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BRIEF REPORT

Use of snail traps for surveillance of schistosome-shedding snails in rice fields and fragile ecosystems

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Abstract

Human schistosomiasis is a waterborne trematode disease that often affects communities already dealing with poverty and limited access to health care. Sampling to look for the snail intermediate host of schistosomiasis is often done in resource-poor settings with a sweep net, but this can be damaging to aquatic plants, such as rice. To address this issue, we tested a baited snail trap to use in fragile ecosystems and rice fields where sweep netting might not be advisable. The trap design and bait options were first tested in the laboratory with *Biomphalaria glabrata* and *Bulinus truncatus* before being tested in the Senegal River Basin in rice fields and canals. The best option was a funnel trap that was also environmentally friendly because it reuses a 1.0- to 1.5-L water bottle and includes mango as bait, a very common fruit in the region. This trap can be used by others looking to sample fragile ecosystems or rice fields for intermediate host snails of human schistosomiasis and the trematodes they harbor.

Keywords Schistosomiasis · Sampling · Snail-borne trematodes · Aquatic ecosystems · Agriculture

Introduction

Schistosomiasis, also known as bilharzia, is caused by parasitic waterborne trematodes of the genus *Schistosoma*. The eggs of *Schistosoma* spp. are shed in infected feces or urine. Eggs hatch and release miracidia, which infect the intermediate host, freshwater snails. Free-swimming cercaria are released from the snail and penetrate the skin of humans to continue the cycle of infection (Centers for Disease Control and Prevention 2018). Schistosomiasis is a neglected tropical disease and thus is often underfunded and affects communities already experiencing health and economic disparities (Booth and Clements 2018). The World Health Organization's most recent guidelines recommend the implementation of snail control alongside mass drug administration (MDA) to combat persistent schistosomiasis in communities with contaminated water sources (World Health Organization 2022). Snail sampling is a relatively low-cost method to monitor sites of potential transmission to humans for targeted MDA and snail control. Snail surveys are a critical part of understanding transmission in an area; by monitoring snails shedding human schistosomes, scientists and decision-makers can identify where humans may be at the highest risk of getting infected.

The occupational risk of schistosomiasis has been documented for those whose work brings them in contact with fresh water (Huang and Manderson 1992). However, there is a research gap on exposure risks for people working in irrigated rice fields. To establish rice fields as a risk for exposure, the presence of infected host snails must first be confirmed in the rice fields. The most common way to monitor ecosystems for host snails is with a scoop or sweep net (Haggerty et al. 2020; Hailegebriel et al. 2022; Marie et al. 2015; Moser et al. 2014), but this method can be damaging to fragile plants, such as rice for example, which can provide a livelihood to the farmers. Our field setting is the Senegal

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River Basin, which is a high-risk area for both urinary (*S. haematobium*) and fecal (*S. mansoni*) human schistosomiasis and has extensive rice cultivation (Léger et al. 2020; Rohr et al. 2023).

Our study proposes the use of baited snail traps in systems where sweep netting is not advisable, such as rice fields or potentially ecologically fragile areas. We tested both baited and non-baited trap designs in the laboratory and a field setting to optimize feasibility, and the number of snails caught in an 18- to 24-h period. We successfully identified a low-cost and effective method that can passively monitor snail hosts in fragile ecosystems that might be useful to other individuals studying snail populations, schistosomiasis, or other snail-borne trematodes.

Methods

For laboratory tests, *Biomphalaria glabrata* and *Bulinus truncatus* were obtained from the Schistosomiasis Resource Center, as these tests were performed in the USA. Snails were maintained in artificial spring water for the duration of laboratory tests (Cohen et al. 1980). Snails had constant access to Agar snail food (a mix of agar (2.6 g), tropical fish flakes (6 g), and spirulina (6 g)) and were not fasted before the experiments. In the Senegal River Basin, four species of *Bulinus* are regularly collected, including three species of *Bulinus* (*B. tuncatus*, *B. globosus*, and *B. senegalensis*) snails that are hosts for *S. haematobium* and *Biomphalaria pfeifferi*, which is the host for *S. mansoni* (Gaye et al. 2021; Haggerty et al. 2020; Jones et al. 2021). Bait options and trap shape were tested with both *B. glabrata* and *B. truncatus* snails in a laboratory setting before being tested in rice fields at the field site.

