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The Control of Swimmer's Itch in Michigan: Past, Present, and Future

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Abstract

The association between a type of dermatitis known as swimmer's itch and the free-living stage of certain digenetic trematodes (nonhuman schistosomes) was delineated in 1928 by Cort at the University of Michigan Biological Station. Following his discovery, studies on swimmer's itch have continued at the Biological Station until the present time. In 1939, the State of Michigan initiated a control program that included the application of copper sulfate to many of the larger recreational lakes. It was assumed that this molluscicide would reduce the prevalence and incidence of swimmer's itch by interrupting the life cycle of the parasite in the snail intermediate hosts. Unfortunately, swimmer's itch continues to be a problem in Michigan despite more than a half century of control efforts. In addition, concerns about the accumulation of toxic copper sulfate in our aquatic ecosystems are being expressed more frequently. In 1985, Blankespoor initiated a new approach to the control of swimmer's itch by treating the definitive host with an antihelminthic drug, Praziquantel. Based on four years of research on Glen Lake, the authors have concluded that controlling swimmer's itch with Praziquantel is more effective than using copper sulfate, less expensive, and has no detrimental effects on the environment. In 1990, the program was expanded to include three additional lakes in Leelanau County, Michigan.

Introduction

Schistosomes represent a family of trematodes that has been known to cause diseases for nearly a century. These unique flatworms are atypical digenetic trematodes for several reasons. First, schistosomes are not hermaphroditic and their life cycle involves two hosts, not three. In the second place, eggs are usually spined and are fully embryonated when passed from the host. And finally, adult worms reside in the blood vessels of vertebrates, usually the veins surrounding the digestive or urinary tract. The word schistosome means "split body" and has reference

to the gynecophoric canal that is characteristic of the males of many species of this family. This ventral canal gives the male the appearance of a body divided into longitudinal halves.

In 1928, Cort reported that some nonhuman schistosomes can be causative agents for a medical condition known as schistosome dermatitis or swimmer's itch (Cort, 1928a,1928b). This condition, although less serious than schistosomiasis caused by some of the species of *Schistosoma*, results when larvae of bird or rodent schistosomes accidentally enter the skin of sensitized swimmers or bathers. After Cort's publications, it became obvious that swimmer's itch was not restricted geographically to Michigan or to the Midwest. Reports of this malady came from other states and countries, usually in temperate regions. In Michigan, swimmer's itch continues to be a problem on many of the larger recreational lakes, especially those located near Lake Michigan. These include Black, Burt, Crystal, Glen, Leelanau, and Torch Lakes in the Lower Peninsula. In addition, reports of swimmer's itch often come from Cadillac, Higgins, Houghton and Mitchell Lakes, located in the northcentral part of the state. In the Upper Peninsula, Indian and Manistique Lakes are sites where people contract schistosome dermatitis. Control efforts begun in the late 1930s have done little to curb this water-related problem. In fact, Wall (1968a) stated that swimmer's itch may be on the increase in Michigan.

Life Cycle

Nonhuman schistosomes must cycle through an aquatic gastropod and a bird or mammal (Figure 1). The snail and vertebrate hosts are called the first intermediate and final or definitive hosts, respectively. Embryonated eggs of the parasite leave the vertebrate host via the feces and upon contact with water hatch into small larval forms called miracidia. The miracidium is a free-swimming, nonfeeding stage that will usually die within a day if a suitable snail is not contacted. The life cycle continues if the ciliated miracidium penetrates the integument of a particular species of aquatic snail. Within the gastropod, the parasite will elongate to form a sporocyst. This germinating sac then produces another generation of sporocysts that usually is located in the hepatopancreas or digestive gland. Several weeks after the snail becomes infected, another aquatic, free-swimming larval stage called the cercaria, emerges from the snail. Like the miracidium, the cercaria's life span is short because it does not feed. Its energy is derived from stored nutrients that originated from the digestive gland of its invertebrate host. Completion of the life cycle takes place when the cercaria penetrates the skin of a suitable species of bird or

