

# Snail intermediate-host occurrence recorded by citizen scientists in rural Uganda and the Democratic Republic of the Congo

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## Abstract

Snail-borne parasitic diseases, such as schistosomiasis and fascioliasis, pose significant public health and economic challenges worldwide. Schistosomiasis affects over 250 million people globally, with most cases occurring in sub-Saharan Africa (SSA), while fascioliasis contributes substantially to livestock morbidity and economic losses. Freshwater snails (*Biomphalaria*, *Bulinus*, and *Radix* spp.) act as intermediate hosts, making their surveillance critical for disease control. Mass drug administration (MDA) alone is insufficient, as high reinfection rates highlight the need for complementary strategies, including targeted snail control. To address limited malacological capacity and logistical constraints, the ATRAP project trained 50 citizen scientists in Uganda and the Democratic Republic of the Congo to monitor intermediate host snails at the genus level. Between 2020 and 2023, citizens recorded 28977 snail occurrences. Data quality was ensured through automatic validation and manual verification of submitted snail pictures. This rigorously curated dataset, combining citizen science with expert validation provides valuable insights for mapping snail distributions, identifying high-risk transmission areas, and developing sustainable, cost-effective snail control strategies.

**Keywords:** snail-borne diseases; citizen science; schistosomiasis; fascioliasis; neglected tropical diseases; Africa; data quality

## 1 Background

Snail-borne parasitic diseases present major public health and veterinary challenges across tropical and subtropical regions [1]. Schistosomiasis, caused by parasitic flatworms of the genus *Schistosoma*, affects more than 250 million people globally, with the majority of cases occurring in sub-Saharan Africa (SSA) [2]. Chronic infections are associated with anaemia, stunted growth, cognitive impairment, and reduced aerobic capacity [3]. Depending on the organs affected, schistosomiasis can also lead to hematuria, infertility, liver and urinary tract fibrosis, and even bladder cancer [3]. In livestock, schistosomiasis is caused by *Schistosoma*

*bovis*, *S. curassoni*, and *S. matthei*, and widespread contributing significantly to animal morbidity [4]. Fascioliasis, a parasitic disease caused by the trematodes *Fasciola hepatica* and *F. gigantica*, poses a dual threat to human health and livestock productivity. It is estimated to affect between 2.4 and 17 million people globally, with the highest burden in Africa and Asia [5]. In livestock, fascioliasis causes substantial economic losses, estimated in billions of dollars each year, due to reduced productivity [6].

Freshwater snails of the genera *Biomphalaria* and *Bulinus* act as intermediate hosts for schistosome parasites, while *Lymnaeidae* snails from the *Radix* genus are the primary intermediate host for *Fasciola* liver flukes [7] [8] [9]. *Biomphalaria* spp. transmits *Schistosoma mansoni*, the causative agent of intestinal and hepatic schistosomiasis, whereas *Bulinus* spp. transmits both *Schistosoma haematobium* and *Schistosoma intercalatum*, which cause urinary and intestinal schistosomiasis, respectively [7] [8].

Despite the widespread implementation of mass drug administration (MDA) programs in high-burden areas, reinfection with schistosomiasis remains common, emphasizing the need for integrated control measures [10] [11]. In Uganda, for instance, *S. mansoni* remains highly endemic, particularly in communities around the Great Lakes region, where prevalence rates continue to exceed 50% despite the implementation of regular MDA campaigns [12] [13]. Recognizing the limitations of drug-based interventions alone, the World Health Organization (WHO) has acknowledged that controlling intermediate snail hosts responsible for transmission is essential for sustainable disease control. As part of its 2030 roadmap for schistosomiasis elimination, the WHO now recommends integrating MDA with snail control and improvements in the water, sanitation and hygiene (WASH) infrastructure [11].

Snail control interventions have shown promise in reducing transmission rates [10] [14]. However, effective and targeted snail control requires detailed mapping of snail habitats and transmission hotspots, a process constrained by the shortage of trained malacologists and the logistical difficulties of monitoring large, remote areas [15]. While chemical molluscicides such as niclosamide are effective in reducing *Bulinus* spp. and *Biomphalaria* spp. popula-

tions, concerns about environmental safety and sustainability persist [16] [14]. Therefore, enhancing snail surveillance and habitat mapping is crucial for informing targeted, ecologically responsible control efforts [17].

