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Schistosoma mansoni in Lake Tana: A comprehensive assessment of parasite, snail vector, and associated factors at Gorgora, Northwest Ethiopia

Aberham Abere[1], Abebe Genetu[2], Adane Derso[1], Dessie Abebaw[3], Ligabaw Worku[1], Mulugeta Aemero[1]

[1]Department of Medical Parasitology, School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar, Gondar, Ethiopia, [2]Coalition for Epidemic Preparedness Innovations (CEPI) Africa Engagement Lead, Addis Ababa, Ethiopia, [3]Department of Epidemiology and Biostatistics, Institute of Public Health, College of Medicine and Health Science, University of Gondar, Gondar, Ethiopia

****Corresponding author:** Aberham Abere, aberhamaber21@gmail.com*

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Abstract

***Background**: Schistosomiasis is one of the neglected tropical diseases of public health importance worldwide. The transmission of this disease is linked to freshwater snails. It has been reported from 78 countries and territories, affecting approximately 290.8 million individuals who required treatment in 2018. The burden of this disease continues to be significant in specific regions, especially in sub-Saharan Africa, despite more than two decades of mass preventive chemotherapy primarily targeting school-aged children. In Ethiopia, the prevalence of the disease in children ranges from 24 to 90% in different localities. While previous studies have primarily concentrated on disease prevalence, there is a lack of attention to the distribution of snails and their infectivity status. This study sought to evaluate the distribution of snails and identify factors related to Schistosoma mansoni infection along Lake Tana at Gorgora, Northwest Ethiopia.*

***Methods:** A community-based cross-sectional study was conducted along Lake Tana in Gorgora town, Northwest Ethiopia from March to May 2020. A total of 385 study participants were selected by systematic random sampling technique. Kato-Katz smears were prepared from stool sample and examined microscopically to confirm S. mansoni eggs. A malacological survey was conducted at 14 sites along Lake Tana shore. Collected snails were put in a small plastic bucket that contained water and plant vegetation, and transported to vector biology laboratory, University of Gondar, within four hours of collection for morphological identification and Cercaria shedding. Data were entered into EpiData version 4.4.2.1 and transferred to SPSS version 20.0 and STATA version 15.0 for analysis. Spatial distribution analysis was done using the ArcGIS system. A P value ≤ 0.05 was considered as statistically significant.*

***Result:** The prevalence of S. mansoni was 36.6% (95% CI: 32.0-41.9). The infection intensity category of Schistosoma mansoni was light (30.5%), moderate (42.5%), and heavy (27.0%). From a total of 1105 snails collected, 546 (49.4%) were Biomphalaria species, 310 (28.1%) were Bulinus species, 105(9.5%) were Lymnae species, and 144(13.0%) were Bivalve. None of the Biomphalaria species collected were infected with human schistosoma. Lake water practice, swimming frequency, and proximity to the lake were significantly associated factors of Schistosoma mansoni infection (P<0.05).*

***Conclusion:** The prevalence of S. mansoni infection was considerable in the study area. Four freshwater snails with a potential of transmitting disease in humans and livestock were identified. Further research and monitoring are essential to comprehensively investigate the factors contributing to the absence of human schistosome cercariae in the hatching results of Biomphalaria snails and to assess the potential impact on schistosomiasis transmission in the region. It is highly recommended to conduct a longitudinal study incorporating molecular techniques to analyze Biomphalaria infection rates and their susceptibility to schistosome infection.*

Background

Schistosomiasis (bilharzia) is a disease caused by a digenetic trematode of the *genus Schistosoma* (1). It is a serious socio-economic and public health problem worldwide. Schistosomiasis is prevalent in many developing countries where poor sanitation and low access to safe drinking water are predominant (2). Schistosomiasis mostly affects poor and rural communities, particularly those engaged in farming and fishing. Moreover, inadequate hygiene and contact with infected water make children and adolescents vulnerable (3). Schistosomiasis has been reported in 78 countries and territories, of which an estimated 85 to 90% occur in sub-Saharan Africa (4). In Ethiopia, numerous studies conducted in different localities have shown that the prevalence of *S. mansoni* is high among school -aged and preschool-aged children. The prevalence of the disease is reported to range from 24 to 90% in different parts of the country, and it is high among schoolchildren (5, 6).

Human infections are caused by blood-dwelling trematodes of the genus *Schistosoma*. Five species of *Schistosoma* are known to infect humans. *Schistosoma haematobium*, *S.japonicum*, and *S. mansoni* are widespread species that infect humans, while *S. mekongi* and *S. intercalatum* are restricted to certain geographical locations. *S. mansoni* and *S. hema-haematobium,* the causative agents of intestinal and urinary schistosomiasis, respectively, are responsible for African schistosomiasis (2, 3).

Schistosoma ova are excreted from the human host into a freshwater environment via urine or feces, depending on the species type. Once an ovum comes in contact with freshwater, it hatches and releases a miracidium, a free-living and ciliated form, which remains infective for 6-12 hours. The miracidium swims by ciliary movement toward its snail intermediate host and penetrates through the soft tissues of the snail (4). Inside the snail, it develops into Cercaria. When the snail sheds the Cercaria, it actively swims and penetrates the skin of humans. Inside the human host, cercariae develop into sexually mature ova-laying worms in the hepatic portal system only for *S. mansoni* (7).

