ECOLOGICAL FACTORS INFLUENCING GASTROINTESTINAL HELMINTHS OF THE MARYLAND MUSKRAT, *Ondatra zibethicus* Linnaeus

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PREFACE

The scope of this study was to consider the ecological factors that may influence gastrointestinal helminths of the Maryland muskrat.

The writer expresses his appreciation to Dr. Roy W. Jones and Dr. E. D. Besch, who served as chairmen on the advisory committee; and to Dr. Bryan P. Glass, Dr. L. H. Bruneau, and Dr. D. E. Howell, who also served on the committee.

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And to my family, thank you for your sacrifices and encouragement.

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CHAPTER I

INTRODUCTION

Helminth parasites of muskrats have been known since the beginnings of parasitology in North America. As far as could be determined, the first mention of a parasite species from the muskrat was made by Joseph Leidy in 1858.

The first extensive studies of the helminths of muskrats were made by Barker and his co-workers (1911-1916). These investigators found 881 helminth parasites, most of which were trematodes, in 42 muskrats. Barker's studies involved descriptions of eight new species of trematodes, two new cestodes, and three new nematodes. His studies are a milestone in American parasitology.

Since Barker's monumental work, numerous studies concerning the helminths of muskrats have been made throughout this country. Some of the earliest of these studies involving helminth parasites were conducted in the Great Lakes region: (Ameel, 1931, 1932, 1934, 1942; Law and Kennedy, 1932; Swales, 1933; and Penner, 1938, 1941, 1949).

Other studies involving helminths in muskrats were conducted in: Maryland (Price, 1931), Tennessee (Harwood, 1939, Byrd and Reiber, 1942), Texas (Chandler, 1941), Louisiana (Penn, 1942), Ohio (Rausch, 1946, Beckett and Gallicchio, 1967), Massachusetts (Rankin, 1946), Oregon (Rider and Macy, 1947, Senger and Neiland, 1955), New York (Edwards, 1949), Maine (Meyer and Reilly, 1950), Virginia (Byrd, 1952), Colorado (Ball, 1952), Illinois (Gilford, 1954), Alaska (Dunagan, 1957), Utah (Senger and Bates, 1957), and Pennsylvania (Anderson and Beaudoin, 1966).

The muskrat, Ondatra zibethicus (Linnaeus, 1766), is the most important fur-bearing mammal in the United States. It leads all other North American fur-bearers in total number taken and value received. Although the individual pelt may bring less in return than the more valuable furs, the total annual value exceeds that of any other species. Louisiana and Maryland are reputed as the nation's leading producers of muskrats. At one time, muskrats in Maryland provided an annual revenue of up to $2,500,000 (Smith, 1938). In addition to its fur value, the muskrat has an added demand as a table delicacy in Maryland. Although important throughout the state, the muskrat is not as important to the economy of western Maryland as it is to the Eastern Shore.

Studies of the muskrat of Maryland have been made in the Dorchester County marshes, particularly the Blackwater Wildlife Refuge by LeCompte (1930), Smith (1938), Forbes (1942), Dozier (1947), Dozier, Markley and Llewellyn (1948), and Harris (1952). The more extensive of the studies were conducted by Smith, Dozier, and Harris. Smith (1938) in his research briefly mentioned some of the helminths that he recovered. Dozier (1947) conducted a study in the Dorchester County marshes and he presented the various aspects of salinity on tidal marshes and their influence on muskrat production. Harris (1952) conducted a study of the biology of the muskrat in Dorchester County. He mentioned that he observed some external parasites.

Many muskrat studies, similar to those of Smith, Dozier, and Harris failed to mention parasites. The information relative to parasitism in muskrats is meager and fragmentary (Meyer and Reilly, 1950). Most of the writings have been concerned with a survey of the helminths of the muskrat in a particular locale. Some investigators have considered a particular helminthiasis of a host from a single locality. Others have conducted life cycle studies (Ameel, 1932; Beaver, 1937; Chandler, 1950; Cuckler, 1940; Goble, 1942; Herber, 1939; Krull, 1935; Kuntz, 1943; Olivier, 1938; Penn, 1942; Price, 1931; Rausche, 1948; Wallace and Penner, 1939; and many others).

Few studies are concerned with the various aspects of ecology that may influence parasitism in the muskrat. Although some dealt with the host-parasite relationship and the influence of the internal environment, the information obtained has been difficult to relate to the population dynamics of the parasite in nature (Anderson and Beaudoin, 1966). The parasitological surveys which might have been expected to give some insight seldom touched on the influence of the external environment, and oftentimes even the habitat in which the survey was conducted was not recorded (Anderson and Beaudoin, 1966). As a result, little information exists concerning the role and influence of the external environment and, more specifically, the influence of host habitat on parasite numbers.

Since much is yet to be learned about the muskrat in relationship to its environment, this study attempted to determine some of the ecological factors which may influence helminth populations in the muskrat of Maryland.

Miller and Kellogg (1953) listed two species of the muskrat: *Ondatra zibethicus*, whose distribution includes the entire United States and which is broken into 15 subspecies; and *O. obscura* (Bangs), the

Newfoundland muskrat. Two of the subspecies of the muskrat, O. zibethicus, exist in Maryland. The muskrat of the Eastern Shore is known as the Virginia or coastal muskrat, Ondatra zibethicus macrodon Miller. It is separated from the other fourteen subspecies by being the largest, by its dark color, and by the absence of the interorbital ridge (Smith, 1938). This muskrat is confined to Delaware, coastal Maryland, Virginia, and North Carolina (Hall and Cockrum, 1953). The muskrat of western Maryland is Ondatra zibethicus zibethicus (Linnaeus). This is the common eastern muskrat, whose distribution is the most extensive of any subspecies in the United States. The two subspecies differ in their habitat and in certain habits.

Maryland's topography makes it a diversified study area, for it consists of three distinct geographic regions; (1) the Coastal Plains, (2) the Piedmont Plateau, and (3) the Appalachian Region.

The Coastal Plains region, which lies on the Eastern Shore, is east of the Chesapeake Bay. The bay is an inland body of marine water that separates the state into eastern Maryland and western Maryland. The Eastern Shore is also known as the Delmarva Peninsula, referring to the states of Delaware, Maryland and Virginia. This area is characterized by flat topography, low elevation, and extensive tidal marshes.

The Piedmont Plateau of Maryland lies in the center of the state, just west of the Chesapeake Bay. It is characterized by gently rolling hills. Its rural nature has been changed drastically by the spreading metropolitan areas of Washington, D.C. and Baltimore. The undulating low hills of the plateau may be as high as 800 feet.

The other habitat is that of the Appalachian Region of western Maryland. The rolling hills of the Piedmont change abruptly to the mountains of the western region. The Appalachian Region consists of a series of parallel mountain ranges and within this region are the Appalachian mountains and the Allegheny plateau.

The Atlantic Coast, with its extensive tidal marshes, is the most important muskrat-producing area in the nation (Smith, 1938). The state of Maryland provides over 200,000 acres of tidal marshes, most of which are on the Eastern Shore. The Virginia muskrat inhabits a region from the upper Delaware Bay to central North Carolina.

Western Maryland includes the counties of Frederick, Washington, Allegheny, and Garrett. This area is northwest of the metropolitan areas and is situated where the Piedmont Plateau and the Appalachian mountain range meet. The farm ponds, streams and rivers of this area are inhabited by the muskrat which extends from western Maryland throughout much of the eastern United States. The muskrat population is not nearly as dense in western Maryland as it is on the Eastern Shore.

Approximately 195 miles separate the study areas of Dames Quarter in Somerset County from the Thurmont area in Frederick County. The Dames Quarter muskrats are marsh dwellers. Rivers, ponds and streams are inhabited by the muskrats of Thurmont.

There has been much cause for concern in Maryland due to the decrease in muskrat populations since 1939. Predation, trapping, and disease have taken their toll of the population. The drought of the eastern United States in the summer of 1966 also contributed to diminishing the population of muskrats.

Some of the ecological factors considered in this study include: (1) climatological; seasonal changes, temperature, precipitation, relative humidity; (2) chemical properties of the water from which the muskrats were taken; pH and salinity; (3) flora and fauna of the collecting areas; (4) the biology of the host muskrat; age, sex, population density; and (5) biological relationships; intermediate host-definitive host cycles and host-predator cycles.

This study was concerned with the kind and number of helminths in the gastrointestinal tract and liver of the muskrat.

An attempt was made to determine these ecological and parasitological relationships with respect to the host. It was hoped that the study would show certain trends, indicating a relationship between the ecology and parasitism of the muskrat.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

Dames Quarter Marshes, Somerset County, Eastern Shore, Maryland

The Eastern Shore of Maryland consists of nine counties which lie on the Delmarva Peninsula between the Chesapeake Bay and the Atlantic Ocean. These vast bodies of salt water, their tributaries, and adjacent land areas are referred to as Tidewater Maryland. Extensive marshes are found in this area, particularly in the southern part. Approximately 194,000 acres of marshes are situated on the Eastern Shore. They vary from fresh water to high salinity types, ranging from 2% to 42% of average sea salinity (Harris, 1952). The marshes are a preferred muskrat habitat in Maryland. Dorchester County contains almost 50% of the marshlands on the Eastern Shore and is the most densely populated county in Maryland for muskrats.

The Eastern Shore area selected for this study was in the Dames Quarter marshes in Somerset County. The area is eleven miles west of Princess Anne, county seat of Somerset, and is situated in the heart of the tidal marshes on the southern Eastern Shore. These marshes lie adjacent to the Deal Island Wildlife Management, a wildlife refuge in the marshes.

Marshes can be classified according to the dominant marsh plants. The most prevalent marsh species on the Eastern Shore of Maryland are: three-square sedge (Scirpus olneyi); saltmarsh three-square (Scirpus robustus); needlerush (Juncus roemerianus); salt grass (Distichlis spicata); saltmeadow cordgrass (Spartina patens); saltmarsh cordgrass (Spartina alterniflora); tall cordgrass (Spartina cynosuroides); and cattail (Typha). The Maryland marshes vary slightly as to the chief muskrat food and vegetation that they provide, and 75% of the muskrat food in Maryland consists of (1) three-square sedge, Scirpus olneyi and (2) cattail, Typha (Harris, 1952).

The six marsh types on the Eastern Shore of Maryland, classed according to dominant vegetative covers are: (1) Cattail-aquatic type, (2) Three-square cattail, (3) Three-square, (4) Three-square Spartina-needle rush type (mixed brackish marsh), (5) Needlerush-saltmarsh type, and (6) Saltmarsh type.

The Dames Quarter marshes consisted of Type IV (Three-square Spartina-needle rush) and Type V (Needlerush-saltmarsh). The three-square Spartina-needle rush marsh is also referred to as the mixed brackish marsh. The principal vegetation of this marsh was Olney's three-square sedge, needlerush, saltmeadow cordgrass and saltmarsh cordgrass. This marsh consists of 37,740 acres in Queen Anne, Dorchester, Wicomico and Somerset Counties. The muskrat population was scattered in this marsh. The needlerush-saltmarsh is vegetated entirely with needlerush and saltmeadow cordgrass. There are 71,996 acres of this marsh type in Queen Anne, Talbot, Dorchester, Wicomico and Somerset Counties. Muskrats are not abundant.

The water of the Dames Quarter marshes is greatly influenced by the tidal salt water bodies, Tangier Sound and the Manokin River and several smaller bodies of water, Big Sound, Fishing Creek, and Broad

Creek. The tides of these bodies of water are irregular and may be greatly modified by the wind (Harris, 1952). The marshes are penetrated by the system of meandering rivers, small ditches, creeks, "guts," and ponds (Dozier, 1947). The sods of the Dames Quarter marshes are soft and boggy.

The physiographic nature of the Dames Quarter area varies. The land region is irregularly bounded by Tangier Sound, Manokin River, Big Sound, Fishing Creek, and Broad Creek. The land is flat. It has few trees and numerous shrubs. The marshes extend from Tangier Sound eastward with only a few trees in sight for three or four miles, and then change abruptly to a thickly wooded area and the forest complex extends eastward throughout most of the county.

The nature of some sections of the marsh area is undergoing alteration due to a drainage system which was installed in an attempt to eliminate mosquitoes.

Muskrat activity is not particularly easy to detect in the Dames Quarter marsh. A large number of muskrats live in muskrat houses. Houses are dome-shaped structures which are located in open marshes. Muskrat dens are the second type of muskrat home in the marshes. These dens are burrows into the banks of either ponds, streams, or marshes, and they house muskrats in western Maryland or muskrats in the marshes of the Eastern Shore. These dens may go undetected in the marshes unless the tides have fallen. It has been estimated that 20% of the total muskrat population in the Maryland marshes are "bank" inhabitants (Dozier, 1947).