Across SSA, schistosomiasis is heterogeneous, but Uganda and the Democratic Republic of the Congo (DRC) present two high-priority settings. In Uganda, intestinal schistosomiasis caused by *S. mansoni* is endemic in more than 65% of the total districts (146) and can exceed 50% prevalence in lakeshore communities, while urogenital schistosomiasis caused by *S. haematobium* is limited to less than 3% of the districts [13]. The DRC, reports the third-highest number of cases of schistosomiasis in SSA [18] [19], both *S. mansoni* and *S. haematobium* are endemic nationwide, with poor sanitation and limited access to healthcare contributing to high rates of reinfection [20] [19]. Yet, data on snail distribution remain scarce, creating a significant challenge for effective snail control measures [21].

To address these challenges, we launched ATRAP in 2019, a citizen science (CS) initiative engaging local communities in monitoring snail intermediate hosts to identify potential disease transmission hotspots.

## 1.1 Context

The ATRAP (Action Towards Reducing Aquatic Snail-borne Parasitic Diseases) project was established to fill critical data gaps in rural areas of Uganda and the DRC, where schistosomiasis prevalence remains high. This citizen science-based initiative aimed to monitor snails intermediate host and generate fine-scale distribution data to guide targeted control interventions.

While CS projects with structured data collection protocols can enhance the scope of monitoring, produce high-quality actionable data, and increase local community engagement [22] [23] [24], concerns about data reliability persist due to its non-expert contributors [25]. To address this, ATRAP recruited and trained 25 citizen scientists in each country to conduct weekly snail monitoring from 2020 to 2023, incorporating rigorous validation protocols to

ensure data quality. The project was a collaboration between ATRAP, Mbarara University of Science and Technology in Uganda, and the University of Kinshasa in the DRC.

## 2 Methods

### 2.1 Study area

#### 2.1.1 Ugandan citizen science network

Data collection for the Ugandan CS network took place in the Lake Albert region (Fig. 1a), an area characterized by significant altitudinal variation, ranging from 620 meters in the lowlands to 1400 meters in the upland areas shaped by the Great Rift Valley. The lower-lying regions near the lake are remote and difficult to reach by road, presenting logistical challenges for fieldwork. The sampling sites captured a variety of hydrological conditions and

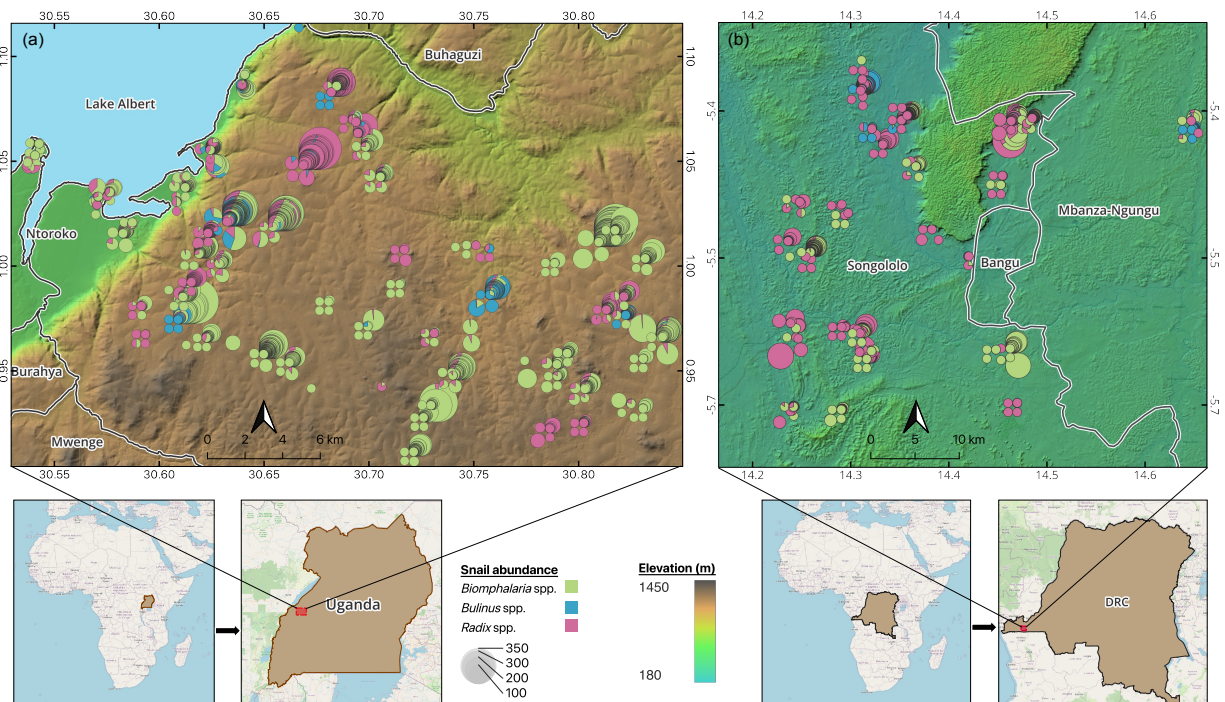


Figure 1: Snail intermediate host abundance based on CS reports submitted between 2020-2023 in (a) Uganda and (b) the DRC. Digital Elevation Model from Copernicus GLO-30 [26]. Legends are standard for both study areas.

