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Research Article

Assessments and Identification of Selected Fish-Borne Zoonotic Parasites in Nile Tilapia and African Catfish Species in Lakes of Haramaya District, Ethiopia

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Global fish consumption increased higher than that of all other animal protein foods. The image of fish as a healthy food is the main reason for increasing demand for fish meat, but there are serious safety concerns related to the presence of fish-borne zoonotic pathogen including parasites. A cross-sectional study was conducted from December 2021 to July 2022 at Lake Haramaya, Lake Tinike, and Lake Adele on *Oreochromis niloticus* and *Clarias gariepinus* fish species to determine the prevalence of *Contracaecum* (Nematoda) and *Clinostomum* (Trematoda) infection. A total of 384 individuals of *C. gariepinus* 241 (62.76%) and *O. niloticus* 143 (37.24%) were sampled from Lake Haramaya 149 (38.8%), Lake Tinike 113 (29.4%) and Lake Adele 122 (31.8%). The overall prevalence of parasite was 30.2% (116/384) and higher overall prevalence of parasite was recorded in Lake Haramaya (36.2%) followed by Lake Adele (27.9%) and Lake Tinike (24.8%). *C. gariepinus* was more affected than *O. niloticus* fish and *Contracaecum* parasite was more prevalent than *Clinostomum* parasite (37.3% and 18.2%) and (29.9% and 14.6%), respectively. The distribution of parasite was significantly affected with respect to species of fish, sex, weight, and length categories, genera of parasite, and location of parasites. The perception of respondents on fish-borne zoonotic parasite (FBZP) was affected by demographic characteristics of respondents. Human and animals were interacted with the lakes and its environment adversely which can perpetuate the life cycle of FBZP. Moreover, unsafe fish meat processing from harvesting to consumption was the main problem at the study area, which can makes surrounding people under the risk of FBZP. However, the risks associated with FBZP can be reduced through the application of good hygiene, fishing practices, inspection of fish meat, proper storage, adequate cooking of fish, and with the promotion of the community awareness.

1. Introduction

Fish and fishery products remain some of the most traded food commodities in the world [1, 2]. It is one of the most important food in human diet because of its high nutritional content and is valued to improve diet quality [3, 4]. Fish are an excellent nutritive and healthy food for human [5]. The most important of these are fish lipids, which contains high amount of long-chain omega-3 fatty acids, good source of easily digestible protein, vitamins and minerals [3, 6, 7], and healthy alternative compared with red meat, due to its high protein content and low-fat percentage [7–9].

Fish-borne zoonotic parasites (FBZPs) have been part of the food-borne zoonotic diseases and are often endemic in certain regions of the world [10, 11]. In recent years, FBZP has emerged as major food safety concern which can impose significant public health and economic impacts [12, 13]. Helminthes are among the most widespread infectious agents that have affected and still affect human populations, particularly in marginalized, low-income, and resource-constrained regions of the world [14]. They are generally found in all freshwater fishes [15]. Fish act as intermediate host for many of the nematodes, trematodes, and cestodes [10].

Nematodes of the *Anisakidae* family have the ability to infect a wide variety of aquatic hosts [16]. They are commonly parasitize in the body cavity, mesenteries, viscera, and flesh of fish while the adult in the gut of piscivorous birds, notably pelicans, cormorants, herons, and darters [17, 18]. The family has an important economic and public health impact [19, 20]. They are cosmopolitan in their distribution [21]. Infective larval stage three (L3) of *Contracaecum* parasite may be incidentally taken by human through eating raw or undercooked fish, which can cause anisakidosis [22].

Fish-borne zoonotic trematodes (FBZT) are also very important and can infect humans via the consumption of raw or poorly cooked fish [20, 23, 24]. *Clinostomum* (Trematoda) occurs in freshwater and estuarine systems worldwide and has a complex lifecycle [25]. Fish are intermediate hosts for different *Clinostomum* metacercariae [25–27]. This parasite causes clinostomiasis (Laryngopharyngitis disease) in people and results in fatalities from asphyxiation [20, 24]. *Clinostomum* metacercariae can be observed on the skin, muscle, or internal organs of fish and amphibians [28, 29].

FBZPs are often neglected in various food safety control systems, even though they can create severe human health problems [12, 13, 23]. In 2012, the WHO estimated that there were approximately 56 million cases of parasite infections due to the consumption of fish products [14]. FBZPs are ranked among the top food-borne parasites globally [12, 13]. The aquaculture and fish industries are significantly threatened by digenetic trematode and nematode infections. Along with the globalization of traveling and trading, fish-borne nematodiases seem to be increasing in number [30, 31].

The image of fish as a healthy food is the main reason for increasing demand for fish meat, but there are serious safety concerns related to fish-borne hazards in fish meat [13, 20, 32, 33]. However, only when food is safe can we fully benefit from its nutritional value and from the mental and social benefits of sharing a safe meal [13]. The public health and economic impact of FBZP are significant and are linked to losses in aquaculture industries due to reduced fish productivity, as well as to restrictions on exports and reduced consumer demand [19, 20].

Studies on FBZP and their epidemiological aspects are very rare and several research articles deal with parasites of fish in different lakes and ponds in Ethiopia (Tana, Hawassa, Ziway, small Abaya, Chercher, Koftu, Sebeta ponds, and selected private fish farms in Wonchi area) [34–42]. This indicates a slow progress in research and much remains to deal with fish-borne zoonotic parasites in the country. There is one study [43], conducted on Tinike and Adelle Lakes of Haramaya District, on the helminthiasis and Gram-negative enteric bacteria; however, there was no investigation of zoonotic parasite and also the study did not include Lake Haramaya. The increasing interfaces among humans, aquatic animals, and environment that where lakes of Haramaya District have faced over a years can adversely impacting resources, fish health, and have public health (zoonotic) concerns. Moreover, evidence-based public health awareness of the community currently working on fishing, fish processing, and fish consumption is paramount as Lake Haramaya returned recently. Therefore, the objectives of this study are given below.

1.1. General Objective. The general objective of this study is to determine the prevalence and associated risk factors for the occurrence of selected FBZP at lakes of Haramaya District, Ethiopia.

Specific objectives of this study are as follows:

(i) to determine the prevalence of *Clinostomum* and *Contraceacum* parasite between *Clarias gariepinus* and *Oreochromis niloticus* among lakes of Haramaya District, Ethiopia,

(ii) to identify major risk factors associated with the occurrence of L3 of *Contraceacum* and encysted metacercariae (EMC) of *Clinostomum* parasites at the target area, and

(iii) to assess communities' current status of knowledge on FBZP.

2. Materials And Methods

2.1. Study Area. This study was conducted on fish population from three public lakes (Lake Haramaya, Lake Tinike, and Lake Adele) which are found in Haramaya District East Hararghe Zone, Ethiopia (Figure 1). Haramaya District is located between 41°51′0′ and 42°9′0′E degree longitude, and 9°4′30″ and 9°31′30′N degree latitude. The District is found on the main road from Addis Ababa to Harar town at a distance of 505 km from Addis Ababa and 20 km northwest of Harar town [43, 44]. Tinike overflows seasonally into Lake Haramaya whilst Lake Adele is separated by a 15 km wide strip of cultivated land. The lakes are surrounded by small hills and derive their water directly from rainfall and from several small streams that drain catchments to the west and north; floods from adjacent watersheds also occur [45].

2.2. Study Population. Nile Tilapia (*O. niloticus*) and Catfish (*C. gariepinus*) which belong to family *Cichlidae* and *Clariidae*, respectively, were the target fish species. Both *O. niloticus* and *C. gariepinus* are commercially the major fish species in Lake Haramaya and Lake Tinike, and *C. gariepinus* was the only important fish in Lake Adele [43].

2.3. Study Design. A cross-sectional study was conducted from December 2021 to July 2022 at Lake Haramaya, Lake Tinike, and Lake Adeleon. *O. niloticus* and *C. gariepinus* fish species to assess and identify the prevalence of selected FBZP infecting fish.

2.4. Sample Size and Sampling Techniques

2.4.1. Sample Size for Fish Sample. The desired sample size was calculated based on the expected prevalence of infection and desired absolute precision according to Thrusfield's [46] study. So, 50% expected prevalence, 95% confidence interval, and 5% precision were used to estimate the sample size:

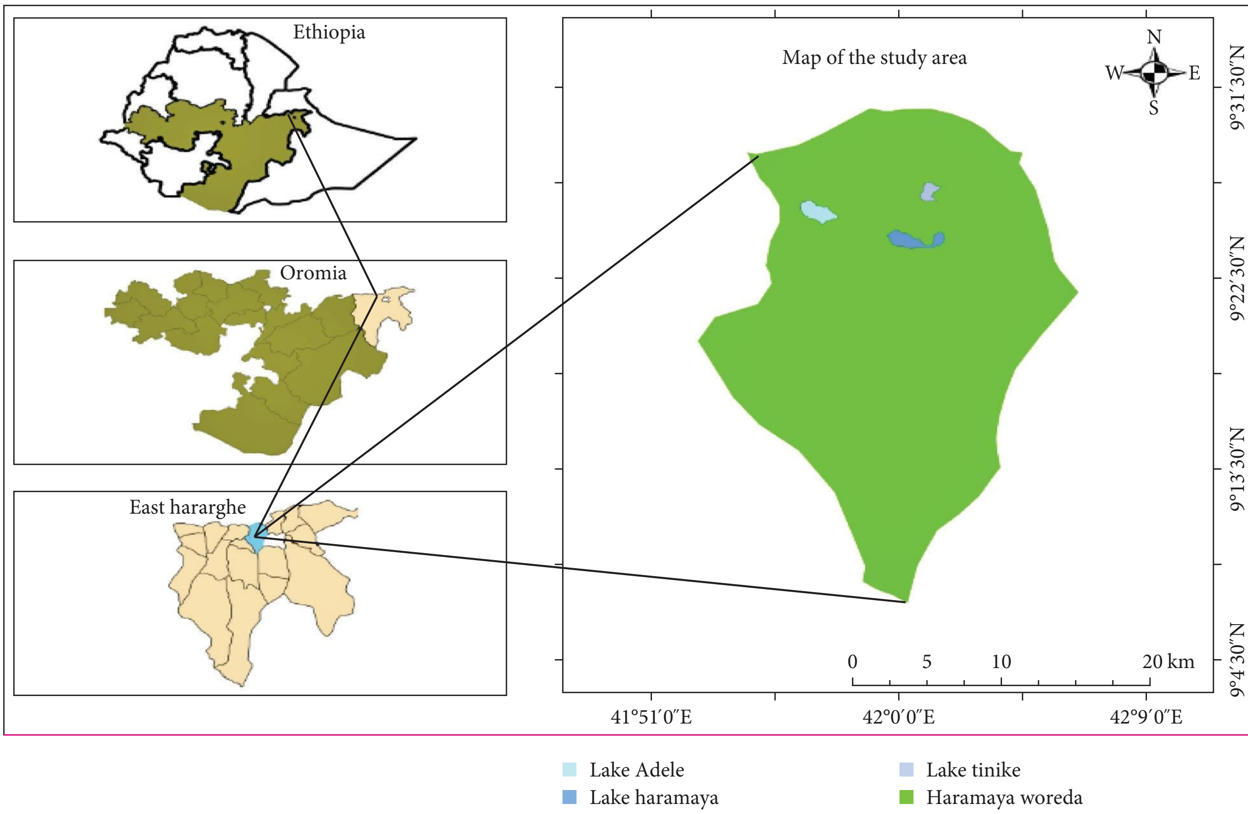


Figure 1: Map of the study area. The map was taken directly from satellite and analyzed by ArcGIS Version 10.8.1 software.

$$n = \frac{1.96^2 P(1-P)}{d^2}, \quad (1)$$

where n is the total calculated sample size, P is the expected prevalence, and d is the absolute precision.

