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 trading, fish-farming, and the increased demand for 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 Contracaecum 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 Contracaecum 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°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 Claridae, 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 Thrushfield’s [46] study. So, 50% expected prevalence, 95% confidence interval, and 5% precision were used to estimate the sample size:
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:

\[
N = \frac{1.96^2 P(1 - P)}{d^2},
\]

(1)

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 \( C. \) contracaecum and \( C. \) 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

![Figure 1: Map of the study area. The map was taken directly from satellite and analyzed by ArcGIS Version 10.8.1 software.](image)
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 parasites from 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 ($\chi^2$) 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 ($\chi^2$) 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 1: Prevalence of parasite in relation to their lake and species of fishes.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of examined fish (%)</th>
<th>Number of affected fish (%)</th>
<th>Prevalence (%)</th>
<th>$\chi^2$</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Haramaya</td>
<td>149 (38.8)</td>
<td>54</td>
<td>36.2</td>
<td>4.469</td>
<td>0.107</td>
</tr>
<tr>
<td>Tinike</td>
<td>113 (29.43)</td>
<td>28</td>
<td>24.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adele</td>
<td>122 (31.77)</td>
<td>34</td>
<td>27.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species of fish (overall)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catfish</td>
<td>241 (62.76)</td>
<td>90</td>
<td>37.3</td>
<td>15.631</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Tilapia</td>
<td>143 (37.24)</td>
<td>26</td>
<td>18.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species of fish (with respect to their lake)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catfish (Haramaya)</td>
<td>68 (17.7)</td>
<td>37</td>
<td>54.4</td>
<td>17.872</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Tilapia (Haramaya)</td>
<td>81 (21.1)</td>
<td>17</td>
<td>21.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catfish (Tinike)</td>
<td>51 (13.28)</td>
<td>19</td>
<td>37.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tilapia (Tinike)</td>
<td>62 (16.15)</td>
<td>9</td>
<td>14.5</td>
<td>7.762</td>
<td>0.005</td>
</tr>
<tr>
<td>Catfish (Adele)</td>
<td>122 (31.77)</td>
<td>34</td>
<td>27.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>384 (100)</td>
<td>116</td>
<td>30.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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).
3.5. 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 provide 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.
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

![Graphs showing prevalence of parasites](image-url)
The 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.

<table>
<thead>
<tr>
<th>Parasite</th>
<th>Lake (with their species of fish)</th>
<th>Number of examined fish (%)</th>
<th>Number of affected fish</th>
<th>Prevalence (%)</th>
<th>$\chi^2$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contracaecum</strong></td>
<td>Haramaya (Catfish)</td>
<td>68 (17.7)</td>
<td>37</td>
<td>54.4</td>
<td>17.872</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td></td>
<td>Haramaya (Tilapia)</td>
<td>81 (21.1)</td>
<td>17</td>
<td>21.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tinike (Catfish)</td>
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<td>19</td>
<td>37.3</td>
<td>7.762</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Tinike (Tilapia)</td>
<td>62 (16.15)</td>
<td>9</td>
<td>14.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adele (Catfish)</td>
<td>122 (31.77)</td>
<td>33</td>
<td>27.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td>384 (100)</td>
<td>115</td>
<td>29.9</td>
<td>4.741</td>
<td>0.093</td>
</tr>
<tr>
<td><strong>Clinostomum</strong></td>
<td>Haramaya (Catfish)</td>
<td>68 (17.7)</td>
<td>12</td>
<td>17.6</td>
<td>0.107</td>
<td>0.743</td>
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<td></td>
<td>Haramaya (Tilapia)</td>
<td>81 (21.1)</td>
<td>16</td>
<td>19.8</td>
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</tr>
<tr>
<td></td>
<td>Tinike (Catfish)</td>
<td>51 (13.28)</td>
<td>9</td>
<td>16.4</td>
<td>0.930</td>
<td>0.335</td>
</tr>
<tr>
<td></td>
<td>Tinike (Tilapia)</td>
<td>62 (16.15)</td>
<td>7</td>
<td>11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adele (Catfish)</td>
<td>122 (31.77)</td>
<td>12</td>
<td>9.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td>384 (100)</td>
<td>56</td>
<td>14.6</td>
<td>4.342</td>
<td>0.114</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Location of larvae and EMC</th>
<th>Lake (with their species of fish)</th>
<th>Number of examined fish (%)</th>
<th>Number of affected fish</th>
<th>Prevalence (%)</th>
<th>$\chi^2$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body cavity</strong></td>
<td>Haramaya (Catfish)</td>
<td>68 (17.7)</td>
<td>35</td>
<td>51.5</td>
<td>19.575</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td></td>
<td>Haramaya (Tilapia)</td>
<td>81 (21.1)</td>
<td>14</td>
<td>17.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tinike (Catfish)</td>
<td>51 (13.28)</td>
<td>17</td>
<td>33.3</td>
<td>6.779</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>Tinike (Tilapia)</td>
<td>62 (16.15)</td>
<td>8</td>
<td>12.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adele (Catfish)</td>
<td>122 (31.77)</td>
<td>33</td>
<td>27.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td>384 (100)</td>
<td>114</td>
<td>29.7</td>
<td>16.260</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td><strong>Muscle</strong></td>
<td>Haramaya (Catfish)</td>
<td>68 (17.7)</td>
<td>22</td>
<td>32.4</td>
<td>5.467</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td>Haramaya (Tilapia)</td>
<td>81 (21.1)</td>
<td>13</td>
<td>16.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tinike (Catfish)</td>
<td>51 (13.28)</td>
<td>10</td>
<td>19.6</td>
<td>3.239</td>
<td>0.072</td>
</tr>
<tr>
<td></td>
<td>Tinike (Tilapia)</td>
<td>62 (16.15)</td>
<td>5</td>
<td>8.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adele (Catfish)</td>
<td>122 (31.77)</td>
<td>20</td>
<td>16.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td>384 (100)</td>
<td>70</td>
<td>18.2</td>
<td>4.471</td>
<td>0.034</td>
</tr>
</tbody>
</table>

