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STUDIES ON THE FEEDING RELATIONSHIPS OF LEECHES (ANNELIDA: HIRUDINEA) AS NATURAL ASSOCIATES OF MOLLUSKS*

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ABSTRACT

This study was designed to determine the degree of host-specificity of leeches of the family Glossiphoniidae, genera *Helobdella*, *Glossiphonia*, and *Marvinmeyeria* in their relation to freshwater mollusks in southern Michigan. Four families and seven species of operculates, three families and nineteen species of pulmonates, and one family of three species of sphaeriacean clams were examined for leeches over a two-year period. Information is also provided on other parasites and symbionts found on mollusks infested with particular species of leeches. Leeches infesting mollusks within several different habitats, such as lakes, ponds, woodland pools, creeks, and roadside ditches are compared.

In the various habitats the habits of both groups coincide. The sites or organs inhabited by the several species of leeches infesting specific snails were mainly the mantle cavity, above and below the mantle, and the kidney. The preferred sites within the snails appeared to be above and below the mantle, but some selection occurred among the various leech species. Evidence was gathered on whether leeches serve as regulators of snail populations under natural conditions. The degree of multiple parasitism and its effect on snails indicate that the mollusk hosts are far more tolerant than anticipated. Many snails infested carried only a single leech; it is possible that snails with multiple infestations did not survive. However, the majority of the multiple infestations were found on the larger pulmonates. Serological tests of the gut contents from certain free-living leeches showed that some species had fed on mollusks and others had not.

An extended literature search a. to the world-wide distribution of leeches revealed that, although the information available is extensive, all too little is known regarding the parasitism or predation of leeches on mollusks. Thus, information, as it relates to the possibility for biological control of snails by leeches, reveals that the leeches studied are not especially promising as organisms for this purpose.

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INTRODUCTION

The Leeches

Whereas leeches (Phylum Annelida, Class Hirudinea) are world-wide in distribution (Soós 1970 for the world and Klemm 1972b, Sawyer 1972, and Davies 1973 for North America) in terms of taxonomic numbers they are few as compared with some of the other major invertebrate groups. The phylum consists of three orders (Rhynchobdellida, Gnathobdellida, and Pharyngobdellida - J.P. Moore, 1959). Among these orders the known leeches in the world are represented by 10 families, 97 genera, approximately 375 species, and 16 subgenera (Soós 1970). A superficial survey of the orders would seem to indicate a homogeneous assemblage since all leeches have structural similarities and are built on the same fundamental annelid plan. There are freshwater, terrestrial, and marine forms, but nearly three quarters of the world's genera are found in freshwater and terrestrial habitats.

Leeches are highly specialized predatory or parasitic annelids with terminal suckers serving for attachment, locomotion, and feeding. They are said to have a wide variety of food habits, but very little is known about their specific feeding requirements. Leech abundance and distribution, however, are regulated by the availability of food organisms. The order Rhynchobdellida includes leeches that suck blood and juices or eat the soft tissues of their prey by means of a protrusible proboscis. This order contains no terrestrial or carnivorous forms and consists only of freshwater and marine species. The members are strictly parasitic (Harding and J.P. Moore 1927), but Croll (1968) cited cases of parasites killing their hosts outright, notably among leeches, and one might consider such a leech a predator rather than a parasite. In this study, parasite and predator are placed in one category under 'predation,' unless a narrow distinction must be made between the two.

The proboscis, a feeding organ, serves as an important characteristic in this group. It is an adaptation of the pharynx which has become highly muscular, free, and protractile and is so very capable of being thrust through the small oral opening in the leech's anterior sucker and into the tissues of its host. Few leeches of this order are large and none reaches the formidable proportions attained by certain predaceous leeches of the orders Gnathobdellida and Pharyngobdellida. Adults may range from 5 to 20 mm in length, and since they are innocuous to mankind, they generally do not attract the attention of the ordinary observer.

Two important freshwater families of this order are the Piscicolidae (facultative fish parasites) and Glossiphoniidae. The latter are said to possess a wide range of hosts and supposedly have somewhat more catholic tastes or have been reported to have unknown feeding habits.

The order Gnathobdellida includes the jawed leeches, usually with dentition and without a proboscis; these are the typical leeches. They are fully adapted to predaceous, sanguivorous, and truly parasitic habits of feeding; with few exceptions they are the largest forms as well as those most intimately affecting man and wild and domestic animals. As far as now known, they are freshwater or terrestrial; none is truly marine. Most species as adults range from two to six inches long when normally extended. In this order, only a few species of the family Hirudinidae were reported occasionally to feed on invertebrates. Many are important blood sucking parasites of man and domestic animals. Some genera tend to have the jaws and dentition reduced or absent and they have become macrophagous in their feeding habits.

The order Pharyngobdellida is made up of leeches without true jaws, dentition, or proboscis. These structures are replaced by a strong muscular, sucking pharynx with which whole organisms are devoured, and these leeches have extreme modifications for predaceous life. The family Erpobdellidae has several species that have been reported to feed on invertebrates, including mollusks; in size the adults range from 10 to 30 mm in length.

Rhynchobdellid leeches have not hitherto attained notoriety as dangerous parasites, and, as already noted, they rarely draw blood from man. Nevertheless, they deserve close investigation to ascertain their feeding requirements and to determine whether they play a part in transmission of diseases of economic importance (Robertson 1909, Barrow 1953, 1958, Mann 1962, Becker 1964, Becker and Katz 1965, Richardson and Hunt 1968, Soltys and Woo 1968, Woo 1969a, 1969b, 1969c, and Botzler *et al.* 1973). It is also important to ascertain their importance as biological control agents of snail populations under natural conditions, especially those of the family Glossiphoniidae. Reductions of snails which are intermediate hosts in trematode cycles would affect the occurrence of trematodes which infect man and other animals, including fish (Hoffman 1970).

The Molluscan Hosts

Freshwater mollusks include univalves (snails) and bivalves (clams or mussels) and they are among the most conspicuous animals constituting the largest invertebrate phylum after the arthropods. More than 80,000 living species have been described. Most of the families (Taylor and Sohl 1962, Te 1972) are represented in nearly all parts of the world. Almost every conceivable type of freshwater environment from the smallest pond and stream to the largest lake and river has characteristic populations of snails or mussels.

The omnipresence of mollusks has made them available to man as sources of food. This relationship is secondary and incidental when compared with the role of mollusks as carriers of parasitic diseases of man and other vertebrates. As vectors of human diseases snails affect the lives of millions of people. They do not attack man directly but are important intermediate hosts for flukes (Trematoda) or worms that cause parasitic diseases of vertebrates, including man (Malek 1961). All known trematodes require molluscan intermediate hosts in part of their life cycle. Some use additional intermediate hosts, such as crustaceans, fishes, frogs, and leeches. Certain blood flukes cause schistosomiasis in man (Malek 1961) and others invade several species of birds and mammals. Man's cosmopolitan distribution has exposed him to these and many other parasites. Also, the changes man has made in his environment have enabled many parasites and their intermediate hosts to increase enormously. It is generally conceded that schistosomiasis has now replaced malaria as a major deterrent to progress in many underdeveloped regions of the world, especially in North Africa (van der Schalie 1960); the alarming increase in schistosomiasis appears to be due to man's manipulation of the aquatic environment. Because of the rapid spread of human blood flukes, it is desirable to find some means of biological control in endemic regions. Certain leeches are known to feed on snails. The feasibility of using these predators for biological control is still in doubt. This study was undertaken in part to learn whether leeches can serve this end.

LITERATURE REVIEW

A review of the literature indicates that several papers have reported that certain leeches in the family Glossiphoniidae and a few species in the families Erpobdellidae and Hirudinidae feed on or devour mollusks. Their mode of feeding is either predatory, parasitic, or both. Some other leeches are associated with aquatic insects, freshwater crustaceans, mollusks, aquatic annelids, frogs, salamanders, turtles, fishes, birds, and mammals.

More specifically, the studies on leech-mollusk feeding relationships were of two general types, survey and experimental. The surveys may include known leeches from unidentified mollusks, known mollusks with unidentified leeches, or both the leeches and mollusks were identified. Such studies are those of the following investigators: Moquin-Tandon 1846, Verrill 1874, Jacquet 1885, Castle 1900, J.P. Moore 1901, 1908, 1920, 1923, 1924a, 1924b, 1929-30, 1939, Harding 1910, Nachtrieb, Hemingway, and Moore 1912, Gee 1913, Elliott, 1917, Annandale, Prashad, and Amin-ud-din 1921, Degner 1921, Henson 1922, Harding and Moore 1927, Wrede 1927, Richardson 1921, Bere 1929, Miller 1929, 1937, Juga 1931, Krull 1931, Whitehead 1935, Antrum 1936, Boycott 1936, Herter 1929, 1936, Pawlowski 1936, 1955, Volz and Fromming 1936, Wesenberg-Lund 1937, Bruun 1938, Richardson 1947, Mathers 1948, 1954, 1963, Dorier 1951, Pennak 1953, Mann 1953a, 1953b, 1962, 1964, Michelson 1957, Dobrowolski 1958, Harry and Aldrich 1958, Malek 1958, Wisniewski 1958, Grasse 1959, Hynes 1960, Karassowska and Mikulski 1960, Keith 1959, Klimek 1960, Paloumpis and Starrett 1960, Lukin 1962, Moore 1964, 1966, Okland 1964, Soós 1964, 1966, 1967a, 1967b, 1967c, 1969, Sikorowa 1965, Taube 1966, Sapkarev 1967, Sawyer 1967, 1968, 1972, Chemberlin 1968, Janiszewska and Zmijewska 1968, McDonald 1969, Kopenski 1969, Klemm 1970, 1972a, Herrmann 1970, Wilkialis 1970b, Crewe and Cooper 1973, and Gale 1973. All of these authors indicated that certain leeches were enemies of mollusks under natural conditions or in aquaria and that the leech-mollusk relationship may be either of the host-parasite type or of the prey-predator type.

The foremost investigators of the survey type of leech-mollusk association are Wilkialis 1964, Gruffydd 1965a, Hatto 1968, Sarah 1971, and Klemm 1973. Wilkialis (1964) investigated the ecology and biology of the leech, *Glossiphonia heteroclita hyalina* (O. F. Müll.), living on various snails in Poland. He concluded that this leech occurred abundantly inside snails in late autumn for shelter and during summer because of their need for food. Gruffyd (1965a) in England and Hatto (1968) in Wales also studied a closely related species of leech, *Glossiphonia heteroclita* (L.) which infested snails. This leech lived as a facultative parasites on snails during winter and became free-living during its breeding season; the life-histories of the leech and snail were closely synchronized.

Sarah (1971) in North America studied *Helobdella lineata* Verrill, *H. papillata* (Moore), and *Glossiphonia complanata* (L.) from two species of pulmonate snails in a creek in Michigan where they seemed to attach themselves selectively to certain snails. Later Klemm (1973), also in Michigan, determined the incidence of a parasitic leech (*Marvinmeyeria lucida* Moore) and two cercarial types in estivating snails (*Stagnicola exilis* Lea) in a woodland pool.

Some of the important experimental investigations are those of Guibe 1936, Brumpt 1941, Chernin, Michelson, and Augustine 1956, Waffle 1963, Wilkialis 1964, McAnnally and Moore 1965, 1966, and Hatto 1968. They showed that certain leeches attack certain snails by sucking snail blood or eating the soft animal tissues while both are confined in the same aquarium. There may have been some discrimination by the leech when given a choice of mollusk species, but certain leeches usually attacked snails without discrimination after a period of fasting. Those studies generally emphasized the prey-predator relationships. These associations and others will be considered in the appropriate sections of this paper.

Summary of all molluscan hosts cited from the literature and this study

A comprehensive review of the published literature on mollusk-leech association (Table 1) revealed that several species of leeches are worldwide in distribution while others are limited to North America. Table 1 is a compilation of the published literature and this study of all known leeches in the family Glossiphoniidae and those leeches in the families Erpobdellidae and Hirudinidae reported to feed on molluscan hosts. This study and the recent investigation of Sawyer (1972) showed some of the earlier reports to be inaccurate. Only accounts with strong proof that the leeches have specific feeding habits should be considered in discussing leech feeding behavior. In addition, Soós (1970) listed 21 genera and more than 140 species of leeches in the family Glossiphoniidae, but for many of them the diets are unknown or questionable or not properly recorded. Also, some species listed in Table 1 appear to have specific molluscan hosts under natural conditions and in aquaria or both. In addition, many species of leeches in the families Erpobdellidae and Hirudinidae have been reported with unknown feeding requirements even though their trophic dynamics do not seem very complex. Only those leeches in these two families which have been reported to feed on mollusks are included in Table 1. Any species listed in Table 1 reported to feed on a specific animal or animal group that may be questionable are shown with a question mark. For other animals which North American leeches feed on, see Klemm (1972a) and Sawyer (1972). The distribution of all North American leeches is given in studies by Klemm (1972b), Sawyer (1972), and Davies (1973).

The feeding behavior of leeches is generally accepted as a form of predation. Nevertheless, whether their position in the trophic scale is specifically that of predator, parasite, or scavenger is often questionable (Croll 1968 and Mann 1962). It is generally accepted that predators kill or eat their prey; parasites may feed on their hosts but without killing them; and scavengers feed on dead organisms.

Leeches in the family Glossiphoniidae have a proboscis and are adapted for sucking blood. In the process they may suck all the body fluids of a snail and they may even devour all the tissues of the animal as well. This process is clearly predation. However, young specimens of the same leech species were observed to live for a period inside its molluscan host, probably taking only an occasional blood meal. This mode of life may reasonably be called parasitism. But supporting evidence in the literature (Elliott 1917, Krull 1931, Antrum 1936, Guibe 1936, Bennike 1943, Chernin *et al.* 1956, Harry and Aldrich 1958, Waffle 1963, Moore 1964, McAnnally and Moore 1965, 1966, Moore 1966, Hatto 1968, Klemm 1972a) also indicates that the leech-mollusk association under laboratory conditions is a predator-prey relationship. However, strong evidence in the literature (Bennike 1943, Wilkialis 1964, Gruffydd 1965a, Hatto 1968, Sarah 1971, Klemm 1973) also shows that under natural conditions the relationship may be a parasite-host association. Experimentally and under natural conditions several investigators (Wilkialis 1964, Moore 1964, Gruffydd 1965a, Hatto 1968, Sarah 1971, Klemm 1972a, 1973) have demonstrated that certain leeches appear to have a food preference for specific mollusks when they are available.

In nature two patterns, parasitism and predation, exist. In both one species obtains food at the expense of another; the method has fundamental importance to the predator or the parasite. The processes are basic to the way food is obtained in the chain above the autotrophic level. As an example, no functional difference exists between an herbivore eating ('preying upon') a plant and a carnivore killing ('preying on') an animal. An often accepted difference between predation and parasitism, generally speaking, is that a predator is usually larger than its prey and attacks its prey from without, while a parasite is usually smaller than its host and consumes it from within. Some believe that since the predator-prey interaction causes a reduction in the prey population, predation is detrimental to it. Such reasoning led to the concept of 'biological control' which seems to have succeeded only with a few terrestrial organisms. Unfortunately with respect to this idea, coevolution among species within natural ecosystems, both terrestrial and aquatic, leads to balanced populations within a given community so that population sizes, whether predator-prey or parasite-host, become interregulated by feedback mechanisms that effectively control the population of both. Hence, they will not drive each other to extinction.

Of the three families, Glossiphoniidae, Hirudinidae, and Erpobdellidae (Table 1), the glossiphoniids include most of the leeches that feed on snails. In this table are included leeches that have generally and specifically been reported as feeding on mollusks, as well as those whose feeding habits are unknown although the are grouped in this family which feeds on mollusks. Leeches which appeared questionable are so indicated; within these families only the North American genera and species will be discussed here.

(Text continued after Table 1, next page *et seq.)*

TABLE 1. Review of the literature and the present study, showing leeches in the family Glossiphoniidae and those other leeches associated with molluscan hosts.

HOSTS AND LEECHES	LEECH DISTRIBUTION
‘**Family Glossiphoniidae**	
Actinobdella Moore (3)	N. America
Fishes, turtles (?)	
Ancyrobdella Oka (1)	Japan
Unknown	
Baicaloclepsis Lukin & Epshtein (2)	Lake Baikal
Unknown	
Batracobdella Viguier (19)	World-wide
Mollusks (?), Crustaceans, fishes, amphibians	
B. kasmiana (Oka)	Japan, China
Mussels (?): *Dipsas* sp., *Anodonta* sp.	
B, michiganensis Sawyer	U.S.A. (Michigan)
Unknown	
B. paludosa (Carena)	Europe, Afghanistan, China, Japan, N. America
Snails (?), tadpole *(Pelobates fuscus)*	
B. phalera (Graf)	N. America
Snails (?), fishes	
B. picta (Verrill)	N. America
Snails (?), amphibians	
B. reticulata (Kaburaki)	India, Malay Peninsula
Anodonta (?)	
B. tricarinata (Blanchard)	S, C, E Africa
Spatha wahlbergi Krauss	
Boreobdella Johansson (1)	N & C Europe, Siberia
Snails	
B. verrucata (Fr. Müll.)	Europe, except S. Europe
Aplexa hypnorum (L.)	
Bythinia tentaculata (L.)	
Lymnaea auricularia (L.)	
L. ovata Draparnaud	
L. palustris O. F. Müller	
L. stagnalis (L.)	
Paludina fasciata (O.F. Müll)	
Planorbis albus (O.F. Müll.)	
**P. corneus* (L.)	
**P. nitidus* (O.F. Müll.)	
**P. planorbis* (L.)	
Sphaerium corneum (L.)	
Valvata piscinalis (O.F. Müll.)	
Dismobdella Oka (1)	Brazil
Unknown	
Glossiphonia Johnson (11 + 3)	World-wide
Aquatic invertebrates, primarily snails, crustaceans, insect larvae, worms, oligochaetes	
G. annandaleri Oka	India
Tai intha Annandale	
G. complanata (L.)	Holarctic Region: (Argentina?), Europe, N. America, India, Zaire
**Bythinia tentaculata* (L.)	
Gyraulus parvus (Say)	
*‘*Helisoma anceps* (Conrad)	
H. campanulatum (Say)	
*‘*H. trivolvis* (Say)	
**Lymnaea reflexa*	
Lymnaea sp.	
**L. stagnalis* (L.)	
**Lampsilis siliquoidea* (Barnes)	
Hydrobia jenkinsi Smith	
**Promenetus exacuous* (Say)	
**Physa fontinalis* Tayler	
**P. gyrina* Say	
**P. heterostropha* Say	
**P. integra* Haldeman	
Pisidium sp.	
**Planorbis corneus* (L.)	
**P. vortex* (L.)	
Sphaerium simile Say	
*‘*S. transversum* (Say)	
G. cruciata Bhatia	India
Gastropods	
G. heteroclita (L.)	Holarctic Region: Europe, N. America, India, C. & E. Africa
**Ancylus sp.*	
**Bythinia tentaculata* (L.)	
Enchytraeus albidus	
**Leptolimnaea glabra* (Müll.)	
**Lymnaea peregra* Müll.	
**L. stagnalis* (L.)	
Pachylabra maura Reeve	
**Physa fontinalis* (L.)	
P. gyrina Say	
P. heterostropha Say	
**Planorbis corneus* (L.)	
**P. contortus* (L.)	
**P. nitidus* O.F. Müll.	
**P. umbilicatus*	
G. var. hyalina (O. F. Müll.)	Europe
**Lymnaea stagnalis* (L.)	
**Planorbis corneus* (L.)	
**Radix ovata* Draparnaud	
**Stagnicola palustris* (Müller)	
G. intermedia Goddard	Australia, Tasmania
Bythinia australis	
G. novaecaledoniae Johnson	New Caledonia
Bythinia australis	
G. swampia (Bosc)	U.S.A. (Carolinas)
Unknown (snails)	
G. tasmaniensis Ingram	Tasmania
Snails	
G. weberi Blanchard	India, Burma, Indonesia, (?Uganda)
Ampullaria sp.	

‘ Hosts are shown in roman and italics; leeches in boldface. C: central, E: eastern, N: northern, S: southern.
Following generic names of leeches, the numbers of species and subspecies (indicated by the +) given in parentheses.
* Indicates snail was eaten by a leech only under laboratory conditions.
*‘ Indicates the snail was eaten by a leech under laboratory and natural conditions.
All others under natural conditions.

Lymnaea sp.	
Paludina sp.	
Viviparus oxytropis Benson	
Haementaria de Fillippi (5)	Neotropical Region
Homoiothermic vertebrates, also man	
Helobdella Blanchard (31)	World-wide, excepting Notogaea
Aquwtic invertebrates, primarily insect larvae, crustaceans, mollusks, tadpoles (?), oligochaetes, **Bulinus truncatus*	
H. elongata (Castle)	
Snails (?), insect larvae, oligochaetes	
H. fusca (Castle)	N, C, and S America
**Australorbis glabratus* (Say)	
*'*Helisoma anceps* (Conrad)	
*'*H. trivolvis* (Say)	
**H. campanulatum* (Say)	
Lymnaea reflexa (Say)	
L. stagnalis (L.)	
*'*Promenetus exacuous* (Say)	
*'*Physa gyrina* Say	
P. integra Haldeman	
P. parkeri 'Currier' De Camp	
Pisidium virginicum (Gmelin)	
H. stagnalis (L.)	Cosmopolitan; unknown from Notogaea
Mollusk (?), insect larvae, oligochaetes, crustaceans	
Asellus aquaticus (L.)?	
Cincinnatia emarginata (Küster)	
**Physa gyrina* Say ?	
**P. integra* Haldeman ?	
**Lymnaea reflexa* (Say) ?	
Promenetus exacuous (Say)	
Planorbis albus O.F. Müll. ?	
**Pisidium* sp. ?	
*'*Sphaerium transversum* (Say)	
Helobdella lineata (Verrill)	N, C, S. America
*'*Helisoma anceps* (Conr.)	
*'*H. campanulatum* (Say)	
*'*H. trivolvis* (Say)	
*'*Physa gyrina* Say	
H. papillata (Moore)	N. America
*'*Helisoma anceps* (Conr.)	
*'*H. parkeri* 'Currier' DeCamp	
*'*H. trivolvis* (Say)	
**H. campanulatum* (Say)	
Lymnaea megasoma Say	
Physa gyrina Say	
Gyraulus parvus (Say)	
Stagnicola elodes (Say)	
H. punctatolineata Moore	Puerto Rico, U.S.A.
**Australorbis glabratus* Say	
**Planorbis corneus* (L.)	
H. transversa Sawyer	U.S.A. (Michigan)
Unknown (snails)	
Hemiclepsis Vejdoysky (5)	Palearctic Region: India, Kashmir, Japan, Sumatra
Fishes, amphibians, rarely mollusks	
H. marginata (O.F.Müll.)	Palearctic Region: Europe, India, Japan, China
Mollusks (?)	
Lamellidens sp. (?)	

H. japonica Oka	Japan
Mollusks (?)	
Marvinmeyeria Soos (1)	North America
Snails	
M. lucida (Moore)	North America
Aplexa hypnorum (L.)	
Gyraulus parvus (Say)	
Helisoma trivolvis (Say)	
**Promenetus exacuous* (Say)	
Planorbula armigera (Say)	
**Physa heterostropha* (Say)	
P. gyrina Say	
Lymnaea emarginata Say	
Stagnicola elodes (Say)	
S. exilis (Lea)	
Oculobdella Antrum (1)	Mexico
Aquatic snails	
O. socimulcensis (Caballero)	Mexico
Physa osculans Haldeman	
Oligobdella Moore (4)	U.S.A., Brazil, Japan, Soviet Union
Amphibians	
Oligoclepsis Oka (1)	Japan
Unknown	
Parabdella Antrum (5)	Ethiopian Region: Ceylon, India, China, India, Thailand
Amphibians, Reptiles	
Paraclepsis Harding	
Turtles, freshwater crustaceans	
Paratorix Lukin & Epshtein (1)	Lake Baikal
Unknown	
Placobdella Blanchard (31)	World-wide
Amphibians, reptiles, fishes	
P. gracilis Blanchard	Java, India
Lymnaea acuminata (?)	
Paratelphusa sp. (?)	
P. montifera Moore	N. America
Mussels (?), Snails (?), fishes	
P. ornata (Verrill)	N. America, Mexico, Japan (Lake Biwa)
Snails (?), Turtles	
P. parasitica (Say)	N. America
Snails (?), *Taia shanensis* ?, turtles	
Podoclepsis Dequal (1)	Ecuador
Unknown	
Theromyzon Philippi	World-wide, except the Notogaea
Birds, reptiles, mammals	

Family Hirudinidae

Macrobdella Verrill (3)	N. and C. America
Sanguivorous (Vertebrates)	
M. decora (Say)	N. America, Mexico
Snails (?), vertebrates, also man	
Haemopis Savigny (7)	Western Palearctic
(=*Mollibdella, Bdellarogatis., Percymoorensis* Richardson)	
Macrophagous, oligochaetes, insect larvae	
H. grandis (Verrill)	N. America
Snails, clams, *Lymnaea stagnalis* (L.)	

