Novel swimmer's itch prevention strategies help shift a long-standing control paradigm

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Introduction

The discovery that avian schistosome cercariae cause cercarial dermatitis ("swimmer's itch") by Cort et al. in 1928 set in motion a nearly century-long quest for control and prevention of this common and troublesome malady. Initial efforts focused on destroying the snail intermediate hosts either lake wide or in select swim areas using a molluscicide such as niclosamide or copper sulfate (Blankespoor et al., 1991). Attempts at controlling the adult parasite by killing worms in waterfowl with praziquantel (trade name Droncit) began in the 1980s (Blankespoor HD, 1991; Reimink RL et al., 1995; Blankespoor CL et al., 2001). Breaking the life cycle by managing either the intermediate or definitive host has proven challenging, however, with unintended ecological consequences and limited effectiveness (Blankespoor et al., 1985; Froelich et al., 2018; Rudko et al., 2022). Adding to the complexity of control was the important discovery by McPhail et al. (2021) of a new and ubiquitous avian schistosome cycling through Canada geese (*Branta canadensis*) and a mollusk genus not previously known to harbor avian schistosomes (Planorbitae).

Riparians have been experimenting with various prevention strategies such as applying barrier lotions to exposed skin before bathing (Salafsky B et al., 1999), rigorously toweling off after leaving the water (Horak et al., 2015), and avoiding onshore winds (Sckrabulis et al., 2020). There is a paucity of scientific studies validating the effectiveness of these or any other prevention strategies, however.

Recent discoveries of the parasite community complexities and ineffectiveness of lake-wide control stimulated our exploration of ways to shift the long-standing lake wide *control* paradigm to one of localized or individual *prevention*. Lake associations in Michigan have spent tens of thousands of dollars annually with hopes of lake-wide or large-scale control, yet often disappointed with the results. New understanding of the temporal-spatial dynamics of cercariae emergence and movement created the opportunity to look for ways to manage cercariae to prevent swimmer's itch. Cercariae emerge most abundantly in the morning and travel up to the water surface due to positive phototaxis and negative geotaxis (Horak et al., 2015) and move around in surface waters due to wind (Froelich et al., 2018), often accumulating in shallow water with onshore winds (Sckrabulis et al., 2020).

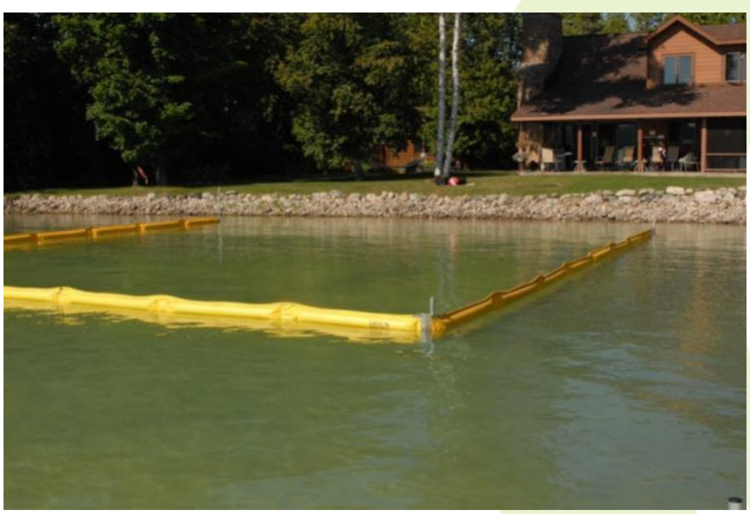
Here we show how creative localized prevention strategies may deliver ways for riparians to swim without fear of vacation-ending cases of swimmer's itch with little effort or cost. We predict continued efforts by scientists and entrepreneurs will successfully shift the paradigm from lake wide control to prevention, and finally offer people easy and inexpensive ways to enjoy recreational waters without the fear of contracting swimmer's itch.

