ABSTRACT OF THESIS

by

John W. McDowell

ABSTRACT

Until recently parasitologists have dealt almost exclusively with the taxonomy of parasites, and comparatively little work has been done in the physiological or ecological phases of the science. The importance of these latter phases has been repeatedly stressed by prominent men in the profession, because of their importance to public health, veterinary medicine, and pure science. As a result of this need a number of investigations of this nature have developed within the past few years. These investigations are outstanding because they provide information relative to the possibilities of wild life acting as reservoir or intermediate hosts for parasites pathogenic to man, domestic and game animals. Vast amounts of information important to pure science, such as contributions to ecology, invertebrate zoology, and many other fields of zoology are also derived from such investigations.

The writer's investigation was primarily an ecological problem, similar to the types mentioned above, and provided information relative to public health and wildlife.

The outline of this investigation follows:

Problem

What kinds of helminths are found in the mammals of Spitzer's Slough, and what is the incidence, relative abundance of types and determinable species?

Problem analysis.--In order to aid in answering the problem question, the following sub-questions are presented:

1. What genera and species of helminths, as far as can be determined, are present in these mammals?
2. Are any of these species of helminths new to science?
3. What degree of host specificity is present and what is its significance?
4. What is the incidence and relative abundance of types and determinable genera of parasites in these hosts?

Delimitation.--This study is limited to an examination of 100 mammals of non-commercial importance, trapped at random in Spitzer's Slough.

Mammals for this study were obtained from Spitzer's Slough, a marsh situated two and one-half miles southeast of Fort Collins on Mount Prospect Road. This was typical Colorado marshland and covered approximately one and one-half acres and was within 200 yards of the

Cache La Poudre River. Museum special rat traps were used to take specimens, and were set at random throughout the slough. Mammals trapped were in the genera, _Microtus_ (Field mice), _Peromyscus_ (Deer mice), _Mus_, (Common mice), and Sorex (Shrew).

The specimens were examined for parasites before decomposition set in. The viscera were removed and parts segregated and examined. The worms recovered were fixed, stained, cleared, and mounted for study. These processes involved standard methods employed by the profession.

Literature dealing with the taxonomy of worms was used in their identification. Results are presented in tabular form.

1. Genus _Microtus_ - Field mice
   1. Cecal trematodes:
      (a) _Quinqueserialis quinqueserialis_ (Barker and Laughlin, 1911)
      (b) _Plagiorchis_ sp.
   2. Cecal nematodes:
      (a) _Syphacia obvelata_ (Rudolphi, 1802) Seurat, 1916
   3. Small intestinal nematodes
      (a) _Longistriata_ sp.
   4. Small intestinal cestodes
      (a) _Paranoplocephala_ sp.

2. Genus *Peromyscus* - Deer mice

   1. Cecal nematodes

      (a) Syphacia obvelata (Rudolphi, 1802) Seurat, 1916

      (b) *Syphacia* sp.

   2. Small intestinal cestodes

      (a) *Hymenolepis* sp.

      (b) *Prochoanotaenia* sp.

3. Genus *Mus* - Common mice

   1. Cecal nematodes

      (a) *Syphacia* *obvelata* (Rudolphi, 1802) Seurat 1916

      (b) *Syphacia* sp.

4. Genus *Sorex* - Shrews

   1. Stomach and intestinal nematodes

      (a) *Capillaria* sp.

   2. Small intestinal cestodes

      (a) Not classified to genera

Three worms found, one each in the genera *Syphacia*, *Longistriata*, and *Capillaria* appeared to be new to science.

Quinqueserialis *quinqueserialis*, *Plagiorchis* sp., *Longistriata* sp. and *Paranoplocephala* sp. in the peromyscus were found to be the most host specific worms, since they occurred only in the type of host mentioned.

Syphacia obvelata and *Syphacia* sp. were found to be the least specific with the former occurring in microtus, peromyscus, and mus and the latter in peromyscus and mus. Those worms with indirect life cycles were the most host specific, whereas those with direct life cycles seemed to be the least specific.

Of the 100 mammals examined, 80 per cent of them were infected with worms and the average incidence was 15.39 worms per animal. On the basis of types of worms it was determined that 13.25 of these were nematodes, 1.09 cestodes, and 1.02 trematodes. The nematodes were far in excess of the other types found in the genera *Microtus*, *Peromyscus*, and *Mus*. This predominance was not the case, however, in *Sorex* where cestodes were more numerous than nematodes. Trematodes, from the standpoint of numbers, had very little significance as compared with nematodes and cestodes, and the incidence was primarily confined to the microtus.

The genus *Syphacia* was found in 57 per cent of the mammals examined, whereas, *Quinqueserialis* was found in only 16 per cent. The genera *Longistriata* and *Prochoanotaenia* each had an incidence of three per cent, while *Hymenolepis* occurred in two per cent, and *Paranoplocephala* in only one per cent of the mammals.

These mice are gregarious species and the shrews solitary, and these habits, apparently, determined to some extent their parasites. The mice harbored parasites that had a direct life history, mainly nematodes, the gregariousness favoring exposure. Shrews, being insectivorous, harbored parasites that had an indirect life history, mainly cestodes, since insects many times are intermediate hosts for cestodes.

Syphacia obvelata, *Hymenolepis* sp., *Longistriata* sp., and *Quinqueserialis quinqueserialis* were considered of public health and economic importance. *Syphacia obvelata* and possibly *Hymenolepis* sp. infest man. *Longistriata* sp. could possibly produce pathological conditions in rats similar to the lesions of plague, since a closely related worm, *Heligmosomum braziliense*, is known to produce such results, which might be a source of error in plague surveys of rats often conducted by public health agencies. *Quinqueserialis quinqueserialis*, a trematode of the muskrat, was recorded from microtus, which serves as a reservoir host of this organism, resulting in transmission to the muskrat.

On the basis of parasite fauna it is strongly suspected that the different species of mice have discriminating food habits because there was a difference in specificity of worms with direct as compared with indirect life histories. There is every reason to believe that food selectivity of the mice is the basis for the difference.

Hymenolepis sp., a worm recorded in the literature from all the hosts in this investigation, was found in peromyscus only, the reasons for this probably being one or a number of the following: Discriminating food habits, specificity of hymenolepis strains, greater suitability of peromyscus as a host, or antagonism between hymenolepis and other worms in hosts.

Some suggestions for future research that evolved as a consequence of this work are as follows:

Determination of the complete life cycle of *Quinqueserialis quinqueserialis*. This would be feasible since so many of these worms were recovered from hosts confined to a relatively small area.

Worm distribution among small animals in the major ecological regions of Colorado should be determined, because knowledge of this nature is valuable to all fields of parasitology.

Further host specificity studies could be made for mammals of Spitzer's Slough, since this would contribute more knowledge to physiology of parasites and food habits of mice.

There are numerous problems in taxonomy, new species are obtainable, and some parasite groups are in need of revision.

Physiological relationships of *Peromyscus* and Hymenolepis should be studied, since present knowledge of specificity in this genus is vague.

Relationship of these mammals to public health should be studied further, since some helminths are common to mice and man.

Surveys of ectoparasites and parasitic protozoa in the mammals of Spitzer's Slough should be made since both groups are important from the public health standpoint.

T H E S I S

SOME HELMINTHS
IN CERTAIN MAMMALS
OF SPITZER'S SLOUGH

Submitted by

John W. McDowell

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado

Agricultural and Mechanical College

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COLORADO AGRICULTURAL AND MECHANICAL COLLEGE

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY JOHN W. MCDOWELL

ENTITLED SOME HELMINTHS IN CERTAIN MAMMALS OF SPITZER'S SLOUGH

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

MAJORING IN ZOOLOGY AND PARASITOLOGY

CREDITS 5

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Chapter I

INTRODUCTION

At the present time very little is known concerning the parasites of wild mammals, particularly with respect to their ecology. This work has been neglected due to a tendency on the part of most workers, with the exception of parasitologists dealing with aquatic animals, to describe parasites of one species of mammal instead of a representative number of mammals from a certain ecological habitat; for example, a marshland. The importance of description of parasites from one type of mammal is not to be underestimated since the science is still young and has not developed beyond the taxonomic phase as yet. However, application of taxonomic and ecological knowledge towards further understanding of the biology of these organisms would be a definite advancement in the science. This thesis is an attempt to correlate taxonomic and ecological material.

The necessity of such investigations from a practical standpoint is quite evident when one stops to consider that many of these wild animals may serve as intermediate or reservoir hosts of parasites of game animals, domestic animals, and man in the particular area being investigated. Furthermore, knowledge of this nature is of value in the fields of Invertebrate Zoology, General Parasitology, and Animal Ecology, from the standpoint of pure science.

The problem is outlined in the following paragraphs.

The problem

What kinds of helminths are found in the mammals of Spitzer's Slough, and what is the incidence, relative abundance of types and determinable species?

Problem analysis.--In order to aid in answering the problem question, the following sub-questions are presented:

1. What genera and species of helminths, as far as can be determined, are present in these mammals?
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Delimitation.--This study is limited to an examination of 100 mammals of non-commercial importance, trapped at random in Spitzer's Slough.

The mammals examined in this problem were limited to those of so-called non-commercial importance and included the following four genera: Peromyscus (Deer mice), Microtus (Field mice), Sorex (Shrews), and Mus (Common mice).

