Ecology and Molecular Characterization of Snail Intermediate Hosts of Schistosomiasis in the Endemic Area of Ibadan, Southwestern, Nigeria

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Chapter One

Introduction

1.1 Background to the study

Schistosomiasis is one of the neglected tropical diseases (NTD) endemic in 78 countries and infects more than 229 million peoples in tropical and subtropical regions [1]. More than 90%ofthese cases are concentrated in Africa [2, 3]. The burden of the disease is even more severe in sub-Saharan Africa. Poor environmental sanitation and suitability of the climate conditions for snail intermediate host contribute to the high endemicity of the region. Schistosomiasis ranks second next to malaria from parasitic infection in terms of socioeconomic and health impact in tropics [4].

Human schistosomiasis is caused by *Schistosoma mansoni, S. haematobium, S. japonicum, S. intercalatum, S. mekongi, S. malayensis,* and *S. guineensis* [5,6,7]. Among these species, S. mansoni, *S. haematobium*, and *S. japonicum* are the major causes of human schistosomiasis globally [8]. *Schistosoma mansoni* and *S. haematobium* are widely dis tributed and the dominant cause of human schistosomiasis in Africa [5]. The endemicity of the disease in the region is linked with the availability of freshwater snail intermediate hosts.

About 350 species of freshwater snails are known to be medically or veterinary important [9]. Among these diverse snails, *Biomphalaria, Bulinus,* and *Oncomelania* snails are the dominant snail genera that are involved in the transmission of human schistosomiasis [4]. The *Biomphalaria* genus consists of *B. pfeifferi, B. glabrata, B. sudanica, B. straminea, B. tenagophila*, B. alexandarina, and *B. choanomphala* [10]. *Biomphalaria* snails serve as the intermediate host for S. mansoni, which is responsible for intestinal and hepatic schistosomiasis. Biomphalaria pfeifferi is the most common and widely distributed snail inter mediate host for *S. mansoni* in Africa. *Bulinus* consists of 37 recognized species, which is grouped mainly into four species groups, namely, *Bulinus africanus, B. forskalii*, *B. truncates/tropicus,* and *B. reticulatus* [10,11.] Bulinus snails serve as intermediate hosts for *S. haematobium*, which is responsible for urinary schistosomiasis. *Oncomelania* snails consist of only a few species mainly reported from Asia. e most common snail intermediate host for *S. japonicum* is *Oncomelania hupensis*, which is found in China, the Philippines, Indonesia, and also Japan [12.]

Prevalence of human schistosomiasis is varied greatly in African countries depending on the level of environmental sanitation and the suitability of the area for the snail intermediate hosts, as well as the type of snail in the area. Similarly, the prevalence of schistosomes cercaria in snail intermediate hosts is varied in different locations within the same country and also from country to country in African [13.] Several epidemiological studies are available on the types and prevalence of human infecting schistosomes among snail intermediate hosts in Africa. However, up to this time, there has not been any single estimate of the prevalence of *S. mansoni* and *S. haematobium* in snail in termediate hosts in Africa that could be used by African policymakers and international organizations working on the prevention and control of schistosomiasis in the continent therefore, this study aimed to provide summarized data on the prevalence and geographical variations of *S. mansoni* and *S. haematobium* cercaria among freshwater snails in Africa [13].

Schistosomiasis disease is known to be endemic in many countries especially in West Africa [13]. Reports by the World Health Organization (WHO) estimated 243 million people in 52 countries require treatment against the disease [14]. Nigeria has the heaviest burden of the disease in sub-Saharan Africa, with a total of 29 million cases [16.] The transmission of the disease is correlated with freshwater snail intermediate host and requires human contact with the parasite infective stage found in contaminated freshwater bodies.

Therefore, communities that live close to snail infested water bodies are mostly at risk of schistosomiasis[18]. Several factors such as social, cultural, environmental and behavioural are known to have direct influence on the prevalence and intensity of schistosomiasis. The role played by various epidemiological factors in the transmission and intensity of the infection has been studied widely using different methods. Distance from the transmission site, migration and emergence of new foci, urbanization, socio economic status, sanitation, water supply patterns and disposal of human wastes (faeces and urine) are among the epidemiological factors [9].

Freshwater snails are organisms that form an important component of food chain and food web of most freshwater ecosystems [13]. Some of the freshwater snails that inhabit freshwater bodies such as lakes, ponds and dams are known to be of medical and veterinary importance. It is estimated that about 350 species are of medical and veterinary importance. The intermediate hosts of human schistosomiasis belong to three genera*; Biomphalaria, Bulinus* and *Oncomelania*. Bulinus species causes urinary schistosomiasis, Biomphalaria species causes intestinal schistosomiasis and *Oncomelania* species causes fascioliasis or liver rot in animals [13.]

The distribution and abundance of freshwater snail populations are influenced by temperature, food supply, predators, parasites, rainfall and water composition. Sunlight, flowering aquatic weeds, abundance of micro-flora and high dissolved oxygen also contribute to the abundance of freshwater snails [14.] Snail abundance, distribution and density vary significantly with season [15]. Biotic factors such as availability and density of aquatic macrophytes have also been reported to play vital roles in the distribution of freshwater snails in different parts of Africa [16]. Physicochemical factors of the water body that are considered as most important factors in the aquatic environment particularly for freshwater snails are temperature, pH, turbidity, dissolved oxygen, calcium, magnesium and phosphate [17].

Various physico-chemical and biological circumstances must be simultaneously taken into consideration for understanding fluctuation of biological populations in water body. Warwade dam, an earth dam is a "weir" constructed in the 1970s solely for the purpose of irrigation; playing a significant role in the socio-economic activities in the lives of communities sorrounding it, especially Warwade village. Other activities observed by Dogara and his co-researchers at the dam sites include fishing, washing of clothes, swimming and bathing. Since Warwade dam as a "weir" is a typical standing water that is likely to harbour vectors that transmit diseases such as malaria, schistosomiasis and lymphatic filariasis [18.]

Reports of surveys from Jigawa State Ministry of Health revealed that the state is endemic for schistosomiasis [19.] The same report showed that school aged children of Warwade town have a prevalence of 7.1% for urinary and intestinal schistosomiasis. The global effort to eliminate schistosomiasis is enshrined in World Health Organization Schistosomiasis plan with a vision of a "World Free of Schistosomiasis" with its end goal to eliminate the disease as a public health problem by 2025 [20.]

The control of schistosomiasis is based on large-scale treatment of at-risk population groups, access to safe water, improved sanitation, hygiene education, and snail control [21]. Snail control is a key component in the global and national programmes for the elimination of schistosomiasis. However, its success largely depends on the understanding of the ecology of freshwater snail vectors. Despite the widespread use of earth dams used in irrigation in Nigeria, little is known of the consequences for mollusks of medical or veterinary importance.

The physicochemical factors measured includes temperature, conductivity, acidity and alkalinity were found to favour the survival of the freshwater snails. This information is not enough to give a realistic picture that could be used in planning and executing freshwater snails control programme that are known to transmit schistosomiasis in Warwade dam. There is therefore the need to understand how intermediate snail hosts abundance will be affected by seasonal changes which mainly influence the prevailing abiotic and biotic factors of their habitats. Again, the period of highest relative abundance must be known if control measures are to be successfully implemented given that the development of an effective control strategy requires the study of population dynamics of the intermediate hosts and its relation to environmental factors [21].

There is also the need to understand the intra-specific competition between the different freshwater snail species in the dam. This work studied the distribution and abundance of the freshwater snails of the dam over a longer period of time in relation to important physicochemical factors.

1.2 Statement of the Problem

Schistosomiasis remains a significant public health concern in many parts of sub-Saharan Africa, including Nigeria, where it affects millions of people, particularly in peri-urban and rural areas. The disease is transmitted by freshwater snails that serve as intermediate hosts for *Schistosoma* parasites. Despite ongoing control efforts, schistosomiasis persists in many endemic communities, partly due to limited understanding of the ecological dynamics and genetic diversity of the snail vectors involved in its transmission.

In Ibadan metropolis, rapid urbanization, environmental degradation, and the presence of numerous freshwater bodies provide ideal habitats for snail populations, potentially increasing the risk of schistosomiasis transmission. However, there is a lack of up-to-date and localized data on the distribution, ecological preferences, and molecular characteristics of the snail intermediate hosts in the region. Most control programs rely heavily on mass drug administration, often neglecting the snail vectors that play a crucial role in sustaining the transmission cycle.

Without detailed ecological and molecular characterization of these snails, control strategies may remain ineffective or misdirected. Identifying the specific snail species present, understanding their environmental requirements, and examining their genetic profiles are essential steps toward developing targeted and sustainable schistosomiasis control measures in Ibadan metropolis.

1.3 Justification of the study

Schistosomiasis continues to be a major neglected tropical disease in Nigeria, contributing significantly to morbidity, particularly among school-aged children and communities with limited access to clean water and sanitation. The transmission of the disease is highly dependent on the presence of specific freshwater snail species that act as intermediate hosts for *Schistosoma* parasites. Effective control and eventual elimination of schistosomiasis require a comprehensive understanding of these snail vectors both ecologically and genetically.

Ibadan metropolis, a densely populated and rapidly urbanizing area, contains numerous freshwater bodies that serve as potential breeding grounds for snail intermediate hosts. However, little is known about the current distribution, abundance, ecological requirements, and genetic makeup of these snails in the region. This lack of localized data undermines control strategies, which are often generalized and not tailored to the specific epidemiological context of Ibadan.

Ecological characterization of snail habitats will help identify environmental factors promoting snail proliferation and potential hotspots for transmission. Molecular identification and genetic analysis will not only enhance the accuracy of species identification especially in cases where morphological similarities existbut will also help detect the presence of cryptic species and infection with *Schistosoma* larvae.

Furthermore, understanding the molecular diversity of snail populations can inform predictions about their susceptibility to infection and potential resistance to environmental changes or control measures. This integrated approach will provide valuable information for policymakers, public health practitioners, and researchers to design targeted, evidence-based interventions for schistosomiasis control in Ibadan and similar endemic settings.Therefore, this study is justified as it fills a critical gap in the knowledge of local transmission dynamics, supports sustainable disease control efforts, and contributes to the broader goal of schistosomiasis elimination in Nigeria.

1.4 Aim and Objectives of the Study

The aim of this study is to evaluate Ecology and Molecular Characterization of Snail Intermediate Hosts of Schistosomiasis in the Endemic Area of Ibadan, Southwestern, Nigeria.

The specific objectives is to;

i. identify the intermediate host morphologically and the distribution within the selected area.

ii. assess the physicochemical parameters of snail habitats influencing snail abundance and diversity.

iii. determine the infection rates of schistosome parasites in collected snail specimens through cercarial shedding and molecular techniques.

iv. evaluate seasonal variations in snail population dynamics and schistosome infection rates across selected sites in Ibadan Metropolis.

v.characterize the schistosome-infected snails using molecular markers, COI gene to identify species.

1.5 Research Questions

i.what species of freshwater snails serve as intermediate hosts of schistosomiasis in Ibadan Metropolis?

ii.how are these snail species distributed across different ecological zones in the study area?

iii.What environmental (physicochemical) factors influence the abundance and distribution of these snail hosts?

iv.what is the prevalence of *Schistosoma* infection among the identified snail hosts, and how can it be detected molecularly?

v. are there genetic variations among the *Schistosoma*-infected snails, and what molecular markers can be used to characterize them?

1.6 Research hypothesis

i.H_0 (Null Hypothesis): There is no significant relationship between environmental factors and the distribution or abundance of schistosomiasis snail intermediate hosts in Ibadan Metropolis.
H_1 (Alternative Hypothesis): There is a significant relationship between environmental factors and the distribution or abundance of schistosomiasis snail intermediate hosts in Ibadan Metropolis.

ii.H_0: Schistosomiasis snail intermediate hosts in Ibadan Metropolis do not show significant genetic variation.
H_1: Schistosomiasis snail intermediate hosts in Ibadan Metropolis show significant genetic variation.

1.7 Scope and Limitation of the Study

This study focuses on the ecological and molecular investigation of freshwater snails that serve as intermediate hosts of schistosomiasis within Ibadan Metropolis. The research will cover selected water bodies across different ecological zones, assessing snail diversity, distribution, habitat characteristics, and seasonal variations. It will also involve laboratory analysis for detecting *Schistosoma* infections and molecular characterization of snail specimens.

Geographical limitation to Ibadan Metropolis only.Focus on freshwater snails associated with *Schistosoma haematobium* and *S. mansoni* transmission.Molecular analysis will be limited to selected genetic markers due to time and resource constraints.Human and animal infection rates will not be covered; the focus is solely on snail hosts.

1.8 Significance of the Study

Schistosomiasis remains a major neglected tropical disease in Nigeria. Understanding the ecology and genetics of snail hosts is critical for breaking the transmission cycle. By identifying key environmental factors and hotspots of snail abundance and infection, the study can guide targeted mollusciciding, habitat modification, and public health interventions. Genetic characterization of infected snails will provide insights into the parasite's diversity and evolution, aiding in the design of molecular surveillance tools and potentially guiding drug or vaccine development. Findings will support local health authorities and NGOs in implementing evidence-based schistosomiasis control programs in Ibadan and similar urban settings. The study contributes to the growing body of knowledge on snail ecology, schistosomiasis transmission, and molecular epidemiology in sub-Saharan Africa.

1.9. Operational terms

Ecological Characterization: The study and description of the natural habitat, environmental factors, and interactions affecting the distribution and abundance of snail intermediate hosts.

Molecular Characterization: The use of molecular biology techniques (like DNA sequencing or PCR) to identify and differentiate between snail species and detect Schistosoma infection. Schistosomiasis: A parasitic disease caused by blood flukes (genus *Schistosoma*), commonly transmitted through contact with contaminated freshwater.Snail Intermediate Hosts: Freshwater snail species that serve as a crucial part of the life cycle of *Schistosoma* parasites by harboring the larval stages.

Characterization: A process of identifying, describing, and analyzing features or traits of organisms or environments.

Intermediate Host: An organism that temporarily harbors a parasite during its developmental stages but is not the final host.

Endnotes

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Chapter Two

2.0 Literature Review

2.1 Conceptual Review

Schistosomiasis is a parasitic disease caused by blood flukes of the genus *Schistosoma*, with at least five species (*S. haematobium*, *S. mansoni*, *S. japonicum*, *S. mekongi*, and *S. intercalatum*) known to infect humans[1]. The disease primarily affects populations in tropical and subtropical regions, particularly in Africa, Asia, South America, and parts of the Caribbean. It is second only to malaria among parasitic diseases in terms of public health impact[2].Transmission occurs when people come into contact with freshwater bodies contaminated with cercariae the free-swimming larval form of the parasite which are released by infected freshwater snails (intermediate hosts)[3]. These cercariae penetrate human skin, develop into schistosomula, and migrate through the bloodstream to organs such as the liver, intestines, bladder, or genital tract, where adult worms mature and produce eggs[4].

The clinical symptoms vary based on the species involved and the organs affected. Acute infection (Katayama syndrome) may include fever, rash, muscle pain, and respiratory issues[5].

Chronic schistosomiasis can result in severe complications such as blood in urine or stool, liver and intestinal damage, bladder cancer, infertility, and neurological disorders due to egg migration to the central nervous system[6].The disease causes significant morbidity and mortality, with over 230 million people infected globally and nearly 800 million at risk. It contributes substantially to the global burden of disease, especially in resource-limited settings[7].

2.2 Epidemology of Schistomiasis

Schistosomiasis is a parasitic illness that spreads through water and is caused by flatworms belonging to the genus *Schistosoma*. It poses significant risks to both human and animal health and is categorized as a neglected tropical disease[8]. The infection affects over 250 million people across approximately 76 countries, with the highest rates found in sub-Saharan Africa and parts of Asia. Globally, the disease accounts for around 1.4 million disability-adjusted life years, making it second only to malaria in terms of disease burden. Children between the ages of 5 and 15 are the most vulnerable, particularly in areas where the disease is widespread. The infection occurs when people come into contact with freshwater containing the infectious larval stage of the parasite, called cercariae[9]. Everyday activities such as collecting water, bathing, fishing, and playing in streams increase the risk of infection. People may also become infected while crossing rivers or streams on their way to farms, schools, or during early morning routines[10].

Schistosoma parasites can infect a wide range of hosts, including humans, domestic animals, and wildlife. Out of 23 recognized species, about 19 are capable of infecting animals, although only a few cause serious illness in livestock. Six species are known to infect humans, with three being the most prevalent: *S. haematobium* (causing urogenital schistosomiasis), *S. mansoni*, and *S. japonicum* (both responsible for intestinal schistosomiasis) [11,12]. While *S. haematobium* and *S. mansoni* are widespread in Africa and the Middle East, *S. mansoni* is also found in the America. *S. japonicum* occurs in parts of Asia such as the Philippines, Indonesia, and China, though it has been eliminated from Japan. Other less common species affecting humans include *S. mekongi*, *S. guineensis*, and *S. intercalatum*, which are found in specific parts of Asia and West/Central Africa. It is possible for a person to be infected with more than one species simultaneously, especially in endemic regions[12]. Most of these parasites, apart from *S. guineensis*, are also known to infect mammals. Animal-infecting species include *S. bovis*, *S. intercalatum*, *S. matthei*, *S. rodhaini*, *S. nasale*, and *S. japonicum*. Among these, *S. bovis* and *S. matthei* are particularly harmful to ruminants[13]. Despite this, schistosomiasis in animals often receives limited attention in veterinary medicine. In Africa, livestock infections mainly involve three species: *S. bovis*, *S. mattheei*, and *S. curassoni*, which affect various mammals including bovids and primates. Research on their distribution, infection rates, and genetic diversity remains scarce[14].Interest in these animal parasites has grown recently due to concerns about their potential to infect humans, especially through inter-species breeding with human schistosomes. Such genetic mixing can lead to hybrids that are more resilient and difficult to treat, complicating control measures[15,20].

The disease is strongly linked to poverty and poor access to clean water. Environmental changes like dam construction and human migration contribute to its spread. As people and animals move, they can carry the parasite to new regions[16]. Some parasites can infect both humans and animals, and interbreeding between species increases their genetic variation, potentially enhancing drug resistance and complicating global eradication efforts[17].

Despite being eradicated from Japan, S. japonicum can be found in other countries of Asia, including China, Indonesia, and the Philippines. Additionally, *S. mekongi, S. guineensis*, and *S. intercalatum* found in some regions of Asia and West/Central Africa are less frequent species that infect people. A person can have many species infections at the same time, particularly in areas where the conditions are endemic12. Along with *S. guineensis*, the majority of these parasites have been associated with infecting mammals. Among the species that infect animals are *S. bovis, S. intercalatum, S. matthei, S. rodhaini, S. nasale,* and *S. japonicum? S. bovis* and *S. matthei* are the most detrimental to ruminants13 among them. Animal schistosomiasis, however, frequently gets little attention in veterinary practice.

The transmission of schistosomiasis depends on a specific relationship between the parasite and certain freshwater snails, which act as intermediate hosts[18]. This relationship is so specialized that schistosome populations are often better adapted to local snail variants than to others of the same species[19]. Different *Schistosoma* species rely on different snail hosts: *Bulinus* snails for *S. haematobium*, *Biomphalaria* for *S. mansoni*, and *Oncomelania* for *S. japonicum*. Consequently, the geographical range of each parasite species is closely tied to the distribution of its respective snail host, which in turn is influenced by environmental and ecological conditions[20].