were classified into four main types: springs, streams, wetlands, and lake shores. A detailed description of these site types can be found in [24], Supplementary Information (S1).

### **2.1.2 DRC citizen science network**

In the Democratic Republic of the Congo (DRC), the CS network operated in the Kimpese region of Kongo Central province (Fig. 1b). In contrast to the varied topography of the Ugandan study area, this region is relatively homogeneous, characterized by plateaus and rolling hills at elevations ranging from approximately 250 to 400 meters. The Lukunga River and its tributaries form an extensive hydrological network, serving as essential water sources for irrigation during the rainy season [27]. Most of the sampling locations corresponded to streams derived from the Lukunga River.

## **2.2 Sampling design and protocol**

In both study areas, sampling locations were identified through a preliminary survey, prioritizing sites where community members frequently engaged in water-related activities such as swimming, washing, bathing, water collection, and open defecation/urination, practices that increase the risk of snail-borne disease transmission. The study included locations where snail intermediate hosts were present, as well as areas where they were absent during initial field assessments.

Citizen scientists conducted standardized snail sampling and submitted reports through KoboCollect documenting freshwater snails that serve as intermediate hosts for *Schistosoma* and *Fasciola* parasites. The survey protocols used in each country are available in Supplementary Material S1. In Uganda, where site types were more heterogeneous, a 10-meter radius sampling protocol was recommended at each site. In contrast, in the DRC, citizen scientists collected snails 5 meters upstream and downstream of the contact point. For streams less than 3 meters wide and 50 cm deep, sampling was conducted on both sides of the stream. Each survey lasted approximately 30 minutes, during which the citizen scientists

used a hand-held scoop net with a two-meter metallic handle while wearing protective gear (latex gloves and gumboots) [22]. Snails were identified and sorted based on morphological characteristics learned during training, with counts and photographs recorded for each specimen. Reliable species-level separation within the genera *Biomphalaria*, *Bulinus* and *Radix* generally requires a combination of shell morphology, soft tissue anatomy, and molecular analysis [28][29][30]; therefore, citizens recorded identifications only to genus level. Snails were categorized into the genera *Biomphalaria*, *Bulinus*, and *Radix*, with a ‘pool’ category reserved for all other taxa. All findings were uploaded to a central server for researcher access and verification [22].

Notably, all 12 *Biomphalaria* species reported from SSA are competent intermediate hosts of *S. mansoni* [31]. In our Ugandan study area, monthly expert surveys with molecular confirmation identified 4 *Bulinus* species: *B. forskalii*, *B. globosus*, *B. nasutus* and *B. truncatus* (Tumusiime et al. 2025, unpublished data). Although *B. globosus* is the recognized vector of *S. haematobium* in Uganda, infected snails and clinical cases of urogenital schistosomiasis have not been reported in the areas surveyed. However, in this part of Uganda *B. nasutus* acts as the intermediate host of *S. bovis*, and infected snails have been reported [32]. In our DRC sites, only *B. globosus* and *B. truncatus* have been reported, and both are proven intermediate hosts of urinary human schistosomiasis [21]. In addition, Brown’s book (1994) [31] highlights a single widespread species, *Lymnaea natalensis* (currently *Radix natalensis*), as the principal intermediate host of *Fasciola* spp. in Africa. Although the ATRAP citizen science project records snails only to genus level, the data are still epidemiologically informative: *Biomphalaria* spp. detections flag possible areas of transmission of intestinal schistosomiasis in both countries, *Bulinus* spp. detections indicate urogenital risk in the DRC and mainly bovine transmission in the Ugandan sites, and *Radix* spp. detections mark potential hotspots for human livestock fascioliasis throughout the study region.