Setting

The slough previously mentioned lies two and one-half miles southeast of Fort Collins on Prospect Road, and covers an area of approximately an acre and a half. It contains mainly the following types of vegetation: Cottonwoods, willows, cat-tails, sedges, salt grass, water cress, and various other types of grasses. Approximately one-third of the area is under water, and at no point is there water free from emerging vegetation. The slough proper appears to be an old "oxbow pond" and is located about two hundred yards from the Cache La Poudre River. The elevation at this point is approximately 4900 feet. In classifying this area according to Merriam's Life Zone, it would be considered a marshland lying in a deciduous niche in the Upper Sonoran Zone.

Definition of terms

Oxbow pond - one formed when a river changes its course.

Upper Sonoran Zone - an arid region ranging from the high plains and foothills of the southern states to the low plains and valleys in the north, never varying below 3000 feet in elevation and never higher than 6000 feet.

Chapter II

REVIEW OF LITERATURE

This study is concerned with the incidence and relative abundance of parasitic worms in certain mammals of Spitzer's Slough, a typical Colorado marshland. An investigation of this nature provides an insight concerning the parasites existing in an ecological habitat; therefore, it could be regarded, in a sense, as an ecological problem.

Problems of this nature are relatively few and new, and, therefore, provide a fertile field of research. A review of literature further emphasizes the necessity and timeliness of such an investigation, and is approached from the historical viewpoint.

The field of parasitology like many similar ones is still going through an evolutionary period of growth. This growth began with the early description of worms associated with obvious pathological conditions. The first worm descriptions on record were made on the Eber's Papyrus (16th century B.C.). This record made by the Accadians referred to conditions associated with ascarid and tapeworm infections. At a later period reports of worms again appeared in literature, this time in the Old Testament, where Moses referred to Dracunculus medinensis, the Guinea-worm, as the "Fiery Serpent" in the wilderness of Sinai. The most interesting early record for helminthologists was the one made by Avianna, a Persian physician, living in 900 A.D., who described longworms (cestodes and nematodes) and flatworms (trematodes). Avianna also associated the condition of Elephantiasis with the presence of a filarid worm.

After the discovery by Frances A. Redi, 1626, of the development of maggots from fly eggs instead of being spontaneously generated, classification of parasites was placed on a more scientific basis. Redi also proved that male and female ascarids existed and that the larval forms of ascaris developed from eggs produced by the female. After this event a number of worms were described, mostly associated with pathogens of man and domestic animals. These descriptions were vague and concerned only with metazoan or parasitic helminths. Leeuwenhoek, 1702, discovered the miscroscope which was the renaissance of science, especially parasitology, since the entire field of parasitic protozoology was uncovered and scientifically accurate worm descriptions were made possible.

In the latter part of the eighteenth and early part of the nineteenth century, a man by the name of

Rudolphi "did for the parasitologists what Linnaeus did for the zoologists" (4:6). He recognized and established the five classes of worms which he named Nematoidea, Acanthocephala, Nematoda, Cestoda, and Trematoda. Rudolphi, 1802, also was the first to describe Syphacia obvelata, a nematode encountered in this investigation. Following the classification established by Rudolphi, many others in the early part of the nineteenth century, including Dujardin, Diesing, Cobbold, and Leidy, described new genera and species of worms. Early data of this nature may be found in most of the modern texts in parasitology.

At the beginning of the twentieth century certain individuals such as Shipley (1908) (24), Stiles and Hassall (1910) (26), Douthitt (1915) (5), Meggitt (1924) (19), Baer (1927) (1), and York and Maplestone (1927) (30) began to group these individual descriptions into check lists and monographs designating certain families, orders, and classes of helminths. These attempts were some of the first in systematic helminthology. At approximately the same time a number of individuals like Hall (1916) (10), Johnston (1916) (14), Moll (1917) (20), Balfour (1922) (2), Fielding (1927) (9), and Stiles and Stanley (1931) (27) began to publish investigations concerned with the kinds of worms found in certain specific host. These studies were namely concerned with taxonomy and little if any ecological or physiological relationships were investigated or discussed.

The period that followed ushered in the beginning of ecological and physiological investigations in parasitology. Previous to this time very little had been done in this connection, except an occasional parasite life history. The observations of Riley (1919) (22) and Kofoid and White (1919) (15), who had determined the presence of syphacia eggs in the feces of man, began to make speculations regarding the etiology of such infections. The first actual biological work in connection with surveys was done by a group of English investigators which was interested in determining the reasons for mammal population fluctuations. Elton, Ford, and Baker (1931) (7) investigated the decreasing rodent population in Bagley's Wood near Oxford. This investigation consisted in live trapping a number of rodents and examining them for external and internal parasites, as well as pathogenic bacteria. The results of their work indicated the presence of quite a few parasites and bacteria in the rodents examined, but no definite conclusion could be made regarding the cause of population fluctuation. Later, however, Elton, Davis, and Findly (1935) (6) found that epizootics among voles (Microtus agristis) in Britain were due to a brain infection by a parasitic protozoan, Toxoplasma. An additional pioneer survey study was done by Tsuchiya and Rector (28) in 1936. This investigation consisted of an examination of 100 rats from Saint Louis for parasites. Their results indicated that mice harbored Endamoeba histolytica, an amoebic dysentery organism of man. They also determined the incidence and relative abundance of worms found. These data were interesting since they recorded an incidence of 0.9 per cent for Syphacia obvelata, a nematode encountered in the writer's study. Harkema (11) also in 1936 conducted a survey of parasites in rodents of North Carolina. His particular interest in this survey was the seasonal distribution of parasites.

At about this time some of the more prominent men in the field began to stress the necessity for more regional surveys of parasites, and for studies concerned with the ecological and physiological relationships between helminths and their hosts. Van Cleave (1937) (29), a foremost authority, made the statement that there should be three points of view from which parasite studies should be considered, "that of host, that of the parasite, and that of the habitat or environment" (29:2). He believed that the static aspects of classification and structure alone were secondary in importance to the biology of the parasites. Cameron

(1938) (2) stated that a knowledge of parasites in wild animals based on a regional survey was essential because of the increasing population of game animals and domestic animals. His reason for this statement was that parasitic diseases depend upon the number of animals confined to a certain region. A dense population of animals invites heavy parasitism, and eventually a condition of disease may result from these increased infections. He further substantiated his statement by giving several examples of parasites indigenous to wild animals which can infect domestic animals and cause disease. These examples were Fascioloides magna and Thysanosoma actinioides. The former, in addition to its regular host, Cervidae, occurs in sheep, whereas the latter normally infests wild ruminants but may be readily acquired by sheep. In reference to public health he showed that Trichinosis can and has been spread to man through a wild animal host. He also cited references to prove that Diphyllobothrium latum, the fish tapeworm of man, was carried by certain wild carnivores.

Cameron concluded that as a result of a survey

> Problems in biology and pathology which are urgent, are in this way brought to light and we are in a position to advise on work done or to be done, and to apply our knowledge to a particular problem (3:18).

As a result of this increasing interest in parasite surveys and distribution, certain publications began to appear regarding generalizations on the distribution of types of parasites. Lucker (1941) (18) published just such an article dealing with the distribution of parasites. He stated that nematodes and trematodes were more abundant in a moist habitat than a dry one, because the eggs of these forms required moisture for proper development.

In 1945 Rankin (21) developed a method whereby a large area, Northrup Canyon, Washington, was divided into many small ecological habitats, namely, unused fields, bunch grass slope, rocky ground sage, grassy sage, open barren ground sage, deciduous brush, moist upland meadow, stream side, upper forest, and rock slides. These areas were trapped for rodents and the animals obtained were examined for parasites. These parasites were identified and the relative abundance of worms in each habitat discussed. In doing this Rankin secured some interesting results. He found, for instance, that the animals of the bunch grass slope were 56.2 per cent parasitized and those of rocky ground sagebrush, 50 per cent. The other habitats produced various degrees of parasitism much lower than the two mentioned. Rankin also computed the over-all incidence of worm species found in these areas. For example, he found Syphacia obvelata in 31.3 per cent of the mammals examined.

Certain studies in the physiology of parasites have resulted from these many investigations. These studies are considered, by the writer, to be by-products and were, therefore, not mentioned in the review, since this portion considered only the main steps in the development of Parasitology. Examples of physiological studies are those by Shorb (1933) (25), Hunninen (1936) (13), Larsh (1943) (16), and Larsh and Donaldson (1944) (17) who investigated the various physiological factors influencing the host-parasite relationship of *Hymenolepis nana* var. *fraterna*, a mouse tapeworm.

Summary and Implications

From the historical review one can see the gradual trend of parasitology towards a better understanding of the biological aspects of parasites. The writer's investigation is one of a biological nature and therefore in accordance with recent developments in the field.

Chapter III

METHODS AND MATERIALS

This investigation was concerned with the incidence and relative abundance of worms in certain mammals of Spitzer's Slough. In order to undertake such a study, a number of techniques had to be applied. These techniques consisted of trapping mammals, collecting worms, preparing worms for study, and cataloguing results.

Mammals were trapped for examination. Museum special rat traps were used for this purpose, and set at random throughout the slough in likely places to secure catches. The mammals trapped were all in the genera, *Microtus* (Field mice), *Peromyscus* (Deer mice), *Mus* (Common mice) and *Sorex* (Shrews).