Methods I

Three 50ft (15.25m) oil containment booms (Elastec Optimax I) were employed in 2 swim areas nearshore (Glen Lake and Lake Leelanau, Leelanau County, MI USA) to create square containment areas of 500ft^2 (232m^2), using shore as the shallow side border in July/August of 2017. Corners were secured with 2in (5.08cm) aluminum dock posts augured into the substrate. Both containment zones were oriented on the west shore of each lake facing lakeward, with the two side booms running east-west and the deep side boom running north-south.

Two divers in full neoprene wetsuits and snorkeling gear systematically removed nearly all host snails (*Stagnicolae emarginata*) known from previous work to harbor avian schistosome at the study sites. This was done by hand picking snails as the divers snorkeled throughout the containment area. The number of snails collected was recorded in 5-minute collection increments. Collecting was halted when no snails were found in the last 5-minute increment. The entire process took 50 minutes to complete.

Water samples were collected using the technique described by Rudko et al. (2018) along either side and within the containment area for 4 days post-construction and then analyzed for avian schistosomes using a pan-avian qPCR assay (Rudko et al. 2019). The 25 one-liter samples were collected randomly throughout the entire containment zone for the inside sample and within 1m outside for the length of each barrier around to the midpoint of the deep-side barrier.



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Results I

A total of 827 *S. emarginata* snails were collected from the baffle site on Glen Lake and 580 *S. emarginata* snails from the site on North Lake Leelanau. No other snail hosts known to harbor avian schistosomes were found at either site.

Table 1 shows the number of schistosome cercariae for each trial at each site.

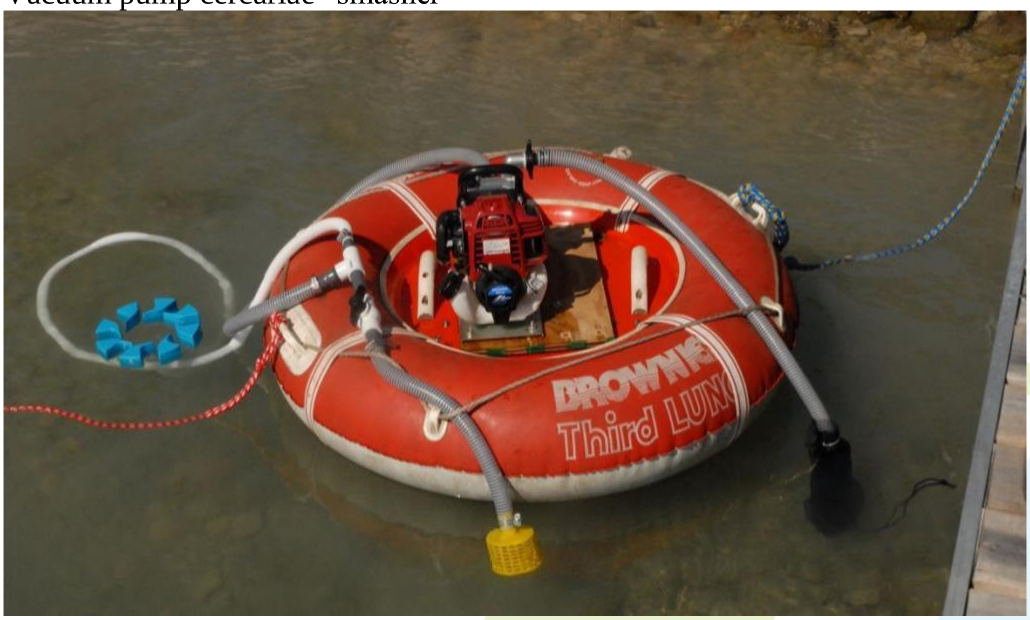
Trial	Date	Wind	Site	Location	Cercariae/25L
1	7/21/17	Calm	Glen Lake	Inside	0.0
1	7/21/17	Calm	Glen Lake	South Side	1.0
1	7/21/17	Calm	Glen Lake	North Side	1.1
2	7/22/17	3kmh NE	Glen Lake	Inside	7.3
2	7/22/17	3kmh NE	Glen Lake	South Side	0.1
2	7/22/17	3kmh NE	Glen Lake	North Side	42.0
3	7/23/17	Calm	Glen Lake	Inside	4.3
3	7/23/17	Calm	Glen Lake	South Side	17.1
3	7/23/17	Calm	Glen Lake	North Side	2.7
4	7/24/17	8kmh N	Glen Lake	Inside	0.0
4	7/24/17	8kmh N	Glen Lake	South Side	1.4
4	7/24/17	8kmh N	Glen Lake	North Side	Unreported

