CHAPTER 16

Swimmer's Itch: Misguided Flatworms

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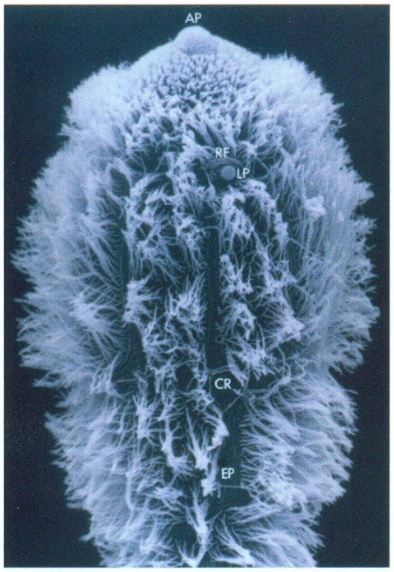
Primarily because some biologists were fascinated with a group of flatworms, parasitological research flourished at UMBS during its first few decades. These scientists worked on the host-parasite relationships of larval trematodes that cause swimmer's itch. Douglas Lake and its neighboring lakes contain a rich fauna of vertebrates and invertebrates, potential hosts for a variety of parasitic worms and protists. It has been estimated, for example, that at least 150 species of digenetic trematodes (including schistosomes) cycle in Douglas Lake. In addition, there continues to be a rich diversity of other helminths such as cestodes, nematodes, and acanthocephalans.

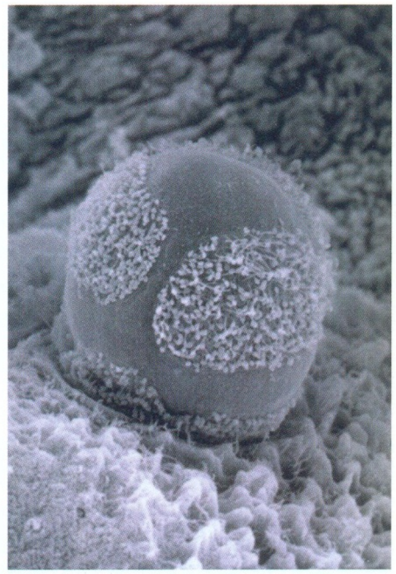
At the Biological Station, one group of trematodes, the schistosomes, has attracted the attention of many parasitologists (including myself) over the past century. This group of helminths is fascinating to investigate because of its host-parasite interactions and its importance to tourism in the northern half of North America. In addition, avian schistosomes cycling in Douglas Lake can be used as model organisms to study a much more serious human disease, schistosomiasis, found in many tropical countries.

Basic Life Cycle of Avian Schistosomes

Although the life cycles of many nonhuman schistosomes have been known for many decades, the actual stages were illustrated in much more detail in the 1970s by myself and other investigators. For example, with the advent of scanning electron microscopy, much better photos exist of the basic life cycle stages of these organisms. Figure 16.1 represents a scanning electron micrograph of a *Gigantobilharzia huronensis* miracidium. In schistosome life cycles, the miracidium hatches after the egg is deposited in water along with host fecal material. Because miracidia are nonfeeders, they continue to swim for 12–24 hours until they deplete their energy reserves. However, if they contact an appropriate snail host, they will penetrate the host's integument within a few minutes (fig. 16.2).

Once inside the gastropod intermediate host, usually a physid or lymnaeid snail, the miracidium will enlongate to form a germinating sac called a sporocyst. A second generation of branching daughter sporocysts will usually occupy the hepato-pancreas, forming more than 50 percent of the snail's biomass. Within 2–3 weeks, daughter sporocysts will produce hundreds of cercariae, the





From left to right:

Fig. 16.1. A scanning electron micrograph (SEM) of a schistosome miracidium showing cilia. (Courtesy Harvey Blankespoor.)

Fig. 16.2. SEM of a miracidium of *Gigantobilharzia huronensis* entering the integument of a snail. (Courtesy Harvey Blankespoor.)

larval stage (fig. 16.3) that leaves the snail and later enters the vertebrate host. Unique to each species, cercariae emerge daily at a specific time, usually triggered by the presence or absence of light. The number of cercariae that emerge depends on the age of the infection, the size of the snail, the species of schistosome, and on water temperature. Cercarial production within the snail is usually enhanced by warmer water temperatures.