As soon as possible after trapping, these mammals were taken to a refrigerator, registering approximately 40 degrees Fahrenheit. This temperature, in addition to preserving the specimens, also prevented any freezing of the internal organs and consequent injury to the worms. It also allowed for relaxation of the worms in their normal isotonic medium. These hosts, to be examined for parasites, were kept in the refrigerator no longer than three days, and in this way decomposition was prevented. If examinations could not be made within the set time limit, the animals were discarded.

The procedure for autopsy consisted in removing the organs to be examined. The stomach, intestine, liver, and lungs were placed in a container filled with cold water. Each individual organ was then removed to a petri-dish also containing cold water. Each organ was then opened and thoroughly washed. The washings were allowed to settle and the clear or semi-clear liquid was decanted off into a separate dish. This washing procedure was repeated several times until the settled material appeared more or less transparent. The material which had been washed was then subjected to a macroscopic examination. This was accomplished by holding the petri-dish under a strong light over a dark background and removing any worms observed in the contents. In addition to the macroscopic examination the contents of the dish also were subjected to a microscopic examination which consisted of a systematic search of the material under appropriate powers of a widefield binocular dissecting microscope.

The same procedure as that outlined above was used to determine whether the decanted material was free from helminths.

The worms, recovered by the above methods, were immediately transferred to a watch glass containing physiological saline. These worms were then treated as follows:

The cestodes were removed from the watch glass and placed on a glass plate. A solution consisting of a mixture of formalin, acetic acid, and 70 per cent alcohol (FAA) was then added to the worm drop by drop to fix it. Two camel hair brushes were employed to stretch the worm, so that the worm when fixed would be in a relaxed condition. Then it was transferred to a small clear vial filled with FAA. After properly labeling the contents of the vial it was stoppered with cotton, which had previously been immersed in FAA, and then dropped into a large storage bottle filled with FAA. After several days the vial was emptied of FAA and a solution of 70 per cent alcohol was added and the vial restoppered and placed in a large storage bottle containing 70 per cent alcohol. Such a procedure as this is necessary for preparing any cestodes for staining and proper preservation.

In the further procedures of preparing the worms for identification they were transferred from storage through successively weaker aqueous dilutions of alcohol, to either an aqueous solution of Carmine or Cochineal. After the proper staining period had elapsed, they were removed from the stain, destained, cleared, and mounted on a slide in Canada Balsam, after which they were ready to be studied.

The trematodes, recovered, were transferred from the watch glass containing physiological saline to a large container filled with cold water. Here they remained anywhere from 15 minutes to several hours. After the proper degree of relaxation had been obtained, they were transferred to a mercuric chloride-acetic acid solution and left for one-half hour. They were then removed, washed with water, and placed in a solution of iodine and 70 per cent alcohol (sufficient iodine to give the solution a "port wine" color) to remove the mercury. The worms remained in this solution anywhere from four to 24 hours. Not later than the maximum time, they were removed and placed in 70 per cent alcohol. The next procedure was to transfer them to a clear glass vial containing 70 per cent alcohol. After proper labeling, the vial was stoppered with cotton and transferred to a large storage bottle filled with 70 per cent alcohol. In addition to this method, some of the worms were fixed in cold 10 per cent formalin, after they had been allowed to relax in cold water. After fixation they were transferred to a glass vial filled with 10 per cent formalin, and this was stored in a larger bottle containing 10 per cent formalin. The trematodes were prepared for study in the same manner as the cestodes.

The nematodes were removed from the physiological saline and placed in hot (50-60 degrees Centigrade) 10 per cent formalin solution for relaxation and fixation. After fixation, they were transferred to a brown glass vial containing 10 per cent formalin. After proper labeling, it was stoppered with a cotton plug and transferred to a large storage bottle containing 10 per cent formalin.

In the further preparation for study they were transferred from 10 per cent formalin to a phenol-alcohol solution to clear them, and at this time a preliminary examination was made. At a later date they were removed from this clearing reagent and placed in an alcohol-glycerine solution in covered containers in preparation for mounting them on slides. This allowed the alcohol to evaporate slowly, leaving the worms in almost pure glycerine. Then they were transferred to slides which had previously been ringed with Black Asphaltum and shellac. To each of these worms a drop of liquid glycerine jelly was added, and a round cover slip placed over the worm so that the edges fell on the asphalt ring. These slides were allowed to dry and then another ring of asphalt was applied which served to seal the cover slip to the mount.

Procedures used in recording data were as follows:

Host-parasite Catalogue, Number One

In this host-parasite catalogue entries as listed were made in sequence as follows, and were made immediately following autopsy.

(1) host number

(2) genus of animal examined

(3) date of examination

(4) number of helminths of each type found

(5) location of these parasites in the host

(6) method of fixation

(7) remarks, if any

Host-parasite Catalogue, Number Two

At a later date after the worms had been prepared for study a second host-parasite catalogue was made. This catalogue consisted of a loose-leaf note-book, divided into three sections - Nematoda, Cestoda, and Trematoda. In each section were recorded the names of the hosts containing worms of that type. One page was allotted for each host and the information recorded in the first host-parasite catalogue was repeated in this catalogue. In addition to this, notes pertaining to method of preparation for study and diagnosis, and any camera-lucida drawings necessary for diagnosis were recorded.

Chapter IV

ANALYSIS OF DATA

This thesis is concerned with the kinds of helminths found in certain mammals of Spitzer's Slough, as well as their incidence and relative abundance. The problem is broken down into four sub-questions that are answered in this chapter.

Sub-question One

What genera and species of helminths, as far as can be determined, are present in these mammals?

This question is answered by tabulating the host genera with their respective worm parasites.

1. Genus *Microtus* - Field mice
    1. Cecal trematodes:
        - (a) *Quinqueserialis quinqueserialis* (Barker and Laughlin, 1911)
        - (b) *Plagiorchis* sp.
    2. Cecal nematodes
        - (a) *Syphacia obvelata* (Rudolphi, 1802) Seurat, 1916
    3. Small intestinal nematodes
        - (a) *Longistriata* sp.

4. Small intestinal cestodes

   (a) *Paranoplocephala* sp.

2. Genus *Peromyscus* - Deer mice

   1. Cecal nematodes

      (a) *Syphacia obvelata* (Rudolphi, 1802) Seurat, 1916

      (b) *Syphacia* sp.

   2. Small intestinal cestodes

      (a) *Hymenolepis* sp.

      (b) *Prochoanotaenia* sp.

3. Genus *Mus* - Common mice

   1. Cecal nematodes

      (a) *Syphacia obvelata* (Rudolphi, 1802) Seurat, 1916

      (b) *Syphacia* sp.

4. Genus *Sorex* - Shrews

   1. Stomach and intestinal nematodes

      (a) *Capillaria* sp.

   2. Small intestinal cestodes

      (a) Not classified to genera

Sub-question Two

Are any of these species of helminths new to science?

A careful study of the available literature was made, and it was determined that the following worms found in this investigation are probably new to science.

1. Syphacia sp.

This worm was found in the cecum of mus and peromyscus and presented a problem in taxonomy. No difficulty was encountered in placing this worm in the genus Syphacia, since the characteristics were obvious. The species, on the other hand, fits no recorded species description. It resembles closely Syphacia peromysci, Harkema, 1938, but the females differ considerably in size and length of eggs, the unknown species being larger in both respects. The males are very similar. These differential characteristics are of sufficient caliber to warrant a new species.

2. Longistriata sp.

This worm was found in the small intestine of microtus. The species is uncertain due to differences between it and available described species. There exists, however, a similarity between this worm and Longistriata carolinensis, Dikmans, 1936. The male of both species have identical bursae. The females, however, differ in size, the one of the unknown species being larger. Since size is of major significance in differentiating species in this genus, a critical study of more material would be necessary before a decision was made.

3. Capillaria sp.

This worm was found in the stomach and small intestine of sorex. The literature on species of this genus in the sorex is very meager. Only two species have been described and both of these were from France and published in 1843 and 1851. The possibility of a new species is therefore very likely, since these references are foreign and very old, and American forms, apparently, are entirely unknown.

Sub-question Three

What degree of host specificity is present in these parasites?

The answer to this question was approached by tabulating all genera and species of worms recorded in the literature for each host genus. The findings of the writer also were tabulated, the lists compared, and a table made showing the host specificity of each worm found in this study.