The elevation of the Dames Quarter marshes is approximately 20 feet above sea level. The rainfall is between 42 to 44 inches per year, and

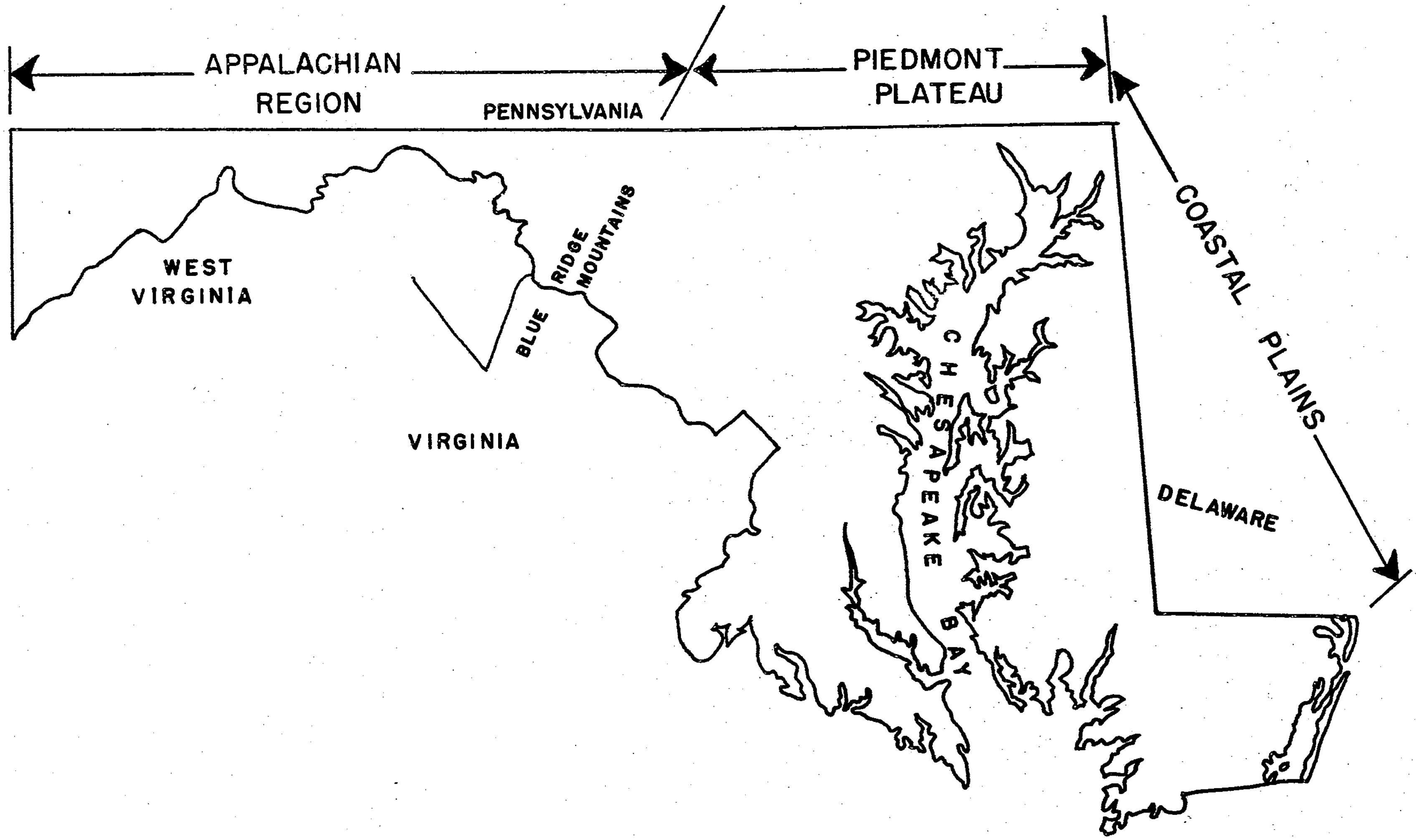

Figure 1. State of Maryland

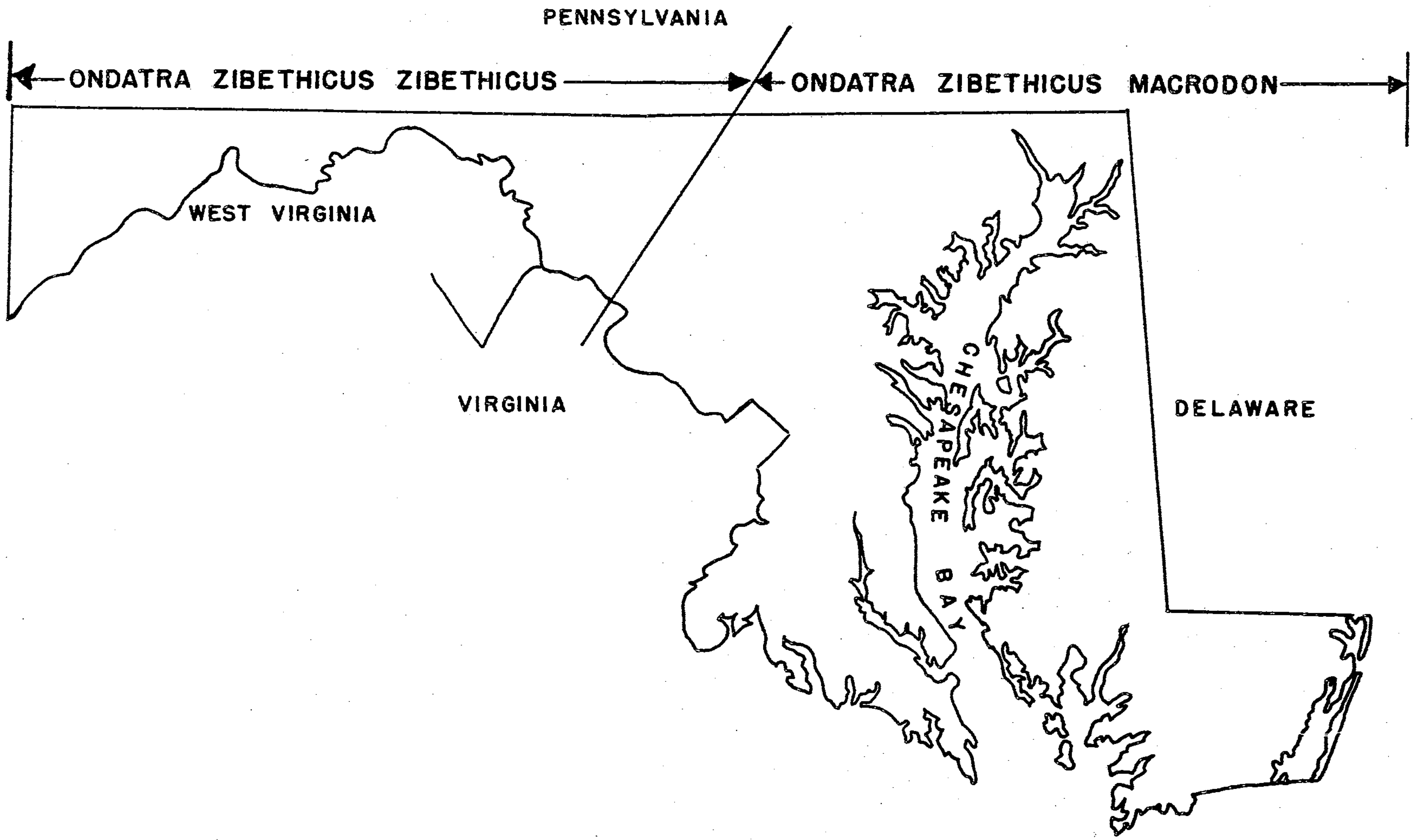

Figure 2. State of Maryland, Indicating the Muskrat Range of the Two Subspecies Which Inhabit the State

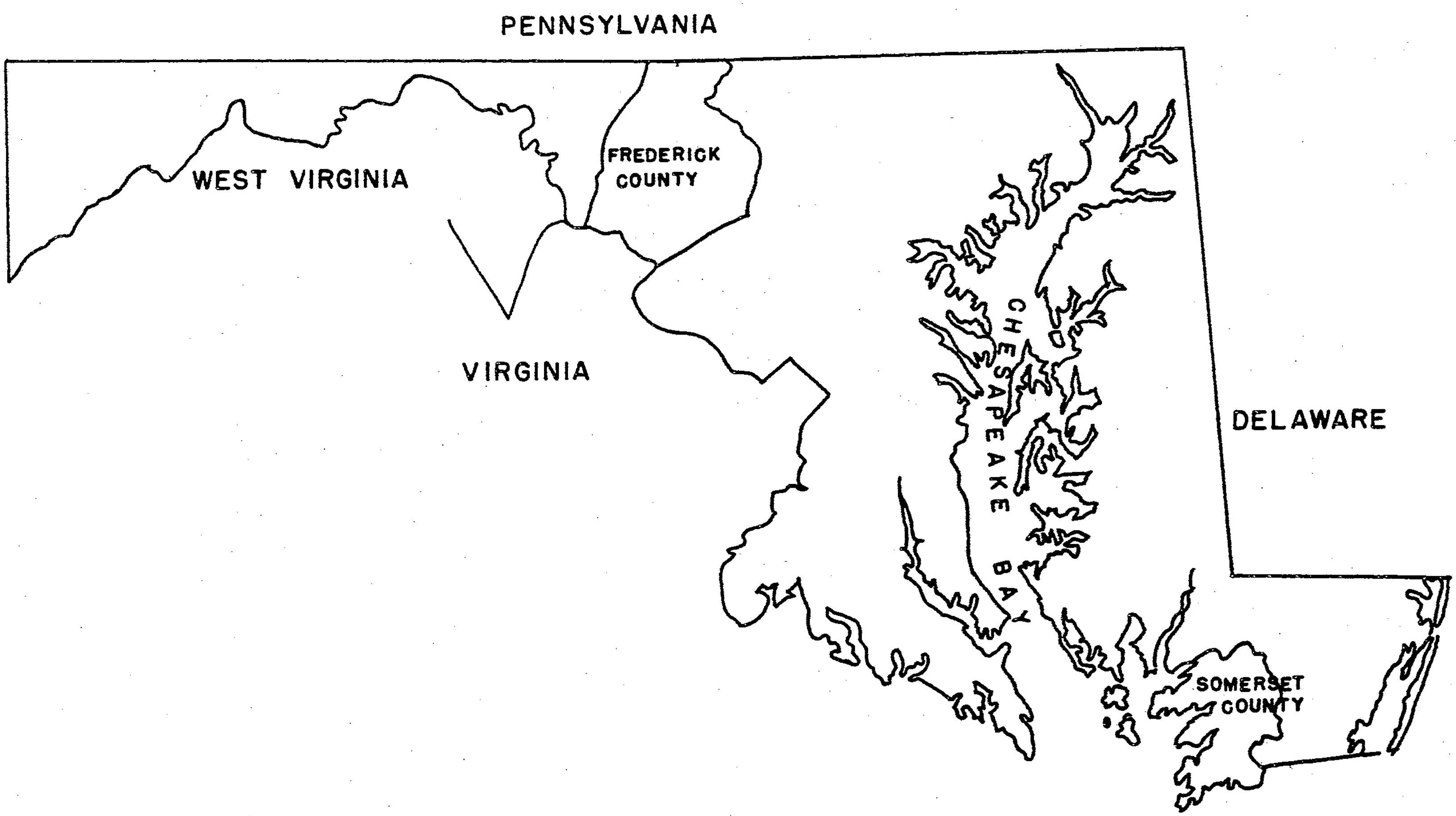

Figure 3. State of Maryland, Indicating the Positions of the Counties Involved in This Study