Physa spp.
Helisoma campanulatum (Say)
Campeloma sp.
Amnicola sp.
Sphaerium spp.

H. plumbea Moore Macrophagous (Snails?)	N. America
H. sanguisuga (L.) Macrophagous (Mollusks?)	W. Palearctic Region
H. marmorata (Say) Moore Snails, pelecypods, slugs, *Physa* spp.	N. America
H. terrestris (Forbes) (=*H. lateralis* (Say) Moore) Macrophagous (snails?)	U.S.A.
H. lateromaculatum Mathers Macrophagous (mollusks?)	U.S.A.
H. kingi Mathers Macrophagous (mollusks?)	U.S.A.
Family Erpobdellidae	
Nephelopsis Moore (1) Macrophagous, oligochaetes, insect larvae	N. America
N. obscura Verrill Snails, oligochaetes, insect larvae	N. America
Dina R. Blanchard (11-1) Macrophagous, oligochaetes, insect larvae	N. America, Soviet Union, Europe, China
D. parva Moore Snails (?)	N. America
Mooreobdella Pawlowski (3) Macrophagous, oligochaetes, insect larvae	N. America
M. bucera (Moore) Snails (?)	N. America (Michigan)
M. fervida (Verrill) Snails (?)	N. America
M. microstoma (Moore) Snails (?)	N. America
Erpobdella Blainville (8-2) Macrophagous, oligochaetes, insect larvae, crustaceans	World-wide: N. America, Europe, Asia, Africa
E. punctata (Leidy) Snails (?)	N. America

Although the glossiphoniid genus *Batracobdella* has a world-wide distribution, in North America its species are among the least known of all leeches. The following four have been reported from this continent: *B. paludosa*, *B. picta*, *B. phalera*, and *B. michiganensis*. *B. picta* and *B. phalera* were reported to feed on invertebrates (Mathers 1948), but this claim probably is doubtful. Evidence adduced by Richardson (1949), Brockleman (1968, 1969), and Klemm 1972a showed that *B. picta* regularly feeds on amphibians. Pearse (1924) supposedly removed this leech from the white sucker *(C. commersonni)* and the yellow perch *(Perca flavescens)*, but that report is doubtful. *B. phalera* was recorded by Bere (1931) feeding on the bluegill *(Lepomis macrochirus)*; fish of the same species were found by Klemm (unpublished data) with this same leech. Waffle (1963) reported that this leech fed on the American toad *(Bufo americanus)* and Graf (1899) found it on a turtle; Blanchard (1894) reported that it fed on the gills of tadpoles. The species *B. michiganensis* has unknown feeding habits but may well be an amphibian feeder.

The two main glossiphoniid genera, *Glossiphonia* and *Helobdella*, have several species known to feed on mollusks, as well as other animals. The members of the almost world-wide freshwater genus *Glossiphonia* that feed mainly on mollusks, are represented in North America by three widely distributed species: *G. complanata*, *G. heteroclita*, and *G. swampiana*. Several investigaters such as Nachtrieb *et al.* (1912), Moore (1924), Miller (1929, 1937), Bhatia (1939), Bennike (1943), Mathers (1948), Pennak (1953), Mann (1955, 1957a) 1962, 1964), Grasse (1959), Waffle (1963), Moore (1966) Soós (1966), Sapkarev (1967), Wilkialis (1970b), Klemm (1972a), Sawyer (1972), and others considered *G. complanata* predominantly a predator on mollusks though it has been reported to feed occasionally on other invertebrates. Under laboratory conditions Moore (1964) reported that it had a feeding preference for *Physa heterostropha* and *Promenetus exacuous* but did not feed on *Lymnaea emarginata*. Sawyer (1972) observed that it fed on *Physa* while still carrying young; the young fed on it also. Sarah (1971) found two juveniles parasitizing both *Helisoma trivolvis* and *H. anceps* in a creek that had a large adult *G. complanata* population. Gale (1973), furthermore, observed it on *Sphaerium transversum* in the field; it also fed on this bivalve in the laboratory. During this study, *G. complanata* fed in the laboratory on *H. trivolvis*, *H. anceps*, *H. campanulatum*, *G. parvus*, *P. exacuous*, *P. gyrina*, and *P. integra*. Immunological data (Fig. 33) showed that the gut contents of adults collected under natural conditions, definitely contained molluscan tissue.

Glossiphonia heteroclita is uncommon in North America (Klemm 1972a, 1972b and Sawyer 1972). Its biology was studied in England by Gruffydd (1965a) and in Wales by Hatto (1968). In some habitats it has been shown to have an intimate relationship with a number of snails (Gruffydd 1965a and Hatto 1968). Gruffydd (1965a) found it in the mantle cavity of *Lymnaea peregra*; Hatto (1968) found that in another habitat it fed mainly on *Lymnaea stagnalis*. Bennike (1943) recorded *Physa nitidus*, *P. contortus* and *L. stagnalis* as food of this species, and Herter (1932) cited *Lymnaea peregra*. Guibe (1936) experimentally fed it on a variety of mollusks (*Lymnaea peregra, Planorbis corneus, P. umbilicatus, Leptolimnaea glabra, Physa fontinalis, Ancylus* sp.); and Mann (1955) observed it on *Bythinia tentaculata*. Pawlowski (1936) considered the statement by Lukin (1929) that *G. heteroclita* feeds on larvae of Tenidpedidae and Oligochaeta as open to doubt. Mathers (1948) reported that in general it fed on aquatic worms, snails, and insect larvae, but its food preference appeared to be snails. Sawyer (1972) stated that, as yet, no evidence of a relationship between *G. heteroclita* and a snail existed in North America. During this study one adult specimen of *G. heteroclita* was found parasitizing *Physa gyrina* which in some areas may be its preferred host. *G. swampina* is very uncommon and is only known from South Carolina (Sawyer, 1973). Its feeding habits are unknown but since it is closely related to *G. heteroclita* its food preference may be snails. At present, more evidence is required.

The genus *Helobdella* is also world-wide and many of its species attack mainly freshwater invertebrates; some of its species prefer mollusks. This genus has its center of distribution in South America (Moore 1939 and Sawyer (1972). Some of its species are the most taxonomically confusing in the Americas due to the unsettled problem of polymorphism in the *H. triserialis* complex in South America and the *H. fusca* complex in North America.

Helobdella stagnalis has been reported to feed on oligochaetes, aquatic insect larvae, and snails (Nachtrieb *et al.* 1912; Miller 1929, 1937; Mathers 1948; Pawlowski 1936; Waffle 1963; Pennak 1953; Bennike 1943; Mann 1955, 1957b, 1962; Miller 1929, 1937 and others). Under laboratory conditions Waffle (1963) observed that it fed on a variety of animals, including mollusks. Moore (1964) experimentally fed it the soft tissues of *Promenetus exacuous;* it would not eat *Helisoma trivolvis, Lymnaea emarginata,* and *Physa heterostropha.* Hilsenhoff (1963) and Thut (1969) observed that it fed readily on chironomid larvae and oligochaetes; Sapkarev (1967) listed chironomid larvae, tubificids, and the amphipod *Hyalella azteca,* and possibly other leeches, rather than feeding on snails. Mann (1957b) also listed chironomid (tendipedid) larvae. Sawyer (1972) in his laboratory was unable to get it to feed on the snails *Physa, Stagnicola* or *Helisoma.* Bennike (1943) also recorded that it sucked larvae and the isopod *(Asellus* sp.) and snails; Moore (1966) experimentally fed this leech chironomid larvae, oligochaetes, and small snails. Gale (1973) found *Helobdella stagnalis* on *Sphaerium transversum* and experimentally fed it this bivalve. During this study it was seen as free-living on sphaeriid clams but was not observed feeding on them under laboratory conditions. Herrmann (1970) stated that in many Colorado waters *Glossiphonia complanata* was found with *Helobdella stagnalis.* While he considered the food habits of these two leeches as similar, subtle dietary differences seemed to be present. Both fed on chironomid larvae, oligochaetes and small snails. However, Pawlowski (1936) stated that snails were preferred by *G. complanata,* but that *H. stagnalis* took oligochaetes and chironomid larvae in preference to snails.

The leech *Helobdella elongata* has been reported to feed on various snails, worms, and insect larvae (Nachtrieb *et al.* 1912 and Mathers 1948), but some of these are probably doubtful as food organisms. Very little is known about its biology except that it does not usually feed on *Tendipes* larvae (Hilsenhoff 1964) under laboratory conditions.

Helobdella fusca and the closely related species *H. lineata, H. papillata,* and *H. punctatolineata* favored snails as food, and it was suggested by Moore (1939), Chernin *et al.* (1956), McAnnally and Moore (1965, 1966) and Hoffman (1970) that these species might serve as a means for biological control.

A literature search gave only one tangible report (Crewe and Cowper, 1973) of an unidentified species of *Helobdella* feeding on a laboratory culture of *Bulinus truncatus* which was obtained in the field of an endemic area of schistosomiasis in Egypt. No field studies, however, have been done under natural conditions.

In North America Sawyer (1972) found *H. fusca* attached to the snail *Helisoma,* a probable host. Klemm (1972a) found it feeding on *H. trivolvis, L. stagnalis,* and *P. parkeri.* Waffle (1963) listed it as consuming *Pisidium virginicum, Physa gyrina, P. integra, Promenetus exacuous* and the insect larvae *Tendipes* sp. During the present study it fed on a variety of mollusks *(H. anceps, H. trivolvis, H. campanulatum, P. gyrina, P. exacuous)* in the laboratory. Under natural conditions there was a snail preference for *H. trivolvis* and *H. campanulatum.*

Helobdella lineata fed on *H. trivolvis* (Klemm, 1972a) and under laboratory conditions it fed on *H. anceps, H. trivolvis, H. campanulatum,* and *P. gyrina.* Sarah (1971) noted a selective association between this leech and *H. trivolvis;* in this study there was also a selective preference for *H. trivolvis.*

Helobdella papillata fed on *H. anceps, H. trivolvis, P. parkeri* (Klemm 1972a). Sarah (1971) indicated a definite food preference for the snail *Helisoma anceps* in the field. In our laboratory it also had a preference for *H. anceps, P. gyrina, S. elodes,* and *L. megasoma.*

Helobdella punctatolineata is widely distributed in Puerto Rico but is found occasionally in North America (Richmond, 1972 and Klemm, unpubl.). J. P. Moore (1939) suggested that this species might possibly serve as a biological control agent against snail intermediate hosts since it was observed to feed on *Planorbis corneus* and *Australorbis (=Biomphalaria) glabratus* (the latter the intermediate host of *Schistosoma mansoni)* in aquaria. Harry *et al.* (1958) found this leech in association with *Australorbis glabratus* under natural conditions. It readily decomated laboratory colonies of snails. McAnnally *et al.* (1965, 1966) experimentally found *Helobdella* leeches were a significant potential hazard among laboratory snail colonies.

Helobdella transversa from southern Michigan (Sawyer 1972) as yet has unknown feeding habits. Like the other similar species in this genus *(fusca, lineata, papillata,* and *punctatolineata)* it probably feeds mainly on mollusks.

The leech, *Marvinmeyeria lucida,* is known only from North America and evidence obtained from various studies has shown that it has definite snail-eating habits. J. E. Moore (1964) observed this species feeding on *Physa heterostropha, Promenetus exacuous,* and *Lymnaea emarginata.* He also found that when *M. lucida* was segregated and supplied with all three of these snails, there was a definite preference for *Physa heterostropha.* Klemm (1972a) removed this species from the mantle cavity of a common woodland pool snail (*Lymnaea palustris).*

Klemm (1973) found young of this leech seasonally parasitizing a variety of snails (*H. trivolvis, P. exacuous, G. parvus, A. hypnorum, P. armigera,* and *S. exilis).*

The genus *Placobdella* is well represented in North America. There is strong evidence that the members of its species feed specifically on turtles, amphibians, and fishes, but not on mollusks. Although *P. ornata* and *P. parasitica* have been reported to feed on mollusks, this is doubtful since evidence by Kopenski (1969), Klemm (1972a), Sawyer (1972), and others indicates that they feed predominantly on turtles but could attack other animals occasionally.

The leech *P. montifera* was reported to feed on mollusks, turtles, fish, frogs, and toads by Mathers (1948) and Nachtrieb *et al.* (1912). The latter (1912) stated that this species habitually enters the shells of living mussels, although it is not known definitely whether it feeds upon their tissues. Evidence by various authors (Harms 1959, 1960; Here 1931; Pearse 1924; Hoffman 1967; Ryerson 1951; Bangham 1933; Bangham and Hunter 1939; Richmond 1972; Poe 1972; Klemm, unpubl. data) have shown that its only specific host records involve a variety of fishes.

The genus *Theromyzon* is cosmopolitan in distribution. The three North American species are true bird leeches as recorded by Sooter 1937; Moore and Meyer 1951; Meyer and Moore 1954; Moore 1966; McDonald 1969; and Klemm 1972a. Records stating that this genus feeds upon mollusks are probably doubtful.

Many hirudinid leeches are blood sucking parasites of man and domestic animals; others live on invertebrates. The North American species are contained in two genera: *Macrobdella* and *Haemopis (=Mollibdella, =Bdellarogatis,* and *=Percymoorensis).* These species have large mouths with no or different degrees of dentition and have either sanguivorous or macrophagous feeding habits.

Macrobdella decora, known only from North America, is a voracious predator, feeding on many vertebrates (Mann 1962, Kopenski 1969, Klemm 1972a, Sawyer 1972). Stomach contents also include large numbers of tubificids, and occasionally insect larvae (Ward 1902 and Nachtrieb *et al.* 1912). Brockleman (1968) stated that it preyed on eggs of *Bufo americanus* and tadpoles of *R. catesbeiana,* and Klemm (1972a) also observed it feeding on salamander eggs.

Haemopis (=Mollibdella) grandis is known only from North America. It lacks jaws and is toothless, and is a predator and scavenger rather than a parasite. Items in stomachs include various pulmonates, bivalve shells, and other leeches. It also eats oligochaetes, leeches, snails, aquatic insects and their larvae, and crustaceans (Nachtrieb *et al.* 1912; Moore 1922, 1923; Ryerson 1915; Miller 1929, 1937; Mathers 1948; Meyer and Moore 1954; and Mann 1962). Rupp and Meyer (1954) found it attached to wounds of brook trout *(S. fontinalis)* caused by *M. decora.* Chemberlin (1968) found in its gut contents a variety of organisms: *Physa, Lumbricus ubellus,* Hydrophilidae, *N. obscura, Dina* sp., *H. campanulatum, Sphaerium* sp., *Amnicola* sp., *L. stagnalis, Campeloma* sp., tadpoles, and unidentified earthworms, leeches, and snail parts.

The rare leech *Haemopis (=Bdellarogatis) plumbea* from North America, is reported to feed on snails, earthworms, aquatic annelids, aquatic insects and crustaceans, according to Nachtrieb *et al.* (1912); Mathers (1948); Miller (1929, 1937); and Mann (1962)

The genus *Haemopis (=Percymoorensis)* is also represented in North America by four other species: *H. marmorata, H. terrestris, H. kingi,* and *H. lateromaculatum.* These are considered somewhat amphibious, especially *H. terrestris* which is reported to be terrestrial (Sawyer 1972).

Sawyer (1972) reported observing *H. marmorata* at night along shorelines eating small invertebrates, especially *Physa,* slugs, and oligochaetes. Young individuals ate the soft parts of snails, but sometimes ingested shell as well. Stomach contents include pulmonate shells and large oligochaetes. This species is a scavenger and predator rather than a parasite and has been reported eating oligochaetes, pelecypods, dead fish, insect larvae, and leeches by Nachtrieb *et al.* 1912; Moore 1924; Moore 1966; Miller 1929, 1937; Mathers 1948; and Mann 1962. Klemm (1972a) found it feeding on the tissues of a dead fish, eating the leech *N. obscura,* and consuming frog eggs.

Haemopis (=Percymoorensis) kingi, found only occasionally in Iowa, is reported by Mathers (1954) probably to feed on many snails, especially *Succinea* spp., slugs, earthworms, and various insect larvae. The leech *H. (=P.) latomaculatum,* known also from Iowa and found only occasionally, was reported by Mathers (1963) as likely to feed on small earthworms, terrestrial and amphibious snails, slugs, and soft bodied insect larvae.

Haemopis (=Percymoorensis) terrestris, a unique and seldom found North American leech, is truly terrestrial (Sawyer 1972) and occurs in damp soil and under rocks and logs. Stomach contents of this leech (Sawyer 1972) contained large oligochaetes. Forbes (1890a, b) also reported it to feed on oligochaetes, and Nachtrieb *et al.* (1912), Miller (1937), and Mathers (1948) recorded its food as an added variety of organisms such as earthworms, aquatic annelids, snails, aquatic insects, and crustaceans.

The family Erpobdellidae has leeches which are adapted for a predaceous way of life. All species have a large mouth, without dentition, some are aquatic, devouring freshwater invertebrates; others take up a burrowing existence at the edge of water where they devour oligochaetes. Four genera and one subgenus are represented in North America, *Mooreobdella (=Dina), Dina, Erpobdella,* and *Nephelopsis.* The genus *Mooreobdella (=Dina)* and *Dina* are widespread in the Northern hemisphere. In feeding widespread in the Northern hemisphere. In feeding they are macrophagous. *M. fervida* and *M. microstoma* were reported to consume aquatic worms insect larvae, and snails (Mathers 1948, Nachtrieb *et al.* 1912, Miller 1929, 1937). Hermann (1970) reported that *M. microstoma* fed extensively on snails, chironomids and tubificids. Moore (1920) reported the stomach contents of *M. fervida* to be mainly tubificid worms and some insect larvae. It was also commonly found on dead animals (coot, duck, shrew) near the edge of water. *M. microstoma* feeds on small tubificid worms (Miller 1929, 1937). *Dina (=M.) bucera* has unknown feeding habits, but it is probably a scavenger and predator like *M. fervida* and *M. microstoma,* rather than a parasite.

Mathers (1948) reported *D. parva* to be predacious feeding upon aquatic insect larvae, snails, and worms. Nachtrieb *et al.* (1912) reported it to be a scavenger, feeding on dead turtles and a dead shrew. Herrmann (1970) reported it extensively fed on snails, chironomids, and tubificids.

The leech species, *D. dubia,* has not been studied in terms of its feeding habits. Sawyer (1972) found insect larvae in its gut contents. Mathers (1948) and Nachtrieb *et al.* (1912) reported its foods as aquatic annelids, snails, insect larvae and crustaceans.

The genus *Nephelopsis* is represented in North America by only one species, *N. obscura.* Stomach contents contained insect larvae according to Forbes (1893), Nachtrieb *et al.* (1912), and J. E. Moore (1966). Mathers (1948) reported it fed on oligochaetes, snails and insect larvae and Herrmann (1970) reported that it fed on snails.

The genus *Erpobdella* is represented in North America by one species, *E. punctata.* Klemm (1972a) found it feeding on a dead fish and also on fairy shrimp *(Chirocephalopsis bundyi)* in a collecting container. Mathers (1948), Nachtrieb *et al.* (1912), and Miller (1937) recorded small worms, leeches, aquatic snails, insect larvae, dead animals, fish, frogs, and crustaceans. Herrmann (1970) reported it fed on snails; Moore (1966) found it fed on various types of beetles, oligochaetes, and chironomid larvae as indicated in its gut contents. Sapkarev (1967) also reported this species to feed on chironomids and oligochaetes. Sawyer (1970) observed it consuming dead earthworms *(Octolasium lacteum),* and eating damselfly nymphs and other small unidentified aquatic insects. This species is also a predator and scavenger rather than a parasite.

Leech and Mollusk Ecology

Many European investigators have stated that eutrophic habitats were usually favorable waters for leeches (Pawlowski 1936, Bennike 1943, Sandner 1951, Mann 1955, Dobrowoski1958, Serafinska 1958, Lukin 1962, Kalbe 1966, Wilkialis 1970a, and Sander and Wilkialis 1972). Others adducing similar data and comparing lentic with lotic waters in the United States, are Kopenski (1969), Herrmann (1970) and Klemm (1972a). In addition, leech communities in these waters were clearly differentiated and their character was mainly dependent on the degree of eutrophication of the specific habitat types.

Data available in the literature show that leeches tend to avoid dystrophic waters and are usually less numerous in oligotrophic ones. Boycott (1936) also reported that aquatic mollusks could generally be scaled so that at one end one would find tolerant mollusks which frequently could be found by themselves or with other species; these tended to have a wide geographic range while other more exacting species often had a number of others living with them which may be equally or less particular and they would have a more restricted distribution.

Most leech and mollusk investigators have emphasized the importance for distribution and abundance of such environmental factors as temperature pH, cleanness of water, suitable substrates presence of places to which these leeches adhere, and desirable foods. According to the literature certain leeches and mollusks prefer cooler waters with alkaline pH ranges; they are reported not usually to tolerate extremes in both for long periods of time (Bennike 1943, Mann 1962, Hermann 1970, Klemm 1972a). Warm waters tent to favor growth and breeding of both leeches and mollusks. Hydrogen ion concentrstions of acid-peaty waters with pH 6 or less usually contain no snails (Boycott 1936) or leeches (Klemm 1972a). As alkalinity increases, the numbers of leeches and mollusks usually also increase.

Parasites of Leeches

Campbell (1973a) reported that lymnaeids and certain leeches in the genus *Helobdella* (Ulmer, unpublished data) could serve as second intermediate hosts in which cercariae encyst and undergo development into metacercariae of the tetracotyle type. He found that the genus *Helobdella* served as secondary intermediate host, along with *Lymnaea stagnalis* and *Stagnicola reflexa,* in the life cycle of *Cotylurus flabelliformis.*

Mann (1962) found in working with *Erpobdella octoculata* that it was often possible to see numerous, clear cysts, called *Tetracotyles typica* in the mesenchyme; they were shown to be metacercariae of strigeid trematodes. Bennike (1943) found tetracotyles in *Haemopis sanguisuga* and *E. octoculata;* they possibly belonged to the trematode species *Apatemon (Strigea) gracilis.* Wesenberg-Lund (1934 and 1937) also felt that these tetracotyles belonged to *Apatemon (Strigea) gracilis.* The tetracotyles of this species were formed from furcocercariae originating in *Bythinia tentaculata* and they developed to mature flukes in ducks (Szidat 1930). Wisniewski (1935) has, furthermore, described a furcocercaria *Cercaria dubia,* which likewise forms tetracotyles in *E. octoculata.* Meyer and Moore (1954) found specimens of *Haemopis (Percymoorensis) marmorata* heavily peppered with metacercariae, and

J. E. Moore (1964) also found young and adult *E. punctata* spotted with metacercariae of strigeid trematodes. Bennike (1943) also found few specimens of *G. heteroclita* infected with tetracotyles.