The tabulations from literature are as follows:

Genus Microtus

Nematoda:

1. Capillaria lemmi (Retzius, 1941) (30)
2. Heligmosomum costellatum (Dujardin, 1845) Railliet and Henry, 1909 (10)
3. Heligmosomum minutum (Dujardin, 1845) (30)

4. Heligmosomum sp. (5)
5. Heligmosomoides linstowi Hall, 1916 (10)
6. Heligmosomoides polygyrus (Dujardin, 1845) Boulenger, 1922 (7)
7. Longistriata carolinensis Dikmans, 1935 (8)
8. Longistriata dalympei Dikmans, 1935 (11)
9. Nematospira turgida Walton, 1923 (11)
10. Oxyuris sp. (21)
11. Physaloptera muris (Gmelin, 1790) (11)
12. Syphacia obvelata (Rudolphi, 1802) Seurat, 1916 (8)
13. Trichuris muris (Schrank, 1788) Hall, 1916 (10)
14. Viannaia polygyra (Dujardin, 1845) Hall, 1916 (10)

Cestoda:

1. Andrya communis Douthitt, 1915 (21)
2. Andrya sp. (8)
3. Anoplocephala campestris Cholodkovsky, 1912 (19)
4. Anoplocephala infrequens Douthitt, 1915 (19)

5. *Bertiella omphalodes* (Hermann, 1783) (19)
6. *Catenotaenia pusilla* (Goeze, 1782) (19)
7. *Hymenolepis asymmatrica* Janick, 1904 (19)
8. *Hymenolepis arvicula* (Blanchard, 1891) (19)
9. *Hymenolepis arvicolina* Cholodkovsky, 1912 (19)
10. *Hymenolepis diminuta* (Rudolphi, 1819) Blanchard, 1891 (21)
11. *Hymenolepis diminutoides* Cholodkovsky, 1912 (19)
12. *Hymenolepis microstoma* (Dujardin, 1845) (7)
13. *Hymenolepis procera* Janicki, 1906 (19)
14. *Paranoplocephala blanchardi* (Moniez, 1891 (7)
15. *Paranoplocephala troeschi* Rausch, (23)
16. *Taenia tenucollis* Rudolphi, 1819 (7)

Trematoda:

1. *Notocotylus hassalli* McIntosh and McIntosh, 1934 (8)

2. Mediogonimus ovalicus (Woodhead and Malewitz, 1936) (8)

3. Monostomum sp. (8)

4. Quinqueserialis quinqueserialis (Barker and Laughlin, 1915) (8)

5. Schistosomatium douthitti (Cort, 1915) (8)

Genus Peromyscus

Nematoda:

1. Aspiculuris americana Erickson, 1938 (8)

2. Longistriata carolinensis Dikmans, 1935 (8)

3. Nippostrongylus muris (Yokogawa, 1920) (8)

4. Rictularia coloradensis Hall, 1916 (10)

5. Syphacia obvelata (Rudolphi, 1802) Seurat, 1916 (8)

6. Syphacia peromysci Harkema, 1936 (8)

7. Syphacia samorodini Erickson, 1938 (8)

Cestoda:

1. Prochoanotaenia peromysci Erickson, (8)

Trematoda:

1. Brachylaemus peromysci Reynolds, 1938 (8)

2. Entosophonus thompsoni Sinitsin, 1931 (8)

3. Scaphiostomum pancreaticum McIntosh, 1934 (8)

Genus Mus

Nematoda:

1. Ascaris sp. (10)
2. Aspiculuris tetraptera Nitzsch, 1931 (30)
3. Capillaria bacillata (Eberth, 1863) (30)
4. Capillaria leidyi (Travassos, 1914) (30)
5. Capillaria muris musculi (Diesing, 1861) (30)
6. Capillaria muris sylvatici (Diesing, 1861) (30)
7. Capillaria papillosa (Polonio, 1860) (30)
8. Capillaria schmidtii (Linstow, 1874) (30)
9. Capillaria tenuissimum Leidy, 1891 (30)
10. Ganguleterakis spumosa Schneider, 1866 (30)
11. Gongylonema musculi (Rudolphi, 1819) Neumann, 1894 (10)
12. Gongylonema neoplasticum (Fibiger and Ditlevsen, 1914) Ransom & Hall, 1916 (10)

13. Hepaticola hepatica Railliet, 1889 (10)

14. Heterakis spumosa (14)

15. Longistriata musculi Dikmans, 1935 (11)

16. Ollulanus tricuspis Leuckart, 1865 (10)

17. Physaloptera africana (Monnig, 1924) (30)

18. Physaloptera circularis Linstow, 1897 (30)

19. Physaloptera getula Seurat, 1917 (30)

20. Physaloptera muris brasiliensis Deising, 1800 (30)

21. Protospirura labiodentata (VonLinstow, 1899) Hall, 1916 (10)

22. Protospirura muris (Gmelin, 1790) Seurat, 1915 (10)

23. Spiroptero guadrialata Molin, 1860 (10)

24. Strongylus lemmi von Siebold, 1837 (10)

25. Syphacia obvelata (Rudolphi, 1802) Seurat, 1916 (10)

26. Syphacia stroma Linstow, 1884 (30)

27. Syphacia tetraptera (Nitzsch, 1821) VonLinstow, 1878 (10)

28. Trichinella spiralis (Owne, 1835) Railliet, 1895 (10)

29. Trichosoma muris-musculi Creplin, (10)

30. Trichuris muris (Schrank, 1788) Hall, 1916 (10)

Cestoda:

1. Catenotaenia pusilla (Goeze, 1782) (19)

2. Davainoides polycalceola (Janicki, 1902) (19)

3. Hymenolepis contracta Janicki, 1904 (19)

4. Hymenolepis crassa Janicki, 1904 (19)

5. Hymenolepis diminuta (Rudolphi, 1819) (19)

6. Hymenolepis diminutoides Cholodkovsky, 1912 (19)

7. Hymenolepis fraterna (Stiles, 1906) (19)

8. Hymenolepis norrida (Linstow, 1900) (19)

9. Hymenolepis inexpecta Cholodkovsky, 1912 (19)

10. *Hymenolepis longior* Baylis, 1922 (19)

11. *Hymenolepis microsoma* (Dujardin, 1845) (19)

12. *Hymenolepis relicta* (Zschokke, 1887) (19)

13. *Mesocestoides lineatus* (Goeze, 1782) (19)

14. *Multicapsiferina quinecnis* (Graham, 1909) (19)

15. *Raillietina blanchardi* (Darona, 1898) (19)

16. *Raillietina celebensis* (Janicki, 1902) (8)

17. *Raillietina trapezoides* (Janicki, 1904) (19)

18. *Taenia brachydera* Diesing, 1854 (19)

19. *Taenia imbricata* Diesing, 1854 (19)

20. *Taenia muris-ratti* Creplin, 1825 (19)

21. *Taenia ratti* Rudolphi, 1819 (19)

22. *Taenia umbonata* Molin, 1858 (19)

Trematoda:

None

Genus *Sorex*

(Note: Many references were taken from U.S.P.H.S. Natl. Inst. Health Bull. 159 in which citations were not given, and in this manuscript they are designated by an asterisk.

It should be stated that the publication was supposed to be an exhaustive compilation, but the writer found numerous references not listed.)

Nematoda:

1. *Capillaria incrassota* (Diesing, 1851) (30)
2. *Capillaria splenacea* (Dujardin, 1843) (30)
3. *Hepaticola soricicolo* Nishigori, 1924 (30)
4. *Nematoideum sorieis-aranei* (27)*
5. *Physaloptera formosana* Yokagawa, 1922 (30)
6. *Soboliphyme soricis* (27)*
7. *Viannaia depressa* (27)*

Cestoda:

1. *Choanotaenia scoricina* (Cholodkovsky, 1901) (19)
2. *Hymenolepis diaphana* (27)*
3. *Hymenolepis furcata* (27)*
4. *Hymenolepis pistillum* (27)*
5. *Hymenolepis russica* Linstow, 1901 (19)
6. *Hymenolepis scalaris* (27)*
7. *Hymenolepis singularis* (27)*
8. *Hymenolepis spinalosa* (27)*
9. *Hymenolepis fiara* (27)*
10. *Hymenolepis uncinata* (27)*
11. *Monopylidium crassiscoles* (27)*

12. *Monopylidium scutigerum* (27)*
13. *Monopylidium soricinum* (27)*
14. *Monopylidium subterranea* (27)*
15. *Taenia crassiscolex* Linstow, 1900 (19)
16. *Taenia neglecta* (27)*
17. *Taenia scutigera* Dujardin, 1845 (19)
18. *Taenia soricis* (19)*

Trematoda:

1. *Distoma exasperatum* (27)*
2. *Distoma soricis* (27)*
3. *Harmostomum migrans* (27)*
4. *Harmostomum fulvum* (27)*
5. *Tetracotyle soricis* (27)*

The writer's tabulated parasite list for hosts of Spitzer's Slough follows:

Genus *Microtus*

Nematoda:

1. *Syphacia obvelata* (Rudolphi, 1802) Seurat, 1916
2. *Longistriata* sp.

Cestoda:

1. *Paranoplocephala* sp.

Trematoda:

1. *Quinqueserialis quinqueserialis* (Barker and Laughlin, 1911)
2. *Plagiorchis* sp.

Genus Peromyscus

Nematoda:

1. Syphacia obvelata (Rudolphi, 1802) Seurat, 1916
2. Syphacia sp.

Cestoda:

1. Hymenolepis sp.
2. Prochoanotaenia sp.

Trematoda:

None

Genus Mus

Nematoda:

1. Syphacia obvelata (Rudolphi, 1802) Seurat, 1916
2. Syphacia sp.

Cestoda and Trematoda:

None

Genus Sorex

Nematoda:

1. Capillaria sp.

Cestoda:

Decomposition of these forms prevented classification.

Trematoda:

Immaturity of forms prevented classification.

A critical study and comparison of these lists indicated that there were certain conclusions that could be drawn with regard to some of these parasites. Various degrees of host specificity were demonstrated by the worms in the hosts of Spitzer's Slough, and these are presented in the following table:

Table 1.--DEGREE OF HOST SPECIFICITY DEMONSTRATED BY HELMINTHS OBTAINED FROM MAMMALS OF SPITZER'S SLOUGH

	Microtus	Peromyscus	Mus	Sorex
1. Syphacia obvelata	W S	W S	W S	
2. Syphacia sp.	O	W O	W O	
3. Longistriata sp.	W	O	O	
4. Capillaria sp.	O		O	W
5. Q. Quinqueserialis	W S			
6. Plagiorchis sp.	W			
7. Paranoplocephala sp.	W O			
8. Hymenolepis sp.	O	W	O	O
9. Prochoanotaenia sp.		W O		

Key to table:

W - indicates that the species of worm in question was found in that host.