Trial	Date	Wind	Site	Location	Cercariae/25L
5	8/2/17	4kmh N	Leelanau	Inside	1.0
5	8/2/17	4kmh N	Leelanau	South Side	0.0
5	8/2/17	4kmh N	Leelanau	North Side	170.2
6	8/3/17	4kmh E	Leelanau	Inside	1.0
6	8/3/17	4kmh E	Leelanau	South Side	6.3
6	8/3/17	4kmh E	Leelanau	North Side	1.2
7	8/4/17	5.8kmh SW	Leelanau	Inside	14.4
7	8/4/17	5.8kmh SW	Leelanau	South Side	104.9
7	8/4/17	5.8kmh SW	Leelanau	North Side	112.8
8	8/7/17	Calm	Leelanau	Inside	1.2
8	8/7/17	Calm	Leelanau	South Side	85.9
8	8/7/17	Calm	Leelanau	North Side	1.1

Methods II

Another containment area was constructed in shallow water (<1m) on North Lake Leelanau as described in Methods I, with the exception that a fourth boom was added on the shore side and the entire area moved away from shore approximately 10m. No snails were removed from this area. Instead, an initial water sample was taken inside the containment area and then the top layer (approximately 5-15cm) of water was "vacuumed" randomly for 30 minutes using a small water pump (Honda Self-Priming Water Pump Model#WX10TA) suspended on an inner tube with intake valves suspended near the water surface. The pump and tube apparatus were pulled back and forth across the entire containment area by researchers stationed on either side pulling ropes attached to the tube. An estimated 3,634L of water passed through the pump in 30 minutes, with all fragile cercariae subjected to the pump's centrifugal forces and collision forces upon exit into a mesh screen upon discharge. Another water sample was taken after vacuuming was complete and both samples were processed via qPCR and analyzed for cercariae numbers as described in Methods I. The entire process was repeated the following week in the same containment area.

Vacuum pump cercariae "smasher"



Results II

Table 2 shows the number of cercariae before and after water vacuuming for both trials.

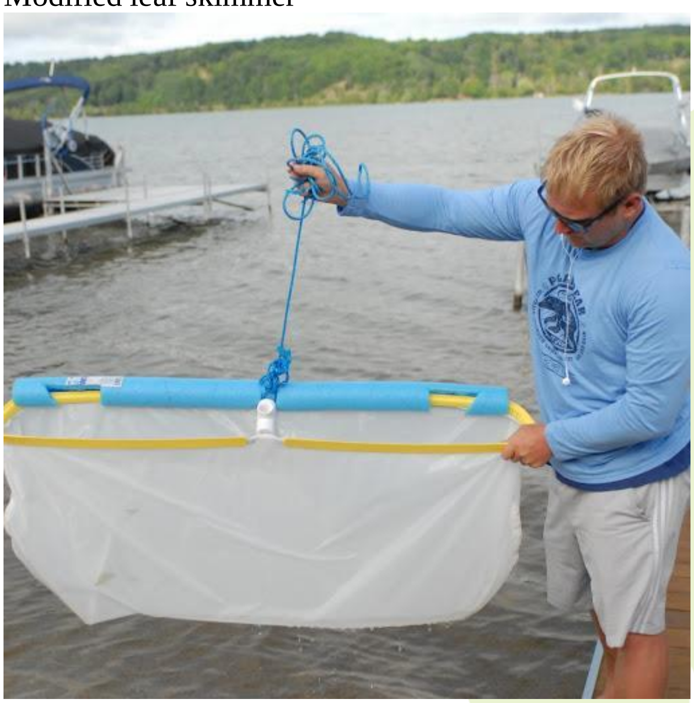
Trial	Date	Site	Sample	Cercariae/25L
1	8/1/17	Leelanau	Before Vacuum	1.8
1	8/1/17	Leelanau	After Vacuum	1
2	8/7/17	Leelanau	Before Vacuum	8.2
2	8/7/17	Leelanau	After Vacuum	1.5