2.3 Global Disease Burden of Schistosomiasis

Schistosomiasis is present in approximately 76 countries around the world, with close to 700 million individuals at risk and nearly 200 million already infected[21]. The disease is responsible for an estimated 300,000 deaths each year, and around 10 million pregnant and breastfeeding women are affected. The vast majority of infections—about 90%—are concentrated in sub-Saharan Africa and parts of Asia. Among all affected countries, Nigeria records the highest number of cases, estimated at around 70 million. Other heavily impacted nations include Ethiopia, the Democratic Republic of Congo, and Kenya, while Angola and Gabon have some of the highest infection rates in terms of population prevalence[22].

The most widespread schistosome species, *Schistosoma mansoni*, is common in many African countries, including Angola, Gabon, Eritrea, Madagascar, Somalia, Mozambique, Kenya, Benin, DR Congo, Nigeria, Tanzania, and Côte d'Ivoire. It is also found in northern African countries such as Egypt, Libya, and Sudan. Collectively, Africa accounts for the vast majority of global cases involving *S. mansoni*. Beyond Africa, this species also appears in parts of the Arabian Peninsula, Brazil, Venezuela, and several Caribbean islands. Another notable species is *Schistosoma japonicum*, responsible for intestinal schistosomiasis in Asia. It is especially prevalent in China, Indonesia, and the Philippines, where over one million people are currently infected, and more than 50 million are at risk. Though it originally emerged in Japan, the disease has been successfully eliminated there since the late 1970s[23,24].

Schistosoma haematobium, which causes urogenital schistosomiasis, has a more limited geographic range than *S. mansoni* but remains a major health concern. It is endemic in more than 50 African countries and also occurs in parts of the Middle East, affecting over 100 million people[25].

While many regions of the world have managed to significantly reduce or eliminate schistosomiasis, progress varies. Northern African countries have implemented large-scale control programs, including widespread distribution of the antiparasitic drug praziquantel, which has reduced the disease's prevalence to as low as zero in some areas[24]. For instance, Egypt has seen prevalence rates drop to between 0% and 13.9%. In contrast, little progress has been made in sub-Saharan Africa, where control efforts are limited. Despite global health campaigns, there has been only modest improvement since the early 1990s, with less than a third reduction in cases from an estimated 290 million infections in 2013[26].

2.4 Epidemiology of Schistosomiasis in Nigeria

Nigeria is one of the countries in sub-Saharan Africa most affected by both urinary and intestinal forms of schistosomiasis, accounting for roughly 14% of global cases [22,27]. It also has the highest number of individuals in need of treatment and preventive measures. The two primary species responsible for the infection in Nigeria are *Schistosoma haematobium* and *S. mansoni*, although the latter is less common and found in fewer regions across the country[28]. A 2015 survey conducted across 19 Nigerian states revealed that urogenital schistosomiasis made up about 80% of all infections, while intestinal schistosomiasis accounted for around 20%. In addition, *S. bovis*, a parasite that typically infects animals, has been identified in some areas of the country[29].

The presence of multiple schistosome species in overlapping regions increases the likelihood of people being infected by more than one type, which could lead to more severe health complications. The earliest recorded case of schistosomiasis in Nigeria dates back to 1908, even though the disease itself was first identified in 1851[30]. Despite its long history in the country, comprehensive and accurate data on the disease's spread and burden have been limited and sometimes inconsistent. Many regions in Nigeria still lack reliable epidemiological records on schistosomiasis[31].

A significant step was taken on June 4th, 2015, when Nigeria's Federal Ministry of Health released official data on the disease's prevalence. According to this report, about 24 million

Nigerians are at risk, with a nationwide infection rate close to 9.5%. Current control strategies rely heavily on drug treatment, particularly the administration of praziquantel to those infected or at risk[32]. These control efforts are led primarily by the Federal and State Ministries of Health. However, the involvement of research institutions, non-governmental organizations, and faith-based groups has been limited. Several challenges hinder the success of eradication efforts, including remote and inaccessible areas, ethnic and religious conflicts, insurgencies, and the widespread presence of water bodies that support the breeding of the snail hosts necessary for disease transmission[33].

To address these obstacles, it has been recommended that health education particularly in schools be combined with routine preventive drug administration. This integrated approach is expected to significantly reduce infection rates, help prevent reinfection, and counter potential drug resistance by the parasite[34].

2.5 Freshwater snail intermediates Hosts of Schistosomiasis

The phylum Mollusca is widely distributed in aquatic ecosystems, in which it is both abundant and variable. Of about 120,000 described molluscan species, approximately 4000 inhabit freshwater such as lakes, rivers, streams, ponds and dams [35]. Freshwater snails play essential roles in the aquatic ecosystem by feeding on fungi, decaying materials, plants and algae, thereby converting them into indirect sources of nutrients for aquatic animals that feed on freshwater snails [36]. They serve as sources of nutrients for other invertebrates, waterfowl, turtles, fish such as trout and sculpins, amphibians, reptiles, birds and man. Some freshwater snails are also sentinels because of their sensitivity to pollution [37].

The dispersal of freshwater snails outside their natural habitat is limited by geographicalbarriers such as deserts, watershed boundaries, oceans and mountains [38]. However, they may evade such restrictions and the introduction of foreign snails may constitute a significant threat to indigenous snail biodiversity. Once introduced species are established, they become hard to eradicate. Their abundance, distribution and competitiveness are unpredictable, making it challenging to understand their impacts on indigenous freshwater populations [39]. The survival of an invasive species depends on its ability to invade (invasiveness) and its suitability in the new habitat (invasibility) [40]. Factors such as rapid fecundity, exponential growth rate, effective dispersal, a wide range of diet, and short generation time assist introduced freshwater snails to become established [41]. The newly established species integrate into their new habitat by developing ecological links with the indigenous species [42].

Invasive freshwater snails have been reported in different African waterbodies. For example, in Nigeria, Bulinus senegalensis (Müller, 1781), a freshwater snail indigenous to Senegal, was first reported in 1980 (Betterton et al. 1983), while Amerianna carinata (Adams, 1861), an indigenous Australian snail, was first collected in 1982 [43]. In 2010, Bulinus camerunensis (Mandahl-Barth, 1957), a freshwater snail indigenous in Cameroon, was recorded for the first time in Nigeria [44]. Freshwater snail distribution and abundance generally including land contour, climate change, soil composition, hydrography, water properties, presence and absence of environment pollutants and sediment types, and biological factors, such as macrophyte abundance and predator-prey interactions [38]. Several natural factors are responsible for the redistribution of invasive species, including water currents (hydrochory), wind (anemochory), and animals (zoochory) [45].

However, their primary mode of dispersal is by anthropogenic activities, which include damming, dredging, trading of aquacultures, plants, and ornamental pets and intercontinental transportation by ships [46]. Billions of live animals are transported yearly as part of the global pet trade [47]. These animals are traded for recreational and ornamental use, and as food for pets [48]. Once these species are in the pet trade, they can be released accidentally by humans. Those species that can integrate successfully into their new habitat become invasive depend on various environmental factors [41].

Some freshwater snails have medical and veterinary health importance serving as vectors of opisthorchiasis, angiostrongyliasis, paragonimiasis, fascioliasis, clonorchiasis, fasciolopsiasis and schistosomiasis [49]. These freshwater snails are essential hosts for parts of the life cycle of trematode parasites. Their abundance and distribution lead to the continuing spread of snail-borne diseases. Some of the vector snails, such as *Physella acuta* (Draparnaud, 1805), *Bulinus globosus* (Morelet, 1866), *Melanoides tuberculata* (Müller, 1774), are introduced species in Nigerian waters [50]. The implementation of preventive chemotherapy to limit helminthic diseases is increasing in Nigeria [51.]

However, the success of this treatment has been marred by re-infection of patients, which can be partly linked to a lack of information on the distribution and abundance of vector snails in Nigerian waters [49]. For effective control and elimination of snail-borne diseases in Nigeria, it is essential to understand the abundance and distribution of these freshwater snails; and the environmental factors that support them In Nigeria, several studies have been conducted onthe biology of freshwater snails. These have suggested that biotic, environmental factors, seasons, and macrophytes, are the major determinants in the distribution and abundance of freshwater snails in aquatic habitat [52]. However, the factors contributing to invasive freshwater snail distribution in Nigerian waters have not been thoroughly studied.

Freshwater snails found in most of Sub-Saharan Africa are commonly distributed and belong to the genus *Biomphalaria, Bulinus, and Lymnaea*. They are common species within the subfamily Planorbidae and Lymnaeidae, respectively [53.] In tropical and subtropical areas of the world, blood-dwelling trematode parasites that pose major health risks to both humans and animals are carried by members of several families of snails [54.]

The estimated billion-dollar losses in agriculture worldwide linked to fascioliasis stem from higher animal mortality and lower productivity. 180 million people are susceptible of infection and approximately 17 million people are affected in endemic areas. 207 million people worldwide are afflicted with schistosomiasis, the majority of whom are from Sub-Saharan Africa, which has the largest disease burden [55].

Snails are typically found near the surface of water bodies with poor or non-existent drainage, adhering to a variety of aquatic plant parts and other substrates like stones, grasses, dead leaves, and discarded plastic containers. Snails are more likely to live in lentic water bodies than lotic ones. The accessibility of ground water determines the existence and range of freshwater vector snails. Nonetheless, research has been done in Nigeria on many kinds of freshwater [56].

2.6. Ecology of Freshwater Snails

The development of dams and their management create new habitats that are conducive for breeding of freshwater snails including those that serve as intermediate host to important human and animal diseases (schistosomiasis,trypanosomiasis, fascioliasis) [57]. Many of such freshwater bodies contain potential snail intermediate host [58]. This increases the transmission risk of waterborne disease [59]. About 350 species of freshwater snails in Africa are estimated to be of medical and veterinary importance [60]. It is estimated that 200 million people are infected with schistosomiasis worldwide and 600 million are at risk. Globally 200,000 deaths are attributed to schistosomiasis annually [61]. In Nigeria, about 101.28 million people suffer from the disease [62]. The diseases are acquired through repeated contact with freshwater during washing, swimming or fishing [63].

In Nigeria, several studies on the distribution of freshwater snails of public and veterinary health importance had been carried out to ascertain their role in the transmission of trematode infection in humans and animals [64, 65, 66, 67.] Similarly in Kaduna State various freshwater snails intermediate host have been collected [68, 69.] Consequently, dams contribute to the spread, endemicity and incidence of water borne diseases especially trematode parasitic diseases that are dependent on water based intermediate host. Several factors such as physical, chemical and biological factors are considered affecting the ecology of freshwater snails and other intermediate host of disease hence, suggesting local investigation to identify important factors in each water body [70, 71].

2.7 Global Prevalence of Schistosomiasis

Over 779 million individuals were at risk of contracting schistosomiasis and 207 million people had schistosoma worm infections in 74 countries where the disease is endemic [72]. Over 660 million people were thought to be at-risk, with 85% of the total estimated at-risk population living in Africa. According to estimates, Africa is home to an estimated 201.5 million schistosome infection (mostly *S. haematobium*), which makes up more than 97% of all estimated infections globally [73].

The majority of schistosomiasis-endemic nations are also within the least developed, and their primary healthcare systems are under a great deal of pressure to deliver basic healthcare. The countries most severely affected are those in Africa (Angola, Central African Republic, Chad, Egypt, Ghana, Madagascar, Malawi, Mozambique, Nigeria, Senegal, Sudan, the United Republic of Tanzania, Zambia), South America (Brazil), South-East Asia (Philippines), South-West Asia (Yemen Arab Republic), and South America [73]. These estimates are based on the size of the endemic areas and the estimated prevalence.

In Africa alone, schistosomiasis claims the lives of about 300,000 individuals every year. In Africa, almost 10 million pregnant women contract the infection. With these species, zoonotic transmission is conceivable since the parasite infects both wild rats and people [74]. Antigua and Barbuda, as well as India, Indonesia, Jordan, Oman, and Saint Lucia are the countries with the lowest reported prevalence rates, or where the projected number of infections is less than 1000. Currently, the most affected nations are 29 African nations, Brazil, and Yemen, which together house over a million cases annually.

2.8 Distribution of vector snails

Distribution and Habitats of Freshwater Snail Intermediate Hosts Trematode diseases are widely spread because their different snail intermediate hosts are as such broadly distributed. This is buttressed by Idris and Ajanusi when they observed that the distribution of snail intermediate hosts and the engagement of free swimming in many contaminated ponds and streams in the villages contributed to the high prevalence of infection. *Bulinus* are widespread in Africa including Madagascar and the Middle East . This genus has not yet been established in the U.S.A, but it is considered to represent a potentially serious threat as a pest‘, an invasive species‘ which could negatively affect agriculture, natural ecosystems, human health or commerce. Therefore, it has been suggested that this species be given top national quarantine significance in the U.S.A [75]

The distribution of the four species groups within the genus Bulinus is reviewed below: a. *Bulinus africanus* group There are 10 species in this group (Brown, 1994), among which are *Bulinus globosus* – Morelet, 1866, *Bulinus africanus* – Krauss, 1848 and others were considered to be from intermediate populations [76]. *Bulinus globosus*: *Bulinus globosus* has the greatest range of any member of its species group.

Bulinus africanus has a scattered distribution in Eastern and Southern Africa, unclear for many areas where critical comparison with *B. globosus* is needed (Brown, 1994). In Southern Africa, *B. africanus* inhabits cooler climate areas whereas *B. globosus* occurs only in the warmer parts [77].

In Nigeria, *Bulinus* is implicated and from the findings of Idris and Ajanusi (2002), *Bulinus globosus* is the species of the *B. africanus* group implicated. A number of species of non-marine molluscs are found in the wild in Nigeria which include *Bulinus globosus* found in areas like Oyan Reservoir, Ogun State, some local government areas in Katsina State Agulu Lake area of Anambra State, Ishienu Local Government Area in Ebonyi State to mention but a few indicating that *B. globosus* is the snail that has been more implicated in the Western, Northern and Southern Nigeria [78, 79,80.]

There are 11 species in this group including *Bulinus barthi, Bulinus browni, Bulinus camerunensis, Bulinus forskalii* and *Bulinus scalarias*. Globally, *B. forskalii* is found to be widespread all over Africa. It is essentially an afro tropical species reaching the Mediterranean only in Lower Egypt. There is recent record in Lake Qaron (Fayoum, Egypt), northern region delta, and Nasser. Egypt is northern extent of species [77]. The range of B. forskalii extends west to Senegal and Southwards to Eastern and Southern South Africa [11].

Bulinus truncatus is a freshwater snail with the widest distribution of all Bulinus species. According to this author, it is found across much of Africa, the near east and the Mediterranean. It occurs in Cameroon, DR Congo and Gabon, Western Kenya, Ujiji, Kigomo in Tanzania, Lake Mutanda in Uganda, in Malawi, Sudan, Ethiopia, Somalia, South Egypt and possibly also in Eritrea and Djibouti. Its southern limits lie in Zaire and Malawi but it has also been recorded as rare in Zimbabwe. The main areas of distribution in Africa are Lower Egypt, Sudan and Westwards into Mauritania. It has been found in all Oases in Northern Africa and widespread in Western and Eastern Africa [82.]

The northern limit of B. truncatus is known to be Portugal, Sardinia and Corsica, and the near east. It has also been recorded in the Mediterranean region and Southwest Asia eastwards to the Khuzistan region of Iran and found throughout the western parts of the Arabian Peninsula [82]. It is present in Saudi Arabia and Yemen, where it seems to be limited to few localities in Sana'a, Ibb, and Taiz districts but not found in Oman. In Saudi Arabia, living populations have been found only in the western regions [82]. The distribution and habitats of other freshwater snail intermediate hosts for parasitic trematodes have been emphasized by many workers [83.]

2.9 Factors affecting the Abundance and Distributions of Freshwater Snail

Freshwater snail abundance and distributions are influenced by not only the availability of the snails' habitat, but also by some biotic and abiotic factors. Changing ecology, global warming and migration, may have led to changes in the prevalence and distribution of the disease in different parts of the state studied [84].

2.9.1Abiotic Factors

2.9.1.1. Physical Factors

Among the physical factors that influence the occurrence and distribution of the snail hosts are variations in rainfall, water temperature, water current and Elevation. The population dynamics of *Bulinus globosus* are negatively correlated with temperature [83]. These authors observed in Zimbabwe that losses of Bulinus due to raining season floods ranged up to 99.1%. The relationship between recruitment and temperature was discovered by a bell-curve, with peak recruitment at 20.6^{0}C, Recruitment rate varied between sites.

Growth rate was positively correlated with temperature. *B. globosus* population has a temperature-dependent season cycle with rapid increases in abundance during period of favourable temperatures. Floods or drought caused variable and irregular reductions in abundance [83]. Idris and Ajanusi observed that infection rate and prevalence of Bulinus tend to fluctuate during the months under study. The highest of which 29 was observed to coincide with the dry season, although towards the onset of the rainy season when the temperature range (20.6°C – 32.8°C) lies within the optimum limits for snail growth and reproduction, it was attributed to increase in abundance of snail species during the dry season to the stability of the aquatic habitat in terms of water level and velocity [84]. It was also reported during the studies in Cross River State, Nigeria observed that the snail population was highest in April, just before the onset of the rains but reduced at peak of the rainy season. Large empty snail shells were recovered in March, just before the population of all snail species showed marked and locally varying seasonal fluctuations and concluded that in general, snail populations fluctuated strongly (numbers decreased at the peak of the rainy season and further reduced during the dry season).

2.10 Snail Intermediate Hosts of Human Schistosomes

Three genera of freshwater snails serve as intermediate hosts for the three major schistosomes. They are *Bulinus, Biomphalaria and Oncomelania* which serve as hosts for *Schistosoma haematobium, Schistosoma mansoni* and *Schistosoma japonicum* respectively. In addition to the three major schistosomes are *S. intercalatum* and *S. mekongi* with snail hosts *Bulinus* and *Neotricula aperta* serving as intermediates respectivel. Bulinus, a genus of small tropical freshwater snails are aquatic gastropods molluscs in the family planorbidae, the ram's hornsnails and their allies. The shell of the species of the genus *Bulinus* is sinistral. It has a very large 39 body whorl and a small spine. The genus is medically important because several species of Bulinus function as intermediate hosts for the schistosomiasis blood fluke [85]. Species within the genus *Bulinus* have been placed into four species groups: the Bulinus africanus group, Bulinus forskalii group, Bulinus reticulatus group and Bulinus truncatus group otherwise known as Bulinus tropicus complex [74].

Biomphalaria, a genus of air breathing freshwater snails are aquatic pulmonate gastropod molluscs also in the family plarnobidae, the ram'shorn snails and their allies. It is the type of genus of tribe biomphalariini. Taphius is a synonym for *Biomphalaria* [85]. The shell of these species like all planorbids is sinistral in coiling, but is carried upside down and thus appears to be dextral. This genus of snail is medically important because the snails serve as intermediate host for the human parasitic blood fluke, *S. mansoni* that infects about 83 million people [86]. The International Association for Medical Assistance to Travelers. Biomphalaria as a snail with a flat disc-shaped shell, dusky brown or reddish in colour with a diameter of 7-22mm. Eighteen species of Biomphalaria are intermediate hosts for *S. mansoni*, seven species of the genus have not been tested for this susceptibility and nine species are resistant [87].

