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*Article*

# Overlooked Hotspots for *Fasciola* and *Schistosoma* Parasite Transmission at the Livestock-Wildlife Interface around Lake Mburo National Park, Uganda

**Daisy Namirembe [1,2,*], Rapheal Wangalwa [1], Anke Weisheit [3], Jovan Ssemanda [1], Jeninah Atwebembeire [1], David Mubiru [1], Casim Umba Tolo [1,3], and Julius Tumusiime [1]**

[1] Department of Biology, Mbarara University of Science and Technology, Mbarara P.O. Box 1410, Uganda

[2] School of Biological Science, Queen's University Belfast, Belfast BT7 1NN, UK

[3] Pharm-Biotechnology and Traditional Medicine Center of Excellence (PHARMBIOTRAC), Mbarara University of Science and Technology, Mbarara P.O. Box 1410, Uganda

[*] Correspondence: namirembedaisy1212@gmail.com or dnamirembe01@qub.ac.uk

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**Abstract:** *Fasciola* and *Schistosoma* parasites are of public health and economic importance. However, most interventions target human disease control, neglecting animal reservoir hosts. A cross-sectional study was conducted at Lake Mburo National Park (LMNP) livestock-wildlife interface, to determine the prevalence of *Fasciola* and *Schistosoma* parasites in cattle and wild mammals and assess watering points' potential as breeding sites for aquatic snail-vectors. Animals in ranch-lands were tracked along transects, and fresh faecal samples collected. In LMNP, samples came from animal paths and grazing areas. Parasite eggs were concentrated using the formal-ether sedimentation method and examined microscopically. Animal watering points were surveyed for 30 min to collect snail vectors, and water physicochemical conditions recorded. Differences in prevalence and snail abundance between sites were assessed using chi-square test and odds ratios were computed from binary logistic regression. *Fasciola* parasites were prevalent among buffaloes (79.6%), waterbucks (54.1%), impalas (51.6%), and cattle (45.1%), but were not detected in baboons and topis. Animals foraging in ranch-lands were more likely to contract liver-flukes (38.9%, OR = 3.374, CI: 1.73–6.561) than those in LMNP. *Schistosoma bovis* was only detected in cattle (2.2%) and buffaloes (2.2%). Watering points, especially valley dams (66.7%) in ranch-lands, harbored more snails on average. Shared grazing and water points could increase risk of parasite cross-transmission between livestock and wild mammals, as each could be reservoir for the other complicating disease control. We recommend targeted molluscicide and fencing off open water sources to reduce contact with snail-infested habitats on farmlands.

**Keywords:** Cross Transmissions; Aquatic Snails; Valley Dams; Livestock-Wildlife Interface; *Fasciola* Species; *Schistosoma bovis*; Hotspots; *Bulinus* Species

## 1. Introduction

Fasciolosis and schistosomiasis are among the most important Neglected Tropical diseases afflicting over 200 million people worldwide [1]. Fasciolosis and schistosomiasis are caused by digenean trematodes, belonging to genera *Fasciola* and *Schistosoma*, respectively. *Fasciola gigantica* and *Fasciola hepatica* are the leading causes of fasciolosis, the latter being more globally distributed and the former majorly in tropical Africa [2]. In addition to

the two major species, *F. nyanzae* is predominantly prevalent in hippos, *F. jacksoni* in elephants, especially in Asia, and *F. magna* and *F. Indica,* which are prevalent mostly in ungulates [3]. On the other hand, schistosomiasis is caused by many species specific to the final host. For example, *S. heamatobium*, *S. mansoni*, and *S. japonicum* are primarily human parasites, whereas *S. bovis*, *S. mattheei*, *S. curasoni*, and *S. rhodhaini* affect animals, including bovines, cupins, and rodents. *Schistosoma japonicum* and *S. mansoni* are zoonotic and infect humans and animals, such as buffaloes and rodents. Additionally, some *Schistosoma* species such as *S. mansoni* and *S. rodhaini*; *S. haematobium* and *S. bovis* are known to hybridize potentially increasing parasite host range [4,5].

*Fasciola* and *Schistosoma* adult flukes release eggs that are expelled in wastes (faeces or urine) by infected final hosts. In the presence of freshwater, the eggs hatch into larvae, which penetrate the appropriate snail intermediate host within 12 h after hatching [6,7]. In the snails, the larvae undergo several development stages (asexual reproduction) forming the cercariae. In the case of *Schistosoma* species, the cercariae are shed and penetrate the definitive host body through the skin while *Fasciola* cercariae attach to vegetation and encyst into metacercariae ready to be ingested by the final host in which they complete the cycle [7]. Therefore, the disease transmission risk is high in locations where intermediate host snails and the definitive mammalian hosts are likely to interface. Whereas livestock are often treated against helminths such as liver flukes, wild animals may act as reservoirs for the flukes to livestock and humans. Thus, there is need to establish the parasite burden and their transmission hotspots at the livestock-wildlife interface to strike a balance between conservation, the economic and social benefits of livestock farming.

*Fasciola* infection in cattle in Uganda causes estimated annual loss of over 92 million USD in Kampala, and over 2,703 USD in Lyantonde [8,9]. On the other hand, the prevalence of schistosomiasis among livestock and wild animals in Uganda remains highly understudied. For instance, recent estimates indicate human schistosomiasis to be highly prevalent in the Great Lakes region of Uganda with about 25% of the national human population infected [10]. However, to the best of our knowledge, data on the prevalence of schistosomiasis among animals in Uganda remains scanty, with no published national records. However, *S. bovis* has been recorded present in the Albertine region by Namirembe et al. [11]. Thus, there is need to conduct extensive studies, especially in rangeland ecosystems to assess the prevalence of fasciolosis and schistosomiasis among livestock and wildlife.