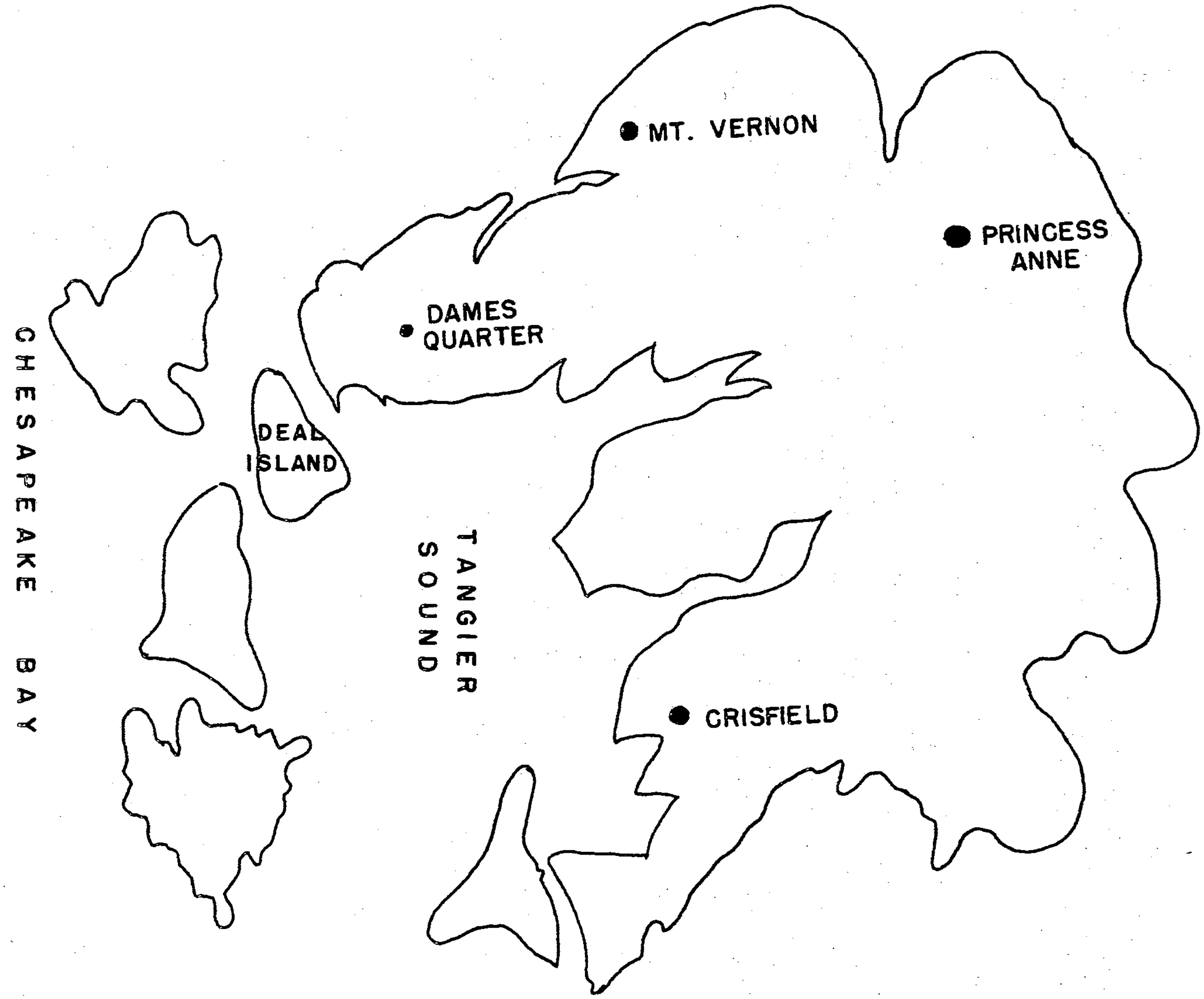

Figure 4. Somerset County, Maryland

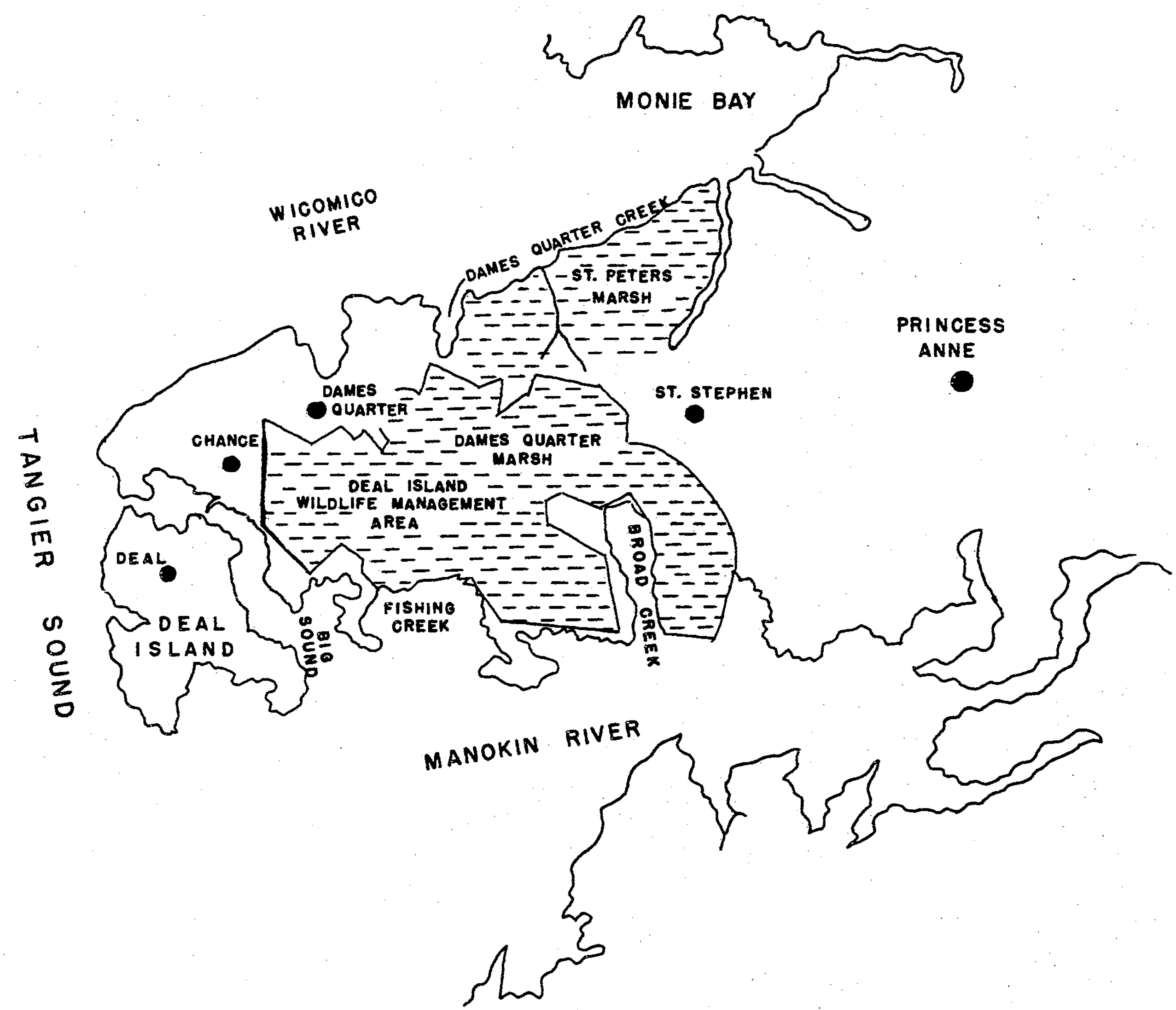

Figure 5. Dames Quarter Area

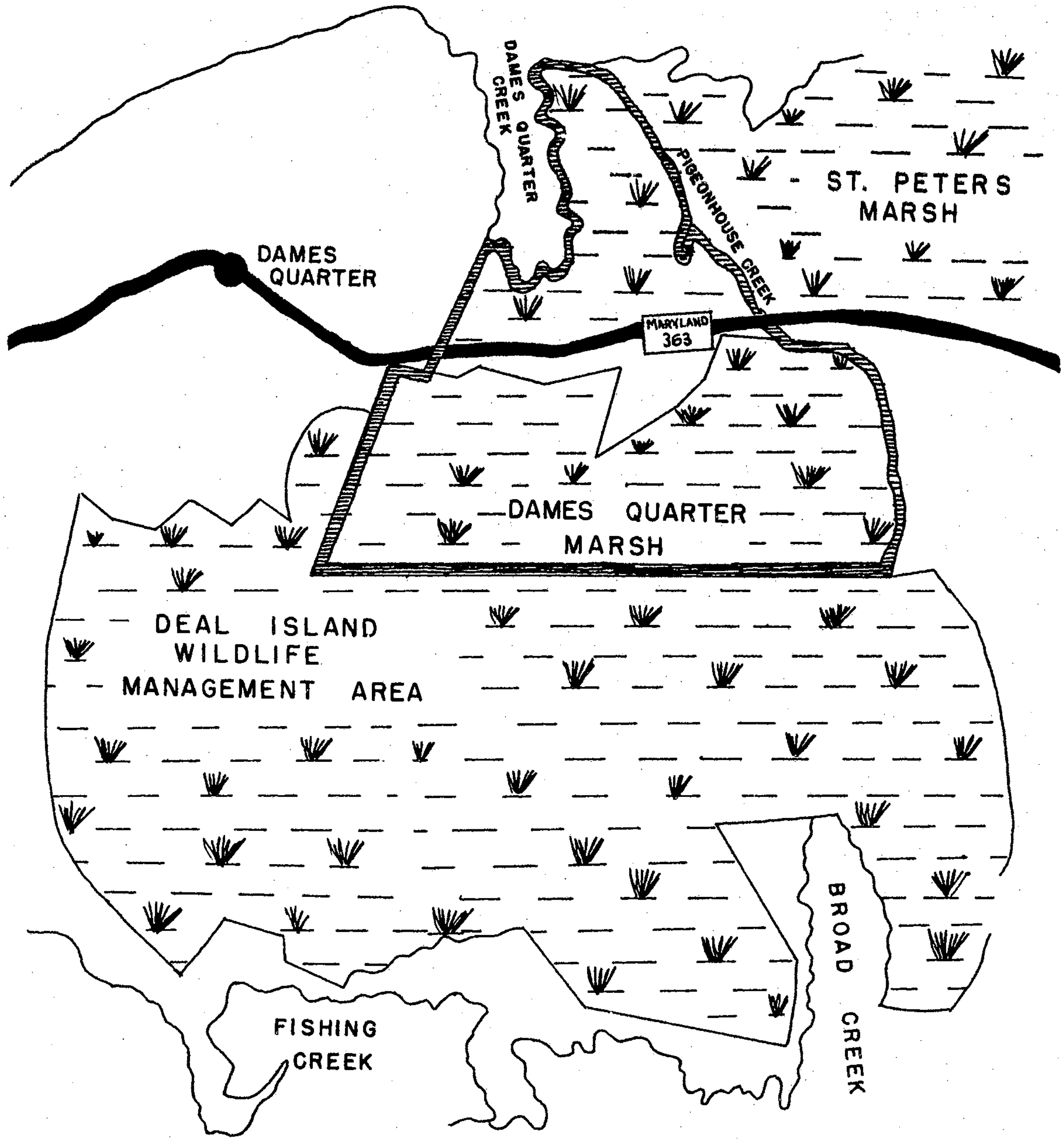

Figure 6. Location of Collecting Areas in Dames Quarter Marshes

generally, the summers are hot and the winters mild. The mean annual temperature is around 58° F (Bard, 1961).

Thurmont Area, Frederick County,

Western Maryland

The western Maryland study area lies along the boundary of the Appalachian Region and the Piedmont Plateau, which separates western Maryland from central Maryland. Here the parallel mountain ranges of Appalachia meet the undulating hills of the plateau. The mountain ranges have an average altitude of 2500 feet.

The Thurmont collecting area in northern Frederick County lies more in the Piedmont Plateau than the Appalachian Region, although it displays characteristics of both regions. It is noted for numerous ponds and streams in a progressive farm area. The largest bodies of water in Frederick County are the Potomac and Monocacy rivers. The Catoctin and South mountains of the Blue Ridge mountain complex are situated in the study area.

The Thurmont collecting area consisted of five ponds and a single stream; (1) Cregger's Pond, (2) Humerick's Pond, (3) Humerick's Stream, (4) Lewistown Pond, (5) Ramsburg's Pond, and (6) Waesche's Pond. Five of these ponds and streams are designated by the names of the land owners, and the sixth, Lewistown, is designated by the name of the nearby community. The Thurmont area is not near salt water regions and these ponds are all fresh water bodies. Generally, the study areas were similar, but not identical, and the investigation has shown them to be different in the characteristics studied.

The average altitude of the mountain ranges is around 2500 feet and the hills of the plateau may reach up to approximately 800 feet. The elevation of Thurmont is 523 feet above sea level and the elevation of the Catoctin mountains at the western edge of the study area is 1250 feet, with the average elevation for the general study area near 600 feet.

The average rainfall in the mountains is around 38 inches yearly. The summers are cool and the winters are severe. The mean annual temperature is around 46° F (Bard, 1961).

Cregger's Pond

This study area consisted of two well managed farm ponds, located approximately five miles northwest of Thurmont. The ponds were surrounded by a very neat yard and meticulous care was evident throughout the year. The ponds were located approximately 50 feet east of the foothills of the Catoctin mountains. The water in the ponds was relatively clear and lily pads were numerous during the summer months. The banks were rocky on three sides. On the west side of the pond, several muskrat dens led into the bank and exited into a small stream on the opposite side from the entrance. The two ponds were of different sizes. The large pond was approximately 108 x 345 feet and between 7 and 8 feet deep. The smaller pond was approximately 120 x 130 feet and 5 feet deep. No wooded area was within 500 yards of the ponds. Snails were conspicuously absent from this study area.

Humerick's Pond

Humerick's pond, the largest of the study areas at Thurmont, was situated approximately two miles east of Thurmont. The pond was approximately 350 x 500 feet in area and between 8 and 10 feet deep. Humerick's stream was south and southwest of the pond. A dense thicket of trees bordered the pond to the south and west. A small pond, with near black water, was located north of the main pond but was not used in this study.