There are 34 species in the genus Biomphalaria among which are 22 American species and 12 species in the Old World comprising Africa, Madagascar and the Middle East [86]. Oncomelania is a genus of very small tropical freshwater snails, aquatic gastropod molluscs in the family Promatiopsidae. The genus was named by Gredler [87]. Oncomelania snails are distantly related to the marine periwinkle and more closely related to the small marine species of the family Rissoidae. There are two species in the genus Oncomelania which are Oncomelania hupensis and Oncomelania minima [88].

Oncomelania hupensis, a polytypic species has a number of subspecies. Japanese Red List Data Book recognized also Oncomelania lindoensis while Japanese Red List Data Book recognizes also Oncomelania shini and Oncomelania sakuyamai [89]. Various Oncomelania spp are significant medically because they can carry the blood fluke parasite and Paragonimus lung fluke parasite [90]. The snail intermediate hosts of S. japonicum (Oncomelania sp) and *S.mekongi* (Neotricula aperta) are amphibious (water and land snails) [91]. Three strains of Neotricula aperta have been recognized (called α, β andΥ), on the basis of shell size and body pigmentation. Although all the three strains are 43 susceptible to Schistosoma mekongi, only the Y-strain is epidemiologically significant [92].

2.12 Taxonomy of freshwater vector snails in Nigeria

When an infected man shedds eggs into the water body or its surroundings, the eggs under optimium conditions hatch into miracidia (singular=miracidium). The miracidia locate and penetrate *Bulinus* snails. Inside the snail host, they develop into mother sporocysts, each of which develops into daughter sporocysts.The fucocercous cercariae develop from daughter sporocysts and start to emerge from the host few weeks after initial penetration of the host by the miracidium. Cercariae alternately swim to the water surface and slowly sink toward the bottom, continuing to live this way for one to three days. If they come in contact with the skin of a prospective host, such as a human, they attach and creep about for a time as if seeking a suitable place to penetrate. They are attracted to secretions of the skin, showing a strongly positive response to the amino acid, arginine from post acetabular glands, thus attracting other cercariae in the neighbourhood [93.] Cercariae require only half an hour or less to completely penetrate the epidermis and they can disappear through the surface in 10 to 30 seconds [94]. Penetration is accompanied by a vigorous wriggling, together with secretion of products from the head organ. The tail drops off in the process. Within 24 hours the schistosomula (immature schistosomes) enter the peripheral circulation and are swept off to the heart.

The spread of diseases from where the snail hosts house their parasites is directly correlated with the spread of snails intermediate hosts [95]. Climate, vegetation, and the kind of water bodies in an area are some of the elements that determine the spread of vector snail hosts. In order to develop steps for preventing the spread of parasites and to assess the possibility for infected snails to colonise water bodies, it is critical to ascertain the geographic distribution of snail carriers of parasites [96.]

Natural barriers including mountains, deserts, and oceans may restrict the range of snails. Freshwater snails can travel very short distances due to animal migration as well as water currents [95.] Due to the possibility of snails or masses of eggs getting stuck on an animal's hooves or in mud, mammals also play a factor. These quick-moving modes of transportation enable the dissemination of snails. Following a survey of 165 freshwater environments in Kano state, several possible intermediate host species for snails were found, including *Bulinus senegalensis, Bulinus* The majority of its habitats lacked aquatic vegetation and had extremely murky waters with conductivities as low as 11µs. In comparison, *Bulinus forksali* was comparatively uncommon, existing in longer-lasting waterways. While it frequently coexisted in hybrid populations with *Bulinus senegalensis,* Bulinus was also found in periodically wet pools. The discovery of seven snail species in 43 distinct habitats in Ibadan includes *Bulinus forksali, Bulinus globosus, Biomphalaria pfeifferi, Lanistes lybicus, Lymnea natalensis,* and *Melania species*. Though the species' preferences for different habitats varied to some extent, the underlying causes were typically unknown. Nonetheless, it was especially apparent that habitats with a small amount of decomposing vegetation or human faeces were home to high populations of *Bulinus globosus*. In comparison, *Bulinus forksali* was comparatively uncommon, existing in longer-lasting waterways. While it frequently coexisted in hybrid populations with *Bulinus senegalensis*, *Bulinus* was also found in periodically wet pools.

The recent discovery of seven snail species in 43 various habitats in Ibadan includes *Bulinus forksali, Bulinus globosus, Biomphalaria pfeifferi, Lanistes lybicus, Lymnea natalensis, and Melania species*. Though the species' preferences for different habitats varied to some extent, the underlying causes were typically unknown. Nonetheless, it was especially apparent that habitats with a small amount of decomposing vegetation or human feces were home to high populations of *Bulinus globosus*.

Snails grouped into vectors fall within the subclass Pulmonata, or pulmonates. The radula of freshwater pulmonates involves many small, uniform teeth, and they are characterized by the lack of an operculum. In general, the shell lacks strong sculpting and has weak walls. Nigeria's freshwater snails are classified into three subclasses under the Gastropoda: Pulmonata, Prosobranchia, and Opisthobranchia. The members of the families belonging to the subclass Pulmonata are displayed in Table 1 below.

Table 1: Members of the Subclass Pulmonata

Pulmonata (Family)	Vector snails
Physidae	*Applexa waterlotti and physa acuta*
Ancyclidae	*Ferrisa chudeaui, Ferrrisa leonnensis*
Lymnaeidae	*Lymnae natalensis*
Planorbidae (subfamily Planorbinae)	*Americana carinata, Segmentorbis, kanisaensis, Segmentorbis augustus, Biomphalaria Pfeifferi, Biomphalaria sudanica, Biophalaria sudanica, Biomphalaria camerunensis, Ceratophallus natalensis, Gyraulus costulatus.*
Planorbidae (subfamily Bulininae)	*Bulinus truncatus, B.natalensis, B. Umbilicatus, B, camerunenesis, B. forksali, B. senegalensis, Indoplanorbis exutus.*

Source: Brown and Kristensen (1991)

2.12 Prevalence of Schistosomiasis in Africa

In many developing nations in tropical and sub-tropical Africa, the Middle East, Southeast Asia, and Latin America, schistosomiasis is a neglected tropical disease (NTD) of poverty that is spread by snails and fresh water [96]. The illness is typically widespread in rural, low-income areas without access to clean water, hygienic conditions, and sufficient medical facilities. Although making up only 13% of the global population, Sub-Saharan Africa (SSA) is home to up to 90% of cases and 280,000 annual deaths from schistosomiasis [96]. Recent reports of locally acquired urinary schistosomiasis patients due to S. haematobium have been made in Corsica, France, where the infection was previously not prevalent. These cases were probably brought in by people who contracted the disease in West Africa [97]. Additionally, there is growing proof that human and animal schistosome species have hybridized, creating new zoonotic illnesses [97]. In order to lower morbidity, community-based preventive chemotherapy (PC) with mass drug administration (MDA) of the broad range anthelminthic medication praziquantel (PZQ) is the main focus of schistosomiasis management initiatives in Africa. Millions of school-age children (SAC) are treated with PZQ supplied annually to endemic nations in Africa [74].Treatment adherence is difficult, particularly for those living in low-socioeconomic areas, due to concerns regarding side effects, the seeming lack of disease symptoms, as well as the stigma associated with symptoms when they do occur[98]. Alternatively, symptoms may be interpreted as a typical puberty-related symptom and not necessitate treatment. Over the past ten years, there have been more initiatives to eradicate schistosomiasis, with the The World Health Organization (WHO) adopted 2030 as the deadline for transmission stoppage in endemic African countries, signifying that efforts to eradicate schistosomiasis have grown more serious throughout the last ten years [99.]

Various governments across the globe have made controlling non-transmissible diseases (NTDs) a top priority by taking advantage of breakpoints in the diseases' life cycles, like implementing snail control, improving sanitation, and increasing accessibility to safe, potable water [100]. But in sub-Saharan Africa, PC continues to be the most widely used strategy. If a person has schistosomula larvae, therapy may not stop them from maturing into adults and causing patency since PZQ is ineffective against migratory schistosomula. Another frequent side effect of PZQ treatment is rapid reinfection [101]. Since SAC are thought to be most susceptible to infection and are more likely to engage in daily activities like fishing and rice farming, they are the primary targets for management. Adults often have effective immune responses against schistosomes, but children from endemic areas are typically susceptible to reinfection following treatment for schistosome infection [102]. Protective immunity systems against schistosomes develop slowly. The age-prevalence and age-intensity curves that are typical of schistosomiasis-endemic regions in Africa can be explained by this finding [103].

2.13 Morbidity and Mortality of Schistosomiasis

In most underdeveloped nations, including Nigeria, the importance of mortality and morbidity brought on by helminthic illnesses, such as schistosomiasis, has been glaringly underestimated. The majority of people affected by the morbidity and mortality linked to schistosomiasis are school-aged children, teenagers, women, and young adult [104]. Population studies of children infected with Schistosoma have revealed that the disease can lead to poor academic performance, growth retardation, tiredness, weakness, loss of memory and cognitive reasoning, and an increased risk of anaemia. These outcomes limit the potential of children infected with Schistosoma. These negative impacts on kids increase society's socioeconomic burden [105]. Schistosomiasis rarely results in death, but it can cause long-term morbidity like anemia from bleeding from the intestinal and urinary tracts that results from worm invasion and movement; iron deficiency is another consequence of the disease that may result to nutritional impairment like malabsorption of nutrients and digestive disorders like diarrhoea. According to a study conducted in Daekena, the Republic of Niger, a region where urinary schistosomiasis is widespread, 41.7% of the 174 schoolchildren had iron insufficiency, and 57.7% had anemia associated with an iron deficiency [105].

It was also reported that longitudinal study carried out in Burkina Faso with 1727 Burkinabe children between the ages of 6 and 17 years showed a substantial rise in hemoglobin concentration after S. haematobium treatment when compared to baseline concentration one year prior. Clinical observation and postmortem results clearly suggest that kidney damage caused by schistosomal infection kills people, especially old patients. An essential risk factor for the spread of the HIV virus is urogenital schistosomiasis. The rate of transmission among male sexual partners and from an HIV-positive male to his partner is increased in women with urogenital schistosomiasis. Furthermore, by raising the plasma concentration of HIV RNA (viral load), it accelerates the course of the illness in those who have already contracted the virus.

A study among Zimbabwean women showed that women with *S. haematobium* eggs in their pap smear had a risk three times higher of having HIV. Studies on animal models and human subjects have established adverse consequences of schistosomiasis on pregnancy outcomes. Sc*histosoma haematobium* infection has been linked to placental inflammation, leading to poor birth-outcomes as a result of placental incompetency.

Heavy *S. mansoni* infection has also been linked to higher risk of anaemia that might subsequently lead to maternal mortality or low birth weight (LBW) babies. The anaemia may be due to urinary iron loss and faecal waste.Pro-inflammatory cytokines from schistosomiasis infection cause pregnant women to lose their appetite or experience anorexia, which may ultimately prevent the mother from gaining enough weight to give birth to an underweight child. Pregnant women in Tanzania were found to have a high incidence of *S. mansoni* infection, and high-intensity of infection puts the women at risk for anemia during pregnancy, according to an observational study. An other Tanzanian study connected the birth of LBW children to infections with parasitic illnesses, such as schistosomiasis, during pregnancy. When comparing cases with single infections, the study has demonstrated an increased progression of liver fibrosis in individuals associated with schistosomiasis and hepatitis C virus, which finally resulted in severe liver.

2.14 Schistosomiasis Diagnosis

For the diagnosis of schistosomiasis and the detection of schistosomes, several methods are employed. Microscopy is the standard method used in Africa to detect eggs in urine or stool.

However, a number of molecular and immunological diagnostic assays have been developed, some of which have been implemented in Africa [106]. Although molecular methods based on quantitative polymerase chain reaction (qPCR) and polymerase chain reaction (PCR) are increasingly being used for screening in high-resource settings worldwide, their current adoption among low socioeconomic endemic field settings is hindered by their high cost, lengthy turnaround periods, and requirement for a substantial laboratory infrastructure and training. Certain challenges can be addressed by isothermal amplification and detection (IAD) techniques, such as the pricey heat cyclers needed for the PCR-based method to identify parasite DNA in urine or feces. IAD tests function similarly to traditional PCR in that target-specific primers are extended using either DNA or RNA polymerase. But isothermal amplification makes amplification easier without requiring the PCR's several cycles of denaturation and annealing. Loop-mediated isothermal amplification (LAMP) is the most well-established IAD technique for schistosome detection [106].Recombinase polymerase amplification (RPA) , helicase-dependent isothermal amplification (HDA) , and nucleic acid sequence-based amplification (NASBA) (Compton, 1991) are other isothermal methods for parasite detection; however, only RPA has been used in the identification of Schistosoma spp. [107, 108, 109.]

Schistosomiasis is most usually diagnosed by microscopic examination of ova in urine (S. haematobium) and stool (S. mansoni), as previously mentioned. To identify S. haematobium infections, urine microscopy is performed first, followed by urine filtration, and then the Kato-Katz (KK) technique is used to detect *S. mansoni* eggs in feaces. A cross-sectional investigation conducted along the southwest coastline of Lake Malawi in Sub-Saharan Africa revealed the presence of S. haematobium eggs in the semen of fisherman. This finding suggests a high rate of egg lodgement in men's reproductive organs [110.]

Uncertainty surrounds the exact origin of eggs detected in semen; they may have started in the bladder, traveled down the urethra with urine droplets, and then been expelled along alongside the semen. Light microscopy makes it easy to identify S. haematobium eggs, and semen has been found to contain cell-free circulating schistosome DNA several weeks following a single PZQ dosage. Enzyme-linked immunosorbent assay (ELISA) or monoclonal antibody-based lateral flow tests can be used to detect active infections in addition to egg detection. These tests can identify worm-derived circulating anodic antigens (CAAs) and circulating cathodic antigens (CCAs) in serum and urine .Early infection detection is possible with these detection techniques [111]. But they don't distinguish between previous infections, ongoing infections, or re-infections, particularly in endemic regions where patients may continue to be seropositive years after treatment [112].

As an indirect diagnostic technique for S. haematobium infection, haematuria and proteinuria reagent strip tests are also available .Strip testing has been proposed as a substitute for the standard urine microscopy method because it has been demonstrated to provide sensitivity and specificity levels of 75% and 87%, respectively, for the identification of *S. haematobium* [113]. Strip testing's significantly greater sensitivity than microscopic techniques and its simplicity of storage make it a potentially helpful tool in sub-Saharan Africa .But the method shows poor sensitivity in detecting low-intensity infections and egg-positive urine post-treatment. Moreover, the test strips also detect haematuria that is not related to a *S. haematobium* infection.

2.15 Prevention and Control of Schistosomiasis

Avoiding contact with fresh water contaminated with Schistosome parasites is the fundamental method of preventing Schistosoma infection. Engaging in aquatic activities such as swimming or wading exposes the epidermis to the potential for cercariae invasion. To help stop cercariae from entering the skin, it is recommended to thoroughly dry the area after brief unintentional contact with contaminated water. To eliminate any potential parasites, groundwater from these sources of clean water must be heated to a boil for a minimum of one minute before being used for bathing or drinking [114]. Before using, let the water sit for at least 24 hours to help avoid infection. The cercariae that might be present in the water can also be filtered using fine-mesh filters. Although using insect repellents topically, like DEET (N,N-Diethyl-meta-toluamide), can stop cercariae from entering the skin, this method is not very effective [115]. It is sometimes impossible to avoid coming into contact with contaminated water, particularly for those living in endemic areas where daily activities or their jobs (such farming or fishing) expose them to toxic waterways. To assist reduce the incidence, severity, and duration of the effects of infection, the WHO has suggested preventative chemotherapy as a morbidity control technique [116].

Preventive chemotherapy can reduce egg production, which in turn reduces the morbidity caused by the egg's deposition in human tissue, even if it cannot prevent re-infection. School-aged children in regions with endemic infections are the target of preventive chemotherapy because of their recognized increased risk of infection. Prevention measures should also be provided to individuals whose are at high risk of infection due to their occupation, such as farmers, fishermen, and irrigation workers, in addition to women who may come into contact with contaminated waters while doing household chores, in regions where the incidence of an infection is at least 10%. Due to their increased risk of acquiring morbidity from schistosomiasis infection, pregnant and breastfeeding women in those regions ought to participate as well in preventative chemotherapeutic campaign [117].

2.16 Control of Schistosomiasis

In the 1920s, Egypt conducted one of the first widespread medication administration programs for the treatment of schistosomiasis in adults and children, employing intravenous tartar emetic. A nationwide approach which involved treatment and/or snail control as disease management techniques was then put into place. Chemotherapy was once again the focus of control tactics after safe medications such as niridazole, metrifonate, oxamniquine, and praziquantel were discovered for treating human infections.

The World Health Assembly supported chemotherapy as the primary method of controlling schistosomiasis by widespread medication administration in resolution 54.19, which was drafted in 2001. By 2010, this resolution aimed to cover 75%–100% of school-age children (ages 5–14) who were vulnerable of morbidity with chemotherapy on a regular basis [117].

However, this goal was not met, as was mentioned at the 65th World Health Assembly in May 2012. About 109 million school-age children needed therapy in 2010, and at least 21 million of them (19%) received it a far cry from the resolution's stated goal. Results was based on findings from 28 (55%) of the 51 countries where schistosomiasis could have been prevented with preventive treatment [118].

By reducing the general prevalence in the community, mass drug administration attempts to limit transmission of the virus and minimize morbidity and mortality caused by it. It is assumed that widespread medicine administration would also result in decreased environmental pollution, snail population infection, and schistosome egg discharge, all of which would reduce the number of human infection sources. But, people who disobey or are not protected by mass drug administration like youngsters of school age whose are not enrolled in school may still transmit the sickness. Similarly, human interactions with hotspots of transmission are inevitable, which makes it impossible for large-scale drug administration to halt the spread of the disease in communities at greatest risk [119].

2.17 Elimination of Schistosomiasis

A crucial component in the treatment of schistosomiasis is health education. The majority of Nigerians who live in rural and some urban regions mostly rely on rivers and ponds where open defecation and urination are common. Praziquantel (40 mg/kg as a single dosage) administered in the community will lessen the illness's impact [120]. A growing number of people and organizations are mobilizing in favor of ending neglected tropical diseases (NTDs). The Global Schistosomiasis Alliance (GSA) has urged international organizations and governments to pledge support and provide resources in the fight against NTD.

Nigeria is the country that receives the most gift of Praziquantel from Merck, a business that supports the World Health Organization in its fight against schistosomiasis. Ghana [121].Regular and prompt dosing of prazoquantel starting in childhood can stop schistosomiasis from progressing into genital lesions and other problems. The World Health Organization is pushing for the provision of routine mass medication administration in every healthcare facility and in high-risk areas. With the goal of preventing, treating, controlling, and completely eradicating NTDs by 2020, Nigeria's Ministry of Health has established five NTD Master Plans [122].

2. 18 Physico-chemical factors of water affecting snail distribution

The inability to distinguish the effects of individual environmental factors from those of other factors is a result of snails being subjected to a variety of interacting environmental influences. A variety of freshwater snails are members of the highly contagious trematode class that is significant to medicine and veterinary care. Since they harbor the parasite's asexual stage, snails are considered intermediate hosts, whereas vertebrates are the parasite's definite host, harboring its sexual stage.Ecologists studying snails have attempted to determine the ranges in which they thrive as well as to link snail dispersal to physical and chemical parameters [123]. Adejumoke came to the conclusion that the majority of pulmonate species are more prevalent during the dry season and tend to become less dense during the wet season. As a result, the snail may have a shaven effect on the chemical properties of water, including dissolve oxygen and biochemical oxygen demand. Research has also demonstrated the significance of aquatic plants in the vector snail's range, pointing to the existence of certain macrophytes like Panicum maximumete and Lugwiga repens. Encourage the presence of *Bulinus globosus* and a few snail vector species [124.]