O - indicates that the genus has been recorded in literature from that host.

S - indicates that the species has been recorded in literature from that host.

Sub-question Four

What is the incidence and relative abundance of types and genera of parasites in these hosts?

Eighty per cent of the mammals examined were infected with helminths and the average incidence was 15.39 worms per animal. When this figure was considered on the basis of types of worms it was determined that 13.28 of these were nematodes, 1.09 cestodes, and 1.02 trematodes.

The data as to relative abundance are presented in Figure 1.

The incidence and relative abundance of genera proved to be very interesting. The genus Syphacia was found in 57 per cent of the 100 mammals examined, whereas Quinqueserialis was found in only 16 per cent. The genera Longistriata and Prochoanotaenia were tied with an incidence of three per cent of 100 mammals, while Hymenolepis infected only two per cent and Paranopocephala only one per cent of the mammals.

The data concerning the relative abundance of helminth genera in mammals of Spitzer's Slough are presented in Figure 2.

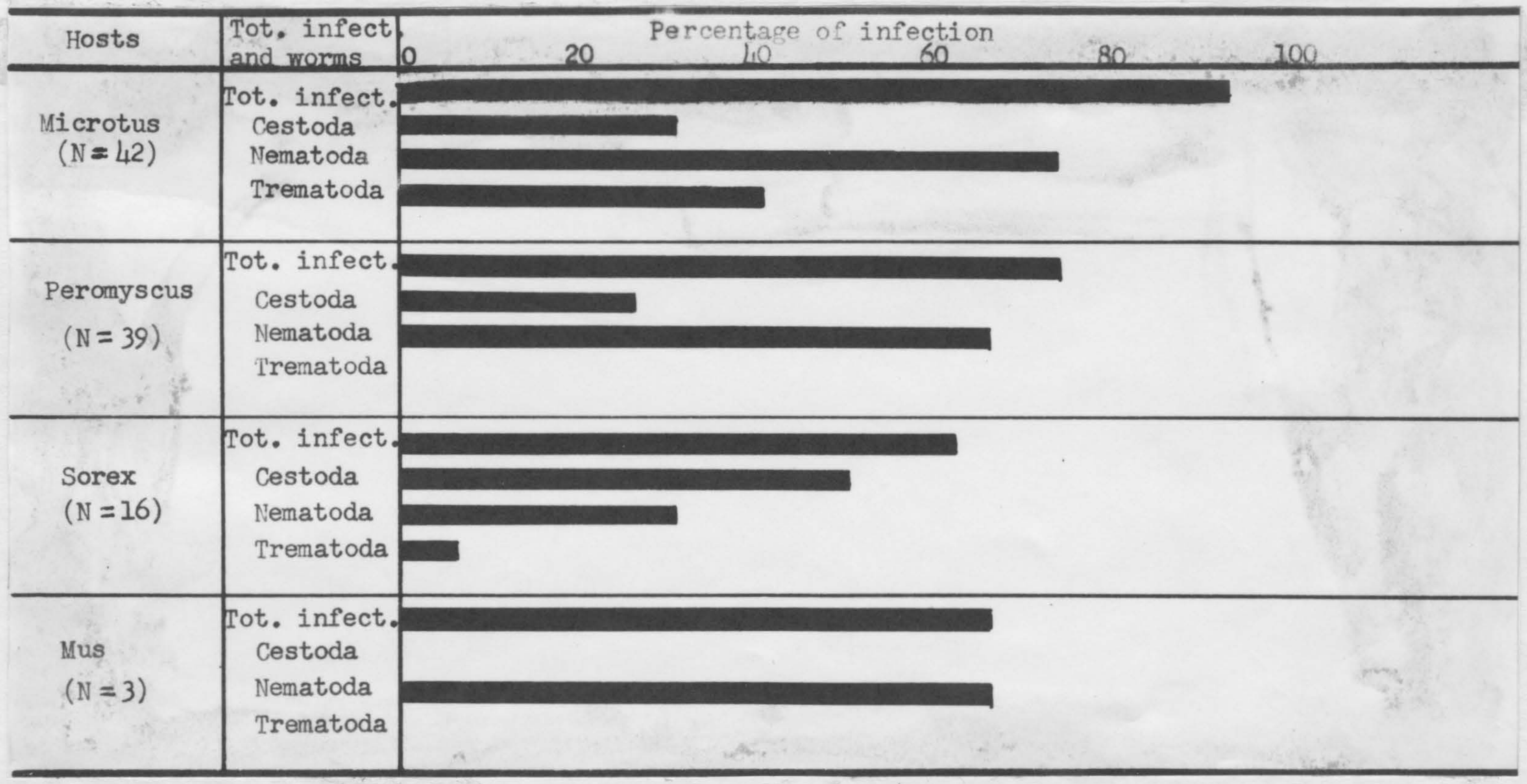

Fig. 1.--The Relative Abundance of Helminths and Helminth Types in Mammals of Spitzer's Slough.

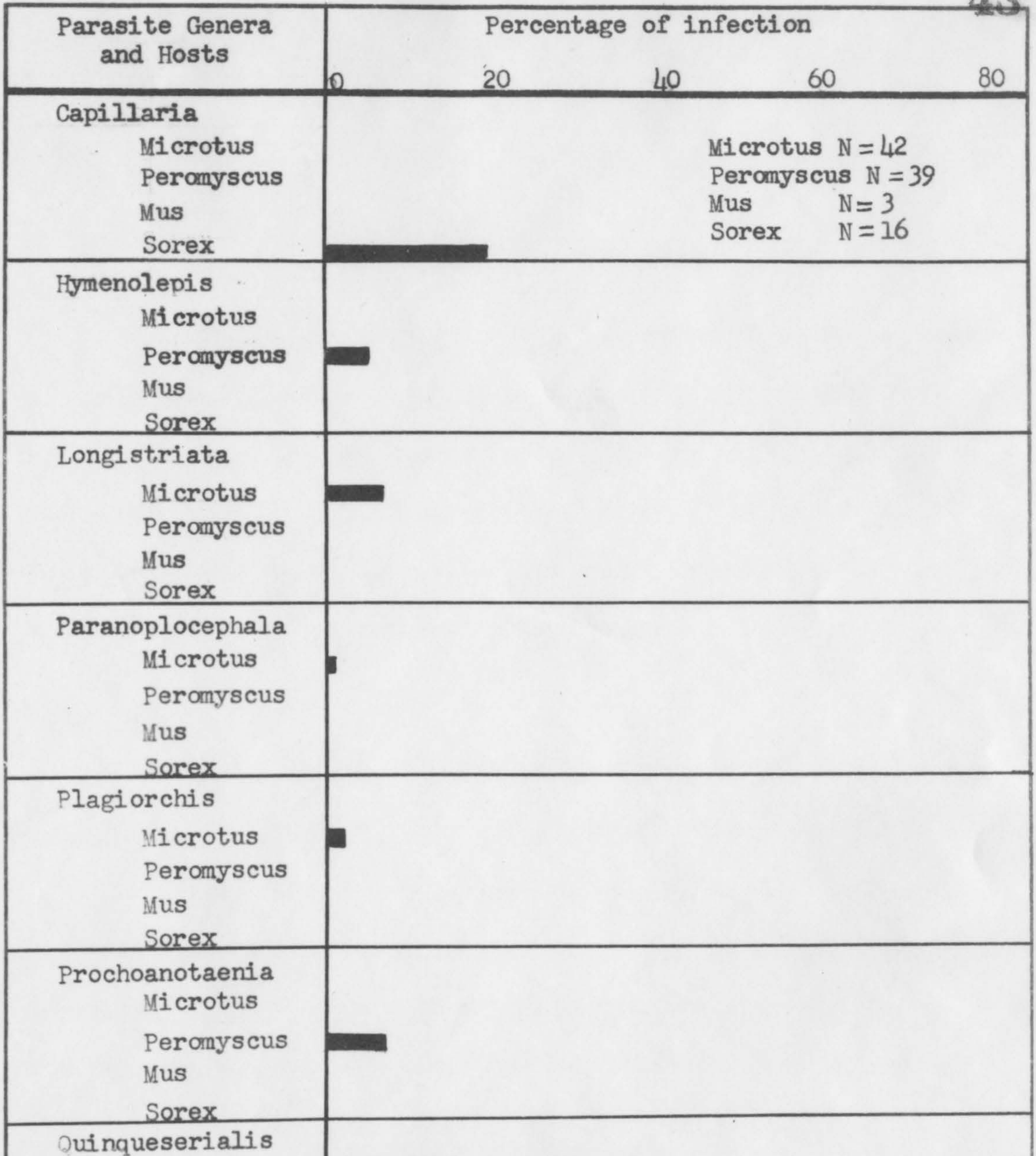

Fig. 2.--The Relative Abundance of Helminth Genera in Mammals of Spitzer's Slough.

Chapter V

DISCUSSION

This investigation is concerned with the types of helminths, their incidence and relative abundance, and species found in the mammals of Spitzer's Slough. It resolves itself into a number of minor divisions which will be considered in detail in this chapter under headings already specified (Chapter I).

Part One

What genera and species of helminths, as far as can be determined, are present in these mammals?

In order to answer the question it was necessary to identify the material that was collected from the mammals, and in order to do this the worms were fixed, stained, cleared, and mounted for study. The study of the material revealed that the three common forms of helminth parasites, namely, cestodes, nematodes, and trematodes were present in these mammals.