After exiting from the snail, cercariae will swim for many hours, until they encounter the proper vertebrate host, usually a bird, or die when their energy reserves are depleted. Wind direction and water currents increase the probability that a cercaria comes in contact with its host. Positive phototaxis and negative geotaxis increase the likelihood of a cercaria coming in contact with the proper final vertebrate host.

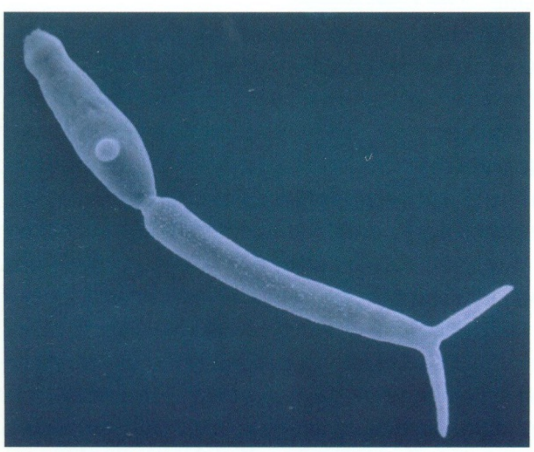
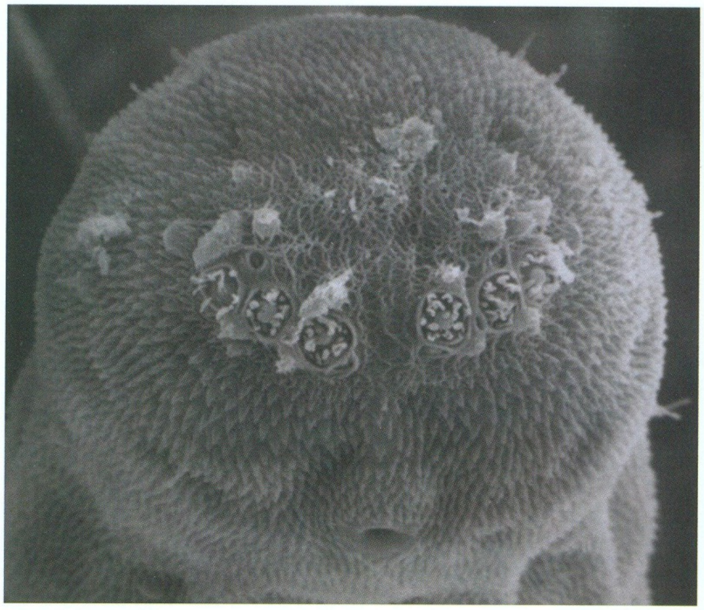
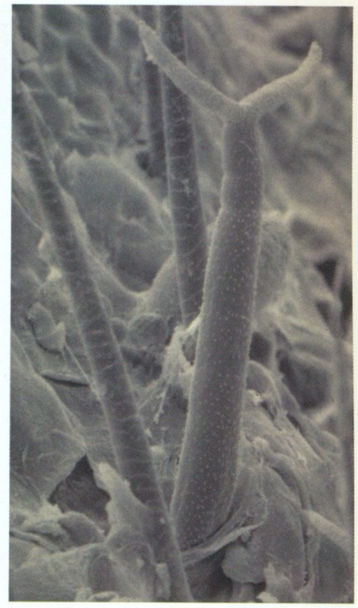


Fig. 16.3. SEM of a schistosome cercariae. (Courtesy Harvey Blankespoor.)

Once the cercaria encounters the final host, it actively burrows into the skin using the enzymes contained in several penetration glands. Paired openings of ducts that lead from these glands can be seen with an anterior view of the body of the cercaria (fig. 16.4). Partial penetration of mammalian skin by a fork-tailed schistosome cercaria is illustrated in figure 16.5. (Note the flaky nature of the host's epidermis with several hair follicles showing in the background.) Once the cercaria enters the skin of its vertebrate host, the tail drops off, and the remaining schistosomule begins migrating. Pene-





From left to right:
Fig. 16.4. SEM of the anterior tip of a schistosome cercariae showing the openings of the penetration glands. (Courtesy Harvey Blankespoor.)
Fig. 16.5. SEM of a schistosome cercaria (fork tail) entering the skin. (Courtesy Harvey Blankespoor.)

tration of the skin by the cercaria usually takes less than five minutes. Inside the vertebrate host, the schistosomule migrates parallel to the skin until it finds a sebaceous gland where the dermis is thinner. It penetrates the skin and enters the circulatory system, migrating to the heart and lungs and then matures in the veins that surround the digestive tract. Within the veins, male and female worms mate; the female worm then migrates to smaller veins to deposit her eggs. These eggs make their way to the gut and are passed out of the bird, completing the life cycle.

