TREMATODE INFECTION IN *Pila ovata* FROM IGUOBO COMMUNITY, OVIA NORTH-EAST LOCAL GOVERNMENT AREA, EDO STATE, NIGERIA

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FACULTY OF LIFE SCIENCES

UNIVERSITY OF BENIN

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A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF ANIMAL AND ENVIRONMENTAL BIOLOGY, FACULTY OF THE LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE IN ANIMAL AND ENVIRONMENTAL BIOLOGY (BSCAEB)

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CERTIFICATION

This is to certify that (Miss) ENOGHENE ONOYOVWERE (LSC2103665**)** carried out this undergraduate project work of the department of Animal and Environmental Biology, University of Benin, Benin City, Edo State, Nigeria.

____________________________ ________________________

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EXTERNAL EXAMINAMER **DATE**

DEDICATION

This work is dedicated to the Almighty God for His help, guidance and provision, and to my parents for their candid support.

ACKNOWLEDGEMENTS

My ultimate gratitude goes to the Almighty God for empowering me with strength, health and vitality to carry out my project seamlessly during the course of my study. My heartfelt gratitude to my parents, Mr. and Mrs. Onodavwerho Onoyovwere and my family for their prayers, constant support, love, advice and provision all through my academic journey.

Special appreciation to my Course advisor and project Supervisor, Dr. (Mrs.) O. Edo-Taiwo for her motherly love, discipline, her time and dedication to ensuring that my project was a success. I am grateful also for her contribution that has me equipped in research writing, she is not just a Supervisor but like a mentor to me, may God bless you Ma.

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TABLE OF CONTENTS

LIST OF PLATES

LIST OF FIGURES

ABSTRACT

This study was carried out to determine the prevalence of trematode parasite infection in *Pila ovata* from Iguobo community, Ovia North-East LGA, Edo State, Nigeria. The snail specimens were collected by hand picking from water puddles within farmlands in Iguobo Community in July, 2025. Sixty-six snails species *Pila ovata*, belonging to the Family Ampullariidae, were examined and only one was found to be infected with trematode larval stages with an overall prevalence of 1.52%. The larval stages of trematodes recovered from the infected snail include rediae, cercariae, metacercariae, and a juvenile trematode. Two types of cercariae were identified namely, gymnocephalous and cercariaeum cercariae. The low prevalence of trematode infection recorded in this study could be attributed to minimal anthropogenic activities in the study area, which likely reduced water contamination. It could also be due to the short period of survey and timing. The study was conducted during wet season; which probably reduced the infection rate due to dilution factor. Although, *Pila ovata* showed low prevalence of trematode infection in this study, it however, exhibited high parasite diversity due to the presence of different larval stages and trematode recovered from the infected snail. This study reports Cercariaeum and gymnocephalous cercariae in *P. ovata* from Nigeria for the first time. Further investigation should be conducted on *Pila ovata* to ascertain the species status of trematode cercariae infecting this snail.

CHAPTER ONE

1.0 INTRODUCTION

1.1 EVOLUTIONARY HISTORY OF SNAILS

Gastropod is the largest and most diverse Mollusca class with its members occupying a wide variety of habitats ranging from the terrestrial to aquatic ecosystem (Miller and Harley, 2007). The Class Gastropoda includes snails, limpets and slugs over 70,000 living and more than 15,000 fossil species. Snails are conspicuous invertebrates with soft bodies enclosed in calcareous shells (Okafor, 2009). Their fossil record dated back to the Cambrian period, which is about 500 million years ago (Fryda *et al.,* 2008). The Permian–Triassic extinction led to the elimination of over 20% of families, genera and species of gastropod, but the surviving gastropod lineage evolved rapidly into new ecological niches during the Mesozoic era (Logan and Hills, 1973). Terrestrial snails diversified during the middle of the Mesozoic era. Although, gastropod were abundance in the late Paleozoic before the End-Permian extinction affected their survival. Earliest gastropod inhabited marine ecosystem, they were said to have Limpet-like shell, asymmetrical shell coiling. In the primitive gastropod, their body was divided into a head, foot still present in the modern gastropod, and visceral hump connected by a neck (Barker, 2001). Cretaceous period marked a shift within the clade Pulmonata, in which the mantle cavity evolved into a functioning lung for their survivability on land (Barker, 2001b).

1.2 TAXONOMY OF SNAILS

Snails belong to the Class Gastropoda of the Phylum Mollusca. Members of the class Gastropoda are distinguished by their torsion and often coiled shell. They include snails and slugs. Gastropods are classified into three main subclasses namely:

Classification of Gastropods

Kingdom: Animalia

Phylum: Mollusca

Class: Gastropoda

Subclass: Opisthobranchia

Subclass: Prosobranchia

Subclass: Pulmonata

Opisthobranchia: These are gastropod whose adult exhibit detorsion by a process of untwisting. The members of this group are mostly marine including, sea hare, sea slug, and nudibranchs (Miller and Harley, 2007b).

Prosobranchia: Members comprises of marine snails and abalone. It includes periwinkle, limpet, conchs, whelks, and cowries (Miller and Harley, 2007c).

Pulmonata: Are gastropod group predominated by freshwater and terrestrial snails, as well as terrestrial slugs (Miller and Harley, 2007d).

1.3 BIOLOGY OF SNAILS

The biological characteristics of snails entail their morphology, physiology, reproduction and development, which often reflect their adaptation to various environments. Snails are described by the presence of the spiral shell and foot for locomotion (Bouchet *et al.,* 2017). However, they are further categorized on the basis of their morphological features which involve the foot and coiled shell, a distinct feature that set them apart from other classes in the phylum Mollusca. The shell is the most important feature in snails because it acts as a defense against predators and environmental threats (Ponder *et al*., 2019).

Terrestrial and freshwater snails both have calcareous shells; the pattern of coil is asymmetrical in compact form, with successive coils or whorls slightly larger than, and ventral to the preceding whorl. Snails possess muscular foot used for locomotion in a crawling motion as seen in terrestrial snails. The head bears sensory tentacles and eyes, most land snails possess four tentacles while the other snail's species has two tentacles. The eyes are attached to the end of the tentacles (Okafor, 2009).

The body structure of snails is coelomate with well-defined organ systems as shown in (Plate1.1). Their digestive system involves the mouth with ribbon-like radula for scraping food such as algae and other small organisms. They have a ciliated digestive tract that is coiled consisting of crop, intestine, stomach and anus. Terrestrial snails possess esophagus and crop for temporary storage of food intake. However, freshwater snails have a strong muscular gizzard that assists in the final digestion (Escobar-Correas *et al.,* 2019).

Gastropod, particularly snails have an open circulatory system with a single heart sac function as the main organ that pumps hemolymph throughout the body cavity (Ponder *et al*., 2019). The blood acts as hydraulic skeleton during transport of nutrients, wastes and gases.

Wastes is excreted through the nephridia, it opens into the mantle cavity and anal opening. Aquatic snails excrete ammonia while terrestrial excrete uric acid (Miller and Harley, 2009). The nephridium modifies waste by selectively reabsorbing some ions and organic molecules.

Many marine snails are dioecious, exhibiting external fertilization while others are monoecious with internal fertilization.

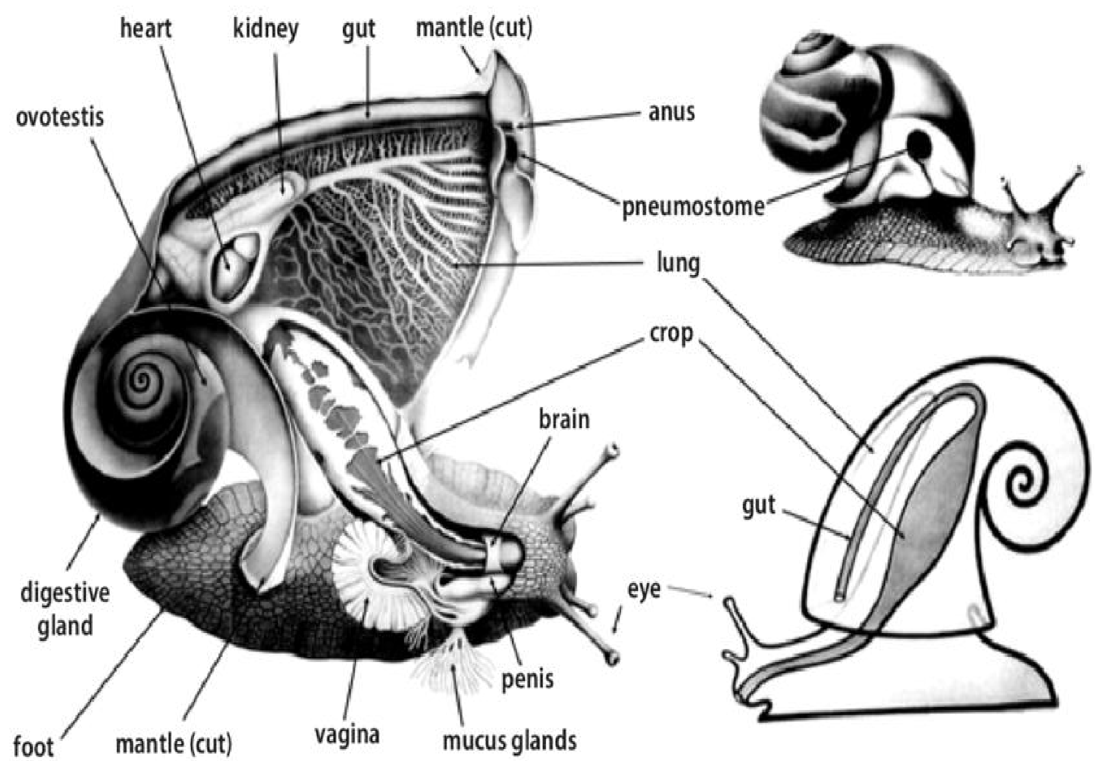

Plate 1.1: Anatomy of a Pulmonate Snail

(Source: Pfurtscheller, as adapted in Oesch *et al.*, 2013)

1.4 ECOLOGY OF SNAILS

Snails are found in wide variety of habitats, from terrestrial, freshwater to marine. They inhabit various habitats ranging from High Mountain, deserts and rainforest. From the tropics to high attitude snails are virtually in different habitats. Many snails are benthic, mainly epifauna, but some are planktonic in nature (Okafor, 2009).

1.4.1 AQUATIC SNAILS

Snails are widely distributed across aquatic ecosystems, inhabiting both freshwater and marine environments. Their abundance and distribution are influenced by a range of ecological factors. In freshwater habitats, snail populations are strongly affected by temperature, food availability, microflora abundance, dissolved oxygen content, sunlight, and the presence of aquatic weeds (Hosea *et al*., 1998). They occur in a variety of freshwater environments such as rivers, lakes, ponds, streams, irrigation channels, aqueducts, borrow pits, flooded areas, and marshes. These habitats range from small stagnant pools to large flowing rivers, with conditions varying across tropical forests, arid zones, and different altitudes. Freshwater snails thrive best at water temperatures between 20–30 °C and are typically associated with shallow, still, or slow-moving waters. They prefer environments with moderate organic content, low turbidity, muddy substrates rich in organic matter, aquatic vegetation, and abundant microfloral. Their tolerance extends across pH values of 5.8 to 9.0 (Barbosa, 1968). Examples of aquatic snails include *Pila ovata*, *Lanistes varicus*, *Melanoides tuberculata*, *Radix* sp, *Oncomelania quadrasi* as presented in (Plate 1.2).

Marine snails, on the other hand, inhabit diverse environments such as the deep sea, intertidal zones, and coral reefs. Their distribution is shaped largely by water salinity, quality, and substrate type (Strong *et al*., 2008). Ecologically, snails play a vital role in aquatic food webs. They contribute to nutrient cycling and serve as a food source for other aquatic organisms. Most species are herbivores or detritivores, feeding on algae, fungi, and bacteria, while a few are carnivorous. They are able to consume tough plant matter and algae through the action of their radula, a specialized structure used for grasping and cutting food (Okafor, 2009).

Plate 1.2: Image of different species of aquatic snails

(Source: Logronio *et al.,* 2020)

1.4.2 TERRESTRIAL SNAILS

In the terrestrial ecosystem, land snails are mainly found in wet and damp areas (Caron *et al.,* 2014). The wet and moist areas serve as a source of refuge for snails' species intolerant to drought, especially during dry season (Prior, 1985).

Anna (2005) reported that sunlight and moisture content are major factor that influence their distribution and abundance in dry habitats. However, other ecological factors that can impact their abundance include herb cover, plant species, habitat humidity and the slope aspect of soil.

Terrestrial snails (Plate 1.3) are found in habitat that provides moisture such as old fogs, under large stones, decaying barks of trees, on wet lichen, plantain leaves, bamboo and decaying leaves (Altaf and Qureshi, 2017). Although, terrestrial snails are mainly found in damp, humid and cool places, a number of pulmonary snail species live in arid, semi-arid and Mediterranean regions (Mizrahi *et al*., 2010). Some snails' species survive severe environmental condition by moving quickly into deep soil layers with moisture content (Hawkins *et al.,* 1997). They consume litters in forest floor, assisting in nutrient cycling.

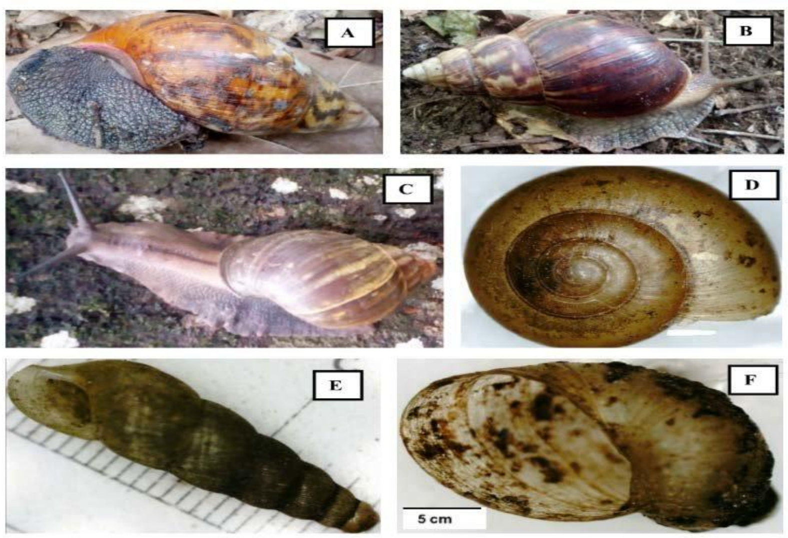

Plate 1.3a-f: Examples of Some Terrestrial Snails

[A, *Achatina achatina*; B, *A. fulica*; C, *Archachatina ventricosa*;

D, *Saphtia lamtoensi*; E, *Striosubulina striatella*; F, Quickia *concise*]

(Source: Pokou *et al*., 2021)

1.5 RELEVANCE OF SNAILS

Snails are soft-bodied invertebrates protected by a hard-calcareous shell that encloses their visceral tissues and part of the muscular foot, which in some species is edible. They are of vital importance to humans and the ecosystem, serving not only as a source of food and livelihood but also functioning as ecosystem engineers whose activities influence soil fertility, nutrient cycling, and ecological balance.