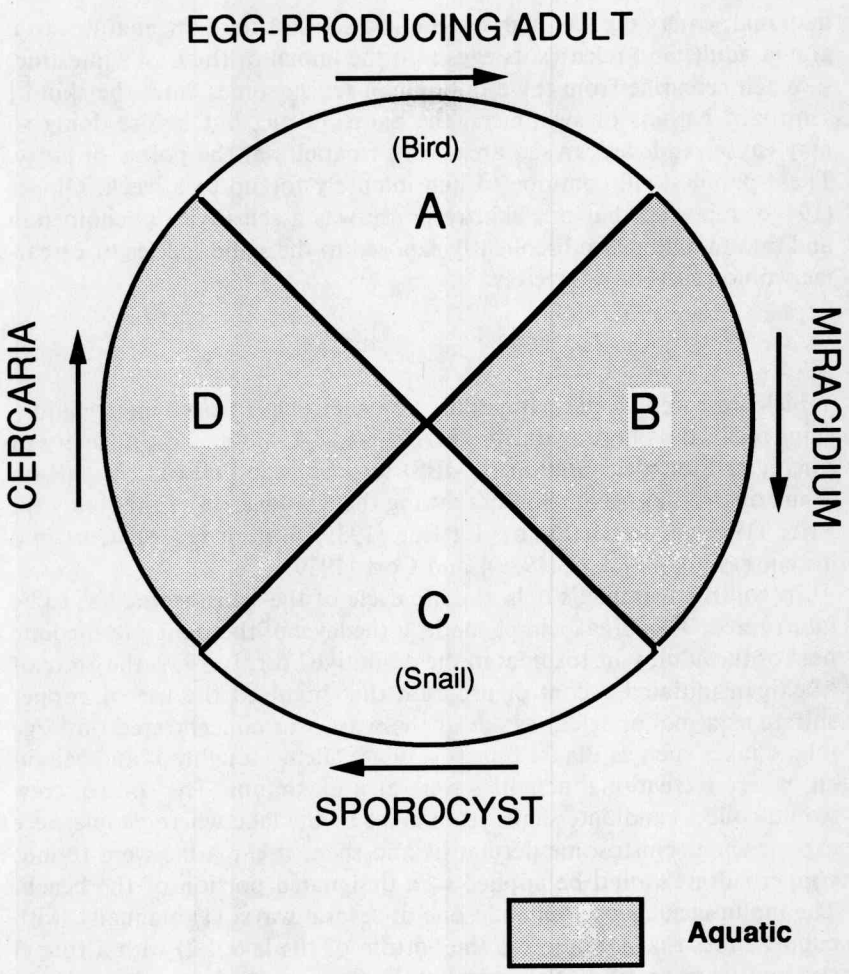

FIGURE 1. Summary of the life cycle of a typical avian schistosome. (One species of rodent schistosome, *Schistosomatium douthitti*, can cause swimmer's itch.) A. Adult schistosomes usually reside in the mesenteric veins of their hosts and produce fully embryonated eggs (often spined) that hatch in water to produce miracidia. B. The nonfeeding miracidium actively swims in water until it dies (usually within 24 hours) or until it penetrates a suitable snail. C. Inside the snail, the miracidium elongates to form two successive generations of germinating sacs called sporocysts. The second generation of sporocyst produces many cercariae each day that the snail lives. D. When the cercaria enters a suitable host, it develops into an adult. If it accidentally enters a sensitized swimmer or bather, a papule forms at the site of entry and may itch intensely for several days.

mammal, enters the vascular system as a schistosomulum, matures to a gravid adult, and releases its eggs into the lumen of the host's intestine.

When cercariae from these nonhuman schistosomes enter the skin of sensitized bathers or swimmers, the parasites die, but before doing so may cause reddened, raised areas called papules at the points of entry. These papules will continue to itch intensely for up to a week. Olivier (1949b) reported that this skin response was a sensitivity phenomenon and that individuals subsequently exposed to the same species of cercariae would react more severely.

Past

Field research in the parasitology of snail-schistosome interrelationships reached its heyday during the 1930s and 1940s at the University of Michigan Biological Station (UMBS) located near Pellston, Michigan. Some of the major contributors during the first decade of that era were Price (1931), Cort (1936a,b), La Rue (1935), Talbot (1936), Cort and Talbot (1936), Brackett (1939), and Cort (1939).