If cercariae of the avian schistosomes accidentally come in contact with the skin of a human or other mammal, they burrow under the epidermis but are unable to penetrate the dermal layer. Instead, they die and cause raised, reddened areas, called papules, to form if the "host" has a delayed hypersensitivity response (fig. 16.6). In 1928, William W. Cort (Biological Station parasitology instructor based at Johns Hopkins University) made the association of swimmers's itch, technically known as schistosome cercarial dermatitis, to the cercarial stage of nonhuman schistosomes. During the past 80 years, it has been determined that many species of avian and nonprimate schistosomes can cause this malady.

Until recently, it has been difficult to assess the scope of the problem, both in the United States and in foreign countries. This is especially true of the geographical distribution of swimmer's itch cases in North America. Lake associations usually prefer not to report cases for fear that they would lower property value and reduce tourism on their lakes.

Fig. 16.6. Papules on the legs of a person exposed to schistosome cercariae approximately 24 hours earlier. (Courtesy Ronald L. Reimink.)

During three years (2002, 2003, and 2006), a swimmer's itch Web site (swimmersitch.org) was established in an effort to determine the distribution of swimmer's itch in North America. It included a questionnaire for people who had contracted swimmer's itch. The Web site includes detailed information on the life cycle of the organisms involved in swimmer's itch, host-parasite relationships, and photographs and an animated description of the life cycle of these parasites along with the symptoms they cause. This helps reduce the number of false responses to the questionnaire. If any information in the response to the questionnaire indicated that the dermatitis was not of schistosome origin, it was not included in the present survey. Nearly one thousand (979) responses were received from late May to mid-September during the three years listed above. Although the responses were received from individuals representing 34 states and seven provinces of Canada, 669 (68 percent) of them came from people who contracted swimmer's itch in only four states: Michigan, Minnesota, Wisconsin, and Washington (table 16.1). A total of 114 (11.6 percent) came from people that had been in Canadian lakes and rivers.

It is important to remember that these figures represent the number of reports and not the number of individuals who got swimmer's itch. Individual reports cited from one to more than a dozen people in their group who showed symptoms. It is hard to decipher what percentage of the total cases in North America is represented by those completing the questionnaire. One can only estimate the number of cases that occur based on reports from other surveys and then compare that number with the number of cases reported on the questionnaire. For example, in 2002, six reports were registered from individuals who contracted swimmer's itch while swimming in Higgins Lake (Michigan). During that same summer, 643 cases were recorded on the hotline established by the lake association. This represents a minimum of 100 cases for every one reported via the questionnaire. It is not uncommon, however, to have daily outbreaks of swimmer's itch on some of the pristine lakes of the northern part of the Lower Peninsula in Michigan. In 1985, for example, there were more than 4,000 cases registered by medical personnel in the Leelanau County area of Michigan.

Snail and Bird Hosts

Since Cort's 1928 isolation of a bird schistosome as a cause of swimmer's itch, many avian and some nonhuman mammalian schistosomes have also been shown to cause this skin response. In Michigan, it is known that at least eight

Table 16.1. Number of Reports of Swimmer's Itch in 2002, 2003, and 2006

State/Province	2002	2003	2006	Total
Alaska	3	11	4	18
Arizona	0	2	0	2
California	3	1	9	13
Connecticut	2	4	2	8
Delaware	0	0	1	1
Florida	0	0	1	1
Hawaii	0	0	11	11
Idaho	2	9	1	12
Illinois	1	1	2	4
Indiana	2	0	1	3
Iowa	2	1	1	4
Maine	4	11	2	17
Maryland	0	0	2	2
Massachusetts	1	3	2	6
Michigan	176	94	116	386
Minnesota	46	37	24	107
Missouri	0	1	0	1
Montana	3	8	5	16
Nevada	0	1	0	1
New Hampshire	8	10	1	19
New Jersey	1	8	0	9
New York	5	12	3	20
North Carolina	0	0	1	1
North Dakota	1	0	0	1
Ohio	0	0	2	2
Oregon	0	5	3	8
Pennsylvania	1	0	0	1
South Carolina	0	0	3	3
Texas	0	2	0	2
Utah	0	2	3	5
Vermont	1	3	0	4
Washington	22	23	25	70
Wisconsin	58	34	14	106
Wyoming	1	0	0	1
Alberta	0	3	7	10
British Columbia	0	8	31	39
New Brunswick	5	0	3	8
Ontario	1	13	20	34
Saskatchewan	0	3	4	7
Quebec	0	2	2	4
Manitoba	0	1	9	10
Newfoundland	0	2	0	2