Freshwater snails play a salient role in the ecology of freshwater, serving as food for numerous other animals and feeding on vast amounts of algae and detritus. An estimated 350 snail species play a significant role in public and veterinary health. Many species of freshwater snails belonging to the family Planorbidae serve as intermediate hosts for a number of infections, such as schistosomiasis, angiostrongyliasis, clonorchiasis, fascioliasis, fasciolopsiasis, opisthorchiasis, and paragonimiasis, in Africa, Asia, and the Americas(5, 6). Human Schistosoma parasites are transmitted by the genera *Biomphalaria*, *Bulinus*, and *Oncomelania,* which serve as important intermediate hosts for *S. mansoni*, *S. haematobium*, and *S. japonicum*, respectively(7, 8).

In addition, snails are common intermediate hosts for most parasitic diseases of animals(8). A snail lays up to 1000 eggs during its life, which may last more than a year(9). This high reproductive capacity makes it difficult to eliminate snails in schistosomiasis endemic areas(10). Within each habitat, the snail distribution may be patchy, and detection requires the examination of different sites. Moreover, snail densities vary significantly seasonally. In general, the aquatic snail hosts of schistosomes occur in shallow water near the shores of lakes, ponds, marshes, streams and irrigation channels(7).

Snail habitats include almost all types of freshwater bodies, ranging from small temporary ponds and streams to large lakes and rivers. The majority of terrestrial snails are found in moist bushy biotopes. *Lymnaea* are found in swampy and irrigation canals, whereas most *Bulinus, Planorbis*, and *Oncomelania* are commonly found at the edges of rivers and near dams. A previous study from Ethiopia reported five different kinds of snail genera: *Helix* (46.1%), *Lymnaea* (23.7%), *Bulinus* (13.2%), *Planorbin* (9.2%) and *Oncomelania* (7.9%)(8).

Another study reported *Bi. pfeifferi* as a predominant snail species, accounting for 66% of the total snails collected and encountered in 40% of the surveyed sites. *Biomphlaria pfeifferi* was collected from rivers, wetlands, a lake and irrigation canals but, it was not encountered in the Gilgel Gibe I Reservoir. *Lymnaea natalensis* was the second most common snail species, accounting for 25% of all snails collected. It occurred in 30% of the surveyed sites and was encountered in all habitat types. *Bulinus globosus* and *Bu. forskalii* accounted for less than 10% of the total collections and were mostly found in river and wetland habitats. The least common snail species was *Bi. Sudanica* which was found only at one river sampling site(9). *Bulinus globosus* (31.7%) was the most abundant snail species, followed by *Lymnaea natalensis* (21.6%), *Lymnaea truncatula* (15.1%) and *Biomphalaria pfeifferi* (14.6%)(10). In Ethiopia, little is known about the distribution of snails and

Schistosoma infection status. Therefore, this study is aimed to assess snail distribution, infection status, and intensity of schistosomiasis in the community of Gorgora town along the shore of Lake Tana.

Method and material

Study design and setting

A community-based cross-sectional study was conducted from March to May 2020 in selected schistosome endemic areas in Gorgora town, Northwest Ethiopia. Gorgora is a small roadside town on the shore of Lake Tana located at 10^0 17'N latitude and 37^0 26'E longitude. It is approximately 818 km away from Addis Ababa. The daily average temperature ranges from 29°C to 31°C, while the annual rainfall is between 900 mm and 1038 mm. Its altitude ranges between 1800 m and 1900 m above sea level. It has a population of 2,500 inhabitants and a 2.89 km square area (11).

Sample **size determination**

For the parasitological examination, the sample size was determined using a single population proportion formula; $N = z^2 p (1-p)/d^2$, where N = Number of participants; Z = Standard normal distribution value at 95% CI, which is 1.96; P= the prevalence of schistosomiasis taken as 0.5; and d = margin of error taken as 5%. Accordingly, the sample size was 385. For the survey of snails, all human-water contact points that had an abundance of >30 snails during observation were included (17).

Sampling Technique

A multistage sampling technique was utilized to select the study participants. In the first stage, villages were selected randomly from three villages. At the second sampling stage, the number of households included in each village was determined by proportional allocation according to the total number of households found in each village/kebel. Then, a systematic random sampling method was employed to select the households. The sampling interval was calculated by dividing the total number of households by the number of households included in the sample for each village. The initial household was randomly selected by the lottery method, and the next households were selected at that interval. Whenever more than one eligible study subject was found in the same selected household, only one of them was chosen using the lottery method. When no eligible candidate was identified in the selected household, the next household was selected, keeping the interval constant afterwards.

Data collection and laboratory methods

Socio-demographic data collection

A well-structured questionnaire that addressed all socio-demographic data and the risk factors for schistosomiasis was developed in English. It was then translated to the local language of the area, Amharic. A pretest was conducted, and additional response categories were added based on the pretest findings. Before data collection, well-trained data collectors were assigned to each village. A person in the selected households was enrolled based on the inclusion criteria. Then, each data collector conducted a house-to-house survey. Each water point and study household were geo-referenced using Garmin64.