Therefore, a total of 384 individuals of *C. gariepinus* (241) and *O. niloticus* (143) were sampled from the study lakes.

2.4.2. Sample Size for Questionnaire Survey. A total of 100 interviews with the fishermen, fish sellers, and consumers (surrounding people) were conducted in this district according to Arsham's [47] study:

$$N = 0.25, \mathrm{SE}^2 = 0.0025, = \frac{N}{\mathrm{SE}^2} = \frac{0.25}{0.0025} = 100, \quad (2)$$

where N is the total sample size and SE is the standard error.

2.5. Study Methodology

2.5.1. Fish Sampling and Transportation. Fish sample was purchased randomly from fishermen. Then, the sample was transported immediately using ice box to Haramaya University Veterinary Parasitology Laboratory. Data about species of fish, length, and weight of fish were recorded. The sexes of fish were determined after dissection and noting the presence of testes or ovaries [48]. Length and weight of both species were categorized into three classes based on their weight and length range. Fish weights were categorized into three classes (Catfish 250–600 gm Class I, 601–1,500 Class II, and >1,501 Class III; Tilapia from 150 to 350 Class I, 351 to 420 Class II, and >421 class III). Their length was also categorized into three classes (Catfish from 32 to 60 cm Class I, from 61 to 80 cm Class II, and >81 cm Class III; Tilapia from 15 to 25 cm Class I, 26 to 35 cm Class II, and >35 cm Class III) [37].

2.5.2. Questionnaire Survey. Structured questionnaires were used to generate data on communities' current status of knowledge about FBZP. Questionnaire format was prepared to obtain general information on the environment of the lakes, fish harvesting, methods of preserving fish, fish marketing, processing, consumption of fish meat, and health problem that occur due to consumption of raw or undercooked fish meat. Focus group discussion was also held with key informants. Randomly, sampled respondents dwelling the vicinity of the lakes were categorized based on their sociodemographic characteristics. The questionnaire were administered through face-to-face interview. Moreover, field observation was undertaken as strengthening part of the questionnaire survey [49, 50].

2.5.3. Parasitological Examination and Identification of Parasites. For the examination of *Contracaecum* and *Clinostomum* parasite, fish samples were thoroughly examined with the naked eye and by hand-held magnifying glass to detect the large-sized EMC on skin, gills, fins, and buccal

Table 1: Prevalence of parasite in relation to their lake and species of fishes.

Variable		Number of examined fish (%)	Number of affected fish	Prevalence (%)	χ^2	P-value
Lake	Haramaya	149 (38.8)	54	36.2	4.469	0.107
	Tinike	113 (29.43)	28	24.8		
	Adele	122 (31.77)	34	27.9		
Species of fish (overall)	Catfish	241 (62.76)	90	37.3	15.631	≤0.001
	Tilapia	143 (37.24)	26	18.2		
Species of fish (with respect to their lake)	Catfish (Haramaya)	68 (17.7)	37	54.4	17.872	≤0.001
	Tilapia (Haramaya)	81 (21.1)	17	21.0		
	Catfish (Tinike)	51 (13.28)	19	37.3	7.762	0.005
	Tilapia (Tinike)	62 (16.15)	9	14.5		
	Catfish (Adele)	122 (31.77)	34	27.9	Species of fish is constant	
	Total	384 (100)	116	30.2		

cavities. Postmortem examination was done using appropriate postmortem kits and standard evisceration technique. The whole tissue and body cavity were opened and examined for the presence of L3 of *Contracaecum* and EMC of *Clinostomum* parasite with the naked eye and hand-held magnifying glass to detect the encysted parasite in mesenteries, subcutaneous and muscle tissues, and brachial and abdominal cavities. The internal organs were dissected and placed separately in Petri dishes containing 0.75% saline solutions to recover parasitesfrom internal organs [17, 24, 37, 51, 52].

Taxonomic identifications were limited to genus level because the fish harbors larval stage and EMC cannot be distinguished to species level morphologically. Visible diagnostic characteristics, such as sex organs, cannot be differentiated with certainty among taxa at this stage [51]. Therefore, L3 of *Contracaecum* was identified under stereo microscope at generic level based on morphological keys stated by Anderson [17], Tesfaye et al. [37], Paperna [51], and Roy [53]. Likewise, EMC from different body parts was morphologically identified using a stereo microscope and light microscope based on international keys for the families of *Clinostomidae* and all parasites were kept in 70% ethanol [24, 54].

2.6. Data Management and Analysis. The collected data were entered and managed by Microsoft Excel and it was analyzed using SPSS (Version 20) software. Chi-square (χ^2) tests were used to determine the association between prevalence of parasite and associated risk factors within and among lakes (difference among the lakes, species of fish, length and weight of fish, sex of fish, genera of parasite, location of parasite, number of larval cyst, and EMC per fish). Likewise, chi-square (χ^2) and descriptive statistics including frequencies and percentages were applied for the analysis of data obtained from respondents. P-value < 0.05 was considered as statistically significant.

3. Results

3.1. Prevalence of Selected Fish-Borne Zoonotic Parasite. A total of 384 individuals of *C. gariepinus* 241 (62.76%) and *O. niloticus* 143 (37.24%) were sampled from Lake Haramaya 149 (38.8%), Lake Tinike 113 (29.4%), and Lake Adele 122 (31.8%). All fish were examined for the presence of *Contracaecum* and *Clinostomum* parasites. The overall prevalence of parasite was 30.2% (116/384). The overall prevalence of parasites among the lakes were 36.2%, 24.8%, and 27.9% in Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and the difference among the lakes were found different but statistically not significant. The overall prevalence of parasite was higher in *C. gariepinus* (37.3%) than in *O. niloticus* (18.2%). Likewise difference between species within a lake were found statistically significant at $P < 0.05$ (Table 1).

The overall prevalence of parasite in females was higher (34.4%) than their male (24.5%) counterparts and prevalence of individual parasite in relation to sexes was also evaluated, and the difference was found statistically significant in overall parasite and in *Contracaecum*, but not significant between the sexes of fish infected with *Clinostomum* parasite (Table 2).

The prevalence of parasites was also evaluated based on their weight categories between species of fishes among three lakes. Therefore, prevalence of 20.0%, 63.0%, and 93.8%; 11.1%, 39.1%, and 80.0%; 17.9%, 28.0%, and 62.5 were recorded from Class I, Class II, and Class III of *C. gariepinus* in Lake Haramaya, Lake Tinike, and Lake Adele, and the difference was found statistically significant ($P \leq 0.001$, $P \leq 0.001$, and $P \leq 0.002$), respectively (Figure 2).

The overall prevalence of parasites was also evaluated based on different body length categories in *C. gariepinus* among three lakes. Hence, prevalence of 40.5%, 66.7%, 90.9%; 12.0%, 57.1%, 80.0%; and 17.9%, 36.7%, 64.3% were recorded from Class I, Class II, and Class III in length categories from Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and the difference was found statistically significant ($P = 0.006$, $P \leq 0.001$, and $P \leq 0.001$) in Lake Haramaya, Lake Tinike, and Lake Adele, respectively (Figure 3).

The overall prevalence of selected zoonotic parasites was also evaluated based on different body weight and length categories of *O.niloticus* fish between two lakes. Hence, prevalence of 13.7%, 25.0%, and 38.9%; 6.2%, 17.4%, and 42.9%

Table 2: Total prevalence of parasite in relation to sexes of fishes.

Variables	Sex	Number of examined fish (%)	Number of affected fish	Overall prevalence (%)	χ^2	P-value
Overall infection with respect to sexes of fish	Male	163 (42.45)	40	24.5		
	Female	221 (57.55)	76	34.4	4.316	0.038
	Overall	384 (100)	116	30.2		
Sex of fish infected with *Contracaecum*	Male	163 (42.45)	39	23.9		
	Female	221 (57.55)	76	34.4	4.895	0.027
	Overall	384 (100)	115	29.9		
Sex of fish infected with *Clinostomum*	Male	163 (42.45)	20	12.3		
	Female	221 (57.55)	36	16.3	1.217	0.270
	Overall	384 (100)	56	14.6		

were recorded from Class I, Class II, and Class III in weight categories from Lake Haramaya and Lake Tinike, respectively, and the difference was found statistically not significant in Lake Haramaya and slightly significant in Lake Tinike ($P=0.04$). With respect to length categories, prevalence of 10.2%, 36.4%, and 40.0%; 4.5%, 33.3%, and 66.7% were recorded from Class I, Class II, and Class III from Lake Haramaya and Lake Tinike, respectively, and the difference was found statistically significant ($P=0.013$ and $P=0.001$) in Lake Haramaya and Lake Tinike, respectively (Figures 4 and 5).

The prevalence of parasites was also evaluated based on genera of parasite among three lakes and between species of fish. The overall prevalence of *Contracaecum* was 29.9%. Likewise, prevalence of *Contracaecum* in *C. gariepinus* fish were 54.4%, 37.3%, and 27.0% from Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and prevalence of 21.1% and 14.5% in *O. niloticus* from Lake Haramaya and Lake Tinike, respectively. The difference of *Contracaecum* infection between the species of fish was found statistically significant (Table 3). The overall prevalence of *Clinostomum* was 14.6%. The prevalence of *Clinostomum* in *C. gariepinus* were 17.6%, 17.6%, and 9.8% from Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and 19.8% and 11.3% in *O. niloticus* from Lake Haramaya and Lake Tinike, respectively (Table 3).

The prevalence of parasites was also evaluated based on the location of parasite among three lakes and between species of fish. Hence, prevalence of parasite in the body cavity were found 51.5%, 33.3%, and 27.0% in *C. gariepinus* from Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and 17.3% and 12.9% in *O. niloticus* in Lake Haramaya and Lake Tinike, respectively. The difference was found statistically significant (Table 4). The prevalence of selected zoonotic parasite in the muscle of fish were 32.4%, 19.6%, and 16.4% in *C. gariepinus* from Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and 16.0% and 8.1% in *O. niloticus* from Lake Haramaya and Lake Tinike, respectively. The difference was found statistically significant (Table 4). The parasite was found in brachial cavity and subcutaneous tissue (Figure 6).