Source: from the Web site swimmersitch.org.

species of snails belonging to the families Lymnaeidae, Physidae, and Planorbidae can carry dermatitis-producing schistosomes. It is interesting to note that in nature, usually less than 1 percent of the snails are infected; however, the biomass of an infected snail may be half parasite. This usually results in the total loss of the snail's reproductive ability. In contrast, a high percentage of bird hosts may be infected, but it is assumed that the adult worms do little or no damage to their avian hosts. These birds usually belong to two taxonomic orders: Anseriformes (ducks, geese, and swans) and Passeriformes (perching birds).

On Douglas Lake, 912 birds representing six species were examined between 1986 and 2004 for schistosome infections (fig. 16.7). Of the four species

Fig. 16.7. Researchers removing ducks from a trap. (Courtesy Harvey Blankespoor.)

found to be hosts, only a high percentage (93.5 percent) of common mergansers (*Mergus merganser*) were positive with schistosomes (table 16.2). The other three infected species, Canada goose, mallard, and wood duck, had quite low rates of infections. No infections were found in Caspian terns or in ring-billed gulls. Furthermore, the level of schistosome infections in common mergansers was extremely high with an average of 136.4 miracidia per gram of feces. The next highest load was 2.8 percent in Canada geese. It is not uncommon to find 100 percent of the mergansers positive with *Trichobilharzia* ssp. This determination can be made by microscopically locating eggs in bird feces diluted with lake water. Eggs of *T. stagnicolae* are boomeranged-shaped, while those of *T. physellae* resemble a flaming torch.

Distribution of Swimmer's Itch in North America

Common mergansers are ideal final hosts for at least two species that cause schistosome cercarial dermatitis. In fact, the distribution of swimmer's itch in North America is determined, to a large extent, by the distribution of the common merganser. Of course, the proper intermediate snail must be present as well because if either host is absent, the schistosomes that cause swimmer's itch will not be present.

The high biotic potential of the schistosomes in infected birds is worth noting. Wilbur Johnson, from Michigan State University's W. K. Kellogg Bird Sanctuary, indicated that most anatid species defecate around 26 times per day. That means that each infected bird puts around 6,850 schistosome eggs in the lake per day. For every miracidium from those eggs that enters a snail intermediate host, up to 2,000 cercariae will be shed daily from that snail during the summer months. The biotic potential of schistosomes in even a single common merganser is astounding.

On Douglas Lake, which is quite typical of many of the lakes in the northern portion of the Lower Peninsula, common mergansers can often be seen on the water as soon as the ice begins to melt. Large numbers can be seen on

Table 16.2. Summary of the Prevalence and Level of Schistosome Infections in Birds from Douglas Lake (1986–2004)

Species	Examined	Infected	% Infected	Miracidia per Gram of Feces
Caspian tern	12	0	0	—
Canada goose	56	6	11	2.8
Common merganser	418	391	94	136
Mallard	301	21	7	2.3
Ring-billed gull	118	0	0	—
Wood duck	7	1	14	2.0


From left to right:
Fig. 16.8. Photograph of the snail intermediate host, *Stagnicola emarginata.* (Courtesy Harvey Blankespoor.)
Fig. 16.9. Common mergansers resting on a dock. (Courtesy Harvey Blankespoor.)

these lakes both during the spring and fall seasons. In the fall, large groups of migrants may accumulate on these lakes until the waterfowl-hunting season begins or until the lakes freeze. Based on studies in my laboratory, schistosome transmission probably slows down as the water temperature in the lake gets cooler.