Lake Mburo National Park (LMNP) is located in Southwestern Uganda, in a rangeland ecosystem and the Masaka-Mbarara cattle corridor characterized by limited rainfall and long dry seasons. Therefore, farmers neighboring LMNP and the Uganda Wildlife Authority (UWA) constructed valley dams (ponds) in which water is collected and stored in the rainy seasons to water livestock and wild animals, respectively, during the long dry spells. Unfortunately, the valley dams are potential breeding habitats for aquatic snail, the intermediate hosts of *Fasciola* spp. and *Schistosoma* spp. Additionally, Lake Mburo National Park is surrounded by local communities whose main economic activity is cattle keeping for cultural and production (meat and milk) purposes [12]. The local communities traditionally grazed in the currently gazetted LMNP and lived side-by-side with wildlife. Unfortunately, the gazetted parkland has undergone habitat change characterized by the dominance of the shrub *Vachellia hockii* (formerly *Acacia hockii*) in most parts, leaving wild grazers with little pasture available [13, 14]. Thus, the wild mammals, especially grazers, move into the neighboring managed ranches and private land, increasing the chances of sharing grazing grounds and water sources with livestock [15]. A study by Nyamukuru [16], reported high abundance of wild mammals grazing from the community ranchlands based on environmental dung counts, which could result in increased chances of parasite cross-transmission. Therefore, the pastoralist communities around the LMNP stand a high risk of economic losses arising from low livestock productivity, stunted growth, and increased susceptibility to other infections due to liver flukes and schistosome infections [8,10].

Despite the high disease risk described above, data on *Fasciola* and *Schistosoma* spp. prevalence in communities around LMNP and the role of watering points, especially the valley dams, as potential breeding sites for snail intermediate hosts remains scanty. Therefore, this study aimed to 1) determine the prevalence of *Fasciol*a and *Schistosoma* spp. in cattle and wild mammals, and 2) assess the potential of watering points, especially valley dams, as breeding sites for snail hosts of *Fasciola* and *Schistosoma* parasites. This study provides baseline data for monitoring and controlling schistosomiasis and fasciolosis outbreaks in livestock and wildlife.

## 2. Methods

### 2.1. Study Area

Lake Mburo National Park (LMNP) is located at 0°19′ to 0°37′ N and 30°46′ to 31°04′ E in Southwestern Uganda [17] within the rangelands and the Masaka-Mbarara cattle corridor (**Figure 1**). The average altitude is about 1,210 m above sea level. The LMNP and the area around it are characterized by a semi-arid savannah climate in which the minimum annual rainfall ranges from 400 mm in the southeast to 700 mm in the west. However, the park and its environments are drier than the surrounding region, lying in a rain shadow caused by the Kabula hills. Rainfall is bimodal, occurring mainly from March to May and between September and November. The LMNP experiences a long, dry season between May and August and a shorter one from December to February. The mean maximum temperature is approximately 27.5 °C, and the mean minimum is 15 °C. Relative humidity is high, averaging between 61% and 84% [17]. Permanent or seasonal swamps and lakes occupy some of the valleys.

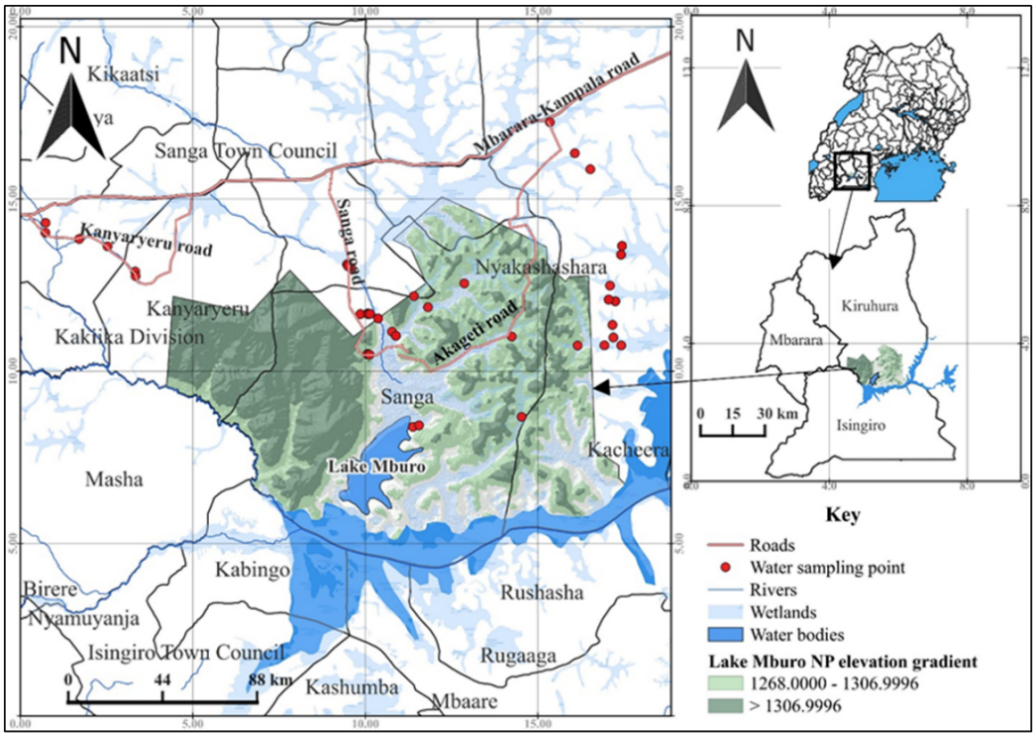


**Figure 1.** A map showing the study area, Lake Mburo National Park and neighboring ranchlands.

### 2.2. Methods of Data Collection

A cross-sectional study was conducted from July to September 2023 and involved collecting animal faecal samples from Lake Mburo National Park (LMNP) and the neighboring community ranchlands in Kirihura district.

#### 2.2.1. Faecal Sample Collection

Faecal samples were collected from both cattle and wild mammals in the ranch-lands along three transects, which included Sanga (11.89 km), Akageti (25.99 km), and Kanyaryeru (7.97 km). The transects were roads leading to LMNP from the Mbarara Kampala highway, along which the cattle ranches, local herds grazing grounds, settlements, and animal watering points were located. Large mammals found in the cattle grazing areas and watering points along the three transects were followed closely, collecting freshly dropped faeces. Overall forty-three (43) sites, including grazing areas, and watering points along the transects were sampled. The sampled sites were fairly distributed along the transects: 16, 13, and 14 sites along the Sanga, Akageti, and Kanyaryeru transects, respectively.

At every site, cattle and wild mammals were followed closely for about 30–60 min. Using an applicator stick,

10 g of freshly dropped faeces were collected and weighed using a digital Ohaus Hand-Held Scale Series Models HH 120. The sample was then preserved immediately in 10% formal saline solution, stored, and later transported to Mbarara University of Science and Technology (MUST) biology laboratory for examination. Fresh faecal samples were identified by directly observing the animal defecating, and immediately collected (observation based collection). Secondly, targeted search (hot sampling) was conducted whereby dung pats were inspected and those that were still warm, moist, and glossy were collected, avoiding dry or cracked samples that had stayed for more than 12 h.