On average, seven L3 of *Contracaecum* were collected per fish, and they were found freely in the body cavity, mesenteries, and muscle of fish. Likewise, average of five EMC of *Clinostomum* was recorded from *Clinostomum*-infected fish. The EMC of *Clinostomum* was found in brachial cavity, gill, abdominal cavity, and muscle (Figures 6 and 7).

3.2. Sociodemographic Characteristics of Respondents. Assessment of communities' current status of knowledge about FBZP was also evaluated. Respondents of the current study were people living around the vicinity of lakes of Haramaya District. A total of 100 interviews were conducted and comprised of different age, sex, educational level, marital status, and occupational status categories (Table 5).

3.3. Communities Current Status of Knowledge on the Environment of Lakes and Fish Harvesting. More than 80% of the respondents have been living around the vicinity of lakes of Haramaya District for a longer period; of which 18% of them have lived there for 5–10 years, 42% of them for 11–20 years, 24% of them for 21–30 years, and 16% of them have been living for >31 years. All of the respondents (100%) state that the major problem of the lakes were environmental contamination, water pollution, siltation, deforestation (shore damage), and over fishing. Majority of fishermen used traditional fishing gears (78%) and modified fishing gears (22%). The most frequently harvested fish was Tilapia (62.5%) than Catfish (37.5%).

3.4. Respondent's Current Status of Knowledge on Preserving, Processing, and Consumption of Fish Meat. The perception of respondents among the groups of sociodemographic characteristics of respondents (Table 6) was evaluated based on knowledge of preserving fish, inspection of fish meat, and method of processing of fish before consumption. Subsequently, there were differences in perception of respondents among the groups of age, sex, educational status, and occupational status. The difference was significantly affected among age group and inspection of fish meat for the presence of parasite, as well as among educational status with respect to method of processing of fish meat before consumption ($P=0.004$ and $P=0.002$), respectively. However, the difference was not significant in other groups of sociodemographic characteristics of respondents (Table 7).

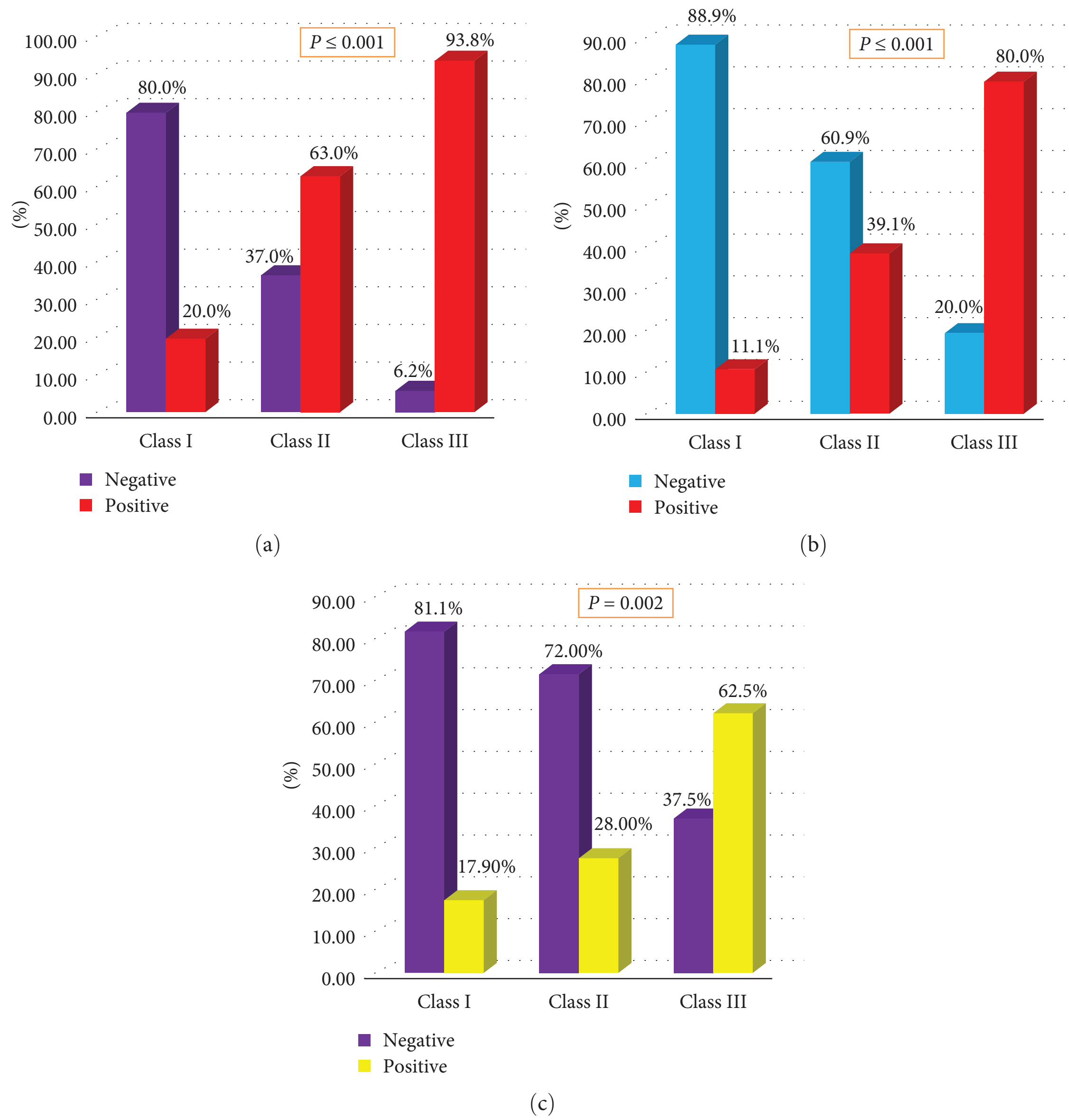


FIGURE 2: Prevalence of parasite with respect to weight categories of *C. gariepinus* fish: from Lake Haramaya (a), Lake Tinike (b), and Lake Adele (c).

3.5. Knowledge of Local People on the Health Problem Occur due to Consumption of Raw or Undercooked Fish Meat. From a total of 100 participant, none of them were delivered any training on FBZP. Only 5% of them believed that they may be suffering from fish-borne parasite after consumption of raw or undercooked fish. All of the respondents (100%) stated that they were not suffer and treated from fish-borne parasitic disease. All of the participant believe that government, nongovernmental organization, and private sectors should providing training for the local community on FBZP, fish harvesting, processing, and consumption of fish. Also, they believe that government and respective bodies should give special attention on the prevention of environmental and water pollution (especially on different waste entered into the lakes from nearby towns and residents) and other lakes management.

While sampling fish and delivering questionnaires, field observation was undertaken from the study area and included as strengthening part of the questionnaire survey. Hence, the lakes ecosystems have been impacted negatively by human and animal interaction. It was contaminated from highly contaminated floods of nearby town and residents which include human and animal excreta, offal and whole died animal, contaminated plastics, and washing of vehicles and clothes. Water from lakes was also used for irrigation purposes by the nearby residents, and floods contain different agricultural chemical often join the lakes. Among three lakes, Lake Haramaya was the most contaminated (especially on the border of Haramaya Town) followed by Lake Adele. Lake Tinike was the most used lake for irrigation purpose. Moreover, carelessly harvested juvenile fish, eviscerated fish, and its offal were thrown back to piscivorous birds which can perpetuate the life cycle of FBZP.

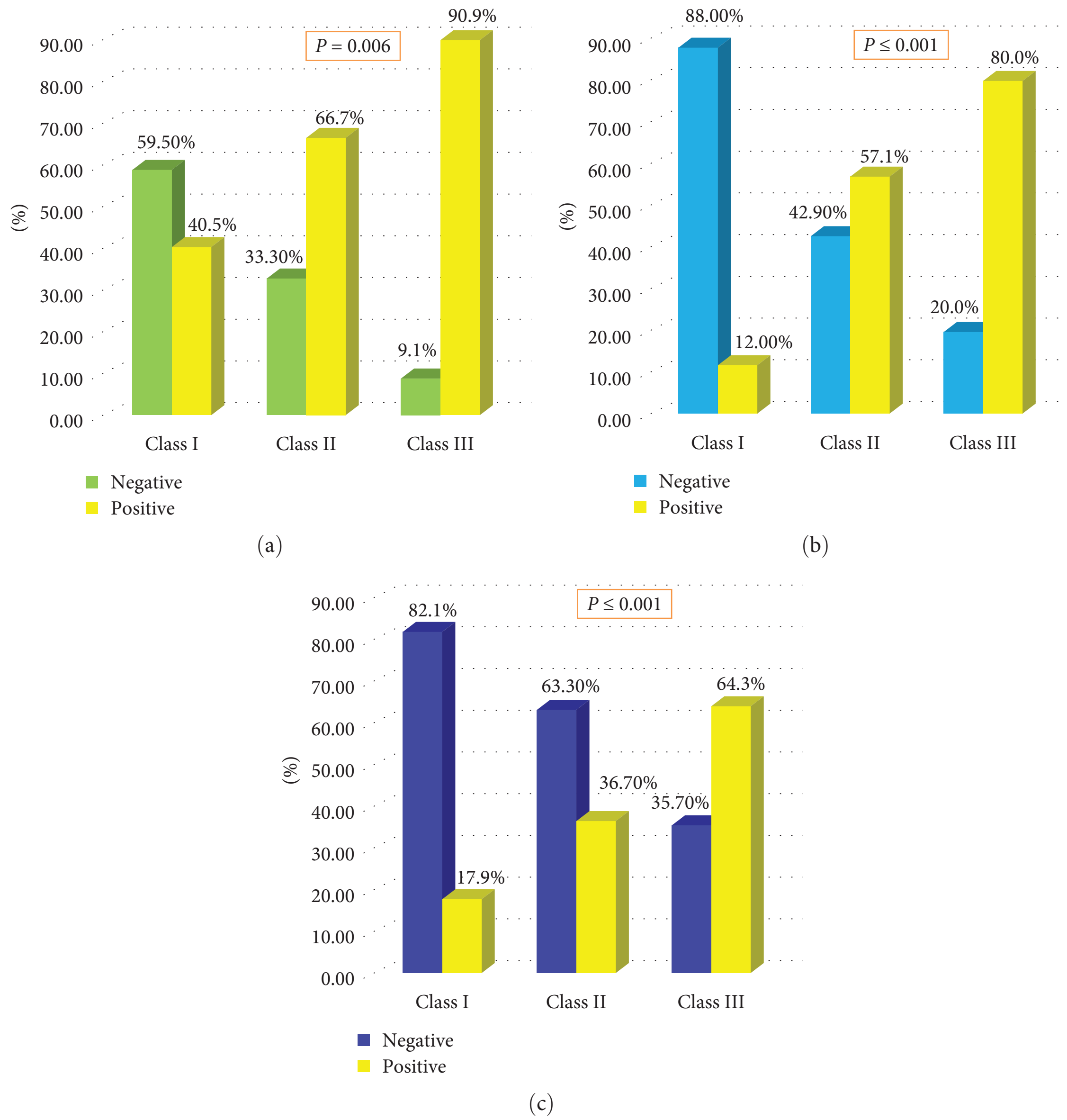


Figure 3: Prevalence of parasite with respect to length categories of *C. gariepinus* fish: from Lake Haramaya (a), Lake Tinike (b), and Lake Adele (c).