To control swimmer's itch, the life cycle of the schistosome has to be interrupted. This break can be made at the level of the snail intermediate host or the adult schistosomes in the definitive host. In 1939, the State of Michigan initiated a control program that involved the use of copper sulfate as a molluscicide. Much of the work was concentrated on large inland lakes such as Black, Burt, Cadillac, Glen, Houghton, and Mitchell, where recreational activities were at a maximum. The control crew would collect candidate snails from areas of the lake where people were experiencing schistosome dermatitis and then, if cercariae were found, copper sulfate would be applied to a designated portion of the beach. The molluscicide was applied in one of several ways: (1) manually, with copper tubes that extended to the bottom of the lake; (2) with a funnel system that put a trail of chemical in the water as the boat advanced; or (3) with airplanes. Pilots sprayed the finely granulated copper sulfate in areas previously delineated with buoys. In many cases, these buoys were put in the same location year after year without prior snail surveys. Although the Department of Natural Resources still requires individual property owners or lake associations to obtain a permit before they are allowed to treat a lake with copper sulfate, funding for the itch crews was terminated many years ago. The results of these applications were variable, depending on lake conditions at the time of application and on the background and expertise of those who applied the chemical.

Swimmer's itch research at the University of Michigan Biological Station continued to flourish in the 1940s. In addition to studies of life cycles, epidemiology, classification, behavior, and distribution, emphasis

was placed on the parasite's pathology, host responses, and control. Major contributors during this decade included McMullen et al. (1940), Brackett (1940), Cort et al. (1940a, 1940b, 1941), McMullen (1941), McMullen and Brackett (1941), Brackett (1942), Adams (1945), McMullen and Brackett (1948), McMullen (1949) and Olivier (1949a, 1949b, 1949c). Two reports published by state agencies appeared early in this decade. The first was published by the Michigan Department of Public Health (1941) and dealt with a new program of chemical treatment (copper sulfate). The second one came two years later (1943) from the Michigan Stream Control Commission, and reported on the control efforts developed during the preceding two years. Because of these efforts, the following programs were begun: (1) state-supported funding for the treatment of public beaches; (2) advisory assistance to private beach owners; and (3) initiation of research at the University of Michigan Biological Station that led to the elucidation of the life cycles of three species of avian schistosomes that were causative agents for swimmer's itch (McMullen and Beaver 1945). Cort (1950) culminated 20 years of research on swimmer's itch with his excellent review of what was known about schistosome dermatitis up to that time. Readers are encouraged to consult his article for more detailed information.

The next two decades of research on swimmer's itch in Michigan proved to be less productive. Najim (1950, 1956) described a new species of schistosome from passerine birds and elucidated its life history. Two papers that dealt with the intramolluscan stages of dermatitis-producing schistosomes were published by Cort et al. (1953) and Cort et al. (1955). Batten (1956, 1957) initiated studies on the histopathology of swimmer's itch. Hendricks and Cort (1956) described *in vitro* studies on antisera from avian schistosomes. In 1960, Fetterolf and Gouine prepared a report on the cause and control of swimmer's itch for the Michigan Water Resources Commission. Wall (1968a, 1968b) analyzed the status of schistosome dermatitis in Michigan in the mid1960s. Based on responses from property owners, resort and camp managers, and park officials, he concluded that this skin disease had been slowly spreading southward in Michigan. Wall (1968a) included a historical account of swimmer's itch, an updated bibliography, control methods current at that time and future recommendations. Two years later, Fetterolf et al. (1970) published a special report for the Michigan Water Resources Commission on the cause and control of swimmer's itch in Michigan. They reviewed swimmer's itch from biological and historical perspectives and gave recommendations for control using copper sulfate to eliminate the snail intermediate hosts. Working at the University of Michigan Biological Station, Clampitt (1970) compared the ecology of two physid snails that can serve as carriers of the larval stage that cause swimmer's itch. Novy et al.