Snails serve as an important source of animal protein for many populations worldwide. Owing to their high nutritional value, snail meat is often recommended as a healthy alternative to conventional livestock protein. For example, powdered snail meat has been incorporated into complementary foods for breast-milk-weaned infants to improve dietary protein intake (Tanyitiku, 2022). Terrestrial snails such as African land snails *Archachatina marginata*, *Achatina achatina*, aquatic species like *Lanistes varicus*, *Pila ovata* are proteinous delicacy in many parts of the world. It also serves as source of livelihood to people, especially those into heliciculture for the purpose of human consumption.

Snails possess notable medicinal properties and have long been used in traditional medicine. Their mucus, particularly from *Helix aspersa* and *Eremina desertorum*, is applied in the treatment of various skin conditions. It contains bioactive compounds with anti-inflammatory and antimicrobial activities, which promote wound healing and aid in managing skin diseases. Additionally, species such as *Bellamya bengalensis* exhibit anti-inflammatory effects and have been found effective in the treatment of rheumatism (Gupta and Khanal, 2024).

Snails are also vital to the ecosystem. Their abundance and presence serve as indicators of ecosystem health and biodiversity because of their specific habitat requirements and sensitivity to environmental changes such as degradation and pollution. This makes them valuable bioindicators of habitat quality and biodiversity (Mathew, 2024). As ecosystem engineers, snails play important roles ranging from bioindicators to decomposers. They facilitate the breakdown of decaying plant material, thereby contributing to soil fertility and nutrient cycling, which in turn supports plant growth. Snails consume a wide variety of plant matter, including leaves, fruits, and fungi, and help fragment organic material into smaller particles. Their presence accelerates the decomposition of plant litter, increasing nutrient availability in the soil (Barker, 2016). Indirectly, they also influence nutrient cycling through interactions with soil microorganisms and by consuming organic matter, while their nutrient-rich excreta enhance soil fertility with elements such as nitrogen and phosphorus (Kourtev *et al*., 2002).

Although snails offer several economic benefits, they are also of medical importance, as they act as intermediate hosts for parasitic diseases that pose significant public health and veterinary concerns. Many trematodes and some nematodes rely on snails as intermediate hosts, and without them, larval development remains incomplete. Parasites such as *Schistosoma*, *Fasciola*, *Angiostrongylus*, *Paragonimus*, and *Clonorchis* utilize snails as intermediate hosts, undergoing crucial developmental stages within snail tissues before moving on to their definitive hosts.

In essence, the relevance of snails to man, animals and the environment transcends in multiple dimensions, from their role as meat protein for consumption, their medicinal value in treatment of certain skin diseases, to serving as indicators of ecosystem health and acting as intermediate hosts for the development of parasitic larval stages.

1.6 SNAILS AS INTERMEDIATE HOST OF PARASITES

In the life cycle of trematode infection, snails play an indispensable role as intermediate hosts, serving either as the first or second intermediate host depending on the parasite. Although snails are predominantly involved in trematode infections, they are also important intermediate hosts for certain nematodes such as *Angiostrongylus cantonensis* (rat lungworm). For the life cycle of *A. cantonensis* to be completed, snails must first become infected with first-stage larvae (L1), either through ingestion or penetration via the body wall or respiratory pore. Within the snail tissues, the larvae develop from the first stage to the infective third stage (L3), which is responsible for causing disease in humans (Lu *et al*., 2018). Both terrestrial and freshwater snails such as *Achatina fulica, Pomacea canaliculata,* and *Biomphalaria glabrata* have been identified as intermediate hosts. In some cases, snails serve as the sole intermediate host, as seen in *Schistosoma* spp. Infections. However, in other trematodes such as *Fasciola, Paragonimus,* and *Clonorchis* spp., snails act as the first intermediate host. For instance, in *Clonorchis siamensis*, after infection by the parasite's eggs, miracidia are released and develop into sporocysts, which later give rise to cercariae that subsequently infect freshwater fish. In contrast, trematodes such as *Paragonimus* and *Fasciola* spp. Infect snails through miracidia, which develop sequentially into mother and daughter sporocysts, rediae, and then cercariae, before invading their second intermediate hosts.

Different snail families serve as intermediate hosts for specific parasites. For example, members of the family Bithyniidae are intermediate hosts of *Clonorchis sinensis, Opisthorchis felineus,* and *O. viverrini*, which are endemic to parts of Asia and Europe including Cambodia, China, Germany, Japan, Korea, Laos, Russia, and Thailand (Guo *et al.*, 2009; Choi, 1984). Snails of the family Planorbidae act as intermediate hosts for *Fasciolopsis buski, Schistosoma haematobium, S. intercalatum*, and *S. mansoni*. Similarly, Thiaridae snails are reported to serve as intermediate hosts for *Paragonimus westermani, Clonorchis sinensis,* and *Schistosoma haematobium*, and are distributed worldwide, with major populations in Africa, Asia, Oceania, North America, and South America (Radev *et al.*, 2000; Sri-Anoon *et al.,* 2010; Kariuki *et al.,* 2004).

Most parasites require a specific snail species as an intermediate host. For instance, the life cycles of *Schistosoma japonicum* and *S. mekongi* depend on *Oncomelania hupensis* and *Neotricula aperta,* respectively. Snails of the genus *Lymnaea*, which are distributed across Africa, Asia, and the Americas, are well-known intermediate hosts of *Fasciola* spp. In Europe, *Galba truncatula* serves as the intermediate host of *Fasciola hepatica*, whereas in Africa, species such as *Lymnaea* and *Radix natalensis* act as hosts for *F. gigantica*, while *G. truncatula* hosts *F. hepatica* (Malatji *et al.,* 2019). Thus, snails play an integral role in the life cycle of a wide variety of parasites, particularly trematodes, since the completion of their development depends on snail hosts. Their distribution, abundance, and diversity are critical factors influencing the epidemiology of parasitic diseases in humans and animals (Lu *et al*., 2018). Effective snail population control through the use of molluscicides serves as a key strategy in reducing the transmission of these diseases.

Snails act as the sole intermediate hosts for parasites like *A. cantonensis* and *Schistosoma mansoni*, while serving as the first intermediate host for species such as *Clonorchis siamensis, Paragonimus westermani,* and *Fasciola* spp. Their role is indispensable, as parasite development and transmission cannot occur without them.

1.7 LIFE CYCLE OF TREMATODES

Trematode has a complex life cycle involving mollusc as the first intermediate host, some trematode requires second intermediate hosts for the completion of the life cycle (Plate 1.4). For instance, *Paragonimus westermani, Clonorchis sinensis*, and *Dicrocoelium dentriticum* uses arthropods as the second intermediate host. Trematodes generally complete a three-host life cycle beginning with a definitive host in which sexual reproduction takes place, the adult female form produces eggs that later develops into miracidia, the first free-living larval stage. These miracidia infect the first intermediate molluscan host, where asexual reproduction occurs through intramolluscan development from miracidia to sporocysts, rediae and cercariae. The cercariae then infect the second intermediate host, where they transform into metacercariae, the dormant infective stage that is transmitted when consumed by the definitive host (Esch *et al.,* 2002; Galaktionov and Dobrovolskij, 2003).

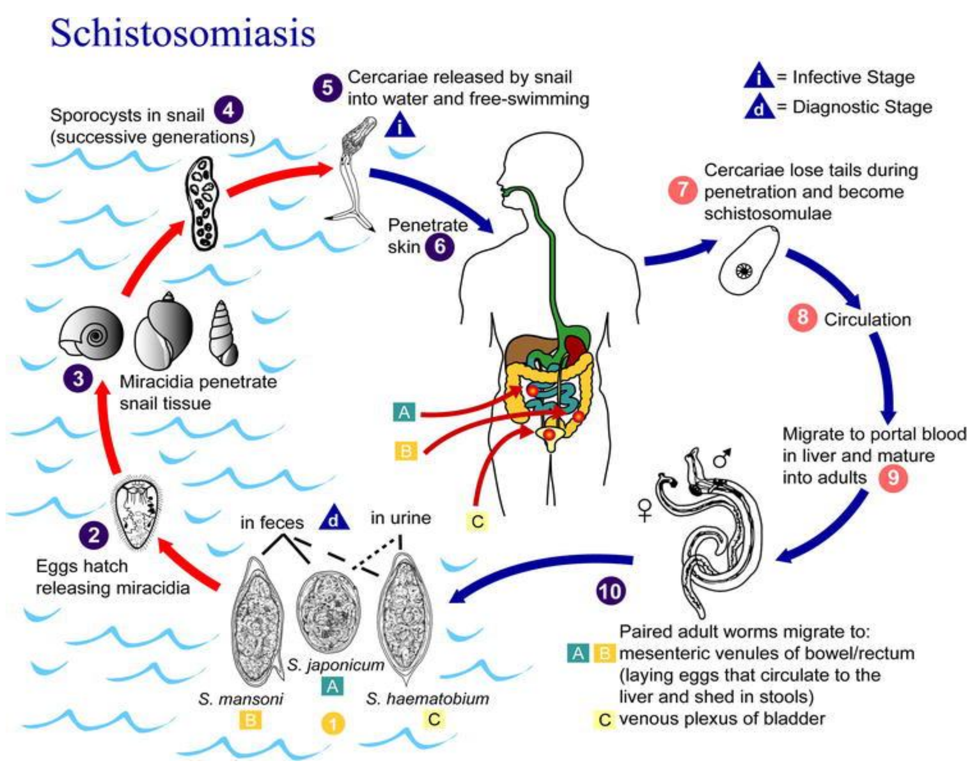

Plate 1.4: Life Cycle of Schistosome

(Source: da Silva and Moser, 2022)

1.8 LARVAL STAGES OF TREMATODE PARASITE

The life cycle of trematode is characterized by five types of larval stages; these include miracidium, sporocysts, radiae, cercariae and metacercariae.

1.8.1 EGG

Digenetic trematode eggs are operculated, with the exception of the eggs of the genus *Schistosoma.* The egg is enclosed by shell or capsule with a developing embryo inside, it is at one end of the egg the operculum is found that enables the escape of the larval stage. In many species, an egg contains a fully developed miracidium by the time it leaves the parent while in some, by the time it leaves the parent, development in embryo has only a few cleavage divisions. However, in *Heronimus mollis* miracidia hatches while still in their parent's uterus (Roberts and Janovy, 2009). The eggs are resistant with quinone-tanned shell. Egg capsule is made up of tanned protein called sclerotinin and a lipoprotein lamella (Otubanjo, 2013). The eggs are unable to resist dessication especially, for eggs that embryonate in the external environment as water or moisture is necessary for the development. In many species, eggs are hatched in water whereas other hatches when ingested by a suitable intermediate host. Hatching of the eggs are influenced by certain external factors like temperature, light and osmotic pressure, particularly for species that hatches in water, *Echinostoma caproni* eggs requires light to hatch. Different trematode species undergo distinct patterns in egg development. In *Schistosoma*, the eggs are already embryonated at the time of release and hatch immediately upon contact with water. However, the eggs of *Schistosoma* are different among the various species; *S. haematobium* has eggs with terminal spine, for *S. mansoni*, the egg has a lateral spine while *S. japonicum* has no spine as a shown in (Plate 1.5). *Paragonimus* eggs also embryonate when laid, but they must further mature in water before hatching. In contrast, *Echinostoma* eggs are unembryonated when released, requiring maturation in water prior to hatching. For *Clonorchis*, the eggs are embryonated upon release, but hatching occurs only after they are ingested by the snail host (Otubanjo, 2013; Roberts and Janovy, 2009).

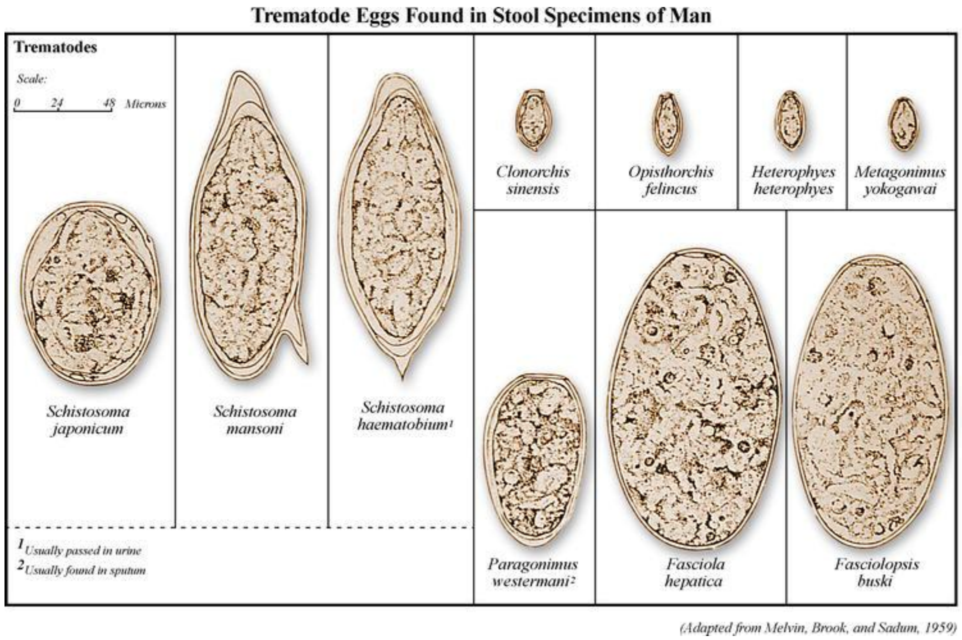

Plate 1.5: Eggs of Different Trematodes Found in Human Feces or Urine

(Source: Melvin, 2022)

1.8.2 MIRACIDIUM

A miracidium is a tiny, cone-shaped ciliated organism that is microscopic and ovoid. It is piriform, with a retractable apical papilla at the anterior end. The apical papilla has no cilia but bears five pairs of openings from glands and two pairs of sensory nerve endings. The gland ducts connect with penetration glands inside the body. They are located on either side of the large apical gland that produces proteolytic enzymes for penetration. It is the penetration glands that produces adhesive that enables the miracidium to attach itself to the mollusc during penetration. This organism has no gut, hooklets, or adhesive structures but it possesses adaptive features that enables it to live freely. Free swimming miracidia are very active and swims at a rate of about 2mm per second to find a host since their life span is very short, only a few hours. Upon contacting a suitable molluscan host, it attaches to it with the apical papilla, which actively contracts and extends in an auger like motion. It takes about 30 minutes for a miracidium to complete its penetration, cilia are shed on invasion of the tissue thereafter it metamorphosis into the sporocysts (Otubanjo, 2013b; Roberts and Janovy, 2009b).