Trap designs consisted of round and bottle funnel traps. The round traps used a plastic 8-oz cylinder deli-style plastic container, and four doors were cut into the trap evenly spaced around the circumference. The round trap was placed upside down with the lid on the bottom of the plastic container in the laboratory or on the substrate in the field (Fig. 1C). The height of the door varied by testing round. The water bottle funnel trap used a plastic, disposable water bottle that had the top of the bottle, where it starts to narrow, cut off, and inserted backward as a funnel (Fig. 1A). The size of the bottle depended on the testing round and availability. Ten similarly sized snails of both species, 20 total, were placed in a half water-filled (30 L) plastic box ($60.0 \times 40.5 \times 34.0$ cm) on the opposite side of the location of each trap. Each trap was baited with an equal-sized piece of snail food. At the 24-h mark, the number of snails of each species in each trap was counted. Fisher's exact test was used to compare the results with the total number of snails inside the trap as the outcome. All statistical tests were run in R studio (R core team, 2024, v. 1.4.1717).

Next, we compared different bait items. A list of potential bait items was developed by combining research conducted on Apple snails (*Pomacea* spp.) (Ranamukhaarachchi and Wickramasinghe 2006; Syamsul et al. 2016; Yoshida et al. 2021), reports from internet message boards on snail traps used by hobby aquarists for aquarium snail pests, and public information from those collecting freshwater snails for food. Eight food items were tested in total and are detailed in Table 1; some choices from the literature and web search were removed without testing because they were unlikely to be readily available on the field site. An exact binomial test was used to test whether the proportion showing a preference for a specific food among snails on food items was greater than expected by chance. Twenty similarly sized snails of each species were placed in an empty plastic box at an equal distance from all three food items. The food items were placed in round traps with large entrances for easy access. At the 24-h mark, the number of snails on each food item was counted by species. Items were randomized with three food items per box at one time, and the most chosen food items were then used in the final test. To have all food items be novel for the final test, new snails were ordered from the Schistosomiasis Resource Center, which had only been reared on lettuce, a food item not included in the final test.

In the Senegal River Basin, we received permission from local farmers to place traps in rice fields. Rice fields in the study area are all irrigated by canals from local rivers. Historically, farmers in this region plant and harvest rice twice per year (once during the dry and wet seasons). However, there has been a recent shift towards more vegetable production during the wet season and rice during the dry season (Brosseau et al. 2021). Most of the fields in this study were used as onion fields during the off-season. From May to June 2022, the most preferred snail trap and the two most preferred foods were tested in rice fields. Snail traps, using 1.5-L water bottles, were placed at five different points in rice fields, evenly spread along the sides and in front of the connection between the canal (water source) and the field. The next morning, we quantified the number of snails in the traps.

Following the field season, a new trap shape was tested with two funnels on each side, and powdered gelatin was used to replace the agar (one envelope of unflavored gelatin for half cup of water, which is half the amount of water suggested on the box). The gelatin substitution was aimed to prevent the snail food from melting in the field. We tested the snail food using either gelatin or agar in the laboratory in the USA, using the previous method. In March 2023, the new bait and trap design was tested in irrigation canals, as rice fields were still dry at this time (Fig. 1B). An exact binomial test was used to test whether the proportion of snails