(1973) conducted a study to determine if copper sulfate had a negative impact on the water quality of Michigan inland lakes. They concluded that the effects are probably only short term. Other publications during this decade covered general aspects of the biology of swimmer's itch, its impact on tourism and the need for an interdisciplinary approach to study this disease (Clampitt, 1972; Blankespoor and van der Schalie, 1976; van der Schalie and Blankespoor, 1978; and van der Schalie, 1979). Sauer, et al. (1975) reported on the low degree of host specificity of the passerine schistosome *Gigantobilharzia huronensis*. Near the end of the 1970s, Guth et al. (1979) surveyed more than 1200 birds representing 43 species at the W. K. Kellogg Bird Sanctuary (Michigan State University) for mature, natural infections of schistosomes. They found 13.6% of the birds with patent schistosome infections. Adult anseriforms (ducks, geese and swans) had a much lower rate of infection (12.0%) than young birds (46.3%).

Responding to the need for nontechnical information on swimmer's itch, Blankespoor and Reimink published several articles during the 1980's (Blankespoor 1980a, 1986b, 1986c; Blankespoor and Reimink 1986, 1987). Kulesa et al. (1982) examined *Physa integra* in southwestern Michigan for natural infections of avian schistosomes. Working on Douglas Lake at the University of Michigan Biological Station, Laman et al. (1984a) and Boss et al. (1984) investigated the depth distribution and dispersal of aquatic gastropods, many of which are potential intermediate hosts for avian and rodent schistosomes. During the same time, Laman, et al. (1984b) isolated avian schistosomes from a small planorbid snail, *Gyraulus parvus* at the W. K. Kellogg Bird Sanctuary. It appears that this gastropod species is not significant in the distribution of swimmer's itch because its habitat is limited to marshy areas where recreational swimming is at a minimum or absent altogether. Strohm et al. (1981) surveyed wild passerine birds in southeastern Michigan for natural infections of *Gigantobilharzia huronensis*. Red-winged blackbirds and common grackles were the most important definitive hosts for *Gigantobilharzia* sp. infections. Evidence was presented by Blankespoor et al. (1985) that snails repeatedly exposed to copper sulfate began showing more resistance to low concentrations. More recently, Blankespoor and Reimink (1986, 1988a, 1988b) have proposed an alternative control method.

Present

Copper sulfate is the only molluscicide approved for swimmer's itch control in Michigan. According to Wandell et al. (1976), approximately 1.67 million pounds of the molluscicide were applied to Michigan inland

lakes between 1947–1973. This amount represents the total copper sulfate that was used by individual cottage owners or lake association personnel who obtained permits from the Michigan Department of Natural Resources. Undoubtedly, much additional chemical was purchased by individuals or agencies who did not bother to apply for a permit. Also, copper sulfate had been used before the time of Wandell's report and continues to be used today.

Although copper sulfate has been used for over six decades, swimmer's itch continues to be a problem in Michigan and in other midwestern states. Copper sulfate programs have had limited success for a number of reasons. First, molluscs represent a very diverse and successful phylum of animals. They have the ability to reproduce and disperse at a surprisingly rapid rate. Second, copper sulfate is annually applied to the same areas of a given lake with minimal time devoted to monitoring snail populations, either quantitatively and qualitatively. In addition, little or no effort is made to determine if snails infected with swimmer's itch schistosomes are actually found in the treated areas. Third, personnel involved in the application of copper sulfate often have limited knowledge and experience. If the chemical is simply applied to the surface of a lake, water currents may cause unpredictable and unacceptable dispersion of this toxic chemical. Fourth, there is some evidence that snail populations exposed to copper sulfate over an extended time are slightly more resistant to the chemical than gastropods which come from untreated lakes (Blankespoor et al. 1985).

Bird Definitive Host

In 1983, swimmer's itch had reached unparalleled proportions at Glen Lake (Leelanau County). At the request of Chris Anderlik, president of the Glen Lake Association, the authors initiated a comprehensive study of the biology and control of schistosome dermatitis on that lake. An important goal was to find an alternative method of control. Research conducted during the first year of the Glen Lake project focused on determining the snail and bird hosts of the schistosomes causing swimmer's itch in the lake. Lymnaeid and physid snails were collected in lake areas where swimmer's itch was known to occur frequently. These snails were isolated in the laboratory and then checked with a dissecting microscope for schistosome cercariae. One snail species, *Stagnicola emarginata* (=*Lymnaea catascopium*) was found to shed cercariae of *Trichobilharzia stagnicolae* as named by Talbot (1936).