The cestodes and nematodes were each represented by three determinable genera, but the trematodes by only two. Most of the forms in these genera, with the exception of one in the trematodes and one in the nematodes, were not determined to species.

In studying the taxonomy involved in this problem a number of difficulties were encountered. Perhaps foremost among these were the difficulties experienced with cestodes. Many of these decomposed before they could be fixed, and, at times, only fragments of worms were recovered from the hosts, in spite of all precautions, making classification practically impossible. The nematodes and trematodes on the other hand presented few difficulties in technique, with the possible exception of a few which had been dead for some time in the host and had disintegrated to the extent that they were of little taxonomic value.

All of the hosts examined in this investigation were considered to be of non-economic importance, and consisted of representatives in the genera Microtus (Field mice), Peromyscus (Deer mice), Mus (Common mice), and Sorex (Shrews).

These hosts were found to be quite abundant in Spitzer's Slough and presented no difficulties in trapping. Forty-two field mice (Microtus sp.), 39 deer mice (Peromyscus sp.), 16 shrews (Sorex sp.), and three common mice (Mus sp.) were examined from the slough.

The subsequent discussion is confined to a consideration of the worms found in these hosts, and they are discussed under the host genera enumerated.

Genus Microtus - Field Mice

Cestodes, nematodes, and trematodes were found in these field mice. The most common species with respect to numbers was a nematode, Syphacia obvelata (Rudolphi, 1802) Seurat, 1911. This syphacia has a world-wide distribution and is commonly found in rodents. Perhaps one of the most interesting facts about this nematode is its possible public health significance. This was first indicated by Riley in 1919 (22) who received a stool specimen taken from an American-Bohemian child residing in Zamboango, Philippines. This stool contained a male and female Syphacia obvelata. Until this time Syphacia obvelata had been considered a parasite of rodents and had never before been recorded from man. Kofoid and White in the same year found Syphacia-like eggs from soldiers in Camp Travis, Texas. The eggs found by Kofoid and White ranged in length from 60 to 132 micra, which is an unusual variation for eggs within a species. However, Riley in making a comparison found the length of the eggs of his specimen to be within this same range, and so it is possible that Kofoid and White were dealing with Syphacia obvelata.

It is obvious on the basis of the evidence presented that Syphacia obvelata infests man and since Kofoid and White found the eggs in 361 soldiers from 22 states, it is possible that infestations are more general than has been previously suspected. Riley endeavored to justify the fact that so few Syphacia obvelata had been recorded from man by suggesting that the females discharge relatively few eggs as compared to other nematodes, and that possibly egg production is influenced by seasonal variation. The author is inclined to agree with Riley's reasoning but, at the same time, wonders how many physicians or technicians when making a diagnosis of Enterobius vermicularis, the usual pin worm of man, would take the time to measure the eggs, which in this case would be necessary in making a differential diagnosis.

During the past number of years the United States has been considered as an endemic area for Bubonic Plague. As a result of this fact certain public health agencies periodically make a survey of rodents, which are considered to be reservoir hosts for this disease. These surveys involve a macro-examination of the internal organs of rodents to determine the presence of plague. Recently Johnston (14) in a publication described the presence of the worm Heligmosomum brazilense in rodents of Brazil and Australia. He stated that this worm was abundant in the duodenum of these mammals and that, as a result of this, the superficial vessels of some of the viscera and especially those of the peritoneum became highly inflamed, and the general appearance of the body cavity resembled that of plague. It would, therefore, not be impossible to believe that various health department technicians might mistake an infestation of this worm or a very similar worm for plague. Since a worm Longistriata sp., found in the microtus in this investigation resembled the above Heligmosomum in morphology and in its location in the host, it would not be inconceivable to suppose that they would both produce the same pathological picture. If such were the case, then an infection of Longistriata sp. could be misinterpreted for a plague infection when surveys were being made.

A trematode found to be prevalent in microtus was Quinqueserialis quinqueserialis (Barker and Laughlin, 1911). Upon perusal of the literature this worm was found to have an interesting economic status. It was first described by Barker and Laughlin (1911) from Nebraska muskrats and was reported later by Law and Kennedy (1932) in muskrats of Ontario, Canada. From the literary sources thus cited it would appear that Quinqueserialis quinqueserialis was a trematode of wide distribution infesting many of the muskrats throughout the country. From the above statements one might reason that microtus could possibly serve as a reservoir host of these worms, perpetuating and thereby increasing their numbers in muskrats. The pathogenicity of these worms for muskrats has not been established, as yet, although the possibility should be kept in mind.

The other trematodes infesting microtus were of the genus Plagiorchis. Very few of these specimens were found and most of them were immature, which made it impossible to determine species. This genus seemed to have no practical significance other than its presence in this location as a new locality record.

The only cestode identified in microtus belonged in the genus Paranoplocephala. Staining difficulties and the general lack of knowledge of the group prevented its specific identification.

Genus Peromyscus - Deer Mice

The deer mice were infected with only nematodes and cestodes.

There were two species of nematodes, both in the genus Syphacia. One of these was unknown, whereas the other was Syphacia obvelata already discussed.

The cestodes recovered from Peromyscus were in the genus Hymenolepis and Prochoanotaenia. In studying these worms it was determined that the genus Prochoanotaenia had no significance other than its presence, whereas Hymenolepis was considered to have a certain public health importance.

At the present time two species of hymenolepis found in rats are considered to infect man. Whether these species existed in the peromyscus examined cannot be stated, since these worms were not classified as to species because of the difficulties previously mentioned. It should, however, be indicated that if these species do exist in the peromyscus then these mammals would have to be considered of public health importance.

Genus *Mus* - Common Mice

These mice are of importance from the viewpoint of public health since many of them spend a great deal of their life near the rural and cosmopolitan communities of man. This association is important because of the protozoan parasitic fauna concerned, and on the basis of the author's findings it is calculated that when more is known they may be important from the standpoint of the metazoan parasites that they carry. As a result of this association and because of the "filthy" habits of the mice, they have been responsible for the dissemination of many diseases of man. These diseases are too numerous to mention but some of the major catastrophies of man, such as Bubonic Plague and Typhus Fever are carried by the mus or closely related forms in the family Muridae. Recently Tsuchiya (28) published an article dealing with the possibilities of mus transmitting and acting as a reservoir host for

Endamoeba histolytica, the organism causing amoebic dysentery of man. This article proved to be very interesting to the writer since he has often wondered why the rate of amoebic dysentery was as high as 10-15 per cent in this country, when our sanitary facilities were, as a rule, comparatively efficient. The work by Tsuchiya may be a clue to the explanation, since these small mammals were proven to transmit this organism. If the truth were known, such information could possibly be extended to the metazoan parasites.

The three mus examined in this investigation were found to be infested only with nematodes, Syphacia obvelata and the same Syphacia species already recorded from peromyscus, and it should be mentioned again that the former also is a parasite of man.

Genus Sorex - Shrews

The parasites of the genus Sorex are quite different from those found in mice, the probable reason for this being the difference in feeding habits.

The only nematode found in the shrews was of the genus Capillaria. This worm proved to be interesting in that it was the only one recovered from the stomach of any host. Other than its presence it had no significance.

Another interesting feature was the presence in the sorex of numerous metacercaria, or larval trematodes, in the intestine. These larval worms were found in only one host and may have been an accidental infection. This finding, however, is interesting and might be a subject for further study. Their identification was impossible because of their immaturity.

None of the cestodes obtained from this animal were classified for reasons already indicated.

In conclusion it may be stated that the findings indicate the presence of certain helminths in mammals of Spitzer's Slough. The implications of such findings can only be conjectured, since there have been few, if any, actual records of these helminths playing an important economic role in the State of Colorado. Nevertheless, the potentialities exist as previously mentioned. In addition to the economic importance, the contribution in the field of pure science of the above study is not to be minimized. These findings are more or less what would be expected from a study of this nature in the present state of development of the science.

Part Two

Are any of these species of helminths new to science?

In the course of this problem three worms were considered to be possible new species, since they did not fit any available descriptions. These worms occurred in the three nematode genera, Longistriata, Syphacia, and Capillaria.

The remaining worms of problematic status, that were not classified in this investigation, demonstrated either immaturity, poor staining qualities, or some other imperfection, previously mentioned in this chapter, that made speciation impossible. The probability of new species existing in this group is apparent, and upon further investigation might prove a reality. A study of this nature is very exacting and would require a good deal of labor beyond the scope of this problem before any definite conclusions could be made and published.

Although the possibilities of new worm species in rodents do not have a decisive economic value, their addition to pure science is a definite contribution, since this not only contributes new forms to the animal kingdom, but offers a better understanding of the hosts.

The results of Part Two would indicate that there are a number of undescribed helminths in wildlife throughout the country. This fact, in the opinion of the writer, would not, however, suggest the need for intensive classification of unknown worms, since the more important phases of Parasitology, such as Physiology and Ecology are further behind in development than classification. For this reason the author chose a problem designed chiefly as an investigation of the biological aspects of worms, rather than one of classification. Before this investigation had progressed very far, it became apparent that a knowledge of the fundamentals of classification were necessary. In consideration of these fundamentals a greater proportion of time was consumed than in any other phase of the problem.

Part Three

What degree of host specificity is present and what is its significance?