Malacological survey

Intermediate snail hosts were surveyed at both lake and human-water contact points. Within the likely habitats, physical parameters such as vegetation abundance, turbidity, the nature of the substrate and stones were also measured. In addition, water contact activities were surveyed(12). Snails were collected by scooping, hand picking using forceps and gloves and put in a plastic bucket that contained a small quantity of water and weeds. Thereafter, the snails were transported to the vector biology laboratory at the University of Gondar for morphology-based species identification following WHO guidelines (13). The initial shedding of cercariae by a snail varies with temperature between a minimum of 17 days at 30-35°C and several months at lower temperatures. Then, snails were examined for natural trematode infections via the shedding method(18). Each snail was placed individually in a shed vial of deionized water and then exposed to electric light for approximately one hour. The Cercaria shed by the snails were identified at the genus level by their tail morphology following the identification key(14).

Parasitological Survey

A single stool specimen of about 2 gm was collected from each study participant using a clean, dry and leak-proof plastic container labeled with a unique identification number. A portion of the sample was processed by the Kato-Katz method using a template with the capacity to hold 41.7 mg of stool (19). Kato-Katz smears were prepared at the study site, and the slides were transported to the Medical Parasitology Laboratory, University of Gondar, where they were examined under

a microscope. A small portion of the stool sample was preserved in 10% formalin, and the test was repeated using the formol-ether concentration technique(19, 20). The slides were left for 24 hours to clear debris for easy visualization of *S. mansoni* eggs. After 24 hours, two experienced laboratory technicians independently examined each slide. Whenever the results of the two laboratory technologists were discordant, a third experienced laboratory technologist examined the slides. The results of the laboratory investigation were recorded in a format prepared for this purpose. The infection intensity of *S. mansoni* was estimated by multiplying the total number of eggs counted by 24, which gives the number of eggs per gram (epg) of stool. In addition, the infection intensity of *S. mansoni* infection was categorized as light (1-99epg), moderate (100-399epg) or heavy (>400epg) according to the threshold set by the WHO (21).

Assessment of physicochemical properties

The physico-chemical parameters were recorded to a depth not exceeding 0.5 meters. The conductivity (µS/cm) was recorded using a multiparameter digital probe recorder (HANNA instrument). The tube was placed in the device for 3 minutes to obtain the value. The hydrophilic potential (pH) was obtained using a pH meter (HANNA instrument) by immersion of a probe. The water temperature (°C) was measured by a flowatch (HANNA instrument) equipped with a submerged propeller at a depth of 0.5 meters (3).

Data Analysis and Interpretation

The data were double entered, coded, cleaned, and verified using EpiData Version 4.4.2.1 software (EpiData Association, Odense, Denmark). Data analysis was carried out using SPSS version 20.0 (IBM Corp. IBM SPSS Statistics for Windows, Armonk, NY, USA) and STATA version 15.0 (Stata Corp. Statistical Software: College Station, TX 77845, USA). Different variables were described and characterized by frequency distribution (*n* (%)). Bivariate and multivariate logistic regression analyses were performed for factors associated with S. *mansoni* infection. Spatial distribution analysis was performed using the ArcGIS system.

Ethical Considerations

Ethical approval (Ref No: SBMLS/2524, Date May 08, 2020) was obtained from the School of Biomedical and Laboratory Sciences Ethical Committee, College of Medicine and Health Science, University of Gondar. A permission letter was obtained from the Central Gondar Zonal Health Office, Western Dembia District Health Office, and Kebele leaders. The purpose, objective and benefits of the study were explained to the inhabitants prior to data collection. Written informed consent was obtained from study participants above the legal age (>18). For children younger than 12 years, written informed consent was obtained from their parents/legal guardians. Assent was obtained from the children aged 12–17 years, and informed consent was obtained from the parents/legal guardians before the data were collected. As stated in the national research ethics review guidelines, working with children who are not capable of providing consent requires assent and the consent of their parents or guardians (Ethiopian National Research Ethics Review Guideline, 2014). Stool examination was carried out free of charge. Study participants who were positive for *S. mansoni* and other intestinal parasite infections were immediately linked to the Gorgora Health Center and treated with a standard dose of anti-schistosoma and anti-helminthic agents (22). The individual results of any findings were kept confidential.

Result

Socio-demographic characteristics of the study participants

A total of 385 study participants, 189 (49.1%) males and 196 (50.9%) females, participated in the study. All the study participants were urban residents of Gorgora town. The mean age of the participants was 23.84 years (range 1-80) (SD ±17.547) (**Table 1)**.

Prevalence of *S. mansoni* infections

Of the total 385 stool samples examined by Kato-Katz*, Schistosoma mansoni* was detected in 36.6% (n=141) (CI: 32.0-41.9) of the samples, of which 19.7% (76/385) were male and 16.9% (65/385) were female. Among the total positive patients, 53.9% (76/141) were males, and 46.1% (65/141) were females (**Table 2**).

Table 1: Socio-demographic profile of the study participants in Gorgora Town, Northwest Ethiopia, 2020 (n=385).

Socio-demographic variables		Frequency	Percentage
Sex	Male	189	49.1%
	Female	196	50.9%
Age	1-4	35	9.1%
	5-9	52	13.5%
	10-14	76	19.7%
	15-19	21	5.5%
	20-24	30	7.8%
	25-29	56	14.5%
	30-34	26	6.8%
	35-39	18	4.7%
	≥40	71	18.4%
Educational level	Illiterate	106	27.5%
	Primary school	167	43.4%
	Secondary school	85	22.1%
	College and above	27	7.0%
Occupational status	Non employed	266	69.1%
	Self-employed	88	22.8%
	Government employee	26	6.8%
	Private employee	5	1.3%
Average monthly income (ETB)*	<1000	309	80.2%
	1001-2000	53	13.8%
	2001-3000	12	3.1%
	>3000	11	2.9%
Marital status	Married	140	36.4%
	Single	226	58.7%
	Divorced	11	2.8%
	Other	8	2.1%

NB: ETB-*Ethiopian birr*

Table 2: Prevalence of *S. mansoni* by sex and age among study participants, Gorgora Town, Northwest Ethiopia 2020 (n=385).