Major outbreaks of swimmer's itch occur because many lakes have shallow, sandy beaches. This habitat is highly desired by (1) lymnaeid snails such as *Stagnicola emarginata* (fig. 16.8); (2) the common merganser (fig. 16.9); and (3) people who swim in shallow, clear water. If there is an onshore wind, cercariae may concentrate near the shore, exacerbating the problem. With these conditions, it is not uncommon for each person to have more than 100 papules over the body. During the summer of 2006, I made an effort to determine if common merganser broods were always located near shore in water that was less than a meter deep. I found that these diving ducks were frequently in water 10 cm in depth or less.

Unlike mallards, broods of common mergansers can be very mobile. Unless disturbed, mallards usually have a home range of less than a half mile. In contrast, common mergansers can frequent the entire shoreline of a lake during any given day, especially if they are disturbed. Once, I observed a brood of common mergansers move nearly two miles in one hour.

Common merganser mobility makes it likely that beds of the snail species, *Stagnicola emarginata*, are probably going to get exposed to the miracidia of avian schistosomes several times, perhaps even daily. Distribution of the snail intermediate hosts and the movement of common merganser broods are important factors that determine the areas of a lake where swimmer's itch will be a problem.

The common merganser is widely distributed throughout the world, inhabiting Asia, Europe, and North America. In North America, its breeding and winterizing distribution includes the middle two-thirds of North America. Its breeding area, roughly, includes the two tiers of states in the northwest and one tier in the Midwest and Northeast (fig. 16.10). In Michigan, Minnesota, and Wisconsin, adults are found on the shallow, sandy beaches of their northern lakes, often those that are adjacent to the Great Lakes.

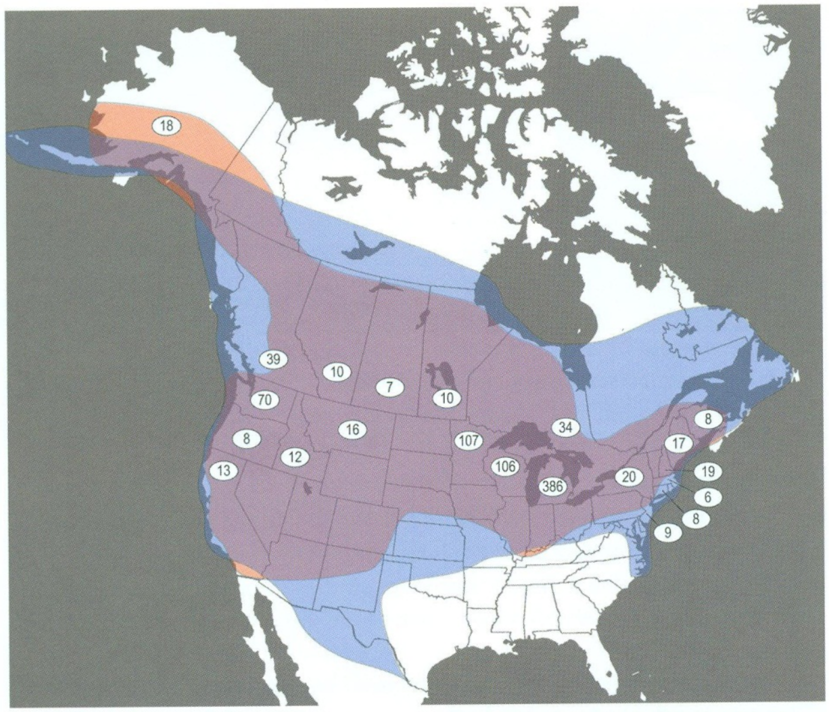


Fig. 16.10. The range of overlap between the common merganser (shaded blue) and the snail species *Stagnicola emarginata* (shaded) compared to the number of cases of swimmer's itch by state or province (numbers in black). (Courtesy Harvey Blankespoor.)

Based on swimmer's itch reports, 735 of 979 were reported from the most northern tier of states. The two provinces that had the most swimmer's itch were British Columbia and Ontario. This coincides well with their counterpart U.S. states: Washington, Minnesota, Wisconsin, and Michigan (fig. 16.10).

Control of Swimmer's Itch

Reports of swimmer's itch date back to the late nineteenth century. This dermatitis was reported by individuals who bathed and swam and by loggers who would use lakes to transport timber.

Once Cort discovered that swimmer's itch was caused by flatworms that cycle through snails and various species of waterfowl, and a few mammals, efforts were undertaken to break the cycle. These efforts focused on killing the snail intermediate hosts. At that time, copper sulfate was the treatment of choice and, to date, is the only chemical authorized by some states in the Midwest for that purpose.