Secondly, in the LMNP, fresh faecal samples collection was carried out under the protection and guidance of the game rangers. The samples were collected from cattle, buffaloes, baboons, impalas, zebras, elands, waterbucks, topis, warthogs, and hippopotami considering their behavioral patterns and the safety of the researchers. For zebras, impalas, eland, topis, and waterbucks, freshly dropped faecal samples were obtained by following them closely within their grazing spots and using the hot sampling technique. For the case of hippopotami, two trails (about 4 km long) stretching from Lake Mburo to their grazing spots, were followed in the early morning hours (between 7 am and 12 noon) and the fresh faecal samples dropped the previous night were collected. Additionally, trails (about 2 km) for buffaloes were also followed, collecting freshly dropped faecal samples. Actively grazing and resting buffaloes were scared using a field vehicle, and as they fled, they deposited faeces from which a sample was collected. Precaution was taken to ensure that subsequent samples were at least five meters apart to avoid multiple sampling of the same individual animal. Cattle faecal samples were also collected from LMNP, mainly in areas close to the boundary separating the park from the community ranchlands.

All samples were immediately added 10% formal saline solution and transported to the MUST biology laboratory. In the laboratory, all fecal samples were subjected to the formal ether sedimentation technique to concentrate the parasite eggs. The final concentrated sediment was observed under a compound microscope at X100 magnification to check for the presence of *Fasciola* and *Schistosoma* parasite eggs using existing identification keys [18,19]. The spindle-shaped eggs, with a broad middle portion and drawn-out rod-like ends with a terminal spine with a length ranging between 139 to 251 µm and a breadth of 39 to 81 µm were identified as *Schistosoma* species [20–22]. Eggs with a yellowish-brown color, ellipsoidal shape with a thin, smooth shell, an operculum at one end and measuring 130–150 µm length and 63–90 µm breadth were identified as *Fasciola* species [23,24] (**Figure 2**).

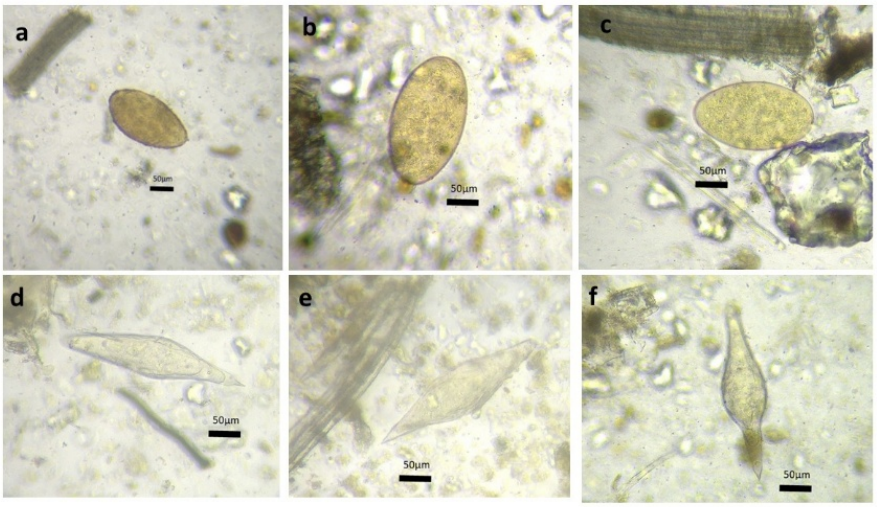


**Figure 2.** (**a**)–(**c**) Pictures of *Fasciola* species, (**d**)–(**f**) *Schistosoma bovis*.
Note: Scale bar = 50 µm; Magnification = X100.

### 2.2.2. Snail Sampling

Watering points sampled included accessible points at the shores of Lake Mburo, streams/wetlands, and valley dams in LMNP and the ranchlands. At each watering point key information such as whether the valley dam was fenced, presence of vegetation, mode of water delivery to animals, and snail presence was recorded. Aesthetic water

parameters (water temperature, pH, electrical conductivity (EC), turbidity, total dissolved solids (TDS), salinity, and dissolved oxygen (DO)) were measured *in situ* using a Hanna multi-probe meter, model HI98194. The parameters were measured in triplicate at each watering point and the average value recorded.

At each watering point, freshwater snail intermediate hosts of *Schistosoma* and *Fasciola* species were actively searched for 30 min using the scooping method [25]. The snails were transported to the MUST biology laboratory, where they were identified to the species level based on morphology using an identification key. Key morphological features including shell characteristic like dextra or sinistral aperture, size and shape of the aperture, shape and size of the spire relative to the snail body and aperture lengths as described by David Brown and Mandahl-Barth [26,27].

The study was approved by the Research Ethics Committee (REC) of Mbarara University of Science and Technology under reference number MUST-2023-1148. The Uganda Wildlife Authority also approved the study and offered a research permit under reference number COD/96/05. In addition, informed verbal consent and official permissions were obtained from each study participant, especially the persons in charge of each ranch and animal watering point.

### 2.3. Data Analysis

The apparent prevalence of the parasite infections was determined by expressing the number of positive samples as a percentage of the total number of samples obtained from each category of animals. A chi-square test was performed to assess the difference in the frequency of animals infected with *Fasciola* and *Schistosoma* parasites. A binary logistic regression was also conducted to determine the odds ratios (which were also interpreted as the likelihood of contracting the parasites) and the confidence interval of animals from ranch-lands and LMNP. The non-parametric Kruskal-Wallis test was performed to determine whether there was a significant difference in the water parameters from different watering points since the data was not normally distributed. A chi-square test was also performed to determine if there was a difference in the abundance of snails obtained from watering points in the community ranch-lands and LMNP. All the tests were conducted in SPSS version 20 at a 95% confidence interval.