There are many obvious economic and social advantages to using rivers, such as irrigation, fishing, leisure, and the production of hydroelectric power. These advantages can occasionally play a significant role in the spread of parasites, particularly helminthes. Activities involving water contact and conventional farming methods are also mentioned as contributing to the spread of illnesses and snail carriers [124.]

Freshwater snails are tolerant to a wide variety of environmental factors, both chemical and physical. Snail populations and species types vary within environments based on the interplay of biological, chemical, and physical factors [125.] Snail populations have been discovered to be directly impacted by a number of physical and chemical factors. Of the former Belgian Congo, Lietar (1956) identified the amount of dissolved oxygen in the water as a limiting factor for *B.*

globosus, while Shiff (1964) in Rhodesia identified temperature and changes in vegetation as limiting factors.

2.18.1 Rainfall

Rainfall significantly affects snail populations by altering their rate of oviposition and survival, generating population fluctuations due to drought and flooding [126]. According to Rollinson et al. (2001), gradually increasing the water level can promote breeding by lessening the population density-dependent inhibition on reproduction. According to Locker et al. (2004), there can be noticeable seasonal variations in apparent annual rainfall. Rainfall, temperature, and related elements all have an impact on the seasonal change in snail populations and infection rates.

Water velocity is acknowledged as the most significant component in lotic habitats determining the dispersion of vector snails; it is governed by geomorphic factors, particularly the resistance provided by various types of bedrock [126]. Appleton (1975) calculated a tolerance range for *Bulinus*, with limits of 0.3 m. When *B. forskalli* was surveyed by Southgate et al. (1994) on the island of Sao Tome, they discovered that the snails were restricted to the northeast of the island, where the water velocity was significantly lower than it was in other areas.

2.18.2 Temperature

The most significant abiotic element affecting snail dispersal in lenthic habitats is thought to be temperature. Temperatures either above or below lethal limits can kill snails [127]. Snails might seek for microhabitats where the temperature is most hospitable, making it challenging to determine the impact of temperature in the field due to the significant temperature variations inside the water body [128]. Temperature affects juvenile growth and reproduction, as well as adult survival, all of which have an impact on snail dispersal [128]. According to O' Keffe (1985), there is an inverse relationship between rising mean water temperatures above 25°C and B. globosus raised in coastal reservoirs in Kenya. However, compared to *Biomphalaria pfeiferi*, which is not found in Kenya's coastal regions, *B.globosus* appears to be more suited to high temperatures. The breeding season is brief in southern Africa due to the colder climate, as evidenced by mark recapture data showing an increase in *B. pfeifferi* recruitment into the population in Zimbabwe within the 13–24°C range. Despite the fact that 25°C is the ideal temperature for *B. globosus* in a lab setting.

2.18.3 Dissolved Oxygen Concentration

Due to the fact that snails rely on dissolved oxygen concentration for respiration, it is a crucial habitat element[128]. Since they are mostly aquatic, young snails depend upon oxygen that is dissolved in the water, whereas adult snails, who reside near bodies of water, occasionally use dissolved oxygen [128].

2.18.4 Hydrogen –Ion Concentration

Numerous water bodies in Nigeria have reported pH values, yet it is challenging to determine the measurements' biological significance [127]. For *B. globosus, Biomphalaria pfeifferi, Physis waterloti,* and *Americana carinatus* in southern and western Nigeria, a pH range of 7.4–8.6 has been documented [127].

2.18.5 Total Dissolved Solids

Total Dissolved Solids (TDS), also known as parts per million (ppm), are the total quantity of mobile ions, such as salts, minerals, or metals, dissolved in each volume of water. TDS is measured in milligrams per volume of water (mg/L). TDS has an impact on everything that uses, consumes, or lives in water and is directly correlated with the efficiency of water treatment facilities and water purity. The measurement of this property depends on the electrical conductivity, or EC, of water, which is often given as equivalents of hundred times the amount of cations or anions.

2.18.6 Salinity

Salinity is generally measured as electrical conductivity, also referred to as total soluble chemical contents. When dissolved salt concentrations are high or low, they restrict the range of pulmonate snails. For instance, in West Africa, the introduction of seawater into rivers during dry periods is known to restrict the range of water snails. Distinct gastropod species gradually disappear at salinities as low as 1%. The fertility and survival of *B. africanus* were negatively impacted by salinities of 1%, with the largest decreases taking place in the range of 3.5% and 4.5%. The Senegal River basin's significant *S. mansoni* and *S. haematobium* outbreak is linked to a decrease in salinity.

2.18.8 Biochemical Oxygen Demand

The quantity of dissolved oxygen required by biological organisms that are aerobic in a body of water to decompose the organic matter found within each water sample at a particular temperature over a predetermined amount of time is known as the biochemical oxygen demand, or BOD. While it is a measure to assess the organic quality of water, it is not an exact quantitative measurement. It is most frequently reported as milligrams of oxygen used per liter of sample for five days (BODs) at 20°C during incubation, and it is frequently employed as a reliable proxy for the amount of organic water present [129].

The amount of dissolved oxygen in streams and rivers is directly impacted by biochemical oxygen demand. Numerous factors influence the degree of oxygen consumption, including pH levels, temperatures, the presence of specific microorganisms, and the sorts of inorganic and organic substances in the water. The rate at which oxygen in the stream is reduced increases with BOD. Higher types of aquatic life will therefore have less access to oxygen. Higher BOD has the same effects as low dissolved oxygen: it stresses and suffocates aquatic life, ultimately leading to their death.Topsoil, leaves, and woody debris, and animal manure wastewater from pulp and paper factories, treatment , and failed septic plants are among the causes of elevated BOD [129].

2.19 Biology of snail Intermediate Host

As vectors of opisthorchiasis, angiostrongyliasis, paragonimiasis, fascioliasis, clonorchiasis, fasciolopsiasis, and schistosomiasis, certain freshwater snails are important for both human and veterinary health [130]. These freshwater snails are crucial hosts for some stages of the trematode parasite life cycle. Snail-borne illnesses continue to proliferate because of their abundance and dispersal. Some of the vector snails found in Nigerian waters are introduced species, including *Bulinus globosus* (Morelet, 1866), *Melanoides tuberculata* (Müller, 1774), and *Physella acuta* (Draparnaud, 1805). In Nigeria, the use of prophylactic chemotherapy to reduce helminthic infections is growing [131.]

However, re-infection of patients has hampered the effectiveness of this treatment, which may be partially attributed to a lack of knowledge regarding the distribution and number of vectors snails in Nigerian water [130]. It is crucial to comprehend the distribution and quantity of these freshwater snails, as well as the environmental conditions that sustain them, in order to effectively control and eradicate snail-borne diseases in Nigeria.

The ecology of freshwater snails has been the subject of numerous investigations carried out in Nigeria. According to these, the main factors influencing the geographical distribution and richness of freshwater snails in aquatic habitat include biotic, environmental, seasonal, and macrophyte factors [117]. As members of the Phylum Mollusca, snails are invertebrate animals. The "shell," a distinctive trait shared by all members of this group of animals (slugs excluded), is one of their primary characteristics. The snails are found in freshwater environments as well as other ecological niches, which means they can be found in a variety of habitats [132.]

Certain snails carry trematodes that can cause sickness in people and other animals, which makes them significant medically. The majority of disorders resulting from snail-borne trematodes are found in tropical and subtropical locations across the globe. These diseases carry a heavy medical and financial cost, which is why they are referred to as neglected tropical diseases (NTDs). The illnesses brought on by trematodes carried by snails, particularly schistosomiasis, are localized. As a result, the distribution of the intermediate snail host greatly influences the spread of the parasites [133.]

First off, the existence and dispersal of these significant snail intermediate hosts, which offer an ideal habitat for the growth of trematode parasites, contribute to the ongoing spread of snail-borne trematode infections in the majority of endemic areas [134]. Second, the majority of people living in endemic settings are without access to basic infrastructure, and the inability of chemotherapy the primary control strategy used in Africa to effectively reduce the economic impact of schistosomiasis led to calls for the adoption of comprehensive control strategies that include snail control in order to eradicate the disease [135].

In addition, the everyday and economic activities of the high-risk population rely primarily on the water bodies where the snail hosts inhabit. Numerous investigations have been done to identify the "supposed enemy," whose impact is significant for public health and has a noticeable burden on those who reside in marginalized areas of tropical and subtropical countries [136]. Few research have demonstrated snail host distinction on local scales, despite the fact that snail hosts studies are important, particularly in Africa where eliminating NTDs is a top priority [137]. Consequently, in order to support control efforts in Africa, it is essential to give sufficient information on the variety and structure of snail host populations at the national and continental levels via molecular techniques. Reliable decision-making and effective control implementation depend on this kind of information. In endemic areas, particularly in sub-Saharan Africa, in which the disease burden is high yet control efforts are hampered by inadequate funding and a lack of political will, this should be a prerequisite for establishing efficient control programs that will be bolstered by proactive monitoring and response systems.

2.19.1 Characteristics of the freshwater vector snails and their habitats

2.19.1.1. *Lymnea natalensis* (Krauss, 1848)

The species *Lymnea natalensis* was discovered in peaceful bodies of water, clinging to fallen tree branches, logs, and plant stems. The size varies from 5.2×3.6mm to 3.7×1.4mm. They are located 20 meters down the length of the shore and two meters in front of the shore. At the locations where they were gathered, they were observed fastened to the stones. The shells of *L. natalensis* are delicate and have a pointed spire on their dextral color. Despite usually being lower than the aperture, the spire is quite erratic. The spiral rows on the shell surface are not very clear. They are the intermediate host of *Fasciola gigantica* in cattle, however they are not observed to be infected.

2.19.1.2 *Bulinus senegalensis* (Muller, 1781)

The aquatic snail *Bulinus senegalensis* prefers slow-moving or stagnant freshwater. It might serve as *S. haematobium's* host. The majority of them are discovered in pools and ponds as soon as water is added.

2.19.1.3. *Biomphalaria pfeifferi* (Krauss , 1848)

Biomphalaria pfeifferi had been found in several still pools of water, clinging onto logs and plant stems. The dimensions are 4.1 x 2.5 mm and 5.1 x 4.2 mm. During the investigation, B. pfeifferi was not discovered in the seasonal pool.

2.19.1.4 *Lanistes libicus* (Morelet 1848)

The genus *Lanistes* comprises freshwater snails with an operculum and gills. These mollusks belong to the Ampullariidae family of aquatic gastropods, which also includes apple snails. Due to their attachment to plant stems, they are herbivores. Dimensions start at 3.4 x 1.5 mm. The torso is dexterously wound.

E

F

G H

Figure 1b:E. ***Bulinus globosus*** **(Morelet, 1866 F.** ***Melanoides tuberculata*** **(Muller, 17**

G. ***Potadoma moerchii*** **(Reeves, 1859) H.** ***Physa acuta***

2.19.5 *Bulinus globosus* (Morelet, 1866)

Bulinus globossus were discovered adhering to logs, plant stems, and stones near the river or stream's edge where water flow is calm, slow, and generally warm. They are located between two and ten meters from the coast, extending forth along the shoreline. They are found adhering to the surfaces of water plants that provide both refuge and food, such as the Nymphae lily and Acroceras zizanoides. The study area included pools, streams, and rivers with sizes ranging from 6.3× 4.2mm to 2.9× 2.2mm. The whorls are somewhat shouldered, the shell is pale white and lacks sculpturing, appearing nearly white in certain situations, and the presence of a pseudobranch identify it.

2.19.6 *Lanistes libicus* (Morelet 1848)

The typical habitat of *Melanoides tuberculata* is a variety of permanent or transient freshwater bodies, including rivers and streams. It is mostly found in the lotic habitat that occurs most commonly, and it feeds on algae. Due to the abundance of food from sewage, they can also be found in streams that have been contaminated. They are located at the bottom of streams and rivers. The snails in the sample range in size between 58.6 to 35.7 mm.

2.19.7 *Potadoma moerchii* (Reeves 1859)

The aquatic gastropod mollusc Potadoma moerchii is a species of freshwater snail belonging to the Pachychiidae family. It has an operculum. They typically attach themselves to the stems of plants and can be found in the ponds and streams that lie in the riverbed. The size ranges from 67.6 x 42.5 mm.

2.19.8 *Physa acuta*

Within the Physidae family of aquatic pulmonate gastropod molluscs, the genus *Physa* comprises small, air-breathing freshwater snails with a left-handed or sinistral (left-opening aperture). In the research region, *Physa acuta* inhabits a variety of freshwater environments, including ponds and rivers. The dimensions vary between 38.8 to 24.2 mm.

Endnotes

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Chapter Three

3.0 Materials and Methods

3.1 Study Area

The study was conducted at Eleyele Dam, created by damming the Ona River, is located in *north- western Ibadan*. Coordinates span approximately 7°20′–7°25′ N latitude and 3°51′–3°56′ E longitude Other sources provide a more precise location for the Eleyele area: Latitude 7.4133° N, Longitude 3.8630° E, A malacological survey (october to may, 2025). A physico- chemical study situated along Eleyele–Oluguneru Road reports Ibadan's city coordinates roughly 7°23′47″ N, 3°55′00″ E (i.e. 7.3964° N, 3.9167° E) (~5–7 m apart), with GPS readings such as:Point A (washing/bathing area): 7.41497° N, 3.85229° E; elevation ~177 m Point B (cassava processing): 7.41492° N, 3.85232° E; elevation ~174 m, Point C (domestic water collection): 7.41491° N, 3.85237° E. These sites illustrate the microhabitats where snail-transmitted schistosomiasis may occur ranging from domestic water use to food processing and bathing. Bodija is a district east of Ibadan's city center (roughly around Latitude 7.432° N, Longitude 3.9152° E) .While direct studies of freshwater snails in Bodija River are limited, Bodija's watercourses especially those influenced by urban runoff, markets, and residential activity can be considered potential snail habitats and worthy of inclusion in urban schistosomiasis research [1].

Figure 1: Map of Ibadan metropolis showing selected rivers for the snail sampling

3.2 Measurement of Physicochemical Parameters of Water Samples

Water samples were collected once every month in the early hours of the day between 7-10 am for six (7) months). The time frame matched three months of the rainy season (June, July, August) and three months of the dry season (March, April, and May).

Environmental Variables A total of seven (7) environmental variables, namely temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD5), turbidity, nitrate (N), and phosphate (P) were selected for this study. They are common variables used to assess alterations in an aquatic ecosystem's physical and chemical compositions and their influence on phytoplankton abundance, composition, and diversity. All instruments were tested to be within the limit of precise accuracy before use. Field meters were calibrated according to manufacturer's specification and care was taken during sampling to avoid contamination. Surface water temperature and pH were determined in situ using a mercury-in-glass thermometer and a pH meter (Hanna model HI 9828) [2].

3.2.1 Dissolved oxygen (DO)

The azide modification of Winkler's method was applied to determine DO. The water sample was collected in sample bottles and fixed with 2 ml of manganous sulfate. To 300 ml of the sample, 2 ml of Alkaline Iodide-Sodium Azide solution and 2 ml of concentrated H2SO4 was added and titrated against 0.0125 N sodium thiosulphate (Na2S2O3(aq)) until a color change to pale yellow. A starch indicator (2 ml) was then added and titrated until the colour changed from blue to colorless and the titre value was recorded.

The DO was then calculated in mg/L.Winkler's method was used for BOD5 determination. The water sample was collected in sample bottles and incubated in the dark. After five days of incubation, 300 ml of the sample containing 2 ml of Alkaline Iodide Sodium Azide solution and 2 ml of concentrated H2SO4 was titrated against 0.0125 N sodium thiosulphate (Na2S2O3(aq)). A colour change from pale to yellow was followed by adding a 2 ml starch indicator and was further titrated until a colour change from blue to colorless and the titre value was recorded. BOD5 in mg/L was calculated as the difference between DO1 and DO5, as described by [3].

Dissolved oxygen (mg/l) was calculated as follows

$$DO\ (mgL^{-1}) = \frac{\text{Volume of 0.0125N Thiosulphate (ml)} \times 101.6}{\text{Volume of sample in ml}}$$

3.2.2.Turbidity

Turbidity was determined using a spectrophotometer model 257 at 430 nm . Distilled water was used as blank.

3.2.3 Nitrate

Nitrate (N) determination was carried out using the phenoldisulphonic acid method according to the protocol of [2]. Briefly, 100 ml of water sample was evaporated to dryness, then adding 2 ml of phenoldisulphonic acid for 10 minutes. Subsequently, 15 ml of distilled water was added, followed by 5 ml of strong ammonia (NH3) solution. The resultant yellow mixture was stirred and allowed to cool. The absorbance was measured at 430 nm on a spectrophotometer model 257, using distilled water as blank. Nitrate concentration in mg/L was then determined using a standard calibration curve.

The stannous chloride method (Clesceri et al., 1998) was used to determine Phosphate (P). To 100 ml of the water sample, 2 drops of stannous chloride were added, followed by 1 ml of Denings reagent. After 10 minutes, the absorbance at 660nm was measured with a spectrophotometer,model 257, using distilled water as blank. Phosphate concentration in mg/L was determined using a standard calibration curve [3.]

3.2.4 Temperature

Temperature at the different stations was measured to the nearest 0.1 ºC with a mercury-in-glass thermometer of range 10 - 110ºC which was inserted at a depth of about 2cm from surface for 3 minutes. The sub-surface temperature was taken immediately after collection with water sampler. The temperature was taken three times at each station and the average was calculated to be the average temperature. The readings were expressed in degrees Celsius (ºC).The pH was measured electrically with an electronic pH meter, Kent 7020 Model. The glass probe of the meter was dipped into the water sample and the pH read at room temperature as recommended by [4].

3.2.5 Conductivity

Conductivity was determined in the laboratory using conductivity and TDS combined meter Matini instruments model. Some quantity of water was poured into a small beaker and the probe was put into the beaker and measured. The results were expressed in µS/m.

3.2.6. Total dissolved solid (TDS)

Total dissolved solid (TDS) was determined in the laboratory using combined meter matini instruments model. Some quantity of water was poured into a small beaker and the probe was put into the beaker and measured. The results were expressed in mg/l.

3.2.7 Nitrite

Nitrite was estimated using indo- phenol colorimetric method and measured using Spectonic 20 model at 520nm level of absorbance. The results were expressed in mg/l.

3.3 Protocol for the collection of snails sampling

The designated collection sites were assessed by using local knowledge, and transmission information from previous report data in the endemic areas. Protective clothing and gloves was worn. The snail were collected using metal mesh paddle scoops, handle length dependent on the depth of the site, scooping for about 15 minutes up to three dredges per sites. The snail's identification were done based on the shell, shape and size (morphological). The snails were placed in container filled with a little water for later processing. The snails were identified using shell morphology according to Brown and Kristensen [5]. This was achieved by holding the snail shell with the apex (pointed edge) pointing upward. When the aperture (shell opening below the body whorl) opens to the right, it is termed dextral but when the aperture opens to the left it is termed sinitral. More so, the sculptural marking on the snail shell would be considered during identification. Other shell components considered during identification include number of whorls, shape of the shell, type of apex (sharp or blunt) and shape of the peristome on the aperture. Plastic containers were label with collection site and date, additionally with collection method (dredge or scoop). Snail collection form were filled with location information: date, time, season (wet/ dry) and global positioning system GPS coordinates. Also, habitat type, substrate, water depth, flow rate. Abundance was expressed as percentage of snail species present in each site.