In Czechoslovakia, Vojtek *et al.* (1967) discovered four metacercariae of trematodes *(Apatemon gracilis, Prohemistomulum* sp., *Prohemistomulum opacum*, and *Cotylurus* sp.) in leeches. In the literature there are reports that certain leeches and mollusks may participate as second intermediate hosts in the life cycles of some flukes that cause dangerous helminthoses to birds. The definitive hosts of these flukes belong mostly in the order Anseriformes. The disease caused by them may be fatal to domestic ducks. In some interesting helminthological localities they found a high intensity and an extensity of invasions in leeches which provided suitable conditions for massive invasions of waterfowl by these flukes. It was also reported by Vojtek *et al.* (1967) that they could not draw any conclusions as to the specificity of these larvae to their second intermediate hosts, although they presumed that the most important supplementary hosts of *A. gracilis* were leeches in the genus *Erpobdella* and the species *Haemopis sanguisuga* Particularly the latter had heavy invasions which may be attributed to the large size of this leech since much smaller leeches in the genus *Erpobdella* would certainly succumb to similar invasions. Since leeches belonging in the Glossiphoniidae are small heavy infections would also kill them and they are, therefore, not suitable as second intermediate hosts for certain trematodes. Campbell (1973b) found that under laboratory conditions successful development occurred in *L. stagnalis* and *S. reflexa* of all sizes, but few tetracotyles developed in the smaller snails; also the number of metacercariae was limited by temperature, snail size, and host species. This relationship may also pertain to certain leeches.

Another metacercaria found in mollusks and leeches (Vojtek *et al.* 1967) was designated as *Tetracotyle typica* de Fillipi; they were recognized for a considerable time in the literature. The data concerning their supplementary host mention both leeches and mollusks. Some authors considered metacercariae from mollusks as belonging to the same species, *Cotylurus cornutus* (Rudolphi 1808); Szidat (1930) and others considered them two species. The species representation of the *Tetracotyle* form from mollusks was confirmed repeatedly in experiments by Ercolani 1881, Lutz 1921, Mathias 1925, Timon-David 1943, Zajicek and Valenta 1964 and Zdarska 1964. Szidat (1930) first succeeded in rearing adult flukes from leeches. The metacercariae found by him in the gonads of *Erpobdella octoculata* and *Haemopis sanguisuga* developed in ducklings into adult flukes, *Cotylurus cornutus*. *Tetracotyles* from leeches are considered the larvae of the species *C. cornutus* also by Timon-David (1943), Dobrowolski (1958) and Wisniewski (1958). Sudarikov (1959) and Sudarikov *et al.* (1962) assumed that tetracotyles from the lacunary system in the following leeches, *E. octoculata, Glossiphonia complanata*, and *Helobdella stagnalis*, probably belonged to another species than *C. cornutus*, therefore, designating them *Tetracotyle* sp. Vojtek *et al.* (1967) are of the opinion that tetracotyles of the genus *Cotylurus* from leeches belong to different, although closely related species, than the tetracotyles from mollusks. Evidence supporting this fact was found in experiments with cercarial invasions of secondary intermediate hosts. The cercariae developed in *Planorbarius corneus* penetrated the leeches of the species *Haemopis sanguisuga, Erpobdella octoculata, Glossiphonia complanata, G. heteroclita, Hemiclepsis marginata*, and *Protoclepsis tesselata*. The larvae of *Cotylurus* sp. were well distributed. In some localities the extensiveness and intensity of invasions was very high. The leech *H. sanguisuga* is probably playing the most important role as the second intermediate host of *Cotylurus* and it may cause serious disease to waterfowl.

As to the metacercariae of *Prohemistomulum opacum* in leeches, no information has been available on the life cycle of these larvae and there are only varied views as to which genus the adult flukes belong. By feeding metacercariae to ducklings, they recovered adult flukes of the genus *Cyathocotyle*. These flukes can be dangerous to waterfowl if the invasion is heavy (Shevtsov, 1958). Metacercariae from five locations indicated it had a wide distribution. The most important second intermediate hosts in the developmental stages of this species are leeches of the species *Haemopis sanguisuga*. Metacercariae of *Prohemistomulum* sp. are similar to *P. opacum*, but when these larvae were fed to young ducklings, coots, crows, and chicks, no adult worms were recovered. This fact and the observation of morphological differences led to the assumption that these larvae were not fully developed larvae of *P. opacum*. Vojtek *et al.* (1967) indicated that these metacercariae most probably belong to the genus *Cyanthocotyle*. These associations and others will be considered in the appropriate sections of this paper.

OBJECTIVES OF THE STUDY

More exact knowledge of the ecology of leeches (Hirudinea) has been needed for many species. Particularly information on the complete diets of most species is unknown even though their general habits are not complex. Many leeches are suspected of feeding on mollusks and other animals. J. P. Moore (1939) indicated that most of the smaller species belonging to the family Glossiphoniidae were habitually malacophagous and that they fed almost exclusively upon aquatic snails. The more predaceous leeches of the families Erpobdellidae and Hirudinidae also fed on snails, as well as other invertebrates and dead animals of all kinds. The true blood sucking aquatic leeches in the families Glossiphoniidae and Hirudinidae were thought usually to confine their attacks to vertebrates, except when hungry; and, if no vertebrates were available, they would occasionally attack invertebrates. Therefore, it seemed important in making a beginning that a thorough review of feeding habits of leeches in the family Glossiphoniidae under natural conditions was necessary. Such information would serve to indicate the number of species that are likely to feed exclusively on the snail hosts of schistosomes as well as other trematodes. The investigation might also reveal the leeches most likely to tolerate the ecological conditions of the snail intermediate host.

Because genera of the family Glossiphoniidae, especially *Helobdella* and *Glossiphonia*, which are world-wide in distribution and include some so-called snail leeches, are abundant in southeastern Michigan, there was ample opportunity to add to the little data available on their feeding requirements under natural conditions. Consequently, this study was initiated to meet the following objectives: (1) to determine the degree of host-specificity among leeches in the family Glossiphoniidae for freshwater mollusks occurring in southeastern Michigan; (2) to learn what other parasites and symbionts are found in mollusks infested with particular species of leeches; (3) to compare and describe leeches infesting mollusks within different habitats such as woodland pools, ponds, lakes, creeks and roadside ditches; (4) to determine the sites inhabited by leeches inside specific snails; (5) by concentrating on winter collecting to observe leech frequency in the snail populations; (6) to find evidence as to whether leeches serve as regulators of snail populations under natural conditions; (7) to determine the degree to which multiple parasitism occurs; (8) to make serological tests of gut contents of free-living leeches to obtain evidence as to their molluscan feeding requirements; (9) to determine from the literature the world-wide status of knowledge on leech-mollusk relationships.

MATERIALS AND METHODS

General Procedure

Periodic collections made during 1972 and 1973 in Michigan yielded a total of 14,479 mollusk specimens. These specimens were from 10 permanent stations and 25 incidental sites representing lakes, ponds, woodland pools, roadside ditches, rivers and creeks. Data on mollusk-leech associations were recorded. The collections of mollusks from the permanent sites were made monthly; incidental stations were sampled only in the different seasons. Groups encountered were as follows:

(1) Order Mesogastropoda. Four families and 7 species of operculates: Viviparidae: *Viviparus (=Cipangopaludina) malleatus (=chinensis)* Reeve, *Campeloma decisum* (Say); Valvatidae: *Valvata tricarinata* Say; Pleuroceridae: *Pleurocera acutum* Rafinesque, *Goniobasis livescens* (Menke); Amnicolidae: *Amnicola limosa* (Say);, *Bythinia (=Bulimus) tentaculata* (Linnaeus).

(2) Order Basommatophora: 3 families with 19 species of pulmonates. Lymnaeidae: *Lymnaea stagnalis appressa* (Say), *L. (=Fossaria) humilis (=obrussa)* Say, *L. (Bulimnaea) megasoma* (Say), *Pseudosuccinea (=Lymnaea) columella* Say, *Stagnicola (=L.) catascopium* Say, *S. (=L.) elodes (=palustris)* (Say), *S. exilis* (Lea); Planorbidae: *Helisoma anceps (=antrosum)* (Conrad), *H. trivolvis* (Say), *H. campanulatum* (Say), *Planorbula armigera* (Say), *Promenetus exacuous* (Say), *Gyraulus (=Armiger) hirsutus* (Gould), *G. (=A.) parvus* (Say); Physidae: *Physa sayii* Tappan, *P. gyrina* Say, *P. integra* Haldeman, *P. parkeri* 'Currier' DeCamp, *Aplexa hypnorum* (Linnaeus).

(3) Order Sphaeriacea: one family yielding 3 species of sphaeriacean clams: Sphaeriidae: *Sphaerium simile* (Say), *S. (=Musculium) lacustre* (Müller), and *S. (=M.) fabale* Prime.

Sampling Methods

It was necessary to select study areas with relatively large mollusk populations since only in such a situation could reliable data be obtained during repeated sampling. The effects of over-collecting, destruction of the aquatic habitat, and interference with the dynamics of a natural population were minimized. The possible adverse effects of over-collecting could have been especially important at the permanent collecting sites because they were sampled monthly for 2 years.

The clustered distribution of mollusks prompted the use of a 'time' capture method which was well established and tried for mollusks by Macan (1950). This method gives ample opportunity to find the places of occurrence most favored by mollusks. The average time to obtain a sample was about 45 minutes.

Within each sampling period at least 25 or more mollusks, sometimes fewer and depending on the species availability, were removed at random. As each specimen was collected it was examined for attached leeches and placed individually in separate plastic bags (sandwich size) with some water. The animals were then taken to the laboratory for careful examination. When collections were large, the mollusks in their respective plastic bags were stored temporarily in a refrigerator until they could be examined. The incidental collecting sites served to provide additional data on leech-snail associations and their distribution; they also yielded other species of snails not found in southeastern Michigan.

Collecting Sites

The 10 permanent stations* at which I obtained collections of mollusks and recorded meteorological, physical, chemical, and biological data were at the following locations in southern Michigan:

Bert Pond (T1S, R3E, S19), E. S. George Reserve,

* These sites were designated using the standard methods on old county maps of Michigan. T: township, R: Range, and S: section.

Livingston County
Crane Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County
George Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County
Lake (T2S, R3E, S1NE), Washtenaw County
Woodland Pool (T2S, R3E, S9SW), Washtenaw County
Fleming Creek (T2S, R6E, S25SE), Washtenaw County
Roadside Ditch (T1S, R3E, S19SE), Washtenaw County
Four-mile Lake (T2S, R4E, S4SE), Washtenaw County
Woodland Pool (T2S, R5E, S28SE), Washtenaw County
Murray Lake (T2S, R7E, S10NW), Washtenaw County

The 25 incidental sites (24 in Michigan and 1 in Ontario, Canada) were as follows:
Northeast Marsh (T1S, R3E, S30NE), E. S. George Reserve, Livingston County
Cressman Pond (T1S, R3E, S30NE), E.S. George Reserve, Livingston County
Roadside Ditch (T25S, R4E, S10SW), Emmet County
Joslin Lake (T1S, R3E, S3NE), Washtenaw County
Duck Lake (T2S, R3E, S12), Jackson County
Triangle Lake (T2S, R4E, S27), Livingston County
Huron River (T2S, R6E, S17SE), Washtenaw County
Sugar Loaf Lake (T2S, R3E, S31NE), Washtenaw County
Fleming Creek (T2S, R7E, S8SE), Washtenaw County
Woodland Pool (T1S, R3E, S29NW), Washtenaw County
Mill Lake (T2S, R3E, S4NE), Washtenaw County
Cedar Lake (T2S, R3E, S9SE), Washtenaw County
Impoundment (T1S, R3E, S29SW), Washtenaw County
Waffle's Pond (T4S, R7E, S33SE), Washtenaw County
Honey Creek (T1S, R4E, S26N), Livingston County
North Lake (T1S, R4E, S18NE), Washtenaw County
*South Lake (T1S, R3E, S10SW), Washtenaw County
Baw Besse Lake (T12S, R16E, S33), Muskegon County
Big Blue Lake (T12S, R16E, S28), Muskegon County
*Roadside Ditch (T23S, R4E, S31S), Missaukee County
*Douglas Lake (T37S, R3E, S27), Cheboygan County
Au Sable River (T26S, R3E, S7&12), Crawford County
Frains Lake (T2S, R7E, S9NE), Washtenaw County
Pond (T2S, R4E, S25SE), Livingston County
Reef Channel, Detroit River (40°09'30") Lat. N., 83°07'30" Long. W), Ontario, Canada.

See Appendix I for the geographic location of all collection sites.

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* Sampled twice

Collecting Methods

Mollusks were collected either individually by hand or with the aid of a rectangular net (14 X 14", mesh size 1/8"). At only one site (Reef Channel, Detroit River) were they collected in 9 feet of water with a clam dredge.

Identification of Mollusks, Leeches, Chaetogasters and Cercarial Types

The snails studied were identified to species using available taxonomic keys (Berry 1943, Baker 1928, Goodrich 1932, Walter and Burch 1957); the sphaeriid clams were identified with keys by Herrington (1962) and Burch (1972). The leeches were identified to species using Klemm (1972b). Chaetogasters were determined with Pennak (1953), Brinkhurst and Jamieson (1971). Trematode cercariae were checked using Dawes (1968) and Schell (1970); the midges with Mason (1973).

Examination of Snails for Parasites and Symbionts

Infestation of snails by leeches, parasite infections with trematode larvae and the presence of symbionts (chaetogasters and midges) were assessed by carefully examining the outer shell of the mollusk; then the shell was crushed with forceps or probe and, after removing broken pieces of shell, the exposed animal was examined. Under a dissecting microscope the animal was carefully teased apart. The chaetogasters and cercariae were placed on slides and identified under a compound microscope. All leeches present in the mollusks were counted and their anatomical associations noted. Chaetogasters or cercarial types were not counted but their locations and relative abundance were recorded.

Meteorological, Chemical, Physical, and Biological Data

At the 10 permanent stations only one chemical component, pH (Appendix II) of the water was measured. The physical methods involved a description of bottom composition, based on a bottom classification system by Roelofs (1944). Water temperature was measured to the nearest degree with a centigrade thermometer. Biological data taken included the identification of the free-living inhabitants which were found along with the mollusks collected at the 10 permanent sites.

Immunological Data

The procedures used were a modified micro-Ouchterlony agar gel diffusion method after Davies (1969) and Burch and Lindsay (1970). Briefly these procedures were as follows: Antibodies against *H. trivolvis* antigens were produced in 2 virgin female rabbits by introducing intravenously into the external marginal vein of each rabbit's ear 2 consecutive series of 5 one ml. injections of whole snail (the antigen) in increasing concentrations, given on alternate days. The injections consisted of the supernatant liquid obtained after centrifugation of the homogenized whole snail tissue. The series were spaced 1 month apart and proceeded according to the following schedule:

Day Started	Weight in mg. of tissue homogenized in 1 ml physiological saline
1, 39	15.00
3, 41	36.00
5, 43	75.00
7, 45	150.00
9, 47	214.00

After 3, 5, and 10 days of the last injections, 50 ml of whole blood were drawn from the external marginal ear vein of the rabbits. This blood was allowed to clot at room temperature for 30 minutes and cooled to 3° C for another 30 minutes to shrink the clot. The clot and the serum were placed separately in centrifuge tubes and spun at 3000 revolutions per minute for 30 minutes, during which time the temperature was maintained at 3° C. The sera from the 2 tubes were combined and similarly spun; this combined serum contained the antibodies. The serum was freeze-dried into a finely powdered substance and stored for further use.

Plates for the micro-Ouchterlony double diffusion test (Ouchterlony 1949) were prepared by fastening a glass ring (21 mm inside diameter and 10 mm in height) to a microscope slide with petroleum jelly (Appendix IV). The semi-solid medium used to fill the rings was a 1% agar gel with 0.4% NaCl and 0.001% merthiolate (mold inhibitor).

The gel medium was prepared by combining 50 gm of 2% deionized agar cubes, and 40 ml of 1% NaCl solution. It was placed in an autoclave and heated to 121° C at 10 lbs. pressure for 30 minutes. The gel solution was cooled to 40° C in a water bath. After adding 10 ml of the 1/1000 merthiolate solution, the gel was ready for use.

Two ml of the gel solution were added to each plate and allowed to cool; as it cooled it solidified. The desired pattern of 4 wells was cut into the gel using a special cutting device devised by J. B. Burch in the Mollusk Division, University of Michigan. The plate was ready for the immunodiffusion test.

The gut contents of starved, fed, and naturally occurring leeches were removed and tested against the prepared anti-snail serum. Four wells were cut in the gel. With this type of well pattern two leeches were tested against each other to show qualitative differences in their antigen-antibody reactions. Differences between homologous and heterologous extracts were seen by comparing the precipitin reactions between wells A and B and between wells A and C, respectively. Proteins occurring in the gut contents of one leech but not in the other, can be observed by the reaction between wells B and C. This is because the antiserum in well B must pass through a surrounding barrier of heterologous antigen, allowing only those antibodies through to react that are not common to the gut contents of the second leech. Thus, one can determine whether or not the leeches in question had eaten or fed on snails, especially *H. trivolvis*.

The presence or absence of precipitin reactions between wells B and A were of prime interest in this study. The space between wells C and A served as control.

The procedure for filling the wells with antigen and antibody was as follows: Well B was filled with the antigen of leech 1. Well C was filled with antigen of leech 2 and wells A were filled with the antibodies of *H. trivolvis*. In preparing these plates, full strength antisera were used. The fluid containing the antigen was the supernatant obtained from centrifuging whole snail tissue homogenized in 4.0 ml physiological saline. The gells were allowed to incubate for 3 to 5 days to allow the migration of protein fractions and then observed for the presence of precipitin bands.

RESULTS

Part I. Mollusks, leeches, chaetogasters, and trematode cercariae listed by habitats under natural conditions

Two objectives of this study were to determine which mollusks were parasitized or eaten by leeches and to learn which other parasites and symbionts were found on mollusks infested with leeches.

Tables 2 through 11 give data gathered from 10 permanent collecting sites. A variety of mollusks was collected from these habitats during 1972 and 1973.

A total of 12,027 mollusks was collected from these 10 permanent stations and examined. Fifteen species of pulmonate snails (*Helisoma trivolvis, H. campanulatum, H. anceps, Physa gyrina, P. integra, P. sayii, Aplexa hypnorum, Lymnaea columella, L. humilis, Stagnicola elodes, S. exilis, Planorbula armigera, Gyraulus parvus, G. hirsutus*, and *Promenetus exacuous*), four species of operculate snails (*Amnicola limosa, Campeloma decisum, Valvata tricarinata, Viviparus malleatus*), and two species of sphaeriacean clams (*Sphaerium (Musculium) lacustre* and *S. (M.) fabale*) were examined.

These data (Tables 2 through 11 show the total number of mollusks examined from each habitat and the total number of leeches on each mollusk species. All the mollusks carrying the symbiont, an oligochaete (*Chaetogaster limnaei* v. Baer), and those mollusks infected with the cercariae of amphistomes, and the distomes (cystocercous, gymnocephalous, echinostome cercariae, xiphidiocercariae, strigea cercariae, furcocercariae, and macrocercous) are also indicated. The total snail-leech-cercarial association and the total cercarial types are given.

The presence of the aquatic oligochaete varied from specimen to specimen and from pond to pond. *Chaetogaster limnaei* was as abundant on snails free of trematode parasites as those infected with trematode larvae and those infested with leeches. The cercarial types varied with the snails, the season

Table 2. Snails examined from Bert Pond (T1S,R3E,S19), E. S. George Reserve, Livingston County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Helisoma trivolvis	885	523	831	17	50	1	0	9	31	14	2	2
Physa gyrina	31	0	31	0	6	0	0	0	0	5	0	1
Lymnaea humilis	1	0	0	0	0	0	0	0	0	0	0	0
Lymnaea columella	24	0	0	0	0	0	0	0	0	0	0	0
Total	941	523	862	17	56	1	0	0	31	19	2	3

Table 3. Snails examined from Crane Pond (T1S,R3E,S19), E. S. George Reserve, Livingston County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Helisoma trivolvis	317	96	317	1	22	0	0	0	10	3	5	4
Helisoma campanul-atum	548	122	548	2	99	1	0	0	49	32	2	16
Helisoma anceps	224	108	224	0	1	0	0	0	1	0	0	0
Physa gyrina	38	5	38	0	3	1	0	0	2	0	0	0
Lymnaea humilis	2	0	0	0	0	0	0	0	0	0	0	0
Stagnicola elodes	7	0	4	0	2	0	0	0	1	0	0	1
Planorbula armigera	4	4	4	0	0	0	0	0	0	0	0	0
Physa sayii	11	0	11	0	0	0	0	0	0	0	0	0
Total	1,151	335	1,146	3	127	2	0	0	61	37	7	21

Table 4. Snails examined from George Pond (T1S,R3E,S19), E. S. George Reserve, Livingston County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Helisoma trivolvis	485	182	485	3	18	0	2	1	11	4	0	0
Lymnaea humilis	19	0	19	0	1	0	0	0	1	0	0	0
Gyraulus parvus	2	0	2	0	1	1	0	0	0	0	0	0
Total	506	182	506	3	20	1	2	1	12	4	0	0

Table 5. Snails examined from a lake (T2S,R3E,S1NE), Washtenaw County, Michigan, Shows total snails, leeches, chaetogasters, snail-leech-cercarial associations and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Helisoma trivolvis	649	104	638	2	41	0	0	0	7	29	5	0
Helisoma campanulatum	59	14	59	0	2	0	0	0	0	2	0	0
Helisoma anceps	16	3	16	0	0	0	0	0	0	0	0	0
Planorbula armigera	4	0	4	0	0	0	0	0	0	0	0	0
Promenetus exacuous	8	1	8	0	0	0	0	0	0	0	0	0
Lymnaea columella	7	0	0	0	0	0	0	0	0	0	0	0
Lymnaea humilis	30	0	30	0	1	0	0	0	0	1	0	0
Physa gyrina	46	0	46	0	5	3	0	0	0	2	0	0
Gyraulus parvus	15	0	15	0	0	0	0	0	0	0	0	0
Amnicola limosa	775	0	0	0	0	0	0	0	0	0	0	0
Total	1,609	122	816	2	49	3	0	0	7	34	5	0

of the year, and the ponds sampled, and no multiple cercarial types were found.

Mollusks from Incidental Aquatic Habitats

A composite of the 25 incidental sites sampled (Table 12) throughout Michigan has the following distribution of habitats: 12 lakes, 3 rivers, 2 roadside ditches, 3 ponds, 2 creeks, 1 woodland pool, 1 marsh, and 1 impoundment. Altogether 2452 mollusks were collected from these various habitats. The sites were sampled to determine distribution of leeches and other species of mollusks found outside the 10 permanent collection stations.

Both the abundance and the diversity of mollusks varied somewhat among these different habitats. This study involved an examination of 18 pulmonates: *H. trivolvis, H. campanulatum, H. anceps, P. gyrina, P. integra, P. parkeri, P. sayii, L. humilis, L. megasoma, L. stagnalis, L. emarginata, L. catascopium, A. hypnorum, P. armigera, S. elodes, S. exilis, P. exacuous, G. deflectus;* 5 operculates: *C. decisum, Pleurocera acutum, Goniobasis livescens, Amnicola limosa, Bythinia tentaculata;* and 1 fingernail clam, *S. simile*, a total of 24 species.

To summarize, these data from the 10 permanent and 25 incidental sites show a wide diversity of mollusks were collected and examined; they harbored an abundance of leeches, trematode larvae, and symbionts. Leeches were especially abundant on *H. trivolvis, H. campanulatum, H. anceps, S. exilis,* and *P. gyrina;* they were found least on *P. exacuous, G. parvus, P. integra, P. armigera, A. hypnorum, S. elodes, L. megasoma, L. stagnalis, P. parkeri,* and *S. simile*. None was found on the pulmonates: *L. columella, L. humilis, P. sayii, G. hirsutus, L. catascopium;* nor on the operculates: *V. tricarinata, C. decisum, V. malleatus, A. limosa, P. acutum, G. livescens;* nor on the sphaeriid clams *S. lacustre* and *S. fabale*. Chaetogasters of the *Chaetogaster limnaei* type were abundant on all mollusks, except *L. columella, A. limosa, V. tricarinata, P. parkeri, L. catascopium,* and *G. deflectus*. The cercarial infections varied not only in terms of the species of mollusk but also from habitat to habitat. No mollusks had multiple cercarial types, and none was infested with multiple species of leeches even though sites harbored infestations with many leeches. Only *H. trivolvis, H. campanulatum, S. elodes, S. exilis, A. hypnorum, H. anceps,* and *P. gyrina* had the leech-cercarial association; *H. trivolvis* and *S. exilis* had the highest number of such associations.