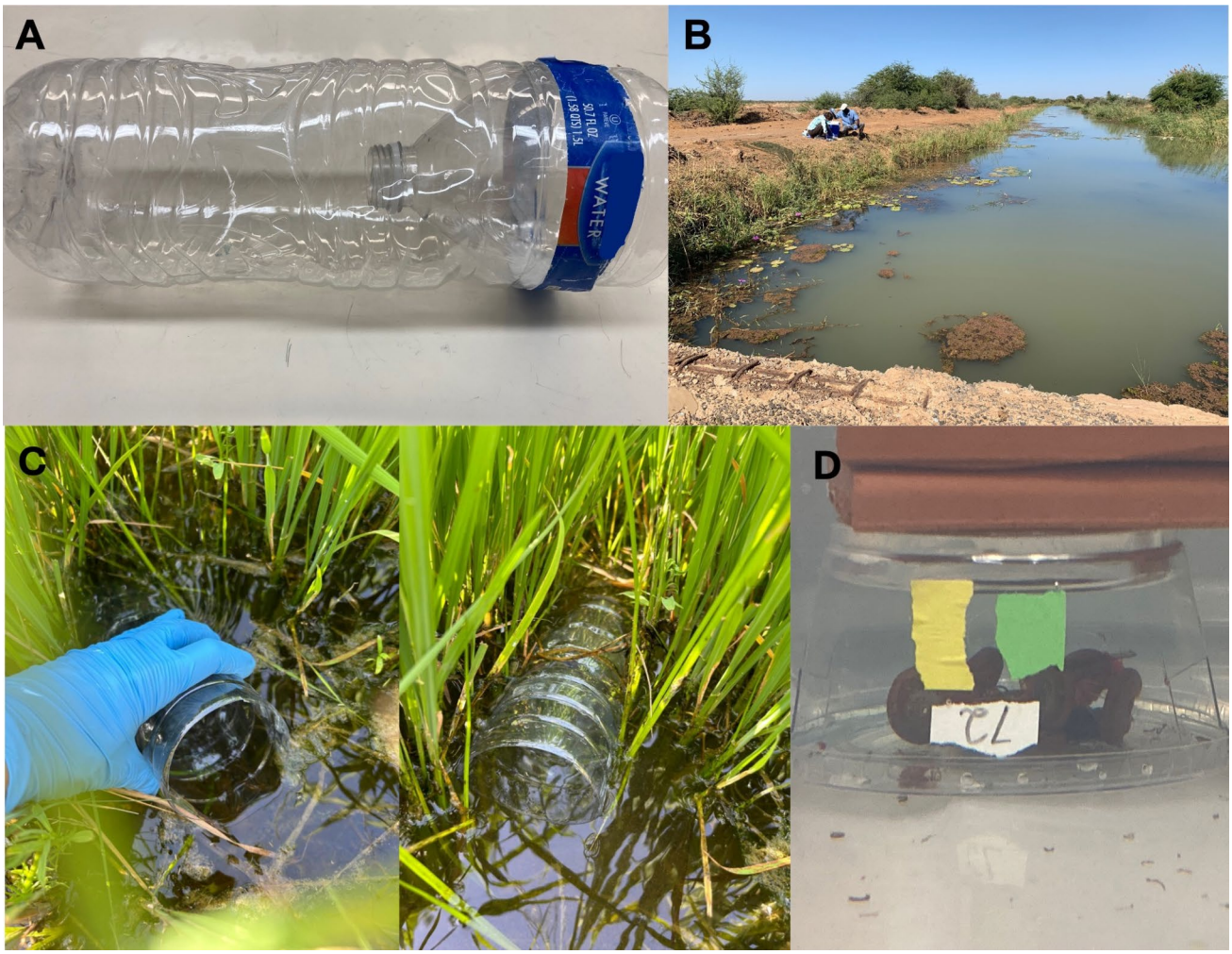

Fig. 1 **A** Funnel trap designs, shown with 1-L bottles. **B** Use of snail traps next to a large rice field irrigation canal, **C** Funnel trap in use in a rice field in the Senegal River Basin study area. **D** Circular half-door trap during laboratory test with agar snail food

showing a preference for a specific trap among snails on food items was greater than expected by chance. All traps were baited with the standard agar snail food.

Results and discussion

In the lab, there was a significant difference between the four trap designs ($p = 0.02$). The most effective snail trap at the 24-h mark for both species was the 1-L bottle funnel trap and the round with half-height doors (Fig. 1, Table 1). There was no significant difference between these two traps ($p = 0.49$). For the food items, both types of mangos performed equally well at attracting snails ($p = 0.03$), as compared together to the lettuce. The agar snail food was significantly preferred over the other two options ($p < 0.001$), and no food was preferred in the third box ($p = 0.40$), but overall, only six snails chose any food item out of the 40 snails in the box. The sardines and peanut butter were chosen from internet chat boards from people who trap food snails but were not effective at capturing the focal snail species, which are herbivorous (El-Assal et al. 2005; Haggerty et al. 2020). The peanut oil could be seen on the surface of the water, and snails were climbing up out of the water. The final trial tested the mango and the agar snail food, which performed equally well in attracting snails ($p = 0.51$, Table 1).