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).
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.
Contracaecum parasite was recorded in Lake Haramaya. However, in both species of Lake Haramaya and Lake Tinike, respectively, and 19.8\% in Lake Adele, respectively, and 11.3\% in Lake Tinike, respectively. The prevalence of Contracaecum C. gariepinus parasite was recorded in Lake Haramaya (54.4\%) than Lake Tinike (37.3\%) and Lake Adele (27.0\%) and also in both species of Lake Haramaya and Lake Tinike (21.1\% and 14.5\%), respectively. The overall prevalence of Clinostomum parasite was recorded in Lake Haramaya (54.4\%) than Lake Tinike (37.3\%) and Lake Adele (27.0\%) and also in both species of 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 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 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 was 29.9\%.

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 of 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

<table>
<thead>
<tr>
<th>Sociodemographic characteristics of respondents</th>
<th>Method of preserving fish (%)</th>
<th>Inspection of fish meat for the presence of parasite (%)</th>
<th>Method of processing before consumption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RP</td>
<td>R</td>
<td>DFW</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18</td>
<td>57.7</td>
<td>19.2</td>
<td>23.1</td>
</tr>
<tr>
<td>19–30</td>
<td>46.9</td>
<td>22.4</td>
<td>30.6</td>
</tr>
<tr>
<td>&gt;40</td>
<td>68.0</td>
<td>12.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>60.3</td>
<td>15.5</td>
<td>24.1</td>
</tr>
<tr>
<td>Female</td>
<td>47.6</td>
<td>23.8</td>
<td>28.6</td>
</tr>
<tr>
<td>Participant educational status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None or preschool</td>
<td>58.3</td>
<td>20.8</td>
<td>20.9</td>
</tr>
<tr>
<td>Primary</td>
<td>45.5</td>
<td>15.2</td>
<td>39.4</td>
</tr>
<tr>
<td>Secondary</td>
<td>60.0</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Higher</td>
<td>61.1</td>
<td>22.2</td>
<td>16.7</td>
</tr>
<tr>
<td>Occupational status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishermen</td>
<td>37.9</td>
<td>31.0</td>
<td>31.1</td>
</tr>
<tr>
<td>Fish sellers</td>
<td>56.5</td>
<td>17.4</td>
<td>26.1</td>
</tr>
<tr>
<td>Consumers</td>
<td>64.6</td>
<td>12.5</td>
<td>22.9</td>
</tr>
</tbody>
</table>

Note: \( P = 0.004 \) (age group \( \times \) inspection of fish); \( P = 0.002 \) (educational status \( \times \) processing method). \( RP = \) rapping by plastic, \( R = \) refrigerator, \( DFW = \) preserve died fish in water, \( NFI = \) not familiar to inspect, \( IDE = \) inspection during evisceration, and \( IWDM = \) inspection while dissecting meat.
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], Mahdy et al. [24], Salem et al. [31], 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, silitation, 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 harvesting and 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 (≥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
The risks associated with FBZP can be avoided through the development policies need to promote food safety [13, 55]. Health, animal health, agriculture, food, trade, and industry interaction. Effective and transparent joint action between public action, as well as prevention 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.

Respondents have also stated that the government, non-governmental 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 Contracaecum 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 meat and 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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