The leaf and litter mold was heavy and it covered the pond bottom. Cattails and four-square reed grass bordered the pond. Collections and observations were difficult to make during the late spring and summer months, due to the algal growth which covered the entire pond surface.

This was a desirable home for muskrats during the winter months, but their presence in the warm season was not obvious. The presence of a large number of snapping turtles in this pond during the summer impeded trapping success. Snapping turtles were frequently caught in the muskrat traps. An abundance of feed holes were situated on all sides of this pond. Feed holes are shallow excavations into the banks that are used exclusively by the muskrat as feeding stations.

The pond was stocked with bluegill sunfish. Snails were present, but not in large numbers. The trees of this study area were: hickory, shag bark oak, cherry, poplar, and spruce.

Humerick's Stream

Humerick's stream ran in a meandering pattern approximately 30 feet south of Humerick's pond. This rapidly moving stream was situated approximately two miles southeast of Thurmont. The stream alternated from a rocky to a sandy bottom, and was approximately two feet deep. Several 'rat excavations were found along the banks, but no activity was detected. Occasional droppings were seen on rocks. A den was detected on a small island in the stream and a muskrat was trapped live from this island in April, 1967.

Algae was present only near the bottom of the stream, and it was sparse. The water in the stream was clear. The stream was bordered by many trees on both sides. The trees lining the banks of this stream were the same species as those observed at Humerick's pond.

Ramsburg's Pond

This study area was a pond located in a field. It was approximately 80 x 50 feet in area and four feet deep. The farm and pond were situated approximately ten miles southeast of Thurmont, and they were in the Piedmont Plateau.

The pond was nestled in the gently rolling hill region, and during the warmer seasons it contained moderate amounts of weeds and grasses along the banks. Algae was present, but did not completely cover the surface of the pond, being found only around the edges.

No muskrats were taken from this pond during the study nor was any recent muskrat activity observed. Inactive excavations along the banks were observed. The water was turbid. No trees were situated near the pond.

Lewistown Ponds

The Lewistown study area consisted of four well-managed square shaped ponds owned by the state of Maryland. They were located six miles southwest of Thurmont. Although some care was given the ponds and the immediate surrounding area, they did not reflect the same meticulous care as Cregger's ponds.

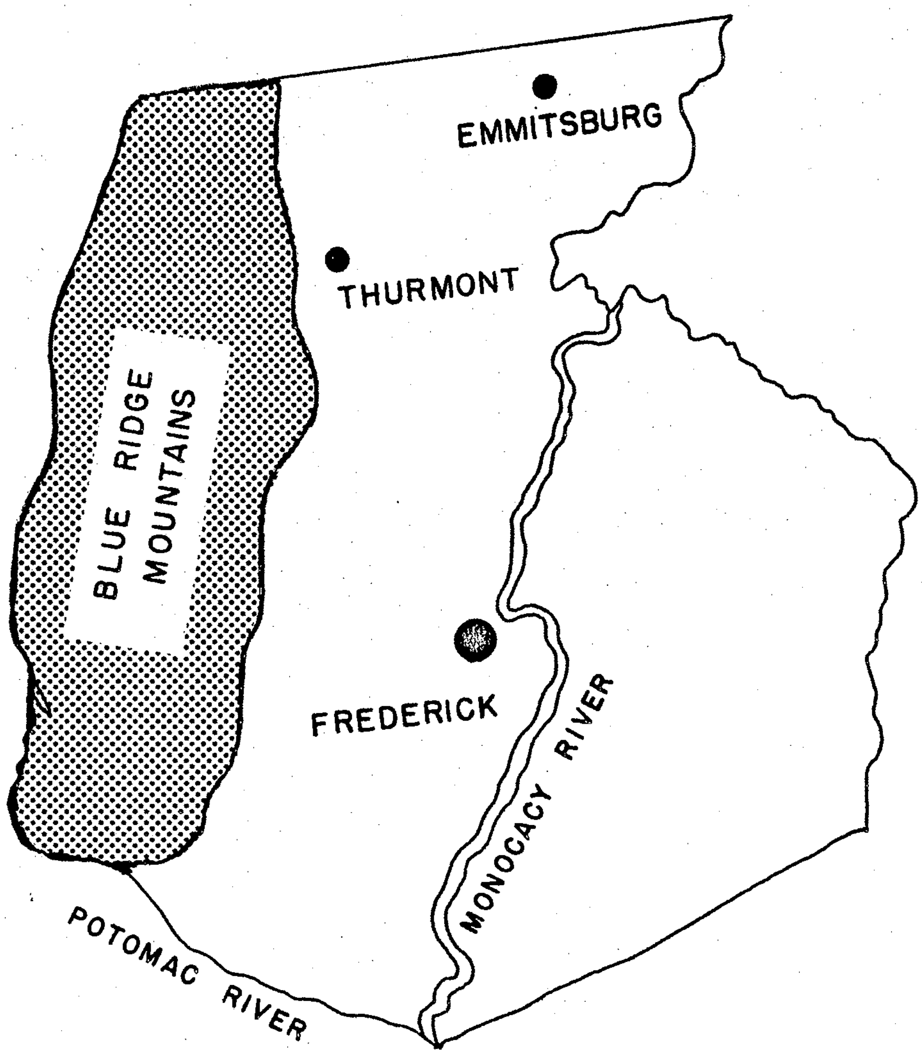

Figure 7. Frederick County, Maryland

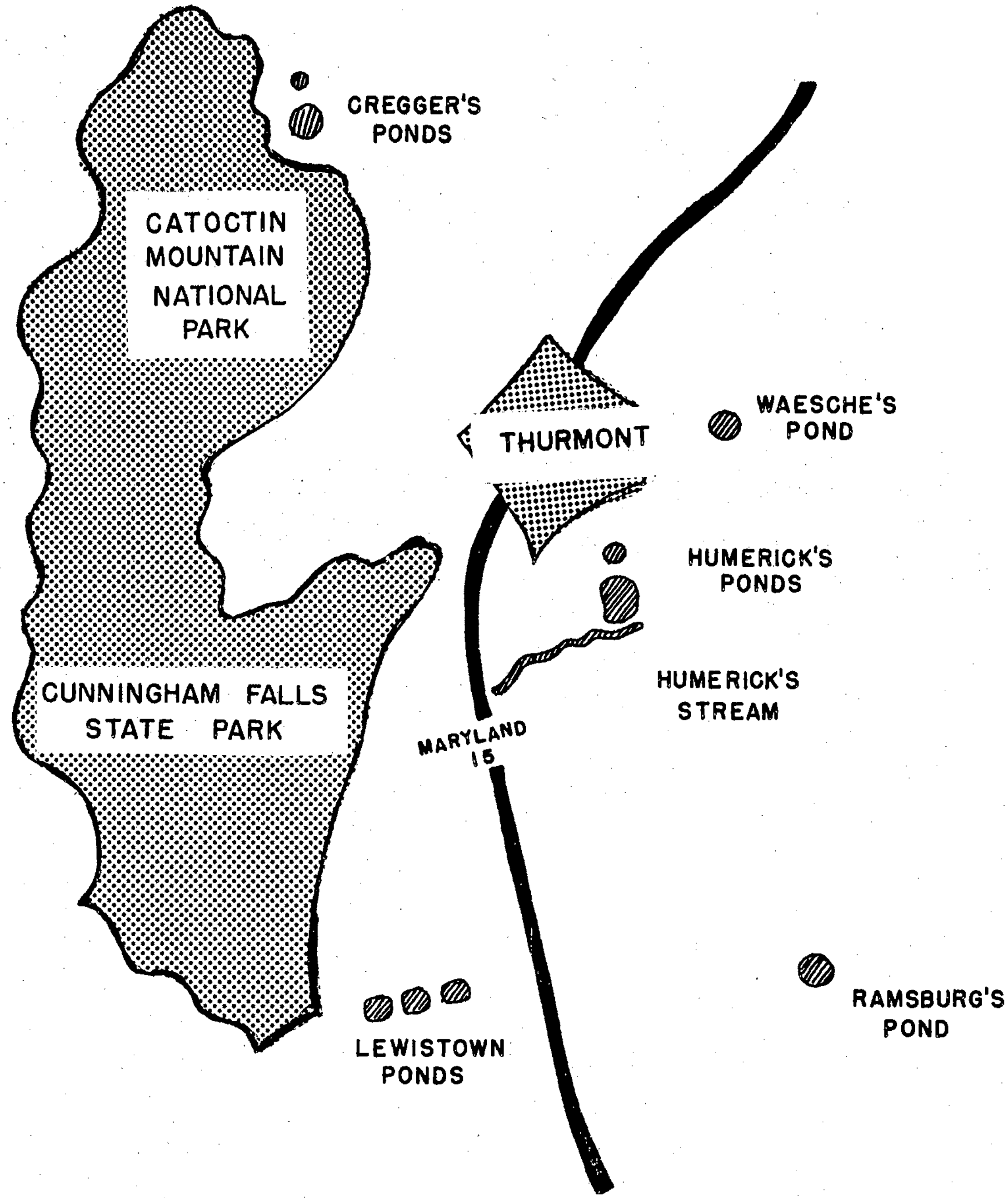

Figure 8. Thurmont Study Areas

During the trapping season this pond was utilized by muskrats, however, it was not consistently occupied, as the water was drained from the ponds in the spring, refilled in the fall, and restocked with fish by the State Department of Conservation. Few snails were present in the ponds.

The water was moderately clear. No trees were located within 150 yards of the ponds. The ponds ranged between 3 and 5 feet in depth and were approximately 100 feet square.

Waesche's Pond

Waesche's pond was located one mile northeast of Thurmont. The pond was bordered by a wooded area on two sides, and the remaining two sides had a heavy growth of short grasses and shrubs.

The pond was around 120 x 180 feet in area and from 5 to 6 feet in depth. The cattail and wild grasses were abundant. A snail population was present and there were frequent signs of the presence of wild and domestic mammals near the pond.

The overall appearance of the pond reflected gross neglect.

Summary of the Thurmont Study Area

The ponds and streams in Frederick County offered such important muskrat habitat requisites as (1) a continuous supply of water at fairly constant levels, (2) food, and (3) sites for burrows (Beshears and Haugen, 1953).

The muskrats in this area seem always to use burrows for homes instead of building houses.

CHAPTER III

MATERIALS AND METHODS

Trapping of Muskrats

Muskrats were trapped during a twelve month period, monthly, from November, 1966 through November, 1967. The animals were taken from the Dames Quarter marshes, Somerset County; and ponds and streams in the Thurmont area, Frederick County.

The muskrats were trapped with a conibear trap, which proved to be very effective. The use of scents, lures, and baits were attempted at the beginning of the study, but this practice was discontinued after it was observed that no significant increase in muskrats trapped resulted from the use of lures.

Prior to selecting sites to set traps an attempt was made to determine where muskrat activity was most frequent. The most positive signs of activity were: (1) droppings on nearby partially-submerged rocks; (2) plant cuttings in the water or at the edge of the bank; (3) den entrances in the banks of streams, ponds, or marshes that appeared active; (4) feed beds; and (5) diggings along the banks. Locations where one or more of these signs were apparent was where traps were set.

Traps were set in the afternoons or early evenings, checked the following morning, and reset. Trapped muskrats were invariably drowned when removed from the traps. An extension chain on the trap was staked in deep water, and the muskrat was unable to get back into the shallow water after being caught.

When long distances to the laboratory from the field were involved, the 'rats were placed in ice chests and kept until they reached the laboratory. They were then either examined immediately or transferred to a laboratory refrigerator.

Post-Mortem Examination of the Muskrat

Routine necropsy protocols were followed in the examination for internal parasites. A ventral midline incision was made extending from below the xiphoid cartilage of the sternum to the hind legs of the necropsied animal. The heart, lungs, liver, stomach, small intestine, caecum, bladder, and kidneys were removed and initially examined grossly for helminths.

The stomach, small intestine, and caecum were tied off, separated, and placed into different containers. After separation, these organs were placed into physiological saline. Starting at one end of an organ, a continuous lengthwise slit was made to expose the lumen to dislodge any helminths that might adhere to the intestinal or stomach wall or mucous membrane. The organ was thoroughly stripped by running it between the fingers.

After stripping and washing the organ the first time, this procedure was repeated to insure the recovery of all helminths.

The stomach and intestinal contents were then placed into pharmaceutical flasks filled with saline, sedimented, and decanted.

The visceral organs (heart, kidney, bladder, liver, and lungs) were removed from the host, minced, transferred into physiological saline and placed in an incubator at 37° C. This procedure caused any existing parasites within the organ to migrate out of the tissue.

Initial observations indicated that the liver, small intestine, and caecum harbored the helminth burden. These organs were examined extensively throughout the study.

Infected livers could be detected by gross examination, as cysts could be seen on the surfaces.

Recovery of Helminths

Infections were observed in livers that were characterized by numerous cysts, which yielded adult tapeworms.