## 2.3 Data validation and quality control

A robust validation protocol was implemented to minimize reporting errors, which are defined as discrepancies between the data collected by citizen scientists and the information submitted in the reports [22] [24]. The protocol included the use of skip logic, prioritized multiple-choice questions, and employed a semi-automatic validation system to detect invalid entries. Additionally, citizen scientists received continuous feedback and participated in annual refresher training sessions to improve the accuracy of their data [22] [24]. For further details on the semi-automatic validation process, see [22].

In addition, manual validation was performed by reviewing the attached field photographs to verify genus identification and flag any possible misidentification. Each snail genus (*Biomphalaria*, *Bulinus*, and *Radix*) was independently verified to ensure that errors in one genus did not affect the validity of other records. The validated reports were then saved to a CSV file for subsequent data cleaning and analysis. This validation protocol was applied to the ATRAP datasets for Uganda and the DRC, which included 6570 and 6891 CS reports, respectively.

### 2.3.1 Reports exclusions

In Uganda, 959 reports were excluded due to participants' inability to sample, citing reasons such as weather, illness, or lack of motivation. Additional exclusions included reports with dates outside the sampling period (4), inaccurate GPS readings (547), and sampling durations outside the 1-60 minute range (150). No reports were excluded due to invalid data for all three snail genera. After these exclusions, 4910 valid reports remained for analysis (Table 1).

In the DRC, reports were excluded for similar reasons, including dates outside the sampling period (236), inaccurate GPS readings (78), sampling durations shorter than 1 minute or longer than 60 minutes (1630), and missing valid data for *Biomphalaria*, *Bulinus*, and *Radix* (26). After exclusions, 4921 valid reports were retained for analysis (Table 1).

### 2.3.2 Sampling events and associated occurrences

In this paper, a report is defined as a sampling event in which a citizen scientist collects data at a specific location and time. Each sampling event can contain up to three associated occurrences corresponding to the abundance of *Biomphalaria*, *Bulinus* or *Radix* snails.

### 2.3.3 Invalid associated occurrences and identification errors

The approach to handling identification errors and invalid associated occurrences differed between Uganda and the DRC due to logistical constraints. In Uganda, validation was conducted in parallel with data collection, allowing real-time feedback to citizen scientists. This immediate verification process significantly reduced errors and improved data quality. Among the 4910 valid reports from Uganda, a total of 14730 associated snail occurrences were recorded. Of these, only 216 occurrences (1.47%) were identified as errors, either due to misidentifications or invalid associated occurrences. Specifically, 34 occurrences of *Biomphalaria*, 103 of *Bulinus*, and 79 of *Radix* snails were excluded from the analysis due to their low frequency, ensuring minimal impact on the overall dataset integrity.

In contrast, data validation in the DRC was conducted after data collection, as real-time feedback was not possible. To address this limitation, the original validation script was refined to correct misidentified occurrences rather than excluding them. Identification errors were systematically corrected, affecting 394 occurrences of *Biomphalaria*, 772 of *Bulinus*, and 3070 of *Radix* snails. The high number of corrections for *Radix* spp. was largely attributed to frequent misidentifications involving *Melanooides* spp., a snail genus with a right-facing shell opening similar to *Radix* snails. This morphological similarity likely contributed to misclassification by citizen scientists in the DRC.

Following the correction of identification errors, invalid associated occurrences were handled separately. These were defined as records lacking images or containing images unrelated to snails. A total of 199 occurrences of *Biomphalaria* spp., 105 of *Bulinus* spp., and 208 of *Radix* spp. were excluded from the DRC dataset due to these issues.

Table 1: Filtering steps applied to the ATRAP datasets

Step	Uganda	DRC
Original dataset	6570	6891
Exclude “no sampling” <sup>a</sup>	5611	6891
Exclude dates outside range	5607	6655
Exclude inaccurate GPS readings <sup>b</sup>	5060	6577
Keep reports with sampling time 1–60 min	4910	4947
Exclude reports where all three snail records were invalid	4910	4921

The three snail genera evaluated were *Biomphalaria*, *Bulinus*, and *Radix*.

<sup>a</sup> Non-sampling instances were not recorded in the DRC.

<sup>b</sup> GPS accuracy greater than 5 m.

### 3 Reuse potential

When combined with other data sources, CS snail intermediate host data can play a key role in creating risk maps and establishing vulnerability assessments for the transmission of schistosomiasis and fascioliasis. By identifying areas of high probability of snail occurrence and understanding seasonal variations, these data enhance the precision of targeted interventions. Such insights can guide the prioritization of areas for WASH initiatives and targeted snail control efforts, improving the efficiency of public health responses. Moreover, vulnerability assessments based on CS data can help identify populations at higher risk, allowing for more focused interventions such as MDA in the most affected areas. By using citizen-collected data, health agencies can allocate resources more efficiently, ensuring a more effective approach to reducing the burden of schistosomiasis. Notably, previous studies [24] [33] have demonstrated a high presence/absence agreement between observed and modeled expert and CS data for the Uganda CS dataset, further validating the reliability of CS data for epidemiological applications.