Methods III

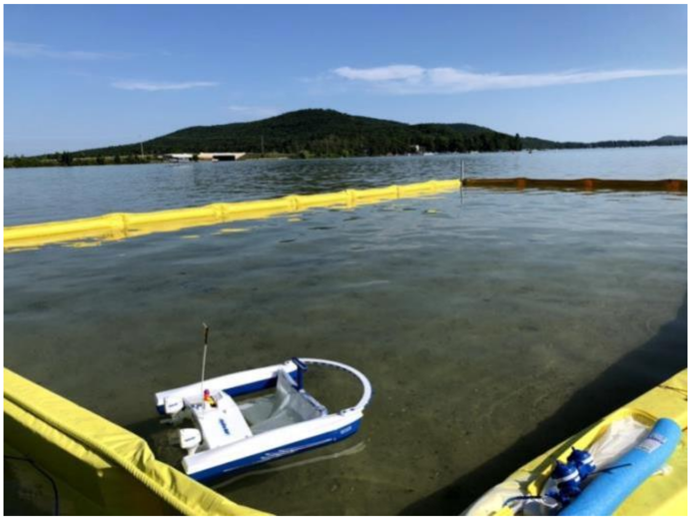
Simpler, less expensive methods for cercariae management within a containment area were designed and tested in 2018. An extra-large leaf skimmer designed and sold for pool maintenance (*Skimmer Rake - Purity Pool SKR48SLT*) was retrofitted with a pool noodle along one edge for buoyancy, a pull rope in place of the rigid extension pole for pulling, and 20um mesh netting replacing the larger leaf-trapping net to trap cercariae. Another device employed a remote-controlled leaf skimming boat sold for pool maintenance (*Jet Net Remote Controlled Pool Skimmer - Hydropool.com*) which was retrofitted with 20um mesh netting. Both devices were designed to skim the top layer of water and remove most of the avian schistosome cercariae residing there.

Standard water samples as described above were collected in duplicate, processed individually, and the cercariae/L values averaged for both pre- and post-treatment assessments. The leaf skimmer was randomly pulled throughout the containment area for 5 minutes for Trial 1 and for 20 minutes for Trial 2. The remote-controlled boat was driven randomly throughout the containment area for 10 minutes for Trial 3. Trials 4 and 5 consisted of 5 minutes of leaf skimmer followed by 5 minutes of boat skimming and 10 minutes of leaf skimmer followed by 10 minutes of boat skimming, respectively.

Modified leaf skimmer



Remote-controlled boat skimmer in containment area



Results III

Table 3 shows the average cercariae/25L of duplicate samples pre- and post-treatment.