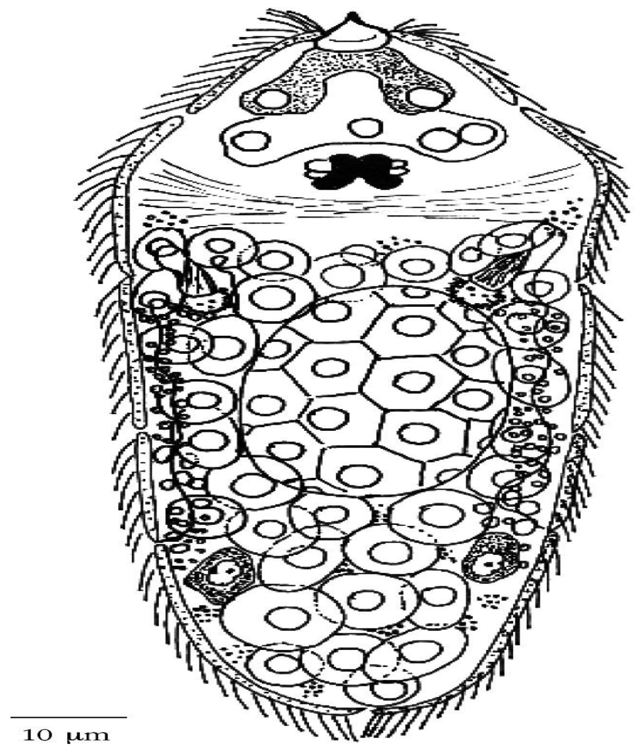

Plate 1.6: Miracidium of *Fasciola hepatica* (Linnaeus, 1758); Redrawn and Adapted from Kearn (1997)

(Source: Francisco *et al*., 2012)

1.8.3 SPOROCYST

Metamorphosis usually occurs close to the penetration site, such as the foot, antenna, or gill of the snail. The sporocyst, which lacks a mouth and digestive system, relies on absorbing nutrients directly from the host tissues, serving primarily as a structure for nurturing developing embryos. In some species, the embryos within a sporocyst may develop into additional sporocysts, referred to as daughter sporocysts, depending on the type of parasite. The sporocyst is organized into three main parts, a central body located in the snail's hepatopancreas, where embryos are produced; a broodsac that extends into the snail's head-foot region and tentacles, and a connecting tube that links the broodsac, where the embryos further develop and eventually mature into cercariae (Roberts and Janovy, 2009).

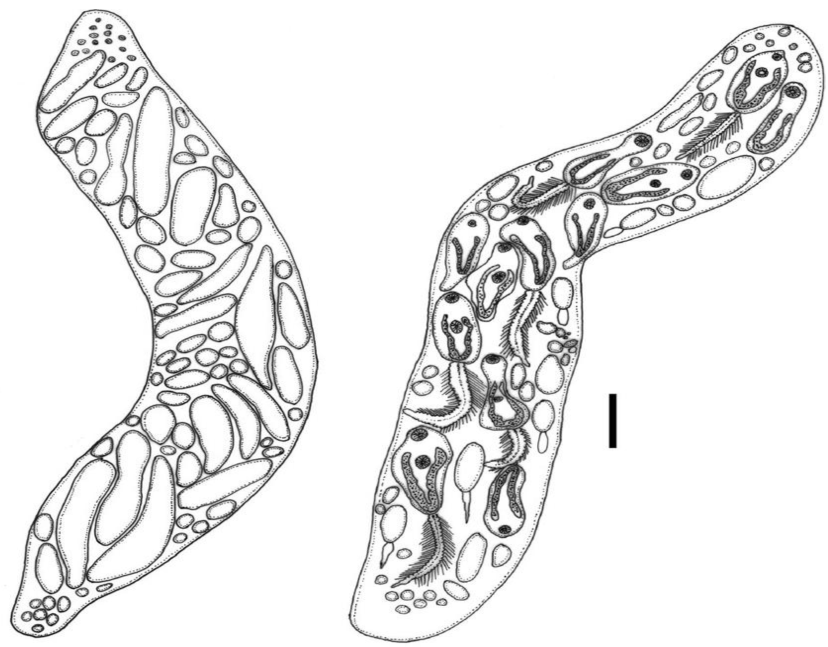

Plate 1.7: Diagram of daughter and mother Sporocyst

(Source: Gargouri *et al.*, 2008)

1.8.4 REDIA

Generations of radiae occur mainly in hepatopancreas from the sporocysts. More than one generation of radiae may be produced after the stage of sporocyst. Radia is elongated with both anterior and posterior ends tapering. It has a miniature simple sac-like, functional blind guy, a muscular pharynx with an anterior terminal mouth. Some rediae on either side of the pharynx, they possess a pair of cephalic glands which give rise to nerve fibers in all directions. Excretory system may or may not be present. It is the central portion of the rediae with germ balls that differentiate into cercariae (Otubanjo, 2013).

1.8.5 CERCARIA

This stage is the juvenile stage of trematode parasite. There are varieties of cercariae with different morphologic forms describe according to the position of the suckers, the shape and size of the tails. Most cercariae have a mouth near the anterior end, surrounded by an oral sucker, a prepharynx and forked intestine. There are different morphologic forms of cercariae and they are species specific. Their excretory system is well developed, in some types the excretory vesicles empties through one or two pores in the tail (Otubanjo, 2013; Roberts and Janovy, 2009).

The following are examples of some common types of cercariae:

a. **Xiphidiocercariae:** Are cercariae with stylet in the anterior margin of the oral sucker, non-bifurcated tail and ventral sucker at the mid region of the body surface. This type of cercariae develops in sporocyst and encysts in invertebrate, amphibians and reptiles (Frandsen and Christensen, 1984).

b. **Monostome cercariae:** Possess only the anterior sucker, with two or three eyespots, a simple tail, and adhesive organ at the posterior end with numerous cystogenous glands in the body.

c. **Amphistome cercariae:** They have two sets of suckers, the oral and posterior suckers which is the ventral sucker, eyespots and an unforked tail.

d. **Gasterostome cercariae:** They have mouth on the ventral side of the body.

e. **Distome cercariae:** This type of cercariae has two suckers, the oral and ventral suckers and a simple tail.

f. **Microcercous cercariae:** Cercariae that has a very short that is knoblike in shape.

g. **Furcocercous cercariae:** Possesses a fork-like tail and a pear shaped oral sucker. They are often the cercariae of species of the genus *Schistosoma.*

(Frandsen and Christensen, 1984; Otubanjo, 2013)

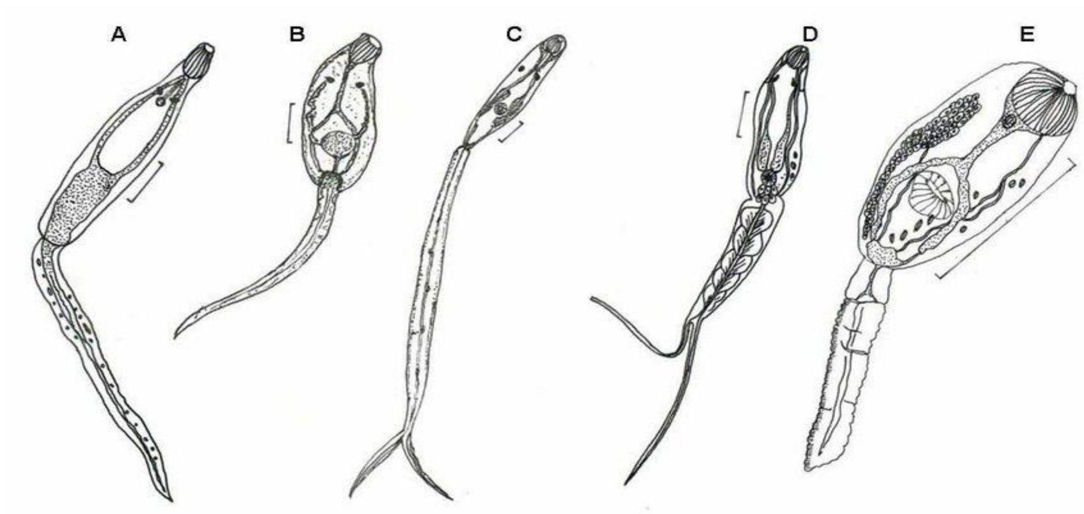

Plate 1.8: Different Types of Cercariae Found in Freshwater Snails

(A, Oculopleurolophocercous; B, Distome; C and D, Furcocercous; E, Gymnocephalous)

(Source: Jayawardena *et al*., 2010)

1.8.6 METACERCARIA

Metacercariae is an important stage in the life cycle of many digenetic trematodes (flukes). They are the encysted, infective stage that develops after the cercariae are released from the first intermediate host, usually a snail. Once released, cercariae either encyst on aquatic vegetation, in water, or within a second intermediate host such as fish, amphibians, or other invertebrates. In this form, the metacercariae are well adapted for transmission to the definitive host, where the adult parasite will eventually develop (Roberts and Janovy, 2009).

Metacercariae are usually enclosed in a cyst wall that protects them from environmental stress and host immune responses. This encysted form enables them to survive for long periods until ingested by the definitive host. Upon ingestion, excystment occurs in the digestive tract, releasing the juvenile fluke which then migrates to its target organ to mature into an adult (Toledo and Fried, 2009).

1.8.7 ADULT FORM

The adult form of trematodes, commonly referred to as flukes, are parasitic flatworms with dorso-ventrally flattened, leaf-like bodies. These bodies are covered by a tegument, which is typically equipped with scale like spines. Trematodes possess two distinct suckers: an oral sucker and a ventral sucker. The mouth leads into an oesophagus, which houses a muscular pharynx to aid in feeding. The intestine lacks a terminal opening and divides into two ceca (blind-ended pouches). Trematodes are characterized by their dorso-ventral symmetry and flat body structure. They are hermaphroditic, meaning they contain both male and female reproductive organs. The suckers serve to anchor the trematode to the host's epithelial layers in tissues such as the intestine, bile ducts, or lung parenchyma (Ortega, 2013; Waikagul *et al*., 2015).

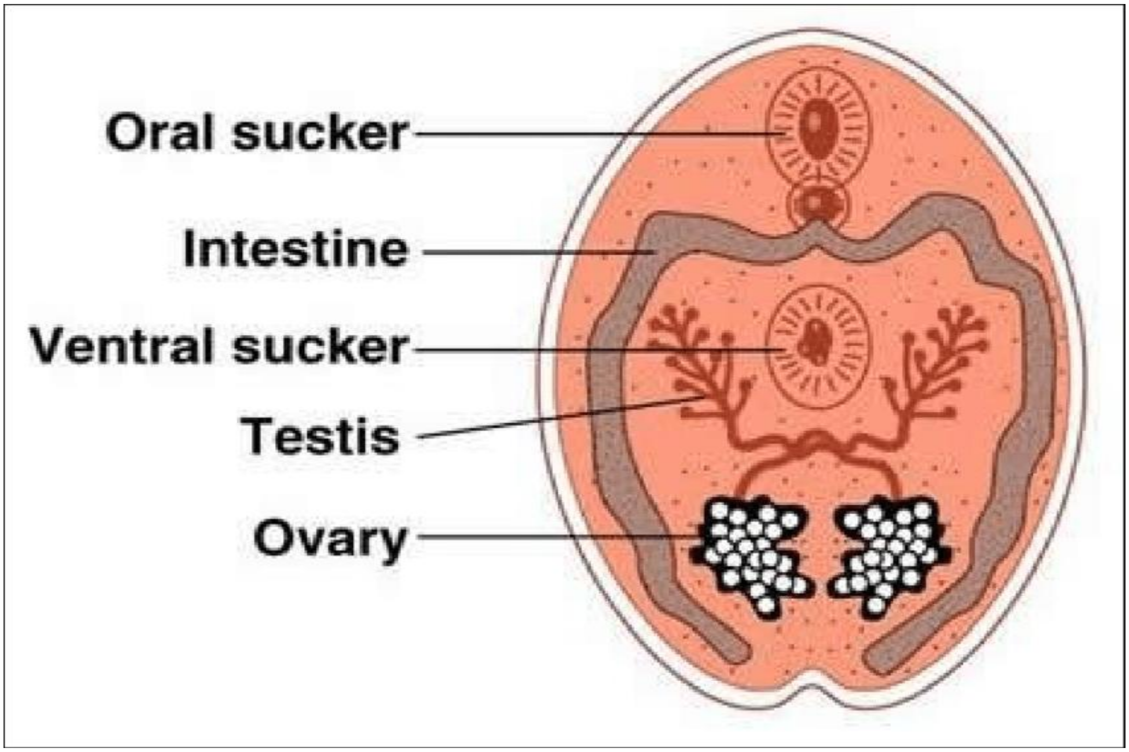

Plate 1.9: Diagram of Digenea Trematode with clear anterior and posterior suckers, intestinal cecae and genital organs in longitudinal section.

(Source: Azzal *et al.*, 2016)

1.9 JUSTIFICATION

Trematode infection in snails has contributed greatly to the underlying public health concerns of snail borne diseases. Understanding parasitic infection rates in snails and factors that facilitates infection in snails the intermediate host and man, will assist in identifying the possible solutions and control strategies for snail borne diseases. Hence, study is conducted to determine the prevalence and diversity of trematode infection and the role of snails in transmission of these parasitic infections. The findings from this study can contribute to the increasing knowledge of snail-borne parasitic diseases, trematode infection in snails while focusing on *Pila ovata*, a freshwater snail, and common in many aquatic freshwater bodies. Furthermore, information on the prevalence and distribution of trematode infection helps to provide appropriate solutions to communities and the public in order to reduce the associated risk of snail borne diseases between humans and animals. Findings from the studying of snail population, rates of infection, types of trematode cercariae, and environmental factors that influence them can help to identify the source of transmission and provide measures that minimize human and animals' exposure to infected snails.

1.10 AIMS AND OBJECTIVES

The aim of the study was to investigate the prevalence and intensity of trematode infections in *Pila ovata* collected from Iguobo Community in Ovia North-East Local Government Area, Edo State, Nigeria.