	Category	Total tested (Kato-Katz)	Number positive (%)	Number negative (%)
Sex	Male	189	76(40.2)	113(59.8)
	Female	196	65(33.2)	131(66.8)
	Total	385	141(36.6)	244(63.5)
Age group	1-4	35	9(25.7)	26(74.3)
	5-9	52	11(21.2)	41(78.8)
	10-14	76	37(48.7)	39(51.3)
	15-19	21	9(42.9)	12(57.1)
	20-24	30	12(40)	18(60.0)
	25-29	56	20(35.7)	36(64.3)
	30-34	26	15(57.7)	11(42.3)
	35-39	18	9(50)	9(50.0)
	≥40	71	19(26.8)	52(73.2)
	Total	385	141(36.6)	244(63.5)

Intensity of *S. mansoni* infection

Among the *S. mansoni*-infected participants, 30.5%, 42.5%, and 27.0% had light, moderate, and heavy infection intensities, respectively. Among the 38 (27.0%) heavy-intensity infections, the highest number of eggs/gram was observed in the 10–14-year-old and >40-year-old age groups (11.7% each). The proportion of heavy-intensity *S. mansoni* infection in males and females was similar (50.0% each). The highest egg count was 3600 eggs per gram of stool (Table 3).

Table 3: Intensity of *S. mansoni* infections among study participants by age group and sex in Gorgora Town, Northwest Ethiopia, 2020 (n=141).

Variables		Intensity category of *S. mansoni* infection (epg)			Total (%)
		Light N (%)	Moderate N (%)	Heavy N (%)	
Age	1-4	3(6.9)	4(6.7)	2(5.3)	9(6.4)
	5-9	4(9.3)	3(5.0)	4(10.5)	11(7.8)
	10-14	10(23.2)	20(33.3)	7(18.4)	37(26.2)
	15-19	2(4.7)	5(8.3)	2(5.3)	9(6.4)
	20-24	6(14.0)	5(8.3)	1(2.6)	12(8.5)
	25-29	5(11.6)	9(15)	6(15.8)	20(14.2)
	30-34	5(11.6)	4(6.7)	6(15.8)	15(10.6)
	35-39	2(4.7)	4(6.7)	3(7.9)	9(6.4)
	>40	6(14.0)	6(10)	7(18.4)	19(13.5)
	Total	43(30.5)	60(42.5)	38(27.0)	141(100)
Sex	Male	23(53.5)	34(56.7)	19(50.0)	76(53.9)
	Female	20(46.5)	26(43.3)	19(50.0)	65(46.1)
	Total	43(30.5)	60(42.5)	38(27.0)	141(100)

** Light (1–99 epg), Moderate (100–399 epg), Heavy (≥400 epg).*

Spatial distribution of *S. mansoni* and snails

A total of 385 study participants were included in the study, and their household and snail collection site locations were mapped. The spatial distribution of intermediate snail hosts of human schistosomes in Lake Tana provided insights into the diversity of snails and their density. *Schistosoma mansoni* infections were clustered near the eastern edge of the surveillance sites (**Figure 1**).

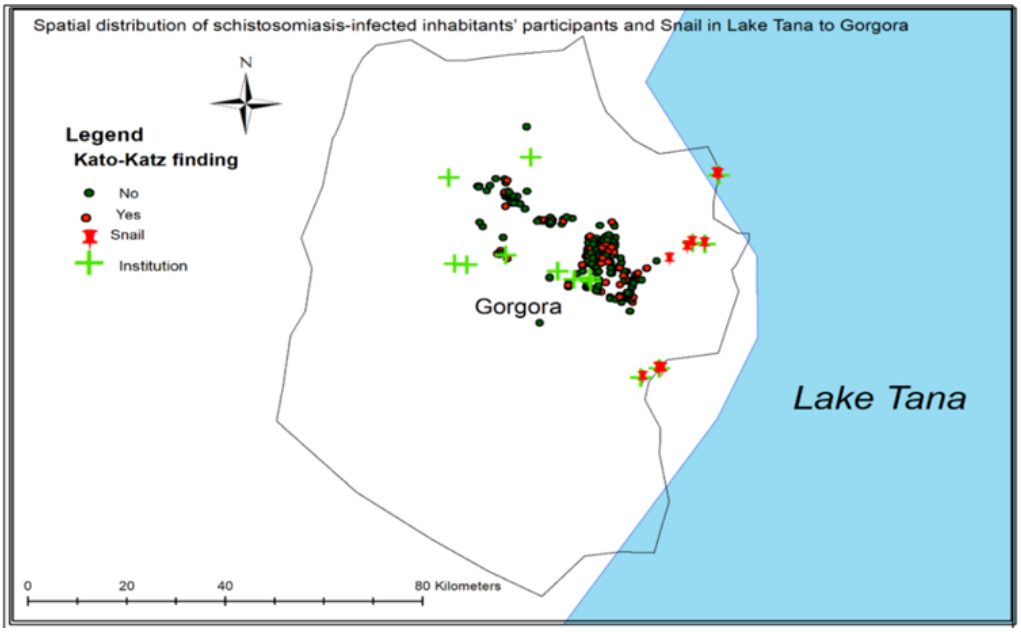

Figure 1: *Spatial distribution of S. mansoni infection and snail survey sites on the shoreline of Lake Tana in Gorgora Town, Northwest Ethiopia, 2020.*