The field tests used 1.5-L water bottles with one funnel in five different fields in three different rice field areas in the Senegal River Basin. We used the 1.5-L water bottles instead of the round traps since we could repurpose plastic bottles at the field site, and the round traps required weight on top to get them to not float and had issues with collapsing when placed in moving water (Fig. 1). The 1.5-L water bottle is the standard larger size found in the study area. We attempted to use the agar snail food in the field, but with temperatures up to 42 °C during the months of June and

Table 1 Number of snails per trap design and food item after 24 h

Round: box	Trap design	Food item	*Biomphalaria* spp.	*Bulinus* spp.	Total
Round 1: box 1 ($n=10$ each)	Round with half-height doors	Agar snail food	10	8	18
Round 1: box 2 ($n=10$ each)	Round with full-height doors		5	4	9
Round 1: box 3 ($n=10$ each)	16-oz funnel trap		5	6	11
Round 1: box 4 ($n=10$ each)	1-L funnel trap		10	10	20
Round 2: box 1 ($n=20$ each)	Round with full-height doors	Dried mango	7	5	12
		Fresh mango	6	7	13
		Lettuce	3	1	4
Round 2: box 2 ($n=20$ each)		Agar snail food	16	12	28
		Apple	0	1	1
		Sweet potato	1	0	1
Round 2: box 3 ($n=20$ each)		Peanut butter	1	2	3
		Sardines	0	0	0
		Bananas	3	0	3
Round 2: box 4 – Final ($n=20$ each)		Agar snail food	11	10	21
		Mango	9	7	16
Round 3: box 1	Round with full-height doors	Gelatin snail food	8	6	14
		Agar snail food	5	3	8
		Mango	2	1	3
Round 3: box 2 ($n=20$ each)	16-oz funnel trap	Gelatin snail food	1	2	3
	1-L funnel trap		9	5	14
	16-oz two-sided funnel trap		3	1	4
	1-L two-sided funnel trap		1	2	3

n number of snails tested. Agar snail food is a mix of agar, tropical fish flakes, and spirulina

July, the food dissolved and was not placeable in the traps. Mangos were in season and accessible throughout the field season. *Bulinus* spp. were caught inside traps in three of the five fields (60%). On average, of traps with snails, two to three (SD = 0.58) *Bulinus* spp. were caught per trap. Only four of the 25 traps caught bycatch; one trap caught two frogs, another trap caught three tadpoles, one trap caught 10 fish, and another one fish.

In a second round of laboratory tests, we tested the agar snail food versus the new version with gelatin to test for a food that would be solid at higher outdoor temperatures. The agar snail food was still significantly preferred ($p=0.02$), though all food items attracted at least one snail of each species. The gelatin version did not disintegrate in the water in lab conditions. We also tried using smaller 16-oz bottles and two-sided funnels. The 1-L funnel continued to be the best trap ($p<0.001$). We decided to test the 1.5-L two-sided funnel in the field as well in case we saw improved capture with two entries in the added complexity of an actual water body. In the field, the new gelatin food still melted and was washed away by water movement and did not stay in the traps. Furthermore, the two-sided traps collapsed when attempting to remove them from the canals. Therefore, our initial trap design of the mango-baited 1.5-L trap with a funnel on only one side remained the preferred trap for all rice field sampling.

In conclusion, we have shown the utility of using baited snail traps for schistosomiasis host snail collection in areas where sweep netting could damage rice. The one-sided 1- to 1.5-L water bottle traps were the best in both field and lab conditions, and the mango worked better than the agar and gelatin food under field conditions with water movement and hot temperatures. Dried or fresh mangos were accessible year-round in most field areas and require no special handling for use in the field, making them an optimal bait option for schistosomiasis host snails. Further testing of food items would be suggested for other species of *Bulinus* and *Biomphalaria* snails in different ecosystems, as food preferences may be population-specific.

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Author contributions AS and ES wrote the main manuscript text and ran the analysis. AS ran the lab tests. JR provided feedback on design and set up on the experiment and field work. SB, AS and ES did the

fieldwork. All authors reviewed the manuscript and responded to the reviewer's suggestions.

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Data availability All the data is included in the manuscript since it is a brief report (Table 1).

Declarations

Competing interests The authors declare no competing interests.

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