The woodland pools had less snail diversity than the lakes or ponds even though some of the same species of snails were present in all of these habitats.

Part II. Seasonal Variations among Snails infested with Leeches from nine Permanent Collecting Stations

The seasonal variations (in percentages) of snail infestation with leeches, as shown by monthly samples during 1972 and 1973, are tabulated in Figures 1 to 25. These data were recorded for one woodland pool, three lakes, three ponds, one creek, and one

Table 6. Mollusks examined from Four-Mile Lake (T2S,R4E,S4SE), Washtenaw County, Michigan, shows total mollusks, leeches, chaetogasters, snail-leech-cercarial associations, and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
						Amphi-stome	Distomes					
							Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Stagnicola elodes	35	0	33	0	0	0	0	0	0	0	0	0
Lymnaea columella	15	0	0	0	0	0	0	0	0	0	0	0
Physa gyrina	109	41	109	0	11	8	0	0	0	3	0	0
Physa integra	31	0	31	0	1	1	0	0	0	0	0	0
Helisoma anceps	2	2	2	0	0	0	0	0	0	0	0	0
Helisoma trivolvis	398	109	390	0	48	1	0	0	39	6	2	0
Helisoma campanulatum	4	3	4	2	3	0	0	0	0	3	0	0
Planorbula armigera	11	0	11	0	0	0	0	0	0	0	0	0
Promenetus exacuous	18	1	18	0	0	0	0	0	0	0	0	0
Gyraulus hirsutus	6	0	6	0	0	0	0	0	0	0	0	0
Gyraulus parvus	75	3	75	0	1	1	0	0	0	0	0	0
Valvata tricarinata	329	0	0	0	0	0	0	0	0	0	0	0
Viviparus malleatus	287	0	0	0	0	0	0	0	0	0	0	0
Campeloma decisum	96	0	96	0	2	1	0	0	0	1	0	0
Amnicola limosa	367	0	0	0	0	0	0	0	0	0	0	0
Clam:												
Sphaerium (Musculium) lacustre	120	0	25	0	3	0	3	0	0	0	0	0
Sphaerium (Musculium) fabale	140	0	39	0	7	0	7	0	0	0	0	0
Total	2,043	159	839	0	77	13	10	0	39	13	2	0

roadside ditch. Each of these stations provided leeches. A percentage figure for infestation was obtained as follows: the number of snails infested divided by the number of snails sampled, then multiplied by 100; this calculation gave the percent frequency of occurrence. In this study if more than one leech species was parasitizing various snails in a particular habitat, these leeches were grouped together, unless otherwise stated.

As shown (Figures 1 to 5), five species of snails, *S. exilis*, *H. trivolvis*, *P. exacuous*, *P. armigera*, and *A. hypnorum*, collected from a woodland pool were leech infested but only one leech species, *M. lucida*, was associated with them. *S. exilis* and *H. trivolvis* were the most abundant snails inthe woodland pool, followed by *A. hypnorum*, *P. exacuous*, and *P. armigera*.

The pool was first sampled in early spring of 1972 and yielded very few *S. exilis*. The snail population increased, and on June 10, 1972, it was infested with leeches. In July when the snail population increased in number and size, the percentage of infestation with leeches also increased. *H. trivolvis* (Fig. 2), *P. exacuous* (Fig. 3), *P. armigera* (Fig. 4), and *A. hypnorum* (Fig. 5) all contained leeches. In July of 1972 the woodland pool began to dry up and by August all of the *S. exilis* collected were removed while aestivating in both decaying and living vegetation. These snails when collected had secreted an epiphragm and were able

Table 7. Snails examined from Murray Lake (T2S,R7E,S10NW), Washtenaw County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations, and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Helisoma campanu-latum	201	24	198	0	21	1	0	0	3	17	0	0
Planorbula armigera	140	1	45	0	0	0	0	0	0	0	0	0
Helisoma trivolvis	35	1	35	0	0	0	0	0	0	0	0	0
Helisoma anceps	6	0	6	0	0	0	0	0	0	0	0	0
Physa integra	30	2	30	0	0	0	0	0	0	0	0	0
Lymnaea columella	5	0	0	0	0	0	0	0	0	0	0	0
Promenetus exacuous	3	0	3	0	0	0	0	0	0	0	0	0
Stagnicola elodes	2	0	0	0	0	0	0	0	0	0	0	0
Amnicola limosa	201	0	0	0	0	0	0	0	0	0	0	0
Total	623	28	317	0	21	1	0	0	3	17	0	0

Table 8. Snails examined from a woodland pool (T2S,R3E,S9SW), Washtenaw County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations, and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Stagnicola exilis	677	321	0	13	79	10	0	0	62	3	4	0
Helisoma trivolvis	48	60	0	0	0	0	0	0	0	0	0	0
Aplexa hypnorum	82	7	0	1	3	0	1	0	1	0	0	1
Planorbula armigera	15	4	0	0	0	0	0	0	0	0	0	0
Promenetus exacuous	19	2	0	9	1	0	0	0	1	0	0	0
Gyraulus parvus	5	0	0	0	0	0	0	0	0	0	0	0
Total	846	394	0	14	83	10	1	0	64	3	4	1

Table 9. Snails examined from a woodland pool (T2S,R5E,S28SE), Washtenaw County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations, and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types: Amphi-stome	Distomes: Cysto-cercous	Distomes: Gymno-cephalous	Distomes: Echinostome cercariae	Distomes: Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Stagnicola elodes	408	0	0	0	40	0	0	8	10	20	2	0
Physa gyrina	157	0	0	0	59	13	0	0	12	28	5	1
Aplexa hypnorum	375	1	0	0	47	0	0	0	0	5	0	42
Promenetus exacuous	268	0	0	0	56	12	0	0	8	3	0	33
Total	1,208	1	0	0	202	25	0	8	30	56	7	76

Table 10. Snails examined from Fleming Creek (T2S,R6E,S25SE), Washtenaw County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types: Amphi-stome	Distomes: Macro-cercous	Distomes: Gymno-cephalous	Distomes: Echinostome cercariae	Distomes: Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Helisoma trivolvis	361	190	361	0	85	4	9	0	7	53	8	0
Helisoma anceps	507	162	507	6	75	0	1	0	2	67	5	0
Stagnicola elodes	266	0	266	0	242	2	0	0	51	182	7	0
Physa gyrina	278	25	278	0	54	0	0	0	24	26	4	0
Total	1,412	377	1,412	6	456	6	10	0	84	328	24	0

Table 11. Snails examined from a roadside ditch (T1S,R3E,S19SE), Washtenaw County, Michigan, shows total snails, leeches, chaetogasters, snail-leech-cercarial associations and cercarial types recovered.

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types: Amphi-stome	Distomes: Macro-cercous	Distomes: Gymno-cephalous	Distomes: Echinostome cercariae	Distomes: Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Helisoma trivolvis	658	333	0	2	57	4	5	0	21	25	0	2
Stagnicola elodes	426	40	0	0	56	0	0	0	21	15	11	9
Physa gyrina	604	157	0	2	67	50	0	0	2	13	1	1
Total	1,688	530	0	4	180	54	5	0	44	53	12	12

to attach themselves to various substrates in the woodland pool. Shells of the other snails, as well as *S. exilis*, apparently had fallen from their place of attachment and were empty. The shells with decaying snail tissues were fed on by small ground beetles, tabanid flies, and sciomyzid flies.

About 50 *S. exilis* were not examined for leeches at that time but were left in a plastic bucket. As conditions of the water changed in the bucket, the snails began to crawl up the sides of the bucket where they secreted an epiphragm to attach themselves to the sides of the bucket. The snails were not disturbed from August to December when several specimens were examined; surprisingly, they were still alive. Several, in fact, were infested with leeches and some infected with trematode larvae. Those snails that had fallen to the bottom of the empty bucket had died.

Although the woodland pool was sampled each month, no snails were found from September, 1972 to the spring of 1973. Water first again appeared in the pool from rains in late September, 1972; it remained a pool over winter 1972 and spring and summer 1973. It did not dry up in 1973. In March 1973 *S. exilis*

Table 12. Mollusks examined from various aquatic habitats throughout Michigan, shows total mollusks, leeches, chaetogasters, snail-leech-cercarial associations, and cercarial types recovered.

Mollusk Host	Total mollusks	Total leeches	Total chaetogasters	Total: snail-leech-cercarial assoc.	Total Infected with Trematodes	Cercarial Types						
							Distomes					
						Amphistome	Macrocercous	Gymnocephalous	Echinostome cercariae	Xiphidiocercariae	Strigea cercariae	Furcocercariae
Northeast Marsh (T1S,R3E,S30NE), E. S. George Reserve, Livingston County, Michigan, June 27, 1972												
Helisoma trivolvis	25	0	25	0	0	0	0	0	0	0	0	0
Planorbula armigera	2	0	2	0	0	0	0	0	0	0	0	0
Sphaerium simile	12	0	0	0	0	0	0	0	0	0	0	0
Total	39	0	27	0	0	0	0	0	0	0	0	0
Cressman Pond (T1S,R3E,S30NE), E.S. George Reserve, Livingston County, Michigan, June 12, 1972												
Helisoma trivolvis	57	1	28	1	22	3	4	0	0	15	0	0
Helisoma campanulatum	20	0	18	0	5	0	0	0	0	0	0	0
Physa gyrina	6	0	0	0	1	0	0	0	0	0	1	0
Planorbula armigera	5	0	5	0	0	0	0	0	0	0	0	0
Lymnaea humilis	12	0	8	0	0	0	0	0	0	0	0	0
Total	100	1	59	1	28	3	4	0	0	20	1	0

Mollusk Host	Total mollusks	Total leeches	Total chaetogasters	Total: snail-leech-cercarial assoc.	Total Infected with Trematodes	Cercarial Types						
							Distomes					
						Amphistome	Macrocercous	Gymnocephalous	Echinostome cercariae	Xiphidiocercariae	Strigea cercariae	Furcocercariae
Roadside Ditch (T35S,R4E,S10SW), Alanson, Emmet County, Michigan, April 18, 1973												
Lymnaea Stagnalis	101	0	101	0	2	0	0	0	0	0	0	2
Lymnaea catascopium	106	0	106	0	0	0	0	0	0	0	0	0
Total	207	0	207	0	2	0	0	0	0	0	0	2
Joslin Lake (T1S,R3E,S3NE), Washtenaw County, Michigan, June 12, 1972												
Helisoma trivolvis	24	0	24	0	3	0	3	0	0	0	0	0
Planorbula armigera	9	0	0	0	0	0	0	0	0	0	0	0
Gyraulus deflectus	15	0	0	0	0	0	0	0	0	0	0	0
Amnicola limosa	40	0	0	0	0	0	0	0	0	0	0	0
Total	88	0	24	0	3	0	3	0	0	0	0	0

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Duck Lake (T2S,R3E,S12), Jackson County, Michigan, June 12, 1972												
Stagnicola exilis	51	2	0	0	6	3	0	0	0	2	1	0
Physa gyrina	5	0	0	0	0	0	0	0	0	0	0	0
Physa integra	22	0	3	0	0	0	0	0	0	0	0	0
Planorbula armigera	5	2	5	0	0	0	0	0	0	0	0	0
Promenetus exacuous	4	0	3	0	2	2	0	0	0	0	0	0
Amnicola limosa	35	0	0	0	0	0	0	0	0	0	0	0
Goniobasis livescens	50	0	0	0	0	0	0	0	0	0	0	0
Total	172	4	11	0	8	5	0	0	0	2	1	0
Triangle Lake (T2S,R4E,S27), Livingston County, Michigan, June 3, 1972												
Campeloma decisum	248	0	0	0	2	0	0	0	0	0	0	2
Huron River (T2S,R6E,S17SE), Washtenaw County, Michigan, June 23, 1972												
Physa integra	102	0	51	0	2	0	0	0	1	1	0	0
Sugar Loaf Lake (T2S,R3E,S31NE), Washtenaw County, Michigan, July 18, 1972												
Helisoma trivolvis	28	0	20	0	1	0	0	0	0	1	0	0

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Fleming Creek (T2S,R7E,S8SE), Washtenaw County, Michigan, April 10, 1972												
Sphaerium simile	48	16	0	0	4	0	4	0	0	0	0	0
Reef Channel, Detroit River (40°09'30" Lat.N., 83°07'30" Long.W.), Ontario, Canada, May 10, 1973												
Bythinia tentaculata	45	0	0	0	0	0	0	0	0	0	0	0
Woodland Pool (T1S,R3E,S29NW), Washtenaw County, Michigan, July 20, 1972												
Stagnicola exilis	30	0	0	0	3	1	0	0	2	0	0	0
Impoundment (T1S,R3E,S29SW), Washtenaw County, Michigan, July 17, 1972												
Helisoma trivolvis	9	2	9	0	0	0	0	0	0	0	0	0
Helisoma campanulatum	1	0	1	0	0	0	0	0	0	0	0	0
Physa gyrina	3	0	0	0	0	0	0	0	0	0	0	0
Promenetus exacuous	2	0	2	0	0	0	0	0	0	0	0	0
Total	15	2	12	0	0	0	0	0	0	0	0	0

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco cercariae
Cedar Lake (T2S,R3E,S9SE), Washtenaw County, Michigan, July 17, 1972												
Helisoma trivolvis	6	0	6	0	0	0	0	0	0	0	0	0
Mill Lake (T2S,R3E,S4NE), Washtenaw County, Michigan, July 17, 1972												
Helisoma trivolvis	6	1	6	0	0	0	0	0	0	0	0	0
Helisoma campanulatum	9	2	9	0	0	0	0	0	0	0	0	0
Total	15	3	15	0	0	0	0	0	0	0	0	0
South Lake (T1S,R3E,S10SW), Washtenaw County, Michigan, June 12, 1972												
Lymnaea humilis	16	0	16	0	0	0	0	0	0	0	0	0
Physa gyrina	18	0	18	0	6	0	0	0	0	0	0	6
Helisoma trivolvis	16	0	16	0	2	0	0	0	0	1	0	1
Promenetus exacuous	5	0	5	0	1	1	0	0	0	0	0	0
Campeloma decisum	40	0	0	0	0	0	0	0	0	0	0	0
Total	95	0	55	0	9	1	0	0	0	1	0	7

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco cercariae
Waffle's Pond (T4S,R7E,S33SE), Washtenaw County, Michigan, June 5, 1972												
Physa gyrina	5	0	0	0	0	0	0	0	0	0	0	0
Physa sayii	8	0	0	0	0	0	0	0	0	0	0	0
Aplexa hypnorum	37	1	0	0	3	0	0	0	0	0	0	3
Helisoma trivolvis	81	3	0	0	0	0	0	0	0	0	0	0
Planorbula armigera	2	1	0	0	0	0	0	0	0	0	0	0
Stagnicola elodes	68	0	0	0	3	0	0	0	0	0	3	0
Total	201	5	0	0	6	0	0	0	0	0	3	3
North Lake (T1S,R4E,S18NE), Washtenaw County, Michigan, July 20, 1972												
Helisoma trivolvis	5	0	5	0	0	0	0	0	0	0	0	0
Physa gyrina	10	0	0	0	4	3	0	0	1	0	0	0
Planorbula armigera	21	0	15	0	0	0	0	0	0	0	0	0
Promenetus exacuous	35	0	12	0	2	0	0	0	2	0	0	0
Campeloma decisum	60	0	0	0	0	0	0	0	0	0	0	0
Sphaerium simile	31	0	0	0	2	0	1	0	0	1	0	0
Total	162	0	32	0	8	3	1	0	3	1	0	0

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types: Amphi-stome	Distomes: Cysto-cercous	Distomes: Gymno-cephalous	Distomes: Echinostome cercariae	Distomes: Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Honey Creek (T1S,R4E,S26N), Livingston County, Michigan, August 19, 1972												
Pleurocera	218	0	0	0	2	0	0	0	0	2	0	0
acuta	218	0	0	0	2	0	0	0	0	2	0	0
Goniobasis livescens	250	0	0	0	5	0	0	0	0	2	0	3
Total	368	0	0	0	7	0	0	0	0	4	0	3
South Lake (T1S, R3E,S10SW), Washtenaw County, Michigan, July 20, 1972												
Helisoma trivolvis	18	2	18	0	0	0	0	0	0	0	0	0
Physa gyrina	2	0	2	0	0	0	0	0	0	0	0	0
Total	20	2	20	0	0	0	0	0	0	0	0	0
Baw Besse Lake (T12S,R16E,S33), Muskegon County, Michigan, July 8, 1972												
Helisoma trivolvis	6	0	1	0	0	0	0	0	0	0	0	0
Helisoma campanu-latum	5	1	2	0	1	0	0	0	0	0	0	1
Total	11	1	3	0	1	0	0	0	0	0	0	1
Big Blue Lake (T12S,R16E,S28), Muskegon County, Michigan, July 15, 1972												
Lymnaea stagnalis	50	0	1	0	0	0	0	0	0	0	0	0
Roadside Ditch (T23S,R4E,S31S), Missaukee County, Michigan, August 10, 1972												
Helisoma trivolvis	36	30	0	6	11	0	0	0	4	7	0	0
Lymnaea megasoma	25	2	0	0	1	0	0	0	0	1	0	0
Total	61	32	0	6	12	0	0	0	4	8	0	0

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types: Amphi-stome	Distomes: Cysto-cercous	Distomes: Gymno-cephalous	Distomes: Echinostome cercariae	Distomes: Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Roadside Ditch (T23S,R5E,S31S), Missaukee County, Michigan, April 18, 1973												
Lymnaea megasoma	39	3	39	0	2	0	0	0	0	2	0	0
Physa gyrina	6	0	6	0	1	0	0	0	0	1	0	0
Helisoma anceps	8	2	8	0	0	0	0	0	0	0	0	0
Helisoma trivolvis	46	53	46	3	18	0	0	0	3	15	0	0
Total	99	58	99	3	21	0	0	0	3	18	0	0
Au Sable River (T26S,R3E,S7SW), Crawford County, Michigan, August 2, 1972												
Lymnaea stagnalis	25	2	0	0	7	0	0	0	0	0	7	0
Frains Lake (T2S,R7E,S9NE), Washtenaw County, Michigan, June 2, 1973												
Physa gyrina	40	0	0	0	0	0	0	0	0	0	0	0
Pond (T2S,R4E,S35SE), Livingston County, Michigan, June 27, 1972												
Helisoma trivolvis	16	0	5	0	7	0	0	0	0	7	0	0

Mollusk Host	Total moll-usks	Total leeches	Total chaeto-gasters	Total: snail-leech-cercarial assoc.	Total Infected with Trema-todes	Cercarial Types						
							Distomes					
						Amphi-stome	Cysto-cercous	Gymno-cephalous	Echinostome cercariae	Xiphidio-cercariae	Strigea cercariae	Furco-cercariae
Douglas Lake (T37S, R3E, S27), Cheboygan County, Michigan, July 5, 1972												
Lymnaea emarginata	4	0	0	0	3	0	0	0	0	0	3	0
Lymnaea humilis	15	0	0	0	0	0	0	0	0	0	0	0
Physa parkeri	19	12	0	0	3	1	0	0	2	0	0	0
Helisoma trivolvis	5	0	0	0	0	0	0	0	0	0	0	0
Helisoma campanulatum	2	0	0	0	0	0	0	0	0	0	0	0
Amnicola limosa	52	0	0	0	0	0	0	0	0	0	0	0
Goniobasis livescens	47	0	0	0	0	0	0	0	0	0	0	0
Total	144	12	0	0	6	1	0	0	2	0	3	0
Douglas Lake (T34S, R3E, S27), Cheboygan County, Michigan, November 5, 1972												
Physa parkeri	12	1	0	0	0	0	0	0	0	0	0	0
Helisoma trivolvis	5	0	0	0	0	0	0	0	0	0	0	0
Total	17	1	0	0	0	0	0	0	0	0	0	0

was last noted when five specimens were collected, but none of them was infested with leeches. An increase in snail population number, size, fecundity, and recruitment was observed from May to July. The percentage of leech infestation also increased from June to August. These data indicated a lag in the fecundity in the leech population and that its reproductive cycle was synchronized with the snail populations. In addition, even though the woodland pool did not dry up in 1973, there was a sharp decline in the snail populations.

As the leeches and snails were collected each month, both the leeches and snails were measured. These data, not included in this study, indicated that *M. lucida* spent its developmental period within the snails as there was an observed increase in size of the leeches from month to month. No leeches were found to be free living or attached to various substrates in the woodland pool.

From two lake habitats (Figures 6 to 11) data are recorded on six species of snails infested with leeches. The first lake at T2S, R4E, S1NW (Figures 6 to 9) yielded four species of snails infested with leeches: *H. trivolvis*, *H. campanulatum*, *H. anceps*, and *P. exacuous*. Of these four species *H. campanulatum* and *P. exacuous* harbored the leech *H. fusca*; *H. anceps* was infested with *H. papillata*, and *H. trivolvis* was host to several species of leeches. The most abundant snail in this lake was *H. trivolvis*, followed by *H. campanulatum*, *H. anceps*, and *P. exacuous*. The lake was first sampled in August of 1971 when 104 *H. trivolvis* were collected and examined for leeches; 29 or 27.8% were infested. This lake was not sampled again until April, 1972, after which it was sampled regularly each month until September, 1973. In April, 1972 very few *H. trivolvis* and *H. campanulatum* were found; there were no specimens of *H. anceps* or *P. exacuous*. From May to September the population of *H. trivolvis* increased, as did the infestations with leeches. Although the infestation with leeches remained low, it was present during all months of the year. No snails were found in December to February, but this failure to find them does not mean they were not there. In *H. campanulatum* the first noticeable infestation occurred in August, then dropped in November of 1972. No snails were found during the winter months. First infestation of 1973 occurred in April; a drop in infestation occurred in March and June, then an increase was again noticed in July and August. Not enough *H. campanulatum*, *H. anceps*, or *P. exacuous* snails were collected to determine whether leeches were in these populations throughout the year.

The second lake, Four-Mile Lake (Figures 10 and 11), harbored snails *H. trivolvis* and *P. gyrina*. It was first sampled in March, 1972. At that time *P. gyrina* was infested only with *H. papillata*, while *H. trivolvis* carried several species of leeches. During the period of March to May (Figure 10) the percentage of infestation by leeches in *P. gyrina* remained even, then it dropped in June and July. In August to September it again increased, only to drop in October. No *P. gyrina* was found from November to February. In March, 1973 *H. papillata* again was found in *P. gyrina*; infestation remained quite even through April, then increased slightly in May. It dropped sharply in June and July, then increased sharply in August and Septem-

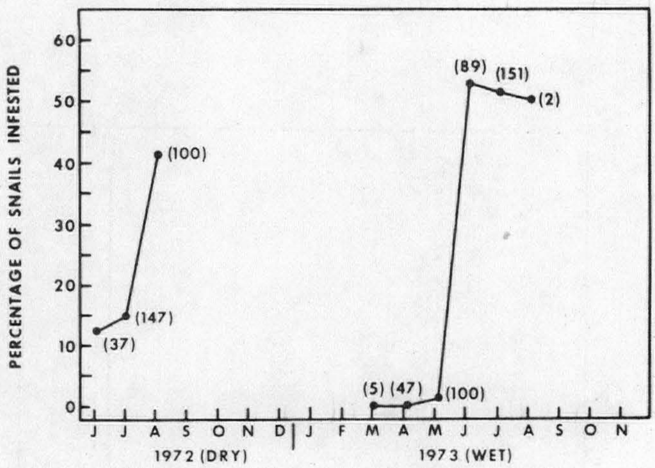

Figure 1. Woodland Pool (T2S, R3E, S9SW), Washtenaw County Michigan. The percentage of Stagnicola exilis infested with Marvinmeyeria lucida. Numbers in parentheses indicate total snails collected.