4. Discussion

Fish-borne parasites have been part of the food-borne zoonotic diseases and are often endemic in certain regions of the world [11, 13, 55]. Nematodes of the *Anisakidae* family have the ability to infest a wide variety of aquatic hosts during the development of their larval stages. The consumption of raw or undercooked fish favors the acquisition of the disease known as anisakidosis [16, 56] and clinostomiasis [20, 24]. The economic impact of FBZP is significant and is linked to losses in aquaculture industries due to reduced fish productivity, as well as to restrictions on exports and reduced consumer demand [20, 55]. In the present investigation, the prevalence of selected FBZP and communities' current status of knowledge on FBZP were identified and assessed.

This study found that an overall prevalence of selected zoonotic parasite infection was 30.2%, which is almost similar with the report of Hailekiros et al. [57], but lower than the previous reports of Amare et al. [38], Reshid et al. [39], Abreha et al. [50], Marshet [58], Muluken [59], Marshet [60], and Onoja-Abutu et al. [61] and higher than reported by Gebawo [40, 62] and Bekele and Hussien [63]. The prevalence of parasites among the lakes were found different, in which overall prevalence of 36.2%, 24.8%, and 27.9% were recorded in Lake Haramaya, Lake Tinike, and Lake Adele, respectively. This shows that parasitic infection rates vary from one area to another and it depends on physical and chemical conditions of water, climate, season, host-parasite relationship, level of environmental, and water pollution which determine the infection levels of parasites in host fish communities [25, 37, 38, 64, 65]. Furthermore, the

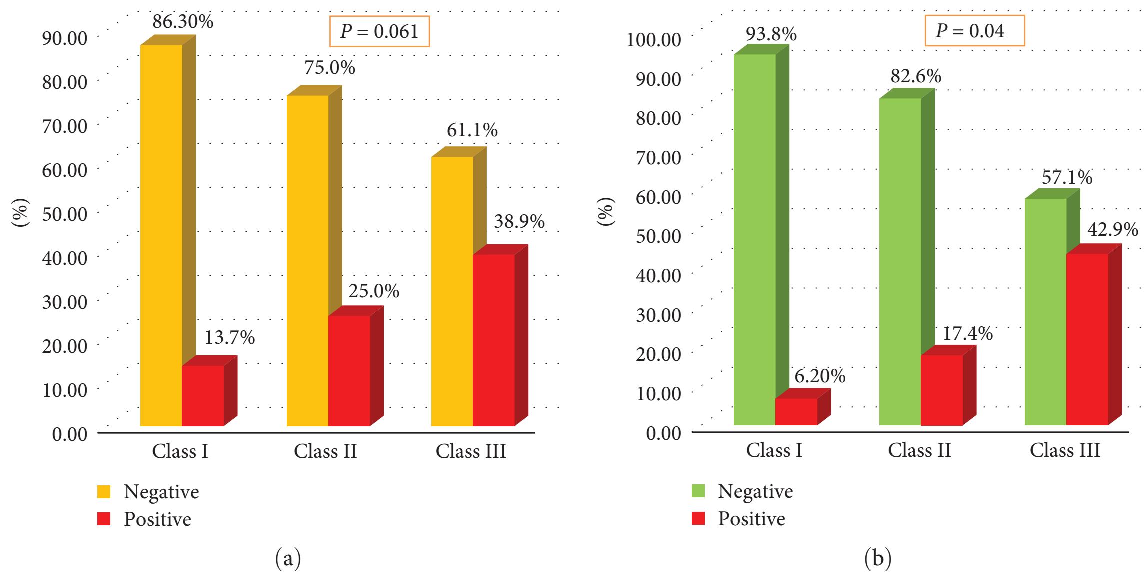


Figure 4: Prevalence of parasites with respect to weight categories of *O.niloticus*: from Lake Haramaya (a) and Lake Tinike (b).

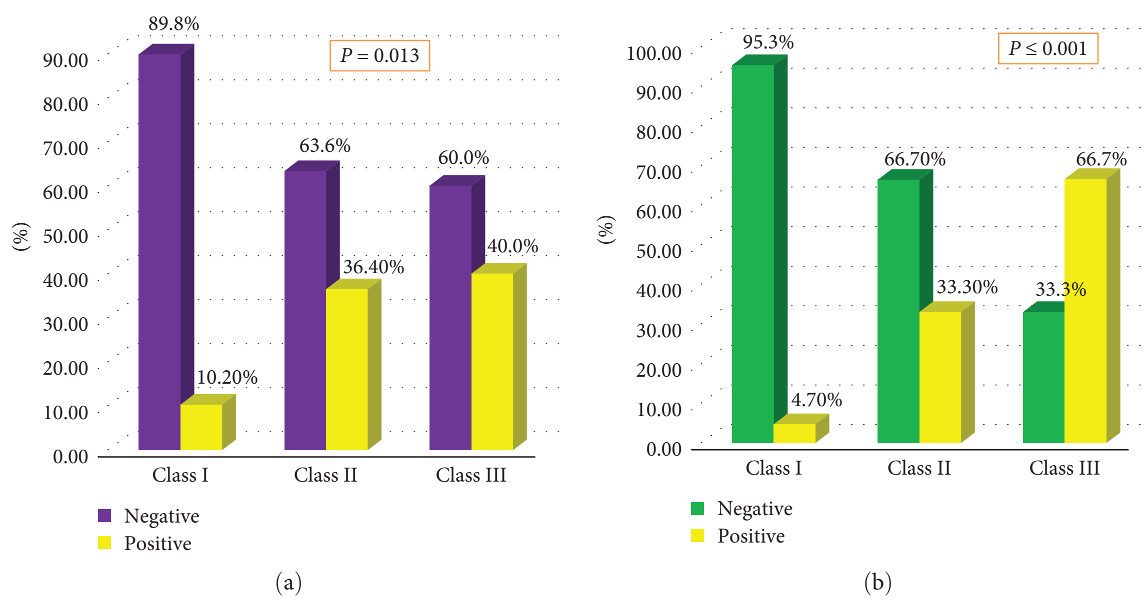


Figure 5: Prevalence of parasite with respect to length categories of *O.niloticus*: from Lake Haramaya (a) and Lake Tinike (b).

spread of FBZP is enhanced by changes in human behavior, demographics, land use and trade, and among other drivers [12, 13].

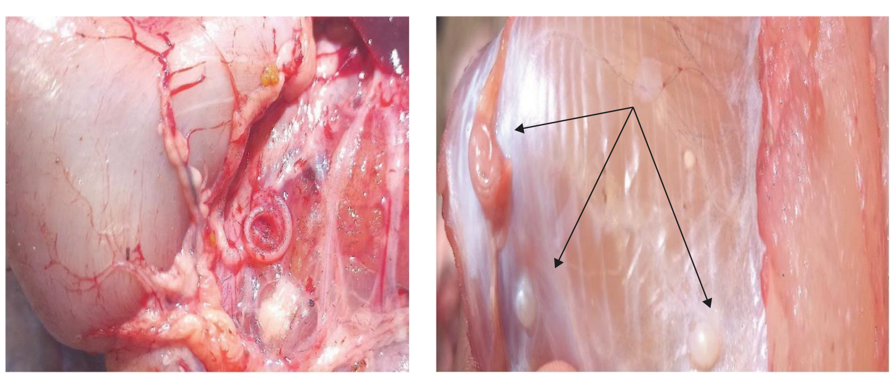
The results reveal that there was a statistically significant difference in the distribution of parasites between species of fish (Table 1). The overall prevalence of parasite was higher in *C. gariepinus* (37.3%) than *O.niloticus* (18.2%). Also, the difference between species among the lakes were found statistically significant at $P < 0.05$ (Table 1), and *C. gariepinus* is more affected (54.4%, 37.3%, and 27.9%) in Lake Haramaya, Lake Tinike, and Lake Adele, respectively, than *O. niloticus* (21.0% and 14.5%) in Lake Haramaya and Lake Tinike, respectively. The result showed that higher prevalence of parasite in *C. gariepinus* fish is almost similar with report of Fasil et al. [36], Tesfaye et al. [37], Amare et al. [38], Yewubdar et al. [66], and Edeh and Solomon [67]. The difference between species are related to difference in feeding habit of fish species. African Catfish ingest a wide variety of food items such as algae, macrophytes, zooplankton, insects, fish prey, detritus, amphibians, and sand grains while Nile Tilapia depends on macrophytes, zooplankton, and insect larvae [68–70]. This behavior could expose it to easy transmission of parasites from invertebrate intermediate hosts and fish intermediate hosts [37, 69]. Moreover, in host fish, infection patterns with endoparasites may be determined by interactions among local species and the presence of infective stages in the ecosystem [25, 65].

Table 3: Prevalence of parasite in relation to genera of parasite among three lakes and between genera of fish.

Parasite	Lake (with their species of fish)	Number of examined fish (%)	Number of affected fish	Prevalence (%)	χ^2	*P*-value
Contracaecum	Haramaya (Catfish)	68 (17.7)	37	54.4	17.872	≤0.001
	Haramaya (Tilapia)	81 (21.1)	17	21.0		
	Tinike (Catfish)	51 (13.28)	19	37.3	7.762	0.005
	Tinike (Tilapia)	62 (16.15)	9	14.5		
	Adele (Catfish)	122 (31.77)	33	27.0	Species of fish is constant	
	Overall	384 (100)	115	29.9	4.741	0.093
Clinostomum	Haramaya (Catfish)	68 (17.7)	12	17.6	0.107	0.743
	Haramaya (Tilapia)	81 (21.1)	16	19.8		
	Tinike (Catfish)	51 (13.28)	9	16.4	0.930	0.335
	Tinike (Tilapia)	62 (16.15)	7	11.3		
	Adele (Catfish)	122 (31.77)	12	9.8	Species of fish is constant	
	Overall	384 (100)	56	14.6	4.342	0.114

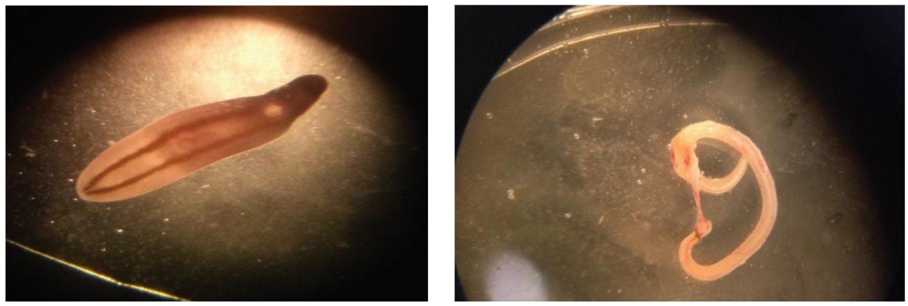
Table 4: Total prevalence of parasite in relation to location of parasite among three lakes and between the genera of fish.