Two methods were employed to examine the stomach and intestinal contents. For the first method, the Aliquot Technique, it was necessary to know the total volume of the collected sample, and then examine 10% of the total known volume with a stereoscopic microscope. Random samples were taken from the remaining 90% and examined microscopically. After examining approximately 40 animals in this manner, and determining the size of the helminths, a second method of helminth recovery was attempted. This method entailed placing a wide strip of gauze material over the top of a wire test tube rack and slowly sieving the intestinal or stomach contents. The contents were poured onto the gauze filter, and the helminths and solid portions of the supernatant were retained on the gauze while the fluid portion passed through.

The latter method of recovery has proven equally successful as well as quicker than the Aliquot Technique.

Helminth Preparation

Fixation

In most cases, the helminths were dead upon recovery, particularly when the animals were not examined for 3 to 5 days after they had been trapped.

Prior to fixation, all portions of mucous and debris was removed from the helminths, which has been maintained in physiological saline.

Since most helminths were dead upon recovery, killing was not a concern. The helminths were fixed in cold 10% formal saline. This fixative is easily prepared, and, it is a good general fixative for the helminths collecting during this study.

The helminths were allowed to remain in the 10% formal saline for varying periods of time, ranging from two weeks to several months. They were then transferred to 5% formalin for storage purposes.

A more delicate fixation for nematodes, A. F. A., was used in some instances. This fixative appeared suitable for all helminths of the study. After the helminths were fixed, they were transferred into 10% formalin with glycerin for storing.

Staining, Dehydration, and Clearing

Alum Cochineal, Borax Carmine, Semichon's Aceto-Carmine, and Delafield's Haematoxylin were used to stain the trematodes. Cestodes and nematodes were identified without staining. All stains used were equally as effective in trematode staining.

The trematodes were exposed to the stains for varying lengths of time. They were stained in Borax Carmine and Alum Cochineal for 24 hours, and Semichon's Aceto-Carmine and Delafield's Haematoxylin for one hour.

Specimens were removed from the stain and placed into distilled water for 3-5 minutes to remove excessive stain. The dehydration series followed, with the specimens introduced into 35% alcohol for 5-10 minutes; 50% alcohol for 10-12 minutes; 70% alcohol for 2-3 minutes; acid alcohol for 5 minutes; then specimens were neutralized in 70% alcohol containing $LiCO_3$ for one hour. The organisms were placed into 95% alcohol for one hour, 100% alcohol for 30 minutes; and another container of 100% alcohol for an additional hour.

Following the staining and dehydrating, two clearing agents were used: Beechwood Creosote and Methyl Salicylate. Beechwood Creosote was considered to be the most effective of the two.

From 100% alcohol, the specimens were transferred into gradually increasing strengths of clearing agent prior to mounting in Canada Balsam.

Examination of Water Samples From Muskrat Habitats

Water samples were taken from the collecting areas, and analyses made to determine pH values and salinity percentages. The water sample studies were conducted over the twelve month period.

A two-quart sample from each trapping area was used for water analysis. Attempts were made to run the analyses as soon after collection as possible, as the longer the time between collection and analysis, the less reliable are the results (A P H A, 1960).

In some instances, half a day elapsed before determining the pH. In such cases a weak solution of formalin was added to the water sample in order to fix specimens and retard biochemical changes that would alter the reliability and validity of the results. Decomposition of microorganisms in a water sample alters the pH.

Sample bottles were thoroughly rinsed in the body of water from which the sample was taken. Then the sample bottle was filled with water that appeared to represent uniform water conditions.

pH Determinations

The pH of the water was determined by a Cenco Electronic pH meter. The manufacturer's instructions were followed. The glass electrode was thoroughly wetted when a reading was made, and the instrument was standardized against a buffer solution. The electrodes were placed in the water sample and recordings were made. The readings were repeated several times, and the average of all readings was taken to be the true pH of the sample.

Salinity Determinations

Salinity tests were employed to determine the sodium chloride concentration in the marsh and fresh water areas.

Salinity determinations were made by means of a Gemware Salinity Set or seawater hydrometer testing set. This method quickly and accurately determined the salinity of the water. The set consisted of three hydrometers calibrated to read the salinity directly, covering the range of 0-15, 14-30, and 28-42 parts per thousand (ppt) of dissolved salts. Included in the set was (1) a set of hydrometers fitted into rubbed-cushioned sections of a wooden board, (2) a temperature correction chart, and (3) a copper hydrometer jar with glass top and thermometer.

The water sample was placed into the hydrometer jar and allowed to remain until the thermometer registered the water temperature. Then the water salinity was corrected against the temperature according to the temperature-correction chart.

Climatological Data

Temperature, humidity, and precipitation determinations were received from weather stations at Emmittsburg, Maryland; and the Maryland State College Weather Station, Princess Anne, Maryland.

Intermediate Hosts

Suspected molluscan intermediate hosts were collected from the body of water in which the muskrats lived, or from near the body of water.

These snails were collected and retained in the water from which they came, placed in a refrigerator in a laboratory to induce shedding of the juvenile stages of the suspected parasites.

The snails were preserved in 10% formalin.

Age Determination of Muskrats

Sophisticated techniques (eye lens weight, wearing of tooth structure) for determining muskrat ages were not attempted in this study. Animals were separated into groups on the basis of size.

This method resulted in the formation of two age groups: (1) subadults -- which weighed less than 1000 grams and were less than 550 mm. long; and (2) adults -- rats weighing over 1000 grams and 550 mm. or longer.

This method of age determination was developed by Errington (1939), who found a definite correlation in muskrat weight, length, testis and ovary size in separating animals into adults and subadults.

CHAPTER IV

RESULTS AND DISCUSSION

Data were collected from November, 1966 through November, 1967. During this period, 154 muskrats were trapped and examined for helminth parasites of the gastrointestinal tract and liver.

Of the 154 animals, 79 from the Thurmont area in Frederick County were Ondatra zibethicus zibethicus Davis and Lowery. The remaining 75 animals from the Dames Quarter marshes in Somerset County were Ondatra zibethicus macrodon Miller.

Climatological records from Princess Anne (Somerset County) and Emmittsburg (Frederick County) revealed the precipitation, temperatures, and relative humidity for the year's study. The recordings were not made at the actual collecting sites, but they were representative of the general area. The distances from the weather stations to the collecting areas were less than 10 miles in all instances.

The study indicated that 70.88% of the muskrats from Thurmont were infected with helminths and that 50.66% of the Dames Quarter muskrats contained helminths. Of the 154 animals studied, 94 (61.03%) were infected with various helminths.

Seven species of helminths were recovered and identified. Three species of trematodes, one of cestodes, and one of nematodes were recovered from the Thurmont muskrats. Two species of trematodes and one nematode inhabited the Dames Quarter muskrats. The same species of nematode was in the muskrats from both areas.

TABLE I

PERCENTAGES OF HELMINTH INFECTIONS OF THE MARYLAND MUSKRAT, FROM NOVEMBER, 1966-NOVEMBER, 1967

Study Area	Total	No. Inf.	% Inf.
Thurmont	79	56	70.88
Dames Quarter	75	38	50.66
Total	154	94	61.03

Table II shows the helminths recovered and their distribution.

Of the muskrats examined, and the helminths recovered from the muskrats of the Thurmont area, it was determined that the trematode, *Echinostoma revolutum* Frohlich was the most common parasite, being present in 53.16% of the animals examined from that area. *E. revolutum* was not found in any of the animals examined from Dames Quarter. This helminth was recovered from the small intestine of the host.

Other investigators indicate that this organism, *E. revolutum*, is relatively widespread, particularly in the Eastern United States. The organism was reported in Massachusetts (Rankin, 1946); New York (Edwards, 1949); Illinois (Gilford, 1954); and Pennsylvania (Anderson and Beaudoin, 1966). In the northwestern United States, *E. revolutum* was recorded in Oregon (Senger and Neiland, 1955; and Rider and Macy, 1947).

TABLE II

A SURVEY OF THE COMPOSITION OF HELMINTHS
OF THE MARYLAND MUSKRAT

Helminth	Location Within Host	Number Animals Examined	Number Animals Infected	% Infected
Thurmont				
Cestodes				
Taenia taeniaeformis	Liver	79	15	18.98
Trematodes				
Echinostoma revolutum	Small intestine	79	42	53.16
Quinqueserialis quinqueserialis	Caecum	79	19	24.05
Wardius zibethicus	Caecum	79	26	32.91
Nematodes				
Trichuris opaca	Caecum	79	7	8.86
Dames Quarter				
Trematodes				
Nudacotyle novica	Small intestine	75	27	36.00
Echinochasmus schwartzi	Small intestine	75	3	4.00
Nematodes				
Trichuris opaca	Caecum	75	18	24.00

Wardius zibethicus (Barker and East, 1915) was recovered in 32.91% of the muskrats from Thurmont, but none were found in the Dames Quarter muskrats. This parasite was recovered from the caecum of the host.

Wardius zibethicus has been reported from Ohio muskrats (Rausch, 1946); muskrats in Michigan (Murrell, 1965); and from Pennsylvania muskrats (Anderson and Beaudoin, 1966).

The trematode, Quinqueserialis quinqueserialis Barker and Laughlin, 1911 was recovered from muskrats in the Thurmont area, but did not occur in the Dames Quarter muskrats. This helminth occurred in the caecum of 24.05% of the muskrats from Thurmont.

Quinqueserialis quinqueserialis was reported from muskrats in Tennessee (Harwood, 1939); New York (Edwards, 1949); Maine (Meyer and Reilly, 1950); Illinois (Gilford, 1954); Oregon (Senger and Neiland, 1955); Alaska (Dunagan, 1957); Utah (Senger and Bates, 1957); and Pennsylvania (Anderson and Beaudoin, 1966).

The cestode, Taenia taeniaeformis (Batsch, 1786), was recovered from 18.98% of the muskrats from Thurmont. All helminths were recovered from the parenchyma of the liver. In practically all instances, the adult form was present in the liver of the muskrat, but several times the larval form of Taenia taeniaeformis, Cysticercus fasciolaris, was present. T. taeniaeformis did not occur in the Dames Quarter muskrats.

Taenia taeniaeformis is commonly parasitic in the small intestine of the domestic cat and other felines. The incidence of T. taeniaeformis varies in wild rat populations, according to locality. It has been reported to range from 8 to 96% of the muskrats of various localities (Gallati, 1956). T. taeniaeformis has also been recorded as being in muskrats in Ohio (Rausch, 1946; and Gallati, 1956); New York (Edwards, 1949); Virginia (Byrd, 1952); Oregon (Rider and Macy, 1947); Illinois (Gilford, 1954); and Alaska (Dunagan, 1957).

The lowest incidence of parasitic infection in the muskrats from Thurmont was that of Trichuris opaca Barker and Noyes, 1915, a whipworm which was recovered from the caecum of 8.98% of the animals examined. By contrast, this nematode was recovered from 24% of the Dames Quarter muskrats. Trichuris opaca is the only helminth in this study that was present in both the Thurmont and Dames Quarter areas.

T. opaca is a widespread nematode which infects muskrats and other wild rodents. The rate of infection has been reported as being low. This helminth has been studied in Michigan (Ameel, 1942); Ohio (Rausch, 1946); New York (Edwards, 1949); Wisconsin (Tiner, 1950); Colorado (Ball, 1952); Illinois (Gilford, 1954); Oregon (Senger and Neiland, 1955); Alaska (Dunagan, 1957); and Pennsylvania (Anderson and Beaudoin, 1966).

Two species of trematodes were recovered from the muskrats of Dames Quarter marshes, Nudacotyle novica and Echinochasmus schwartzi.

The most frequently-occurring of the flukes from the Dames Quarter area, Nudacotyle novica Barker, 1916, was found in 36% of the muskrats from that locality.

N. novica was first described by Barker (1916) from the Lake Chicago area in Minnesota. It has also been studied in Texas (Chandler, 1941). The study by Chandler was conducted in the slightly brackish marsh waters of east Texas. N. novica was studied in Louisiana (Penn, 1942) in the muskrats of the Louisiana marshes. Both localities bear similarities to the Dames Quarter marshes, the area where the helminth was recovered in Maryland. This helminth has been recovered from muskrats in certain inland localities; Ohio (Rausche, 1946); New York (Edwards, 1949); Maine (Meyer and Reilly, 1950); and Illinois (Gilford, 1954).

The other trematode, Echinochasmus schwartzi Price, 1931 occurred less frequently than any other helminth in this study (4%). This fluke was reported in Maryland (Price, 1931); Texas (Chandler, 1941); Louisiana (Penn, 1942); and Tennessee (Byrd and Reiber, 1942).

An analysis was made of the number of individual helminths that were recovered from muskrats collected for this study.