The objectives of the study were to:

1. determine the prevalence and intensity of trematode infecting *Pila ovata* from Iguobo Community, in Ovia North-East Local Government Area, Edo State, Nigeria; and
2. identify the type of trematode infecting *Pila ovata* from the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

Snails have drawn significant scientific attention not only for their ecological diversity and economic value but also due to their crucial role as intermediate hosts in the transmission of three major classes of helminths: trematodes, nematodes, and cestodes (Chakraborty and Joy, 2020; Lopatek *et al.,* 2022). Globally, many public health diseases are caused by parasitic organisms, and a substantial proportion of these are snail-borne trematode infections, which pose serious health and veterinary concerns (Gaye *et al.,* 2024). Hence, the study of snail populations is vital for understanding and controlling the spread of these parasitic diseases.

2.1 GLOBAL PARASITES INFECTION IN SNAILS

2.1.1 FRESHWATER SNAILS

Richard and Merritt (1967) carried an investigation on *Angiostrongylus cantonensis* infection in 20 freshwater snails of 26 species from New Orleans, Louisiana. The first larval stage of *A. cantonensis* recovered from rat faeces were introduced into the snails where they developed into the third stage larva. The authors noted that in *Biomphalaria glabrata* the load of larvae were about 2000 per snails with some larvae surviving up to a year. Although, the first-stage larvae of *A. cantonensis* were susceptible to drying, but they were able to survive up to three weeks in freshwater and remain infective in snails after two weeks in both freshwater and sea water. Furthermore, through ingestion *B. glabrata* was constantly infected with infected rat faeces, in which the first-stage larvae were observed penetrating the intestinal wall of the snails. Third-stage larvae were also susceptible to desiccation, but survived up to 11 days in *B. glabrata* kept out of water, and they remained viable for four days after the death of the snails. Richard and Merritt (1967) noted that the presence of the *A. cantonensis* in the snails was as a result of ingestion of infected rat faeces. Findings from the study suggested that freshwater snails can potentially become intermediate host of the parasite.

Chao *et al*. (1993) studied the prevalence of larval helminth in freshwater snails of the Kinmen Island, Thaiwan, and Republic of China. A total of 726 freshwater snails were examined for helminth infection, *Bithynia fuchsiana, Radix auricularia swinhoei,* and *Cipangopaludina chinensis* were found to have high infection prevalence with echinostome metacercariae, while *Austropeplea ollula* and *Gyraulus spirillus* had less infection rates. The authors reported natural infection with rat lungworm *Parastrongylus catonensis* of the infective third stage larvae in *Ampullarius canaliculatu* (4.9%), *Sinotaia quadrata* (14.2%), *Hippeutis umbilicalis contor* (1.4%), and *Gyraulus spirillus* (2.3%). Additional cercarial forms, such as *Centrocestus formosanus, Haplorchis pumilio,* and a xiphidiocercaria, were recovered from *Thiara tuberculata.* Findings from the study highlighted the significant role of freshwater snails in Kinmen as intermediate and paratenic hosts for helminths of both medical and veterinary importance.

Farahnak *et al.* (2006) investigated the nematode parasites of *Ballamya bengalensis* in Khouzestan province, Southwest Iran. They examined 1143 *Bellamya* snails collected from Aboudasht, Chogha Mish regions and fish ponds in central areas of Khouzestan province for the presence of nematodes. Twenty-seven (2.36%) snails of the total snails examined were found to be infected with *Oionchus* nematode. The authors then conducted an investigation for the fish disease caused by *Oionchus* nematode since some of the infected snails were collected from fish pond, where some of the fishes had eye infection. Infected *Bellamya* snails were placed in an aquarium containing healthy *Gambosia affinis*, the fishes were examined daily for notable eye injuries for one month. However, after 20-30 days post infection in the aquarium, cloudy appearance of cornea was observed in the eyes of the fishes. The authors reported that *Bellamya* snail infected with *Oionchus* nematode could pose health risk to fish and human.

Komalamistra *et al.* (2009) conducted an experimental study on *Pila ampullacea* and *Pomacea canaliculata* for their possibility as paratenic host in Bangkok, Thailand. The snails were infected with the third stage larvae (L3) of the nematode *Gnathostoma spinigerum*, which was found to encapsulate the tissue of the snail's foot and its internal organs. Infection rates with L3 larvae were high in both snail species, with *P. ampullacea* showing 80% on day 7 and 14, declining to 60% on day 30 and 50% on day 60. Similarly, *P. canaliculata* exhibited 80% on day 7 and 14, 60% on day 30, and 75% on day 60. Transfer experiments confirmed that both species can serve as paratenic hosts, as encapsulated but motile L3 were recovered from the tissues of the snails, with morphology identical to L3 obtained from eels. Results from the study revealed that *Pila ampullacea* and *Pomacea canaliculata* can be suitable paratenic host of the third stage larvae of the nematode *Gnathostoma spinigerum*. The parasite is the causative agent of Gnathostomiasis in humans. The study uncovered the first evidence that not only vertebrate but invertebrates like snails can be paratenic host of the parasite.

Sri-Aroon *et al.* (2010) carried an investigation on freshwater and brackish water snails for trematode infection in southern Thailand. Out of the 13,335 snails examined, 7,991 were freshwater snails and 5,344 were brackish water snails including 12 land snails, *Achatina fulica,* family Achatinidae. The fresh-water snails were *Pomacea canaliculata, Pila angelica, P. gracilis, P. polita, Filopaludina martensi, F. polygramma, Melanoides tuberculata, Indoplanorbis exustus, Radix rubiginosa, Helicorbis umbilicalis* and *Gyraulus convexiusculus* while the brackish water snails were *Cerithidea cingulata, C. djadjarensis, C. alata, Sermyla riqueti,* and *Achatina fulica.* Parasitological investigation in the snails revealed infection in *Melanoides tuberculata,* *Filopaludina programma* and *Indoplanorbis exustus.* Five types of cercariae were recovered from the infected snails namely; Xiphidio, Microcercous, Furcocercous, Echinostome, and a cercaria without eyespots but a tail with hair. Similarly, the authors reported infection in three species of brackish water snails, *Cerithidea cingulata*, *C. djadjariensis* and *C. alata* positive with six types of cercariae. Cercariae that are cystogenous with eyespot and collar spines, cystogenous without eyespots or collar spines, cercariae with excretory granules in branches of excretory tubes with collar spines, cercariae with excretory granules in branches of excretory tubes without collar spines or tail fins, cercariae of the small stylet type, and cercariae with eyespots, large excretory bladder and a ventral sucker. However, some radiae of trematodes were also present in *C. cinculata* and *C. djadjariensis*.

McKoy *et al.* (2011) investigated the association between trematode larval and annelid in the freshwater snail *Thiara granifera* from Mona reservoir in Jamaica. A total of 3,575 snails were analyzed for trematode infection, two trematodes were recovered: a monostomate that belonged to the family Noticotylidae and the other *Philophthalmus* sp. (Philophthalmidae). The overall prevalence of infection of the noticotylid and *Philophthalmus* sp. was 15.3% and 1.3% respectively. The authors reported fecundity of 78.5% from the total of snails examined. However, only 3.0% of the trematode infected snails were fecund in comparison to the 90.3% uninfected snails. *Chaetogaster l. limnaei* was also isolated from the mantle cavity and outer body of *T. granifera* with an overall prevalence of (2.3%). McKoy *et al.* (2011) noted that snails uninfected with trematode cercaria but harbouring *C. l. limnaei* shows no adverse physical effect in their tissue. They reported that Notocotylid larvae occurred in 32.5% of the snails that are harbouring *C. l. limnaei*, compared with 14.9% of snails without the annelid. Similarly, only 1 snail harboured both Philophthalmus sp. and *C. l. limnaei*, while 47 (1.6%) of 2,972 snails that neither had *C. l. limnaei* nor noticotylids were infected with *Philophthalmus* sp. The authors concluded that there was no predation on the parasites by *C. l. limnaei* and the study it was the first to report ectosymbiotic association of annelid, notocotylid and *Philophthalmus* sp in *T. granifera* in Jamaica.

Qureshi *et al*. (2015) investigated trematode infection in freshwater snails of Punjab, Pakistan. The study was conducted for a period of one year on a monthly basis of which a total of 23,922 snails, comprising eight genera, were collected from six water bodies and among these, prevalence of the genus *Indoplanorbis* was found highest (23.4%), followed by *Bulinus* (21.5%), *Oncomelonia* (15.4%), *Lymnaea* (14.9%), *Bellamya* (10.6%), *Gyraulus* (7.6%), *Melanoides* (3.8%) and *Physa* (2.8%). Overall prevalence of trematode infection was 14.8%. Four morphologically distinct types of cercariae were identified, Schistosome furcocercous cercariae, fasciola cercariae, xiphidiocercariae and Amphistome. Findings from the research reported *Lymnaea* sp. to have the highest infection, harbouring three different cercariae, Amphistome (67.07%), Xiphidiocercariae (0.82%) and *Fasciolia* sp. cercariae [(Gymnocephalous) 22.11%]. No cercaria was recovered from *Oncomelania, Bellamya, Melanoides, Gyraulus* and *Physa.* The authors also noted the presence of amphistome cercariaae in *Indoplanorbis* and *Bulinus*, while *Indoplanorbis* was also harbouring *Schistosoma* cercariae (Furcocercous). The study highlighted preliminary information about the distribution and prevalence of *Fasciola* and other larval trematode species in snail population of some areas of Punjab which can be helpful to develop control strategies for snail-borne parasites of medical and veterinary importance.

Kulsantiwong *et al. (*2015) conducted an extensive survey on freshwater snails of the family Bithyniidae to investigate trematode infections. The study, which spanned from October 2008 to July 2009, involved the collection of 5,492 snails from 17 different locations across Thailand.

The snails were classified into 10 subspecies, all within the Bithyniidae family (*Bithynia funiculata, Gabbia pygmaea, Bithynia siamensis goniomphalos, Wattebledia siamensis, Wattebledia crosseana, Bithynia siamensis siamensis, Hydrobioides nassa, Gabbia wykoffi, Wattebledia baschi* and *Gabbia erawanensis*). An overall trematode infection rate of 3.15% was recorded. Six distinct cercarial types were identified: amartae*,* monostome*,* mutabile*, Opisthorchis viverrini,* virgulate, and an unknown type. Cercarial emergence observed in 173 snails (3.15%) were as followed, highest infection rate was found in *B. s. goniomphalos* (5.60%), followed by *W. siamensis* (5.19%), *W. crosseana* (3.85%), *G. wykoffi* (1.69%), and *B. s. siamensis* (1.65%). In *B. s. goniomphalos*, the detected cercariae comprised amartae (0.55%), mutabile (0.74%), *Opisthorchis viverrini* (1.07%), virgulate (2.87%), and an unidentified type (0.37%). *B. s. siamensis* exclusively hosted monostome (1.10%) and virgulate (0.55%) cercariae. Meanwhile, *W. crosseana* and *W. siamensis* were infected only with virgulate cercariae (3.85% and 5.19%, respectively), whereas *G. wykoffi* carried solely unidentified cercariae (1.69%). The study marked the first recorded instance of trematode infections in *Gabbia wykoffi, Wattebledia crosseana,* and *Wattebledia siamensis* within Thailand, expanding the known host range of these trematodes.

Mohammad K. Mohammad (2015) carried out a parasitological study on freshwater snails in Central Iraq. Seven snail species namely, *Melanopsis praemorsa, Melanoides tuberculata, Radix sp., Bellamya bengalensis, Physella acuta, Theodoxus jordani* and *Gyraulus huwaizahensis* were investigated for natural parasitic infection. The study was a monthly investigation that range from January to December, 2014 providing a total of 1793 snails species examined by the author. The parasite recovered from the study were *Chaetogaster limnaei* (Oligochaeta) and oxyurid nematode from *Bellamya bengalensisa,* Furcocercous cercaria, Echinostomous cercaria, Xiphidiocercous cercaria and Parapleurolophocercous cercaria. Parasitic infection rates varied widely among species, with *M. praemorsa* exhibiting the highest infection prevalence (57.4%), followed by *M. tuberculata* (32.9%) and Radix sp. (16.4%). Other species such as *Theodoxus jordani* and *Gyraulus huwaizahensis* were not infected. The study provided a monthly documented of parasitic infection rates in snails species in Central Iraq.

Mereta *et al.* (2019) studied trematode infection in snails of Omo Give River basin, Southwest Ethiopia. The study reported the investigation of 3,107 snails from 130 observation sites in lakes, wetlands, rivers, reservoirs, and irrigation canals collected during the dry season from March to May (2016). The examined snail species includes *Biomphalaria pfefferi, Bi. sudanica, Bulinus globosus, B. forskalli, Lymnaea natalensis,* and *L. truncatula. Bi. pfefferi* accounted for 85% of the infection representing 66% of the total snail collection harbouring seven morphologically distinct cercariae. The overall trematode infection (cercariae) prevalence as reported by the authors was (3.6%), of which eight morphologically different cercariae were detected which are echinostome cercariae, brevifurcate apharyngeate distome cercariae, amphistome cercariae, brevifurcate apharyngeate monostome cercariae, xiphidiocercariae, longifurcate apharyngeate distome cercariae, strigea cercariae, and an unidentified cercariae. Brevifurcate apharyngeate distome cercariae and echinstome cercariae were the most abundant cercariae with record of 36% and 34% infection respectively. However, the study revealed that echinostome and xiphidiocercariae was isolated from *Lymnaea natalensis*, while two *Bi. Pfeifferi* were infected with both echinostome and amphistome cercariae. Similarly, Mohammed *et al* (2016) also reported double infection in their research in Khartoum State, Sudan in which *Bulinus truncatus* and *Cleopatra bulinoides* had double infection. The authors conclude from their findings that besides Schistosome other trematode larval stage can use the same intermediate host as that of

Schistosoma, in that, the trematode cercariae recovered from the snail species which are schistosoma intermediate host were not schistosome cercariae.

Rabone *et al.* (2019) conducted a four and half year longitudinal study July 2011 to January 2016 in the Niger River Valley, analyzing *Bulinus* spp., *Biomphalaria pfeifferi,* and *Radix natalensis* intermediate hosts for *Schistosoma* and *Fasciola* parasites. Of the 59,674 snails collected from ponds and irrigation canals, infection rates varied by species; *B. pfeifferi* (3.45%), *B. truncatus* (0.8%), and *B. forskalii* (0.2%). Findings from the study showed that the prevalence of *Schistosoma* spp. in *Bulinus truncatus* was higher in ponds suggesting a higher transmission potential, however most were *Schistosoma bovis* which can be attributed to the water contact of cattle in the ponds. The study identified *Bi. pfeifferi* as a key concern due to its higher infection prevalence, suggesting a potential risk for *Schistosoma mansoni* transmission. Additionally, seasonal and habitat variations significantly influenced snail abundance and parasite dynamics as more specimen were collected in the dry season which was in correspondence to the transmission of *Schistosoma*.