Snail population distribution, diversity, and infection rate

A total of 1,105 freshwater snail specimens were collected from 14 different sampling sites along the shores of Lake Tana. The highest number of snails were collected from military camps (298 snails), followed by fish farms (279 snails). On the basis of shell morphology, 546 (49.4%) of the snails collected were putatively identified as *Biomphalaria* species. The remaining 310 (28.1%), 105 (9.5%), and 144 (13.0%) were identified as *Bulinus* spp., *Lymnae* and *Bivalve,* respectively (**Table 4**).

Table 4: Snail population distribution by species in Gorgora town, Northwest Ethiopia 2020.

Habitat name	*Bi. pfeifferi*	*Bulinus* spp.	*Lymnae*	*Bivalve*	Total
Deber Sina (Tem.=21.2°C, pH =9, Con.=204.3 µS/cm)	61	4	0	0	65
Tim & Kim (Tem.=25.4°C, pH =8.3, Con.=126.0 µS/cm)	67	64	41	50	222
Military Camp 5th (Tem.=24.5°C, pH =9, Con. =200.1 µS/cm)	116	89	40	53	298
Fish Farm Center (Tem.=24.2°C, pH =9, Con. =195.2 µS/cm)	104	110	24	41	279
Port Hotel (Tem.=25.7°C, pH =7.84, Con. =129.1 µS/cm)	71	16	0	0	87
Port Transport (Tem.=24.3°C, pH =8.97, Con. =151.1 µS/cm)	62	6	0	0	68
Market Area (Tem.=24.3°C, pH =9, Con =124.1 µS/cm)	65	21	0	0	86
Total	546(49.4%)	310(28.1%)	105(9.5%)	144(13.0%)	1,105

Note: Tem. =Temperature; Con. = Conductivity

Among the 546 *Biomphalaria* species collected, 500 *Biomphalaria* snails were alive; however, none of them shed human Schistosome Cercaria. However, eight (1.6%) shed birds had Echinostome Cercaria (**Figure 2**) (**Table 5**).

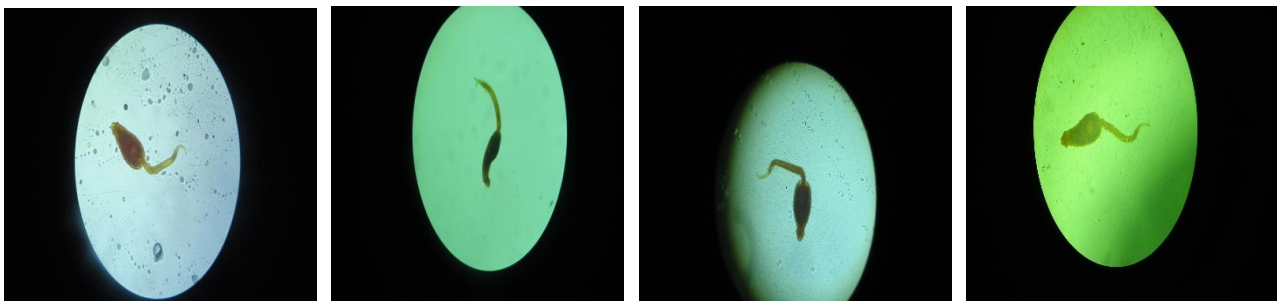

Figure 2: *Microscopic view of the bird Echinostome Cercariae emerging from Biomphalaria pfeifferi* along *Lake Tana, Northwest Ethiopia, 2020.*

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Table 5: Total number of snails collected and infestation rate in Lake Tana, Gorgora Town, Northwest Ethiopia, 2020.

Habitat Name (n=14)	Total no. of Snail collected	No. of *Bi. pfeifferi* collected (%)	No. of *Bi. pfeifferi* tested (%)	No. of *Bi. pfeifferi* shed larvae (%)
Deber Sina (DS1 & DS2)*	65(5.9)	61(11.2)	60(12.0)	1(1.7)
Tim & Kim (TK1& TK2)*	222(20.1)	67(12.3)	60(12.0)	2 (3.3)
Military Camp 5th (MC1& MC2)*	298(27.06)	116(21.2)	100(20.0)	3(3)
Fish Farm Center (FF1& FF2)*	279(25.2)	104(19.0)	100(20.0)	2(2)
Port Hotel (PH1& PH2)*	87(7.8)	71(13.0)	60(12.0)	0(0)
Port Transport (TP1&TP2)*	68(6.2)	62(11.4)	60(12.0)	0(0)
Market Area (MA1&MA2) *	86(7.8)	65(11.9)	60(12.0)	0(0)
Total	**1,105(100)**	**546(49.4)**	**500(91.6)**	**8(1.6)**

** Habitat name code (total=14)*

Factors associated with schistosomiasis

Potential variables that showed a P value of <0.25 in the bivariate analysis were included in the multivariate model to control for confounding factors and observe the independent effects of variables. Assessment of the variables generally revealed that lake water practices, swimming frequency, and proximity to the lake were significantly associated with schistosoma infection (P<0.05).