Beyond direct epidemiological applications, the release of snail images offers further research opportunities. These images can support the development of identification methods [34] and facilitate studies of size distribution within intermediate host snail genera. Integrating image-based analysis with on-site surveillance data further improve fine-scale, cost-

effective monitoring contributing to disease control strategies.

## 4 Data availability

The dataset described here is available from the GBIF-RMCA repository [35]. The associated images (snail photographs) in the RMCA BioCase repository [36] [37].

## 5 Declarations

### 5.1 List of abbreviations

- ATRAP: Action Towards Reducing Aquatic snail-borne Parasitic diseases
- DRC: Democratic Republic of the Congo
- CS: Citizen Science
- GPS: Global Positioning System
- MDA: Mass Drug Administration
- SSA: Sub-Saharan Africa
- WASH: Water, Sanitation and Hygiene
- WHO: World Health Organization

### 5.2 Ethical Approval

This study was approved by the Ethics Review Committee of Mbarara Technology with reference number MUREC 1/7 and by the Uganda National Council of Science and Technology with reference number NS148ES for Uganda. For the DRC, by the Department of Tropical Medicine from the UNIKIN with reference number SP-2020-023-MED TROP. In addition,

written informed consent was obtained from the citizen scientists who participated in this study for both countries. The extent of disclosure of the information the citizen scientists provided and their facilitation were fully discussed and formalised in a memorandum of understanding before the commencement of the data collection process. The memorandum of understanding was renewed annually after a refresher training to allow citizen scientists to share their experiences and expectations.

### **5.3 Consent for publication**

Not applicable.

### **5.4 Competing Interests**

The authors declare that they have no competing interests.

### **5.5 Funding**

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### **5.6 Author's Contributions**

NVB: Writing – original draft, Writing – review and editing, Data validation and curation, feedback CS network, Funding acquisition. LB: Writing – original draft, Data validation and curation. JT: surveillance, coordination CS network, GK: surveillance, coordination CS net-

work, DN: surveillance, coordination CS network, CUT: Coordination, Supervision, Project administration, Funding acquisition, GRK: Supervision, Project administration, Funding acquisition, PMP: Supervision, Project administration, Funding acquisition, JM: Coordination, Supervision, Project administration, Funding acquisition, LJ: Conceptualization, Supervision, Validation, Funding acquisition, Writing – review and editing, TH: Conceptualization, Funding acquisition, Supervision, Writing – review and editing.

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## References

- [1] Xiao Ting Lu et al. “Snail-borne Parasitic Diseases: An Update on Global Epidemiological Distribution, Transmission Interruption and Control Methods”. In: *Infectious Diseases of Poverty* 7.1 (Apr. 2018), pp. 1–16. ISSN: 2049-9957. DOI: 10.1186/s40249-018-0414-7. URL: <https://idpjournal.biomedcentral.com/articles/10.1186/s40249-018-0414-7>.
- [2] Nathan C. Lo et al. “Review of 2022 WHO Guidelines on the Control and Elimination of Schistosomiasis”. In: *The Lancet Infectious Diseases* 22.11 (Nov. 2022), e327–e335. ISSN: 1473-3099. DOI: 10.1016/S1473-3099(22)00221-3. URL: [https://www.thelancet.com/journals/laninf/article/PIIS1473-3099\(22\)00221-3/fulltext](https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(22)00221-3/fulltext).
- [3] Daniel G Colley et al. “Human schistosomiasis”. In: *The Lancet* 383.9936 (June 2014), pp. 2253–2264. ISSN: 01406736. DOI: 10.1016/S0140-6736(13)61949-2. URL: <https://linkinghub.elsevier.com/retrieve/pii/S0140673613619492>.
- [4] Charlotte M. Gower, Louise Vince, and Joanne P. Webster. “Should We Be Treating Animal Schistosomiasis in Africa? The Need for a One Health Economic Evaluation”. In: *Transactions of the Royal Society of Tropical Medicine and Hygiene* 111.6 (June 2017), pp. 244–247. ISSN: 0035-9203. DOI: 10.1093/trstmh/trx047. URL: <https://pubmed.ncbi.nlm.nih.gov/29044372/>.
- [5] Santiago Mas-Coma, M. Adela Valero, and M. Dolores Bargues. “Fascioliasis”. In: *Advances in Experimental Medicine and Biology*. Vol. 766. Springer, 2014, pp. 77–114. ISBN: 978-1-4939-0915-5. DOI: 10.1007/978-1-4939-0915-5\_4. URL: [https://link.springer.com/chapter/10.1007/978-1-4939-0915-5\\_4](https://link.springer.com/chapter/10.1007/978-1-4939-0915-5_4).