## 3. Results

### 3.1. Prevalence of *Fasciola* spp. and *Schistosoma bovis*

Overall, 553 faecal samples were collected constituting 415 cattle, 6 elands, 9 impalas, 9 waterbucks, 111 zebras, and 1 hippopotamus from the ranch-lands. However, no samples from buffaloes, baboons, or topis were obtained from the ranch-lands. On the other hand, a total of 332 samples were obtained in LMNP from baboons (n = 19), buffaloes (n = 93), hippopotami (n = 20), waterbucks (n = 28), elands (n = 4), impalas (n = 22), zebras (n = 88), topis (n = 7), warthogs (n = 23), and cattle (n = 28), respectively (**Table 1**).

**Table 1.** Prevalence of *Fasciola* species in cattle and wild mammals from the ranch-lands and Lake Mburo National Park (LMNP).

| Variable | n | Positives | Prevalence (%) | R | SE | *p*-Value | OR | 95% CI | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower | Upper |
| **1. Animal** | | | | | | | | | |
| Baboons | 19 | 0 | 0 | −16.708 | 9,220.900 | 0.999 | 0.000 | 0.000 | – |
| Buffaloes | 93 | 74 | 79.6 | 5.855 | 0.589 | <0.001 | 348.931 | 110.052 | 1,106.323 |
| Cattle | 443 | 200 | 45.1 | 3.151 | 0.467 | <0.001 | 23.356 | 9.343 | 58.389 |
| Eland | 10 | 4 | 40 | 3.318 | 0.812 | <0.001 | 27.599 | 5.623 | 135.459 |
| Hippo | 21 | 2 | 9.5 | 2.154 | 0.907 | 0.018 | 8.618 | 1.457 | 50.976 |
| Impala | 31 | 16 | 51.6 | 4.224 | 0.616 | <0.001 | 68.326 | 20.413 | 228.702 |
| Topi | 7 | 0 | 0 | −16.708 | 15,191.515 | 0.999 | 0.000 | 0.000 | – |
| Warthog | 25 | 1 | 4 | 1.154 | 1.140 | 0.311 | 3.172 | 0.339 | 29.650 |
| Waterbuck | 37 | 20 | 54.1 | 4.386 | 0.604 | <0.001 | 80.319 | 24.600 | 262.240 |
| Zebra | 199 | 5 | 2.5 | – | | | 1.00 | Reference | |
| **2. Location** | | | | | | | | | |
| LMNP | 332 | 107 | 32.2 | −1.216 | 0.339 | <0.001 | 0.296 | 0.152 | 0.576 |
| Ranchlands | 553 | 215 | 38.9 | 1.216 | 0.339 | <0.001 | 3.374 | 1.735 | 6.561 |

Note: n: sample size, SE: Standard Error, OR: Odds ratio, CI: Confidence interval, R: Correlation coefficient. (–): The upper confidence interval could not be calculated (approaching infinity) due to zero cell count or prevalence as no participants in this category were positive for *Fasciola* species infection.

A considerably high number of wild animals grazing and sharing water sources were observed in ranch-lands, including zebras, waterbucks, impalas, elands, and hippopotami, among others (**Table 1**). *Fasciola* parasites were detected in both cattle and wild mammals. Buffaloes (79.6%) presented the highest prevalence, followed by waterbucks (54.1%), impalas (51.6%), cattle (45.1%), and elands (30%) ($\chi^2 = 802.75$, $p < 0.001$). *Fasciola* parasites were also detected among zebras, warthogs, and hippos at a prevalence of less than 10%. However, no *Fasciola* infections were detected among the baboons and topis (**Table 1**). Additionally, based on the odds ratios computed using a binary logistic regression test, buffaloes (OR = 348.931) were most likely to contract liver flukes (*Fasciola* spp.), followed by waterbucks (OR = 80.319), while warthogs (OR = 3.172) presented the lowest (**Table 1**) in reference to zebras.

It was also observed that most of the animals infected with *Fasciola* parasites were from the ranchlands at a prevalence of 38.9% and 3.374 times more likely to contract the parasites than those from LMNP (32.2% and an odds ratio = 0.152). Additionally, the high liver flukes' prevalence in the community ranch-lands was mainly contributed to by cattle, zebras, waterbucks, elands, and impalas. On the other hand, buffaloes, waterbucks, impalas, cattle, elands, warthogs, hippos, and zebras in that order were the main contributors to the prevalence obtained for LMNP (**Figure 3**).

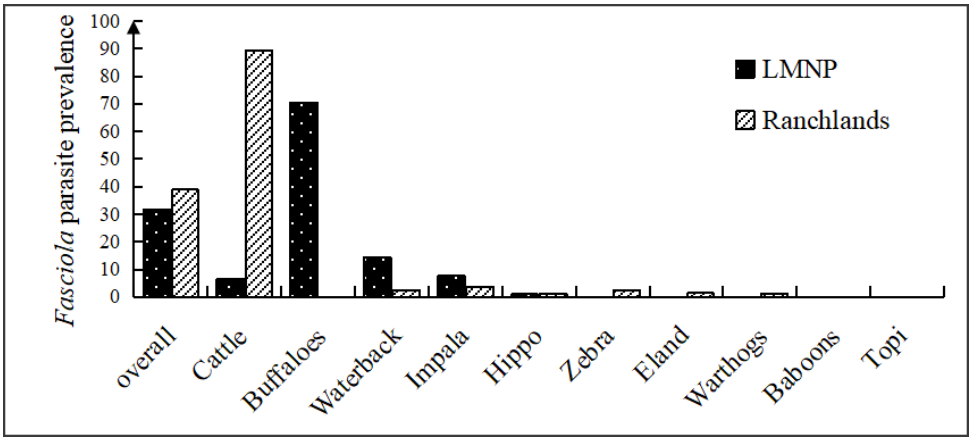


**Figure 3.** Prevalence of *Fasciola* parasites in cattle and wild mammals from ranch-lands and Lake Mburo National Park.

On the other hand, *Schistosoma bovis* was detected in cattle and buffaloes only (overall 11 out of 885 animals). The prevalence of *S. bovis* in cattle from community ranchlands was 2.2% (n = 415) and 2.2% (n = 93) in buffaloes from the LMNP (**Table 2**). Additionally, all animals infected with *Schistosoma bovis* were negative for *Fasciola* parasites.