3.4 Release Pattern and identification of cercariae

To determine if cercarial shedding was present or absent, the emergent method of cercarial release. A little, clearly labeled plastic rubber container filled with distill water was used to hold the freshwater snails that were obtained from the test sites individually. The cercariae were then forced to shed by exposing the snails to direct sunlight from 9:00 a.m. to 1:00 p.m. everyday. After the exposure to sunlight, each specimen container's water was placed into a petri plate, the water was checked for the presence of cercariae (18) using X40 microscope.

3.5 Mean Intensity

The parasite's mean intensity was calculated using the formula below. Collect a representative sample of snails from your study area. Record the **total number of snails collected.**

$$\text{Mean Intensity} = \frac{\text{Total number of schistosomes counted}}{\text{Number of infected snails}}$$

3.6 Genomic DNA extraction from snails

Genomic DNA was extracted from each snail using a modified method of Stothardet al. (1996). Each snail was removed from 70% ethanol and soaked in TE buffer, pH 7.4 (10mM TrisHCl and 1mM EDTA) overnight so as to remove the remaining ethanol. Tissue from each of the snails was placed in a sterile 1.5-ml microcentrifuge tube, with 500ml of CTAB solution (0.2% 2-mercaptoethanol; 2% hexadecyltrimethyl-ammonium bromide (CTAB); 100mM Tris (hydroxymethyl) amino-methane; 16mM EDTA; 1.4M sodium chloride) and the tissue homogenized. Proteinase K solution (10ml at 20 mg/ml) was added and the digests were incubated at 55oC for 1 h, with occasional gentle mixing. Genomic DNA was extracted from the digests by adding an equal volume of chloroform/isoamyl alcohol (24:1) to each tube. The organic and aqueous layers were gently mixed for 5 min and spun at 13,000 g for 20 min. For each sample, the upper aqueous layer was removed into another sterile micro-centrifuge tube and an equal volume of 100% ethanol was added, mixed and the whole incubated at -20oC overnight in order to enhance DNA precipitation. The precipitate was spun at 13,000 g for 20 min and the pellet washed with 70% ethanol and spun for another 20 min. The supernatant was removed and the pellet was dried at room temperature. When completely dry, the pellet was re-suspended in 25ul of purified water and stored at 4oC until used.

3.7 Molecular Screening of Snails for Schistosomiasis

Genomic DNA was extracted from the sample received using the Quick-DNA™ Miniprep Plus Kit (Zymo Research, Catalogue No. D4068). The target region was amplified using OneTaq® Quick-Load® 2X Master Mix (NEB, Catalogue No. M0486) with the primers presented in Table 1, 2 and 3. The PCR products were run on a gel and cleaned up enzymatically using the EXOSAP method. The extracted fragments were sequenced in the forward and reverse direction (Nimagen, BrilliantDye™ Terminator Cycle Sequencing Kit V3.1, BRD3-100/1000) and purified (Zymo Research, ZR-96 DNA Sequencing Clean-up Kit™, Catalogue No. D4050). The purified fragments were analyzed on the ABI 3500xl Genetic Analyzer (Applied Biosystems, ThermoFisher Scientific) for each reaction for every sample, as listed in Section 1. BioEdit Sequence Alignment Editor version 7.2.5 was used to analyse the. ab1 files generated by the ABI 3500XL Genetic Analyzer and results were obtained by a BLAST search (NCBI).

3.8 Molecular identification of snails

Snails identification was performed by PCR amplification of the snails' ribosomal internal transcribed spacer (ITS) region using forward primer Etts1 5'TGCTTAAGTTCAGCGGGT3' and reverse primer Etts2 5'TAACAAGGTTTCCGTAGGTGAA3' (Ten Hove et al., 2008.) The amplification was confirmed by visualization on 1.5% agarose gel and the amplified products were digested with RsaI, a 6-base cutting restriction enzyme, following the method of Stothardet al (Ten Hove et al., 2008). The digest was visualized on 1.5% agarose gel followed by photo documentation using Gel Documentation.

3.9 Data Analysis

Results were expressed as mean and ± SD for continuous variables and percentage (%) for categorical variables. One way Analysis of variance (ANOVA) was used to compare mean abundance of snails within snail species. The correlation coefficient was calculated to determine the relationship between snail abundance and physicochemical parameters, and also the relationship between snail species. The $P < 0.05$ was considered statistically significant. Statistical Package for Social Sciences (SPSS) software for windows (version 20) was used for the analysis. Percentage and Chi Square (X^2) values were used to calculate the association between different variables and P value <0.05 was considered statistically significant.

Endnotes

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Chapter Four

4.0 Results and Discussion of Findings

A total of 2,284 freshwater snail intermediates were collected from all the four rivers in the period of 9 months, the monthly collection slight to high variation in the distribution and the snail abundance.

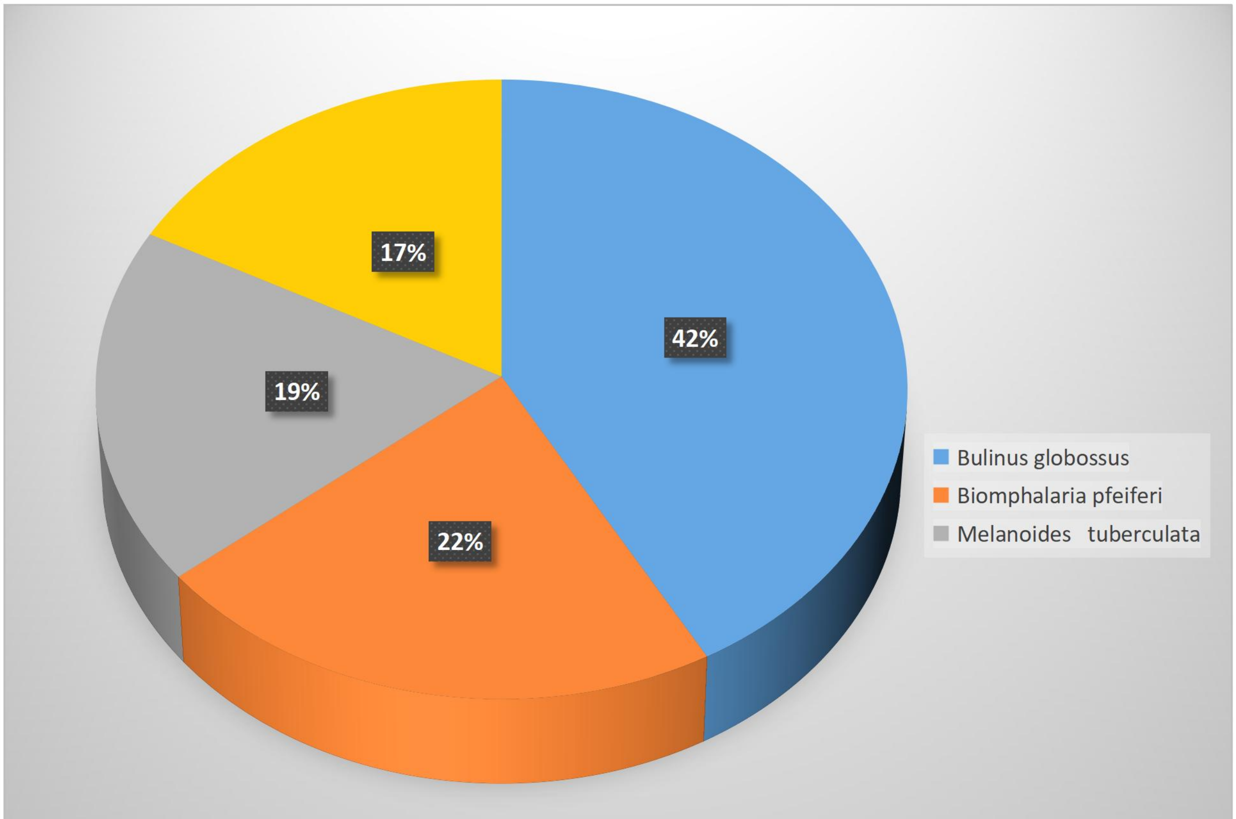


Figure 2:Occurrence of vector snails in the study Area

The results presented in Figure 1 provides a comprehensive overview of the percentage occurrence of various vector snail species within the study rivers. The species observed *Bulinus globossus*, *Biomphalaria pfeifferi*, *Melanoides tuberculata*, and *Physa acuta* are all recognized as important vectors in the transmission of parasitic diseases, particularly schistosomiasis, and their presence and distribution offer crucial insights into potential public health risks in the area.

The most dominant species observed was *Bulinus globossus*, accounting for 41.8% (956) of the total snail population sampled. This high prevalence is significant because *B. globossus* is a known intermediate host for *Schistosoma haematobium*, the causative agent of urogenital schistosomiasis. The species' dominance suggests a heightened risk for the transmission of this form of schistosomiasis in the selected rivers, particularly in communities that rely on these water bodies for domestic, recreational, or occupational activities.

The widespread presence of *B. globossus* could be attributed to its ecological adaptability. It is known to thrive in shallow, slow-moving freshwater environments that are often rich in aquatic vegetation conditions commonly found in rural rivers. Moreover, anthropogenic activities such as agriculture, laundry fishing, and bathing can enhance the habitat suitability for this species by increasing nutrient levels and altering flow regimes. These factors might collectively explain its dominance in the study area.

Biomphalaria pfeifferi, the second most common species, represented 509 (22.2%) of the total snail population. This species serves as the primary intermediate host for *Schistosoma mansoni*, which causes intestinal schistosomiasis. Although its occurrence was nearly half that of *B.*

globossus, it still represents a considerable population and indicates a tangible risk for intestinal schistosomiasis transmission in the region.

The relatively high presence of *B. pfeifferi* may be influenced by several environmental and biological factors, including water pH, temperature, and presence of aquatic plants. Like *B. globossus*, *B. pfeifferi* prefers habitats with calm waters and can often coexist with other freshwater snails. This coexistence raises the potential for co-infection scenarios in humans and complicates control strategies, particularly in areas where both urogenital and intestinal schistosomiasis are endemic.

The third most prevalent species was *Melanoides tuberculata*, accounting for 425 (18.6%). Although not a direct vector for schistosomiasis, *M. tuberculata* is of epidemiological interest due to its role in the ecology of freshwater ecosystems. This snail is known to compete with and sometimes displace native or vector snails through competitive exclusion or habitat alteration. Some studies have also documented its association with other trematodes, and in rare instances, it has been implicated in the indirect transmission of parasitic diseases.

Its notable presence could indicate potential ecological competition with medically significant snails, possibly affecting the population dynamics of species like *B. globossus* and *B. pfeifferi*. However, this species' ability to reproduce parthenogenetically and tolerate a wide range of environmental conditions likely contributes to its resilience and spread. Thus, while it may not directly contribute to schistosomiasis transmission, its ecological interactions with other snails may influence the overall transmission dynamics of parasitic diseases in the area.

Physa species, though the least prevalent in this study 395 (17.2%), still represent a significant portion of the snail community. This genus includes *Oncomelania hupensis*, the recognized vector of *Schistosoma japonicum* a major cause of schistosomiasis in East Asia. The presence of *Physa Acuta* in the study area may be of less direct epidemiological concern suggests that environmental conditions could support the establishment of this disease if introduced.

Given its relatively low prevalence compared to the other species, *Oncomelania* may occupy more specialized niches or be affected by specific ecological constraints in the study rivers. Nonetheless, its presence should not be overlooked, as environmental changes such as increased irrigation or climate shifts could alter its abundance and distribution, thereby changing the regional epidemiology of vector-borne diseases.

The diverse snail fauna observed in the selected rivers underscores the importance of sustained monitoring and integrated control measures. The high prevalence of known schistosomiasis vectors (*B. globossus* and *B. pfeifferi*) confirms that the region is at considerable risk for disease transmission. Efforts should be made to couple snail control with public health interventions, such as health education, mass drug administration, and improved water, sanitation, and hygiene (WASH) infrastructure.

Moreover, the coexistence of multiple vector species in the same habitat can increase the complexity of disease control. Integrated surveillance systems that monitor both snail populations and human infection rates are necessary for early detection and timely response to potential outbreaks. it is essential to consider that any intervention targeting snail populations must account for potential ecological consequences. Snails play essential roles in nutrient cycling and as food sources for other aquatic organisms. Unselective use of molluscicides could disrupt aquatic ecosystems, leading to unintended consequences such as algal blooms or the proliferation of other pest species. Hence, eco-friendly and sustainable snail control approaches, such as biological control using natural predators or habitat modification, should be prioritized wherever possible.

Table 4.1: Mean intensity of cercariae shed by snail intermediate hosts

Snail	No. Examined	No. infected (%)	Schistosome counted	Mean Intensity
Bulinus globossus	956	256	304	1.19
Biomphalaria pfeiferi	509	84	102	1.21
Melanoides tuberculata	425	0	0	0
Oncomelania	395	26	54	2.08
Total	2284	366	460	

Source: Field Survey, (2025).

The results from Table 4.1 offer a critical examination of the mean intensity of schistosome cercariae shed by different species of snail intermediate hosts found in the selected rivers. Understanding both the infection prevalence and cercarial output of snail hosts is essential for evaluating transmission dynamics, estimating infection risks for humans, and designing targeted control interventions for schistosomiasis. The data present notable patterns of host–parasite interactions that vary significantly between species, reflecting both biological compatibility and ecological influences.

Bulinus globossus was the most frequently infected snail in the study, with 256 out of 956 individuals (26.8%) found shedding schistosome cercariae. This represents the highest infection prevalence among all species examined. Despite the high infection rate, the mean intensity of cercarial shedding was relatively modest at 1.19 cercariae per infected snail.

This combination of high prevalence and moderate intensity suggests a stable transmission cycle of *Schistosoma haematobium*, for which *B. globossus* is the principal intermediate host. The high number of infected individuals indicates widespread exposure to miracidia, likely from human contamination of freshwater sources. The moderate cercarial output per snail may reflect chronic infections or environmental and physiological constraints on cercarial production.

Cercarial output in natural populations often varies depending on factors such as temperature, snail age, parasitic load, and availability of nutrients. For example, environmental stressors or poor water quality could suppress the metabolic activity of the snail or the developmental rate of the parasite. Additionally, snails may experience multiple infections or competition among trematode species, which could limit the number of cercariae released at any one time.Nevertheless, due to its abundant population size and high infection prevalence, *B. globossus* remains a major contributor to urogenital schistosomiasis transmission in the region.*Biomphalaria pfeifferi* had a lower infection prevalence than *B. globossus*, with 84 out of 509 individuals infected (16.5%). However, the mean intensity of cercarial shedding was slightly higher, at 1.21 cercariae per infected snail. This marginal difference, while not dramatic, is epidemiologically relevant, especially considering that *B. pfeifferi* is the main vector for *Schistosoma mansoni*, the agent of intestinal schistosomiasis.

The lower infection prevalence in *B. pfeifferi* could be due to several reasons. It is possible that this species inhabits areas of the river system with less frequent human contact or contamination. Alternatively, environmental conditions such as water velocity, substrate type, and availability of macrophytes could influence habitat suitability and host–parasite encounters.The slightly higher mean cercarial output per infected snail suggests that once infected, *B. pfeifferi* may be a more efficient transmitter of schistosome parasites than *B. globossus*, on a per-snail basis. This could be linked to biological factors such as host–parasite compatibility, immune suppression by the parasite, or the ability of the snail to sustain long-term infections with continued cercarial release.

From a public health perspective, the combination of moderate infection prevalence and reasonable cercarial output reinforces *B. pfeifferi*'s role as a significant vector for intestinal schistosomiasis, necessitating its inclusion in any control or surveillance strategies.Interestingly, *Melanoides tuberculata*, which accounted for 18.6% of the total 425 snail population, exhibited no infection with schistosome cercariae. Consequently, its mean intensity of shedding was zero.This finding is consistent with existing knowledge that *M. tuberculata* is not a natural host for human schistosomes such as *S. haematobium*, *S. mansoni*, or *S. japonicum*. The absence of infection in this species confirms its non-vectorial status in schistosomiasis transmission cycles in the study area.

However, the epidemiological and ecological role of *M. tuberculata* should not be dismissed. As a prolific and invasive snail, it has been documented to affect local snail communities by outcompeting native species, including schistosome vectors. Its parthenogenetic mode of reproduction, rapid growth, and tolerance for a wide range of environmental conditions allow it to colonize diverse freshwater habitats and potentially displace medically important snails.

In some settings, *M. tuberculata* has even been considered for biological control of vector snails. However, this strategy carries risks, as *M. tuberculata* may also host other trematode parasites of veterinary or minor public health importance. In the context of the present study, its ecological interactions with *B. globossus* and *B. pfeifferi* warrant further investigation to determine whether its presence suppresses or enhances overall transmission risk.*Oncomelania* was the least infected among the shedding snails, with only 26 out of 395 (6.6%) testing positive for schistosome cercariae. However, this species showed the highest mean intensity of shedding, at 2.08 cercariae per infected snail nearly double that of the other species.

The presence of *Oncomelania* in the region could be due to natural range expansion, introduction through human activities, or favorable environmental changes. Regardless, the species' capacity to shed a high number of cercariae once infected suggests that its role in disease ecology should be monitored closely, especially in regions vulnerable to parasite importation due to migration, trade, or environmental changes.The collective data reveal that schistosome transmission in the study area is actively maintained, primarily through *Bulinus globossus* and *Biomphalaria pfeifferi*. These two species demonstrate a combination of high abundance (Table 1), high infection prevalence, and moderate shedding intensities, making them the key targets for control interventions.

Molluscicide application in high-risk water bodies, ensuring it is targeted and environmentally safe.Biological control approaches that consider species interactions, especially with *Melanoides tuberculata*. Community education and behavioral change, including promoting avoidance of unsafe water contact and provision of clean water alternatives.Regular mass drug administration (MDA) with praziquantel, particularly in areas with high snail infection prevalence.

This implies that mean intensity of cercariae shedding across four snail species highlights complex interplays between host biology, parasite transmission, and environmental factors. *Bulinus globossus* and *Biomphalaria pfeifferi* remain the primary drivers of schistosomiasis transmission due to their high infection prevalence and widespread distribution., while *Melanoides tuberculata* appears epidemiologically inactive in this context.An integrated, evidence-based approach to snail control and public health interventions is critical to breaking the transmission cycle and achieving lasting reductions in schistosomiasis burden in the study area.

Table 4.2: Number of freshwater snails shedding cercariae

Snail Species	**Number collected**	**Number Infected**
Bulinus globossus	956	256
Biomphalaria pfeiferi	509	84
Melanoides tuberculata	425	0

Physa acuta	395	0
Total	**2284**	

Source: Field Survey, (2025).

Table 4.2 shows that high infection prevalence in *Bulinus globossus*. *Bulinus globossus* shows the highest infection prevalence (26.8%) among collected snails. This is strikingly higher than many reports in the literature, and suggests this species is a major vector in the surveyed rivers. A prevalence of this magnitude indicates active and intense transmission of schistosomes in water bodies where *B. globossus* is present.Moderate infection in *Biomphalaria pfeifferi* .With 16.5% of *B. pfeifferi* individuals infected, this species also plays a substantial role, though less so than *B. globossus*. Together, these two species account for most infections observed, indicating that urogenital and intestinal schistosomiasis risk is present.