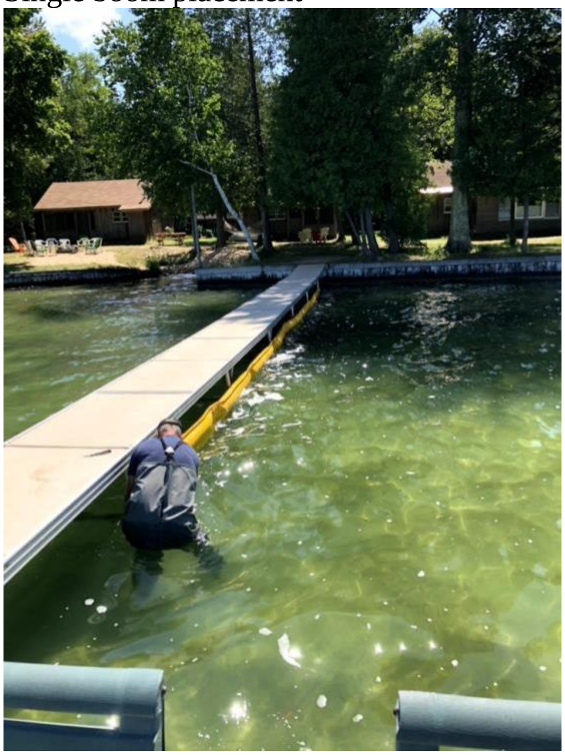
Trial	Date	Site	Treatment	Cercariae/25L
1	7/24/18	Glen Lake	Before 5m Skimmer	480.4
1	7/24/18		After 5m Skimmer	16.2
2	7/25/18	Glen Lake	Before 20m Skimmer	122.0
2	7/25/18		After 20m Skimmer	45.8
3	7/26/18	Glen Lake	Before 10m Boat	0.9
3	7/26/18		After 10m Boat	0.0
4	7/30/18	Glen Lake	Before 5m Skimmer/ Boat	2361.9
4	7/30/18		After 5m Skimmer/Boat	97.0
5	7/30/18	Glen Lake	Before 10m Skimmer/Boat	571.6
5	7/30/18		After 10 Skimmer/Boat	0.6

Methods IV

Results to this point indicated that only one boom running perpendicular to shore (alongside a dock, for example) may be necessary to protect a swimming area, since our data indicate booms provide a sufficient barrier to drifting cercariae, which accumulate on the windward side of a barrier. While cercariae accumulate on the windward side, cercariae released in the morning from snails on the leeward side of the boom would conceivably be pushed down the shore, out of the swim area as long as there was sufficient alongshore wind.

Five individual 50ft (15.25m) oil containment booms were employed alongside docks at 5 different locations on both Glen Lake and Lake Leelanau. Standard water samples were collected in duplicate, processed individually, and the cercariae/L values averaged for both windward side (cercariae accumulating) and leeward side (cercariae dispersing) assessments.

Single boom placement



Results IV

Table 4 shows the average cercariae/25L of duplicate windward and leeward samples with sufficient winds (>3kmh)

Trial	Date	Site	Wind Speed (kmh)	Sample	Cercariae/25L
1	8/5/18	Glen Lake A	17.1	Windward	0.0
1	8/5/18	Glen Lake A	17.1	Leeward	4.4
2	8/5/18	Glen Lake B	7.5	Windward	14.0
2	8/5/18	Glen Lake B	7.5	Leeward	1.2
3	8/5/18	Glen Lake C	5.5	Windward	22.7
3	8/5/18	Glen Lake C	5.5	Leeward	1.4
4	8/6/18	Leelanau A	7.1	Windward	0.0

4	8/6/18	Leelanau A	7.1	Leeward	0.0
5	8/6/18	Glen Lake C	5.5	Windward	8.9
5	8/6/18	Glen Lake C	5.5	Leeward	1.5
6	8/6/18	Glen Lake B	4.6	Windward	0.0
6	8/6/18	Glen Lake B	4.6	Leeward	6.6

Table 5 shows the average cercariae/25L of duplicate windward and leeward samples with insufficient winds (<3kmh)

Trial	Date	Site	Wind Speed (kmh)	Sample	Cercariae/25L
1	8/5/18	Glen Lake A	2.5	Windward	0.0
1	8/5/18	Glen Lake A	2.5	Leeward	4.4
2	8/5/18	Glen Lake B	2.6	Windward	14.0
2	8/5/18	Glen Lake B	2.6	Leeward	1.2

Discussion

Nearly a century of effort has gone into attempting to break avian schistosome life cycles by attacking the intermediate mollusk and/or definitive avian hosts. New discoveries utilizing recent advances in molecular diagnostic tools suggest new approaches addressing other stages of the life cycle are needed. Although the idea of managing swimmer's itch by targeting the mobile miracidial or cercarial stages is not new (Horak et al., 2015), to our knowledge the novel ways presented here to manage emergent cercariae found near the water surface have never been tried.