**Table 2.** Prevalence of *Schistosoma bovis* (%) among animals in Lake Mburo National Park (LMNP) and surrounding ranch-lands.

| Animals | Total (n) | LMNP | | | Ranchlands | | |
|---|---|---|---|---|---|---|---|
| | | n | Positive | % | n | Positive | % |
| Baboons | 19 | 0 | 0 | 0 | 0 | 0 | 0 |
| Buffaloes | 93 | 93 | 2 | 2.2 | 0 | 0 | 0 |
| Cattle | 443 | 28 | 0 | 0 | 415 | 9 | 2.2 |
| Eland | 10 | 4 | 0 | 0 | 6 | 0 | 0 |
| Hippo | 21 | 20 | 0 | 0 | 1 | 0 | 0 |
| Impala | 31 | 22 | 0 | 0 | 9 | 0 | 0 |
| Topi | 7 | 7 | 0 | 0 | 0 | 0 | 0 |
| Warthogs | 25 | 23 | 0 | 0 | 2 | 0 | 0 |
| Waterbuck | 37 | 28 | 0 | 0 | 9 | 0 | 0 |
| Zebra | 199 | 88 | 0 | 0 | 111 | 0 | 0 |
| Total | 885 | 332 | 2 | 0.60 | 553 | 9 | 1.63 |

Note: n: sample size; %: percentage prevalence, LMNP: Lake Mburo National Park.

## 3.2. Animal Watering Points Exposure and Snail Abundance

A total of 36 watering points, including valley dams (n = 29), streams/wetlands (n = 5) and accessible points to Lake Mburo (n = 2) were sampled.

It was observed that privately owned valley dams were cleared of aquatic vegetation. Therefore, 17.2% (n = 5) valley dams had no aquatic vegetation covering the edges and in the water which would affect aquatic snail survival. It was also observed that most of the ranches 48.3% (n = 14), livestock especially cattle drunk directly from the valley dams, followed by troughs 34.5% (n = 10) to which were pumped from the valley dams. Lastly, at 17.2% (n = 5) valley dams, herders fetched water manually from the valley dams to the trough for animal drinking (**Table 3**), and this increases the risk of contracting aquatic snail-borne parasitic infections.

**Table 3.** Observations recorded at the animal watering points.

| Variable | Observations | Valley Dams (n (%)) | Streams/Wetlands (n (%)) | L. Mburo (n (%)) | Total (n (%)) |
|---|---|---|---|---|---|
| Mode of watering | Pumped | 10 (34.5) | 0 | 0 | 10 (27.8) |
| | Direct from the dam | 14 (48.3) | 5 (100) | 2 (100) | 21 (58.3) |
| | Manual fetching | 5 (17.2) | 0 | 0 | 5 (13.9) |
| Vegetation present | Yes | 24 (82.8) | 4 (80) | 1 (50) | 29 (80.6) |
| | No | 5 (17.2) | 1 (20) | 1 (50) | 7 (19.4) |
| Snails present | Yes | 19 (65.5) | 4 (80) | 1 (50) | 24 (66.7) |
| | No | 10 (34.5) | 1 (20) | 1 (50) | 12 (33.3) |
| *Radix sp.* | Yes | 13 (44.8) | 4 (80) | 0 | 17 (47.2) |
| | No | 16 (55.2) | 1 (20) | 2 (100) | 19 (52.8) |
| *Bulinus spp.* | Yes | 12 (41.4) | 4 (80) | 1 (50) | 17 (47.2) |
| | No | 17 (58.6) | 1 (20) | 1 (50) | 19 (52.8) |
| *Biomphalaria spp.* | Yes | 1 (3.4) | 0 | 0 | 1 (2.8) |
| | No | 28 (96.6) | 5 (100) | 2 (100) | 35 (97.2) |

It was also observed that 24 (66.7%) of the watering points were inhabited by snail intermediate hosts for *Fasciola* species and *Schistosoma* species, that is; *Radix natalensis* and *Bulinus* species, respectively (**Table 3**).

*Radix natalensis* presented the highest abundance (n = 553), followed by *B. truncatus* (n = 473), *B. forskalii* (n = 155) and lastly, *Biomphalaria* (n = 30) species ($p = 0.000$; $\chi^2 = 620.422$; **Figure 4a**). *Biomphalaria pfeifferi* snails, the intermediate hosts for *S. mansoni*, were only obtained from one of the valley dams located in the ranchlands.

Of the 553 *R. natalensis* snails obtained, 94.21% were from valley dams in ranch-lands, and none from park valley dams and Lake Mburo ($p = 0.00$; $\chi^2 = 247.6$; **Figure 4b**). Similarly, of the 473 *B. truncatus* obtained, 95.77% were collected from valley dams in ranch-lands and none from any of the watering points in the LMNP ($p = 0.00$; $\chi^2 = 396.38$). Lastly, a total of 155 *B. forskalii* were obtained; 92.9% were collected from the valley dams in the ranchlands, 4.52% from Lake Mburo access points, and lastly, 2.58% from the valley dams in LMNP ($p = 0.00$, $\chi^2 = 247.6$; **Figure 4b**).

Therefore, the average number of snails intermediate hosts for liver fluke and schistosomes was highest among water sources located in community ranchlands compared to those in LMNP. The average number of *R. natalensis*, *B. truncatus* and *B. forskalii* (19, 17, and 6 snails per site, respectively) was highest in valley dams in ranch-lands followed by streams/wetlands in ranch-lands (16, 10, and 2 snails per site, respectively), followed by Lake Mburo access points (0, 0 and 6 snails per site, respectively) (**Figure 4c**).

Water parameters were measured as summarized in **Table 4**. Lake Mburo presented the highest mean pH (8.01 ± 0.11). Valley dams from both LMNP and in the ranch-lands had a neutral mean pH of 7.78 ± 0.12 and 7.271 ± 0.06, respectively, and it was lowest in wetland/streams in the ranchlands (6.45 ± 0.14; $p < 0.001$). Temperatures varied significantly between different watering points and ranged between 18 °C and 25 °C ($p < 0.001$). Valley dams in LMNP presented the highest mean Total Dissolved Solids (TDS) at 240.66 ± 16.84 mg/L, followed by streams in ranchlands (181.67 ± 37.28 mg/L) and lowest at Lake Mburo access points (78.5 ± 1.77 mg/L; $p = 0.001$). Generally, salinity levels were low and ranged between 0.03 and 0.33 psu across all watering points, and the highest mean was observed among Valley dams in LMNP (0.23 ± 0.02 psu, $p = 0.002$). Valley dams in LMNP showed the highest mean turbidity (165.48 ± 12.13 FNU) and electrical conductivity (482.11 ± 34.16 µsm) compared to the rest of the sites ($p = 0.018$ and $p = 0.001$ respectively, **Table 4**). Dissolved Oxygen (DO) significantly varied between watering points. Lake Mburo access points (5.46 ± 0.61 mg/L) and the valley dam in ranch-lands (3.04 ± 0.18 mg/L) presented the highest mean DO, while the wetland/streams in ranch-lands (1.83 ± 0.04) and valley dams in LMNP (0.96 ±

0.4 mg/L) presented the lowest ($p$ = 0.000, **Table 4**). Statistical analysis of water parameters indicated that they significantly vary across all the sites (all $p$-values < 0.05, **Table 4**).