There no infection infections in *Melanoides tuberculata* Despite 425 sampled, zero infections in *M. tuberculata* suggest that this species is not serving as an intermediate host for human schistosomes under the conditions present in these rivers. This is consistent with many reports that *M. tuberculata* is generally not a compatible host for human- infecting *Schistosoma* spp.

Lower but non- negligible infection in *OncomelaniaOncomelania* individuals show 6.6% infection (26/395). While lower than *B. globossus* or *B. pfeifferi*, this is not trivial. *Oncomelania* is a known vector for *Schistosoma japonicum* in Asia; depending on the species of *Oncomelania* present and whether *S. japonicum* (or related species) is present, this may represent a transmission risk .Across all snail species, 16% of collected snails were infected. This is considerably higher than many (but not all) snail infection rates reported in meta- analyses. It indicates that the selected rivers are high- infection foci, with likely high exposure risk for people using these waters.

A recent systematic review and meta-analysis in Africa found pooled prevalence among *Bulinus globosus* of 12.3% (95% CI: 6.2–18.3%) for *S. haematobium*. For *Biomphalaria pfeifferi*, the pooled prevalence in that same meta- analysis was 5.1% (95% CI: 4.1–6.2%) for *S. mansoni*. Another meta-analysis reported Prevalence and correlations among humans and intermediate snail hosts) reported *overall* snail infection rates of 8.6% (95% CI: 7.7–9.4%), with *Biomphalaria spp.* 12.1% and *Bulinus spp*. 6.9%.

In Ingwavuma, KwaZulu-Natal (South Africa), *Bulinus globosus* had higher infection rates than *B. pfeifferi*, consistent with higher prevalence of *S. haematobium* than *S. mansoni*. However, the infection rate for *B. globosus* there was 8.9%. Thus, the 26.8% infection in *B. globossus* and 16.5% in *B. pfeifferi* in your study are substantially higher than the typical rates in many regions. This suggests particularly conducive transmission conditions in your study rivers.

Rivers may have slow or stagnant stretches, aquatic vegetation, suitable temperatures, and sufficient shade all favorable for miracidia survival and snail proliferation.Water bodies heavily used by humans (for bathing, washing, urination/defecation) may provide large inputs of schistosome eggs, increasing miracidia exposure. High numbers of *B. globossus* and *B. pfeifferi* increase the probability of encountering miracidia. If sampling occurred in seasons with peak water temperatures, dryness, or post-rainy season when water levels drop, snails are concentrated and infection pressure increases.If there is little or no molluscicide application, limited sanitation infrastructure, poor water management, the snails can thrive, and human infection cycles continue.*B. globossus* is known to be highly susceptible to *S. haematobium*. *B. pfeifferi* is similarly suited for *S. mansoni*. The compatibility between parasite and snail species, as well as parasite strain, immune response, etc., may favour higher infection.

The method of detecting infection affects rates. Shedding methods can underestimate infection because some snails may be pre-patent or shedding low levels.

Melanoides tuberculata with zero infection confirms that while abundant, this species does not contribute to human schistosome transmission in this region. This is consistent with many studies; *M. tuberculata* is typically not susceptible to human schistosomes.*Oncomelania*'s 6.6% is lower than *Bulinus* and *Biomphalaria* here, but significantly above zero. Given that *Oncomelania* is less common in many African systems for *S. japonicum*, this suggests either a non- human schistosome species is present, or perhaps movement/introduction of parasites or niche overlap allowing *Oncomelania* infection.The high infection rates in *B. globossus* relative to *B. pfeifferi* suggest that urogenital schistosomiasis (due to *S. haematobium*) may be more intense in selected area than intestinal schistosomiasis, or that the transmission ecology of *S. haematobium* is more favourable.

The elevated infection rates in vector snails indicate a high risk of schistosomiasis transmission to humans who come into contact with these rivers. Activities such as bathing, washing clothes, fishing, fetching water, or children playing in water are likely routes of exposure.

Since both *B. globossus* and *B. pfeifferi* are infected at significant rates, co- endemic transmission of urogenital and intestinal schistosomiasis may occur. This complicates control, diagnosis, treatment, and public health messaging.High prevalence in snails often translates into sustained reinfection in human populations even after mass drug administration (MDA), unless snail control and water sanitation interventions are implemented.Given these high rates, control programmes should include environmental sanitation (to reduce egg contamination), snail control (e.g. targeted molluscicides, modifications of habitat), and health education. Overreliance on MDA may be insufficient if transmission sources (snails) remain heavily infected.

As noted, shedding methods miss prepatent infections; molecular detection tends to reveal higher prevalence. Snail mortality and infection dynamics: Snail infection may reduce survival or reproduction, affecting observed abundance and infection prevalence. Infected snails may die or be expelled before shedding much.

The findings from this study especially the high infection prevalence in *Bulinus globossus* (26.8%), significant infection in *Biomphalaria pfeifferi* (16.5%), and non-infection in *Melanoides tuberculata* indicate strong potential for active schistosomiasis transmission in the selected rivers. Compared with broader African averages, your results are higher than many documented norms, suggesting that these river systems are hotspots.The implications are serious for communities dependent on these water sources. Effective control will require integrated efforts: snail surveillance and control, improved water, sanitation, behavior change, and appropriately targeted mass treatment. Further, precise species and parasite identification, and temporal/spatial monitoring will be critical to tailor interventions and evaluate.

Table 4.3: Prevalence of freshwater snail infection in the study area

Snail Species	Number	Infection

	Infected	prevalence (%)
Bulinus globossus	256	26.8
Biomphalaria pfeiferi	84	16.5
Melanoides tuberculata	0	0
Physa acuta	0	0
Total	**340** **16.0**	

Bulinus. globossus shows the highest relative infection, followed by *B. pfeifferi*. *Melanoides tuberculata* appears to play no direct role, while *Oncomelania* has a modest, but non-negligible infection prevalence.A systematic review and meta-analysis covering 51 studies in Africa found that the **pooled prevalence of schistosome cercariae infection in freshwater snails** was about **5.5 %** (95 % CI: 4.9–6.1 %) across Bulinus and Biomphalaria.Among *B. globosus*, the pooled prevalence was **12.3 %** (95 % CI: 6.2–18.3 %) Among *B. pfeifferi*, pooled prevalence was **5.1 %** (95 % CI: 4.1–6.2 %).

In Nigeria specifically, the highest country-level pooled prevalence for Bulinus snail infections was **19.6 %** for *S. haematobium* among *B. globosus*, and ~14.5 % among *B. pfeifferi* for *S. mansoni* in some reports.

Zaria, Kaduna State (A.B.U. Campus): Ayanda (2018) collected 648 snails (392 *B. globosus*, 256 *B. pfeifferi*) and found infection prevalence among *B. globosus* of **≈ 18.37 %** (for *S. haematobium*) and among *B. pfeifferi* **≈ 20.31 %** (for *S. mansoni*).**PCR-based study, Nkalagu, Southeastern Nigeria**: Among 212 *B. pfeifferi* snails, 164 (77.4 %) were infected (by general schistosome markers), although *only* 16 (9.76 %) were positive specifically for *S. mansoni* by nested PCR.**Doma LGA, Nasarawa State**: Of 308 snails (various species including *B. globosus, B. pfeifferi,* and *M. tuberculata*), none were found infected by trematode cercariae using light microscopy or crushing methods.

The results of our findings where 26.8 % for *B. globossus*, 16.5 % for *B. pfeifferi* are **substantially higher** than the African pooled averages (12.3 % for *B. globossus*, 5.1 % for *B.*

pfeifferi) seen in meta- analysis They are more comparable to some localized studies in Nigeria (18- 20 %) though even those are lower for *B. globossus* than your figure of 26.8 % [4]. This suggests your study area may represent a particularly intense transmission zone, possibly due to ecological, human or methodological factors.The finding that *Melanoides tuberculata* shows zero infection aligns with other studies: *M. tuberculata* is generally not compatible with human schistosomes and is rarely or never found infected in snail surveillance, except possibly with non-human trematodes. This is in line with findings in Nasarawa State.

The overall prevalence (16.0 %) across all snail species is markedly above both the African average (5.5 %) and many national estimates in Nigeria when using shedding methods. For example, the A.B.U. Zaria study had prevalence in that ballpark (18- 20 %) but only for specific snail species and season.If snails were held longer for shedding, or if molecular assays (PCR) were used, detection rates often increase significantly. The meta- analysis indicates PCR detection gives much higher prevalence (26.7 %) than shedding alone (4.5 %).If shedding was combined with microscopy more intensively, early or low-intensity infections might be captured.

Water bodies with frequent human contamination (open defecation or urination), slow flow, aquatic vegetation, warmer temperatures all these favor higher miracidia survival and snail contact. Many studies show increased snail infection during or just after wet seasons or in dry seasons when animals/humans concentrate water use. For example, in Niger River Valley, infection prevalence varied seasonally, peaking in dry months.**High host density and repeated exposure**. From this study, it is presumably that *B. globossus* and *B. pfeifferi* are abundant; greater snail density increases chance of infection.Frequent human contact increases egg input, raising miracidia load.Areas with poor sanitation and unprotected water sources tend to show higher snail infection prevalence. Nigeria's hyperendemic zones often overlap with such features

The elevated prevalence, especially for *B. globossus*, indicates that urogenital schistosomiasis may be extremely common in the areas surveyed. *B. pfeifferi* prevalence suggests substantial risk of intestinal schistosomiasis as well.**Potential for co- endemic transmission**: Because both vectors are significantly infected, populations may be exposed to both forms, complicating diagnosis, morbidity, and control measures.High prevalence zones require more than just periodic mass drug administration (MDA). Interventions may include snail control (chemical or ecological), improved sanitation, public health education, and monitoring.Regular snail surveys (seasonal) and possibly molecular diagnostics would help track changes in infection prevalence and assess the impact of interventions.Snail mortality, snail aggregation, and habitat suitability influence infection prevalence.

This study reveal **remarkably high infection prevalences** for *Bulinus globossus* (26.8 %) and *Biomphalaria pfeifferi* (16.5 %) relative to African pooled averages and many local Nigerian studies. These elevated values point to intense schistosomiasis transmission pressure in this study area.Comparisons with some research in Nigeria show your findings exceed many national and regional norms, aligning more with high- transmission foci like Iyanda in Zaria. The zero-prevalence in *Melanoides tuberculata* is consistent with its known non-vector status, while *Oncomelania*'s infection suggests either unusual parasitic dynamics From a public health perspective, these results underscore urgent need for comprehensive schistosomiasis control: snail surveillance and control; sanitation improvements; community education; possibly molecular diagnostics; and sustained MDA.

Table 4.4: Seasonal Occurrence and Abundance of Freshwater Snail Species Collected in the Study 2024-2025

Seasons	**Months**	***Bulinus globossus***	***Physa acuta***	***Melanoides tuberculata***	***Biomphalaria***	**Total**
Dry season	Nov.	205	82	134	143	564
	December	133	58	56	78	325
	January	86	37	43	43	209
	February	45	25	16	30	116
	March	34	6	6	22	68
Total		**503**	**208**	**255**	**316**	**1282**
Wet season	April	14	17	25	5	58
	May	56	49	45	18	168
	June	89	75	68	74	306

	July	167	30	28	53	278
	August	68	16	18	26	128
	September	2	0	6	15	23
	October	0	0	0	0	0
Total		**453**	**187**	**170**	**191**	938
Grand total		**956**	**395**	**425**	**509**	**2284**

Source: Field Survey, (2025).

Freshwater snails of the family Planorbidae, notably species within the genera *Biomphalaria*, *Bulinus*, and *Oncomelania*, play a critical role in the epidemiology of human schistosomiasis, a debilitating parasitic disease affecting over 240 million people globally [8]. These snails act as obligatory intermediate hosts for trematode parasites of the genus *Schistosoma*. The transmission cycle is complex, involving the release of parasite eggs from infected humans into freshwater via excreta, the hatching of miracidia that infect specific snail species, and the subsequent release of cercariae from the snails that penetrate human skin [9]. The population dynamics of these intermediate host snails are therefore a primary determinant of transmission risk.

The study offers a compelling longitudinal study, capturing the population densities of four snail genera *Bulinus*, *Oncomelania*, *Melanoides tuberculata*, and *Biomphalaria* across both dry and wet seasons. The total count of 2284 snails indicates a significant and active snail habitat. The presence of *Bulinus* (a known host for *S. haematobium*), *Biomphalaria* (a host for *S. mansoni*), and *Oncomelania* (a host for *S. japonicum*) suggests a potential multi-species schistosomiasis transmission focus, which presents a complex public health challenge. *Melanoides tuberculata*, while not a primary schistosome host, is an important ecological competitor and can influence the dynamics of the host snail populations [10].

The seasonal variations observed presented in the data above, discuss the ecological implications, and compare these findings with similar ecological studies conducted in Nigeria, a country that bears a high burden of schistosomiasis.The study reveals a stark and ecologically significant contrast in snail population dynamics between the dry and wet seasons. The **dry season** (November to March) accounts for a substantially higher total number of snails (956, 41.9% of the annual total) compared to the **wet season** (April to October, 453 snails, 19.8% of the annual total). This pattern is counterintuitive to the common assumption that rain and increased water volume lead to population booms and requires careful interpretation.

The high counts during the early dry season suggest optimal environmental conditions. As the dry season progresses, water bodies contract into perennial pools and slow-flowing streams. This concentration effect can lead to higher snail densities per unit area sampled, making them easier to collect [11]. Furthermore, these stable, reduced-habitat conditions can concentrate nutrients and provide a protected environment for snail eggs and juveniles, leading to stable populations until environmental carrying capacity limits are reached. The gradual decline from November to March likely reflects increasing resource competition, predation, and the gradual desiccation of some habitats as the dry season intensifies.

The sharp decline at the onset of the wet season is the most striking feature. Heavy rainfall and resulting floods can have a profoundly disruptive effect on snail populations. Sudden increases in water volume, flow velocity, and turbidity can dislodge snails, wash them away, and bury them under silt, leading to high mortality [12.] The initial flush of rainwater may also alter water chemistry creating temporarily unfavorable conditions. The recovery observed from May through July represents a classic recolonization pattern. As water levels stabilize post-flush, surviving snails and those from refugia (like submerged vegetation) begin rapid reproduction to exploit new habitats and abundant nutrients washed into the water system. The subsequent decline from August to October, culminating in zero *Oncomelania* and *Melanoides* in October, may be linked to the end of the reproductive peak, increased predation, or the complete drying up of temporary habitats as the wet season transitions back to dry.

A genus-level analysis reveals distinct ecological niches and resilience, which directly informs disease control strategies, species demonstrates the highest resilience and abundance across both seasons. Its peak in the dry season (503) and significant presence in the wet season (453) indicate a high adaptability to fluctuating conditions. *Bulinus* species are often associated with permanent or semi-permanent water bodies with vegetation[13.] Their sustained population makes them a perennial source of *S. haematobium* transmission, necessitating year-round surveillance and control.

Showing a similar but less abundant pattern than *Bulinus* (Total: 509), *Biomphalaria* also thrives in the dry season (316). This genus is typically found in quieter, more vegetated waters compared to *Bulinus*. Their population recovery in the mid-wet season highlight their capacity for rapid repopulation, posing a significant risk for *S. mansoni* outbreaks following the rains.

The thiarid snail *M. tuberculata* is a biological control agent of interest. Its population trajectory is similar to the host snails. While it competes with host snails for resources, its decline in the wet season suggests it is similarly affected by flooding and may not provide stable suppression during periods of high transmission risk. Its role is likely more pronounced in stable, dry-season habitats.

Nigeria is hyperendemic for both urinary and intestinal schistosomiasis, and numerous studies have documented snail seasonality, providing an excellent point of comparison. The finding of high snail densities during the dry season is strongly supported by research in Nigeria. For example, a study in Zaria, Northern Nigeria, found that populations of *Bulinus* and *Biomphalaria* peaked during the dry season, precisely due to the concentration effect in shrinking water bodies [13.] Similarly, in Southwestern Nigeria, *B. globosus* and *B. pfeifferi* populations were highest from January to April, with a dramatic crash at the onset of rains [14.] This consensus underscores that the dry season is not a period of low risk but rather one of intense, focused transmission around permanent water sources where human water-contact activities (bathing, washing, farming) are also concentrated.

This parallel highlights a critical intervention point. Many control programs focus efforts during the wet season. However, this data from both locations suggests that dry-season snail control using mollusciciding or environmental management to target these concentrated populations could be highly effective in reducing the inoculum for the upcoming wet season, potentially breaking the transmission cycle more efficiently [15.]

The disruptive effect of the early wet season on snail populations is also a common theme in Nigerian studies, though the recovery rate can vary by region and specific ecological conditions.

The data shows a recovery in snail numbers by June-July. This pattern is observed in many Nigerian studies. For instance, in Osun State, Nigeria, a study found that after an initial decline, *Bulinus* and *Biomphalaria* populations rebounded significantly during the peak of the rains (August-September) [16.] This rebound is attributed to the creation of new, temporary breeding sites (puddles, footprints, roadside pools) and the influx of nutrients that fuel algal growth, the primary food source for snails.

However, some Nigerian ecosystems show different patterns. In the Niger Delta region, characterized by permanent water bodies and less drastic seasonal fluctuation, snail populations may remain more stable throughout the year or even increase during the wet season due to an expansion of habit [17]. This contrast emphasizes that local hydrology is a key determinant. The provided data likely comes from a region with a more pronounced seasonal flood pulse, similar to the savanna regions of Nigeria, rather than a rainforest or river delta ecosystem.

The expansion of water bodies brings snails into closer contact with human communities, and agricultural activities increase human exposure to infested water. Furthermore, the recolonizing snail population may initially be free of infection, but once miracidia from infected humans enter the water, these new populations can quickly become potent transmission sites [18.]

The interpretation of this snail survey data reveals a complex ecological system where the highest snail densities occur during the dry season, contrary to lay intuition. This pattern is consistent with findings from many regions in Nigeria, indicating a broader ecological principle applicable across West Africa and similar tropical climates. The presence of multiple potential intermediate host genera signifies a potential area of high multi-species schistosomiasis risk.

Control programs should prioritize mollusciciding and environmental sanitation (e.g., clearing vegetation from key water contact points) during the dry season when snail populations are concentrated, vulnerable, and in close proximity to human activity. The initial rains disrupt snails, the subsequent rebound and expansion of habitats necessitate continued surveillance and health education. Warning communities about the high risk of infection after the first rains and promoting preventive chemotherapy (e.g., mass drug administration with Praziquantel) before the peak transmission season is essential.

An effective control strategy must therefore be **integrated and seasonally tailored**. It should combine with targeted mollusciciding in perennial dry-season habitats, modifying water contact points to reduce habitat suitability (e.g., improving drainage, lining canals), investigating the potential of *M. tuberculata* as a competitor, though its efficacy may be seasonally limited and timing MDA to have the greatest impact on breaking transmission, potentially just after the wet season begins to treat infections acquired during the high-risk dry season.

Future research in this specific location should focus on determining the infection rates (shedding cercariae) within these snail populations across seasons to move from measuring risk potential to quantifying actual transmission dynamics. This integrated, ecologically-informed approach is vital for the sustainable control of schistosomiasis.

Heavy rains perhaps cause flooding, fast flow, physical disturbance, or wash snails away. In wet season, habitats may be unstable or less favorable (e.g. submerged vegetation, increased turbidity). In dry season, slower flows, more stable water bodies, more exposed substrata, possibly better for snail survival and reproduction.Dry season might lead to more stable shallow water warm spots, which could favour snail growth if water doesn't dry out completely.