Generally, counting individual helminths was not a problem. However, in a few instances counting became tedious and when the parasite count exceeded 100, estimations were used instead of actual counts because of the number of flukes and their minute size. This was the case with the trematodes Nudacotyle novica and Quinqueserialis quinqueserialis. Nudacotyle novica had a parasite count exceeding 100 in six instances and Quinqueserialis quinqueserialis had a parasite count exceeding 100 three times.

A table showing the degree of infection occurring in the various body regions that contained the helminths in this study is presented.

These data indicate that the small intestine was more frequently parasitized in muskrats from the Thurmont and Dames Quarter study areas. The second most frequently parasitized body region of the host was the caecum.

Table IV relates the frequencies of helminth infection of the muskrats in Thurmont and Dames Quarter.

TABLE III

OCCURRENCE OF HELMINTH INFECTIONS WITHIN BODY REGIONS OF THE MARYLAND MUSKRAT

Locality	Number Examined	Number Infected	Stomach	Liver	Small Intestine	Caecum
Thurmont	79	56	1	15	43	39
Dames Quarter	75	38	0	0	28	18

The seasonal influence was one of the ecological factors taken into account in this study. Data summarized in Table V represents the number of muskrats collected by season and by area.

It can be observed from Table V that marked differences existed as to the number of muskrats that were taken on a seasonal basis. Muskrat trapping was more successful during the late fall and winter. During these seasons, muskrats are mostly restricted to their dens, bank burrows, and houses. Their activity is readily detected during the colder seasons, and particularly by paths of bubbles under the ice which usually mark their routes of travel.

By contrast, during the warmer seasons, muskrat activity was not restricted in range. Their activity covered a wider territory, they migrated from pond to pond, and some of their activity was conducted outside the water. Many of the muskrat signs of activity that were observed during the winter were not present during the warmer seasons and it was more difficult to determine where activity was taking place. Some of the signs that appeared during the warmer seasons may not aid in trapping success.

TABLE IV

FREQUENCIES OF HELMINTH INFECTIONS IN THE MARYLAND MUSKRAT

Locality and Parasite	Location in Host	Number Hosts Exam.	Number Hosts Inf.	1-10	11-20	21-50	50-100	100
Thurmont								
Taenia taeniaeformis	Liver	79	15	13	1	0	0	1
Echinostoma revolutum	Small intestine	79	42	28	8	5	0	1
Quinqueserialis quinqueserialis	Caecum	79	19	9	2	2	3	3
Wardius zibethicus	Caecum	79	26	24	2	0	0	0
Trichuris opaca	Caecum	79	7	7	0	0	0	0
Dames Quarter								
Nudacotyle novica	Small intestine	75	27	13	5	3	0	6
Echinochasmus schwartzi	Small intestine	75	3	3	0	0	0	0
Trichuris opaca	Caecum	75	18	18	0	0	0	0

TABLE V

SUMMARY OF MUSKRAT CATCH IN THURMONT AND DAMES QUARTER, MARYLAND, ACCORDING TO SEASON

Season	Total	Thurmont	Dames Quarter
Fall, 1966	32	17	15
Winter, 1966-67	42	21	21
Spring, 1967	28	10	18
Summer, 1967	28	20	8
Fall, 1967	24	11	13

It appeared that when trapping season commenced during the fall and winter months, the muskrat populations were at their maximum for the year. However, during the winter the cold weather, predation, and trapping decreased the population and it was at its minimum during the spring and early summer months. The population gradually increased through the warmer season and practically reached a maximum by the next trapping season (beginning November 15 in Frederick County and January 1 in Somerset County).

Data were available to determine whether the seasons may influence the incidence of helminth infections in the Maryland muskrat. Interpretation of these data indicates that helminth infections were higher during the fall and winter seasons in Thurmont, with the highest incidence being 100% in the fall of 1967. The second highest rate of infection in muskrats at Thurmont was 85.71% in the winter of 1966-67.

The highest rate of infection in Dames Quarter occurred in the spring of 1967 (61.11%). The second highest rate of infection for that area was 52.38% during the winter of 1966-67.

TABLE VI

OCCURRENCE OF HELMINTH INFECTIONS IN THE MARYLAND MUSKRAT, ACCORDING TO SEASON

Season	Total Collected	Thurmont Coll.	Thurmont Inf.	Thurmont % Inf.	Dames Quarter Coll.	Dames Quarter Inf.	Dames Quarter % Inf.
Fall, 1966	32	17	11	64.70	15	7	46.66
Winter, 1966-67	42	21	18	85.71	21	11	52.38
Spring, 1967	28	10	5	50.00	18	11	61.11
Summer, 1967	28	20	11	55.00	8	4	50.00
Fall, 1967	24	11	11	100.00	13	5	38.46
Total	154	79	56	70.88	75	38	50.66

Since the muskrats of Thurmont were taken from five study areas (six areas were studied), a survey was made of these study areas. The distances between all study areas in the Thurmont area ranged from three to ten miles.

Table VII shows the ponds studied in the Thurmont area and the percentage of infection of muskrats from each of the ponds.

The incidence of helminth infection in muskrats at Thurmont ranged from a low (36.84%) at Cregger's ponds, to a high (91.66%) rate of infection at the Lewistown ponds. The average rate of infection for the Thurmont area was 70.88%.

TABLE VII

PERCENTAGES OF HELMINTH INFECTIONS OF MUSKRATS TRAPPED IN SIX THURMONT COLLECTING AREAS

Ponds	Number of 'rats Trapped	Number of 'rats Infected	% Infection
Cregger's	19	7	36.84
Humerick's	36	29	80.55
Humerick's Stream	1	1	100.00
Lewistown	12	11	91.66
Waesche's	11	8	72.72
Ramsburg's	0	0	0.00
Total	79	56	70.88

Contributing factors which may have caused the variation in the incidence of helminth infection of muskrats examined will be discussed later after certain biological relationships have been discussed.

The data concerning the incidence of various helminth species observed in animals from the Thurmont area are summarized in Table VIII. This summary shows the muskrats from four of the study areas being most frequently infected with Echinostoma revolutum. The muskrats from

TABLE VIII

INCIDENCES OF VARIOUS HELMINTHS RECOVERED FROM
THE MUSKRATS OF THE THURMONT PONDS

Helminth	THURMONT COLLECTING AREAS																	
	Cregger's			Humerick Pond			Humerick Stream			Lewistown			Waesche's			Ramsburg		
	No. Trap.	Inf.	%	No. Trap.	Inf.	%	No. Trap.	Inf.	%	No. Trap.	Inf.	%	No. Trap.	Inf.	%	No. Trap.	Inf.	%
Taenia taeniaeformis	19	2	10.52	36	7	19.44	1	1	100.00	12	1	8.33	11	4	36.36	0	0	0
Echinostoma revolutum	19	6	31.58	36	19	52.77	1	1	100.00	12	11	91.66	11	5	45.55	0	0	0
Quinqueserialis quinqueserialis	19	5	26.31	36	10	27.77	1	0	0.00	12	4	33.33	11	0	0.00	0	0	0
Wardius zibethicus	19	2	10.52	36	11	30.55	1	1	100.00	12	9	75.00	11	3	27.27	0	0	0
Trichuris opaca	19	3	15.78	36	3	8.33	1	0	0.00	12	1	8.33	11	0	0.00	0	0	0

Lewistown pond had a 91.66% infection with this species; muskrats from Humerick's pond had a 52.77% rate of infection; the muskrats from Waesche's pond had a 45.55% rate of infection; and the muskrats trapped from Cregger's pond had a 31.58% rate of infection.

The majority of the muskrats harbored only one kind of parasite, but in some instances, multiple or mixed infections existed. Table IX shows the occurrence of multiple infections in the Maryland muskrat.

TABLE IX

OCCURRENCE OF MULTIPLE HELMINTH INFECTIONS
IN THE MARYLAND MUSKRAT

Locality	Mixed Infections 2 Par.	Mixed Infections 3 Par.	Mixed Infections 4 Par.	Single Infection 1 Par.	Total
Thurmont	22	13	2	19	56
Dames Quarter	10	0	0	28	38
Total	32	13	2	47	94

Mixed infections occurred most frequently in the muskrats from Thurmont. At no time did more than two species of helminths occur in a muskrat from Dames Quarter.

These data suggest that Echinostoma revolutum and Wardius zibethicus, the most frequently occurring helminths in the Thurmont muskrats, also occurred in mixed infections more frequently.

Nudacotyle novica, the most frequently-occurring helminth in muskrats of the Dames Quarter marshes, occurred in a mixed infection more frequently among muskrats from this area than any other helminth recovered from Dames Quarter muskrats.

Table X shows the frequencies of the mixed helminth infections and Table XI shows the various combinations of the mixed helminth infections of the muskrats in this study.

Certain factors concerning the host muskrat were taken into account. One of these factors was the sex of the muskrats examined. Data indicating the sex of muskrats are summarized in Table XII. It is apparent from these data that more male muskrats were caught than females, 96 to 58, a ratio in favor of males, of 1.66 : 1.

Smith (1938) pointed out in his study that more male muskrats were caught in Dorchester County (Maryland) marshes than females. In Harris' studies (1952) more males were trapped than females. It is possible that this was due to (1) a greater number of males, (2) a higher death rate of females, or (3) differential susceptibility to trapping. Observations made by trappers and investigators indicate that males are generally more active during the winter trapping season, and that females are more active during the warmer seasons (Johnson, 1925).

Table XII shows the sex of all muskrats trapped and examined in this study. Table XIII summarized the degrees of helminth infection according to the sex of the host.

The literature, and this study, reveals that females generally have a higher degree of parasitic infection than males. No specific reasons can be provided for this variance other than the speculation that females are more confined to the vicinity of the house than males,

TABLE X

FREQUENCIES OF MIXED HELMINTH INFECTIONS OCCURRING
IN THE MARYLAND MUSKRAT

Helminths and Localities	Parasite Alone	Parasite and 1 Other Para.	Parasite and 2 Other Para.	Parasite + 3 Para.	Parasite + Total
Frederick County					
Echinostoma revolutum	9	19	13	1	42
Quinqueserialis quinqueserialis	1	6	9	3	19
Wardius zibethicus	4	13	7	2	26
Taenia taeniaeformis	4	5	4	2	15
Trichuris opaca	1	1	4	1	7
Somerset County					
Nudacotyle novica	17	10	0	0	27
Echinochasmus schwartzi	1	2	0	0	3
Trichuris opaca	10	8	0	0	18

TABLE XI

COMBINATIONS OF MIXED HELMINTH INFECTIONS
OCCURRING IN THE MARYLAND MUSKRAT

Parasite Combination(s)	Number of Occurrences
Frederick County	
Two-helminth Combinations	
E. R. - Q. Q.	3
E. R. - W. Z.	11
E. R. - T. T.	4
Q. Q. - T. T.	1
W. Z. - Q. Q.	2
E. R. - T. O.	1
Three-helminth Combinations	
E. R. - T. O. - Q. Q.	3
E. R. - W. Z. - Q. Q.	5
E. R. - W. Z. - T. O.	1
E. R. - T. T. - W. Z.	3
E. R. - Q. Q. - T. T.	1
Four-helminth Combinations	
T. O. - T. T. - W. Z. - Q. Q.	1
E. R. - Q. Q. - W. Z. - T. T.	1
Somerset County	
Two-helminth Infections	
N. N. - T. O.	8
N. N. - E. S.	2

TABLE XII

SEX OF MARYLAND MUSKRATS EXAMINED FOR GASTROINTESTINAL HELMINTHS

Season	Thurmont M	Thurmont F	Dames Quarter M	Dames Quarter F
Fall, 1966	9	8	14	1
Winter, 1966-67	13	8	12	9
Spring, 1967	8	2	13	5
Summer, 1967	9	11	7	1
Fall, 1967	5	6	6	7
Total	44	35	52	23

TABLE XIII

OCCURRENCE OF HELMINTH INFECTIONS IN THE MARYLAND MUSKRAT, ACCORDING TO THE SEX OF THE HOST

Locality	Total Collected	Males Coll.	Males Inf.	Males % Inf.	Females Coll.	Females Inf.	Females % Inf.
Thurmont	79	44	27	61.36	35	29	82.85
Dames Quarter	75	52	27	51.92	23	11	47.82
Total	154	96	54	56.25	58	40	68.96

and the nests may provide a contamined area where females are more exposed to infection (O'Neal, 1949).

Table XIV shows the degree of parasitic infection as associated with host age. The host muskrats were divided into two age groups: adults and subadults.

TABLE XIV

OCCURRENCE OF HELMINTH INFECTIONS IN THE MARYLAND MUSKRAT, ACCORDING TO HOST AGE

Locality	Total	Adults			Subadults		
		Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.
Thurmont	79	24	20	83.33	55	36	65.45
Dames Quarter	75	39	21	53.84	36	17	47.22
Total	154	63	41	68.58	91	53	56.33

Of the 154 muskrats taken in this study, 63 were adults and 91 were subadults. The incidences of parasitism were higher in the adults (68.58%) than in the subadults (56.33%). Anderson and Beaudoin (1966) studied age as a factor in the prevalence of intestinal helminths in Pennsylvania muskrats and their findings were similar. These investigators found that the infection percentage ranged from 28.7% in young animals to 60.3% in the adult class. They concluded that helminths were able to survive in the host for periods exceeding one year and that immunity seemingly failed to develop.