Location of larvae and EMC	Lake (with their species of fish)	Number of examined fish (%)	Number of affected fish	Prevalence (%)	χ^2	*P*-value
Body cavity	Haramaya (Catfish)	68 (17.7)	35	51.5	19.575	≤0.001
	Haramaya (Tilapia)	81 (21.1)	14	17.3		
	Tinike (Catfish)	51 (13.28)	17	33.3	6.779	0.009
	Tinike (Tilapia)	62 (16.15)	8	12.9		
	Adele (Catfish)	122 (31.77)	33	27.0	Species of fish is constant	
	Overall	384 (100)	114	29.7	16.260	≤0.001
Muscle	Haramaya (Catfish)	68 (17.7)	22	32.4	5.467	0.019
	Haramaya (Tilapia)	81 (21.1)	13	16.0		
	Tinike (Catfish)	51 (13.28)	10	19.6	3.239	0.072
	Tinike (Tilapia)	62 (16.15)	5	8.1		
	Adele (Catfish)	122 (31.77)	20	16.4	Species of fish is constant	
	Overall	384 (100)	70	18.2	4.471	0.034



(a) (b)

Figure 6: L3 of *Contracaecum* parasite encysted in the body cavity and muscle by thin membrane. Typical coiling appearance of L3 of *Contracaecum* found in the abdominal cavity encapsulated by thin membrane and attached to the mesenteries of fish by thin membrane (a). L3 of *Contracaecum* encysted in subcutaneous tissue and muscle (b).



(a) (b)

Figure 7: Metacercaria of *Clinostomum* (a) and L3 of *Contracaecum* parasite (b) under sterio microscope.

Table 5: Sociodemographic characteristics of respondents.

Variable	Categories	Frequency (n)	Percentage (%)
Age	<18	26	26
	19–40	49	49
	>40	25	25
Sex	Male	58	58
	Female	42	42
Participant educational status	None or preschool	24	24
	Primary	33	33
	Secondary	25	25
	Higher	18	18
Occupational status	Fishermen	29	29
	Fish sellers	23	23
	Consumers	48	48

Table 6: Respondent's current status of knowledge on preserving, processing, and consumption of fish meat.

Variable	Categories	Frequency (n)	Percentage (%)
Method used to preserving fish meat	Rapping by plastic	55	55
	Refrigerator	19	19
	Preserve died fish in water	26	26
Consumer preference for species of fish	Tilapia	64	64
	Catfish	25	25
	Both species	11	11
Consumer preference for size of fish	Larger size	60	60
	Medium size	24	24
	Smaller size	16	16
Inspection of fish for presence of parasite	Not familiar to inspect	69	69
	Inspect during evisceration	25	25
	While dissecting fish meat	6	6
Perception of respondents on fish-borne parasite	Not familiar with fish-borne parasite	100	100
Processing method of fish meat	Using raw with spice	27	27
	Fried	73	73

The overall difference between sexes was statistically significant (Table 2), i.e., higher prevalence in female (34.4%) was observed than their male (24.5%) counterparts and moreover the difference was statistically significant between the sexes of fish infected with *Contracaecum*, although not significant between the sexes of fish infected with *Clinostomum* (Table 2). This observation corresponds with the findings of Fasil et al. [36], Tesfaye et al. [37] Amare et al. [38], Moa and Anwar [41], Muluken [59], and Eyiseh et al. [71] in which higher prevalence of parasitic infection was recorded

Table 7: Perception of respondents among groups of sociodemographic characteristics in relation to method of preserving, inspection of fish, and processing method used before consumption.

Sociodemographic characteristics of respondents		Method of preserving fish (%)			Inspection of fish meat for the presence of parasite (%)			Method of processing before consumption (%)	
		RP	R	DFW	NFI	IDE	IWDM	Raw	Fried
Age	<18	57.7	19.2	23.1	73.1	15.4	11.5	30.8	69.2
	19–30	46.9	22.4	30.6	53.1	40.8	6.1	24.5	75.5
	>40	68.0	12.0	20.0	92.0	4.0	4.0	32.0	68.0
Sex	Male	60.3	15.5	24.1	63.8	27.6	8.6	34.5	65.5
	Female	47.6	23.8	28.6	73.8	21.4	4.8	19.0	81.0
Participant educational status	None or preschool	58.3	20.8	20.9	70.8	25.0	4.2	20.8	79.2
	Primary	45.5	15.2	39.4	63.6	27.3	9.1	12.1	87.9
	Secondary	60.0	20.0	20.0	60.0	32.0	8.0	32.0	68.0
	Higher	61.1	22.2	16.7	83.3	11.1	5.6	61.1	38.9
Occupational status	Fishermen	37.9	31.0	31.1	62.1	31.0	6.9	24.1	75.9
	Fish sellers	56.5	17.4	26.1	78.3	13.0	8.7	17.4	82.6
	Consumers	64.6	12.5	22.9	66.7	27.1	6.2	35.4	64.6

Note: $P = 0.004$ (age group × inspection of fish); $P = 0.002$ (educational status × processing method). *RP* = rapping by plastic, *R* = refrigerator, DFW = preserve died fish in water, NFI = not familiar to inspect, IDE = inspection during evisceration, and IWDF = inspection while dissecting meat.

in female than male fish. Female fish are more liable than male to parasite infections due to the difference of their physiological condition of the female's especially gravid ones [72, 73].

There were statistically significance difference in the prevalence of parasite among different body weight and length classes. The result showed that the overall prevalence of parasites was higher in Class III than that of Class II and Class I in both species by weight and length categories. The difference among classes of both weight and length of fish was almost in agreement with different reports, which stated that larger fishes were heavily parasitized than the smaller sized fish [37, 50, 59, 66, 74]. Smaller fish harbor lower numbers of parasites than bigger fish as there is a longer duration of exposure to parasitic agents in the environment which increases the chance of acquiring more parasites [75]. Because larger fish ingest a wide variety of food items than smaller fish which can affect chance of acquiring more parasite.

Contracaecum parasite was more prevalent than *Clinostomum* parasite in lakes of Haramaya district. The difference is related to abundance of final host, presence of infective stages in the ecosystem, and life cycle of parasite [25, 37]. The overall prevalence of *Contracaecum* parasite was 29.9%. However, in both species of fish, the highest prevalence of *Contracaecum* parasite was recorded in Lake Haramaya (54.4%) than Lake Tinike (37.3%) and Lake Adele (27.0%) and also in both species in Lake Haramaya and Lake Tinike (21.1% and 14.5%), respectively. The overall prevalence of the present study of *Contracaecum* parasite is lower than the previous reports of Tesfaye et al. [37], Amare et al. [38], Moa and Anwar [41], and Necho and Awake [74] and higher than reported by Abdullah et al. [18], Fasil et al. [36], Hailekiros et al. [57], and Bekele and Hussien [63].

Prevalence of *Contracaecum* in *C. gariepinus* in Lake Haramaya is almost similar with Mitiku [35] and Tesfaye et al. [37], but lower than Amare et al. [38], Lima et al. [56], and Corrêa et al. [76] and higher than Abdullah et al. [18, 77]. Prevalence of *Contracaecum* in *O. niloticus* in Lake Haramaya is also similar with Amare et al. [38] but lower than Tesfaye et al. [37], Reshid et al. [39], Gebawo [40], and Necho and Awake [74] and higher than reported by Mitiku [35], Hailekiros et al. [57], and Muluken [59]. Prevalence of *Contracaecum* in *C. gariepinus* in Lake Tinike is also lower than Tesfaye et al. [37] but higher than reported by Marshet [78] and Fasil et al. [36]. Prevalence of *Contracaecum* in *O. niloticus* in this Lake is lower than reported by Mitiku [35], Amare et al. [38], Reshid et al. [39], Gebawo [40], Moa and Anwar [41], Hailekiros et al. [57], Bekele and Hussien [63], and Necho and Awake [74] and higher than reported by Muluken [59]. However, prevalence of *Contracaecum* in *C. gariepinus* in Lake Adele is similar with Bekele and Hussien [63], but lower than Tesfaye et al. [37] and Corrêa et al. [76] and higher than reported by Marshet [78] and Fasil et al. [36]. However, this study was disagree with the report of Hiko et al. [43] which stated that all the *C. gariepinus* fish obtained from Lake Adele were negative both for the cestodes and nematodes.

The overall prevalence of *Clinostomum* was 14.6%. However, prevalence of *Clinostomum* in *C. gariepinus* were 17.6%, 17.2%, and 9.8% in Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and 19.8% and 11.3% in *O. niloticus* from Lake Haramaya and Lake Tinike, respectively. The prevalence of *Clinostomum* in Lake Haramaya and Lake Tinike in *C. gariepinus* are almost the same, but different in *O. niloticus*. The results showed that the overall prevalence and prevalence of *Clinostomum* among the lakes between species are lower than the previous reports of Mahdy et al. [24], Salem et al. [31], Mitiku [35], Amare et al. [38], Gebawo [40], Temesgen and Getachew [42], Mahdy et al. [52], Mutengu and Mhlanga [79], Bera et al. [80], and McAllister and Robison [81] and higher than reported by Calhoun et al. [25], Hailekiros et al. [57], Muluken [59], and Bekele and Hussien [63].

The overall prevalence of selected zoonotic parasites was also evaluated based on the location of parasite among three lakes and between species of fish. Hence, prevalence of parasite in the body cavity were found 51.5%, 33.3%, and 27.0% in *C. gariepinus* from Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and 17.3% and 12.9% in *O. niloticus* in Lake Haramaya and Lake Tinike, respectively. However, the result of total overall prevalence of parasite in the body cavity was 29.7%, which is higher than the previous reports of Muluken [59], Bekele and Hussien [63], and McAllister and Robison [81], but lower than Abdullah et al. [18], Mahdy et al. [24], Salem et al. [31], Tesfaye et al. [37], Mahdy et al. [52], Lima et al. [56], Marshet [58], Corrêa et al. [76], and Bera et al. [80]. The overall prevalence of parasite in the muscle of fish were 32.4%, 19.6%, and 16.4% in *C. gariepinus* from Lake Haramaya, Lake Tinike, and Lake Adele, respectively, and 16.0% and 8.1% in *O. niloticus* from Lake Haramaya and Lake Tinike, respectively. The results of total overall prevalence of parasite in the muscle was 18.2%, which is lower than the previous reports of Aghlmandi et al. [82] and Nitta and Ishikawa [83].

On average, seven L3 of *Contracaecum* were collected per fish and they were found freely in the body cavities, mesenteries, and muscle of fish. The results of the present study showed that the average number of larvae of *Contracaecum* parasite is similar to that of reported by Tesfaye et al. [37] but higher than reported by Abdullah et al. [18], Mitiku [35], and Lima et al. [56] and lower than Corrêa et al.'s [76] report. Also, the average of five EMC of *Clinostomum* was recorded from *Clinostomum* infected fish, which is lower than reported by Bera et al. [80], McAllister and Robison [81], and Aghlmandi et al. [82], but higher than reported by Mitiku [35] and Mahdy et al. [24]. Therefore, detection of FBZP in the fish from Haramaya District lakes indicates potential public health risk associated with consumption of fish meat from these lakes.