Our data from Method I (snail removal) suggest several things. (1) Removing host snails from inside a containment area drastically reduces the parasite levels within the study area, at least for several days post removal. The average number of cercariae inside (3.7 cerc./25L) for all trials was significantly less than on either side outside the barrier (27.1/25L south and 47.3/25L north). A few snails may have been missed while collecting or infected snails could have migrated into the containment area over the study period, thus elevating the numbers inside. Additionally, it is conceivable cercariae accumulated outside the barrier due to wind and water currents could have been forced under the boom by wave energy from passing boats. (2) Containment booms effectively prevent near-surface zooplankton, such as cercariae, from drifting beyond the barrier. With directional wind >3kmh, cercariae accumulated on the windward side and decreased on the leeward side, presumably because they were free to drift down the shore. Cercariae numbers averaged 105.7 cerc./25L on the accumulating windward side compared to 28.6 cerc./25L on the dispersing leeward side. However, it should be noted those differences would be even more drastic except for Trial 7 where there was a less directional SW wind. (3) As reported by others (Sckrabulis et al., 2020; Froelich et al., 2019; Rudko et al., 2018), wind has a directional and accumulating impact on viable cercariae. (4) Trained divers using proper equipment can efficiently and cost-effectively remove candidate host snails from a targeted swim area. Substrate conditions were near ideal for this process at both study sites, however, consisting of sand devoid of vascular plants. Removing much smaller host snails, such as *Gyraulus* sp. or *Physa* sp., or snails with greater density than what was encountered (3.6/m2 Glen Lake; 2.5/m2 Lake Leelanau) for this study would make snail removal much more challenging and costly. Work is ongoing within our group to develop effective snail barriers that could be placed along the containment area perimeter once snail removal within the swim area is complete.

Although trials were insufficient to make definitive conclusions regarding Methods II (floating vacuum pump), initial data suggest fragile cercariae could possibly be "vacuumed" from a swim area each morning, exposed to mechanical forces sufficient to break apart and kill the two-parted cercariae, and render the swim area safe from viable parasites for the day. Significantly fewer cercariae were found in water samples post-treatment (10.0 pre- versus 2.5 post-treatment). Due to greater costs and considerable engineering required, we sought simpler and less expensive alternatives in 2018.

Methods III describes two ways planktonic cercariae can be physically removed from an area with minimal time or effort. Although more trials are required for statistical significance, initial results show promise. The average cercariae/25L before skimming by either a modified leaf rake or modified leaf-skimming, remote-controlled boat was considerably higher (707.4) than after for all treatment regimens (31.9). It is conceivable that a solar-powered leaf skimmer designed for pools (Solar Breeze NX2 Solar Powered Pool Skimmer), retrofitted with 20um mesh netting, could be employed within the boundaries of a swim area bordered by barrier booms and produce similar positive results with even less human effort. This holds promise for an effective, inexpensive method a municipality could employ for public swim areas.

We demonstrate in Methods IV the most passive method to date for managing planktonic cercariae, assuming sufficient wind to direct the cercariae. The windward side (cercariae accumulating) cercariae averaged 7.6 cerc./25L while the leeward side (cercariae dispersing) averaged 2.5 cerc./25L when sufficient winds (>3kmh) were present. Four of the 6 trials showed less cercariae on the leeward side, as predicted. Trial 1 results were not predicted but had much higher winds present (17.1kmh) than any other trial. Since the single boom barrier did not run all the way to shore, it is possible high winds could have funneled the cercariae to shore and around the barrier to the leeward side. Wind direction was not strongly perpendicular to the boom barrier in Trial 6, the other unpredicted result. This could have affected the results and directed more cercariae to the leeward side. We would expect less definitive results when winds are light (<3kmh). Only two trials were run with light winds, one showing expected results for windy conditions and the other just the opposite. More trials are needed to discern what is actually happening.