Table XV summarizes sex, age, and seasonal influence as related to the incidence of helminth infection.

All female adult muskrats (100%) trapped and examined from Thurmont harbored helminths. The adult female muskrats from Dames Quarter marshes harbored the highest incidence of helminths from that area (83.33%). The lowest incidence from both study areas was in the sub-adult female muskrats of Dames Quarter (40.00%).

The occurrence of the various helminths during certain seasons is depicted in Table XVI. Taenia taeniaeformis was the most frequently occurring helminth during the spring of 1967 (50%). For trematodes, Echinostoma revolutum occurred most frequently during the winter of 1966-67 (80.95%), Quinqueserialis quinqueserialis occurred most frequently during the fall of 1967 (45.45%), and Wardius zibethicus occurred most frequently during the winter of 1966-67 (42.85%). Trichuris opaca occurred most frequently during the fall of 1966 at Thurmont (17.64%) and during the winter of 1966-67 at Dames Quarter (42.85%). Nudacotyle novica was the most frequently-occurring helminth at Dames Quarter and its incidence was heaviest in the spring of 1967 (50%).

It appeared that the heavier infections occurred during the winter season, but this pattern was not consistent.

Table XVI summarizes the occurrences of the various helminths that were recovered.

The number, kind and type of helminth infection have provided an insight as to the helminths which exist in the Thurmont and Dames Quarter areas.

TABLE XV

SUMMARIZATION OF AGE, SEX, AND SEASONAL INFLUENCE ON THE INCIDENCE OF HELMINTH INFECTIONS IN THE MARYLAND MUSKRAT

Season	THURMONT												DAMES QUARTER											
	Adults						Subadults						Adults						Subadults					
	Male			Female			Male			Female			Male			Female			Male			Female		
	Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.	Coll.	Inf.	% Inf.
Fall, 1966	4	2	50.0	4	4	100.0	5	2	40.0	4	3	75.0	10	6	60.0	0	0	0	5	1	20.0	0	0	0
Winter, 1966-67	4	3	75.0	2	2	100.0	9	7	77.7	6	6	100.0	8	2	25.0	5	4	80.0	4	3	75.0	4	2	50.0
Spring, 1967	4	1	25.0	1	1	100.0	3	2	66.6	2	1	50.0	9	5	55.4	0	0	0	5	3	60.0	4	3	75.0
Summer, 1967	2	1	50.0	3	3	100.0	7	4	57.1	8	3	37.5	3	2	66.6	0	0	0	4	2	50.0	1	0	0
Fall, 1967	2	1	100.0	1	1	100.0	3	3	100.0	3	3	100.0	1	1	100.0	1	1	100.0	5	2	40.0	6	1	16.6
Totals	16	9	56.2	11	11	100.0	27	18	66.6	25	18	72.0	31	16	51.6	6	5	83.3	23	11	47.8	15	6	40.0

TABLE XVI

OCCURRENCE OF THE VARIOUS HELMINTHS OF THE MARYLAND MUSKRAT, ACCORDING TO SEASON

Frederick County	Number Examined	T. T.	%	E. R.	%	Q. Q.	%	W. Z.	%	T. O.	%
Fall, 1966	17	2	11.76	9	52.94	6	35.29	4	23.52	3	17.64
Winter, 1966-1967	21	1	4.76	17	80.95	1	4.76	9	42.85	0	0.00
Spring, 1967	10	5	50.00	2	20.00	2	20.00	3	30.00	1	10.00
Summer, 1967	20	2	10.00	8	40.00	5	25.00	6	30.00	3	15.00
Fall, 1967	11	5	45.45	6	54.45	5	45.45	4	36.36	0	0.00
Total	79	15	18.98	42	53.16	19	24.05	26	32.91	7	8.86

Somerset County	Number Examined	T. O.	%	N. N.	%	E. S.	%
Fall, 1966	15	4	26.66	4	26.66	0	0
Winter, 1966-1967	21	9	42.85	6	28.57	0	0
Spring, 1967	18	3	16.66	9	50.00	1	5.55
Summer, 1967	8	1	12.50	3	37.50	1	12.50
Fall, 1967	13	1	7.69	5	38.46	1	7.69
Total	75	18	24.00	27	36.00	3	4.00

Physical factors in the environment are important in controlling the abundance and distribution of parasites and possible intermediate hosts that are necessary in life cycle completion. Since muskrat helminths must have an exposure to the external environment at some stage of the life cycle, some of these external conditions, such as temperature, relative humidity, precipitation, physical and chemical nature of the water, will serve as limiting factors in the distribution of helminths. Life cycle studies of muskrat helminths of this study indicate that in most cases, an intermediate host is essential in life cycle completion. Molluscan intermediate hosts are the most desired and essential intermediate hosts for life cycle success. Since mollusks may be terrestrial, fresh water, or salt water forms, their geographic distribution is fixed and their range is influenced by the aquatic nature of the physical environment.

The free stages of the helminths and their possible intermediate hosts must have optimum requirements for temperature, relative humidity, precipitation, pH, salinity, and other physical and chemical factors of the environment. The distribution of intermediate hosts influences the distribution of parasites, and even with the presence of the intermediate host, any of the physical factors making up the environment may prevent the development of the parasite.

The effects of temperature and moisture are closely related. These factors may independently have an effect on the distribution of parasites, or the combined climatic conditions may be the cause of the absence or presence of certain helminths.

The actual extent of these influences is determined, in part, by the more exacting the conditions that are required by a parasite to complete its life history and the extent of the physiological adjustments that may be necessary due to extremes of the physical environment. Bioclimatographs may show these relationships when the optimum temperature-moisture requirements for the parasite are known. Without these data, a bioclimatograph is meaningless, since each parasite has its individual optimum temperature-moisture requirements.

Temperature was one of the climatic factors that was studied. Daily temperatures recorded from November, 1966 to November, 1967, were taken from the official weather stations at Emmittsburg (Frederick County) and Princess Anne (Somerset County). Both recording stations are within ten miles of the study areas.

The mean temperatures for each collecting area are summarized in Table XVII. The mean temperatures recorded for Thurmont were slightly lower than at Dames Quarter. The annual mean temperature for the Dames Quarter area, and the Somerset County marshes is around 58° F, while it is approximately 54° F in the Thurmont region.

The temperatures shown in Table XVII are consistent with the data compiled by the Maryland Weather Service for the same areas, over a 30-year period.

Relative humidity, the second climatic factor, was also compiled from the two general study areas, beginning in November, 1966, and ending in November, 1967.

Temperature and moisture, expressed as relative humidity, are so related that they are conceded as the most important part of the climate (Odum, 1959). The monthly averages for relative humidity for these two areas is shown in Table XVIII. These data were recorded daily at 5 P.M.

TABLE XVII

SUMMARY OF MEAN TEMPERATURES BY MONTH FOR THURMONT AND DAMES QUARTER, AT 5 P.M., NOVEMBER, 1966-NOVEMBER, 1967

Months	Thurmont	Dames Quarter
November, 1966	45.8	51.0
December, 1966	35.7	40.3
January, 1967	39.8	43.7
February, 1967	31.8	37.4
March, 1967	45.3	47.8
April, 1967	60.6	61.0
May, 1967	59.3	64.2
June, 1967	76.7	73.0
July, 1967	75.2	79.9
August, 1967	73.6	78.4
September, 1967	68.0	71.9
October, 1967	58.0	62.7
November, 1967	43.8	48.8
Average	54.8	58.4

TABLE XVIII

SUMMARY OF RELATIVE HUMIDITY AVERAGES FOR THURMONT AND DAMES QUARTER, AT 5 P.M., NOVEMBER, 1966-NOVEMBER, 1967

Month	Thurmont	Dames Quarter
November, 1966	64.17	54.60
December, 1966	69.40	63.29
January, 1967	61.93	60.13
February, 1967	59.00	53.96
March, 1967	58.58	55.93
April, 1967	48.76	45.65
May, 1967	60.22	54.29
June, 1967	46.85	52.75
July, 1967	62.80	61.90
August, 1967	64.90	69.10
September, 1967	57.86	57.57
October, 1967	59.80	59.41
November, 1967	52.73	54.60
Average	59.00	57.16

The average relative humidity was slightly higher in the Thurmont area than at Dames Quarter. In Maryland, average relative humidity is lowest in the winter and early spring from February through April and highest in the late summer and early fall from August through October.

Total rainfall was recorded for the two general study areas. The annual precipitation for both areas is expected to range from 42 to 44 inches annually. However, during this one-year study, the Thurmont area received approximately nine inches more rainfall than Dames Quarter. Although the rainfall at Dames Quarter was almost nine inches below normal, over half (18.23) of the total precipitation occurred during the warmest four months of the year, when droughts are more frequent and damaging.

The climatic data for November, 1967 represents the first fifteen days of the month. The climatological conditions for the twelve-month study generally do not appear to deviate from the normal. However, short-term climatological data can be meaningless. Climatological data for several years could be more useful.

Chemical factors associated with the aquatic habitat are important. Samples of water from Thurmont and Dames Quarter were collected monthly, with salinity and pH determinations being made.

Table XX shows monthly pH recordings for the twelve-month period. The pH differences of the fresh water of Thurmont and the brackish water of Dames Quarter were slight. Water samples were taken each month and at no specific hour during the day. Philip (1927) concluded that the practice of making one pH determination for a particular day was not an accurate index of the true hydrogen ion activity in an aquatic community. pH is not a valuable index of total pond conditions, since

TABLE XIX

SUMMARY OF PRECIPITATION (RAINFALL) FOR THURMONT AND DAMES QUARTER, NOVEMBER, 1966-NOVEMBER, 1967

Month	Thurmont	Dames Quarter
November, 1966	2.88	0.76
December, 1966	3.36	3.01
January, 1967	1.56	1.45
February, 1967	1.80	4.13
March, 1967	5.04	1.70
April, 1967	4.45	1.44
May, 1967	3.72	4.06
June, 1967	1.88	1.13
July, 1967	6.80	3.91
August, 1967	5.74	9.13
September, 1967	2.08	1.97
October, 1967	3.45	1.47
November, 1967	0.95	0.32
Total	43.71	34.50

TABLE XX

SUMMARY OF pH DETERMINATIONS FROM THURMONT AND DAMES QUARTER, NOVEMBER, 1966-NOVEMBER, 1967

Month	Thurmont	Dames Quarter
November, 1966	6.9	7.0
December, 1966	7.1	7.0
January, 1967	6.7	7.0
February, 1967	6.9	7.2
March, 1967	7.2	6.8
April, 1967	7.3	6.9
May, 1967	7.0	7.2
June, 1967	7.0	7.0
July, 1967	7.0	7.05
August, 1967	7.0	7.0
September, 1967	7.0	7.0
October, 1967	7.01	7.0
November, 1967	--	7.05
Average pH	7.04	7.02

it varies from one section of the water to another and pH fluctuations are diurnal.

The pH of Thurmont was slightly higher than that of Dames Quarter for this particular study.

Table XXI shows monthly salinity representations for the two areas during the twelve month period. The monthly salinities from Dames Quarter ranged from a high of 16 to a low of 10, with the average being 11.91. These percentages represent parts per thousand of dissolved salts.

Dozier (1947) suggested that the salinity of marsh water had an influence on the natural wildlife resources in the tidal marsh area of the Atlantic Coast tidewater region. It would affect the success of the existence of the muskrat, possible intermediate hosts, and the surrounding vegetation which is a preferred plant food of the muskrat. The abundance of certain vegetation is also important in gastropod distribution (Allen, 1954).

The fresh water ponds of Thurmont apparently remained free from salt pollution, so the factor of salinity or brackishness did not have to be contended with by the organisms at Thurmont.

A range exists in which salt water and brackish water is defined according to parts per thousand of dissolved salts. The water of the marshes varies from nearly fresh to high saline types. The waters of some of the Chesapeake Bay estuaries grade from fresh to about 17% near the mouth (Reid, 1961).

Salt water has a detrimental effect on the muskrat, vegetation, and various forms of animal life in the marshes. Dozier (1947) reported that the drought of 1930 killed the animal life and marsh vegetation in

TABLE XXI

SUMMARY OF MONTHLY SALINITY RECORDINGS FOR THURMONT AND DAMES QUARTER, DECEMBER, 1966-NOVEMBER, 1967

Month	Thurmont	Dames Quarter
December, 1966	0	11.0
January, 1967	0	11.0
February, 1967	0	11.0
March, 1967	0	16.0
April, 1967	0	16.0
May, 1967	0	12.0
June, 1967	0	12.0
July, 1967	0	10.0
August, 1967	0	11.0
September, 1967	0	11.0
October, 1967	0	10.0
November, 1967	0	12.0
Mean Annual Salinity	0	11.91

large numbers. Drought conditions greatly increased the salinity of the marshes. By 1933, the rains had returned the conditions of the marshes to normal and the flora and fauna was abundant once again.