The odds of *S. mansoni* infection among individuals who sometimes swim were 7.70 times greater than those among individuals who did not (AOR: 7.70; 95% CI: 2.42-24.5; P=0.001). The odds of *S. mansoni* infection among individuals who swam frequently were 10 times greater than those who did not swim (AOR: 10.0; 95% CI: 3.19-36.6; P=0.000). The odds of *S. mansoni* infection among individuals living within one km of the shoreline were 1.70 times greater than those among individuals living one km away from the shoreline (AOR: 1.70, 95% CI: 1.03-2.84; P=0.039). The odds of *S. mansoni* infection among individuals engaged in fishing and farming were 7.90 times greater than those among individuals who were not exposed to fishing and farming (AOR: 7.90, 95% CI: 2.15-29.1; P=0.002) (**Table 6**).

Table 6: Bivariate and Multivariable logistic regression analysis of factors associated with S. mansoni infection in Gorgora Town, Northwest Ethiopia, 2020.

Variables	Schistosoma infection			OR (95% CI)		
	Positive (%)	Negative (%)	Total (%)	COR	AOR	P value
Sex						
Female	65(33.2)	131(66.8)	196(50.9)	1.00*	1.00*	
Male	76(40.2)	113(59.8)	189(49.1)	1.35(0 .89- 2.05)	1.19(0.7-2.04)	0.532
Age group						
1-4	9(25.7)	26(74.3)	35(9.1)	1.00*	1.00*	
5-9	11(21.2)	41(78.8)	52(13.5)	0.77(0.28-2.12)	0.51(0.15-1.76)	0.289
10-14	37(48.7)	39(51.3)	76(19.7)	2.74(1.14-6.62)	1.4(0.4-4.61)	0.629
15-19	9(42.9)	12(57.1)	21(5.5)	2.26(0.68-6.83)	1.05(0.39-4.69)	0.940
20-24	12(40.0)	18(60.0)	30(7.8)	1.93(0.67-5.52)	0.70(0.17-2.83)	0.624
25-29	20(35.7)	36(64.3)	56(14.5)	1.60(0.63-4.08)	0.49(0.13-1.83)	0.294
30-34	15(57.7)	11(42.3)	26(6.8)	3.94(1.33-11.67)	1.09(0.3-4.46)	0.894
35-39	9(50.0)	9(50.0)	18(4.7)	2.88(0.87-9.54)	0.94(0.20-4.35)	0.940
≥40	19(26.8)	52(73.2)	71(18.4)	1.05(0.41-2.65)	0.56(0.10-1.75)	0.323
Educational level						
Illiterate	29(27.4)	77(72.6)	106(27.5)	1.00*	1.00*	
Primary	64(38.3)	103(61.7)	167(43.4)	1.64(0.97-2.79)	0.95(0.44-2.01)	0.896
Secondary	36(42.4)	49(57.6)	85(22.1)	1.95(1.06-3.57)	1.18(0.50-2.79)	0.694
College and above	12(44.4)	15(55.6)	27(7.0)	2.12(0 .88-5.07)	2.7(0.68-10.7)	0.156
Occupational status						
Non employed	88(33.1)	178(66.9)	266(69.1)	1.00*	1.00*	
Self-employed	41(46.6)	47(53.4)	88(22.9)	1.76(1.08-2.88)	1.7(0.79-3.09)	0.164
Government employee	10(38.5)	16(61.5)	26(6.8)	1.26(0.55-2.90)	1.4(0.29-7.33)	0.645
Private employee	2(40.0)	3(60.0)	5(1.3)	1.34(0.22-8.22)	1.9(0.23-16.18)	0.543
Average monthly income (ETB)						
<1000	106(34.3)	203(65.7)	309(80.3)	1.00*	1.00*	
1001-2000	29(54.7)	24(45.3)	53(13.8)	2.31(1.28-4.17)	1.25(0.48-3.26)	0.641
2001-3000	4(33.3)	8(66.7)	12(3.1)	0.95(0.28-3.25)	0.58(0.09-3.89)	0.578
>3000	2(18.2)	9(81.8)	11(2.9)	0.43(0.09-2.01)	0.22(0.19-2.47)	0.221
Household drinking water source						
Lake	1(16.7)	5(83.3)	6(1.6)	1.00*	1.00*	
Spring	3(50.0)	3(50.0)	6(1.6)	4.99(0.34-72.7)	2.9(0.14-59.7)	0.486
Pipe Water	137(36.7)	236(63.3)	373(96.9)	2.90(0.33-25.1)	2.71(0.24-29.6)	0.415
Lake water practice						
Washing	117(36.3)	205(63.7)	322(83.6)	1.00*	1.00*	
Fetching	6(37.5)	10(62.5)	16(4.2)	1.01(0.36-2.81)	1.2(0.40-3.98)	0.605
Swimming/Playing	6(37.5)	10(62.5)	16(4.2)	0.76(0.40-1.43)	0.68(0.33-1.38)	0.290
Fishing/Farming	12(38.7)	19(61.3)	31(8.1)	9.9(2.81-37.7)**	7.9(2.15-29.1)**	0.002**
Latrine practices						
No	140(36.6)	240(63.4)	382(99.2)	1.00*	1.00*	
Yes	1(33.3)	2(66.7)	3(0.8)	0.86(0.08-9.61)	1.6(0.07-52.6)	0.801
Swimming frequency						
No contact	4(2.8)	54(22.1)	58(15.1)	1.00*	1.00*	
Sometimes	79(56.0)	128(52.5)	207(53.8)	8.3(2.91-23.9)**	7.7(2.42-24.5)**	0.001**
Frequent	58(41.1)	62(25.4)	120(31.2)	12.6(4.30-37.1)**	10.0(3.19-36.6)**	0.000**
Proximity to Lake Tana						
<1 km	115(81.6)	176(72.1)	291(75.6)	1.70(1.03-2.84)**	1.89(1.05-3.36)**	0.033**
≥1 km	26(18.4)	68(27.9)	94(24.4)	1.00*	1.00*	