However, if dry season is too severe and habitats dry out completely, then snail mortality would increase. In your data, perhaps dry season is not too severe or some habitats persist (perennial water bodies), so snails can persist.During dry season vegetation around the margins may increase or stabilize, providing better habitat; in wet, vegetation may be submerged or washed off.Wet season may bring in predators, more fish, more disturbance, which reduce snail abundance.For *Biomphalaria* and *Bulinus*, their life cycles (miracidia, cercariae) are tied to human infection patterns. Human contact may be more frequent in dry season when water bodies shrink and people congregate at remaining sources. That can increase snail infection and possibly population growth. Dissolved oxygen, pH, conductivity, temperature, turbidity etc. can shift across seasons; some species may be more tolerant than others. For example *Melanoides tuberculata* is often quite hardy, but may not thrive in heavily diluted or high flow habitats.

It was also reported from Bauchi State longitudinal study [19].This studies is in tandem with some key studies in Nigeria which Observed that population density of Bulinus and Biomphalaria increased following rains, with peaks at the end of the rainy season and/or beginning of dry season. Dry season sees decline due to temperature increases and desiccation. Temporary habitats had short-duration transmission (October-December). Some perennial habitats have longer transmission (October through March). Abundance of *Bulinus spp*. and Biomphalaria pfeifferi significantly seasonal, with greater numbers associated with dry season months in first half of year. Wet season months (particularly peak rainfall) had negative associations for B. truncatus and R. natalensis. Infection prevalence highest in the middle of dry season; lowest in rainy season.

In Makurdi, Benue State, Distribution of freshwater snail hosts showed increase from June through September (wet months), for species like *Melanoides tuberculata*, *Bulinus globosus*, etc. However in contrast, from the study of **Ingwavuma, South Africa** *B. globosus* numbers high at end of cold-dry to hot-dry season; decline during rains. *Biomphalaria* more associated with stream habitats; numbers sensitive to rainfall.

Higher abundance in dry season Just as in Niger River Valley and Bauchi, from our findings, snail counts are generally higher in dry season. This supports the idea that stable, less turbulent water bodies in dry season favor snail survival and population buildup.

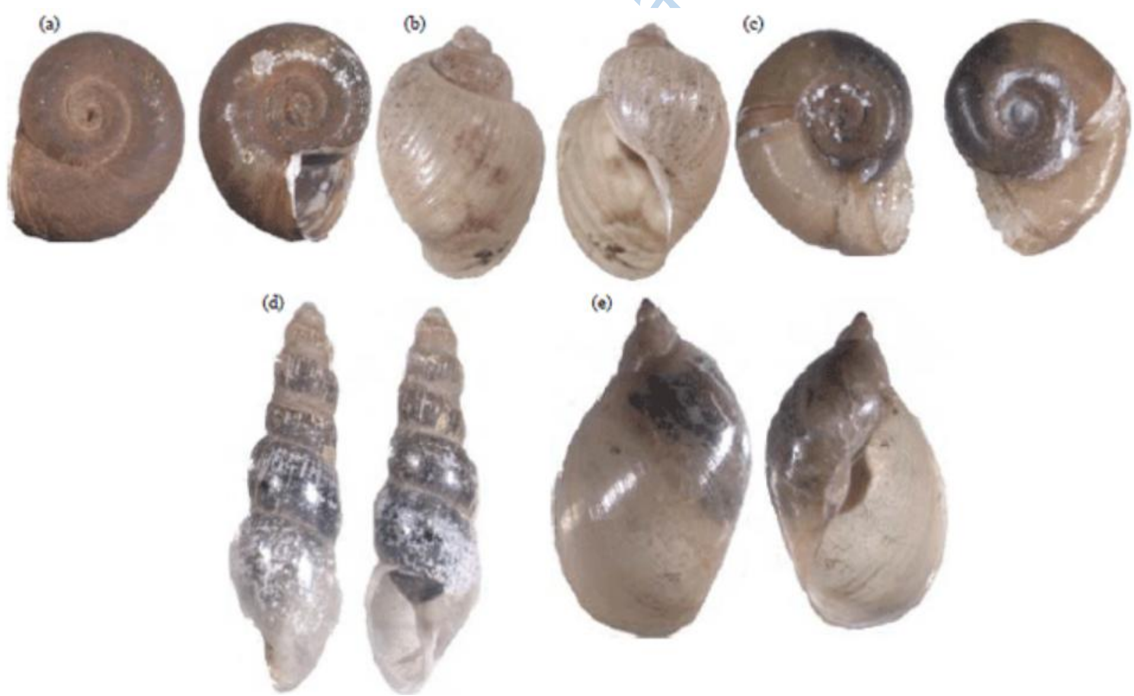


Figure 3: sample freshwater snails from the study area (a) *Biomphalaria pfeifferi*, (b) *Bulinus truncatus, (c) Indoplanorbis exustus* (d) *Melanoides tuberculata*

Plate 1: Snail samples belonging to the genus *Physa* collected from the study area

Plate 2: Showing snail in the Field Sampling at Ikolaba

Source: Field Work, 2024

Plate 3: Showing snail habitat from Eleyele River, Ibadan

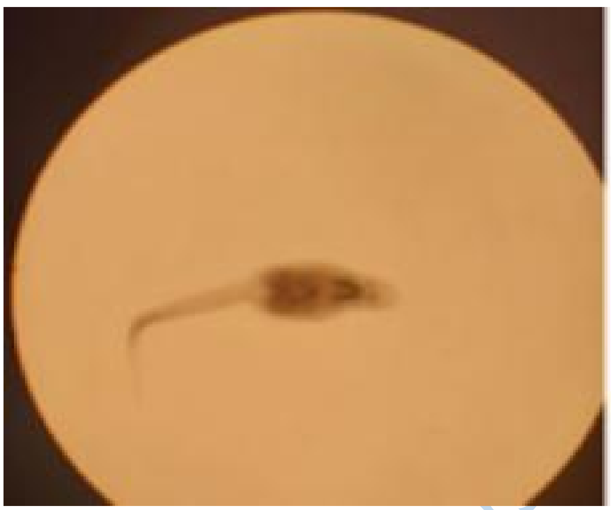
Source: Field Work, 2025

Plate 4: Showing snail habitat in Adeyi river, Ibadan

Source: Field Work, 2025

Plate 5: Showing *Biomphalaria species* from the Laboratory Work

Source: Laboratory Work, 2024



Source: Laboratory Work, 2024

Plate 4: Trematode cercaria shed by *Biomphalaria* snails on a slide view of × 100 magnification

Table 4.5: Median and Range values of the physico- chemical characteristics of water collected from eight sites (L1-L8) in the study Area

Location	pH	Temperature	Chloride (mg/l)	Turbidity (ntu	D.O (mg/l)	TDS (mg/l)	BOD (mg/l)	COD (mg/l)	Hardness (mg/l)	Conductivity (ps/cm)	TSS (mg/l)
LI	7.4 (7.3-7.5)	32.7 (32.3-33.0)	15.3 (12.05-18.60)	0.61 (0.04-1.18)	1.25 (1.00-1.50)	460 (220-700)	275(250-300)	35 (30-40)	74 (58-90)	92.5 (65-120)	840 (780-900)
L2	7.5 (7.2-7.8)	32.8 (32.6-32.9)	16.7 (14.10-19.20)	0.53 (0.06-1.00)	1.5 (1.25-1.70)	481 (312-650)	288 (266-310)	36 (32-40)	73 (60-86)	98 (56-140)	850 (800-900)
L3	7.5 (7.3-7.7)	33.5 (33.1-33.8)	16.5 (13.40-19.50)	0.59 (0.08-1.10)	1.55 (1.40-1.70)	475 (270-680)	295 (270-320)	34.5 (30.5.38.5)	70 (60-80)	125 (80-170)	920 (860-980)
L4	7.4 (7.0-7.8)	32.8 (32.4-33.1)	16.5 (14.30-18.60)	0.53 (0.06-1.00)	1.6 (1.40-1.80)	535 (320-750)	290 (280-300)	36 (34-38)	75 (62-88)	130 (60-200)	890 (860-920)
L5	7.5 (7.15-7.85	32.8 (32.3-33.3)	15.5 (13.0-18.0)	0.53 (0.05-1.00)	1.5 (1.30-1.60)	550 (400-	280 (260-300)	36.5 (32-41)	77 (64-90)	103 (58-148)	920 (880-

	)					700)					960)
L6	7.5 (7.30-7.70)	32.9 (32.5-33.2)	16.8 (14.40-19.20)	0.54 (0.08-1.00)	1.5 (1.40-1.60)	520 (280-760)	274 (268-280)	37 (33-41)	70 (55-85)	122 (64-180)	930 (860-1000)
L7	7.6 (7.30-7.85)	32.5 (32- 33)	15.5 (12.50-18.50)	0.56 (0.20-1.10)	1.4 (1.2-1.6)	540 (300-780)	277 (266-288)	36.1 (32.4-39.8)	78 (66-90)	113 (72-154)	915 (840-990)
L8	7.5 (7.1-7.8)	32.7 (32.4-32.9)	17.3 (14.50-20.0)	0.62 (0.24-1.00)	1.5(1.3-1.7)	465 (450-780)	285 (270-300)	37 (32-42)	80 (70-90)	113 (76-150)	890 (880-900)

Keywords: L1=Kongi 1, L2= Kongi II, L3= Ikolaba1,L4= Ikolaba 2, L5=Adeyi 1, L6=Adeyi2, L7=Eleyele 1, L8=Eleyele 2

4.2 Discussion of Results

This study sought to identify the role of physicochemical parameters on biodiversity indices of fresh water snails in selected rivers in Oyo State. We found out that physicochemical parameters had significant role to play in snail richness, snail diversity and richness. First is the pH, which shows a negative correlation with snail diversity and Bulinus richness.This implies that increase in pH will significantly reduce the snail diversity and Bulinus richness.

Similarly, increase in chloride concentration and BOD were also found to significantly reduce snail richness and snail diversity while COD is negatively correlated withsnail richness. Noting from the result of this study, the significant variation in snail richness.snail diversity and Bulinus richness observed across sampling points may not be unconnected with the significant variation in pH and Chloride contents across the sampling points.

Emphasis has been laid on the role of pH in survival of fresh water snail with reports that water snails are well adapted to habitat with pH levels ranging from 6.5 – 8.5. Lower values of pH have been reported to increase the solubility potential of other toxic elements especially heavy metals which make them available for absorption by aquatic organisms [20.]

In a study carried out by Onyekachi to determine the species diversity, distribution, and abundance of freshwater snails in KwaZulu-Natal, South Africa, snails were found in sites with pH levels ranging from 6.42–7.98, which is similar to what wasobtained in the current work where maximum pH across sampling sites recorded was 7.28 ±0.15 and minimum value of 6.71 ± 0.36. The role of pH on the life cycle of trematodes and their vector host such as freshwater snail cannot be overemphasized. At low pH values (acidic conditions), the snails may be killed thereby reducing their abundance and subsequently leading to low infection rate since most snails may not be able to reach the miracidia before their death [21,]

Chloride concentration in this study ranged between 14.77 to 33.65mg/l and was observed tobe negatively correlated with snail richness and diversity. This is in agreement with the studycarried out in the Ethiopian Rift Valley region to determine the environmental and biotic factors affecting freshwater snail intermediate hosts. In the study, abundance of *B. Globosus* was negatively correlated with chloride concentration. A major problem of elevated chloride in aquatic ecosystem is chronic toxicity which is harmful to aquatic lives as it interferes with their balance of body fluids and also increases water corrosivity [22,23.]

Biochemical Oxygen Demand (BOD) which is the measure of organic material contamination in water or measure of amount of dissolved oxygen required for the biochemical decomposition of organic compounds, was found to be negatively correlated with snail richness and diversity. This is not unprecedented as increased level of BOD leads to reduced dissolved oxygen (DO) and subsequently causing oxygen deprivation for the aquatic organisms including the fresh water snails. Highest BOD value of 82.25 mg/l was recorded at Erin Osun against 5 mg/l which is the EPA standard limit for river water [24]. This may be connected with both organic and inorganic matter pollution evident at the site during sampling period. Study has shown that high level of organic pollution of river waters can result in higher demand for oxygen (BOD), COD and total dissolved solids [24]. The highest BOD and COD recorded in Erin Ijesa might be the cause of the site returning lowest number of snails and this is evident from analysis of variance result which shows that all other sites differed significantly from Erin Osun in terms of snail richness, diversity and bulinus abundance.

Also, this work is similar to the work of Sunday et al, who found a positive correlation between dissolved oxygen and bulinid species [24,26]. Such relationship may be explained by poor aeration which usually occurs in an oxygen deficient medium due to decomposition of organic matters from aquatic lives such as algae and other aquatic plants. This view, that dissolved oxygen is positively correlated with bulinus abundance is widely supported by other researchers [20]. However, differences in the number of species collected may be due to the differences in sampling methods, duration of sampling, the number of sampling sites, size of water body, and ecological variables among other factors.

Table 4.6: **rrnL-nad1 Primer sequences**

Name of Primer	Target	Sequence (5' to 3')
16SAR	16S	CGCCTGTTTATCAAAAACAT
16SBR	16S	CCGGTCTGAACTCAGATCATGT

The extracted fragments were sequenced in the forward and reverse direction (Nimagen, BrilliantDye™ Terminator Cycle Sequencing Kit V3.1, BRD3-100/1000) and purified (Zymo Research, ZR-96 DNA Sequencing Clean-up Kit™, Catalogue No. D4050). The purified fragments were analyzed on the ABI 3500xl Genetic Analyzer (Applied Biosystems, ThermoFisher Scientific) for each reaction for every sample, as listed in Section 1. BioEdit Sequence Alignment Editor version 7.2.5 was used to analyse the. ab1 files generated by the ABI 3500XL Genetic Analyzer and results were obtained by a BLAST search (NCBI).

Table 4.7: **Sequence Prediction Report**

S/no	Sample ID	Organism	Sequence length (bp)	% identity	Accession no of BLAST hit
S1	BL01ADEYI	*Biomphalaria*	501	99.00%	OQ561512.1
S2	ML02ADEYI	*Melanoides tuberculata*	516	99.81%	AY010517.1

S3	KG01 kongi	*Biomphalaria*	520	99.82%	PQ 23456.1
S4	Ik01 Ikolaba	*Bulinus globossus*	121	99.80%	RT 45237.1
S5	El 01 Eleyele	*Bulinus globossus*	121	99.80%	RT 45237.1
S6	EL02 Eleyele	*Bulinus globossus*	121	99.80%	RT 45237.1
S7	El03 Eleyele	*Bulinus globossus*	121	99.80%	RT 45237.1

Source : Laboratory work, 2025

Sequence Prediction Report

>BLKONGI

TAATTTTTATTGTCGATATCTTCTGCCCGGTGTTTATATAACCGGCCGCAGTACCTTG

ACTGTGCTAAGGTAGCATAATCAATTGGCTATTAATTGTAGTCTAGTATGAATGAAG

TAATGAATAGTAACTATAATAAAAAATATTATTTTAATTTAATGAACTGGTGAAAAT

ACCAGTATATAGAAAAAAGACGAGAAGACCCTTAGAGTTTTTGAAATAAAGATTGT

TTAAGACTTTAATTTATACTACTCTTAAAGTAATTATACAATACACTTTTTTGTTGGG

GCGACAAGAAAGCAATATAACCTTTCTATTGACACTAAAAGTGGTATTAGATCTGAC

GATATTATTATGAATGACTAAACTACCTGAGGGATAACAGCATAATGATAAATATTA

GTTTGTGACCTCGATGTTGGACTAGGGACTAGTACACTAACCGTGATAAAAGCTTGT

TCTGTTCGAACAATAAACCCCTACATGATCTGAGTTCAGACCGG

> ML02ADEYI

TCGCCTGTTTATCAAAAACATGGCTCTCTGACAAAAACATATAGAGAGTCGAACCTG

CCCAGTGAACAGTTTAACGGCCGCGGTACCCTGACCGTGCAAAGGTAGCATAATCA

TTTGCCTTATAATTGAAGGCTTGTATGAATGGTCTGACGAAAGCAATACTGTCTCTTC

TTTATTATCTAGAAATTAACCTATGGGTGAAGAGGCCTATATTATATTGAAGGACAA

GAAGACCCTGTCGAGCTTTAGAGTAAAGCAGGAATATAAGTATTAAAAAAAATCAA

TGACTACATAACTCTTTAGTTGGGGCGACTAAGGAACAAATAAAGCTTCTTTTAGTT

TTTTAGATCAATAAATTTAGATCCAGCAAAGCTGATTAAAAGAATTAGTTACCGCAG

GGATAACAGCATAATCTCTCTTGAGAGACCTAATCGAAAGAGGGGGTTGTGACCTC

GATGTTGGACTAAAATATCCTGAAGATGCAGACGTCTTCGAAGGTTGGTCTGTTCGA

CCATT

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GCTAATTTTTATTGTCGATATCTTCTGCCCGGTGTTTATATAACCGGCCGCAGTACCT

TGACTGTGCTAAGGTAGCATAATCAATTGGCTATTAATTGTAGTCTAGTATGAATGA

AGTAATGAATAGTAACTATAATAAAAAATATTATTTTAATTTAATGAACTGGTGAAA

ATACCAGTATATAGAAAAAAGACGAGAAGACCCTTAGAGTTTTTGAAATAAAGATT

GTTTAAGACTTTAATTTATACTACTCTTAAAGTAATTATACAATACACTTTTTTGTTG

GGGCGACAAGAAAGCAATATAACCTTTCTATTGACACTAAAAGTGGTATTAGATCTG

ACGATATTATTATGAATGACTAAACTACCTGAGGGATAACAGCATAATGATAAATAT

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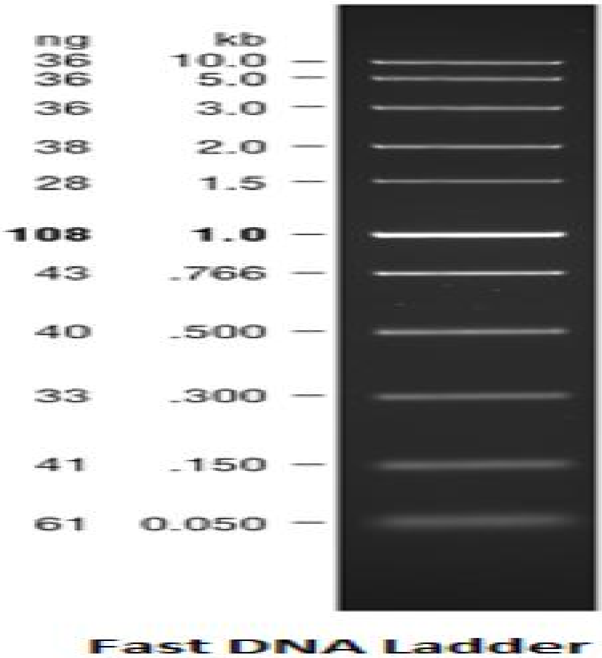

Figure 4: A photographic image of an agarose gel indicating the amplification of the COI target region

4.3. Molecular Characterization Freshwater snails

The use of molecular techniques, particularly the amplification of the cytochrome oxidase subunit I (COI) and ribosomal 16S gene regions, enabled precise taxonomic identification which would have been challenging using morphological characteristics alone due to the close resemblance between juvenile and adult stages or among sympatric snail species. These results provide reliable baseline data for snail species distribution in the study area and contribute to the broader understanding of host-parasite relationships in schistosomiasis transmission.