Concurrent studies were made of the anseriforms and several other bird species found on Glen Lake and associated habitats. Fresh fecal samples were collected from all the species of ducks, geese and swans that remained as summer residents (Table 1). Emphasis was placed on

TABLE 1
Prevalence of Natural Schistosome Infections in Glen Lake Birds (1983)

Species	No. Examined	No. Infected	% Infected
Mute swan (*Cygnus olor*)	17	0	0
Canada goose (*Branta canadensis*)	45	4	9
Mallard (*Anas platyrhynchos*)	17	4	24
Wood duck (*Aix sponsa*)	2	2	100
Common merganser (*Mergus merganser*)	27	24	89
Ruffed grouse (*Bonasa umbellus*)	1	0	0
Ring-billed and herring gulls (*Larus* spp.)	48	0	0
Barn swallow (*Hirundo rustica*)	9	0	0
Common crow (*Corvus brachyrhynchos*)	5	0	0
Black-capped chickadee (*Parus atricapillus*)	1	0	0
American robin (*Turdus migratorius*)	1	0	0
Red-winged blackbird (*Agelaius phoeniceus*)	9	0	0
Common grackle (*Quiscalus quiscula*)	29	2	7
Rose-breasted grosbeak (*Pheucticus ludovicianus*)	1	0	0
TOTALS	212	36	17

young birds because they were flightless and could only harbor schistosomes from that lake.

To determine if the schistosomes in the common merganser were the ones responsible for swimmer's itch on Glen Lake, miracidia from hatch-year birds were placed in vials containing young, laboratory-reared *Stagnicola emarginata*. These exposed snails were kept in the laboratory

for at least a month and then isolated and examined for emerged cercariae. The cercariae from the laboratory-reared snails were compared with those obtained from naturally infected snails of the same species collected from areas on Glen Lake where people were reporting swimmer's itch. Based on comparative studies with light microscopy, the cercariae from both groups of snails were found to be identical. This indicated that the common merganser is the definitive host for the swimmer's itch schistosome on Glen Lake and that *Trichobilharzia stagnicolae,* as described by Talbot (1936), naturally cycles through the common merganser. This paper represents the first published record of the natural definitive host to *T. stagnicolae.*

Before the study at Glen Lake was begun, the authors were of the opinion that individuals in summer populations of anseriforms moved a great deal from one inland lake to another. Data obtained during the summers of 1984–86 indicated that such was not the case (Figure 2). Typically, adults arrive as soon as there is open water. They will remain on the lake for up to three weeks, depending on the weather. As soon as more northern lakes thaw, most individuals migrate north. Those that remain on Glen Lake usually establish pair bonds and begin the repro-

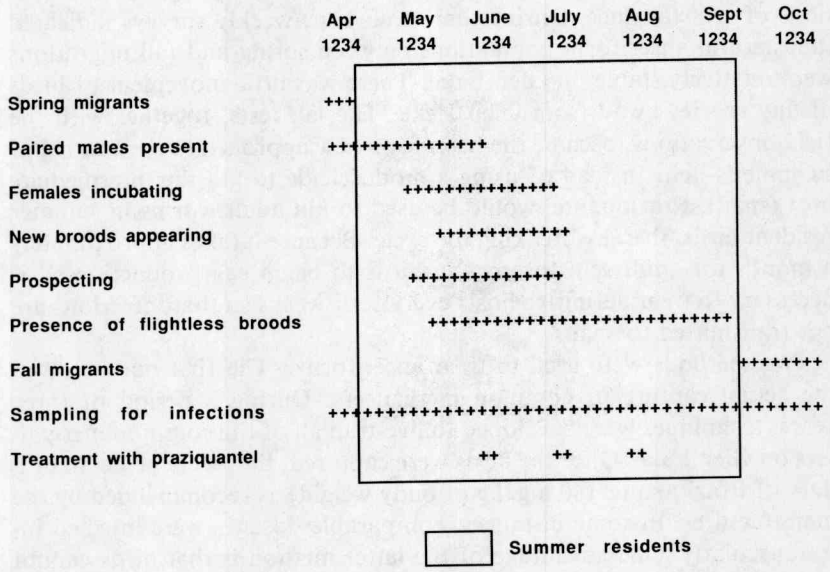

FIGURE 2. Weekly activities of the common merganser (*Mergus merganser*) on Glen Lake in 1985. Numbers below month designations represent weeks.

ductive cycle. Typically, males remain on the lake for a week or two after the females begin incubation.