In this study, it has been proved by all of the respondents (100%) that the major problems of the lake were environmental contamination, water pollution, siltation, deforestation (shore damage), and over fishing, indicating a future threat for the lakes and its ecosystem. These findings are similar with different reports of Ethiopian lakes [50, 84–87]. The safety of food is affected by the health of animals, plants, and the environment within which it is produced [13]. Environmental change can affect parasite and host individuals directly by changing the ecological settings in which the interaction takes place [88, 89]. It can negatively affect fish host via altering its ability to manage the parasite; the parasite via effects on virulence, transmission, or reproduction; invertebrate host via increasing reproduction; and human host via increasing aquatic-derived zoonoses [88, 90].

Majority of fishermen used traditional fishing gears (78%) and modified fishing gears (22%). In this method, fishermen harvest without selection and after harvesting, juvenile and died fishes are thrown back to the lake and for piscivorous birds, which can directly be influencing the resistance of fish and transmission of parasites [37, 88]. Changes in fishing gear, changes in types of fishing businesses, and patterns of working relationships have undergone very significant changes in the socioeconomic life of the fishing community [91]. Majority of respondents preserved fish rapping by plastic (55%), died fish in water (26%), and only 19% of them used refrigerator. Fishery sector in Ethiopia is hampered by several factors such as lack of harvestingand processing technologies, appropriate transportation facilities, and established supply chain management systems [92, 93]. Contamination of the aquatic ecosystem and unhygienic handling practices along the fish supply chain can lead to a contaminated fish [55, 94]. Respondents were choice 64%, 25%, and 11% of Tilapia, Catfish, and both species of fish, respectively. However, both species of fish have a high socioeconomic value worldwide and are identified as a zoonotic parasite reservoir [37, 69, 70, 95].

Majority of respondents were choice larger size (60%) followed by medium (24%) and all size (16%). Likewise, in this study, larger fishes were heavily parasitized than the smaller fish, which are almost similar to the finding of [37, 59, 74]. Majority of respondents 69% were not familiar to inspect fish meat for the presence of FBZP and only 25% of them inspect during evisceration and 6% of them while dissecting fish meat into pieces; however, none of them can experience about FBZP. Food safety authorities can play an important part by using the guidance provided by Codex Alimentarius regarding animal production, food processing, and meat inspection [55]. Furthermore, 77% of participants consume fish after cooking and 23% of them consume raw using spice only. Therefore, the people living around the vicinity of lakes of Haramaya District are under the risk of FBZP, because consumption of raw or under cooked fish is a major source of fish-borne parasitic infections in humans [13, 55, 94]. The good news is that most food-borne diseases are preventable. Our behavior, the way we build food systems and how we organize food supply chains can prevent FBZP [13]. To decrease the risk of fish-borne parasitic disease, fish meat must treated by hot or cold temperatures ($\geq$70 or -20°C for 7 days) [55].

The perception of respondents among the groups of sociodemographic characteristics of respondents were evaluated based on knowledge of preserving fish, inspection of fish meat, and method of processing of fish before consumption. The difference was significantly affected among age group and inspection of fish meat for the presence of parasites, as well as among educational status with respect to method of processing of fish meat before consumption ($P = 0.004$ and $P = 0.002$), respectively. The spread of food-borne parasitic diseases is enhanced by changes in human behavior, demographics, environment, climate, land use, and trade [13, 55, 84, 85].

From a total of 100 participants, none of them were delivered any training on FBZP. Only 5% of them believe that they may be suffer from fish-borne parasite after consumption of raw fish meat. All of the respondents (100%) stated that they were not affected, showed any symptom and treated from fish-borne parasitic disease after consumption of fish. However, this do not reflect the true prevalence or incidence of the disease occurrences in human, because food-borne parasites are often referred to as neglected diseases. From the food safety perspective, they have not received the same level of attention as other food-borne biological and chemical hazards [12, 13]. Therefore, it show the limitation of information and awareness regarding FBZP and hygienic status of fish handling practices in Ethiopia [12, 94]. Moreover, most infected persons do not show any signs or symptoms, and the signs depend on the number of parasites [13, 55].

Respondents have also stated that the government, nongovernmental organization, and private sectors should provide training for the local community on the fish-borne parasitic disease, fish harvesting, processing, and consumption, as well as prevention of environmental and water pollution. Effective and transparent joint action between public health, animal health, agriculture, food, trade, and industry development policies need to promote food safety [13, 55]. The risks associated with FBZP can be avoided through the application of good hygiene, fishing practices, and with the promotion of the community awareness [55]. Furthermore, field observation was also undertaken and lakes ecosystems have been impacted negatively from human and animal interaction. Among three lakes, Lake Haramaya was the most contaminated (especially on the border of Haramaya Town) followed by Lake Adele, and Lake Tinike was most used for irrigation purpose. The lake's quality is deteriorating due to untreated wastewater, sediment inflow, and using lakes water for irrigation purpose [84, 85, 96].

5. Conclusion and Recommendations

Fish-borne parasites have been part of the food-borne zoonotic diseases and are often endemic in certain regions of the world. This study was conducted to determine the prevalence of *Clinostomum* and *Contraceacum* parasite between *C. gariepinus* and *O. niloticus* among Lake Haramaya, Lake Tinike, and Lake Adele and also to assess the current status of knowledge of local people on FBZP. The result of current study revealed that *C. gariepinus* and *O. niloticus* fish species were infected by *Contracaecum* and *Clinostomum* parasites. The highest overall prevalence of parasites was recorded in Lake Haramaya, than Lake Tinike and Lake Adele. The lakes were negatively impacted by human and animal interaction, which can perpetuate the life cycle of parasites. The spread of FBZP is enhanced by changes in human behavior, demographics, environment, climate, land use and trade, and among other drivers. Therefore, the people living around the vicinity of lakes of Haramaya District are under the risk of FBZP. The risks associated with FBZP can be reduced through the application of good fishing practices, hygienic practice, and the promotion of the community awareness. Based on above conclusion, the following recommendations are forwarded:

(1) Government and respective bodies should give special attention to the prevention and control of environmental and water pollution. Proper waste and offal disposal methods should be implemented to prevent contamination of the lakes environment and to break the life cycle of parasites.
(2) Creating community awareness on FBZP transmission and risks associated with eating raw and undercooked fish meatand develop a network with relevant partner agencies to train beneficiaries and creating awareness are paramount.
(3) Implementation of prevention measures applicable to most food-borne parasites include application of good hygiene, fishing practices, inspection of fish meat before cooking, proper storage methods, and adequate cooking of fish prior to consumption are crucial.
(4) Reforestation of area surrounding lakes is important to prevent siltation (shore damage).

Furthermore, this study recommends further studies of molecular characterization of genus *Contracaecum* and *Clinostomum* to identify it to species level and also for the other types of FBZP.

Data Availability

The research data that support the findings of this study are available from the corresponding author (Zinabu Tesfaye (DVM, MSc); email: zinetesfu15@gmail.com) upon reasonable request. However, research data will not be shared before the paper will be accepted and/or published.

Disclosure

This research paper is only deposited on the Library deposit of Haramaya University being it was submitted as MSc Thesis online (http://ir.haramaya.edu.et/hru/handle/123456789/6348) before published on Aquaculture Journal [97].

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] FAO, *The State of World Fisheries and Aquaculture 2018*, Food and Agricultural Organization of the United Nations, Rome, 2018.

[2] FAO, *The State of World Fisheries and Aquaculture*, Food and Agricultural Organization of the United Nations, 2020.

[3] P. Jag, B. N. Shukla, K. M. Ashish, O. V. Hari, P. Gayatri, and Amitha, "A review on role of fish in human nutrition with special emphasis to essential fatty acid," *International Journal of Fisheries and Aquatic Studies*, vol. 6, no. 2, pp. 427–430, 2018.

[4] L. O'Meara, P. J. Cohen, F. Simmance et al., "Inland fisheries critical for the diet quality of young children in sub-Saharan Africa," *Global Food Security*, vol. 28, Article ID 100483, 2021.

[5] H. H. Mahboub, K. Shahin, S. M. Mahmoud et al., "Silica nanoparticles are novel aqueous additive mitigating heavy metals toxicity and improving the health of African catfish, *Clarias gariepinus*." *Aquatic Toxicology*, vol. 249, no. 1, pp. 99–110, Article ID 106238, 2022.

[6] FAO, *The State of World Fisheries and Aquaculture*, Food and Agricultural Organization of the United Nations, Rome, 2016.

[7] S. Maulu, K. Nawanzi, M. Abdel-Tawwab, and H. S. Khalil, "Fish nutritional value as an approach to children's nutrition," *Frontiers in Nutrition*, vol. 8, pp. 780–844, 2021.

[8] S. P. T. Prado and D. M. Capuano, "Relato de nematóides da família anisakidae em bacalhau comercializado em Ribeirão Preto, SP," *Revista da Sociedade Brasileira de Medicina Tropical*, vol. 39, no. 6, pp. 580-581, 2006.

[9] B. P. Mohanty, "Fish as health food," in *Handbook of Fisheries and Aquaculture*, vol. 35, pp. 843–861, ICAR-DKMA, New Delhi, 2nd edition, 2011.

[10] V. U. Odoh, O. O. Abuh, M. M. Haruna, M. A. Yisa, A. A. Bids, and I. W. Zaliya, "Medically important parasites of *Clarias Garipienus* (catfish) in Nigeria," *Advances in Biotechnology and Microbiology*, vol. 15, no. 1, Article ID 555904, 2019.

[11] W. Cong and H. M. Elsheikha, "Biology, epidemiology, clinical features, diagnosis, and treatment of selected fish-borne parasitic zoonoses," *The Yale Journal of Biology and Medicine*, vol. 94, no. 2, pp. 297–309, 2021.

[12] FAO and WHO, *Multicriteria-Based Ranking for Risk Management of Food-Borne Parasites*, Microbiological Risk Assessment Series, Food and Agriculture Organization of the United Nations and World Health Organization, Rome, 2014.

[13] FAO and WHO, *A Guide to World Food Safety Day*, Food and Agriculture Organization of the United Nations and World Health Organization, 2022.

[14] WHO (World Health Organization), "Research priorities for helminth infections: technical report of the TDR disease reference group on helminth infections," WHO, Technical report series; no. 972. ISBN 978 92 4 120972 4, 2012.

[15] A. Hafiz, K. Abdulmajid, and A. Muhammad, "The prevalence of cestode infection in a freshwater catfish, sperata sarwari," *Punjab University Journal of Zoology*, vol. 21, no. 1-2, pp. 41–47, 2006.

[16] J. C. Ángeles-Hernández, F. R. Gómez-de Anda, N. E. Reyes-Rodríguez et al., "Genera and species of the anisakidae family and their geographical distribution," *Animals*, vol. 10, no. 12, Article ID 2374, 2020.