During the past few years an entirely new study in the field of Parasitology has arisen. This study is concerned with host specificity, or the adaptations of a worm for one host and not for another. In regard to this subject several ideas conflict as to the correct meaning of the term "host specificity." Some scientists consider this to be a broad term taking in a large number of parasites which are adapted to some groups of animals and not to others because of mechanical and physiological impossibilities, or the difference in feeding habits of the host, while others consider this term to define only those worms which cannot live in another host because of certain inhibiting physiological factors. The writer is inclined to favor the latter definition, since it is more generally accepted by professional parasitologists.

This phase of the study attempts to point out trends in the specificity of certain worms for the hosts obtained from Spitzer's Slough. Before considering this specificity it was first necessary to understand any differences existing in the mammals examined which might serve to interfere with true specificity. These differences were encountered in only the shrew, whose feeding habits varied considerably from the others. This fact made specificity relationships between this animal and the others impossible; therefore, the parasites of the shrew are eliminated from this discussion.

With the elimination of the shrew, specificity relationships could only be demonstrated in three rodents encountered in this problem. This specificity existed in various degrees, the most specific worms being found in the microtus and peromyscus. These worms were *Quinqueserialis quinqueserialis*, *Plagiorchis* sp., *Longistriata* sp., and *Paranoplocephala* sp. in the former and *Prochoanotaenia* sp. in the latter. They were definitely restricted to the respective host genus. An unknown species of *Syphacia* was second in specificity being found in two hosts, peromyscus and mus. The least specific worm of all was *Syphacia obvelata* which was found in all three genera of rodent.

In consideration of these possible specificities it is interesting to note that, in general, the least specific have a direct life cycle, whereas the more specific have an indirect life cycle. This situation again brings up the possibility of discriminating food habits even among these rodents that are considered by many authorities to have the same general feeding habits.

In conclusion it may be stated that a detailed study of food habits in mice, aside from parasitology, may prove to be very interesting, particularly from an economic standpoint, because of their great abundance. Such a study would probably show that species of mice differ considerably in their economic importance.

Part Four

What is the incidence and relative abundance of types and determinable genera of parasites in these hosts?

This discussion is divided into two separate parts, one dealing with types and the other with genera.

The incidence and relative abundance of worm types found in mammals presented several interesting facts. First and foremost was the occurrence of a large number of nematodes in the genera of host examined. These nematodes were far in excess of the other types found in the genera Microtus, Peromyscus, and Mus. This predominance was not the case, however, in Sorex. Cestodes were much more numerous than nematodes in this genus. The reason for this difference between rodents and shrews is probably based on their contrasting feeding habits. Shrews and other insectivores are carnivorous and the greater portion of their diet consists of insects. Insects are excellent intermediate hosts of cestodes, which would account for the dominance of cestodes in the genus Sorex. In gregarious animals nematodes are usually predominant, since most of their life cycles are direct and afford an easy source of infection to animals consistently exposed to the bodily discharges of their fellows. Such would be the case with rodents which are gregarious, and many of them occupy the same burrows, stumps, and runways. Shrews, unlike the rodents, are solitary.

The incidence and relative abundance of trematodes had very little significance in comparison to those of nematodes and cestodes. However, it should be mentioned that the incidence of trematodes in the genus Microtus was higher than the incidence of cestodes. Since these animals were so heavily infected there is reason to believe that they ingest many terrestrial snails, which, on the basis of known life histories, are the most likely hosts. This serves to emphasize conclusions regarding food habits of mice.

The incidence of infestation for the 100 mammals examined was 80 per cent. This percentage surpassed that of Rankin (21) who found a 56.2 per cent incidence in 32 mammals trapped on a Bunch Grass Canyon slope. Since the rodents in the author's investigation and those of Rankin were trapped in long grass areas, one could possibly conclude that, because of the similar conditions, the results should have been the same. However, such was not the case, the reason for this probably being the greater amount of moisture found in Spitzer's Slough. Lucker (18) pointed out the necessity of moisture for the propagation of round worms and flukes.

Another interesting phase in considering types of helminths found, was the incidence of multiple infections in the genera examined. Many of these animals were infested with not only one, but two or three types of worm.

Of the mice, Microtus, apparently, was more prone to infection with three types or two types of helminths per host, whereas Peromyscus and Mus had the greatest incidence of only one type per host. Sorex was second to Microtus with infections of two or three types of worms per host, and the relative incidence, compared with mice, of those with one type, was smaller.

The incidence and abundance of genera are quite important in that they give several points of comparison between this and similar investigations. They also demonstrate the wide distribution and prevalence of some of the helminth genera encountered in these mammals.

The genus Syphacia proved to have the greatest incidence and relative abundance of any worm genus encountered in this study, showing that it is widely distributed in mammals of Spitzer's Slough. In addition to this local distribution, Syphacia has been recorded by Hall (10) and Johnston (14) as occurring on all of the continents.

This genus was encountered in all the mammal genera examined, except *Sorex*, the reason for this being the probable differences in feeding and social habits of the shrew as compared to those of the rodents, as mentioned earlier in this chapter.

Previous to the writer's study a number of similar problems were investigated and published. Many of these works include a consideration of the incidence of the genus *Syphacia* in the animals examined. Rankin's (21) indicated that only 31 per cent of 131 rodents in Northrup Canyon, Washington were infected with the genus *Syphacia*; Johnston (14) found that only 26 per cent of 73 mus trapped in Australia were infected with *Syphacia*; and Tsuchiya (28) and Fielding (9) observed that only two per cent of 100 rats from Saint Louis and 0.9 per cent of 222 rats of England, respectively, were infected with this genus of nematode.

On the basis of these citations from literature it would follow that the syphacia incidence in the writer's investigation was unusually high, since at no time did the per cent of infection in the reports surpass the incidence of 31 per cent recorded from the mammals of Spitzer's Slough.

Another interesting fact that came to light in this study was the presence of worms of the genus

Hymenolepis in only one genus of mammal, *Peromyscus*. This façt was unusual since hymenolepis has been recorded in literature from all four host genera examined in this investigation.

There are four possible explanations for this limitation: One being the presence of the larval hymenolepis in an intermediate host eaten only by the peromyscus, another being the lack of adaptability of the peromyscus strain to any of the other mammals, the third reason being the greater suitability of peromyscus as a host, and the last being the possible interference of other worms with the development of hymenolepis. The first of these four reasons has been discussed previously in connection with host specificity, part two of this chapter. The second reason could possibly be explained on the basis of Shorb's work (25), who found that some mouse strains of hymenolepis show a greater specificity for mice than rats. This indicates the possibility of specificity of strains. The third reason was substantiated by Larsh (16) who recorded the suitability of peromyscus for hymenolepis infection over its suitability for mus. In connection with the last explanation, Larsh and Donaldson (17), showed the absence of hymenolepis in mus infected with *Nippostrongylus muris*, a small intestinal nematode.

This may account in part for the lack of hymenolepis in microtus, since that animal was infected at times with a small intestinal nematode of the genus Longistriata closely related to Nippostrongylus.

These limited studies show that there are some very interesting aspects concerning hymenolepis infections and the further need for investigation is apparent.

The findings in this study have at present very little practical importance; however, the more information accumulated on the physiological and ecological relationship of worms to their hosts, the more chance we have of solving some of the major problems in connection with our economically important helminths.

During the course of this study many interesting problems appeared. These problems could be considered as recommendations for further study, and are as follows:

1. The complete life cycle of Quinqueserialis quinqueserialis could be discovered since so many of these worms were recovered from a host confined to a relatively small area.

2. Further investigations could be made on worm distribution among small animals in the major ecological regions of Colorado. Investigations of this nature could be compared to the present study and conclusions reached as to the distribution of types and

genera throughout the state.

3. An investigation could be made relative to host specificity, since host specificity does exist in the animals examined, and an adequate supply of cheap laboratory animals could be obtained from the slough.

4. Further problems in taxonomy could be devised, since three probable new species existed in the mammals examined, and some of the groups in which these belong are sadly in need of revision.

5. Better techniques for mammal examination could be devised since a number of worms were probably not collected from their hosts, due to the faults of the techniques used.

6. The relationship of these mammals to public health could be further investigated, by making a study of the susceptibilities of these mammals to human parasites.

7. A problem similar to the one just completed by the author could be done for ectoparasites and parasitic protozoa.

Chapter VI

SUMMARY

Until recently parasitologists have dealt almost exclusively with the taxonomy of parasites, and comparatively little work has been done in the physiological or ecological phases of the science. The importance of these latter phases has been repeatedly stressed by prominent men in the profession, because of their importance to public health, veterinary medicine, and pure science. As a result of the need a number of investigations of this nature have developed within the past few years. Perhaps foremost among these are the surveys of parasites in mammals of certain ecological regions. Extensive surveys also have been made for fishes which have proved to be important in a number of ways. These investigations are outstanding because they provide information relative to the possibilities of wildlife acting as reservoir or intermediate hosts for parasites pathogenic to man, domestic and game animals. Vast amounts of information important to pure science, such as contributions to ecology, invertebrate zoology, and many other fields of zoology, are derived from such investigations.

The writer's investigation was primarily an ecological problem, similar to the types mentioned above. This study was concerned with the identification, incidence, abundance, relative abundance of types and genera, and host specificity of worms removed from 100 mammals of Spitzer's Slough, a typical northern Colorado marshland. In the course of this investigation considerable information was obtained pertaining to parasites of man and game animals. Other information of a taxonomic or biological nature was secured and constitutes a contribution to pure science.