Females begin incubating around the middle of May with the first broods appearing on Glen Lake from late May to the middle of June. This is the time when the first naturally infected snails begin shedding schistosome cercariae. Young birds remain flightless on Glen Lake until August or September. It should be noted that little if any movement of common mergansers from one lake to another takes place once the majority of spring migrants have departed north.

Controlling Swimmer's Itch With Praziquantel

For more than half a century, copper sulfate was used as a molluscicide to reduce the prevalence and intensity of swimmer's itch. An alternative method of controlling swimmer's itch involves the use of an antihelminthic drug such as Praziquantel, to eliminate adult worms from the veins of the vertebrate host. Praziquantel is a chemotherapeutic agent that has a broad spectrum of activity against flatworms. It was developed in Germany in the early 1970s as a drug to combat schistosomiasis. Although costly, the drug is quite effective and causes few or no side effects.

In 1985, laboratory tests conducted by the senior author documented successful use of Praziquantel to treat mallards containing natural infections of schistosomes. During that same year, weekly surveys indicated that natural anseriform populations between spring and fall migrations were relatively stable on Glen Lake. There was little movement of birds of any species away from Glen Lake. The lab tests, together with the field observations, became the basis for a new approach to the control of swimmer's itch. Instead of using a molluscicide to kill the intermediate host (snail), Praziquantel would be used to kill adult worms in summer resident birds, thereby breaking the cycle. Because it takes approximately a month for adult schistosomes in birds to begin egg production, it is necessary to treat definitive hosts every four weeks so that infections are not transmitted to snails.

Two methods were used to treat anseriforms. The first one involved the actual capture of common mergansers. During a period of three years, techniques were developed to live-trap all of the common mergansers on Glen Lake. Once the birds were captured, they were given an oral dose of Praziquantel (40 mg/kg of body weight) as recommended by the manufacturer. In some instances, comparable dosages were injected intramuscularly. One advantage of the latter method is that birds cannot regurgitate the drug. On some occasions, the female and her brood were trapped and then transported to other lakes where there was little or no recreational activity or where suitable intermediate snail hosts were ab-

sent. Band returns from fall hunters indicated that the birds survived the procedure.

For species of anseriforms that feed on grain or grain products, Praziquantel was placed in fresh bread and then fed to females and their broods. Prebaiting was helpful to condition the broods to take the bread. With practice, it is possible to distribute the drug so that all birds get treated without severely overdosing some. An advantage of Praziquantel is that even in oral doses exceeding 50X the necessary amounts, young birds in the laboratory were not adversely affected. Drug treatments must be repeated at monthly intervals because birds may become reinfected once the chemotherapeutic agent is excreted or metabolized. Control of swimmer's itch using Praziquantel began at Glen Lake in 1985. Since that year, all breeding common mergansers have either been treated or transported to other areas.

The new method of control was evaluated in two ways. First, property and resort owners from Glen Lake were contacted on a weekly basis regarding the prevalence and intensity of swimmer's itch cases. At the end of the 1985–86 summers, a questionnaire was sent to each of approximately 20 resort owners on Glen Lake asking them if they observed a reduction in the frequency and severity of swimmer's itch. With few exceptions, they responded that swimmer's itch was greatly reduced. Second, the frequency of mature infections in snails was checked. Regular collections of *Stagnicola emarginata* were made at eight locations around the lake. Snails were taken to the laboratory and examined to determine what percent harbored mature or patent infections. Natural infections of avian schistosomes from *S. emarginata* from Glen Lake (1983–90) are summarized in Figure 3. It clearly shows that there has been a dramatic decrease in the infection in snails after 1985 when control efforts using Praziquantel were initiated.