[17] R. C. Anderson, *Nematode Parasites of Vertebrates: Their Development and Transmission*, pp. 1–16, Centre for Agriculture and Biosciences International (CABI), 2nd edition, 2000.

[18] Y. S. Abdullah, S. M. A. Abdullah, and R. H. Hussein, "Morphology and molecular studies of *Contracaecum* larvae (nematoda: anisakidae) in some fish species from Sulaimani province, Kurdistan region, Iraq," *Basrah Journal of Agricultural Sciences*, vol. 34, no. 1, pp. 93–110, 2021.

[19] E. Ozuni, A. Vodica, M. Castrica et al., "Prevalence of *Anisakis* larvae in different fish species in Southern Albania: 5-year monitoring (2016–2020)," *Applied Sciences*, vol. 11, 2021.

[20] WHO (World Health Organization), "Food borne trematode infection," 2021.

[21] B. Szostakowska and H.-P. Fagerholm, "Molecular identification of two strains of third-stage larvae of *Contracaecum rudolphii* sensu lato (Nematoda: Anisakidae) from fish in Poland," *Journal of Parasitology*, vol. 93, no. 4, pp. 961–964, 2007.

[22] A. E. Younis, A. I. Saad, and J. M. Rabei, "The occurrence of *Contracaecum sp.* larvae (nematoda: anisakidae) in four teleostean species from Lake Nasser, Egypt: morphological and molecular studies," *The Journal of Basic and Applied Zoology*, vol. 78, no. 1, pp. 1–13, 2017.

[23] S. S. Labony, M. A. Alim, M. M. Hasan et al., "Fish-borne trematode infections in wild fishes in Bangladesh," *Pathogens and Global Health*, vol. 114, no. 2, pp. 91–98, 2020.

[24] O. A. Mahdy, S. Z. Abdel-Maogood, M. Abdelsalam, M. Shaalan, H. A. Abdelrahman, and M. A. Salem, "Epidemiological study of fish-borne zoonotic trematodes infecting Nile tilapia with first molecular characterization of two heterophyid flukes," *Aquaculture Research*, vol. 52, no. 9, pp. 4475–4488, 2021.

[25] D. M. Calhoun, K. L. Leslie, T. B. Riepe et al., "Patterns of *Clinostomum marginatum* infection in fishes and amphibians: integration of field, genetic, and experimental approaches," *Journal of Helminthology*, vol. 94, pp. 1–12, 2020.

[26] S. Yasumoto, T. Kabayama, M. Kondo, and Y. Takahashi, "Mass mortalities of goldfish *Carassius auratus* infected *Clinostomum* metacercariae, associated with elevated water temperature," *Fish Pathology*, vol. 53, pp. 44–47, 2018.

[27] S. Shamsi, S. Day, X. Zhu et al., "Wild fish as reservoirs of parasites on Australian murray cod farms," *Aquaculture*, vol. 539, Article ID 736584, 2021.

[28] L. B. Lemke, N. Dronen, J. G. Fox, and P. R. Nambiar, "Infestation of wild-caught American bullfrogs (*Rana catesbeiana*) by multiple species of metazoan parasites." *Journal of the American Association for Laboratory Animal Science: JAALAS*, vol. 47, no. 3, pp. 42–46, 2008.

[29] F. J. Sutili, G. L. Tourem, and L. F. Vilani de Pelegrini, "*Clinostomum* complanatum (trematoda, digenea): a parasite of birds and fishes with zoonotic potential in southern Brazil: a review," *Revista Brasileira de Higiene e Sanidade Animal*, vol. 8, pp. 99–114, 2014.

[30] J. C. Eiras, G. C. Pavanelli, R. M. Takemoto, and Y. Nawa, "An overview of fish-borne nematodiases among returned travelers for recent 25 years—unexpected diseases sometimes far away from the origin," *The Korean Journal of Parasitology*, vol. 56, no. 3, pp. 215–227, 2018.

[31] M. A. Salem, S. Z. Abdel-Maogood, M. Abdelsalam, and O. A. Mahdy, "Comparative morpho-molecular identification of *Clinostomum phalacrocoracis* and *Clinostomum complanatum* metacercaria coinfecting Nile Tilapia in Egypt," *Egyptian Journal of Aquatic Biology and Fisheries*, vol. 25, no. 1, pp. 461–476, 2021.

[32] D. Ljubojevic, N. Novakov, V. Djordjevic, C. Radosavljevic, M. Pelic, and M. Cirkovic, "Potential parasitic hazards for

humans in fish meat," *Procedia Food Science*, vol. 5, pp. 172–175, 2015.
[33] S. Mekonnen, M. Gezahegne, and A. Lemma, "Major fish-borne bacterial and parasitic zoonoses in Ethiopia," *International Journal of Fauna and Biological Studies*, vol. 6, no. 4, pp. 50–58, 2019.
[34] A. Hussen, M. Tefera, and S. Asrate, "Gastrointestinal helminth of clarias gariepinus (catfish) in lake Hawassa Ethiopia," *Scientific Journal of Animal Science*, vol. 1, no. 4, pp. 131–136, 2012.
[35] M. A. Mitiku, "Parasite species richness of fish from fish ponds and fingerling sources in central Ethiopia: it's implication on aquaculture development," *International Journal of Zoology and Animal Biology*, vol. 4, no. 4, 2021.
[36] N. Fasil, T. Teshome, and D. Sheferaw, "Prevalence of *Contracaecum* parasite infestation of Nile Tilapia and African catfish in Lake Ziway, Ethiopia," *Journal of Fisheries and Aquaculture Development*, 2017.
[37] Z. Tesfaye, B. Ferede, N. Pavanasam, and K. B. Workagegn, "Prevalence of nematode parasite, *Contracaecum*, in Nile tilapia, African catfish and Barbus species in Lake Hawassa, Ethiopia," *Aquaculture Research*, vol. 51, no. 10, pp. 3993–3998, 2020.
[38] A. Amare, A. Alemayehu, and A. Aylate, "Prevalence of internal parasitic helminthes infected oreochromis niloticus (Nile Tilapia), clarias gariepinus (African catfish) and cyprinus carpio (common carp) in lake Lugo (Hayke), northeast Ethiopia," *Journal of Aquaculture Research & Development*, vol. 3, no. 3, Article ID 233, 2014.
[39] M. Reshid, M. Adugna, Y. T. Redda, N. Awol, and A. Teklu, "A study of *Clinostomum* (trematode) and *Contracaecum* (nematode) parasites affecting oreochromis niloticus in small Abaya lake, Silite zone, Ethiopia," *Journal of Aquaculture Research & Development*, vol. 6, no. 3, Article ID 316, 2015.
[40] T. B. Gebawo, "Seasonal variation of parasites of fishes in lake charcher west Hararghe, Oromia region, Ethiopia," *Nigerian Journal of Fisheries*, vol. 11, pp. 728–732, 2014.
[41] M. S. Moa and N. A. Anwar, "Larvae of *Contracaecum* nematode in tilapia fish (*Oreochromis niloticus*) from fishing grounds of northern lake Tana, Ethiopia," *Scientia Parasitologica*, vol. 15, no. 1–4, pp. 33–37, 2014.
[42] B. Temesgen and T. Getachew, "Study on helminth parasites in Tilapia nilotica from lake Zeway," *International Journal of Advanced Research in Biological Sciences*, vol. 4, no. 10, pp. 21–25, 2017.
[43] A. Hiko, K. Tasisa, and G. E. Agga, "Helminthiasis and gram negative enteric bacteria in freshwater fish from selected lakes of Haramaya district, Ethiopia," *Fisheries and Aquaculture Journal*, vol. 9, no. 2, Article ID 242, 2018.
[44] N. Tadesse, K. Bheemalingeswara, and M. Abdulaziz, "Hydrogeological investigation and groundwater potential assessment in Haromaya Watershed, Eastern Ethiopia," *Momona Ethiopian Journal of Science*, vol. 2, no. 1, pp. 26–48, 2010.
[45] Birdlife International, "Important bird areas factsheet: lakes Alemaya and Adele," 2022.
[46] M. Thrusfield, "Sampling," in *Veterinary Epidemiology*, pp. 179–284, Black Well Science Ltd., London, 3rd edition, 2005.
[47] H. Arsham, "Questionnaire design and surveys sampling," 2020.
[48] T. S. Imam and R. A. Dewu, "Survey of piscine ecto and intestinal parasites of clarias sppsold at Galadima road fish market, Kano metropolis, Nigeria," *Bioscience Research Communications*, vol. 22, no. 4, pp. 209–214, 2010.
[49] S. W. Kiprono, *Fish Parasites and Fisheries Productivity in Relation to Exreme Flooding of Lake Baringo, Kenya*, Kenyatta University, pp. 1–93, 2017.
[50] T. Abreha, T. Awot, B. Tilaye et al., "A survey on occurrence of internal and external fish parasites and causes of fish population reduction in lake Hashenge, Tigray, Ethiopia," *Ethiopian Veterinary Journal*, vol. 21, no. 2, pp. 75–91, 2017.
[51] I. Paperna, "Parasites, infections and diseases of fish in Africa," pp. 157–170, 1996, An update FAO/CIFA technical paper.
[52] O. A. Mahdy, M. A. Mahmoud, and M. Abdelsalam, "Morphological characterization and histopathological alterations of homologs heterophyid metacercarial coinfection in farmed mullets and experimental infected pigeons," *Aquaculture International*, vol. 28, no. 6, pp. 2491–2504, 2020.
[53] P. E. Y. Roy, "Nematode (roundworm) infections in fish," UF/IFAS Extension, University of Florida, 2017.
[54] M. Caffara, N. Davidovich, R. Falk et al., "Redescription of *Clinostomum* phalacrocoracis metacercariae (digenea: clinostomidae) in cichlids from lake Kinneret, Israel," *Parasite*, vol. 21, Article ID 32, 2014.
[55] FAO, *Parasites in Food: An Invisible Threat*, Food and Agricultural Organization of the United Nations, Bangkok, Thailand, 2021.
[56] F. Lima, A. Pozza, and P. Lehmann, "*Contracaecum* spp. (Nematoda: Anisakidae) and *Eustrongylides* spp. (Nematoda: dioctophymatidae) nematode larvae with zoonotic potencial found in two fish species from Tramandaí river Basin, Southern Brazil," *Boletim do Instituto de Pesca*, vol. 45, no. 3, Article ID e495, 2019.
[57] G. Hailekiros, D. Hailu, and K. T. Assefa, "Prevalence of internal helminth parasites of fish in Gilgel-Gibe river and three selected ponds in and around Jimma Town, South west Ethiopia," *Turkish Journal of Fisheries and Aquatic Sciences*, vol. 20, no. 9, pp. 693–699, 2020.
[58] A. Marshet, "Prevalence and associated risk factors of Nile tilapia (*Oreochromis niloticus*) and African big barb (*Labeobarbus intermidus*) fish parasites in Gigel gibe-I dam, Jimma zone, Ethiopia," *Ethiopian Institute of Agricultural Research (EIAR)*, vol. 1, pp. 27–30, 2016.
[59] A. Muluken, "Prevalence of helminthes parasite of fish, *Orechro musniloticus* and *Cyprinus carpio* in pond of national fishery and other aquatic life research center, Sebeta, Ethiopia," *International Journal of Advanced Research in Biological Sciences*, vol. 8, no. 4, pp. 82–89, 2021.
[60] A. Marshet, "The prevalence of fish parasites of Nile Tilapia (*Oreochromis niloticus*) in selected fish farms, Amhara regional state," *Ethiopian Journal of Agricultural Sciences*, vol. 30, no. 3, pp. 119–128, 2020.
[61] A. E. Onoja-Abutu, M. A. Okpanachi, L. Alkazmi, C. A. Yaro, and G. E.-S. Batiha, "Branchial chamber and gastrointestinal tracts parasites of fish species in Benue and Niger rivers, north central, Nigeria," *International Journal of Zoology*, vol. 2021, Article ID 6625332, 10 pages, 2021.
[62] T. B. Gebawo, "Study on the prevalence and temporal abundance of parasites of fishes in lake Elan," *Global Journal of Fisheries and Aquaculture*, vol. 3, no. 7, pp. 265–269, 2015.
[63] J. Bekele and D. Hussien, "Prevalence of internal parasites of *Oreochromis niloticus* and *Clarias gariepinus* fish species in lake Ziway, Ethiopia," *Journal of Aquaculture Research & Development*, vol. 6, no. 2, Article ID 308, 2015.