In Bangladesh, Khanum *et al.* (2020) studied helminth infection in aquatic snails around Dhaka, Khulna and Kishoreganj regions. The study spanned from July 2011 to June 2013, in which three snail genera (*Bellamya, Pila,* and *Brotia)* collected from pond ecosystems were investigated for parasitic infection from twenty three locations which include eleven from Dhaka, six locations from Khulna and six from Kishoreganj. Parasites isolated include two cestodes species (*Polypocephalus* sp. and *Trilocularia* sp.), a tubellarian *(Paravortex* sp.) and one pentastomida (Angiostrongylus sp.) from *Pila globosa*. In the study, the authors classified and described the parasites recovered on the basis of body shape or type, presence of scolex, type of scolex, presence of hooks and suckers; they reported the recovered parasites as a new record from snails in Bangladesh.

Outa *et al.* (2020) investigated the occurrence of digenean trematode larvae in snails from the Kenyan part of Lake Victoria. A total of 1,145 snail specimens, belonging to 13 species, were analyzed, of which 13.0% were infected with digenean larvae. Overall, seven snail species were found to be infected, while five showed no infection. The prevalence of infection among the positive species varied, with *Melanoides tuberculata* showing the highest rate (64.5%), followed by Pila ovata (15.4%), *Radix natalensis* (9.5%), *Bulinus ugandae* (9.1%), *Bellamya unicolor* (8.9%), *Biomphalaria pfeifferi* (7.3%), and *Biomphalaria sudanica* (4.4%). In total, 17 species of digenean trematodes were identified, including *Haplorchis pumilio, Thapariella prudhoei, Nudacotyle* sp., *Renicola* sp., and *Bolbophorus* sp., which were reported for the first time in the region. Parasite and host associations were also recorded. *B. ugandae* hosted furcocercaria, *Bolbophorus* sp., and ornate xiphidiocercariae, while *R. natalensis* carried *Plagiorchis* sp. and *Fasciola gigantica*. Double infections were noted in *M. tuberculata*, with combinations such as *Renicola* sp. and *H. pumilio*, as well as *H. pumilio* and Loxogenoides bicolor. *Pila ovata* harbored *T. prudhoei* metacercariae along with three Echinostome species, whereas *B. unicolor* was infected with virgulate xiphidiocercaria, *Acanthatrium hitaense*, and armatae xiphidiocercaria. The dominant parasite overall was *T. prudhoei* (metacercaria), and this was only the second report of the species in Africa. Additionally, an unknown xiphidiocercaria was recovered from *P. ovata*, sharing similarities with *Haematoloechus dimilis* but differing in body size and stylet length, and did not match any available records. The authors concluded that snail populations in areas with minimal direct anthropogenic disturbance showed the highest prevalence and diversity of digenean species, highlighting the role of environmental conditions in influencing parasite occurrence.

Krupenko *et al.* (2020) investigated *Sulcospira daulzenbergiana*, a freshwater snail from a stream in Cát Tiên National Park, South Vietnam. Forty-one snails were examined for digenean larvae, and infection was detected in a single snail harboring daughter sporocysts containing an unidentified xiphidiocercaria. The cercariae were reported as unusual, although the presence of a stylet suggested affinity with Xiphidiata, their large body size and I-shaped excretory bladder set them apart from known xiphidiocercariae. The authors named this form *Cercaria cattieni 1* and based on phylogenetic analysis inferred that it belongs to the larval stage of Pachypsolidae. This study represented the first documentation of this new type of xiphidiocercaria

Rekha *et al*. (2021) investigated freshwater water snails in ten different ponds of Madurai district and Tamil in South India. They examined a total of 1250 snails for their diversity and patterns of distribution of *Schistosoma* belonging to six species. Of the snails diversity assessed, *Bellamyia dissimilis* had the highest percentage (60%) of individuals followed by *Pila globosa* (18%), *Lymnaea luteola* (8%), *Paludomas tranchauricus* (7%), *Gyralus convexiusculus* (5%) and *Indoplanorbis exuxtus* (2%). The authors reported cercariae infection in four snail species, of which *Lymnaea* species has the highest prevalence of 45%, and *Bellamya dissimilis* is 33%, two snails, *Gyralus convexiusculus* and *Pila globosa* had no cercariae infection. The authors reported to identify *Schistosoma japonicium* among the four species of snails infected with cercariae. The findings suggest that maintaining the natural water bodies such as marshes and ponds and regulating human settlement in areas of schistosome infection are efficient measures to control schistosomiasis.

A parasitological Investigation was conducted by Abd El-Hafeez *et al.* (2021) in Al-fayoum governorates in Egypt for the presence of parasitic infective stage in aquatic snails. The survey took place seasonally from spring 2018 to winter 2019 in eight different watercourses of the rural districts at Al-fayoum governorates. A total of 8,799 snails belonging to eleven species (*Biomphalaria alexandrina, Bulinus truncatus, Lymnaea natalensis, Melanoides tuberculata, Lanistes carinatus, Cleopatra bulimoides, Pila ovata*, *Theodoxus niloticus, Bellamya unicolor, Pseudosuccinea columella,* and *Physa acuta*) were examined. Trematode infections were detected in five of these species. The study recorded three cercarial types *Schistosoma mansoni*, *Schistosoma haematobium*, and *Echinostoma liel* emerging from *B. alexandrina* and *B*. *truncatus*. Among the snail species, *B. alexandrina*, the vector of *S. mansoni*, exhibited the highest distribution (91.77%) and an infection rate of 44.69%, whereas *B. truncatus* showed a much lower distribution (1.8%) but with a 21.38% infection rate. The authors also noted that snail abundance varied with both habitat type and seasonal changes, with the greatest numbers recorded in spring 2018 when the mean water temperature was 22.9°C and the lowest counts in winter 2019, when the mean water temperature dropped to 14.4°C. The study revealed that Fayoum water canals harbours many freshwater snails of which some are infected with trematode cercariae of medical importance.

Tolley-Jordan *et al.* (2022) carried out a parasitological survey of *Melanoides tuberculata* in Florida, USA. A total of 264 snails were collected from 25 water bodies, of which six sites showed trematode infections. Thirty-six snails were infected, yielding five distinct trematode morphotypes belonging to the families Heterophyidae (*Haplorchis* sp. and *Centrocestus formosanus*), Philophthalmidae, Renicolidae, and Lecithodendriidae. The parasites identified included the gill fluke *Centrocestus formosanus, Haplorchis pumilio, Philophthalmus* sp. (eye fluke), an unidentified kidney fluke (*Renicolidae* sp.), and an unidentified bat fluke (*Lecithodendriidae* sp.). The study reported *Renicolidae* sp. and *Lecithodendriidae* sp. As new records for North America, while all trematodes detected except *C. formosanus* were recorded for the first time in Florida. These findings emphasizes on the importance of monitoring invasive snails such as *M. tuberculata* and their associated parasites.

Sinare *et al.* (2023) studied the ecology of snail's parasites in central Plateau region of Burkina faso. Out of 936 snails examined, belonging to four families, six genera, and eight species (*Cleopatra bulimoides, Cleopatra* sp., *Melanoides tuberculata, Biomphalaria pfeifferi, Bulinus jousseaumei, Lanistes ovum, Lanistes lybicus*, and *Bellamya unicolor*), an overall infection rate of 6.6% was recorded. A total of 705 parasites were identified, consisting of 568 trematodes and 137 annelids. The parasites identified includes *Lecithodendrium* sp., *Haematoloechus* sp., *Apatemon* sp.1, *Apatemon* sp.2, *Apatemon* sp.3, *Acaudate xiphidiocercaria* sp.1, *Acaudate xiphidiocercaria* sp.2, *Aporocotyld* sp.1, *Aporocotyld* sp.2, *Plagiorchioid* sp., *Tubifex* sp., Furcocercaria 1, and Cercariae 1. Parasites displayed tissue-specific distribution, with most species located in the foot muscle. *Lecithodendrium* sp., *Apatemon* sp.1, *Apatemon* sp.2, *Acaudate xiphidiocercaria* sp.1 and sp.2, as well as *Aporocotyld* sp.1 and sp.2 were found in the foot muscle, while annelids were restricted to the digestive tract. The hepatopancreas harbored *Lecithodendrium* sp., *Haematoloechus* sp., and *Apatemon* sp. 2. However, only *Lecithodendrium* sp. and *Apatemon* sp. 2 occurred in both the foot muscle and hepatopancreas. According to Sinare *et al.* (2023), *Melanoides tuberculata* was the most abundant species (23.8%), though it showed no infection, similar to *Bulinus jousseaumei* and *Biomphalaria pfeifferi.* The study also noted that *Tubifex* occurred consistently throughout the survey.

Rachprakhon and Purivirojkul (2024) investigated freshwater snails in Bangkok, Thailand for trematode infection. Total snails collection examined in the study was 29,240 from 24 species, collected from 35 sites across administrative zones in the Bangkok Metropolitan Region (BMR) canal network which spanned from January 2018 to October 2019. Of the all the snails examined for trematode infection, 1,275 snails from 12 species were infected, leading to an overall prevalence of 4.3%. The study inferred that *Bithynia siamensis siamensis* which was the second most prevalent snail species with the greatest cercarial diversity of 11 morphotype and 15 distinct types, however *Melanoides tuberculata* showed the highest cercarial infection rate (9.9%) among the 24 snail's species examined. The authors reported high infection prevalence of 5.9% in the wet season and 2.4% during the dry season. Trematode cercariae recovered were a total of 37 morphological distinct cercariae within 15 morphotype which includes mutabile cercariae, vivax cercariae, dichotoma cercaria, clinostomatoid cercariae, liphocercous apharyngeate cercariae, brevifurcate apharyngeate cercariae, cystophorus cercaria, virgulate xiphidiocercaria, ubiquita Xiphidiocercaria, armatae xiphidiocercariae, monostome cercaria, echinostome cercariae, megalurous cercaria, pleurolophocercous cercariae and parapleurolophocercous cercariae. Among the 15 cercarial morphotype detected by the authors, armatae xiphidiocercariae was the most prevalent (1.8%) with the greatest cercarial diversity of 8 distinct type. The study reported the first instance of Gymophallid digenean cercarial morphotype of marine trematodes in four freshwater snails' species *Filopaludina martensi \martensi, Filopaludina sumatrensis polygramma Bithynia siamensis siamensis*, and *Wattebledia siamensis* in Thailand with infection prevalence of 0.1%. It was the first to document Gymophallid larval fluke identified to be dichotoma cercariae as freshwater snail intermediate host.

In the Democratic Republic of Congo, Balgawa *et al.* (2024) conducted a study to investigate the distribution of freshwater mollusks in Lake Kivu, covering a period from January to December 2019. A total of 1,331 freshwater snails, representing six families and nineteen species, were collected. Among these, *Biomphalaria pfeifferi* exhibited the highest infection rate, with 50.8% of the specimens found to be infected. Importantly, *Schistosoma mansoni* was identified in *Bi. pfeifferi*, indicating its role as a key intermediate host. The study emphasized the need for further research on the prevalence of trematode infections among local populations surrounding Lake Kivu, as the limited data on snail species distribution hinders a full understanding of the transmission risk of waterborne parasitic diseases in the region.

Aligolzadeh Kenarsari *et al.* (2024) investigated the prevalence of cercariae infection in freshwater snails from the Lymnaeidae and Physidae families in Guilan province, northern Iran. The study spanned for duration of one year across 117 regions in Guilan province. A total of 39,486 snails of three species were investigated in which, 19,726 were *Lymnaea auricularia* (49.96%), 4,911 *Lymnaea palustris* (12.44%) and 14,849 were *Physa acuta* (37.6%). An overall trematode cercariae infection prevalence of 2.36% was recorded in the study, with 3.65% infection rate in *Lymnaea auricularia*, 4.29% in *Lymnaea palustris* and no cercariae infection in *Physa acuta.* Cercariae recovered were identified from the groups of Xiphidiocercariae, Gymnocephalous, Echinostome, Lophocercous and Furcocerous. However, the prevalence of *Lymnaea auricularia* with Xiphidiocercariae was 1.58%; Gymnocephalous, 0.04%; Echinostome, 1.28%; with Lophocercous, 0.32%; and Furcocerous, 0.43%. While in *Lymnaea palustris*, xiphidiocercariae was 1.11%; Echinostome, 1.39%; and Furcocerous, 1.79%. The study further revealed that water temperature and pH negatively influenced cercarial prevalence, while salinity and electrical conductivity were positively associated with snail abundance. Overall, the findings highlight that physicochemical characteristics of water play a significant role in snail abundance and their infection rates with cercariae.

2.1.2 TERRESTRIAL SNAILS

In Thailand, Viyada Seehabutr (2005) investigated the presence of nematodes in the alimentary tracts of Giant African Snails (*Achatina fulica*). A total of 200 snails were assessed, of which nematode was recovered from the alimentary tract. The author identified the nematode to be *Rhabditis* sp., a free-living nematode. Both the male and female were observed and measured with equal body sizes of about 571 µm in length and 27 µm in width. The study revealed that Rhabditis sp. has also been reported in the intestinal tracts of several terrestrial gastropods, including *Hemiplecta distincta* and *Parmarion* sp. Viyada Seehabutr (2005) concluded that *Rhabditis* sp. in *A. fulica* was an accidental parasite because the infected snail was not damaged by the round worm.

Valente *et al*. (2016) studied nematodes from *Achatina fulica* in northeast of Argentina. A total of 373 snails were examined for infection, parasites isolated are cysts of nematodes containing the third stage larvae (L3) of *Strongyluris* sp. Found in the mantle cavity. The overall prevalence of infection in the snails was 23.0%, as 87 snails were infected with the cyst. The authors noted that the genus *Strongyluris* are intestinal parasites of reptiles and amphibians describe to have a monoxenous life cycle but (Barreto-Lima and Alves dos Anjos, 2014) reported that *S. oscari* have a heteroxenous life cycle using arthropods as the intermediate host. Valente et al (2016) suggested that the presence of *Strongyluris* sp. Larvae in *Achatina fulica* could be as a result of the snail acting as intermediate or paratenic host of the parasite. The study further noted that smaller-sized snails showed no infections, suggesting a minimum size threshold for susceptibility. Additionally, no other nematode larval stages were detected.