Future

There are a number of reasons why the swimmer's itch problem might worsen in Michigan. First, increasing human populations in the states surrounding the Great Lakes will exert more pressure on inland lakes for recreational uses, and more people will be exposed to the parasite. Second, water quality is likely to improve in individual bodies of water and snail species diversity will increase. With more species and a larger number of individuals within a species, swimmer's itch can only become more common. Third, breeding ranges of some bird species that host schistosomes have increased. Examples include the Canada goose and the mute swan. Although mallards have recently decreased in North America, they are common on many of the inland lakes of Michigan, such as Cadillac,

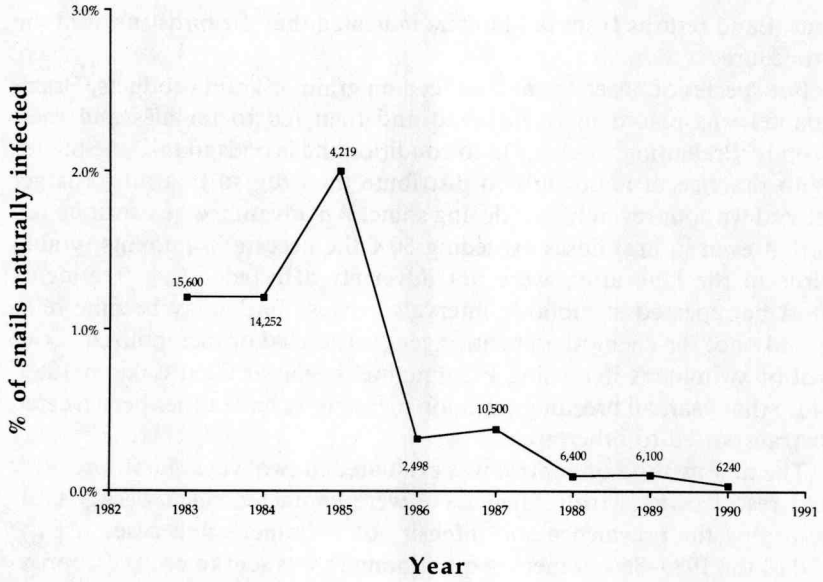

FIGURE 3. Percentage occurence of avian schistosomes occurring naturally in *Stagnicola emarginata* (= *Lymnaea catascopium*) from Glen Lake (1983–1990). Figures at data points are numbers of snails examined.

Houghton, Leelanau, and Mitchell. Fourth, medical doctors and public health officials are becoming more aware of this form of water-related dermatitis. This results in more accurate documentation of clinical cases.

There is great need for additional descriptive work in Michigan on the host-parasite relationships of avian schistosomes. Since the work of Cort and his colleagues, few studies have been published on this aspect of the swimmer's itch problem. The complete life cycles of only a few schistosome species are known at the present time. The authors believe that there may be as many as 20 species of nonhuman schistosomes in Michigan alone. Additional research is needed, first to recover the minute adult worms from their avian hosts and then to describe new species of this group of trematodes. This descriptive work is necessary if other host-parasite relationships are to be elucidated. In addition, these field and laboratory studies may form the basis for other control methods for swimmer's itch.

Even if copper sulfate could be demonstrated to be effective in the control of swimmer's itch in Michigan and other states, environmental

concerns regarding the toxicity and long-term effects of copper on aquatic ecosystems are being voiced more often than before. After a lake is treated with copper sulfate, copper is known to precipitate as copper carbonates and then to accumulate in sediments in the deeper parts of the lakes. High levels of copper from the carbonate could become dissolved in the water column if the buffering properties of a lake were altered by conditions such as acid rain. Not only would aquatic organisms be severely affected, but the recreational value of our lakes would be greatly reduced.

The new method of controlling swimmer's itch using Praziquantel to treat the avian host has been successful at Glen Lake. This program is being expanded to three additional lakes of Leelanau County. Supported by the Leelanau Conservancy, the authors began research on Leelanau, Lime, and Little Traverse Lakes in 1990. This program focused primarily on the biology of the schistosomes and their hosts during the first year with the emphasis shifting toward control during the second and third. If successful on these lakes, the program will be expanded to other lakes in Michigan. This method appears to be more effective in controlling swimmer's itch than using copper sulfate as a molluscicide, and at the same time reduces the costs and environmental risks.

Acknowledgments

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