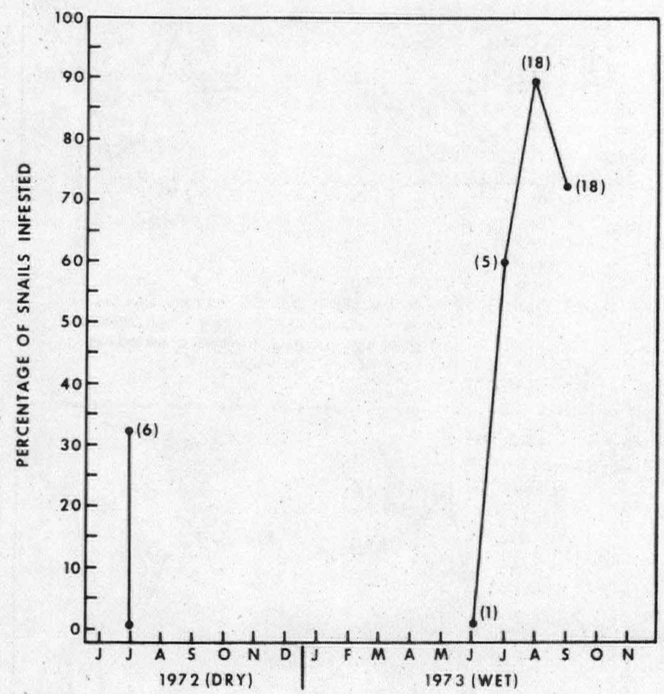

Figure 2. Woodland Pool (T2S, R3E, S9SW), Washtenaw County, Michigan. The percentage of Helisoma trivolvis infested with Marvinmeyeria lucida. Numbers in parentheses indicate total snails collected.

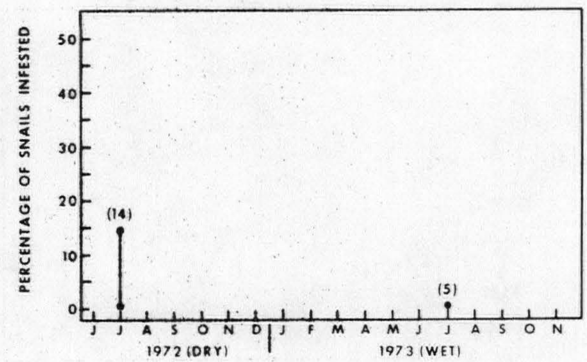

Figure 3. Woodland Pool (T2S, R3E, S9SW), Washtenaw County Michigan. The percentage of Promenetus exacuous infested with Marvinmeyeria lucida. Numbers in parentheses indicate total snails collected.

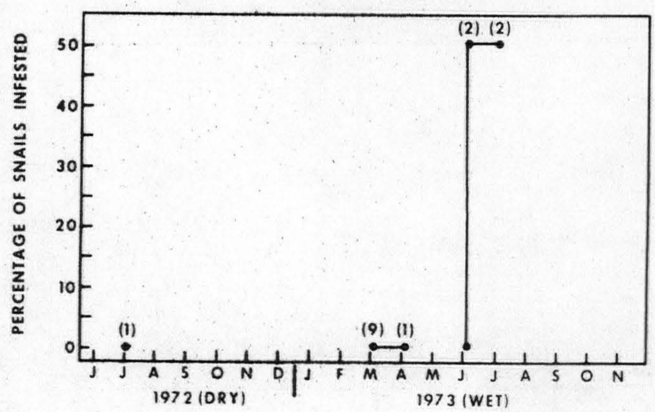

Figure 4. Woodland Pool (T2S, R3E, S9SW), Washtenaw County, Michigan. The percentage of Planorbula armigera infested with Marvinmeyeria lucida. Numbers in parentheses indicate total snails collected.

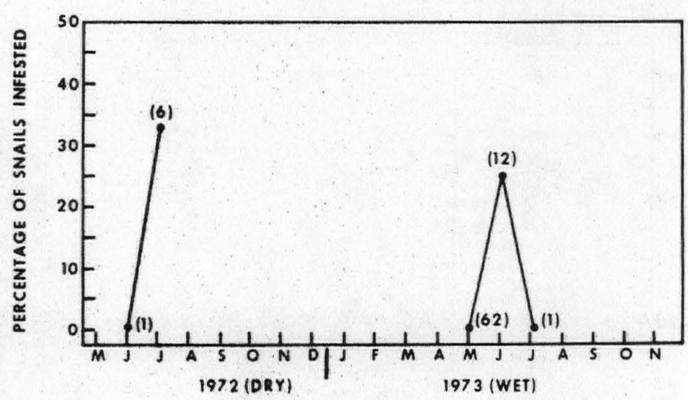

Figure 5. Woodland Pool (T2S, R3E, S9SW), Washtenaw County, Michigan. The percentage of Aplexa hypnorum infested with Marvinmeyeria lucida. Numbers in parentheses indicate total snails collected.

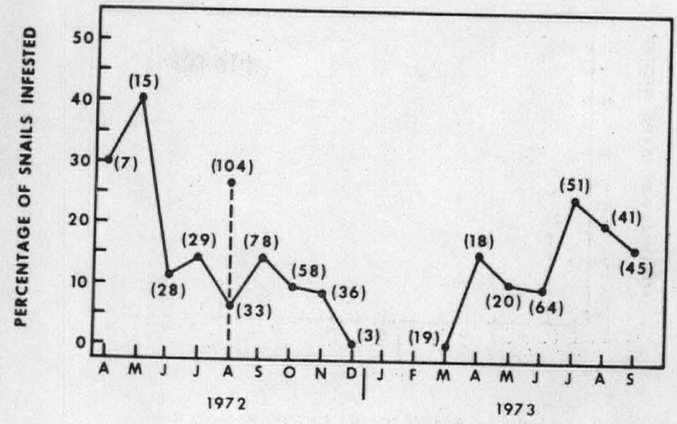

Figure 6. Lake (T2S, R4E, S1NW), Washtenaw County, Michigan. The percentage of Helisoma trivolvis infested with leeches. Numbers in parentheses indicate total snails collected.

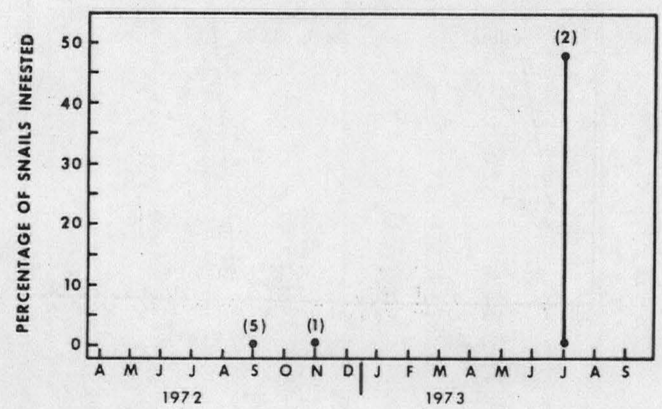

Figure 9. Lake (T2S, R4E, S1NW), Washtenaw County, Michigan. The percentage of Promenetus exacuous infested with Helobdella fusca. Numbers in parentheses indicate total snails collected.

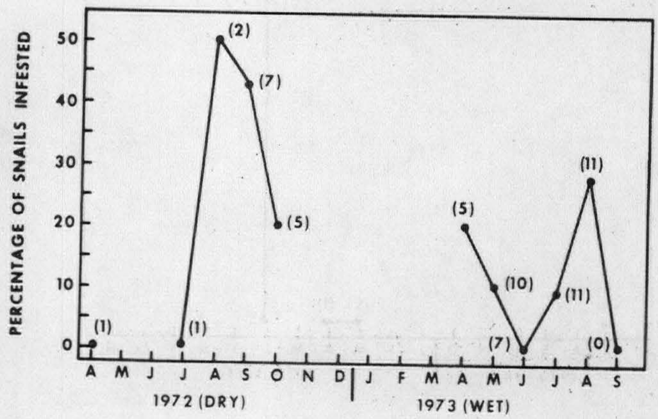

Figure 7. Lake (T2S, R4E, S1NW), Washtenaw County, Michigan. The percentage of Helisoma camplanulatum infested with Helobdella fusca. Numbers in parentheses indicate total snails collected.

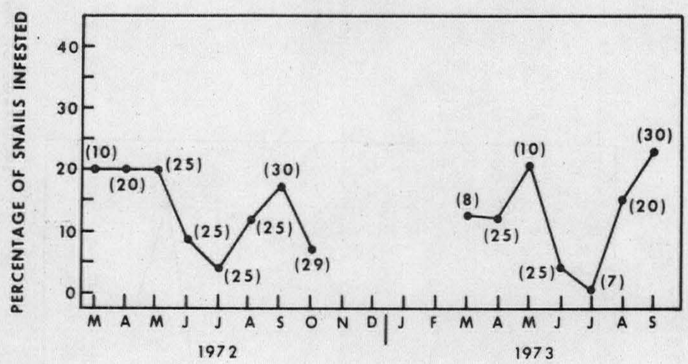

Figure 10. Four-Mile Lake (T2S, R3E, S4SE), Washtenaw County, Michigan. The percentage of Physa gyrina infested with Helobdella papillata. Numbers in parentheses indicate total snails collected.

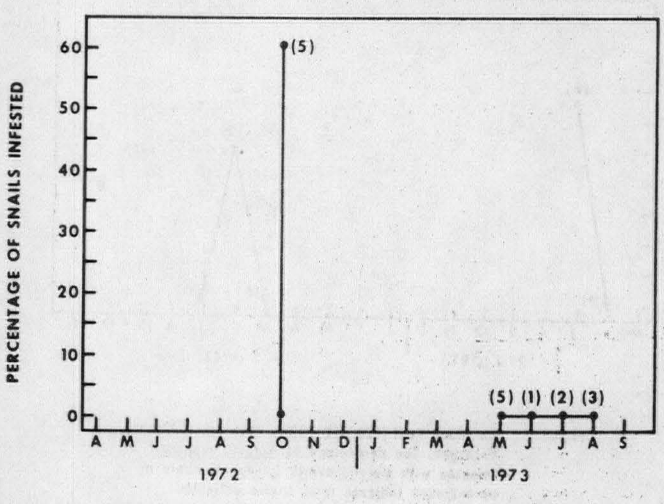

Figure 8. Lake (T2S, R4E, S1NW), Washtenaw County, Michigan. The percentage of Helisoma anceps infested with Helobdella papillata. Numbers in parentheses indicate total snails collected.

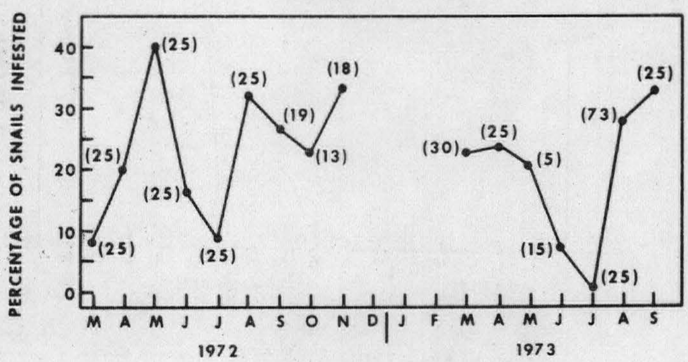

Figure 11. Four-Mile Lake (T2S, R3E, S4SE), Washtenaw County, Michigan. The percentage of Helisoma trivolvis infested with leeches. Numbers in parentheses indicate total snails collected.

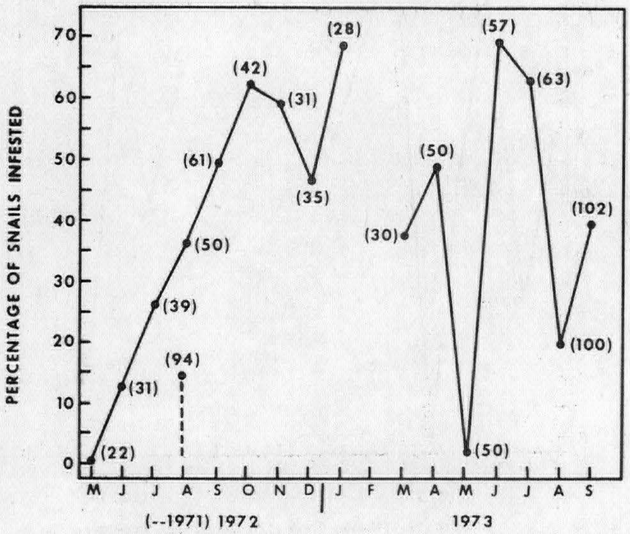

Figure 12. Bert Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County, Michigan. The percentage of Helisoma trivolvis infested with leeches. Numbers in parentheses indicate total snails collected.

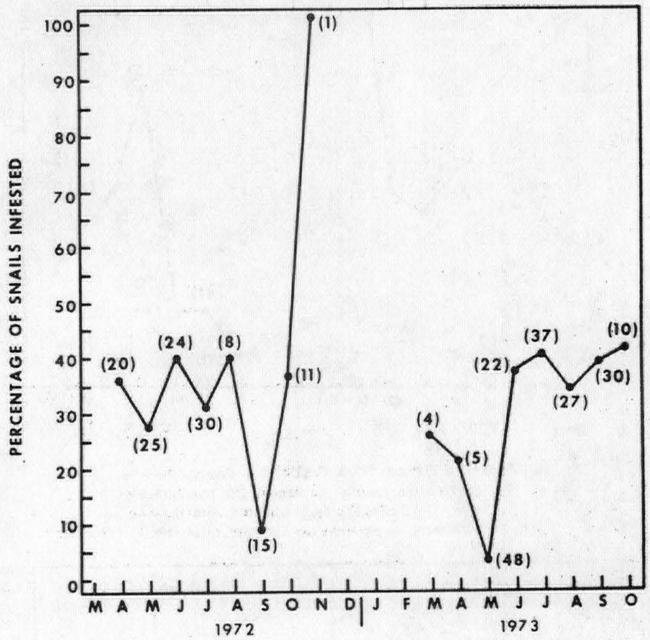

Figure 14. Crane Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County, Michigan. The percentage of Helisoma trivolvis infested with leeches. Numbers in parentheses indicate total snails collected.

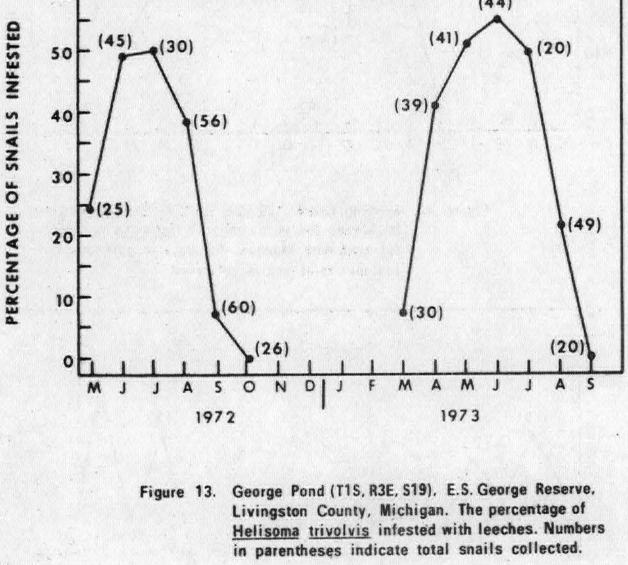

Figure 13. George Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County, Michigan. The percentage of Helisoma trivolvis infested with leeches. Numbers in parentheses indicate total snails collected.

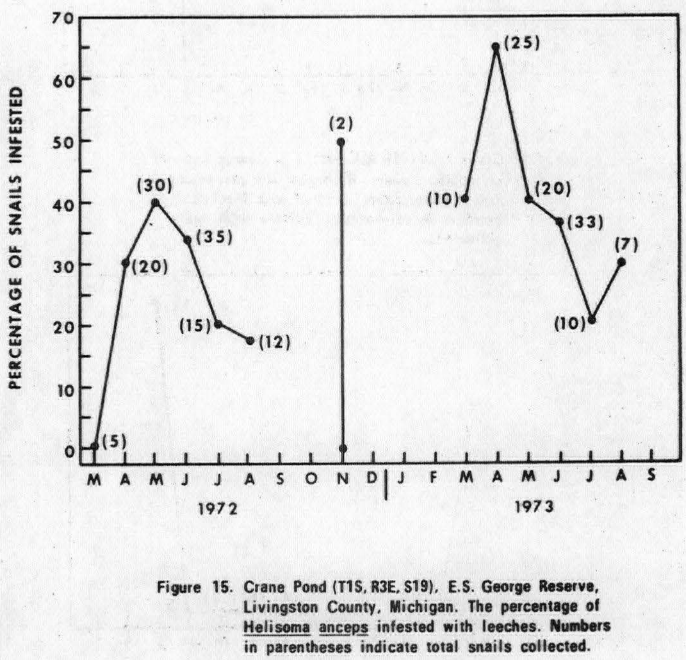

Figure 15. Crane Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County, Michigan. The percentage of Helisoma anceps infested with leeches. Numbers in parentheses indicate total snails collected.

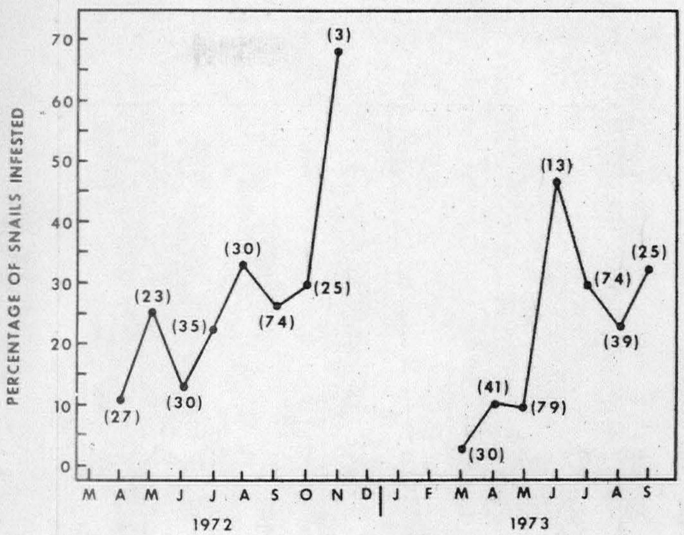

Figure 16. Crane Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County, Michigan. The percentage of Helisoma campanulatum infested with leeches. Numbers in parentheses indicate total snails collected.

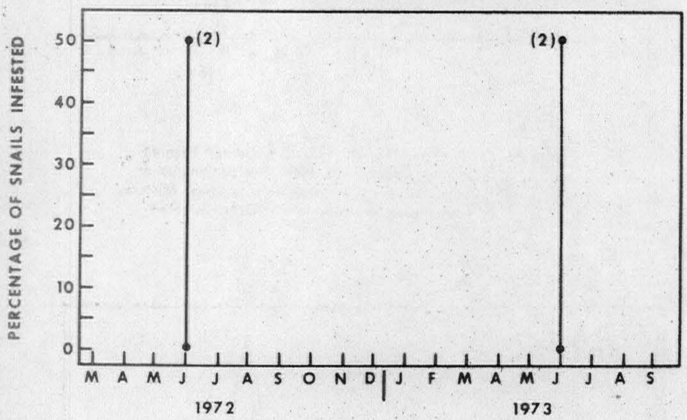

Figure 17. Crane Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County, Michigan. The percentage of Planorbula armigera infested with leeches. Numbers in parentheses indicate total snails collected.

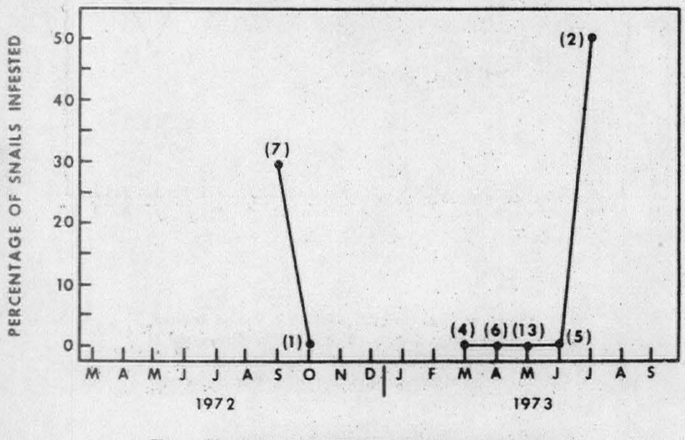

Figure 18. Crane Pond (T1S, R3E, S19), E.S. George Reserve, Livingston County, Michigan. The percentage of Physa gyrina infested with leeches. Numbers in parentheses indicate total snails collected.

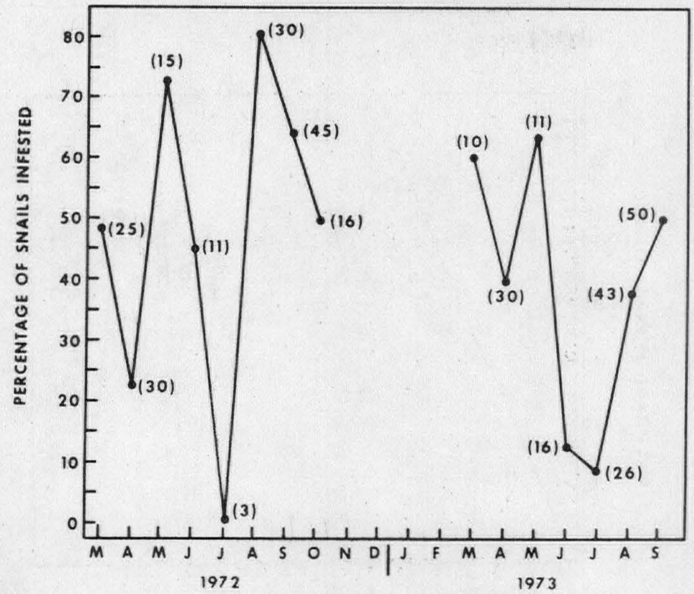

Figure 19. Fleming Creek (T2S, R6E, S25SE), Washtenaw County, Michigan. The percentage of Helisoma trivolvis infested with leeches. Numbers in parentheses indicate total snails collected.

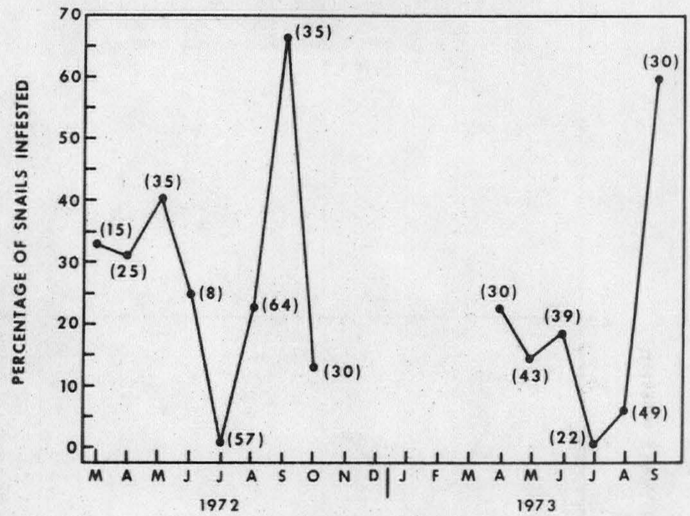

Figure 20. Fleming Creek (T2S, R6E, S25SE), Washtenaw County, Michigan. The percentage of Helisoma anceps infested with leeches. Numbers in parentheses indicate total snails collected.

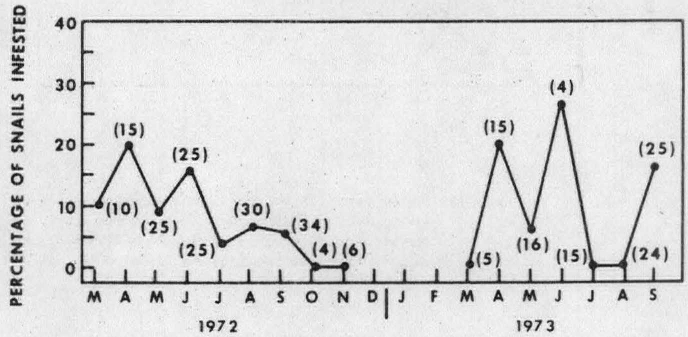

Figure 21. Fleming Creek (T2S, R6E, S25SE), Washtenaw County, Michigan. The percentage of Physa gyrina infested with Helobdella papillata. Numbers in parentheses indicate total snails collected.