A study was conducted by Oliveira and Santos (2019) on *Achatina fulica* in Bowdich. A bimonthly study that took place from 2007, 2008, 2010 and 2011 in Vila Dois Rios (VDR) and Vila do Abraão (ABR) in south of the Rio de Janeiro state. Of the 851 specimen analyzed, 141 (16.6%) were reported to be harbouring *Strongyluris* spp. cysts, summing up to a total of 1,898 cysts. Parasite cysts were observed in the secondary pulmonary vein, the kidney, pericardial sac and in the rectum. Cyst distribution varied across sampling sites. In snails from VDR, a total of 629 cysts were recovered, with the majority located in the SPV (592; 95%), followed by the kidney (14; 2%), rectum (16; 2%), and pericardial sac (7; 1%). In contrast, snails from ABR yielded 1,269 cysts, most of which were found in the SPV (1,070; 84.3%), with additional cysts in the kidney (164; 13%), pericardial sac (20; 1.5%), and rectum (15; 1.2%). The authors inferred that the bigger snails, host a higher number of cysts, as they usually present a larger biomass and a larger area of the pallial system, allowing efficient parasite colonization. The study indicated that the high concentration of cysts in the vascularized region of the pallial system of *Achatina fulica* was likely due to increased hemolymph circulation in that area, which provided more nutrients to support larval development.

2.1.3 MARINE SNAILS

A survey on brackish water snails was conducted by Sri-Aroon *et al.* (2004) in Eastern Thailand to determine the natural infection with trematodes. The survey took place in July 2003, of which 6,013 were examined belonging to thirty-five species. Of the snails assessed 859 (14.29%) were brackish-water species from Samut Prakan Province. In addition, 100 (1.66%), 1,472 (24.48%), 2,152 (35.79%), 831 (13.82%), and 599 (9.96%) snails were obtained from Chachoengsao, Chon Buri, Rayong, Chanthaburi, and Trat Provinces, respectively. In the study, the authors reported that among the snail species examined only nine species is known to harbour trematode infection namely, *Dostia violacea, Littorinopsis scabra, Assiminea brevicula, Sermyla riqueti, Cerithidea quadrata Sowerby, Cerithidea cingulata*, *C. djadjariensis, Cassidula aurisfelis,* and *C. mustelina.* Seven types of cercariae were recovered from the study, cercaria with cystogenous glands but lacking eye-spots and collar spines, cercaria with both eye-spots and cystogenous glands, small stylet-bearing cercaria, cercaria with eye-spots, four and three penetration gland cells arranged in two rows, and a tail with a fin, cercaria with eye-spots, seven penetration gland cells in a row, and a finned tail, cystophorous cercaria developing within a large redia, and cercaria with a large excretory bladder. In addition, one undetermined type of cercaria and one nematode worm were also recorded. The cercariae found appeared to be of veterinary importance, since most of them had eye-spots. From the study, the authors concluded that eastern Thailand is rich in brackish-water snails, some of which are important trematode hosts, but more studies are needed on their life cycles and their potential use as ecological indicators.

In New Zealand, Martorelli *et al.* (2008) investigated trematode cercariae in the intertidal snail *Zeacumantus subcarinatus.* Four types of cercariae were isolated from the examined snails, a distome xiphidiocercaria assigned to the genus *Renicola*, a monostome xiphidiocercaria belonging to the genus *Microphallus*, a magnacerous cercaria, and a cercaria of the genus *Philophthalmus*. The morphological features of these cercariae were compared with previously described species from the same genera noting similarities in morphological features such as body shape, tail morphology, and the presence of stylets. Notably, the philophthalmid cercaria readily encysted on artificial substrates in the laboratory inside the petri dish, leading to the description of its metacercaria. It was described as flask-like metacercarial cyst showing multilayered cyst wall while the other was a metacercarial with tail attached to the cyst, they were attributed to the family Philophthalmidae, genus *Philophthalmus*. The authors concluded that their findings increase the number of digenean trematodes known to infect *Z. subcarinatus* to six, highlighting the significant ecological and evolutionary impact of these parasites on the host snail.

A survey by Gilardoni *et al.* (2018) investigated trematodes in 1,758 intertidal gastropods from Patagonia, Argentina, representing seven snail species (*Crepipatella dilatata, Fissurella radiosa, Nacella magellanica, Paueuthria fuscata, Siphonaria lessonii, S. lateralis,* and *Trophon geversianus*). Digenean trematodes were detected in six species, with F. radiosa being the only uninfected host. Twelve digenean species from nine families were identified, including *Maritrema madrynense* and *Gymnophalloides nacellae,* as well as larval stages such as rediae, sporocysts, metacercariae, and cercariae. Of these, 11 species used gastropods as first intermediate hosts, while *G. nacellae* was found as metacercariae in limpets, showing the highest prevalence (83.67%). Other notable prevalences included microphallids (16.5%), *M. madrynense* (9.2%), renicolids (4.64%), and lepocreadiids (3.49% and 3.76%). Host-specific patterns were also observed, *S. lessonii* harbored three digenean species, *C. dilatata, N. magellanica, P. fuscata,* and *T. geversianus* each hosted two, while *S. lateralis* carried only one lepocreadiid and one zoogonid. Similarly, Bagnato *et al.* (2015) reported 12 digenean larvae in Puerto Deseado, with seven species using shorebirds and four using fish as definitive hosts. Gilardoni *et al.* (2018) concluded that the diversity of gastropods and benthic organisms promotes trematode diversity and abundance by attracting varied shorebird and fish hosts, which disperse eggs and support the parasites life cycles.

Ni and Doherty (2022) conducted a survey on intertidal snails in Portobello, Dunedin, New Zealand to investigate the effects of parasitic infection in correlation with the tidal locomotion. In the study, two snail species were investigated 195 *Austrolittorina cincta* and 183 *A. antipodum*.

Parorchis sp. cercariae were isolated from the examined snails with infection prevalence of (38.8%) for *A. antipodum* and (58.9%) for *A. cincta*. It was reported in the study that infected individuals were significantly larger than uninfected snails which the authors attributed to be a variation in positive function of age as a result of cumulative risk of parasitic infection. Secondly, the smaller snails were found in lower vertical zones in high shores due to the weaker tolerance to physical stressors hence during vertical migration the larger ones are brought closer to vicinity with shorebird faeces harbouring trematode eggs increasing their chances of getting infection. Furthermore, the larger snails are trematode-induced castration, stemming from alterations in energetic allocation between growth and reproduction upon infection. In the study, Ni and Doherty (2022) conducted a controlled experiment on vertical upward movement and photo tactic behaviour of the intermediate host and how the infection alters it, they found that *Parorchis* sp. infection altered the vertical upward movement in *A. cincta* but not in *A. antipodum*, suggesting adaptive host manipulation. Photo tactic responses were unaffected in both species. These findings highlight the complexity of parasitic infections, demonstrating that behavioral effects can differ even among closely related host species.

2.2 PARASITES INFECTION IN SNAILS FROM NIGERIA

2.2.1 FRESHWATER SNAILS

In the metropolis of Port-Harcourt, Awi-waadu *et al.* (2020) assessed snails of medical importance. A total of 1812 freshwater snails were examined, *Lymnaea natalensis, Physa* sp., *Indoplanorbis exitus* and *Oncomelania* were the species found. None of the snail were found to shed cercariae, although, the authors reported that the lack of infection in the snails was not unusual but that the presence of snail vectors of Schistosome and *Fasciola* in the study area posed danger and risk of potential transmission of snail borne diseases such as fascioliasis, trematode infection and schistosomiasis. Finding from the study, shown that the survival of snails in their habitats mainly depends on the physicochemical properties of the water of which DO (dissolve oxygen) was the most important. The study reported the absence of *Bulinus* sp. in the region at the time of the investigation but Arene *et al.* (1989) reported to have found few species of *Bulinus* years back. However, Awi-waadu *et al.* (2020) attributed the absence of *Bulinus* sp. to the changes in the physicochemical parameters of the water bodies resulting from human activities and environment modification.

Obisike *et al*. (2022) conducted a study on freshwater snails in Okigwe, Imo State. A total of 1407 snails belonging to *Lymnaea* sp. and *Bulinus* sp. were examined, with report of an overall infection rate of 54.2%. The study the took place in May to July 2021, detecting the highest infection rate in snails collected in the month of May as compared to those collected in June and July, the rate was 69.2%, 50.1% and 33.6% in the months of May, June and July respectively. Physico-chemical parameters of the water were evaluated; findings showed that dissolved oxygen (DO), Biological oxygen demand (BOD) and PH significantly influenced snail distribution in the area, noting that the presence of snails increased the biomass of filamentous green algae and decrease the biomass of periphyton thereby reducing the DO of the water which is needed by aquatic organisms for existence. From the findings in the study, the snails examined are intermediate host of *Schistosoma* and *Fasciola*, which the authors reported that will contribute a quota to support the WHA resolution to maintain a world free of Schistosomiasis by controlling its morbidity and eliminate it.

Ugbomoiko *et al.* (2022) conducted a study in four communities from Osun State, Llie, Oree, Oba-lle and Oba-oke in the characterization of freshwater snail intermediate hosts of schistosomes. The authors examined 100 snails of which five were positive for schistosome infection; the snails were screened for Infection by PCR amplification of the schistosome *Dra 1* gene. Molecular identification of the snails was done by PCR amplification of their entire internal transcribed spacer region including the 5.8S ribosomal RNA gene and RFLP. Snails infected were identified to belonging to the freshwater snails of the genus *Physa* and the other two were identified as *B. truncatus* and *B. globosus*, respectively. The study also confirmed earlier works of Akinwale *et al.* (2011) that it is difficult to separate the different *Bulinus* snail species due to their morphological uniqueness, but they can be identified by the use of restriction fragments length polymorphism (RFLP) without DNA sequencing.

Peletu *et al.* (2023) investigated cercariae shedding pattern and infection of Schistosoma intermediate host snails in Owena reservoir, Ondo State. The investigation took 24 months between August 2013 and July 2015. Five snail species were examined, *Bulinus* sp., *Biomphalaria pfeifferi, Melanoides tuberculat*a, *Pila ovata* and *Potodama freethi*. The study reported *Bulinus globosus* to have the highest infection rate of 3.2%. The authors highlighted that *B. globosus* and *B. truncatus* plays an important role in the transmission of *Schistosoma haematobium* in Owena reservoir.

In Hadejia River Valley, Jigawa State, Qadeer *et al.* (2023) carried out a parasitological research on the distribution, abundance and infection rate of aquatic snails. In the study, 150 and 437 snails were examined during dry and rainy season respectively. Out of the 150 snails investigated in the dry season, the overall cercariae infection rate was 7.33% while during the rainy season; overall infection rate by cercariae was 12.2%. *Pila ovata* was reported to be the most abundance snail species during rainy season with *Lanistes varicus* being the least. In contrast, only *Pila ovata* were collected during the dry season. From the study, *Pila ovata* has the highest prevalence of cercariae and the highest infection levels occurred in snails collected from farm during the dry season and the ones examined from river during the rainy season. The study revealed that physio-chemical parameters, such as the water temperature which is (19–25°C), pH (10.0–11.5), rainfall (144–198.5 mm), and relative humidity (1.599–2.420), influenced snail abundance. The authors concluded that seasonal variation played a critical role in snail abundance and infection dynamics, with higher infection rates observed during the rainy season.

A parasitological survey was conducted in Ojo area of Lagos by Ajijola-Alabua *et al*. (2024) on freshwater snails. The study explored the seasonal abundance and distribution of the 135 snail's species (*Bulinus senegalensis, Biomphalaria pffeiferi, Lymnaea natalensis, Pila ovata, Bulinus truncatus* and *Segmentorbis kanisaenis*) collected and examined between 2021 and 2022. In the study, snails from nine drainages and seven ponds within Lagos State University (LASU) and two rivers were assessed. The microscopic inspection of the snail's tissues revealed that no intramolluscan stages were present; no infection was reported in any snail. The authors inferred that the absence of infection was in correlation with the physicochemical quality, sanitation and water contact behaviour of the inhabitants. However, the authors reported that the absence of infection in snails examined during the rainy season from drainages within LASU may be due to the lack of exposure of the snails to contaminated human or animal faeces and urine. The study revealed that freshwater snails were recovered only in the rainy season but absence in dry season even in half-filled drainage which was attributed to aestivation.

Elijah and Chessed (2025) conducted a study on the infectivity and transmission potential of freshwater snails at Lake Njoboliyo in Adamawa State. In the study, a total of 1602 snails species were examined, they were *Melanoides tuberculata* (490, 30.6%), *Bellamya unicolor* (387, 24.2%), *Pila ovata* (328, 20.5%), *Lanistes* ovum (288, 17.9%), *Lymnaea natalensis* (74, 4.6%), *Bulinus globosus* (19, 1.2%), *Cleopatra bulimoides*(10, 0.6%), and *Bulinus truncatus*(6, 0.4%).

The authors reported *Pila ovata* and *Lanistes ovum* as the snail species that shed cercariae having an overall prevalence of 2.75% of the eight snail species examined, with *Lanistes ovum* and *Pila ovata* showing infection rates of 10.70% and 3.96%, respectively. However, other specimen was uninfected, although, the snails are known to serve as intermediate hosts for *schistosome* and *fasciola* species, such as *Bulinus* spp. and *Lymnaea natalensis* but none shed cercariae because only juvenile snails of these species were observed during the study period. From the findings, the authors noted that snails from the study area are naturally infected with cercariae but the cercariae found in *Pila ovata* and *Lanistes ovum* were non-human schistosomes.

In Ovia South West Local Government Area, Edo State, Adeyemi *et al.* (2025) investigated freshwater snails in Schistosomiasis endemic communities (Siluko, Ugbogui, Okponha, Aden, Igbobor, Ikoha and Okopon). In the study, total of 468 snails of four genera were investigated (*Melanoides*, *Radix*, *Bulinus*, and *Lanistes*). The main snail vector of Schistosomiasis (*Bulinus* sp.) collected from the endemic area was uninfected with *Schistosoma* cercariae. The study revealed that *Radix* sp. was the only snail species found to be infected, from which a brevifurcate apharyngeate distome furcocercaria with distinct eye spots was isolated. Although the research focused on areas endemic for schistosomiasis, none of the recognized snail intermediate hosts were infected; only *Radix* sp. harboured cercaria. The cercariae observed resembled those of *Schistosoma* spp., but the presence of conspicuous eye spots indicated that they did not belong to *Schistosoma*.

2.2.2 TERRESTRIAL SNAILS

Awharitoma and Edo-Taiwo (2012) investigated terrestrial snails for parasitic infections in southern Nigeria, covering Edo, Kogi, and Cross River States. Seven hundred and forty terrestrial snails, comprising three species (*Archachatina marginata ovum*, *A. papyracea,* and

Limicolaria aurora), were examined. Parasite recovered from the examined snails was a nematode identified as *Rhabditis axei.* In the study, the infection prevalence varies across the three snail species. A prevalence of 48.1% was recorded in *A. marginata ovum* while *A. papyracea* and *L. aurora* had prevalence of 23.3% and 10.1%, respectively. All the snail species were definitive host of the nematode. The authors reported that small sized *A. marginata ovum* had higher infection load of *R. axei* than the big sized ones. The report of *Rhabditis axei* in *L. aurora* was a new host record in Nigeria while in Edo State; *A. marginata ovum* was a new geographical record. The study reported that both infected and uninfected *A. marginata ovum* and *L. aurora* were very much active.