In late spring or early summer, copper sulfate is applied to areas of the beach where swimmer's itch was a problem and where *Stagnicola emarginata* were found. Copper sulfate is applied in one of the following ways: (1) manually, usually from a boat; (2) broadcast from a boat using a device; or (3) distributed from a small airplane flying over areas designated by large buoys. At one point, it was estimated that more than 108,000 pounds of copper sulfate were applied to Lakes Cadillac, Houghton, and Mitchell annually to deal with their swimmer's itch problem. Although some states do not allow the use of copper sulfate, others do only under specific conditions. First, not less than one mile of shoreline can be treated. Second, infected snails must be isolated from the area to be treated. This is seldom enforced because, without training, it is difficult to distinguish schistosome cercariae. And finally, a permit must be obtained from the state agency that oversees the control efforts. In Michigan, it is the Department of Environmental Quality (DEQ), formerly known as the Department of Natural Resources.

In the 1930s and 1940s, high school teachers were hired by the state to work as a swimmer's itch control team. This "itch crew" would go to lakes whose members requested control efforts from the state. The lake association had to pay for the chemical and, in some cases, for the application. Later, these efforts were discontinued after use of copper sulfate became controversial because of its long-term negative effects and its potential misuse. Copper is toxic to more than just snails, and can kill fish and other aquatic organisms. When improperly applied, wind and water currents can cause the copper sulfate to spread to areas of the lake where there are no snails, doing little to deter swimmer's itch. Sometimes too much copper sulfate was applied, and often it was applied on days with nonideal weather conditions, since application days needed to be scheduled in advance. In these cases, some snails survived, and migrated back from adjacent areas. Furthermore, copper sulfate forms copper carbonates that go to the deeper areas of the lake. This can lead to potentially adverse conditions in the future.

More recently, nonchemical methods of control have been sought. For example, some lake associations are encouraging lake users to remove candidate snails by physical means. The removal of adult snails prior to egg-laying shows some potential in reducing swimmer's itch, but at the present, it is not known how successful it will be over several years. However, its benefits include the fact that no chemicals are introduced and that local residents can initiate and do control on their own to save time and money.

A factor that may hamper such control measures is that schistosome cercariae often go to the the surface of the lake and may be carried long distances by lake currents or by wave action. Frequently, major outbreaks of swimmer's itch occur following a prolonged period of onshore wind.

On many lakes where there are major outbreaks of swimmer's itch, beaches owned and operated by the government are either closed altogether or are posted with signs on the beach warning bathers that swimmer's itch may be a problem (fig. 16.11). People often use specific beaches where swimmer's itch is not a problem, or they choose to swim in deeper portions of the lake where cercariae are absent.

Once the importance of the common merganser as the bird host for the adult schistosomes became clear, I initiated a new approach. This method requires trapping a female common merganser and her brood, treating them with a drug and relocating them to lakes or river systems where the birds will not only survive, but where the snail intermediate hosts are not found. Because

Fig. 16.11. On many lakes where swimmer's itch is a perennial problem, this warning sign is posted. (Courtesy Harvey Blankespoor.)

Stagnicola emarginata, the main snail host for swimmer's itch, is not able to survive the wind-swept shores of the Great Lakes, female common mergansers and their broods are often relocated there.

To capture common mergansers, a sophisticated trap was developed to catch the female and her brood. The most recent version of the trap involves submerging a net below the water in a rectangular or triangular pattern. The net is attached to three or four vertical poles. When the mergansers pass between the poles, a remote-controlled radio signal triggers the trap to pull up the net. Within a second or two, the birds are enclosed in a net that extends up to five feet above the water. Because mergansers are diving ducks, they can't lift out of the water like dabblers such as mallards. Mergansers need some distance or a strong facing wind to gain altitude. Female mergansers, especially with younger broods, are vulnerable to such traps. Individual lake associations pay per brood to have the birds removed, treated, and relocated. This is done from late May to early August. State and federal permits are required to catch, to treat, and to relocate the birds.

A final control possibility would prevent cercariae of schistosomes (human and nonhuman species) from penetrating the skin while the person is in the water. Recently, there is a renewed interest in developing such a lotion. If successful, it would greatly reduce the prevalence of swimmer's itch, and more importantly, reduce the level of humans infected with other schistosomes (schistosomiasis), currently estimated to infect around 400 million people in warmer regions of the world.

FURTHER READING

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