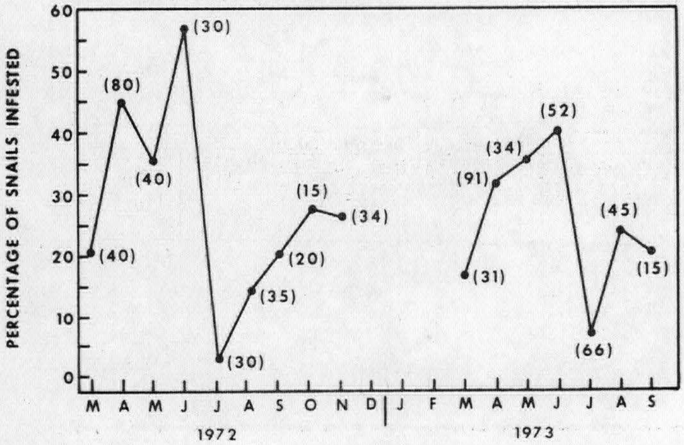

Figure 22. Roadside ditch (T1S, R3E, S19SE), Washtenaw County, Michigan. The percentage of Helisoma trivolvis infested with leeches. Numbers in parentheses indicate total snails collected.

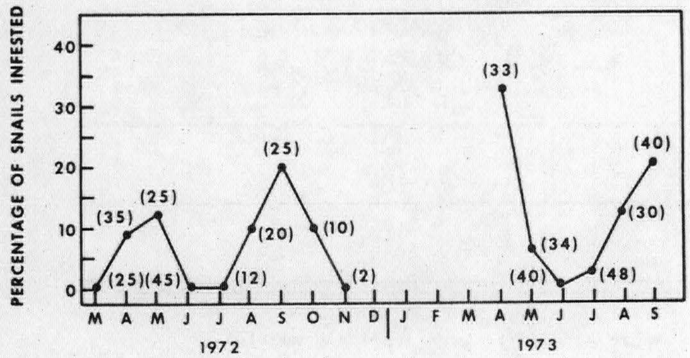

Figure 23. Roadside ditch (T1S, R3E, S19SE), Washtenaw County Michigan. The percentage of Stagnicola elodes infested with Helobdella papillata. Numbers in parentheses indicate total snails collected.

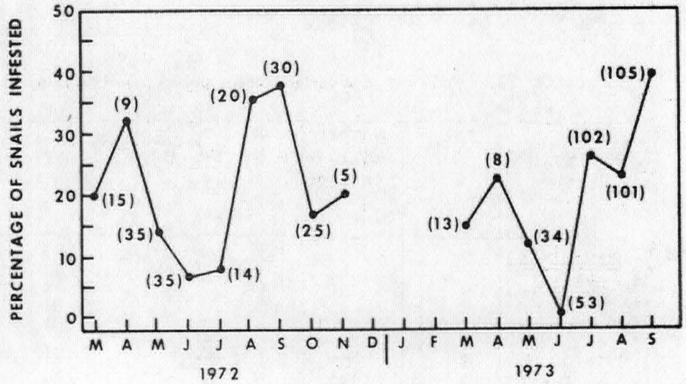

Figure 24. Roadside ditch (T1S, R3E, S19SE), Washtenaw County, Michigan. The percentage of Physa gyrina infested with leeches. Numbers in parentheses indicate total snails collected.

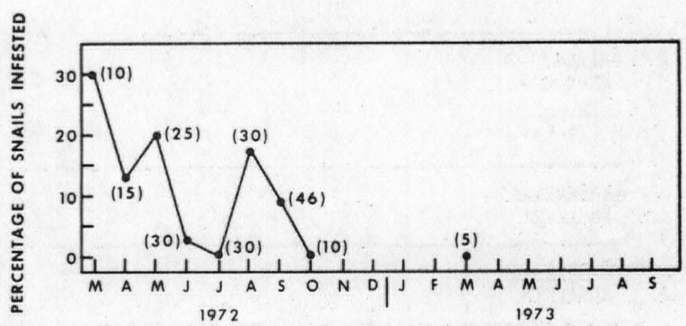

Figure 25. Murray Lake (T2S, R7E, S10NW), Washtenaw County, Michigan. The percentage of Helisoma campanulatum infested with Helobdella fusca. Numbers in parentheses indicate total snails collected.

ber. There was a decline in October. The pattern of infestation in *H. trivolvis* was similar to *P. gyrina*. Again no *H. trivolvis* was found from December to February. The pattern of infestation was similar in both snail species.

For three ponds studied the annual percentage of infestation of five species of snails, *H. trivolvis, H. campanulatum, H. anceps, P. armigera,* and *P. gyrina*, is given in Figures 12 to 18. Of the five, only *H. trivolvis* was collected in all three ponds. Bert Pond (Figure 12) was first sampled in August of 1971; the snails collected had a 15% infestation. In 1972 *H. trivolvis* was first collected in May, when the snails examined were free of leeches. From June to October there was an increase in leech infestation. In November and December the percentage dropped slightly, then went up again in January. No snails were found in February. In March and April, 1973 the snail infestations with leeches again increased. A drop came in May; it then climbed sharply, then dropped between July and August, only to increase again in September. In this pond leeches infested the snails every month they were collected, except in May. These data show the percentage of infestation was quite similar in each August of 1971, 1972, and 1973.

In George Pond (Figure 13) the percentage of infestations in *H. trivolvis* was seasonally different as compared with Figure 12. The snails collected in May were infested; the infestation increased in June and July and decreased from August to October. No snails were found between November and February. In March, 1973 the percentage of infestation was low. It increased sharply from April to June, again decreasing from July to September. The percentages and seasonal variations of infestation in the two years were significantly similar.

In Crane Pond (Figures 14 to 18) the percentage

Table 13. Mollusk infestations from a woodland pool (T2S,R3E,S9SW), Washtenaw County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Stagnicola exilis	(1)	194	0	0	0	0	0	5
	(2)		0	0	0	0	0	268
	(3)		0	0	0	0	0	42
	(4)		0	0	0	0	0	6
Total		194	0	0	0	0	0	321
Helisoma trivolvis	(1)	34	0	0	0	0	0	1
	(2)		0	0	0	0	0	2
	(3)		0	0	0	0	0	4
	(4)		0	0	0	0	0	53
Total		34	0	0	0	0	0	60
Aplexa hypnorum	(1)	5	0	0	0	0	0	3
	(2)		0	0	0	0	0	4
Total		5	0	0	0	0	0	7
Promenetus exacuous	(2)	2	0	0	0	0	0	2
Planorbula armigera	(2)	2	0	0	0	0	0	4

Location in host:
(1) mantle cavity
(2) under mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney

and seasonal similarities of five snail species, *H. trivolvis*, *H. anceps*, *H. campanulatum*, *P. armigera*, and *P. gyrina*, were recorded. These data show that *H. trivolvis*, *H. anceps*, and *H. campanulatum* were infested during the summer and fall of 1972. No snails were found from December to February. In 1973 leech infestations from March to September showed only slight percentage differences. Very few *P. armigera* and *P. gyrina* were found during 1972 and 1973 The former showed an infestation in June of 1972 and 1973; the latter was infested with leeches in September of 1972 and July of 1973. The data on these two species of snails still coincide with the pattern of infestations of *H. trivolvis*, *H. anceps* and *H. campanulatum* during 1972 and 1973.

For the Fleming Creek area (Figures 19 to 21) the data show a seasonal similarity among the snails infested with leeches. The three species infested, *H. trivolvis*, *H. anceps*, and *P. gyrina*, were positive from March to June, 1972. Only *P. gyrina* was infested in July. All these snails were infested in varying degrees from August to October. Few snails were found from October to March, 1973. In April, 1973 some snails were again infested with leeches. In July, 1973 only *H. trivolvis* was infested, but in August to September both *H. trivolvis* and *H. anceps* showed an increase, while *P. gyrina* showed none in July and August, and an increase in September.

From a roadside ditch (Figures 22 to 24) the percentages of leech infestations were disclosed for three species of snails, *H. trivolvis*, *P. gyrina*, and *S. elodes*. The first samples were taken in March, 1972, and only *H. trivolvis* and *P. gyrina* were found infested with leeches. *S. elodes* was first found infested in April, 1972 and showed an increase in leech infestation to May. *H. trivolvis* showed an increase from May to June, while *P. gyrina* showed a drop in June but an increase during the months of August and September and then a decrease once again. *H. trivolvis* showed a marked increase for the month of June. followed by a sharp decline in July but an increase in August to October. No snails were found from December to February for *H. trivolvis* and *P. gyrina*. *S. elodes* was not found from December to March. In March, 1973 *H. trivolvis* and *P. gyrina* disclosed an increase in leech infestation. *S. elodes* showed an increase in April. 1973 and a sharp decrease for the months of May and June. *H. trivolvis* showed a sharp decrease in July, while *P. gyrina* showed a decrease

Table 14. Mollusk infestations from a woodland pool (T2S,R5E,S28SE), Washtenaw County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Aplexa hypnorum	(2)	1	0	0	0	0	0	1

Table 15. Mollusk infestations from George Pond (T1S, R3E, S19), E. S. George Reserve, Livingston County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma trivolvis	(1)	152	7	2	0	0	0	0
	(2)		46	17	0	0	0	0
	(3)		74	16	0	0	0	0
	(4)		5	15	0	0	0	0
Total		152	132	50	0	0	0	0

Location in host:
(1) mantle cavity
(2) under mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney

in June. All three species showed an increase in August, but only *S. elodes* and *P. gyrina* showed an increase for September. All three species of snails illustrated a seasonal similarity of infestations for the years 1972 and 1973.

In Murray Lake (Figure 25) *H. campanulatum* was first collected in March, 1972 and it was then infested with leeches. In April there was a decline; in May a slight increase, followed by a sharp decrease in June and July. Snails examined in August had an increase in leech infestation with a gradual decrease in September to none in October. No snails were found from November to February. In March, 1973 only five specimens were found; none was infested. The reason no snails were found from April to September appears to be that the littoral zone at this station was cleared, covered with sand, and made into a swimming beach. The data collected on snail infestation by leeches in 1972 indicates the same seasonal similarities of the other lakes and ponds studied.

III. Locations and species of leeches recovered from mollusks under natural conditions

The species of mollusk infested and the leeches recovered are shown in Tables 13 through 23. The organs in the infested mollusks were restricted to five locations: the mantle cavity, beneath the mantle in the area of digestive gland and aorta, outside the mantle *(i. e.,* between the shell and mantle), in the kidney, and outside the mollusk on its shell (Tables 13-23). These data were given for 14 species of pulmonate snails and one species of sphaeriid clam. Tables 13 through 22 tabulate the data for the ten permanent stations sampled; Table 23 the data for the incidental sites. Altogether six species of leeches, *H. fusca, H. lineata, H. papillata, G. complanata, G. heteroclita,* and *M. lucida,* were recovered from these mollusks. Infestations were by a single leech species; parasitism of a snail by more than one species of leech was not observed.

The five species of snails in a woodland pool (Table 13), *S. exilis, H. trivolvis, A. hypnorum, P. exacuous,* and *P. armigera,* were infested with only one leech species, *M. lucida.* Among the 194 *S. exilis* infested, 5 specimens of *M. lucida* were removed from the mantle cavity, 268 from under the mantle, 42 from above the mantle, and 6 from the kidney. Of 24 *H. trivolvis* infested, 1 *M. lucida* was in the mantle cavity, 2 under the mantle 4 above the mantle, and 53 in the kidney. The 5 *A. hypnorum* were infested with 3 *M. lucida* from the mantle cavity and 4 under the mantle. *P. exacuous* had 2 *M. lucida* under the mantle; *P. armigera* had (Table 14) had 1 *A. hypnorum* with 1 *M. lucida* in its mantle cavity.

In George Pond (Table 15) *H. trivolvis* snails were parasitized by two leeches, *H. fusca* and *H. lineata.* The 152 *H. trivolvis* infested yielded 132 *H. fusca* and 50 *H. lineata.* Among the 132 *H. fusca* found, 7 were in the mantle cavity, 46 under the mantle, 74 above the mantle, and 5 in the kidney.

Table 17. Mollusk infestations from Crane Pond (T1S,R3E,S19), E. S. George Reserve, Livingston County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma trivolvis	(1)	90	5	0	1	0	0	0
	(2)		57	0	0	0	0	0
	(3)		23	0	3	0	0	0
	(4)		7	0	0	0	0	0
Total		90	92	0	4	0	0	0
Helisoma anceps	(1)	80	0	0	7	0	0	0
	(2)		1	0	83	0	0	0
	(3)		0	0	14	0	0	0
	(4)		0	0	3	0	0	0
Total		80	1	0	107	0	0	0
Helisoma campanulatum	(1)	115	4	0	1	0	0	0
	(2)		90	0	0	0	0	0
	(3)		7	1	10	0	0	0
	(4)		3	0	4	0	0	0
Total		115	104	1	15	0	0	0
Planorbula armigera	(3)	2	3	0	0	0	0	1
Physa gyrina	(2)	3	1	0	0	0	0	0
	(3)		3	1	0	0	0	0
Total		3	4	1	0	0	0	0

Location in host:
(1) mantle cavity
(2) under mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney

Table 16. Mollusk infestations from Bert Pond (T1S,R3E,S19), E. S. George Reserve, Livingston County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma trivolvis	(1)	328	19	5	0	0	0	0
	(2)		52	10	0	0	0	0
	(3)		195	109	0	0	0	0
	(4)		113	20	0	0	0	0
Total		328	379	144	0	0	0	0

Location in host:
(1) mantle cavity
(2) under mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney

Table 18. Mollusk infestations from a lake (T2S,R3E,S1NE), Washtenaw County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma trivolvis	(1)	97	5	0	2	0	0	0
	(2)		25	0	1	0	0	0
	(3)		60	2	0	0	0	0
	(4)		9	0	0	0	0	0
Total		97	99	2	3	0	0	0
Helisoma camplanulatum	(2)	11	7	0	0	0	0	0
	(3)		6	0	0	0	0	0
	(4)		1	0	0	0	0	0
Total		11	14	0	0	0	0	0
Promenetus exacuous	(2)	1	1	0	0	0	0	0
Helisoma anceps	(3)	3	0	0	3	0	0	0

Location in host:
(1) mantle cavity
(2) under mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney

H. fusca appeared to have a preference for two locations, under and above the mantle. *H. lineata* occurred in almost equal numbers in three locations with 17 under the mantle, 16 above the mantle, and 15 in the kidney; only two *H. lineata* were in the mantle cavity.

In Bert Pond (Table 16) one snail species, *H. trivolvis*, was parasitized by two leeches, *H. fusca* and *H. lineata*. Within the 328 *H. trivolvis* infested were 379 *H. fusca* and 144 *H. lineata*, distributed as follows: 19 *H. fusca* in the mantle cavity, 52 under the mantle, 195 above the mantle, and 113 within the kidney. In this snail population, possibly because of their size, more leeches were removed from above the mantle and the kidney than from the mantle cavity or under the mantle. Of the 144 *H. lineata* found, 5 were in the mantle cavity or under the mantle. Of the 144 *H. lineata* found, 5 were in the mantle cavity, 10 under the mantle., 109 above the mantle, and 20 from the kidney. These data indicate that *H. lineata* preferred an area intermedium to above the mantle rather than the mantle cavity, under the mantle, or in the kidney.

In Crane Pond (Table 17), five snails occurred, *H. trivolvis*, *H. anceps*, *H. campanulatum*, *P. armigera*, and *P. gyrina*, and four leeches, *H. fusca* *H. lineata*, *H. papillata*, and *M. lucida*, were found parasitizing them. In the 90 *H. trivolvis* infested with leeches, 92 *H. fusca* and 4 *H. papillata* were found: 5 *H. fusca* from the mantle cavity, 57 under the mantle, 23 above the mantle, and 7 within the kidney. One *H. papillata* was in the mantle cavity and 3 above the mantle. A preference for the site above the mantle and under the mantle was shown by *H. fusca*. Eighty *H. anceps* were infested with 107 *H. papillata* and 1 *H. fusca*; *H. papillata* appeared to have a preference for under the mantle with 83 specimens found there. *H. campanulatum* carried three species of leeches, of which 104 were *H. fusca*, 1 *H. lineata*, and 15 *H. papillata*. The preference was shown by 90 *H. fusca* for under the mantle, while 10 *H. papillata* were removed from above the mantle. The snails *P. armigera* and *P. gyrina* had the lowest infestations. Three specimens of *H. fusca* were removed from under the mantle of *P. armigera* and also one specimen of *M. lucida*. *P. gyrina* had 1 *H. fusca* from under the mantle, 3 from above the mantle, and 1 *H. lineata* from above the mantle. These data show that *H. fusca* had a preference for *H. trivolvis* and *H. campanulatum*; *H. papillata* preferred *H. anceps*.

From a lake habitat (Table 18) four snail species, *H. trivolvis*, *H. campanulatum*, *P exacuous* and *H. anceps*, were infested with leeches. *H. trivolvis* was parasitized by *H. fusca*, *H. lineata*, and *H. papillata*. *H. campanulatum* and *P. exacuous* were infested by *H. fusca*; and *H. anceps* was parasitized by only *H. papillata*. These data indicate that *H. fusca* may prefer *H. trivolvis* and *H. campanulatum*, while *H. papillata* may have a preference for *H. anceps*. Also, *H. fusca* preferred sites under the mantle and intermedium of the mantle in *H. trivolvis*.

Four-Mile Lake (Table 19) provided six species of snails, *H. trivolvis*, *H. campanulatum*, *H. anceps*,

Table 19. Mollusk infestations from Four-Mile Lake (T2S,R3E,S4SE), Washtenaw County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma trivolvis	(1)	83	18	0	0	0	0	0
	(2)		25	0	0	0	0	0
	(3)		38	0	0	0	0	0
	(4)		28	0	0	0	0	0
	(5)		0	0	1	0	0	0
Total		83	109	0	1	0	0	0
Helisoma campanulatum	(3)	2	3	0	0	0	0	0
Helisoma anceps	(3)	1	0	0	1	0	0	0
Gyraulus parvus	(3)	3	2	0	1	0	0	0
Promenetus exacuous	(1)	1	1	0	0	0	0	0
Physa gyrina	(1)	41	0	0	3	0	0	0
	(2)		0	0	31	0	0	0
	(3)		0	0	5	0	0	0
Total		41	0	0	41	0	0	0

Location in host:
(1) mantle cavity
(2) below mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney
(5) outside on shell

Table 20. Mollusk infestations from Murray Lake (T2S,R7E,S10NW), Washtenaw County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma campanulatum	(2)	20	18	0	0	0	0	0
	(4)		6	0	0	0	0	0
Total		20	24	0	0	0	0	0
Planorbula armigera	(2)	1	1	0	0	0	0	0
Physa integra	(2)	2	2	0	0	0	0	0
Helisoma trivolvis	(2)	1	1	0	0	0	0	0

Location in host:
(1) mantle cavity
(2) under mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney

Table 21. Mollusk infestations from Fleming Creek (T2S,R6E,S25SE), Washtenaw County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma trivolvis	(1)	165	0	25	0	0	0	0
	(2)		0	115	0	0	0	0
	(3)		0	45	1	0	0	0
	(4)		0	4	0	0	0	0
Total		165	0	189	1	0	0	0
Helisoma anceps	(1)	112	0	0	26	0	0	0
	(2)		0	0	103	0	0	0
	(3)		0	2	30	0	0	0
	(4)		0	0	1	0	0	0
Total		112	0	2	160	0	0	0
Physa gyrina	(1)	24	0	0	2	0	0	0
	(2)		0	0	14	0	0	0
	(3)		0	0	9	0	0	0
Total		24	0	0	25	0	0	0

Location in host:
(1) mantle cavity
(2) below mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney

G. parvus, *P. exacuous*, *P. gyrina*, infested with leeches. The two species of leeches recovered were *H. fusca* and *H. papillata;* 83*H. trivolvis* were infested with 109 *H. fusca* and 1 *H. papillata*. In the *H. trivolvis* population, 18 *H. fusca* were recovered from the mantle cavity, 25 from below the mantle, 38 from above the mantle, and 28 in the kidney. One *H. papillata* was found on the outside of the shell of this snail. *H. campanulatum* had three specimens of *H. fusca* above the mantle; *H. anceps* had one *H. papillata* above the mantle. *G. parvus* had 2 *H. fusca* and 1 *H. papillata* above the mantle. *P. gyrina* were infested with *H. papillata:* 3 in the mantle cavity, 31 below the mantle, and 5 from above the mantle. There appeared to be a selective preference of *H. fusca* for *H. trivolvis* and *H. papillata* for *P. gyrina*.

Four snail species, *H. campanulatum*, *P. armigera*, *H. trivolvis*, and *P. integra* from Murray Lake (Table 20) were infested with one leech species, *H. fusca*. In the 20 infested specimens of *H. campanulatum*, 18 *H. fusca* were under the mantle and 6 in the kidney. In *P. armigera* *H. trivolvis*, and *P. integra*, all of *H. fusca* were recovered from under the mantle.

The snail population of Fleming Creek (Table 21) included three species, *H. trivolvis*, *H. anceps*, and *P. gyrina*, infested with leeches. Both *H. lineata* and *H. papillata* were on *H. trivolvis* and *H. anceps*, while only *H. papillata* was on *P. gyrina*. It is evident that *H. lineata* at this station had a preference for*H. trivolvis*. Of the 189 specimens of *H. lineata*, 25 were from the mantle cavity, 115 below the mantle, 45 above the mantle and 4 within the kidney. Only one *H. papillata* was recovered from this snail. Also, thepreference of *H. papillata* for *H. anceps* was obvious with the recoveryof 160 specimens of *H. papillata;* 26 were in the mantle cavity 103 below the mantle, 30 above the mantle, and 1 in the kidney. Both leeches preferred to locate in the site below the mantle. For *P. gyrina*, 2 *H. papillata* were found in the mantle cavity, 14 below the mantle, and 9 above the mantle.

From a roadside ditch (Table 22) three snail species, *H. trivolvis*, *S. elodes*, and *P. gyrina*, were infested with leeches. *H. trivolvis* had 7 *H. fusca:* 4 below the mantle, 2 above the mantle, and 1 on the outside of the shell. Of the 326 *H. papillata*, 27 were from the mantle cavity, 254 below the mantle, and 45 above the mantle. *S. elodes* was infested only with *H. papillata;* 3 in the mantle cavity, 30 below the mantle, 5 above the mantle, and 2 from the outside of the shell. *P. gyrina* had four species of leeches,*H. fusca*, *H. papillata*, *G. heteroclita*, and *M. lucida*. Among the 137 *P. gyrina* infested, 14 *H. fusca* were found; 2 were from the mantle cavity, 10 below the mantle, and 2 above the mantle. *H. papillata* infestations in *P. gyrina* included 8 from the mantle cavity, 97 below, and 31 above the mantle. Only one specimen of *G. heteroclita* parasitized *P. gyrina;* it was removed from above the mantle. Six *M. lucida* were in *P. gyrina;* 2 from the mantle cavity and 4 below the mantle. These data indicate that *H. papillata* had a preference for all three snails.

Table 22. Mollusk infestations from a roadside ditch (T1S,R3E,S19SE), Washtenaw County, Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Helisoma trivolvis	(1)	182	0	0	27	0	0	0
	(2)		4	0	254	0	0	0
	(3)		2	0	45	0	0	0
	(4)		0	0	0	0	0	0
	(5)		1	0	0	0	0	0
Total		182	7	0	326	0	0	0
Stagnicola elodes	(1)	40	0	0	3	0	0	0
	(2)		0	0	30	0	0	0
	(3)		0	0	5	0	0	0
	(5)		0	0	2	0	0	0
Total		40	0	0	40	0	0	0
Physa gyrina	(1)	137	2	0	8	0	0	2
	(2)		10	0	97	0	0	4
	(3)		2	0	31	0	1	0
Total		137	14	0	136	0	1	6

Location in host:
(1) mantle cavity
(2) below mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney
(5) outside on shell

Eleven of the 25 incidental sites are given in Table 23. It includes nine species of pulmonate snails and one species of sphaeriid clam infested with leeches. These data show the leech-mollusk association outside the ten permanent collecting stations and also include mollusks not found in southeastern Michigan.

