as use of molluscicides (Gordon et al., 1959), biological control (Berg, 1953, 1964; Boray, 1964; Lynch, 1965), and drainage (Walton, 1918). Since low pH is not conducive to the life cycle of both snails and the parasite, carbonate-rich compounds such as calcium carbonate should be dumped into ponds or other aquatic habitats. However, the parasite aspect can also be considered. Possible avenues for control may rest with medication of infected cattle or prevention of cattle from contact with snails by fencing off snail-infected parts of the pasture (Price, 1953).

With respect to Oklahoma, however, special consideration should be paid to cattle movement through and/or into the state and to educating farmers to ensure that the cattle they bring into their herds are fluke-free. Since many boggy areas are present, especially in the southeastern portion of the state, the farmers alone should not be left to solve the problem of drainage and molluscicide dressing. Government aid is necessary in the provision of engineering equipment and its operation if farms are expected to curtail losses. In the meantime, fencing snail sites is an affordable asset. The farms suspected of fascioliasis should be studied and the cattle treated to limit the spread or contamination of pastures with fluke eggs.

VITA 2

Henry Kipkemei Cheruiyot

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE DISTRIBUTION AND FACTORS INFLUENCING THE ESTABLISHMENT OF *FASCIOLA HEPATICA* LINNAEUS 1758, IN NATIVE OKLAHOMA CATTLE

Major Field: Veterinary Parasitology and Public Health

Biographical:

Personal Data: Born at Kericho, Kenya, September 26, 1942, the first son of Mr. and Mrs. Cheruiyot arap Kimeto.

Education: Graduated from Kericho High School, Kenya, with Cambridge School Certificate in 1964; received the Cambridge Higher School Certificate from Friends School, Kamusinga, Kenya, in 1966; received the Bachelor of Science degree from the University of East Africa in Nairobi, in June, 1970; received the Master of Science degree from Oklahoma State University in May, 1975; completed the requirements for the Doctor of Philosophy degree at Oklahoma State University in July, 1978.

Professional Experience: Assistant Manager, Quality Control, Edible Oil Processing Plant in Kenya, 1970 to 1972; laboratory assistant, Zoology Department, University of Nairobi (during vacations).

Professional Societies: American Society of Parasitologists, American Society of Tropical Medicine and Hygiene, Southwestern Society of Parasitologists.

Other: Member of Kenya Amateur Athletic Association.