Here we show promising new ways to manage the trematodes responsible for causing swimmer's itch in recreational waters by focusing on prevention strategies around the motile cercarial stage instead of control methods focused on the intermediate or definitive hosts. Once fully validated, these and other prevention strategies should provide lake associations, municipalities, and individual riparians options for swimming without fear of contracting swimmer's itch. This paradigm shift from control to prevention offers several advantages. Lake associations won't have to spend large sums of money annually for labor intensive and costly control activities. Protection results would be nearly instant compared to months or even years for some control methods. Environmental impact, both known and unknown, would be considerably less using prevention strategies compared to killing all the snails or removing waterfowl. Maybe most importantly, riparians would have complete control over the outcome and not have to rely on others to manage the problem successfully. We predict as more research is conducted and entrepreneurs take prevention strategy tools to market, swimmer's itch will become less of a concern and more time and effort will go towards protecting inland waters from pollution and invasive species.

Acknowledgements

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Literature Cited

Blankespoor HD, Reimink RL. 1991. The control of swimmer's itch in Michigan: past, present and future. Mich Acad 24:7–23.

Blankespoor HD, Cameron SC, Cairns J, Jr. 1985. Resistance of pulmonate snail populations to repeated treatments of copper sulfate. Environ Manage 9:455– 458.

Blankespoor CL, Reimink RL, Blankespoor HD. 2001. Efficacy of praziquantel in treating natural schistosome infections in common mergansers. J Parasitol 87:424 – 426.

Cort WW. 1928. Schistosome dermatitis in the United States (Michigan). JAMA 90:1027–1029.

Froelich, K., Reimink, R. L., Rudko, S. P., VanKempen, A. P., & Hanington, P. C. (2019). Evaluation of targeted copper sulfate (CuSO4) application for controlling swimmer's itch at a freshwater recreation site in Michigan. *Parasitol. Res.*, *118*, 1673–1677.

Haas W, Haberl B, Kalbe M, Stoll K. 1998. Traps for schistosome miracidia/cercariae, p 359 – 363. *In* Tada I (ed), IXth International Congress of Parasitology. Monduzzi Editore, Bologna, Italy.

Horak et al January 2015 Volume 28 Number 1 Clinical Microbiology Reviews

MitchellAJ. 2002. A copper sulfate citric acid pond shoreline treatment to control the ramshorn snail *Planorbella trivolvis*. N Am J Aquacult 64:182–187.

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Reimink RL, DeGoede JA, Blankespoor HD. 1995. Efficacy of praziquantel in natural populations of mallards infected with avian schistosomes. J Parasitol 81:1027–1029.

Rudko, S. P., Reimink, R. L., Froelich, K., Gordy, M. A., Blankespoor, C. L., & Hanington, P. C. (2018). Use of qPCR-based cercariometry to assess swimmer's itch in recreational lakes. *EcoHealth*, *15*, 827–839.

Salafsky B, Ramaswamy K, He YX, Li J, Shibuya T. 1999. Development and evaluation of LIPODEET, a new long-acting formulation of N,N- diethyl-m-toluamide (DEET) for the prevention of schistosomiasis. Am J Trop Med Hyg 61:743–750.

Sckrabulis, J. P., Flory, A. R., & Raffel, T. R. (2020). Direct onshore wind predicts daily swimmer's itch (avian schistosome) incidence at a Michigan beach. Parasitology, 147, 431–440.

Wulff C, Häberlein S, Haas W. 2007. Cream formulations protecting against cercarial dermatitis by *Trichobilharzia*. Parasitol Res 101:91–97.