The molluscan hosts of Thurmont are fresh water forms and the Dames Quarter mollusks are salt water forms. Salinity appears to be a limiting factor in the distribution of possible molluscan hosts and helminths. No fresh water snails were observed in the marshes, and no salt water snails were observed at Thurmont.

Biological relationships existing in the respective collecting areas, and which were considered included: (1) host-intermediate host relationships; and (2) host-predator cycles. Numerous animals living in the study areas are possible hosts for the parasites that exist in muskrats at Thurmont and Dames Quarter.

Since the specificity of the molluscan host is a long-established relationship in trematode life cycles, a brief survey was made of the gastropods in the study areas.

The snails observed in the Thurmont ponds were: Heliosoma trivolvis; Pseudosuccinea columella and Physa sp. Heliosoma trivolvis is reported as the intermediate host for Wardius zibethicus and Echinostoma revolutum (Fallis, 1934). Pseudosuccinea columella is reported as being the intermediate host for a number of echinostomes, including Echinostoma coalitum from a Maryland muskrat (Krull, 1935). Pseudosuccinea may serve as the first and second intermediate host for a number of parasites. E. revolutum cercariae have been recovered from Physa. Other life cycle studies indicate that fresh water snails are indispensible in life cycle completion. Gyraulus parvus (Say), an intermediate host for Quinqueserialis quinqueserialis, was not observed in this study. However, it is a fresh water snail and its distribution includes the eastern United States from Alaska to Florida (Baker, 1928). Another fresh water snail, Pomatiopsis lapidaria, is a naturally infected snail host for the fluke, Nudacotyle novica. The geographic range of P. lapidaria includes central and western Maryland.

Littorina irrorata, a salt marsh snail, was observed and collected at Dames Quarter, where it was abundant. The survey of Dames Quarter snails was not extensive but Allen (1954) reported ten genera of salt water gastropods from the Crisfield (Somerset County) area, which is only about 10 miles from the Dames Quarter area, and has a similar marsh habitat.

Gastropods reported by Allen from the Crisfield vicinity were: Melampus bidentatus lineatus, Phytia myosotis marylandica, Odostomia bisuturalis, Syncera modesta, Crepidula convexa, Bittium varium, Ilyanassa obsoleta, Nassarius trivillatus, Littoridinops sp., and Littorina irrorata. L. irrorata was the most abundant gastropod of Allen's study. None of these snails appear to be appropriate intermediate hosts for the trematodes of this study.

Nudacotyle novica was reported from fresh water habitats in Michigan (Ameel, 1944), where the snail Pomatiopsis lapidaria was present. This fluke has also been reported from other brackish water localities by Chandler in Texas (1941) and Penn (1942) in the Louisiana marshes.

The trematode, Echinochasmus schwartzi, found in muskrats from the Dames Quarter marshes, has been reported in muskrats from fresh and brackish water habitats. Price (1931) first described this fluke in muskrats from the Dorchester County (Maryland) marshes. E. schwartzi has been reported by Chandler (1941) in Texas and Penn (1942) in Louisiana; and from a fresh water habitat in Tennessee by Byrd and Reiber (1942).

The presence of *N. novica* and *E. schwartzi* in muskrats from fresh and brackish water habitats must be dependent upon appropriate intermediate hosts and the ability of the parasite to live in fresh or brackish water areas.

Life cycle studies indicate that larval stages of parasites may be carried through some host-predator cycle such as the rodent-racoon or rodent-housecat, and that the muskrat could pick up the eggs after they had been released in the feces of the carnivorous host (Byrd, 1952). Ameel (1942) states that some parasitisms of muskrats might be an accidental occurrence.

The nematode, *Trichuris opaca*, which was recovered from muskrats of Dames Quarter and Thurmont, is parasitic in a wide variety of mammalian hosts. All *Trichuris* species possess direct life cycles (Cheng, 1965). Since intermediate hosts are not required, the cosmopolitan distribution of this parasite and its wide host range seem to insure life cycle completion in most habitats.

Taenia taeniaeformis, also infects a wide variety of hosts, mostly mammalian. It is found in the small intestine of domestic cats, wildcats, and related carnivores (Morgan and Hawkins, 1949; and Dikmans, 1945). The intermediate host for this parasite may be a vertebrate or an invertebrate. Rodents such as *Ondatra*, *Sigmodon*, *Sciurus*, *Mus* and *Rattus* may be infected with this parasite (Byrd, 1952). With such a wide range of host, this parasite could likely complete its life cycle in fresh or brackish water regions.

McAtee (1941) reports on the mammals of the Atlantic Coastal region. *Microtus pennsylvanicus*, the meadow mouse; *Didelphis virginiana*, the eastern opossum; *Procyon lotor*, the racoon, are additional mammals that frequent the marshland. The mammalian fauna of Thurmont is not restricted to these forms above.

Ameel (1944) suggested that animals which are closely related and share the same habitat and food may tend to have similar parasitisms. Harris (1953) noted that the meadow mouse, *Microtus pennsylvanicus* and the rice rat, *Oryzomys palustris*, tend to make their home in muskrat houses during unfavorable weather conditions. These animals live together in muskrat houses in the Maryland marshes. Ameel (1944) showed in his life history studies of *Nudacotyle novica*, that this trematode inhabits the small intestine of the muskrat and the bile duct of the meadow mouse. Herber (1939) reported in his life history studies of *Quinqueserialis quinqueserialis*, that this fluke also inhabits the caecum of *Ondatra zibethicus* and *Microtus pennsylvanicus*.

Food habits may be meaningful in ecological studies. The contents of the stomachs and intestines of the muskrats were examined in an attempt to determine the composition of the diet. Most of the muskrats had finely ground vegetative matter in their digestive tracts, and no evidence of animal matter was observed in any of the 154 muskrats examined. Trappers and investigators report that mussels, clams, crayfish, small fish and other aquatic animals may be eaten by muskrats, especially in fresh water areas when the preferred muskrat food is limited (O'Neal, 1949). During this study in Maryland, there apparently was not a paucity of the preferred muskrat food at any time.

It is speculated that the management of the ponds in the Thurmont area is a factor in the incidences of helminth infection. Snails were not noted at Cregger's pond during this study, and these ponds were meticuously managed the year round. The grass was cut and raked frequently, the algae was killed during the warm months, and water levels manipulated. Cregger's ponds had the lowest percentage of infection during this study. There appeared to be little attraction for other wildlife forms to frequent this area. Cregger's ponds were not typical of the general physical makeup of the other study areas at Thurmont.

A small to moderate number of snails were observed in the Waesche, Humerick and Lewistown ponds. Muskrats from these ponds had a higher incidence of helminths. These three ponds were situated near heavily wooded areas with heavy undergrowths shielding the ground. Weeds and wild grasses completely surrounded the ponds. These ponds appear well able to support various forms of wildlife.

Many acres of marshland on the Eastern Shore were all similar in the degree of brackishness of the water, height of water levels, type of vegetation, and extent of muskrat distribution. A uniform ecology appeared to exist in this region.

It may be concluded that many factors are woven into the picture, as to the incidence and number of helminths in the study, but the most influential factor in the environment appears to be in the salinity of the water, which limits or permits the presence of those intermediate hosts which must be present for life cycle completion of certain helminth species to take place.

CHAPTER V

SUMMARY AND CONCLUSIONS

Muskrats, totalling 154, were trapped from two geographical areas in Maryland that represented different ecological conditions. These muskrats were examined for helminth parasites of the gastrointestinal tract and liver.

Five species of trematodes, one of cestodes, and one of nematodes were recovered in 94 of 154 (61.03%) muskrats studied. 70.88% of the muskrats from Thurmont and 50.66% of the muskrats from Dames Quarter were parasitized. There was a notable difference in the helminth fauna recovered from these two areas. Three species of trematodes, one of cestodes, and one of nematodes existed in the Thurmont area muskrats. Two species of trematodes and one of nematodes existed in the Dames Quarter muskrats. Of these seven helminth species, only the nematode, Trichuris opaca, occurred in muskrats from both areas.

Data were accumulated on ecological conditions to determine which factors influenced the incidence and species of helminths recovered. These conditions on which observations were made included: climatological data, pH and salinity of the water from which the muskrats were trapped, and general observations of the biology and habitat of the muskrat.

Small differences in temperature, relative humidity and temperature were observed between the Thurmont and Dames Quarter habitats.

So minor were these differences, that it is concluded that these climatic factors did not have a bearing on the differences in the helminth fauna. To conclude that climatological conditions were a limiting factor in parasite distribution, optimum temperature-moisture requirements for each parasite studied must be known. The climatological data provided on a bioclimatograph are meaningless if the optimum temperature-moisture requirements for these helminths are not available.

The chemical nature of the water from which the muskrats were trapped varied in salinity content, but was consistent in pH.

The salinity average for the Dames Quarter marshes during the study was 11.91%. The fresh water ponds and streams of Thurmont failed to reveal any salt pollution. The degree of salinity of any body of water is a limiting factor as to the success of the flora and fauna. Other studies showed that muskrats, possible intermediate hosts for helminths, and vegetation are influenced by the salt content of the aquatic environment. High salt content is detrimental to muskrats and the preferred muskrat food. Salt content also influences the distribution of mollusks, which are important intermediate hosts, and various forms of wildlife.

The presence of muskrats and their preferred plant food existed in both study areas, but the differences in the gastropod fauna between the Dames Quarter and Thurmont areas probably accounts for the differences in the helminth fauna. The failure of appropriate fresh water snails, which are important in life cycle completion of the trematodes of this study, to endure the brackish water habitat of Dames Quarter obviously prevents the success of helminths that depend upon mollusks for life cycle completion. The salt water mollusks at Dames Quarter are not reported as intermediate hosts for helminth life cycle completion. The presence or absence of certain mollusks governs the distribution of helminths that rely upon the mollusk for life cycle completion. On the other hand, the presence of two trematodes in the brackish marshes of Dames Quarter, is apparently due to the ability of the parasite and some intermediate host to persist in salt or brackish water habitats. The presence of a nematode species in both study areas can be attributed to the direct life cycle, which is characteristic of the particular nematode, an intermediate host not required.

Recordings show the pH from both study areas very similar, with averages ranging from 7.02 at Dames Quarter to 7.04 at Thurmont. However, these pH determinations are not an accurate index of the true hydrogen ion activity in the aquatic situations studied.

Several other factors appear to have an influence on the incidences of the helminths in the muskrats, but not on the differences of the helminth fauna between Dames Quarter and Thurmont.

It was observed that there was a higher degree of infection among adults over subadult muskrats in this study. It is concluded that the older an animal becomes, his chances for becoming infected increase.

Female muskrats harbored a greater number and incidence of helminths in the gastrointestinal tract and liver than males. It is presumed that females are more confined to the vicinity of the house and a concentration of infective larvae likely builds up in the vicinity of the house. More male muskrats are trapped than females, possibly decreasing the life span of most males, giving males a shorter life span in which to possibly become infected, and decreasing the incidence of helminths among males.

Heavier infections were noted during the fall and winter months, and lower incidences of infection occurred during the spring and summer months in the muskrat populations. Open season for muskrat trapping in Maryland is during the fall and winter months when a large number of adult muskrats are taken. An increased number of kits and subadults were trapped during the warmer seasons. There seems to be a correlation with age of the host and season, and the connection seems not due to a temperature gradient, but due to the age of the majority of animals taken in a particular season.

The degree of helminth infection in muskrats in the western Maryland area may be influenced by the nature of the immediate area surrounding the ponds and streams. The areas that seemed best able to support a variety of wildlife forms also had a snail population in the ponds. These areas had a higher incidence of infection. The study area that was carefully managed and which lacked a snail population had a muskrat population with a lesser degree of helminth infection. The habitats of the Dames Quarter marshes were uniform in appearance and composition, and the helminths collected from the muskrats in this area were more similar in number and species.

Two factors, taxonomic and attitudinal differences, which were taken into account at the beginning of this study did not seem to influence the differences in the helminth fauna.

Two subspecies of the muskrat are distributed in Maryland: *Ondatra zibethicus zibethicus* of the western Maryland area; and *Ondatra zibethicus macrodon* of Eastern Shore Maryland. Taxonomic differences at the subspecies level does not appear to influence the variation in helminth burden. Species of helminths recovered from the muskrats from Maryland have been reported to occur throughout the United States in thirteen subspecies of the muskrat.

Altitudinal differences exist between Dames Quarter and Thurmont. The Dames Quarter elevation is near 25 feet above sea level; and the Thurmont area elevation averages around 600 feet above sea level. There is no evidence to indicate that these differences influenced the differences in helminth fauna.

Finally, it is evident by the results of this study and by the works of other investigators that there is a considerable variation in the parasites from one locality to another. It is demonstrable that these differences correlate with both biological and physical environments.

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