Igbinosa *et al.* (2016) studied land snails in four towns in Edo State, Benin, Uromi, Ekpoma and Auchi. Terrestrial snails such as *Achatina achatina, Achatina fulica, Acharchatina marginata, Limicolaria aurora, Limicolaria flammea* and *Limicolariopsis* sp. were analyzed. *Strongyloides stercoralis* was recovered from the various snails' species, with 54.04% prevalence. The study reported to isolate *Alaria* mesocercariae from *L. aurora, L. flammea* and *Limicolariopsis*. However, cercariae of *Drocoelium dendriticum* were isolated from few *L. flammea*. In *A. fulica*, larvae of *Angiostrongylus cantonensis,* sporocyst of *Fasciola gigantica* and *Schistosoma mansoni* were discovered. Although, the nematode (*Angiostrongylus cantonensis*) found is a parasite of rat that causes the neurologic rat lungworm disease (Jarvi *et al.,* 2012), Lwanowicz *et al*. (2015) also reported to have isolated the nematode from *A. fulica.* The authors inferred that *S. stercoralis* was the most prevalent parasite of terrestrial snails.

Alari *et al.* (2023) examined the biology of *Postharmostonum ntouri* (Trematoda: Brachylaimidae) based on intermediate and definitive hosts in Ase (Delta State) and Tombia (Bayelsa State), Nigeria. A total of 62 terrestrial snails from four species *Archachatina marginata*, *A. papyracea*, *Limicolaria aurora, Limicolaria* sp., and *Thapsia oscitans* were screened for parasites. Only *L. aurora* and *Limicolaria* sp. contained sporocysts with cercariae, indicating their role as first intermediate hosts. Metacercariae were recovered from *Limicolaria* spp. And *Archachatina* spp., suggesting these snails act as second intermediate hosts. The recovered metacercariae were successfully cultured in 14-day-old domestic chicks (*Gallus gallus domesticus*), from which adult *P. ntouri* were progressively isolated at 7, 14, 21, and 28 days post-infection. This confirmed that the domestic chicken is not only a susceptible experimental host but also the definitive host of the parasite, consistent with previous findings in Ghana. The study highlights the need for further research into the host range of *P. ntouri* in Nigeria, given its reported infections in Guinea fowl in Ghana.

2.2.3 MARINE SNAILS

Awharitoma *et al.* (2011) carried out a study on trematode parasites of Periwinkle in Niger Delta, from Elume, Sapele, Warri, Koko and Escravos Rivers, all in Delta State and from Ilaje River in Lagos State. Of the 4,429 snails they examined (*Tympanotomus fuscatus* and *Patodoma moerchi*), 4.8% was infected with larval stages of trematode and only *T. fuscatus* was observed to harbour infections. Periwinkles from Koko River had the highest prevalence of 15.7%, while the prevalence in snails from other locations spread from 1.3% to 4.9%. Parasites isolated includes rediae, sporocysts and cercariae, four types of cercariae were recovered namely gymnocephalous, xiphidiocercariae, furcocercous and echinostome, while no infection was found in *P. moerchi*. The authors reported the *in vitro* encystment of gymnocephalous and echinostome cercariae to form metacercariae which was incubated for 7 weeks and 1 week respectively, giving rise to juvenile trematodes. However, the juvenile trematode of gymnocephalous cercariae was unidentified but those of echinostome cercariae were observed to be echinostomatid worms characterized by the collar spines. Although, Xiphidiocercariae did not form metacercariae *in vitro*, the study suggested that the juvenile stage may be *microphallus* species which occurs in the shell fishes collected from locations in Niger Delta. The authors revealed the widespread of furcocercous cercariae in the study and lack of identification of the parasite producing these cercariae in brackish water as schistosome species are known to release such cercariae in freshwater environments.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted in Iguobo Community, located in Ovia North-East Local Government Area of Edo State, Nigeria. The administrative headquarters of the Local Government is situated in Okada town. Geographically, Iguobo lies within a region defined by specific latitude and longitude coordinates 06°39.847N and 005°25.830E, respectively as shown in Figure 3.1 and is part of Southern Nigeria. Iguobo is a small rural community with a local economy primarily based on agriculture. The main economic activities include subsistence farming, animal husbandry, particularly the rearing of goats, palm oil production, and small-scale trading.

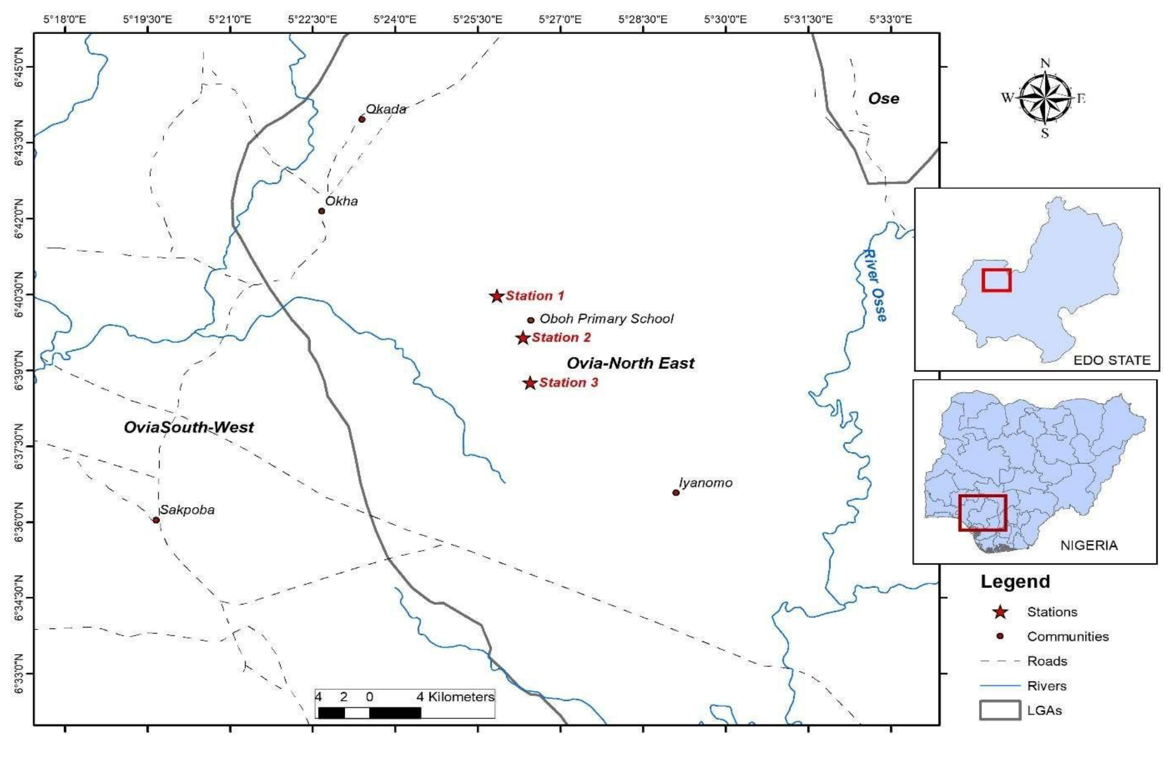

Figure 3.1: Map of Study Area showing the sampled locations

3.2 HABITAT AND CLIMATE

The community is located within the tropical rainforest belt of Nigeria. This zone is characterized by dense vegetation comprising tall hardwood trees such as mahogany, oil palm, and a variety of shrubs. Portions of the forest have been cleared and are cultivated for crops including cassava, plantains, and yams. Two seasons is paramount to the study area, the rainy season, which typically spans from April to October and the dry season which occurs from November to March.

Plate 3.1: Water Puddles where *Pila ovata* was collected at Iguobo Community, Ovia North-East LGA

3.3 SAMPLING TECHNIQUES

Snail collection was carried out manually through hand-picking, using protective gloves to ensure safety. Samples were gathered from shallow waters within farmland areas (Plate 3.1) in Iguobo community. The collection took place between 11.15 am and 12.51 pm during the month of July. Majority of the snails were found in puddles across three distinct sampling stations. Some snails were observed floating or swimming in the water, while others were located within decaying vegetation submerged in the water puddles. A total of four individuals participated in the collection process. The collected snails were placed in ventilated containers with perforated lids to allow air into the container. Small quantity of water was added to the containers which were subsequently transported to the Laboratory of Public Health and Veterinary Parasitology, Department of Animal and Environmental Biology for identification and examination for trematode infection.

3.4 IDENTIFICATION OF SNAILS

Snails were counted and identified by the pattern of shell, using distinctive morphological characteristics like the apex, aperture shape and the direction of shell coil. The direction of shell coil of all the snails were to the right, the identification process follows the guidelines provided in the freshwater snail manual by Brown and Kristensen (1989), and freshwater Gastropoda (Dillon, 2006). Morphometric of each snail was taken using a plain white paper and measuring ruler to take their length and diameter.

3.5 EXAMINATION OF SNAILS FOR PARASITE INFECTION

The snails were placed separately in beakers to which little quantity of water was added and a light was focused on them from an electric light source for 2 hours to enable the shedding of cercariae if present. This procedure was repeated for 5 days, after which the snails were dissected for further parasitological investigation. The snails were placed on a flattened wooden board where they were crushed with a hammer. The shells were removed from the crushed snails and then placed in a petri dish containing saline solution. The visceral was separated from the foot and thereafter teased using a dissecting pin gently and observed under a dissecting microscope for the presence of parasite (cercariae or sporocyst). The sporocysts/cercariae found in infected snails were isolated into another petri dish. Pasteur pipette was used to pick some of the cercariae into microscope slides, covered with cover slips and examined under a compound microscope. If the parasite was a sporocyst/redia, it was crushed to release cercariae by applying slight pressure on the cover slip.

3.6 IDENTIFICATION AND PRESERVATION OF PARASITES

Cercariae recovered from the crushed snails were initially examined under a dissecting microscope. Following this, individual cercaria was transferred onto clean microscope slides and observed under a compound microscope for detailed identification. Morphological identification was carried out based on key diagnostic features, including the presence and arrangement of suckers, tail morphology, body shape, and the presence or absence of stylets. The identification process followed the taxonomic keys established by Frandsen and Christensen (1984). These criteria provided a reliable basis for differentiating cercarial types commonly associated with trematode infections in freshwater snails.

Cercariae were fixed with 5% formal saline on a clean microscope slide to kill and flatten the larvae, thereby enhancing the visibility of their morphological features during identification. They were fixed for about 5 minutes and thereafter recovered and preserved with the same fixative in a well labeled bottle. Some of the cercariae and sporocysts were preserved in 96% ethanol in Eppendorf tubes for further molecular analysis. These tubes were kept in the refrigerator at 4°C. The parasites were then photographed with Amyscope Microscope Digital camera 14MP APTINA CMOS attached to the eyepiece of the compound microscope and connected to a laptop. After observation and identification of the parasites in a compound microscope, a graduated eyepiece was inserted in the microscope to take the measurements of the recovered parasites. The length and width of both the ventral and anterior sucker and overall length were taken at X10 magnification.

3.7 DATA ANALYSIS

Graphical representations were used to illustrate the length and diameter range of the snails. Prevalence of infection was calculated as the percentage of infected snails relative to the total number examined.

$$\text{Prevalence of infection} = \frac{\text{Number of infected snails}}{\text{Total number of snails examined}} \times 100\%$$

CHAPTER FOUR

4.0 RESULTS

4.1 Prevalence of Parasite Infection in *Pila ovata* from Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

Sixty-six snails, *Pila ovata* (Plate 4.1A, B) from Iguobo Community, Ovia North-East LGA, Edo State, Nigeria were examined for parasite infection. Of these 66 snails, only one was infected with parasites with an overall prevalence of 1.52% after crushing. The parasites recovered from the infected snails were larval stages of trematode at different stages of development. Among these trematode larval stages were: Redia (Plate 4.2), Gymnocephalous cercariae (Plate 4.3A-E), Cercariaeum cercaria (Plate 4.4) and metacercaria (Plate 4.5). Also recovered was an unidentified juvenile trematode (Plate 4.6).

Plate 4.1A, B: *Pila ovata* from Iguobo Community, Ovia North-East LGA, Edo State, Nigeria. A, Ventral View; B, Dorsal View

Plate 4.2: Redia from *Pila ovata* in Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

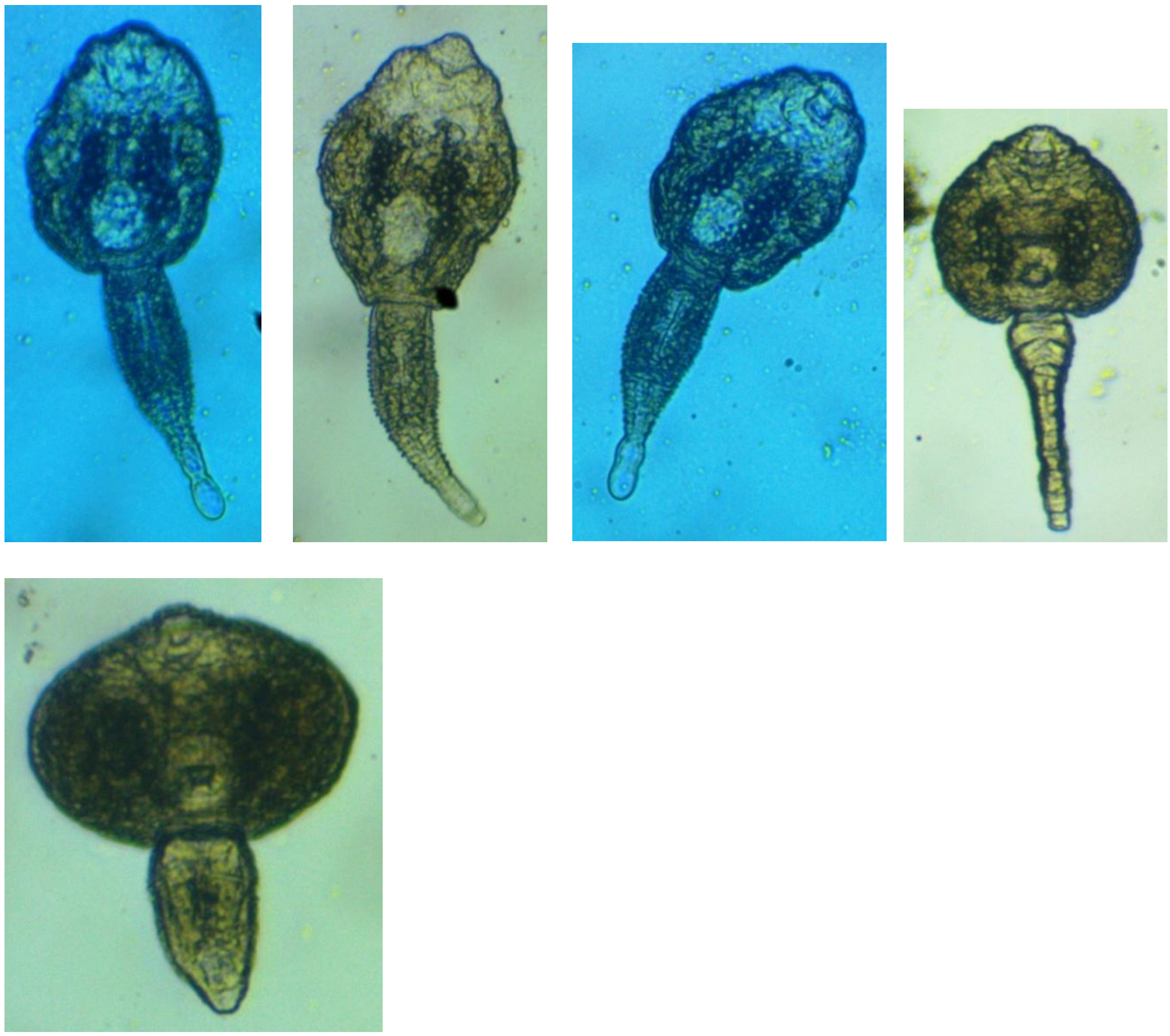

Plate 4.3A-E: Gymnocephalous cercariae from *Pila ovata* in Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