As a basis for the study 100 mammals were trapped at random from Spitzer's Slough. The mammals taken were in the genera *Microtus* (Field mice), *Peromyscus* (Deer mice), *Mus* (Common mice), and *Sorex* (Shrews).

The genera and determinable species of helminths present in mammals of Spitzer's Slough

Nine different worms were present in the mammals of Spitzer's Slough and were determined to be Syphacia obvelata, *Quinqueserialis quinqueserialis*, *Longistriata* sp., *Plagiorchis* sp., *Syphacia* sp., *Hymenolepis* sp., *Paranoplocephala* sp., *Capillaria* sp., and *Prochoanotaenia* sp.

When consideration was given to the importance of these worms it was found that four of them, Syphacia obvelata, Quinqueserialis quinqueserialis, Longistriata sp., and Hymenolepis sp., might have a possible public health or economic significance. Syphacia obvelata, Hymenolepis sp., and Longistriata sp. could be important from the public health viewpoint, since the first two mentioned possibly infect man, and the last one probably produces a pathological condition in rodents, similar to that produced in plague. Therefore, in cases of mistaken identity, plague survey results on rats often undertaken by public health organizations could be in error. Quinqueserialis quinqueserialis was interesting from an economic standpoint because this parasite is well known from the muskrat and in this investigation was observed to be abundant in microtus.

Worms new to science

Three worms were considered to be new to science, Syphacia sp., found in the peromyscus and mus, Capillaria sp., in the sorex, and Longistriata sp., in the microtus. These were established as new helminths on the basis of non-conformity with described species of their genera.

Host specificity

In this investigation host specificity was considered to mean the physiological adjustment of a worm for one host and not for another. To determine specificity or physiological preference of a worm, it would be imperative that the hosts considered would have to be, in general, morphologically similar and have the same feeding habits. Such a condition prevailed in the mice examined, which made host specificity comparisons possible.

It was determined that Quinqueserialis quinqueserialis, Plagiorchis sp., Longistriata sp., and Paranoplocephala sp. found in the microtus and Prochoanotaenia sp. found in the peromyscus were the most host specific since they occurred only in the hosts mentioned respectively. The least specific ones were Syphacia obvelata and Syphacia sp., the former being found in microtus, mus and peromyscus and the latter in peromyscus and mus. Since the more specific worms had, in general, indirect life cycles and those least specific had direct cycles, there remains the possibility that a difference in food habits rather than true specificity accounted for the distribution of worms in these mice. If such is the case, then very little host specificity was demonstrated.

Incidence and relative abundance of worm types and genera

The overall incidence of infection for the mammals examined was 80 per cent, and the average number of worms was 15.39 specimens per host, and of these, 13.28 were nematodes, 1.09 cestodes, and 1.02 trematodes. The nematodes prodominated in the mus, peromyscus, and microtus, but cestodes were dominant in sorex. This difference was probably due to the gregarious habits of the mice and the solitary habits of the shrew. A gregarious animal would be more prone to infection with nematodes, since these worms generally have a direct life cycle and could easily be transmitted from host to host through bodily discharges. The solitary animal would not be in constant contact with these discharges, which would account for the decreased number of nematodes. On the other hand, an insectivorous animal, such as the shrew, would be more prone to cestode infection since these worms are many times transmitted by insects, which constitute the greater part of its diet.

The predominant genus of worm in this study was Syphacia, a helminth genus of wide distribution, species of which have a direct life cycle, and would be readily acquired by gregarious mice. The other worm genera encountered in this study demonstrated a low incidence and no relative abundance because each genus was represented by a single species. One of these genera, Hymenolepis, was restricted to the peromyscus, an interesting fact since it is recorded in literature as infecting all of the hosts examined in this study.

Upon further investigation of literature concerned with the physiology of this helminth it was found that various strains of hymenolepis existed which preferred certain hosts and, also, that infections of the host by certain nematodes would exclude the possibility of infection with hymenolepis. These facts were considered to possibly explain the preference of hymenolepis for the peromyscus and no other hosts.

A P P E N D I X

HN	H				Nematoda							umw			uiw			Cestoda							Trematoda						
	m	P	m	S	nn	RS	AI	SO	SS	LS	CS	C	Si	St	C	Si	St	nc	RS	AI	HS	PS	AS	W	nT	RS	AI	99	PL	DD	LF
69	/				3		/	3♀										0							0						
70				/	0													5	/					5	0						
71				/	0													0							0						
72				/	0													0							0						
75	/				5		/	3♀							2			0							0						
76		/			0													0							0						
77		/			0													0							0						
79				/	0													0							0						
80				/	1		/								1			16	/					16	m					/	
81				/	0													0							0						
82	/				6		/	2♀							4			2	/	/				2	0						
83		/			0													1	/	/				10	0						
84	/				22	/		3♀										1	/	/				1	5	/		5			
85	/				0													1	/	/				1	0						
86	/				0													0							1	/		1			
87				/	0													0							0						
89		/			20	/			8♀									0							0						
90		/			2		/	2♀										2	/		2				0						
91		/			0													1	/				1		0						
92		/			15	/									10			0							0						
93		/			12										12			0							0						
94		/			202	/			7♀4♂						12			0							0						
95		/			23	/			10♀12♂									0							0						
96		/			1		/								1			0							0						
97	/				47	/		3♀3♂										0							0						
98		/			5				2♀						3			0							0						
99		/			0													0							0						
100		/			15	/			1♀1♂						3			1	/					1	0						
101	/				0													0							6	/		6			
102				/	0													10	/					10	0						
103	/				2		/	2♀										0							3	/		3			
104				/	0													7	/					7	0						
105		/			116	/			4♀2♂									0							0						
106		/			10	/			3♀						5			0							0						
107	/				2		/	1♀		1♀								31	/						31	/		10			
108		/			34	/			7♀1♂						2			0							0						
109	/				3		/	3♀										0							0						
110	/				0													0							5	/		5			
111	/				0													0							1	/		1			
112	/				3		/	3♀										0							5	/		5			
113	/				2		/			1♀					1			0							0						
114	/				4		/	3♀							1			0							0						
115	/				0													1	/					1	6	/		6			
116		/			26	/			4♀						6			0							0						
117	/				0													0							1	/		1			
118	/				1			1♀										0							0						
119		/			112	/			3♀2♂						5			0							0						
120	/				4			3♀							1			0							2	/		2			
121	/				3		/	1♀							2			1	/					1	0						
122		/			17	/			3♀						2			0							0						
123		/			30	/			10♀									0							0						
124		/			24	/									10			0							0						
125		/			15	/			2♂						8			0							0						
127	/				0													0							0						
128		/			14	/									10			0							0						
129		/			1		/								1			0							0						
130	/				1		/	1♀										0							12	/			4		
131	/				1			1♀										0							0						
132		/			104	/		6♀							2			0							0						
134	/				0													0							3	/		3			
135		/			0													0							0						
136	/				4		/	2♀		1♀1♂								0							0						
137				/	0													0							0						
138		/			3		/		1♂						2			0							0						
139				/	14		/				13♀				1			0							0						
140				/	5		/				3♀				2			6	/					6	0						
141	/				1		/								1			2	/					2	0						
142	/				3		/	3♀										0							1	/		1			
143	/				0													0							0						
144	/				0													0							0						
145	/				18	/		5♀2♂							3			1	/					1	0						
146				/	0													0							0						
147		/			7		/		2♂						2			0							0						
148		/			4		/								4			0							0						
149		/			0													0							0						
150	/				1		/	1♂										0							2	/		2			
151	/				3		/	2♂							1			0							2	/		2			
152		/			36	/			1♀1♂						8			0							0						
153		/			0													0							0						
154		/			0													0							0						
155				/	0													18	/					18	0						
156	/				4		/	2♀										1						1	0						
157	/				4		/	4♀										2	/					2	0						
158	/				6		/	4♀							2			0							0						
159			/		28	/			4♀						1			0							0						
160	/				2										2			2	/					2	16	/		16			
161		/			0													0							0						
162		/			7		/		5♀						2			0							0						
163		/			0													0							0						
164				/	4		/				4♀							12	/					12	0						
165	/				2			2♀										0							0						
166	/				2			1♀							1			0							0						
167		/			0													2	/		2				0						
168		/			130	/			5♀						9			2	/				2		0						
169		/			6		/								6			0							0						
170			/		0													0							0						
171	/				1										1			1	/			1			0						
172	/				21	/									10			2	/				2		0						
173		/			0													0							0						
175		/			0													0							0						

Key

HN = Host number
H = Host
m = Microtus
P = Peromyscus
m = Mus
S = Sorex
nn = number of nematodes
RS = Random sample examined
AI = All examined
SO = Syphacia obvelata (location - cecum)
SS = Syphacia species (location - cecum)
LS = Longistriata species (location - small intestine)
CS = Capillaria species (location - stomach and small intestine)
umw = unidentified mature worms
C = cecum
Si = Small intestine
St = Stomach
uiw = unidentified immature worms
nc = number of cestodes
HS = Hymenolepis species (location - Small intestine)
PS = Paranoplocephala species (location - Small intestine)
AS = Prochoanotaenia species (location - Small intestine)
W = unidentified (Small intestine)
99 = Quinqueserialis quinqueserialis (location - cecum)
nT = number of trematodes
PL = Plagiorchis species (location cecum)
DD = worms discarded because of decomposition
LF = worms lost in fixing process
♂ = male
♀ = female

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