- [6] Mramba Nyindo and Abdul-Hamid Lukambagire. “Fascioliasis: An Ongoing Zoonotic Trematode Infection”. In: *BioMed Research International* 2015 (2015), pp. 1–8. ISSN: 2314-6133, 2314-6141. DOI: 10.1155/2015/786195. URL: <http://www.hindawi.com/journals/bmri/2015/786195/>.
- [7] J. A. T. Morgan et al. “*Schistosoma mansoni* and *Biomphalaria* : past history and future trends”. In: *Parasitology* 123.7 (Nov. 2001), pp. 211–228. ISSN: 0031-1820, 1469-8161. DOI: 10.1017/S0031182001007703. URL: [https://www.cambridge.org/core/product/identifier/S0031182001007703/type/journal\\_article](https://www.cambridge.org/core/product/identifier/S0031182001007703/type/journal_article).
- [8] D. Rollinson, J. R. Stothard, and V. R. Southgate. “Interactions between intermediate snail hosts of the genus *Bulinus* and schistosomes of the *Schistosoma haematobium* group”. In: *Parasitology* 123.7 (Nov. 2001), pp. 245–260. ISSN: 0031-1820, 1469-8161. DOI: 10.1017/S0031182001008046. URL: [https://www.cambridge.org/core/product/identifier/S0031182001008046/type/journal\\_article](https://www.cambridge.org/core/product/identifier/S0031182001008046/type/journal_article).
- [9] Santiago Mas-Coma, M. Adela Valero, and M. Dolores Bargues. “Human and Animal Fascioliasis: Origins and Worldwide Evolving Scenario”. In: *Clinical Microbiology Reviews* 35.4 (Dec. 2022). ISSN: 1098-6618. DOI: 10.1128/cmr.00088-19. URL: <https://doi.org/10.1128/CMR.00088-19>.
- [10] Susanne H. Sokolow et al. “Reduced transmission of human schistosomiasis after restoration of a native river prawn that preys on the snail intermediate host”. In: *Proceedings of the National Academy of Sciences* 112.31 (Aug. 4, 2015), pp. 9650–9655. ISSN: 0027-8424, 1091-6490. DOI: 10.1073/pnas.1502651112. URL: <https://pnas.org/doi/full/10.1073/pnas.1502651112> (visited on 04/03/2025).
- [11] World Health Organization. *Ending the neglect to attain the Sustainable Development Goals: a road map for neglected tropical diseases 2021–2030*. URL: <https://www.iapb.org/wp-content/uploads/2021/02/A-roadmapfor-neglected-tropical-diseases-2021-30-eng.pdf>.

- [12] Narcis B. Kabatereine et al. “Epidemiology and geography of *Schistosoma mansoni* in Uganda: implications for planning control”. In: *Tropical Medicine & International Health* 9.3 (Mar. 2004), pp. 372–380. ISSN: 1360-2276, 1365-3156. DOI: 10.1046/j.1365-3156.2003.01176.x. URL: <https://onlinelibrary.wiley.com/doi/10.1046/j.1365-3156.2003.01176.x>.
- [13] Moses Adriko et al. “Time to change implementation units for mass drug administration against schistosomiasis in Uganda: Evidence from Communities levels data validation and its implication in planning”. In: *Parasite Epidemiology and Control* 27 (Nov. 2024), e00394. ISSN: 24056731. DOI: 10.1016/j.parepi.2024.e00394. URL: <https://linkinghub.elsevier.com/retrieve/pii/S2405673124000588>.
- [14] Nathan C. Lo et al. “Impact and cost-effectiveness of snail control to achieve disease control targets for schistosomiasis”. In: *Proceedings of the National Academy of Sciences* 115.4 (Jan. 23, 2018). ISSN: 0027-8424, 1091-6490. DOI: 10.1073/pnas.1708729114. URL: <https://pnas.org/doi/full/10.1073/pnas.1708729114>.
- [15] Clive Shiff. “Why reinvent the wheel? Lessons in schistosomiasis control from the past”. In: *PLOS Neglected Tropical Diseases* 11.10 (Oct. 26, 2017). Ed. by Giovanna Raso, e0005812. ISSN: 1935-2735. DOI: 10.1371/journal.pntd.0005812. URL: <https://dx.plos.org/10.1371/journal.pntd.0005812>.
- [16] Charles H. King and David Bertsch. “Historical Perspective: Snail Control to Prevent Schistosomiasis”. In: *PLOS Neglected Tropical Diseases* 9.4 (Apr. 23, 2015). Ed. by Matty Knight, e0003657. ISSN: 1935-2735. DOI: 10.1371/journal.pntd.0003657. URL: <https://dx.plos.org/10.1371/journal.pntd.0003657>.
- [17] Asrat Meleko et al. “Schistosomiasis Control in Ethiopia: The Role of Snail Mapping in Endemic Communities”. In: *Tropical Medicine and Infectious Disease* 7.10 (Sept. 28, 2022), p. 272. ISSN: 2414-6366. DOI: 10.3390/tropicalmed7100272. URL: <https://www.mdpi.com/2414-6366/7/10/272>.