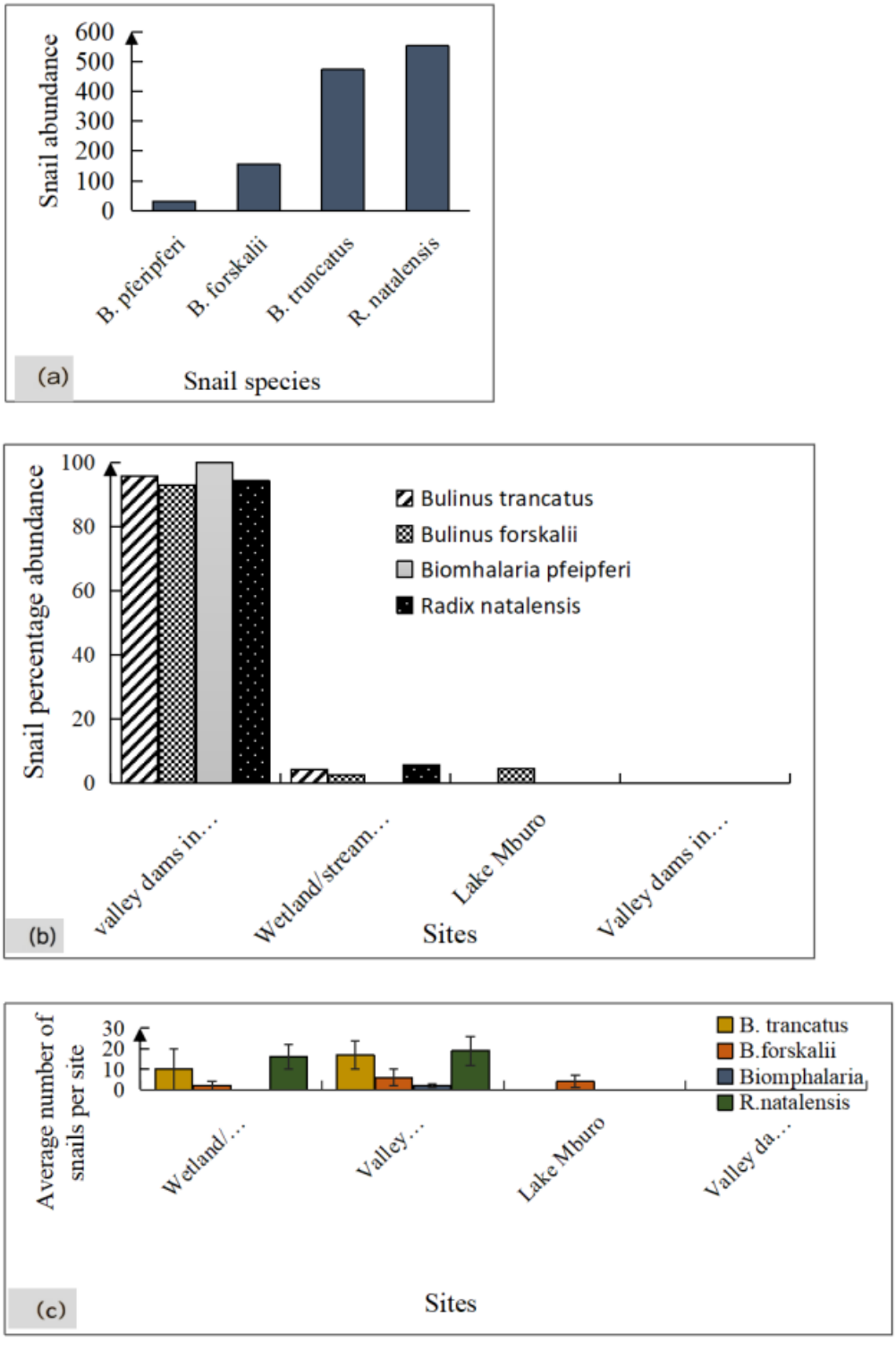


**Figure 4.** Abundance of snail intermediate hosts collected from different watering points in ranchlands and Lake Mburo National Park. (**a**) Number of aquatic snail species obtained, (**b**) Total percentage of snail species obtained at different sites, (**c**) Average number of snail species obtained per site.