From Cressman Pond only one *H. trivolvis* was found infested with one *H. fusca*. Duck Lake's snail population included two species, *S. exilis* and *P. armigera;* both carried the leech *M. lucida*, recovered from below the mantle. In Fleming Creek 16 *G. complanata* leeches were on the outside shell of the small bivalve, *S. simile*. From an impoundment two *H. trivolvis* were found with *H. fusca*, and both came from below the mantle. Two snails, *H. trivolvis* and *H. campanulatum*, examined from Mill Lake, were infested with *H. fusca* below their mantles. From the Au Sable River two *L. stagnalis* were infested with *H. fusca* in the area above the mantle. In South Lake, two *H. trivolvis* were infested with two specimens of *H. fusca*, and in Baw Besse Lake one *H. campanulatum* was also infested with *H. fusca*. Both species of snails had leeches below their mantles. From Douglas Lake, 13 *P. parkeri* were infested with *H. papillata*, all located below the mantle. In a roadside ditch three species, *H. trivolvis*, *H. anceps*, and *L. megasoma*, were infested with the leech *H. papillata*. Thirty-two *H. trivolvis* were infested with 83 leeches, 53 below the mantle and 30 above the mantle. *H. anceps* had two *H. papillata* removed from below the mantle, and *L. megasoma* had five above the mantle. From Waffle's Pond three snail species, *H. trivolvis* *A. hypnorum*, and *P. armigera*, were infested with leeches. One of three *H. trivolvis* had *H. lineata* below its mantle; two had *M. lucida* below the mantle. Both *A. hypnorum* and *P. armigera* were infested with *M. lucida*, and both had this leech below their mantles.

Part IV. Mollusk-Leech-Cercarial Association; Leeches with Tetracotyles

A search of the literature indicated a lack of data on other parasites infecting snails infested with leeches. However, it was learned that several leeches serve as second intermediate hosts for metacercariae of the tetracotyle parasites (Castle 1900, Szidat 1939, Wesenberg-Lund 1934, 1937, Bennike 1943, Meyer and Moore 1954, Mann 1962, and J. E. Moore 1964, Vojtek, J. Opravilova and Vojtkova, L. 1967). Leeches occasionally served as intermediate hosts for the cysts or cysticercoids of certain cestodes (Mann 1962). Ulmer (unpublished data) indicated that several lymnaeid snails, as well as certain leeches in the genus *Helobdella*, may serve as second intermediate hosts in which cercariae encyst and undergo the development into metacercariae of the tetracotyle type.

Table 23. Mollusk infestations from various aquatic habitats throughout Michigan

Mollusk Host		Number of mollusks infested	Species of leeches recovered					
			Helobdella fusca	Helobdella lineata	Helobdella papillata	Glossiphonia complanata	Glossiphonia heteroclita	Marvinmeyeria lucida
Roadside ditch (T23S, R4E,S31S), Missaukee County, Michigan								
Helisoma trivolvis	(2)	32	0	0	53	0	0	0
	(3)		0	0	30	0	0	0
Total		32	0	0	83	0	0	0
Helisoma anceps	(2)	2	0	0	2	0	0	0
Lymnaea megasoma	(3)	5	0	0	5	0	0	0
Waffle's Pond (T4S,R7E,S33SE), Washtenaw County, Michigan								
Helisoma trivolvis	(2)	3	0	1	0	0	0	2
Aplexa hypnorum	(2)	1	0	0	0	0	0	1
Planorbula armigera	(2)	1	0	0	0	0	0	1
South Lake (T1S,R3E,S10SW), Washtenaw County, Michigan								
Helisoma trivolvis	(2)	2	2	0	0	0	0	0
Baw Besse Lake (T12S,R16E,S33), Muskegon County, Michigan								
Helisoma campanulatum	(2)	1	1	0	0	0	0	0
Cressman Pond (T1S,R3E,S30NE), E.S. George Reserve, Livingston County, Michigan								
Helisoma trivolvis	(3)	1	1	0	0	0	0	0
Duck Lake (T2S,R3E,S12), Jackson County, Michigan								
Stagnicola exilis	(2)	2	0	0	0	0	0	2
Planorbula armigera	(2)	2	0	0	0	0	0	2
Fleming Creek (T2S,R7E,S8SE), Washtenaw County, Michigan								
Sphaerium simile	(5)	16	0	0	0	16	0	0
Impoundment (T1S,R3E,S29SW), Washtenaw County, Michigan								
Helisoma trivolvis	(2)	2	2	0	0	0	0	0
Mill Lake (T2S,R3E,S4NE), Washtenaw County, Michigan								
Helisoma trivolvis	(2)	1	1	0	0	0	0	0
Helisoma campanulatum	(2)	2	2	0	0	0	0	0
Douglas Lake (T37S,R3E,S27), Cheboygan, Michigan								
Physa parkeri	(2)	13	0	13	0	0	0	0
Au Sable River (T26S,R3E,S7SW), Crawford County, Michigan								
Lymnaea stagnalis	(3)	2	2	0	0	0	0	0

Location in host:
(1) mantle cavity
(2) below mantle (digestive gland and aorta)
(3) above mantle (between shell and mantle)
(4) in kidney
(5) outside on shell

Table 24. Mollusks parasitized with leeches and cercarial types, and leeches infected with tetracotyles from Bert Pond (T1S,R3E,S19), E. S. George Reserve, Livingston County, Michigan

Mollusk Host	Number of mollusks examined	Number of mollusks parasitized	Species of leeches recovered	Number of leeches recovered	Cercarial types recovered	Total leeches with tetracotyles	Date
Helisoma trivolvis	831	21	Helobdella fusca	1	Echinostome cercariae	0	8-5-71
			"	1	"	0	8-15-71
			"	1	"	0	8-15-71
			"	1	"	0	8-19-71
			*Helobdella lineata	1	-	1	12-10-72
			* "	1	-	1	"
			* "	1	-	1	4-12-73
			* "	2	-	2	"
			"	1	Echinostome cercariae	0	"
			"	1	Xiphidiocercariae	0	5-24-73
			Helobdella fusca	2	Echinostome cercariae	0	6-25-73
			"	4	Xiphidiocercariae	0	7-9-73
			"	4	Echinostome cercariae	0	"
			"	4	"	0	"
			"	2	"	0	"
			"	2	"	0	"
			"	1	Strigea cercariae	0	"
			"	1	Echinostome cercariae	0	"
			"	2	"	1	"
			Helobdella lineata	1	Echinostome cercariae	0	8-27-73
			"	1	Furcocercariae	0	8-27-73
Total	831	21		35		6	

(*) leeches infected with tetracotyles infesting snails

As indicated (Tables 24-29), six pulmonate snails (*H. trivolvis*, *H. campanulatum*, *H. anceps*, *P. gyrina*, *S. exilis*, and *A. hypnorum*) were collected during 1972 and 1973, and had the leech-cercarial association. *H. trivolvis* infested with three species of leeches (*H. fusca*, *H. lineata*, and *H. papillata*) also had cercariae of six types: echinostome cercariae, xiphidiocercariae, strigeid cercariae, furcocercariae, amphistome cercariae, and macrocercous cercariae. No multiple cercarial types were encountered; however, several *H. trivolvis* had multiple leech infestations involving either *H. fusca*, *H. lineata* or *H. papillata*. These data show that of the 2,020 specimens of *H. trivolvis* examined, 37 (1,8%) carried the leech-cercarial type association. Four *H. campanulatum* out of 552 also had such a leech-cercarial association. Only the leech *H. fusca* was found on *H. campanulatum*, and two snails had multiple infestations. Cercarial types found with the leech association were of three types: amphistome cercariae, echinostome cercariae, and xiphidiocercariae. Among the 552 *H. campanulatum* examined, 4 (0.7%) had the leech-cercarial association.

In the snail, *P. gyrina*, both the leech, *H. papillata*, and an amphistome were found: among 157 *P. gyrina* examined only 2 (1,3%) had this leech-cercarial type association. One multiple *H. papillata* infestation occurred with the amphistome type.

Some *H, anceps* snails had two leech species, *H. lineata* and *H. papillata*, and one cercarial type, xiphidiocercariae. Several multiple leech infestations also occurred: of 162 *H. anceps* recovered, only 6 (3.7%) had the leech-cercarial type association.

From a woodland pool, 13 of 677 *S. exilis* collected had the leech-cercarial association. The leech *M. lucida* was present along with three cercarial types: echinostome cercariae, furcocercous cercariae, and xiphidiocercariae. Several multiple leech infestations occurred with all three cercarial types, but no multiple cercarial types were found. Thirteen *S. exilis* of the 677 examined (1.9%) had a leech-cercarial type association. Also, from the same pool, among 82 *A. hypnorum* collected only one (1.2%) had the leech *M. lucida* and the echinostome cercarial type association. Many more snails were found infested with leeches but not the leech-cercarial association. Of the 2,023 snails infested with leeches, only 63 (3.1%) carried a leech-cercarial type association.

While examining snails for the leech-cercarial associations, it was discovered that several leeches (*H. fusca* and *H. lineata*) were infected with tetracotyles. Only two snail species, *H. trivolvis* and *H. campanulatum*, had these leeches infected with tetracotyles; and only 2 (3.9%) of the leeches

Table 25. Mollusks parasitized with leeches and cercarial types, and leeches infected with tetracotyles from a Woodland Pool (T2S,R3E,S9SW), Washtenaw County, Michigan

Mollusk Host	Number of mollusks examined	Number of mollusks parasitized	Species of leeches recovered	Number of leeches recovered	Cercarial types recovered	Total leeches with tetracotyles	Date
Stagnicola exilis	677	13	Marvinmeyeria lucida	1	Echinostome cercariae	0	6-17-72
			"	2	Furcocercariae	0	7-20-72
			"	3	Echinostome cercariae	0	"
			"	1	" "	0	"
			"	2	" "	0	"
			"	2	" "	0	"
			"	1	" "	0	"
			"	2	" "	0	"
			"	2	" "	0	"
			"	1	" "	0	"
			"	2	Xiphidiocercariae	0	"
			"	2	"	0	"
Aplexa			"	1	Echinostome cercariae	0	8-18-73
hypnorum	82	1	"	1	" "	0	7-20-73
Total	759	14		23		0	

Table 26. Mollusks parasitized with leeches and cercarial types, and leeches infected with tetracotyles from two roadside ditches

Mollusk Host	Number of mollusks examined	Number of mollusks parasitized	Species of leeches recovered	Number of leeches recovered	Cercarial types recovered	Total leeches with tetracotyles	Date
Roadside Ditch (T2S, R4E, S31S), Missaukee County, Michigan							
Helisoma trivolvis	85	1	Helobdella fusca	1	Strigea cercariae	0	7-17-72
		10	Helobdella papillata	1	Xiphidiocercariae	0	"
			"	1	"	0	"
			"	1	"	0	"
			"	1	"	0	"
			"	1	"	0	"
			"	1	"	0	"
			"	1	"	0	"
			"	1	"	0	"
			"	1	Echinostome cercariae	0	"
			"	3	Amphistome cercariae	0	5-15-73
Total	85	11		13		0	
Roadside Ditch (T1S, R3E, S19SE), Washtenaw County, Michigan							
Helisoma trivolvis	658	2	Helobdella papillata	1	Echinostome cercariae	0	7-17-73
			"	1	" "	0	"
Physa gyrina	157	2	"	2	Amphistome cercariae	0	"
			"	1	" "	0	"
Total	815	4		5		0	

Table 27. Mollusks parasitized with leeches and cercarial types, and leeches infected with tetracotyles from Fleming Creek (T2S,R6E,S25SE), Washtenaw County, Michigan

Mollusk Host	Number of mollusks examined	Number of mollusks parasitized	Species of leeches recovered	Number of leeches recovered	Cercarial types recovered	Total leeches with tetracotyles	Date
Helisoma anceps	162	6	Helobdella lineata	1	Xiphidiocercariae	0	8-21-71
			"	1	"	0	"
			Helobdella papillata	1	"	0	10-12-72
			"	2	"	0	"
			"	2	"	0	"
			"	1	"	0	8-13-73
Total	162	6		8		0	

Table 28. Mollusks parasitized with leeches and cercarial types, and leeches infected with tetracotyles from three ponds

Mollusk Host	Number of mollusks examined	Number of mollusks parasitized	Species of leeches recovered	Number of leeches recovered	Cercarial types recovered	Total leeches with tetracotyles	Date
Cressman Pond (T1S, R3E, S30NE), E. S. George Reserve, Livingston County, Michigan							
Helisoma trivolvis	25	1	Helobdella fusca	1	Amphistome cercariae	0	4-27-72
Crane Pond (T1S, R3E, S19), E. S. George Reserve, Livingston County, Michigan							
Helisoma trivolvis	317	1	Helobdella fusca	1	Xiphidiocercariae	0	9-28-72
Helisoma campanulatum	548	2	"	1	Amphistome cercariae	0	10-18-73
			"	2	Echinostome cercariae	0	10-18-73
Total	865	3		4		0	
George Pond (T1S, R3E, S19), E. S. George Reserve, Livingston County, Michigan							
Helisoma trivolvis	182	3	Helobdella fusca	1	Echinostome cercariae	0	6-25-73
			Helobdella lineata	2	Macrocercous	0	6-25-73
			"	1	Xiphidiocercariae	0	"
Total	182	3		4		0	

associated with cercariae infections contained tetracotyles.

Part V. The Distribution of Leeches on Mollusks under Natural Conditions

The distribution of leeches found on 12 species of pulmonate snails and one species of sphaeriacean clam is presented separately in tables 30-38, where the arrangement is by habitats. Included are the number of mollusks infested, number of leeches per mollusk; the total leech distribution and the mollusks from each habitat are also given. While multiple infestations occurred, most infested mollusks contained only one leech.

One woodland pool (Table 30) yielded five snail species, *S. exilis*, *H. trivolvis*, *A. hypnorum*, *P. exacuous*, and *P. armigera*, infested with leeches. Of 194 *S. exilis* infested, 31 (16%) had 2 leeches, 11 (6%) had 3, 4 (2%) had 4, 6 (3%) had 5, 3 (2%) had 6, 2 (1%) had 8, and 1 had 10 leeches. Of 34 *H. trivolvis* infested, 11 (32%) had 2, 4 (12%) had

Table 29. Mollusks parasitized with leeches and cercarial types, and leeches infected with tetracotyles from two lakes

Mollusk Host	Number of mollusks examined	Number of mollusks parasitized	Species of leeches recovered	Number of leeches recovered	Cercarial types recovered	Total leeches with tetracotyles	Date
Four-Mile Lake (T2S,R4E, S4SE), Washtenaw County, Michigan							
Helisoma campanulatum	4	2	Helobdella fusca	1	Xiphidiocercariae	0	7-25-72
			"	1	"	0	"
			"	2	"	2	5-18-73
Total	4	2		4		2	
Lake (T2S,R3E, S1NE), Washtenaw County, Michigan							
Helisoma trivolvis	104	2	Helobdella fusca	1	Xiphidiocercariae	0	6-24-72
			"	1	"	0	4-3-73
Total	104	2		2		0	

Table 30. Distribution of leeches on mollusks collected from two woodland pools

Woodland Pool (T2S, R3E, S9SW), Washington County, Michigan

Distribution of leeches among 677 Stagnicola exilis

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	483	136	31	11	4	6	3	0	2	0	1	0	0	677
Number of leeches	0	136	62	33	16	30	18	0	16	0	10	0	0	321

Distribution of leeches among 48 Helisoma trivolvis

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	14	17	11	4	1	1	0	0	0	0	0	0	0	48
Number of leeches	0	17	22	12	4	5	0	0	0	0	0	0	0	60

Distribution of leeches among 82 Aplexa hypnorum

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	77	3	2	0	0	0	0	0	0	0	0	0	0	82
Number of leeches	0	3	4	0	0	0	0	0	0	0	0	0	0	7

Distribution of leeches among 19 Promenetus exacuous

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	17	2	0	0	0	0	0	0	0	0	0	0	0	19
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Distribution of leeches among 15 Planorbula armigera

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	13	1	0	1	0	0	0	0	0	0	0	0	0	15
Number of leeches	0	1	0	3	0	0	0	0	0	0	0	0	0	4

Total distribution of leeches among 841 Pulmonates

Total:

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	604	159	44	16	5	7	3	0	2	0	1	0	0	841
Number of leeches	0	159	88	48	20	35	18	0	16	0	10	0	0	394

Woodland Pool, Zeeb Rd., (T2S, R5E, S28E), Washtenaw County, Michigan

Distribution of leeches among 375 Aplexa hypnorum

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	374	1	0	0	0	0	0	0	0	0	0	0	0	375
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Table 31. Distribution of leeches on mollusks collected from a roadside ditch (T1S,R3E,S19SE), Washtenaw County, Michigan

Distribution of leeches among 658 Helisoma trivolvis														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	476	101	48	18	7	3	2	1	0	0	2	0	0	658
Number of leeches	0	101	96	54	28	15	12	8	0	0	20	0	0	333
Distribution of leeches among 426 Stagnicola elodes														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	386	40	0	0	0	0	0	0	0	0	0	0	0	426
Number of leeches	0	40	0	0	0	0	0	0	0	0	0	0	0	40
Distribution of leeches among 604 Physa gyrina														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	467	125	7	2	3	0	0	0	0	0	0	0	0	604
Number of leeches	0	125	14	6	12	0	0	0	0	0	0	0	0	157
Total distribution of leeches among 1,688 Pulmonates														
Total:	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of leeches/snails	1,329	266	55	20	10	3	2	1	0	0	2	0	0	1,688
Number of snails	0	266	110	60	40	15	12	7	0	0	20	0	0	530

Table 32. Distribution of leeches on mollusks collected from two ponds

Bert Pond (T1S, R3E, S19), E. S. George Reserve, Livingston County, Michigan														
Distribution of leeches among 885 Helisoma trivolvis														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	557	212	74	23	10	6	2	0	0	0	0	0	1	885
Number of leeches	0	212	148	69	40	30	12	0	0	0	0	0	12	523
George Pond (T1S, R3E, S19), E. S. George Reserve, Livingston County, Michigan														
Distribution of leeches among 485 Helisoma trivolvis														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	333	136	10	5	0	0	0	0	0	0	0	1	0	485
Number of leeches	0	136	20	15	0	0	0	0	0	0	0	11	0	182

3, one (3%) had 4, and one (3%) had 5. Two *A. hypnorum* had 2 leeches, and one *P. armigera* had 3. The other woodland pool (Table 30) on Zeeb Road yielded only one snail of 375 *A. hypnorum* with only one leech infestation.

Of the infested *H. trivolvis* collected from a roadside ditch (T1S, R3E, S19SE) (Table 31), 48 (26%) had 2 leeches, 18 (10%) had 3, 7 (4%) had 4, 3 had 5, 2 had 6, 1 had 7, and 2 had 10. Also, a roadside had 40, *S. elodes* with 1 leech; 137 *P. gyrina* had 7 (5%) with 2 leeches, 2 with 3, and 3 with 4.

In Bert Pond (Table 32) the 328 *H. trivolvis* infested with leeches had 74 (23%) with 2 leeches, 23 (7%) with 3, 10 (3%) with 4, 6 with 5, 2 with 6, and 1 with 12 leeches. George Pond (Table 32), however, had 152 infested *H. trivolvis*, of which 10 (7%) had 2 leeches, 5 (3%) had 3, and 1 had 11 leeches.

Fleming Creek (Table 33) had three snail species, *H. trivolvis*, *P. gyrina*, and *H. anceps*, infested with leeches. Of 165 *H. trivolvis* 12 (7%) had 2, 4 (2%) had 3, and 1 had six leeches. Of 112 *H. anceps* infested, 11 (10%) had 2, 7 (6%) had 3, 2 (2%) 4, 2 had 5, and 1 had 7 leeches.

Table 33. Distribution of leeches on mollusks collected from Fleming Creek (T2S,R6E,S25SE), Washtenaw County, Michigan

Distribution of leeches among 658 Helisoma trivolvis

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	196	148	12	4	0	0	1	0	0	0	0	0	0	361
Number of leeches	0	148	24	12	0	0	6	0	0	0	0	0	0	190

Distribution of leeches among 278 Physa gyrina

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	254	23	1	0	0	0	0	0	0	0	0	0	0	278
Number of leeches	0	23	2	0	0	0	0	0	0	0	0	0	0	25

Distribution of leeches among 507 Helisoma anceps

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	395	88	11	7	2	2	1	1	0	0	0	0	0	507
Number of leeches	0	88	22	21	8	10	6	7	0	0	0	0	0	162

Total distribution of leeches among 1,146 Pulmonates

Total: Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	844	259	24	11	2	2	2	1	0	0	0	0	0	1,146
Number of leeches	0	259	48	33	8	10	12	7	0	0	0	0	0	377

Table 34. Distribution of leeches on mollusks collected from Crane Pond (T1S,R3E,S19), E. S. George Reserve, Livingston County, Michigan

Distribution of leeches among 317 Helisoma trivolvis

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	227	86	2	2	0	0	0	0	0	0	0	0	0	317
Number of leeches	0	86	4	6	0	0	0	0	0	0	0	0	0	96

Distribution of leeches among 224 Helisoma anceps

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	144	65	8	3	3	0	1	0	0	0	0	0	0	224
Number of leeches	0	65	16	9	12	5	6	0	0	0	0	0	0	108

Distribution of leeches among 4 Planorbula armigera

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	2	0	2	0	0	0	0	0	0	0	0	0	0	4
Number of leeches	0	0	4	0	0	0	0	0	0	0	0	0	0	4

Distribution of leeches among 38 Physa gyrina

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	35	2	0	1	0	0	0	0	0	0	0	0	0	38
Number of leeches	0	2	0	3	0	0	0	0	0	0	0	0	0	5

Distribution of leeches among 548 Helisoma campanulatum

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	433	110	4	0	1	0	0	0	0	0	0	0	0	548
Number of leeches	0	110	8	0	4	0	0	0	0	0	0	0	0	122

Total distribution of leeches among 1,131 Pulmonates

Total: Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	841	263	16	6	4	0	1	0	0	0	0	0	0	1,131
Number of leeches	0	263	32	18	16	0	6	0	0	0	0	0	0	335

Table 35. Distribution of leeches on mollusks collected from a lake (T2S,R3E,S1NE), Washtenaw County, Michigan

Distribution of leeches among 649 <u>Helisoma trivolvis</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	552	93	2	1	1	0	0	0	0	0	0	0	0	649
Number of leeches	0	93	4	3	4	0	0	0	0	0	0	0	0	104

Distribution of leeches among 59 <u>Helisoma campanulatum</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	48	8	3	0	0	0	0	0	0	0	0	0	0	59
Number of leeches	0	8	6	0	0	0	0	0	0	0	0	0	0	14

Distribution of leeches among 8 <u>Promenetus exacuous</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	7	1	0	0	0	0	0	0	0	0	0	0	0	8
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Distribution of leeches among 16 <u>Helisoma anceps</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	13	3	0	0	0	0	0	0	0	0	0	0	0	16
Number of leeches	0	3	0	0	0	0	0	0	0	0	0	0	0	3

Total Distribution of leeches among 732 Pulmonates

Total:

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	620	105	5	1	1	0	0	0	0	0	0	0	0	732
Number of leeches	0	105	10	3	4	0	0	0	0	0	0	0	0	122

Table 36. Distribution of leeches on mollusks collected from Murray Lake (T2S,R7E,S10NW), Washtenaw County, Michigan

Distribution of leeches among 201 <u>Helisoma campanulatum</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	181	19	0	0	0	1	0	0	0	0	0	0	0	201
Number of leeches	0	19	0	0	0	5	0	0	0	0	0	0	0	24

Distribution of leeches among 104 <u>Planorbula armigera</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	139	1	0	0	0	0	0	0	0	0	0	0	0	140
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Distribution of leeches among 30 <u>Physa integra</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	28	2	0	0	0	0	0	0	0	0	0	0	0	30
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Distribution of leeches among 35 <u>Helisoma trivolvis</u>

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	34	1	0	0	0	0	0	0	0	0	0	0	0	35
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Total distribution of leeches among 406 Pulmonates

Total:

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	382	23	0	0	0	1	0	0	0	0	0	0	0	406
Number of leeches	0	23	0	0	0	5	0	0	0	0	0	0	0	28

Table 37. Distribution of leeches on mollusks collected from Four-Mile Lake (T2S,R4E,S4SE), Washtenaw County, Michigan

Distribution of leeches among 109 Physa gyrina														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	69	39	1	0	0	0	0	0	0	0	0	0	0	109
Number of leeches	0	39	2	0	0	0	0	0	0	0	0	0	0	41
Distribution of leeches among 398 Helisoma trivolvis														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	315	72	4	2	4	0	0	1	0	0	0	0	0	398
Number of leeches	0	72	8	6	16	0	0	7	0	0	0	0	0	109
Distribution of leeches among 4 Helisoma campanulatum														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	2	1	1	0	0	0	0	0	0	0	0	0	0	4
Number of leeches	0	1	2	0	0	0	0	0	0	0	0	0	0	3
Distribution of leeches among 75 Gyraulus parvus														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	72	3	0	0	0	0	0	0	0	0	0	0	0	75
Number of leeches	0	3	0	0	0	0	0	0	0	0	0	0	0	3
Distribution of leeches among 18 Promenetus exacuous														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	17	1	0	0	0	0	0	0	0	0	0	0	0	18
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Distribution of leeches among 2 Helisoma anceps														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	1	0	1	0	0	0	0	0	0	0	0	0	0	2
Number of leeches	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Total distribution of leeches among 606 Pulmonates														
Total:														
Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	476	116	7	2	4	0	0	1	0	0	0	0	0	606
Number of leeches	0	116	14	6	16	0	0	7	0	0	0	0	0	159

Crane Pond (Table 34) had five snail species, *H. trivolvis*, *H. anceps*, *P. armigera*, *H. campanulatum*, and *P. gyrina*. Of 90 *H. trivolvis*, 2 (2%) had 2 and 2 (2%) had 3 leeches. Of 80 *H. anceps*, 8 (10%) had 2, 3 (4%) had 3, 3 (4%) had 4, and 1 had 6 leeches. The 2 *P. armigera* had 2 leeches, 1 *P. gyrina* had 3; of 115 *H. campanulatum*, 4 (3%) had 2 leeches and 1 had 4 leeches.