[64] S. Qasim and Z. Ayub, "Prevalence and intensity of parasites in edible fishes landing at Karachi fish harbour," *Pakistan Journal of Zoology*, vol. 44, pp. 1467–1471, 2012.

[65] S. Khan, S. Ahmed, M. Serajuddin, and M. K. Saifullah, "Variation in seasonal prevalence and intensity of progenetic metacercariae of *Clinostomum complanatum* infection in *Trichogaster fasciatus fish*," *Beni-Suef University Journal of Basic and Applied Sciences*, vol. 7, pp. 310–316, 2018.

[66] G. Yewubdar, Y. Eshetu, A. Kassahun, and B. Jemere, "Study on parasitic helminths infecting three fish species from Koka reservoir, Ethiopia," *SINET: Ethiopian Journal of Science*, vol. 36, no. 2, pp. 73–80, 2013.

[67] C. Edeh and R. J. Solomon, "Endoparasites of *Oreochromis niloticus* and *Clariasgariepinus* found in Utako flowing gutter," *Direct Research Journal of Agriculture and Food Science*, vol. 4, no. 12, pp. 361–373, 2017.

[68] D. Admassu, L. Abera, and Z. Tadesse, "The food and feeding habits of the African catfish, *Clarias gariepinus* (Burchell), in lake Babogaya, Ethiopia," *Global Journal of Fisheries and Aquaculture*, vol. 3, no. 4, pp. 211–220, 2015.

[69] T. Abebe, F. Tadesse, and G. Abebe, "Food and feeding habits of juvenile and adult Nile Tilapia, *Oreochromis niloticus* (L.) (pisces: cichlidae) in lake Ziway, Ethiopia," *SINET: Ethiopian Journal of Science*, vol. 43, no. 2, pp. 88–96, 2020.

[70] T. Agumassie, "Feeding biology of the African catfish *Clarias gariepinus* (Burchell) in some of Ethiopian lakes: a review," *International Journal of Fauna and Biological Studies*, vol. 5, no. 1 Part A, pp. 19–23, 2018.

[71] T. E. Eyiseh, S. O. Amos, and I. T. Adeniyi, "Incidence of parasitic infection in adult and juvenile *Clarias gariepinus* in a private fish farm, Yola, Adamawa state," *International Journal of Fisheries and Aquatic Studies*, vol. 10, no. 1, pp. 38–45, 2022.

[72] T. I. I. Ibiwoye, A. M. Balogun, R. A. Ogunsusi, and J. J. Agbontale, "Determination of the infection densities of mudfish *Eustrongylides* in *C. gariepinus* and *C. anguillaris* from Bida floodplain of Nigeria," *Journal of Applied Sciences and Environmental Management*, vol. 8, no. 2, pp. 39–44, 2004.

[73] A. B. Al-Zubaidy, "Prevalence and densities of *Contracaecum* sp. larvae in liza abu (Heckel, 1843) from different Iraqi water bodies," *Journal of King Abdulaziz University: Marine Sciences*, vol. 20, pp. 3–17, 2009.

[74] A. Necho and M. Awake, "Prevalence of nematode (*Contracaecum*) and cestode (*Ligula intestinalis*) parasites infection in two fish species at lake Tana," *International Journal of Advanced Research*, vol. 2, no. 3, pp. 43–50, 2018.

[75] E. O. Otachi, "*Studies on Occurrence of Protozoan and Helminth Parasites in Nile tilapia (O. niloticus) from Central and Eastern Provinces, Kenya*," , Egerton University, Kenya, 2009.

[76] L. L. Corrêa, M. S. B. Oliveira, J. G. da Costa Eiras, M. Tavares-Dias, and E. A. Adriano, "High prevalence and intensity of fish nematodes with zoonotic potential in the Brazilian Amazon, including a brief reflection on the absence of human infections," *Revista de Patologia Tropical/Journal of Tropical Pathology*, vol. 50, no. 2, pp. 150–162, 2021.

[77] Y. S. Abdullah, S. M. A. Abdullah, and R. H. Hussein, "Ultramorphology and molecular studies of *Contracaecum* larvae (nematoda: anisakidae) collected in five cyprinid fish species from Sulaimani province, Kurdistan region-Iraq," *Helminthologia*, vol. 58, no. 1, pp. 41–58, 2021.

[78] A. M. Marshet, *Parasite Species Richness of Fish from Fish Ponds and Fingerling Sources in Central Ethiopia: It's Implication on Aquaculture Development*, pp. 1–56, University of Natural Resources and Life Sciences (BOKU), 2017.

[79] C. Mutengu and W. Mhlanga, "Occurrence of *Clinostomum* metacercariae in *Oreochromismossambicus* from Mashoko Dam, Masvingo province, Zimbabwe," *Scientifica*, vol. 2018, Article ID 9565049, 6 pages, 2018.

[80] A. K. Bera, N. Das, S. Bhattacharya et al., "Molecular confirmation of metacercaria of *Clinostomum complanatum* recovered from one-stripe spiny eel *Macrognathus aral*," *Aquaculture Research*, vol. 52, no. 9, pp. 4362–4370, 2021.

[81] C. T. McAllister and H. Robison, "Clinostomum marginatum (digenea: clinostomidae) from fishes of crooked creek, boone and marion counties, Arkansas," *Journal of the Arkansas Academy of Science*, vol. 74, no. 9, pp. 31–36, 2020.

[82] F. Aghlmandi, F. Habibi, M. A. Afraii, A. Abdoli, and S. Shamsi, "Infection with metacercaria of *Clinostomum complanatum* (trematoda: clinostomidae) in freshwater fishes from southern Caspian Sea Basin," *Revue de Medecine Veterinaire*, vol. 169, pp. 147–151, 2018.

[83] M. Nitta and T. Ishikawa, "Metacercariae of *Clinostomum complanatum* (platyhelminthes: trematoda: clinostomidae), a parasite of the Northern Medaka, *Oryzias sakaizumii* (beloniformes: adrianichthyidae), from Yamagata prefecture, Japan," *Biogeography*, vol. 21, pp. 17–21, 2019.

[84] H. Berhe Dagnaw, "Implications of environmental pollutions and climate changes on ethiopian fisheries: review study," *Frontiers in Environmental Microbiology*, vol. 7, no. 4, pp. 85–95, 2021.

[85] D. Reddythota and M. Teferi Timotewos, "Evaluation of pollution status and detection of the reason for the death of fish in Chamo lake, Ethiopia," *Journal of Environmental and Public Health*, vol. 2022, Article ID 5859132, 12 pages, 2022.

[86] B. Berehanu, B. Lemma, and Y. Tekle-Giorgis, "Chemical composition of industrial effluents and their effect on the survival of fish and eutrophication of lake Hawassa, southern Ethiopia," *Journal of Environmental Protection*, vol. 6, no. 8, pp. 792–803, 2015.

[87] S. M. Lencha, J. Tränckner, and M. Dananto, "Assessing the water quality of lake Hawassa Ethiopia—trophic state and suitability for anthropogenic uses—applying common water quality indices," *International Journal of Environmental Research and Public Health*, vol. 18, no. 17, Article ID 8904, 2021.

[88] C. Bailey, A. Rubin, N. Strepparava, H. Segner, J.-F. Rubin, and T. Wahli, "Do fish get wasted? assessing the influence of effluents on parasitic infection of wild fish," *PeerJ*, vol. 6, Article ID e5956, 2018.

[89] A. Goutte and N. Molbert, "Benefits of parasitism in polluted environments: a review and perspectives," *Frontiers in Ecology and Evolution*, vol. 10, Article ID 847869, 2022.

[90] M. Ziarati, M. J. Zorriehzahra, F. Hassantabar et al., "Zoonotic diseases of fish and their prevention and control," *Veterinary Quarterly*, vol. 42, no. 1, pp. 95–118, 2022.

[91] S. Alwi, E. Susilowati, and S. K. dan Widodo, "Environmental change and modernization of fishing gear for fishermen in depok beach," in *The 6th International Conference on Energy, Environment, Epidemiology, and Information System (ICENIS 2021)*, 2021.

[92] C. Breuil and D. Grima, "Baseline report Ethiopia smart fish programme of the Indian Ocean Commission," Fisheries Management FAO component, Ebene, Mauritius, 2014.

[93] A. A. Wake and T. C. Geleto, "Socioeconomic importance of fish production and consumption status in Ethiopia: a review," *International Journal of Fisheries and Aquatic Studies*, vol. 7, pp. 206–211, 2019.
[94] T. D. Bedane, G. E. Agga, and F. D. Gutema, "Hygienic assessment of fish handling practices along production and supply chain and its public health implications in central Oromia, Ethiopia," *Scientific Reports*, vol. 12, no. 1, Article ID 13910, 2022.
[95] V. J. A. Pérez, J. C. Ángeles-Hernández, V. Vega-Sánchez et al., "Prevalence of parasitic infections with zoonotic potential in Tilapia: a systematic review and meta-analysis," *Animals*, vol. 12, no. 20, Article ID 2800, 2022.
[96] L. B. Merga, A. A. Mengistie, J. H. Faber, and P. J. Van den Brink, "Trends in chemical pollution and ecological status of Lake Ziway, Ethiopia: a review focussing on nutrients, metals and pesticides," *African Journal of Aquatic Science*, vol. 45, no. 4, pp. 386–400, 2020.
[97] "Selected fish borne zoonotic parasites in Nile tilapia and African catfish species in iakes of Haramaya district, Ethiopia," 2022, http://ir.haramaya.edu.et/hru/handle/123456789/6348.