**Table 4.** Physical-chemical water parameters for the different watering points for cattle and wild mammals.

| Parameter | Type of Water Source | Min | Max | Mean ± SE | *p*-Value |
|---|---|---|---|---|---|
| pH | Valley dams in ranchlands | 6.26 | 9.22 | 7.271 ± 0.06 | <0.001 |
| | Wetland/Streams in ranchlands | 6.12 | 6.85 | 6.45 ± 0.14 | |
| | Valley dams in LMNP | 7.44 | 8.4 | 7.78 ± 0.12 | |
| | LMNP | 7.84 | 8.55 | 8.01 ± 0.11 | |
| Temperature (°C) | Valley dams in ranchlands | 18 | 29.64 | 23.75 ± 0.3 | 0.001 |
| | Wetland/Streams in ranchlands | 20.25 | 22.04 | 20.94 ± 0.26 | |
| | Valley dams in LMNP | 20.45 | 26.84 | 22.69 ± 0.86 | |
| | LMNP | 25.12 | 26.3 | 25.81 ± 0.2 | |
| TDS (mg/L) | Valley dams in ranchlands | 37 | 341 | 118.31 ± 10.41 | 0.001 |
| | Wetland/Streams in ranchlands | 95 | 266 | 181.67 ± 37.28 | |
| | Valley dams in LMNP | 196 | 315 | 240.66 ± 16.84 | |
| | LMNP | 74 | 84 | 78.5 ± 1.77 | |
| Salinity (psu) | Valley dams in ranchlands | 0.03 | 0.33 | 0.12 ± 0.01 | 0.002 |
| | Wetland/Streams in ranchlands | 0.09 | 0.26 | 0.18 ± 0.04 | |
| | Valley dams in LMNP | 0.19 | 0.31 | 0.23 ± 0.02 | |
| | LMNP | 0.07 | 0.08 | 0.08 ± 0.0001 | |
| Turbidity (mg/L) | Valley dams in ranchlands | 3.1 | 294 | 51.35 ± 7.42 | 0.018 |
| | Wetland/Streams in ranchlands | 3.3 | 43.2 | 25.14 ± 4.02 | |
| | Valley dams in LMNP | 0 | 285 | 165.48 ± 12.13 | |
| | LMNP | 44.1 | 89.2 | 60.12 ± 7.97 | |
| EC (µS/cm) | Valley dams in ranchlands | 73 | 682 | 237.25 ± 20.82 | 0.001 |
| | Wetland/Streams in ranchlands | 189 | 532 | 363.33 ± 74.56 | |
| | Valley dams in LMNP | 390 | 633 | 482.11 ± 34.16 | |
| | LMNP | 149 | 168 | 157.5 ± 3.57 | |
| DO (mg/L) | Valley dams in ranchlands | 0.26 | 7.06 | 3.04 ± 0.18 | <0.001 |
| | Wetlands/Streams in ranchlands | 1.72 | 1.98 | 1.83 ± 0.04 | |
| | Valley dams in LMNP | 0.22 | 3.35 | 0.96 ± 0.4 | |
| | LMNP | 2.99 | 6.88 | 5.46 ± 0.61 | |

Note: DO: Dissolved Oxygen; EC: Electro conductivity; TDS: Total Dissolved Solids; Min: Minimum; Max: Maximum; SE: Standard Error.

## 4. Discussion

### 4.1. Prevalence of *Fasciola* Parasites and *Schistosoma bovis*

The current study revealed a considerably high number of wild animals grazing and sharing water sources in the ranch-lands, including zebras, waterbucks, impalas, elands, and hippopotami, among others (**Table 1**), and a similar observation was reported by Nyamukuru, 2019 [16].

*Fasciola* parasites were detected in both cattle and wild mammals. Buffaloes (79.6%, OR = 348.931), waterbucks (54.1%, OR = 80.319), and impalas (51.6%, OR = 68.326) presented highest apparent prevalence and likelihood of contracting liver flukes than cattle (45.1%, OR = 23.356). This was attributed to no anthelmintic treatment given to wild mammals and their higher access to water and vegetation contaminated with *Fasciola* infective stage compared to cattle. The current study presented a higher prevalence rate of *Fasciola* parasite infection in buffaloes (79.6%) compared to that reported by Pandya et al. [28] at 26.98% in Ahmadabad district, India. Similarly, a lower prevalence of 32% of *Fasciola hepatica* in water buffaloes raised in the Notecka Forest region in the Wielkopolska Province, Poland and 9.8% of the free-ranging African buffaloes in protected wildlife areas in Tanzania were reported infected with *Fasciola* species [29,30].

In this study liver flukes were detected in both cattle and buffaloes; however, the prevalence was higher in buffaloes than in cattle at 79.6% and 45.1%, respectively. This was in agreement with Gupta et al. [31], who reported a higher prevalence of *Fasciola gigantic* in buffaloes (6.77%) than in cattle (0.99%) in Jabalpur, Madhya Pradesh, India, also in Minas Gerais, Brazil at 18.75% in cattle and 28.37% in buffaloes [32] and as well in Qena, Egypt with the incidence at 3.43% and 4.26%, in cattle and buffaloes, respectively [33]. The *Fasciola* spp. infection in cattle and wild mammals was attributed to animals grazing on grass contaminated with metacercariae in water-logged places and drinking from watering points infested with *Radix* snails which were observed in 66.7% of the watering points in the study area. Additionally, wild mammals like buffaloes, waterbucks, elands, and impalas presented a higher prevalence and likelihood of contracting *Fasciola* spp. than cattle. This was attributed to the feeding ecology of the animals and their resistance to infection. For example, impalas and elands are exposed to the helminths of both browsers and grazers; waterbucks like water, are good swimmers, and flee into water if pursued [34] whereas hippopotami are amphibious and are mostly in water during the day, placing them at a high risk of grazing pasture contaminated with *Fasciola* metacercariae. Additionally, since impalas, waterbucks, zebras, and hippopotami shared pastures and watering points with livestock on the ranch-lands, a considerable overlap

between the helminth fauna of cattle, and wild mammals occurs. A similar observation was reported on ranches in South Africa where impalas shared grazing grounds and drinking water with livestock such as sheep and cattle.

It was also observed that most infected animals with *Fasciola* parasites were from the ranch-lands (38.9%) and they were 3.374 times more at risk of getting infected than those animals from the LMNP. This was attributed to the availability of more water sources particularly valley dams harboring a higher abundance of *Radix natalensis,* the intermediate host for *Fasciola* parasites which qualifies them as transmission hot spots in the ranch-lands. Additionally, the ranch-lands are composed of large open grasslands, which attract wild mammals from LMNP and consequently increase interaction between wild mammals and livestock and the risk of cross-transmission of *Fasciola* parasites.

*Schistosoma bovis* was observed in cattle (2.2%) and buffaloes (2.2%) from the community ranch-lands and LMNP, respectively. Similarly, Namirembe et al. 2024 [11] reported *S. bovis* in cattle and goats from the regions south of Lake Albert, Uganda. This was attributed to the presence of high abundance of *Bulinus* species, the confirmed intermediate hosts for *S. bovis* [35], recorded in the watering points, particularly valley dams in the ranch-lands and Lake Mburo access points, often used by either cattle or wild mammals. The buffaloes by nature intend to graze over swampy or water-logging pastures, and bath mad which favors the propagation and contraction of the developmental stages of the parasite [36]. *Schistosoma* parasites were not detected in waterbucks, impalas, elands, baboons, hippos, and toppis. This was contrary to previous studies where waterbucks were reported as primary definitive hosts for *S. leiperi* [35] and 18% waterbucks from Yankari Game Reserve and Sumu Wildlife Park in Bauchi State in Nigeria were infected with *Schistosoma* spp [37]. In the current study, it was observed that most of the animal watering points, especially valley dams, had snail intermediate hosts for *Schistosoma* parasites and had aquatic vegetation, which increases the risk of transmission of the snail-borne parasitic diseases [38]. Both cattle and wild mammals are naturally infected with *Fasciola* and *Schistosoma* parasites, serving as reservoirs for each other.