- [18] Peter J. Hotez and Aruna Kamath. “Neglected Tropical Diseases in Sub-Saharan Africa: Review of Their Prevalence, Distribution, and Disease Burden”. In: *PLoS Neglected Tropical Diseases* 3.8 (Aug. 25, 2009). Ed. by Michael Cappello, e412. ISSN: 1935-2735. DOI: 10.1371/journal.pntd.0000412. URL: <https://dx.plos.org/10.1371/journal.pntd.0000412>.
- [19] Joule Madinga et al. “Schistosomiasis in the Democratic Republic of Congo: a literature review”. In: *Parasites & Vectors* 8.1 (Dec. 2015), p. 601. ISSN: 1756-3305. DOI: 10.1186/s13071-015-1206-6. URL: <http://www.parasitesandvectors.com/content/8/1/601>.
- [20] Jack E. T. Grimes et al. “The Relationship between Water, Sanitation and Schistosomiasis: A Systematic Review and Meta-analysis”. In: *PLoS Neglected Tropical Diseases* 8.12 (Dec. 4, 2014). Ed. by Stephen T. McGarvey, e3296. ISSN: 1935-2735. DOI: 10.1371/journal.pntd.0003296. URL: <https://dx.plos.org/10.1371/journal.pntd.0003296>.
- [21] Germain Kapour Kieng Katsang et al. “Mapping of intermediate host snails for schistosomiasis in the Democratic Republic of Congo: a systematic review”. In: *Folia Parasitologica* 71 (May 6, 2024). ISSN: 00155683, 18036465. DOI: 10.14411/fp.2024.010. URL: <http://folia.paru.cas.cz/doi/10.14411/fp.2024.010.html>.
- [22] Jef Brees et al. “The Potential of Citizen-Driven Monitoring of Freshwater Snails in Schistosomiasis Research”. In: *Citizen Science: Theory and Practice* 6.1 (July 13, 2021), p. 18. ISSN: 2057-4991. DOI: 10.5334/cstp.388. URL: <https://theoryandpractice.citizenscienceassociation.org/article/10.5334/cstp.388/>.
- [23] Joseph M. Hulbert. “Citizen science tools available for ecological research in South Africa”. In: *South African Journal of Science* 112.5 (May 26, 2016), p. 2. ISSN: 1996-7489. DOI: 10.17159/sajs.2016/a0152. URL: <https://sajs.co.za/article/view/4070>.