Note: COR: *crude odd ratio;* ***CI:*** *confidence interval;* ***AOR:*** *adjusted odd ratio; * Reference; **significant*

Discussion

Schistosomiasis is the most prevalent helminthic infection in Ethiopia. For various reasons, the prevalence of *S. mansoni* ranges from less than 1% to more than 90% in Ethiopia. In the Western Dembia District, numerous studies conducted in different localities have shown a high prevalence of *S. mansoni* among school-aged and preschool-aged children. The present study aimed to assess the distribution of snails and the factors associated with *S. mansoni* infection in proximity to water contact points in Lake Tana, Gorgora Town.

The prevalence of intestinal schistosomiasis in the current study was 36.6%. This result is higher when compared to studies carried out in Western Kenya 16.3% (15); Kwale, Kenya, 0.0% (16); Western Uganda 27.8%(17); Sesse Islands, Uganda (31.4%) (18); Nyanza, Western Kenya (13%) (19); Chuahit, Northwest Ethiopia (11.2%) (20); Gorgora, Northwest Ethiopia (20.6%) (21); Hawassa, Southern Ethiopia (31%) (22); the Zegie Peninsula, Northwestern Ethiopia (29.9%) (23); the Jimma Zone, Southwest Ethiopia (27.6%) (24); Sanja, Northwest Ethiopia (16.67%) (25); and Addiremet town, Ethiopia (26.3%) (26). This difference might be because of differences in ecological and climatic conditions, sample sizes, personal behaviors and abundances of intermediate snail hosts in water bodies. On the other hand, the current prevalence is comparable to that of Sanja, Northwest Ethiopia, where 35% of the prevalence is reported (6).

The prevalence of Schistosoma infection in the present study was lower than that in previous studies conducted in Mbita Causeway, Western Kenya (45.1%)(27), Uganda (47.5%)(28), Mbita District, Western Kenya (76.8%)(29), Sanja, Northwest Ethiopia (83.3%)(30), Wolaita, Southern Ethiopia (81.3%) (31), Yachi, Southwestern Ethiopia (42.9%)(32), and Sanja, Northwest Ethiopia (76.3%) (5). This variation might be due to differences in the sociodemographic characteristics of the study area, the ecological distribution of intermediate snail hosts, the local endemicity of the parasite, the sample size, the differences in the study period and the awareness of residences regarding transmission and prevention.

Of the 141 *S. mansoni*-infected individuals, 30.5%, 42.5% and 27.0% had light, moderate, and heavy infection intensities, respectively. The heavy infection intensity in the present study was greater than that in previous reports from Bahir Dar, Ethiopia (34.1%) (33); Western Kenya (9.8%) (15); Sanja, Northwest Ethiopia (18.7%) (34); Northwest Ethiopia (36.3%) (30); and Addiremet town, Ethiopia (16.7%) (26). On the other hand, 42.4% heavy infection intensity was reported in Wondo Genet Southern Ethiopia (35). Moreover, studies carried out in the Wolaita Zone, southern Ethiopia, reported 56.4% heavy infection intensity (31). This variation might be due to a low level of education, poor hygiene practices, the absence of control and preventive measures in the area, and the infection rate and frequency of contact with cercariae-contaminated water bodies while helping their family in outdoor activities.

The diversity of the snail species was assessed using morphological methods. Among the collected snails, 546 (49.4%) were putatively identified as *Biomphalaria* species, whereas 310 (28.1%), 101 (9.1%), and 147 (13.3%) were identified as *Bulinus* spp*., Lymnaea* and *Bivalve,* respectively. This finding is consistent with the malacological survey conducted in freshwater bodies in Sanja, Northwest Ethiopia, between January and April, which reported *Bi. Pfeifferi*, *B. forskalii* and *L. natalensis* (5). In northwestern Nigeria, 788 (47.94%) *L. natalensis*, 492 (29.93%) *B. trophicus,* and 364 (26.14%) *B. forskalii* were reported (36). This similarity in abundance and occurrence of snail species might be due to similarities in water quality and climate.

A study from Kpong Head Pond, Ghana reported five different snail species. The dominant schistosome vector species found was *Bu. Truncates;* 735/1034 (71.0%), followed by *Biomphalaria* 125/1034 (12.0%), and *Bu. globosus* (6,1%)(37). In the Niger River Valley, West Africa, *Bu. truncatus* was the most abundant species found, followed by *Bu. forskalii*, *Ra. natalensis* and *Bi. Pfeifferi.* This abundance of snails had a significant positive association with the dry season and a significant negative association with the wet season (38). A study in Mecha, northwestern Ethiopia, reported 23.7% *Helix*, 13.2% *Lymnae*, 9.2% *Bulinus*, and 7.9% *Oncomelania* (8). This variation might be due to the seasonality of snail abundance and the influence of water pollution.