## 4.2. Are Animal Watering Points Parasite Transmission Hotspots?

Twenty-four out of thirty-six (66.7%) watering points had snails morphologically identified as *R. natalensis*, *B. truncatus*, *B. forskalii*, and *Biomphalaria pfeiferi* which are known intermediate hosts for *Fasciola* and *Schistosoma* parasites. *Radix natalensis* presented the highest abundance compared to *Bulinus* and *Biomphalaria* species. Similar observations have been reported in Zobe Dam, Dutsin-Ma, North-West, with 47.94% *R. natalensis*, 29.93% *B. tropicus* and 26.14% *B. forskalii* [39]. On the contrary, higher abundances of the schistosome competent snails, the *Bulinus* species, were reported in KwaZulu-Natal province [40] and from manmade water bodies in Imire Rhino, Wildlife Conservancy and Mhakwe villages, Wedza district of Zimbabwe [41]. The presence of snail intermediate hosts, especially in the valley dams, was attributed to the favorable conditions such as the temperature (20–25 °C) of the watering points [42] and as well as the ability of snails like *R. natalensis* to occur throughout the dry and rainy seasons [43].

Over 90% of the snails collected were obtained from valley dams in ranch-lands and less than 10% from both streams/wetlands and Lake Mburo access points. However, no snails were obtained from Valley dams in LMNP. This was contrary to the report by Mudavanhu et al. 2024 [41] where they obtained more freshwater snails in streams (n = 64, 81%) and fewer (n = 15, 19%) in dams in KwaZulu-Natal province. Additionally, the average number of snails per site was highest in valley dams (6–19 snails per site) followed by streams/wetlands in ranchlands (2–16 per site), Lake Mburo access points (0–6 snails per site) and lastly valley dams from LMNP. On the contrary, a higher snail abundance ranging between 0 and 173 per site, in villages and the lowest in the farm section outside conservancy areas in Imer in Zimbabwe was observed [41]. More to that snails were obtained in the built-up areas compared to the farmland in Nigeria [43]. Furthermore, snails including *Radix*, *Bulinus* or *Biomphalaria* species were not observed in an artificial lake, Bakolori Reservoir in Zamfara State, Nigeria [44]. The presence of snail intermediate hosts in watering points in this study, was associated with their favorable conditions for snails' survival, including optimal water physicochemical conditions, presence of vegetation, organic matter, and limited disturbances of the water from large mammals observed in most valley dams and other watering points in the ranch-lands. Unlike the valley dams in LMNP, from which no live snails were obtained because of the highly disturbed water from frequent wild mammals stumbling such as hippopotami. Additionally, very low dissolved oxygen and high turbidity were recorded in the Valley dams in LMNP, which could not be favorable for snail intermediate host survival. The *Bulinus*

species groups were noticed only in valley dams in ranch-lands and Lake Mburo access points. This was attributed to the ability to colonize various environments, including the crater lakes, lakes [44–47] and in the Afromontane regions highlands, with the average altitudinal range between 639 m and 1,317 m [47] and dams [48].

In addition to harboring snail intermediate hosts, valley dams located in the ranch-lands, herders were involved in risky behaviors that could maintain the liver flukes and schistosome life cycle. These included letting livestock drink direct from the valley dams, which exposed them to the infective larval stages of the parasites. It was also observed that some herders stepped direct in the valley dams drawing water for livestock to drink, which predisposes them to *Schistosoma* cercariae infections.

The observations above suggest that while solutions such as constructing valley dams help mitigate climate change effects like water scarcity, they are also habitats for disease vectors, thereby expanding their distribution and sustaining the parasite lifecycle. Therefore, it is crucial to balance climate change mitigation efforts with vector control, particularly in regions with high levels of livestock, wildlife, and human interactions.

This study was limited by the reliance on morphological identification of parasite eggs and aquatic snails, which may cause misidentification, particularly among cryptic groups such as *Bulinus* group species. Additionally, faecal egg detection may underestimate prevalence due to intermittent shedding and low infection intensity, underscoring the need for molecular techniques.

## 5. Conclusions

In summary, *Fasciola* species were found in both cattle and wild mammals, whereas *Schistosoma bovis* appeared only in cattle and buffaloes. Water sources located in ranch areas provide more suitable environments for snail intermediate hosts of helminths than those within LMNP, where frequent animal activity disrupts snail habitats. Therefore, although dams are valuable for water storage, they can also serve as significant hotspots for the development and spread of waterborne parasites, especially in areas where they can attract numerous mammals and facilitate high levels of animal interaction. Fencing away water reservoir dams, use of water trough to avoid livestock direct contact with water harboring snails and most importantly use of eco-friendly molluscicides to completely break the parasite life cycle is recommended.

## Author Contributions

D.N.: conceptualization of the research study, acquisition of funding, organized and conducted fieldwork for sample collection, did the lab work including examination of samples and recording of data, analyzed and interpreted data; wrote the manuscript and revised the manuscript. R.W.: conceptualization of the study and funding application. J.T.: study conceptualization, participated in fieldwork and data collection, and revision of the manuscript. A.W.: conceptualization and writing of the research study. D.M.: supported and participated in field work and data collection, and revised the manuscript. J.S.: assisted in lab work including examination of samples and creation of the study area map. C.U.T.: conceptualization and writing of the research idea. J.A.: supported in the fund acquisition and revision of the manuscript. All authors have read and agreed to the published version of the manuscript.

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## Data Availability Statement

All data generated or analyzed during this study are included in this published article.

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## Conflicts of Interest

The authors declare no conflict of interest.

## AI Use Statement

The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

## Abbreviations

| Abbreviation | Full Name |
|---|---|
| CI | Confidence Interval |
| LMNP | Lake Mburo National Park |
| MUST | Mbarara University of Science and Technology |
| OR | Odds Ratio |
| Spp. | Species |
| USD | United States dollar |
| UWA | Uganda Wildlife Authority |

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