From a lake (T2S, R3E, S1NE) (Table 35) four snail species, *H. trivolvis*, *H. campanulatum*, *P. exacuous*, and *H. anceps*, had leeches. The 97 *H. trivolvis* had 2 (2%) with 2, 1 with 3, and 1 with 4 leeches. *P. exacuous* and *H. anceps* had single infestations. Of 11 *H. campanulatum* infested, 3 (27%) had 2 leeches.

In Murray Lake (Table 36) four snail species, *H. campanulatum*, *H. trivolvis*, *P. integra*, and *P. armigera* were infested with leeches. Of 20 *H. campanulatum* infested with leeches, one specimen had 5. *P. armigera*, *H. trivolvis*, and *P. integra* all had single infestations.

Six snails, *P. gyrina*, *H. trivolvis*, *H. campanulatum*, *G. parvus*, *P. exacuous*, and *H. anceps*, from Four-Mile Lake (Table 37) were infested with leeches. Of 40 *P. gyrina* only one had 2 leeches; and one *H. campanulatum* had 2 leeches. Of 83 *H. trivolvis*, 4 (5%) were infested with 2, 2 (2%) with 3, 4 (5%) with 4, and 1 with 7 leeches. *G. parvus* and *P. exacuous* had single infestations, and one *H. anceps* had 2 leeches.

Most mollusks infested with leeches from the incidental stations, (Table 38), Cressman Pond, Duck Lake, Fleming Creek, Waffle's Pond, South Lake, Baw Besse Lake, Impoundment, Mill Lake, Douglas Lake, Au Sable River, and a roadside ditch (T23S, R4E, S31S), had single infestations. the roadside ditch, in addition, had specimens of *H. trivolvis* infested with multiple number of leeches. Of the 32 specimens infested with leeches, 10 (31%) were infested with 2 leeches, 5 (16%) with 3 leeches, 9 (28%) with 4 leeches, and 1 (3%) with 5 leeches. Mill Lake, another incidental site, had one specimen of *H. campanulatum* infested with two leeches.

Part VI. The Symbionts: Chaetogasters and Midges

Only two symbionts, an oligochaete *(Chaetogaster*

Table 38. Distribution of leeches found on mollusks collected from various aquatic habitats

Cressman Pond (T1S,R3E,S30NE), E. S. George Reserve, Livingston County, Michigan

Distribution of leeches among 57 *Helisoma trivolvis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	56	1	0	0	0	0	0	0	0	0	0	0	0	57
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Duck Lake (T2S,R3E,S12), Jackson County, Michigan

Distribution of leeches among 51 *Stagnicola exilis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	49	2	0	0	0	0	0	0	0	0	0	0	0	51
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Distribution of leeches among 5 *Planorbula armigera*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	3	2	0	0	0	0	0	0	0	0	0	0	0	5
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Fleming Creek (T2S,R7E,S8SE), Washtenaw County, Michigan

Distribution of leeches among 48 *Sphaerium simile*

Number of leeches/bivalves	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of bivalves	32	16	0	0	0	0	0	0	0	0	0	0	0	48
Number of leeches	0	16	0	0	0	0	0	0	0	0	0	0	0	16

Waffle's Pond (T4S,R7E,S33SE), Washtenaw County, Michigan

Distribution of leeches among 81 *Helisoma trivolvis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	78	3	0	0	0	0	0	0	0	0	0	0	0	81
Number of leeches	0	3	0	0	0	0	0	0	0	0	0	0	0	3

Distribution of leeches among 37 *Aplexa hypnorum*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	36	1	0	0	0	0	0	0	0	0	0	0	0	37
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Distribution of leeches among 2 *Planorbula armigera*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	1	1	0	0	0	0	0	0	0	0	0	0	0	2
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

South Lake (T1S,R3E,S10SW), Washtenaw County, Michigan

Distribution of leeches among 18 *Helisoma trivolvis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	16	2	0	0	0	0	0	0	0	0	0	0	0	18
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Baw Besse Lake (T12S,R16E,S33), Muskegon County, Michigan

Distribution of leeches among 5 *Helisoma trivolvis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	4	1	0	0	0	0	0	0	0	0	0	0	0	5
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

TABLE 38 (CONTINUED)

Impoundment (T1S,R3E,S29SW), Washtenaw County, Michigan

Distribution of leeches among 9 *Helisoma trivolvis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	7	2	0	0	0	0	0	0	0	0	0	0	0	9
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Mill Lake (T2S,R3E,S4NE), Washtenaw County, Michigan

Distribution of leeches among 6 *Helisoma trivolvis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	5	1	0	0	0	0	0	0	0	0	0	0	0	6
Number of leeches	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Distribution of leeches among 9 *Helisoma campanulatum*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	8	0	1	0	0	0	0	0	0	0	0	0	0	9
Number of leeches	0	0	2	0	0	0	0	0	0	0	0	0	0	2

Douglas Lake (T37S,R3E,S27), Cheboygan County, Michigan

Distribution of leeches among 31 *Physa parkeri*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	18	13	0	0	0	0	0	0	0	0	0	0	0	31
Number of leeches	0	13	0	0	0	0	0	0	0	0	0	0	0	13

Au Sable River (T26,R3E,S7SW), Crawford County, Michigan

Distribution of leeches among 25 *Lymnaea stagnalis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	23	2	0	0	0	0	0	0	0	0	0	0	0	25
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Roadside ditch (T23S,R4E,S31S), Missaukee County, Michigan

Distribution of leeches among 82 *Helisoma trivolvis*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	50	7	10	5	9	1	0	0	0	0	0	0	0	82
Number of leeches	0	7	20	15	36	5	0	0	0	0	0	0	0	83

Distribution of leeches among 8 *Helisoma anceps*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	6	2	0	0	0	0	0	0	0	0	0	0	0	8
Number of leeches	0	2	0	0	0	0	0	0	0	0	0	0	0	2

Distribution of leeches among 64 *Lymnaea megasoma*

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	59	5	0	0	0	0	0	0	0	0	0	0	0	64
Number of leeches	0	5	0	0	0	0	0	0	0	0	0	0	0	5

Total distribution of leeches among 538 mollusks

Number of leeches/snails	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of snails	451	61	11	5	9	1	0	0	0	0	0	0	0	538
Number of leeches	0	61	22	15	36	5	0	0	0	0	0	0	0	139

limnaei v. Baer) and three species of dipteran midges (*Chironomus* sp., *Glyptotendipes* sp., and *Poly. pedilum* sp.) were found either in conjunction with leeches and cercarial types or alone on the various mollusk species collected under natural conditions in 1972 and 1973. Tables 2 through 12 show that small oligochaetes, *C. limnaei*, were usually abundant on many of the mollusks; their presence varied somewhat with the species of mollusk and the habitat. The 15 pulmonate snails harboring *C. limnaei* were: *H. trivolvis*, *H. campanulatum*, *H. anceps*, *P. gyrina*, *P. sayii*, *P. integra*, *G. parvus*, *G. hirsutus*, *P. exacuous*, *L. stagnalis*, *L. catascopium*, *L. columella*, *L. humilis*, *S. elodes*, and *P. armigera;* it was on only one operculate snail, *Campeloma decisum*, and two sphaeriid clams (*S. lacustre* and *S. fabale*).

Chaetogasters were not found on the following operculate snails: *A. limosa*, *V. tricarinata*, *G. livescens*, *P. acutum*, *V. malleatus*, *B. tentaculata;* none were on the pulmonates *L. emarginata*, *P. parkeri*, *S. exilis*, *G. deflectus*, nor on the finger nail clam, *S. simile*. No chaetogasters were found on the following snails: *S. exilis*, *H. trivolvis*, *A. hypnorum*, *P. armigera*, *P. exacuous*, *G. parvus*, and *S. elodes*, living in woodland pools; nor on the snails: *H. trivolvis*, *S. elodes*, *P. gyrina*, *L. megasoma*, and *H. anceps* living in roadside ditches, even though several of these species carried chaetogasters in other habitats.

Neither the numbers of chaetogasters present on these mollusks nor the time of year they were observed was recorded; most were seen throughout the year. On several occasions leeches were observed not only to feed on the snails but they also fed on chaetogasters, which could be seen in the leech's gut. Also, in a few instances, cercariae were observed in the gut of several chaetogasters.

The presence of midges was infrequent since only three species were discovered in the mantle cavity of 3 *H. trivolvis*, 2 *P. gyrina*, and 1 *H. campanulatum;* 2 specimens of *Chironomus* sp. and 1 specimen of *Glyptotendipes* sp. in *Helisoma trivolvis*, 1 specimen of *Chironomus* sp. and *Polypedilum* sp. in *Physa gyrina*, and 1 specimen of *Glyptotendipes* sp. in *Helisoma campanulatum*.

Part VII. Leech Gut Contents Studied with Immunological Data

The contents of the guts of leeches found inside of their molluscan hosts were not tested serologically to determine whether there was any parasitism. However, previous studies (Hatto 1968 and Klemm 1973) showed serologically that leeches inside of snails definitely parasitized them. Consequently it was assumed that any leech with opaque material in its gut and found inside a molluscan host more than likely fed on and was parasitic on that host.

Only six species in the family Glossiphoniidae, *H. fusca*, *H. lineata*, *H. papillata*, *G. complanata*, *G. heteroclita*, and *M. lucida*, parasitized mollusks. Sixteen *G. complanata* parasitized the sphaeriacean clam *S. simile;* one *G. heteroclita* was inside *P. gyrina*. *H. fusca*, *H. lineata*, *H. papillata*, and *M. lucida* were common in the mollusk examined. The following leeches: *H. fusca*, *H. lineata*, *H. papillata*, and *G. complanata*, were the only species living both on and off of mollusks.

Many other species in three families, Glossiphoniidae, Erpobdellidae, and Hirudinidae, were free swimming or attached to various substrates other than mollusks in various habitats (Appendix III).

Several authors (Harding and Moore 1927, Miller, 1929, 1937, Mathers 1948, Pennak 1953, Waffle 1963, and others) have claimed that *G. complanata* and *H. stagnalis* were always associated with snails on which they feed; consequently, they were commonly called 'snail leeches.' Hilsenhoff (1963), Thut (1969), and Sawyer (1972) showed that *H. stagnalis* fed on small oligochaetes, aquatic insects, and possibly other leeches rather than on snails. Sarah (1971) found juveniles of *G. complanata* infesting 10.8% of 210 snail specimens he examined. In the present study, out of many mollusks examined only 16 *G. complanata* infested *S. simile*. An abundance of *G. complanata* and *H. stagnalis* were found free-living. It was, therefore, decided to collect these two species from the various collecting stations and test their gut contents serologically to see whether they had been feeding on molluscan tissues.

The body wall of leeches is transparent when starved, and, after a meal, the stomach and lateral gastric caeca, in which large quantities of ingested food may be stored for long periods prior to digestion, are filled with opaque matter.

Prepared anti-*Helisoma trivolvis* serum was used since this species was the most abundant snail found in most of the various habitats studied. The antiserum was tested against homologous and heterologous animal antigens, and it was found that the reactions were given only against members of the class Gastropoda. No cross reactions were noted with members of other phyla. The results of serological tests on the gut contents of *G. complanata* and *H. stagnalis* are shown in Figure 26. Ten specimens of both *G. complanata* and *H. stagnalis* were tested, five whose gut contents contained opaque material and five which had been starved. The starved leeches served as control, showing that the tissues of *G. complanata* and *H. stagnalis* themselves did not react with the anti-*Helisoma trivolvis* serum. The positive reactions, presence of precipitin arcs, must be regarded as definite proof that *G. complanata* fed on molluscan tissues from the various collecting sites; the negative results of *H. stagnalis* are proof that they did not feed on snails but on some other organisms.

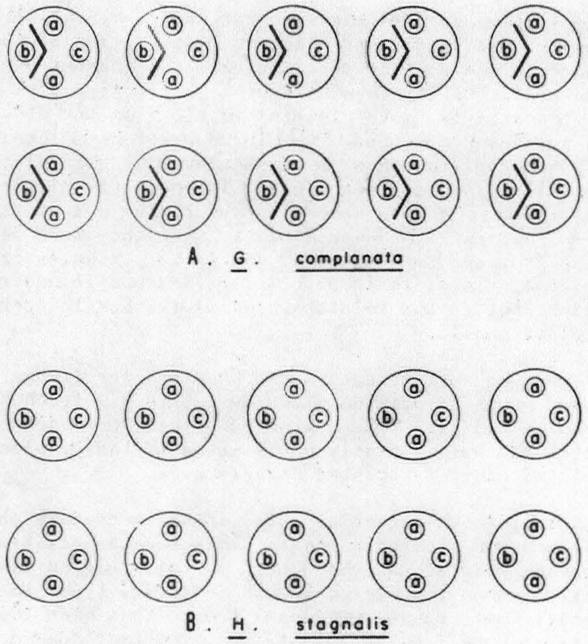

Fig. 26. Examples of agar gel diffusion plates showing the reactions of the gut contents of *Glossiphonia complanata* and *Helobdella stagnalis* with the anti-*Helisoma trivolvis* anti-serum.

A. *Glossiphonia complanata*, a: anti-*Helisoma trivolvis* anti-serum, b: antigen, opaque matter from gut contents, c: starved gut contents. Presence of precipitin arcs, positive reactions.

B. *Helobdella stagnalis*, a: anti-*Helisoma trivolvis* anti-serum, b: antigen, opaque matter from gut contents, c: starved gut contents. Absence of precipitin arcs, negative reactions.

DISCUSSION

Part I. The Study Areas

To assess leech-mollusk associations and to add new information to the growing knowledge of leech ecology, a comprehensive survey of mollusks, which included pulmonates, operculates, and certain bivalves, was carried out in Southeastern Michigan. The study areas were selected mainly for their richness in both leeches and mollusks. In addition, 25 incidental stations throughout Michigan were also sampled at least once excepting those indicated as necessary to determine the distribution of leeches associated with some of the same mollusk species in the permanent sites and certain species found only outside the permanent localities.

It was found that larger bodies of water tended to have more leeches and mollusks since they usually provided a greater variety of microhabitats. Waters with steep shores usually offered poor habitats for leeches and mollusks. In some of the areas studied the leeches and mollusks seemed to prefer a degree of current in the water; however, none was completely dependent on it. The ten permanent stations, therefore, were characterized by using the same environmental factors previously mentioned as important in the ecology of both leeches and mollusks.

In these studies it appeared that both leeches and mollusks were most numerous in shallow waters; they were scarce or absent in strong currents or in situations where the edge of a habitat was undercut and dropped off directly into deep water. In broad terms of habitat study, most leeches and mollusks were more common in sheltered microhabitats with vegetative belts in the littoral zone where emerging rooted plants (e.g. water lilies with floating leaves) and submerged rooted plants were found. Whereas a good supply of submerged vegetation was in every way favorable to leeches and mollusks, too thick a plant growth appears to be harmful to mollusks (Boycott 1936).

At the ten permanent sites studied, collections were made over a wide range of both water temperatures (1° - 32° C) and pH (6.0-7.5) (Appendix II). These factors were not considered in limiting the distribution and abundance of these animals.

Substrate types were also found to be important factors in determining the presence and abundance of leeches and mollusks. In this study both groups were collected from habitats with a variety of bottom types (see Appendix II). Sapkarev (1967), Bennike (1943) and Herrmann (1970) reported on the substrate preferences among some species of leeches, especially the glossiphoniids. Klemm (1972a) found most leech species in waters containing a variety of submerged and floating objects. It may be generally assumed that such materials were important since they protect both leeches and mollusks from predation, provide resistance to currents, offer more niches for feeding, and furnish substrates on which eggs can be deposited and where the eggs and young of some species may develop.

In rivers and creeks, Pennak (1971), Wilkialis (1971) and Hynes (1970) reported that no single factor has greater biological significance than the physical nature of the substrate. In this study such factors as changes in bed and bank configuration, decreases in water level, lack of placesfor attachment, lack of reproductive sites, and disappearance of stagnant environments (backwaters), lack of suitable plants, certain muds, and excess detritus---all appeared to reduce the number of both leeches and mollusks.

Part II. Total Leeches, Symbionts, and Cercarial Types recovered from Mollusks in various Habitats

Most leech-mollusk studies of the past were of the survey type in which the investigator collected known species of leeches from unidentified snails or known species of snails were found with unidentified leeches.

The present study (Table 2-12) provides added information and identifies both the leeches and the mollusks, the symbionts and the cercarial types recovered. These data showed precisely which species attacked which species of mollusks in nature from a variety of habitat types in southeastern Michigan. This information made possible interpretations of some additional predator-prey and parasite-host relationships.

Although the species diversity of leeches from the different habitats was quite high (Appendix III), the number of different leeches infesting the many mollusk species was low and limited to five species (Tables 13 through 23); three were in one genus, *Helobdella (H. fusca, H. lineata,* and *H. papillata),* and one in the genus *Glossiphonia (G. heteroclita)* and one in the genus *Marvinmeyeria (M. lucida)* of the family Glossiphoniidae.

The field data (Tables 2—12) showed that the leeches recovered were found associated with a variety of pulmonate snails or with sphaeriid clams. None was recovered from the six operculate snails examined. Others, such as Bennike 1943, Annandale *et al.* 1921, Wesenberg-Lund 1937, and Thompson 1973, reported leeches from operculates. This association was probably unusual and perhaps species-specific, for some operculate snails have a strong mechanical defense against leeches when they close their opercula. Among those leeches studied here none was shown to penetrate snails with opercula. Annandale *et al.* (1921) reported that almost every specimen of *Vivipara oxytropis* in India was infested by the leech *Glossiphonia weberi.* More than 30 of these leeches were found in the branchial chamber of a single specimen, while the branchial chamber of *Lecythoconcha* from the same habitat was invariably empty. He speculated that the contraction of the powerful columellar muscle closes the chamber much more effectively than that of *V. oxytropis,* with a comparatively more feeble muscle. On the other hand, Wesenberg-Lund (1937) found a very small leech, *G. heteroclita,* when he dissected the operculate snail, *Bythinia tentaculata.* Thompson (1973) also stated that leeches were observed coming out of *Viviparus* snails in South America, when they were being preserved. Obviously additional studies are needed to confirm these observations and to understand better the relationships of leeches to operculate snails.

Only one oligochaete worm, *Chaetogaster limnaei,* was found associated with the mollusks, leeches, and cercarial types studied. Their presence on mollusks was evidently not limited by the presence of the other associated organisms.

Snail-leech-cercarial associations were only observed in limited numbers. This rare association may be related to the heavy parasite burden that exists when both leeches and cercarial types in a snail may cause its death sooner than when they have a more limited infestation. Another consideration to explain its rarity may involve a principle of exclusion. Additional studies are warranted to determine its causes.

There were seven cercarial types in a variety of mollusks from the different habitats sampled. Such infections are normal for mollusks, since they generally are prime intermediate, or sometimes second intermediate hosts for a variety of trematodes.

ADDENDUM

Helobdella punctatolineata occurs commonly in Puerto Rico (Moore, 1939). Several reports of this species occurring in the United States (Sapkarev, 1967, Klemm, 1972b, and Richmond, 1972) remain questionable. However, specimens which closely resemble this species have been identified recently from southern Lake Michigan (Klemm, unpubl.). Additional collecting could extend the known range of *H. punctatolineata,* or experimental breeding may demonstrate that specimens which resemble this species are colored variants of either the polymorphic *H. fusca* or *H. lineata.*

(To be continued in Sterkiana No. 59, September 1975)

GULELLA BICOLOR (HUTTON) IN TEXAS

Recent mention by D. S. Dundee (Sterkiana no. 55: 25, 1975) and R.W. Fullington and W. L. Pratt. Jr. (Dallas Mus. Nat. Hist., Bull. 1, pt. 3: 24, 1974) appear to be the first reports of this species in Texas.

Gulella bicolor was collected alive by the author under the leaf litter of a shrub near the U.S.D.A. Research Laboratory in Weslaco, Hidalgo County, Texas in 1971 and 1973. As several specimens were collected each time it would appear that *G. bicolor* may be establishing itself in the general vicinity of the laboratory.

Collected with *G. bicolor* were *Polygyra texasiana*, *P. septemvolva*, *Praticolella berlandieriana*, and *Lamellaxis gracilis*. The flesh of *G. bicolor* was orange and the color could be seen through the shell. *L. gracilis* was yellow in color which could also be seen through the shell as could eggs which several specimens contained.

Voucher specimens will be deposited in the Dallas Museum of Natural History and the U. S. National Museum in Washington, D.C. as soon as possible.

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BAGWORM CASES AS PSEUDOGASTROPODS

Recently, La Rocque (1973) reviewed several cases of pseudogastropods, animals originally believed to be gastropods due to gross external morphology. Additional examples were given by Corgan (1974).

An instance of mistaken identity similar to heliciform caddisfly cases involves certain species of bagworm moths (Lepidoptera:Psychidae). The bagworm larva remains in a self-constructed bag which it carries as it feeds on leaves of various plants. The best known species in the United States is the evergreen bagworm, *Thyridopteryx ephemaeriformis* (Haworth), which is most common in urban areas on arbor vitae. The bag of most species is cylindrical in shape. However, a few species have bags which are helically coiled like gastropods. Certain species of Asian and African bagworm moths with such cases were originally sent to the British Museum as land snails by the original collector (Holland 1903: 360).

In the United States there is a single species which has a case 'resembling a helical land snail with 2½ to 3½ coils' (Davis 1964: 41). This species, *Apterona crenulella* form *helix* (Siebold), is not native to the United States. This native of central and eastern Europe and western Asia has been found in California, Utah, Idaho and New York. Snail-like in some habits, the larvae of *Apterona* generally feed only at night after fastening their cases to a leaf surface much as snails aestivate.

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