This finding was consistent with a study carried out in Kisumu city, Western Kenya, where out of the 1,059 snails collected, 407 (38.4%) were putatively identified as *Bi. sudanica*, 425 (40.1%) were *Bi. pfeifferi,* and 227 (21.5%) were *Bu. globosus* (39). A study from the Omo Gibe River Basin, Southwest Ethiopia, reported that 66.8% (2072) of *Bi. pfeifferi,* 0.2%

(7.0) *Bi. Sudanica,* 4.8% (148) *Bi. globosus,* 4.3% (133) *B. forskalii,* and 24% (747) *L. natalensis* (40). The main reason for this variation might be the difference in organic matter, which increases the concentration of detritus and possibly the proliferation of algae that form the diet of *planorbid* and *prosobranch* snails.

In the present study, none of the *Biomphalaria species* collected were infected with human Schistosoma. This could be associated with seasonality of infection or resistance to infection. However, other studies from Sanja, Northwest Ethiopia, reported 16.9% and 0.027% shedding rates during February and April, respectively (5). Other previous studies in Ethiopia reported Cercaria shedding Biomphalaria, such as Omo Gibe River Basin, 4.6%(40); Hayk town, Ketie Stream, 3.2%(41); and Maksegnit and Enfranz towns, 14.3% (42). This could be explained by the role of parasites. Once a parasite inhabits a snail host, it initiates chemical changes that alter the host's attractiveness to other invading parasites(43).

Regression analysis of potential factors related to *S. mansoni infection* revealed that the frequency of swimming, lake water practices, and proximity to the lake were significantly associated with schistosomiasis (P<0.05). Individuals with frequent swimming habits are 10 times more likely to contract schistosomiasis than those who have no habit of contact. This finding is supported by previous studies carried out in Western Kenya (15), the Wolaita Zone, southern Ethiopia (31), Tigray, Ethiopia (44), the Jimma Zone, southwestern Ethiopia (24), southern Ethiopia (22), Sanja, Northwest Ethiopia (25), and Jiga town, Northwest Ethiopia (45). In contrast, a study carried out in Blantyre, Malawi, reported the absence of a significant association between the frequency of water contact and schistosomiasis (46). This variation might be due to differences in the immune status of the inhabitants.

The odds of *S. mansoni* infection among individuals engaged in fishing and farming were 7.90 times greater than those among individuals engaged in other activities. This finding is in line with studies conducted in Lake Hawasa, southern Ethiopia (22) and Lake Victoria, western Kenya (15), which reported a greater risk of infection among individuals engaged in fishing and farming. A significantly greater prevalence of *S. mansoni* infection was detected among individuals living within 1 km of the shoreline than among those living 1 km away from the shoreline of Lake Tana. This finding is supported by a previous report from Western Kenya where the school nearest to the lake (<1 km) had a higher prevalence, and the mean prevalence decreased at distances of 4 km and more kilometers (15). In another study from Kwale, Kenya, there was a significantly lower infection risk among participants who were residing far from the river (16). Similarly, in Blantyre, Malawi, the odds of contracting *S. mansoni* infection among individuals living less than 1 km away were greater than those among individuals living 1 km away (46). This is because individuals who live closer to the lake are more likely to have contact with water on a regular basis. In contrast, a study carried out in Nyanza, Western Kenya, reported that distance from the lake was inversely associated with *S. mansoni* incidence (r = -0.7, P = 0.0004)(19).

Limitations of the study

This study was performed using a single Kato-Katz smear that might have decreased the sensitivity to detect light infections, which underestimates the prevalence of *Schistosoma mansoni*. The COVID-19 pandemic also created a challenge in data collection.

Conclusion and recommendation

The current study revealed that schistosomiasis is still a public health problem in Gorgora town. A total of four freshwater snail species with the potential to transmit diseases of human and veterinary importance were identified. None of the *Biomphalaria* species captured were infected with human schistosome cercariae. Swimming habits, proximity to the lake, and engaging in fishing and farming activities were associated factors for contracting schistosomiasis. Health education, snail control and a safe water supply are highly recommended. Moreover, a molecular study should be performed to assess the compatibility of schistosomes with snails and the susceptibility of snails to schistosome infection. Furthermore, the vector potential of *Bulinus* species should be investigated from human and veterinary health perspectives.

Abbreviations

ArcGIS= Architecture Geographical Information System, *DALYs*= Disability Adjusted Life Years, EPG= Eggs Per Gram, EFMOH= Ethiopian Federal Ministry of Health, EPHI= Ethiopian Public Health Institute, GPS= Global Positioning System, HH= House Holds, ICE= Information, Communication, and Education, LMIC=Low- and Middle-Income Countries, MDA= Mass Drug Administration, NTD= Ne-

glected Tropical Disease, PC= Preventive Chemotherapy, PZQ= Praziquantel, SOP= Standard Operating Procedure, STH= Soil Transmitted Helimenth, WASH= Water, Sanitation and Hygiene, WHO= World Health Organization

Declaration

Consent for publication

Not applicable. This study does not contain any individual or personal data.

Availability of data and materials

All data are available in the manuscript.

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Authors' contributions

AA, MA, LW, AG, AD, and DA were involved in study conception, data analysis, and manuscript drafting. AA collected and processed the samples. AA and MA reviewed the manuscript. All authors have read, edited and approved the manuscript.

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Competing interests

The authors declare that they have no competing interests.

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