- [24] Julius Tumusiime et al. “Citizens can help to map putative transmission sites for snail-borne diseases”. In: *PLOS Neglected Tropical Diseases* 18.4 (Apr. 4, 2024). Ed. by Guilherme L. Werneck, e0012062. ISSN: 1935-2735. DOI: 10.1371/journal.pntd.0012062. URL: <https://dx.plos.org/10.1371/journal.pntd.0012062>.
- [25] Margaret Kosmala et al. “Assessing data quality in citizen science”. In: *Frontiers in Ecology and the Environment* 14.10 (2016), pp. 551–560. DOI: <https://doi.org/10.1002/fee.1436>. eprint: <https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/fee.1436>. URL: <https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.1436>.
- [26] Copernicus Data Space Ecosystem. *Copernicus DEM — Global and European Digital Elevation Model*. Accessed 4 October 2024. 2024. URL: <https://dataspace.copernicus.eu/explore-data/data-collections/copernicus-contributing-missions/collections-description/COP-DEM> (visited on 10/04/2024).
- [27] Ministry of Rural Development DRC. “THE STUDY ON COMMUNITY DEVELOPMENT PLAN IN CATARACTES DISTRICT, BAS-CONGO PROVINCE IN THE DEMOCRATIC REPUBLIC OF THE CONGO.” In: (Jan. 1, 2010). URL: <https://openjicareport.jica.go.jp/pdf/11980349.pdf> (visited on 04/03/2025).
- [28] Scott P. Lawton et al. “Unravelling the Riddle of Radix: DNA Barcoding for Species Identification of Freshwater Snail Intermediate Hosts of Zoonotic Digeneans and Estimating Their Inter-Population Evolutionary Relationships”. In: *Infection, Genetics and Evolution* 35 (Oct. 2015), pp. 63–74. ISSN: 1567-1348. DOI: 10.1016/j.meegid.2015.07.021. URL: <https://www.sciencedirect.com/science/article/pii/S156713481500283X>.
- [29] Raquel G. S. Palasio et al. “Diversity of *Biomphalaria* spp. Freshwater Snails and Associated Mollusks in Areas with Schistosomiasis Risk Using Molecular and Spatial Analysis Tools”. In: *Biota Neotropica* 19.4 (Aug. 2019), e20190746. ISSN: 1676-0611.

DOI: 10.1590/1676-0611-bn-2019-0746. URL: <https://www.scielo.br/j/bn/a/bm98gLy8QVJXbY8MNQkygcr/>.

- [30] Richard A. Kane et al. “Molecular Characterization of Freshwater Snails in the Genus *Bulinus*: A Role for Barcodes?” In: *Parasites and Vectors* 1.1 (June 2008), p. 15. ISSN: 1756-3305. DOI: 10.1186/1756-3305-1-15. URL: <https://link.springer.com/article/10.1186/1756-3305-1-15>.
- [31] David S. Brown. *Freshwater Snails of Africa and Their Medical Importance*. CRC Press, May 1994. ISBN: 9780429094941. DOI: 10.1201/9781482295184. URL: <https://www.taylorfrancis.com/books/mono/10.1201/9781482295184/freshwater-snails-africa-medical-importance-david-brown>.
- [32] Julius Tumusiime et al. “An Accident Waiting to Happen? Exposing the Potential of Urogenital Schistosomiasis Transmission in the Lake Albert Region, Uganda”. In: *Parasites and Vectors* 16.1 (Dec. 2023). ISSN: 1756-3305. DOI: 10.1186/s13071-023-06017-3. URL: <https://pubmed.ncbi.nlm.nih.gov/37919743/>.
- [33] Noelia Valderrama-Bhraunxs et al. “Great Minds, Map Alike: Citizen and Expert Distribution Models of Schistosome Snail Hosts in Rural West Uganda”. In: *Authorea Preprints* (May 2025). Preprint. DOI: 10.22541/au.174282884.44757684.v3. URL: <https://www.authorea.com/doi/pdf/10.22541/au.174282884.44757684/v3>.
- [34] Kin Ho Chan et al. “The Potential of Deep Learning Object Detection in Citizen-Driven Snail Host Monitoring to Map Putative Disease Transmission Sites”. In: *Citizen Science: Theory and Practice* 9.1 (Oct. 4, 2024), p. 25. ISSN: 2057-4991. DOI: 10.5334/cstp.724. URL: <https://account.theoryandpractice.citizenscienceassociation.org/index.php/up-j-cstp/article/view/724>.
- [35] Noelia Valderrama Bhraunxs, Larissa Bonifacio, and Tine Huyse. *The ATRAP Project: Citizen Scientists Reporting Snail Intermediate Host Occurrence in Uganda and the Democratic Republic of the Congo*. Version 1.3. Occurrence dataset accessed via GBIF

on 27 Jun 2025. Royal Museum for Central Africa, Belgium, 2025. DOI: 10.15468/t2vtd5. URL: <https://doi.org/10.15468/t2vtd5> (visited on 06/27/2025).

- [36] “Index of snail photographs from Uganda”. In: (Mar. 4, 2025). URL: [https://biocase.africamuseum.be/images/kobo\\_uganda/](https://biocase.africamuseum.be/images/kobo_uganda/).
- [37] “Index of snail photographs from DRC”. In: (Mar. 4, 2025). URL: [https://biocase.africamuseum.be/images/kobo\\_congo/](https://biocase.africamuseum.be/images/kobo_congo/).