The Seven of the ten snails were positive for schistosome infection. The use of molecular techniques, particularly the amplification of the cytochrome oxidase subunit I (COI) and ribosomal 16S gene regions, enabled precise taxonomic identification profiles showed bands of different sizes for 10 snails including the schistosome-infected ones. The analysis showed that 5 of the snails belonged to the freshwater snails of the genus Biomphalaria while 5 belonged to the freshwater snails of the genus Bulinus, The species of the remaining three snails could not be resolved using the reference profiles.

The molecular characterization of freshwater snail samples collected from schistosomiasis-endemic areas was carried out through DNA extraction, PCR amplification of the mitochondrial gene regions, and sequencing. The generated sequences were subjected to BLAST analysis against the NCBI GenBank database to determine species-level identity. Seven samples were successfully amplified and sequenced. The first four samples, displayed a 99.00% sequence similarity to Bulinus. The other two sample, showed a 99.81% sequence similarity with Biomphalaria and one sample *Melanoides tuberculata*. These high-percentage matches strongly confirm the identity of the snail species with a high degree of accuracy, indicating the effectiveness of the molecular techniques employed.

The results of this findings underscore the importance of integrating ecological assessment with molecular diagnostics in the management of schistosomiasis. It is not enough to identify the presence of snail vectors; understanding their ecological distribution, population dynamics, and genetic identity is essential for effective control strategies. The dominance of *Bulinus* and *Biomphalaria* in the study area, especially in densely populated areas like Eleyele, signals the potential for continued disease transmission if proactive control measures are not implemented.

Cercaria sheddings have been used for detection of snail infection with schistosome miracidia, but this method is limited because pre-patent infection can last for several weeks with only a small proportion of the snails making the stage for cercariae sheddings. Considering the relationship between the parasite and the snail hosts, evidence-based research focused on accurate identification of the snail host and the parasite would not only define species diversity but also block the transmission, and thus control infection.

Endnotes

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Chapter Five

5.0 Summary, Conclusion and Recommendation

5.1 Summary

This study has established the occurrence of aquatic snails, some of which are known vectors of schistosomiasis as well as confirming the transmission of schistosomiasis in Ibadan, Oyo State. It also revealed that snails are focal in occurrence and density. Moreover, the focal distribution of snails in Bodija, Rivers and River Eleyele could be attributed to chemical properties of water such as Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD). In addition, the study has highlighted the importance of aquatic plants in snail distribution.

Snails have a wide range of importance to humans both economically and medically. A sizeable number, especially the aquatic forms of freshwater snails in tropical freshwater are known to be inevitable agents of trematode diseases of man and his domestic animals *Schistosoma spp.* that causes schistosomiasis disease uses several species of subclass Pulmonata as intermediate hosts. In Nigeria, schistosomiasis is a disease of considerable and growing importance due to inadequate portable water and activities related to water resource development schemes for irrigation, fishing, and hydro-electricity. This, in addition to natural habitats, sustains transmission in any water bodies where the intermediate host (bulinid snails) can find many suitable breeding sites.

Similarly, aquatic vegetation and physical factors such as water current, temperature, turbidity, transparency and distribution of suspended solids, chemical factors such as ion concentration and dissolved gases in water as well as biological factors such as availability of food, competition and predator-prey interactions have been identified to affect the ecology of snails and other intermediate hosts of diseases, hence their focal and seasonal distributions.

Having identified the importance of snail intermediate hosts in *Schistosoma* life cycle, an adequate knowledge of its ecology, bionomics and population dynamics will enhance an effective control strategy. Although human infection with *Schistosoma haematobium* has been reported in several areas in Nigeria. And since ecological factors vary significantly from one ecological zone to the other and even from one water body to the other, there is therefore the need to identify important factors that can exacerbate the risk of *schistosoma* infection in these rivers in Ibadan, Oyo State

5.2 Conclusion

The findings from this study especially the high infection prevalence in *Bulinus globossus*, significant infection in *Biomphalaria pfeifferi*, and non-infection in *Melanoides tuberculata* indicate strong potential for active schistosomiasis transmission in the study rivers. Compared with broader African averages, your results are higher than many documented norms, suggesting that these river systems are hotspots.

The implications are serious for communities dependent on these water sources. Effective control will require integrated efforts: snail surveillance and control, improved water, sanitation, behavior change, and appropriately targeted mass treatment. Further, precise species and parasite identification, and temporal/spatial monitoring will be critical to tailor interventions and evaluate.Physicochemical parameters such as pH, chloride content, BOD and COD play significant role in biodiversity indices of fresh water snails. Environmental modification of these parameters can go a long way in snail bound infection control.

5.3 Recommendations

Based on my Findings, I herby make the following recommendations:

i. Conduct regular snail surveys across seasons to track changes in infection prevalence.

ii. Use both shedding and molecular methods to detect infection, including prepatent infections.

iii. Map snail species distributions, human contact points, and water use behavior to identify high- risk zones.

iv. Focus control on *B. globossus* and *B. pfeifferi* as they are contributing most to infections.

v. Habitat modification (eliminating vegetation, improving water flow) to reduce snail breeding.

vi. Reducing contamination of rivers with human excreta (both urine for *S. haematobium* and feces for *S. mansoni*) through improved toilets and latrines.

vii. Health education for communities about risks of water contact, safe water practices.

viii. Given the high snail infection prevalence, MDA alone is unlikely to interrupt transmission without combined approaches.

ix.Ensure sufficient coverage and repetition of MDA; coordinate with environmental interventions.

5.4 Suggestion for Further Research

The present study provides a crucial baseline on the diversity, distribution, and infection status of schistosome-intermediate host snails in Ibadan. To translate these findings into effective public health interventions, the following further studies are highly recommended.Conduct studies over multiple seasons (dry vs. wet) and across several years to understand the population dynamics of snail hosts. This will identify high-risk transmission seasons and help correlate snail abundance with climatic variables (rainfall, temperature) in the Ibadan context.Expand the sampling to include more communities within and surrounding Ibadan, especially rapidly urbanizing and peri-urban areas where water contact practices and habitat suitability may be changing. This will create a high-resolution risk map for the entire region.Use more discriminatory molecular markers (e.g., COI, ITS, SSR microsatellites) on infected snails to identify the specific strains or species of Schistosoma present. This is critical for understanding transmission zoonoses and reservoir hosts.

Investigate the genetic basis of compatibility between local snail strains (Bulinus spp.) and local schistosome strains. This can explain why some sites have high snail densities but low infection rates and vice versa. Perform a population genetic study on the primary snail hosts. Also, using Employ GIS and remote sensing to precisely model snail habitat suitability using variables like vegetation indices (NDVI), land surface temperature, proximity to settlements, and soil type. Assess the community's understanding of the snail's role in schistosomiasis transmission. This information is vital for designing effective and culturally appropriate communication messages.

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Bio- data

Full Name: **KOLAWOLE** Tunde Azeez

Address: Eniak's Lodge Olopoto Area, Oke-Iserin, Igboora.

E- mail Address**:** kolawole.tunde@gmail.com

Phone Number**:** 08059544993

Date of Birth: 27th June,1978.

Place of Origin: Oyo

Place of Birth: Igboora

Nationality: Nigeria

Language spoken : Yoruba and English

Name of Next of Kin: Mrs. Kolawole S. O 08061973110 Eniak's Lodge Olopoto Area, Oke-Iserin,Igboora.

B. Educational Background (with dates and Qualification)

1. Primary Education

I.M.G Primary School Molete Ibadan 1984-1989 Primary School Certificate

Secondary Education

2. St.Teresa's College Oke-Ado Ibadan 1990-1995 SSCE

3.Higher Education Institutions

School of Medical Laboratory Science, U.C.H Ibadan. 1998-2001 AIMLT

Lead City University Ibadan 2019 – 2021 PGD

C. Working Experience with Dates

St.Mary's Catholic Hospital, Eleta, Ibadan 2003-2007

Institution Attended with Dates:

Lead City University, Ibadan 2024-2025

Olabisi Onabanjo University, Ago-Iwoye, Ogun State 2020-2022

University of Agriculture Abeokuta, Ogun State 1997-2001

Federal College of Education Abeokuta, Ogun State 1990-1993

Methodist Grammar School, Igboora 1982-1987

Academic Qualification With Dates:

M.Sc in Parasitology 2025

PGD in Zoological and Environmental Biology(Parasitology) 2022

B. Sc (Biological Science) 2001

Nigeria Certificate in Education (Integrated Science Double Major) 1993

West African School Certificate 1987

General Certificate in Education 2012

Professional Qualification with Dates

Teachers Registration Council 2005

Previous Work Experience

National Teacher Institute, Kaduna, Igboora study centre
(Part-Time Lecturer) 2002 to Date

Maku Grammar School, Tapa (Class Teacher) 2002-2012

WHO/TDR Project Base in the African (Research Assistant)
Health Education Centre, University of Ibadan, May-June 2002

Rockfeller Foundation Based in the African Health Education
Centre, Department of Health Promotion and Education, College of Medicine,
University of Ibadan (Research Assistant) 2000-2001

Guinea Worm Eradication Programme, global 2000 (Field Officer) 2001 to 2002

Government Technical College, Igboora (Part-Time Teacher) 1994-2006

Methodist Grammar School, Igboora (Class Teacher) 1994-1998

Previous Work Experience in the College

Assistant Lecturer, Fisheries Technology Department 2012-2013

Assistant Lecturer, Science laboratory Technology Department 2013-2015

Present Work in the College

Lecturing Science Laboratory Technology Department	2013-till date
Supervision of students project	2015 till date

Administrative Experience

(a) **Contribution to the Department**

i	Member, Department Examination Committee	2013 till date
ii.	Member, Departmental Admission Committee	2019 till date
iii.	Member, Social and welfare committee	2019 till date

(b) **Contribution to the Faculty**

i.	Sub-Dean, Faculty of Science	2023 till date

(c) **Contribution to the College**

i.	Sub-Dean, Faculty of Science	2023 till date

(d) **Contribution to the Community**

a Secretary, Fund Raising Committee, Lajorun Development Council, Igboora

b Secretary, Nawair-u-Deen Grammar School Planning Committee

S/N	COURSE CODE	COURSE TITLE	COURSE UNITS
1.	STB 101	Plant and Animal Taxonomy	2
2.	STB 204	Ecology	2
3.	STB 316	Parasitology	3
4.	STM 415	Immunology and Public Health	3
5.	STB 103	Morphology and Physiology of Living things	2

6.	STB 204	Pathology	2
7.	STB 203	Pests and Pests control	2
8.	STM 321	Mycology	3
9.	GNS 205	Introduction to Biology	1

26. **LIST OF COURSES TAUGHT AND THEIR UNITS**

27. LIST OF STUDENTS PROJECT SUPERVISION

S/N	Name	Matric Number	Title	Year
1.	ADETOLA, Precious Anuoluwapo	HND/231120	Antibacterial activities of Heliotropium angiosperm against selected pathogenic bacteria	2025
2.	Azeez Waris	HND/231223	Evaluation of the antibacterial activities Of cassia occidentaly leaf extract against pathogenic bacteria	2025
3.	Olonade Ruth K.	HND/2014/043	Isolation and characterization of bacteria from Gut of Frog	2025
4.	Lukman Faidat Ayanwunmi	HND/231245	Antibacterial effect of mango seed on pathogenic bacteria.	2025
5.	DAIRO, Rokiba Omolola	SLT/2014/040	Preralence of intestinal parasite on vegetable sold in Igboora market.	2025
6.	IBRAHIM, Zainab Jumoke	SLT/2014/048	Bioactivity of Delonix vegra seed against maize.	2025

7.	ADEKUNLE, Oluwatobiloba Iyanuoluwa	SLT/2014/011	Relative Abundancce of Earthworm in an Ecosystem unit of Oyo State College of Agriculture, Igboora.	2025
8.	MARK, Chidinma Preasure	ND/150262	Ecological Survey of Freshwater Snails in Eleyele River, Ibadan.	2025
9.	ADEWUYI, Stella Adediwura	ND/150258	Ecological Survey of Earthworm in OYSCATECH Ecosystem, Igboora.	2025
10.	OLAKUNLE, Mary Oluwabukola	ND/150265	Prevalence of Intestinal Parasite in Open seed consumed from two market in Igboora.	2025
11.	ADEKANBI, Muinat Adebimpe	ND/150269	Effect of Ethanol extraction of Neem leaf against grasshopper.	2025
12.	ADEYEMO, Temitope Islamiat	ND/150577	Toxicity of Crude Neem seed against Beans weevil.	2025
13.	OLAWOORE, Damilola Christiana	ND/150069	Evaluation of Anarcadium occudentale on maize weevils.	2025
14.	OLABISI, Gbenga Bolaji	ND/150294	Effect of Neem leaf extract against Mosquito.	2025
15.	AJALA,Christiana Ifeoluwa	ND/150407	Insecticidal activities of Tobacco leaf against maize weevil.	2025

28. **MEMBERSHIP OF PROFESSIONAL BODIES/LEARNED SOCIETY**

1. Member, Teacher Registration Council of Nigeria (TRCN)

Research Publication

i. Thesis/Dissertation

Kolawole, T. A. (2025) Ecological and Molecular Characterization of snail vector

ii. Books or Monographs (Chapter in a Book or Chapter in Books) with ISBN

1. *Oyelakin, A.O. **Kolawole, T.A.** Adaramola,K.A. Oladejo,S.M. Oladokun,P.O. andBada,V.I. Practical Hand Book. Department of Science Laboratory Technology, Oyo

ii. Amusat A. I, Kolawole T. A. Pest and Pest control for College and Polytechnics ISBN:978-77557-066-01

c. **Published Article (s)**

1. *Adedokun Mathew Adewale, A. O. Ayanboye, O. B. Adelodun and **T. A. Kolawole** (2017) Inventory and Impact of Dominant Fishing Gear and Method of Eleyele Lake, Oyo State, Nigeria. *Asian Journal of Environment and Technology 4(2): 1-10*

2. *Amusat A. I., **Kolawole, T. A.** Adedokun A., Oladokun, P. O. And Okpoto, R. O (2017). Comparative Study of the Effect of Ginger Extract and Salt on the Microbial Load of Fermented African Locust Bean Seed *(Parkia biglobosa). Moor Journal of Agricultural Research 18, 79-87*

3. Tairu H. M., **Kolawole T. A.**, Adaramola K. A., Oladejo S. M., Oladokun P. O. And Bada T. V. (2015). Impact of human population and household latrines on groundwater contamination in Igboora Community, Ibarapa Central Local Government Area of Oyo State, South-Western Nigeria. *International Journal of Water Resources and Environmental Engineering vol. 7(6) Pp. 84-91*

** Publications after last promotion*

Amusat, A. I., Amuzat A. I., Olubode, T. P., Kolawole, T. A. and Fabunmi, A. O. (2022) Limnological assessment of selected rivers in Igboora, Ibarapa Local Government Area of Oyo State, Nigeria. *OYSCATECH Journal of Engineering and Environmental Studies (OYSCATECH-JEES); Vol. 1,* Kolawole, T. A., Sulaimon N. O., Tairu H. M. (2023) Bacteriological Assessment of Selected well water sources in Igboora, Ibarapa Central Local Government Area, of Oyo State, Nigeria JAMTECH, Igboora.

d. **Manuscript accepted for publication**

Amusat, A. I., Amuzat A. I., Olubode, T. P., Kolawole, T. A. and Fabunmi, A. O. (2022) Limnological assessment of selected rivers in Igboora, Ibarapa Local Government Area of Oyo State, Nigeria. *OYSCATECH Journal of Engineering and Environmental Studies (OYSCATECH-JEES); Vol. 1,*

Kolawole, T. A., Sulaimon N. O., Tairu H. M. (2023) Bacteriological Assessment of Selected well water sources in Igboora, Ibarapa Central Local Government Area, of Oyo State, Nigeria JAMTECH, Igboora.

e. **Conference/Workshop Proceedings**

1. *Tairu, H. M, Adelodun, O.B, Olawale B. R., Adaramola, K. A., **Kolawole T. A.,** Akande, A. And Wilson-Imere, M.(2018). Microbial Examination, Organoleptic Proximate Composition of Clove on Safety and Shelf Life of Smoked Tilapia Fish. Nigeria society for Microbiology of Afe Babalola University, Ado-Ekiti. Southwest zonal Annual Symposium. 14-16 May,2018.
2. *Olawale, B. R., Tairu, H. M., **Kolawole, T. A.,** Adaramola, K. A., Adedokun, A. and Wilson-Imere, M (2018). Microbial Load and Shelf Life of Fermented Locust Beans Seed (*Parkia biglobossa*) under selected natural preservative. Nigeria society for Microbiology of Afe Babalola University, Ado-Ekiti. Southwest zonal Annual Symposium. 14-16 May,2018.
3. ***Kolawole, Tunde Azeez,** Adedokun, M. A., Adejumo, M. M., and Tairu, H. M (2016). The population density and characterization ofEarthworm at Ecosystem Units of Federal University of Agriculture, Abeokuta Nigeria. 1st International

conference of the School of Science and Engineering of Oke-Ogun polytechnic,Saki, Oyo State, Nigeria. 28th -31st August, 2016.

4. *Adedokun A., Tairu, H. M., **Kolawole, T. A.,** Oladejo, S. M and Olubode, T. P (2016). Genotoxicity of water Samples from 'Oba' River Detected in *Allium cepa* Chromosome Aberration Assay. 41st Annual Conference of Nigeria society for Animal production of Federal University of Agriculture, Abeokuta, Nigeria. 20th-24th March,2016.

5. *Tairu, H. M., Oyelakin, A. O, Adaramola, K. A. **Kolawole, T. A** and Adedokun, A (2016) Microbial assessment of Garlic on the Safety and Shelf life of Smoked Tilapia Fish (Oreochromis niloticus). 41st Annual Conference of Nigeria society for Animal production of Federal University of Agriculture, Abeokuta, Nigeria. 20th-24th March,2016.

6. Tairu H. M., **Kolawole, T. A** Alaro, S. M., Olawale B, R and Olubode, T. P (2014). An evaluation of the Effect of Tyrosinase on Youghurt produced from skimmed milk. 13th Annual National Conference of School of Business Studies of Federal Polytechnic, Ede, State of Osun. March 3 – 7, 2014.

vi. Exhibition/Designs/Project/Inventions etc Nil

vii. Workshop/Conference Attended

1. Southwest Zonal annual symposium of Nigeria society for Microbiology held at Afe Babalola university, Ado ekiti-Nigeria. 14th-16th May, 2018

2. 1st International conference of the School of Science and Engineering of Oke-Ogun polytechnic, Saki, Oyo State, Nigeria.28th -31st August, 2016.

3. 41st Annual Conference of Nigeria society for Animal production of Federal University of Agriculture, Abeokuta, Nigeria. 20th-24th March,2016.

4. 13th Annual National Conference of School of Business Studies of Federal Polytechnic, Ede, State of Osun, 3rd-7th March, 2014.

30. **RESEARCH IN PROGRESS**

(2) Kolawole, T. A. (2025) Ecology and Molecular Characterization of snail Schistosomiasis vector in some selected rivers in Ibadan metropolis

31. **EXTRA CURRICULAR ACTIVITIES**

Reading and Travelling

32. **OTHER RELEVANT INFORMATION:** Nil

Referees

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The University Compliance Certification

This is to certify that, this Thesis written by **Azeez, KOLAWOLE with Matric Number LCU/PG/00006297,** in the Department of Biological Science, Faculty of Natural and applied Science Lead City University Ibadan is in full compliance with the approved university format and style.

Signature **Date**

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