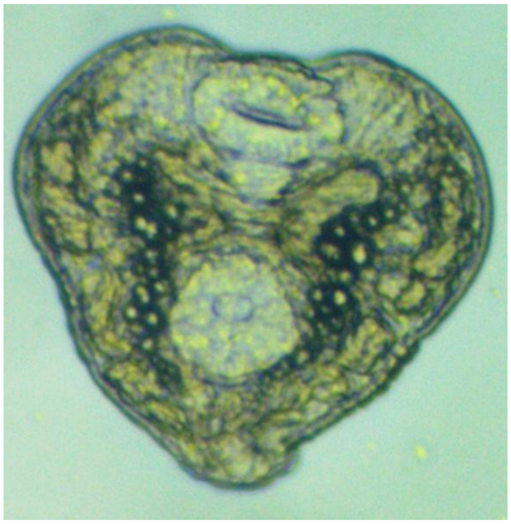

Plate 4.4: Cercariaeum cercaria from *Pila ovata* in Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

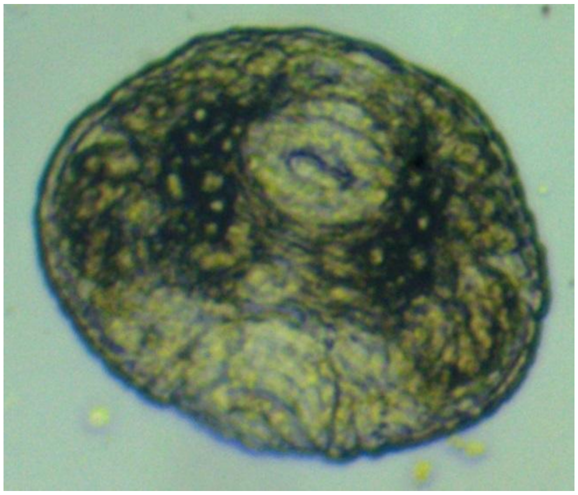

Plate 4.5: Metacercaria from *Pila ovata* in Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

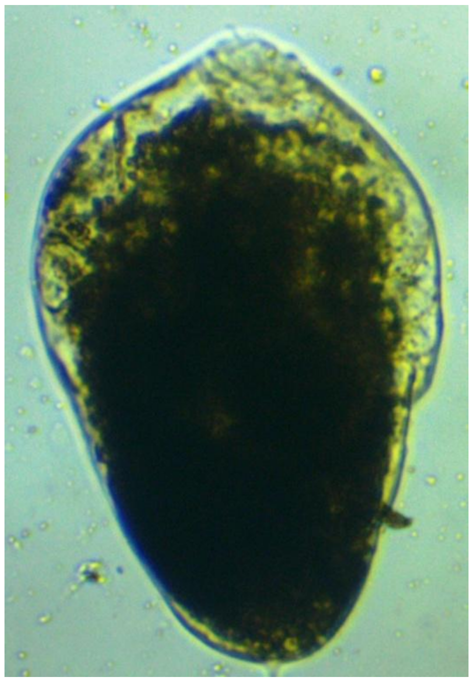

Plate 4.6: Juvenile trematode from *Pila ovata* in Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

4.2 Morphometric of *Pila ovata* from Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

The shell length and diameter of *Pila ovata* of the 66 snails examined were measured. The mean length of *P. ovata* was 3.425 ± 0.726 while the diameter was 2.855 ± 0.632. The overall length of the 66 specimen ranged between 1.5 – 4.9 cm while the diameter was between 1.3 – 4.6 cm. Based on the measurements, the smallest snails recorded were two snail with lengths of 1.5 and 1.9 cm. Seven snails measured between 2.0 and 2.5 cm, while twelve were of medium size, ranging from 2.6 to 3.1 cm. Seventeen snails fell within the range of 3.2 to 3.7 cm, and fifteen measured between 3.8 and 4.3 cm. The largest snails observed measured between 4.4 and 4.9 cm. From the measurements of shell diameter, three had diameters ranging between 1.3 – 1.8 cm, while thirteen fell between 1.9 - 2.4 cm. The shell diameter in others progressively range from 2.5 to 3.0 cm in twenty-five snails, 3.1 to 3.6 cm in fifteen snails and 3.7 to 4.2 cm in six snails. Only one snail fell between the range of 4.3 – 4.8 cm, as presented in (Figure 4.2) and (Figure 4.3).

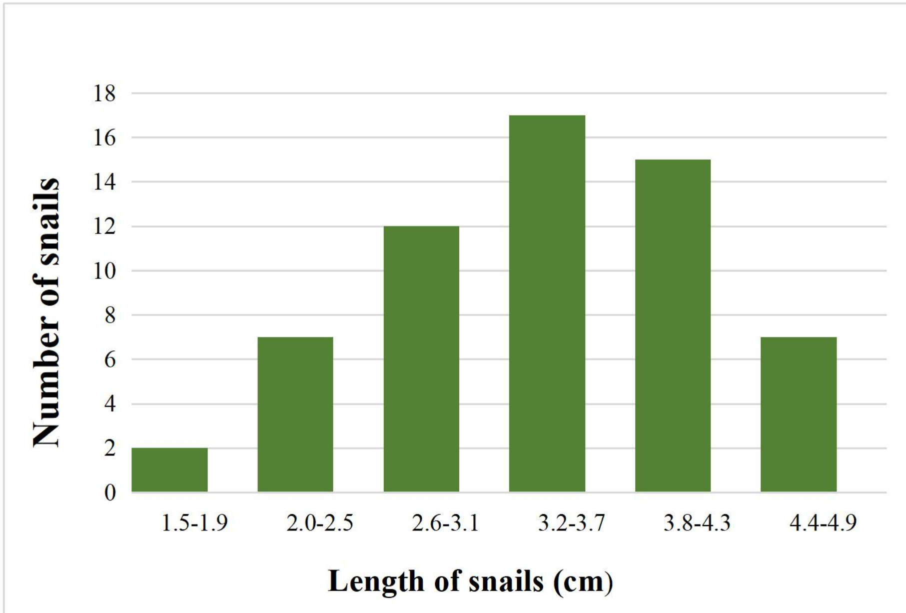

Figure 4.2: Length of *Pila ovata* from Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

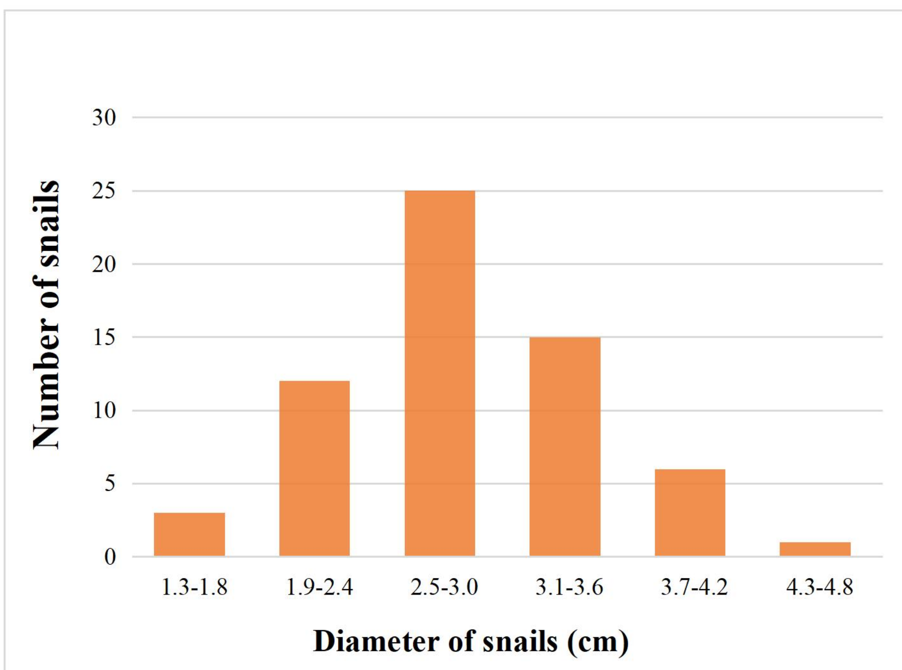

Figure 4.3: Diameter of *Pila ovata* from Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

4.3 Morphometric of Parasites Recovered in *Pila ovata* from Iguobo Community, Ovia North-East LGA, Edo State, Nigeria

Trematode larval stages recovered from the infected snail have distinct variations in body size and morphological features during observation. The cercariaeum cercariae (Plate 4.4) identified had no tail while the gymnocephalous cercaria (Plate 4.3A-E) had a simple tail with ventral and oral sucker. For each of the larval stage, the total length, anterior body length, tail length, maximum width at anterior region, oral and ventral suckers width were recorded at X10 magnification using ocular micrometer, and the values are expressed in units. The gymnocephalous cercaria had a mean total length of 22 units; anterior length and width were 9.9 and 9.5 units, respectively; while the tail length was 9.2 units (width, 2.5 units). The sucker measurements were: oral sucker, length was 1.5 units while width was 2.5; ventral sucker, length 2.0 was and width 2.5 units. The cercariaeum cercaria had a total length of 9.6 units and total width 10.0 units, with a ventral sucker length of 5.0 units and width 4.0 units. The juvenile trematode recovered from the *Pila ovata* measured 18.0 units in total length with width of 12.0 units; oral sucker was diameter 3.0 units.

CHAPTER FIVE

DISCUSSION

An investigation of *Pila ovata* from Iguobo Community Ovia North-East LGA, Edo State for parasite infection was conducted in this study. Of the 66 *P. ovata* examined, none shed cercaria when exposed to light irrespective of the duration of exposure. However, after crushing, one was found to be infected with parasites. The parasites recovered from the infected snail were larval stages of trematode and these include redia, two types of cercariae: Gymnocephalous and Cercariaeum cercariae (Frandsen and Christensen, 1984), metacercaria and an unidentified juvenile trematode. However, the prevalence of trematode infection recorded in this study was low (1.52%) when compared when compared to previous studies. This low prevalence could be attributed to minimal anthropogenic activities in the study area, which likely reduced water contamination. According to Mereta *et al.* (2019) human activities such as farming, livestock grazing, open defecation, and swimming significantly influence the abundance of cercariae in snail population. In this study, farming was the only notable human activity in the study area (farmland), with no evidence of livestock grazing. The absence of these anthropogenic activities which influenced the abundance of cercarial infection, occurrence and infectivity in snails, could have probably contributed to the low level of contamination and subsequent low prevalence of infection in the snails. The low prevalence could also be due to the short period of survey and the timing. The study was conducted during the wet season; which probably reduced the infection rate due to dilution factor.

Although, *Pila ovata* showed low prevalence of trematode infection in this study, it however, exhibited high parasite diversity due to the presence of different larval stages and juvenile trematode recovered from the infected snail. Gymnocephalous cercaria is considered one of the simpler types of cercaria. It is characterized by a non-bifurcated tail and the presence of both an oral and ventral sucker, with the ventral sucker at the mid ventral surface of the body. In this cercaria, stylet, collar, and eyespots are absent and the body contains numerous cystogenous glands. It develops in rediae and encysts in external surfaces (Frandsen and Christensen, 1984). On the other hand, Cercariaeum cercaria is tailless, with both an oral and ventral sucker present. It also develops in rediae and encysts in snails. It is of no economic importance produced by snail species of genera *Biomphalaria, Gabbielle and Lymnaea* (Frandsen and Christensen, 1984).

In contrast to the low prevalence and larvae types reported in this study, other studies have reported higher prevalence and different parasites infection in *P. ovata*. Avbara (2002) reported prevalence of the presence of 2.6% and trematode larval stages [sporocyst, rediae and two types of cercariae (Xiphidiocercariae and amphistome cercariae)]. Irorere (2007) reported a prevalence (32.5%) of parasite infection from *Pila ovata* in Edo State, where both nematode and trematode larvae (sporocysts and xiphidiocercariae) were isolated. The author inferred that the high prevalence of infection in the snails could be attributed to the period of sampling (dry season); in the study the highest prevalence was observed during the dry season. Awharitoma and Ehigiator (2012) also recorded higher parasite infection prevalence (9.3%) and diversity in *Pila ovata* from Bayelsa, Edo and Delta States. Sporocysts, radiae, xiphidiocercariae, amphistome cercariae and nematode larvae were the parasites they reported. Awharitoma and Enabulele (2018) reported xiphidiocercariae in *Pila ovata* from Obazuwa, Edo State. In the investigation they used partial large subunits of ribosomal DNA to ascertain the phylogenetic construction of the parasite, which indicated that it belongs to the *Microphallus* sp. In Southwest Ethiopia, Mereta *et al.* (2019) reported an overall prevalence of 3.6% and 8 cercarial type namely *Echinostoma,* brevifurcate apharyngeate distome, amphistoma, brevifurcate apharyngeate monostome, xiphidiocercariae, longifurcate pharyngeate distome, strigea cercariae and an unidentified cercariae from *Biomplaria pfeifferi, Biomphalaria sudanica, Lymnaea natalensis, Bulinus globosus,* and *B. forskalii*. Dunghungzin and Chontananarth (2020) reported an overall prevalence of 2.45%, and five groups of cercariae: cercariaeum, echinostome, xiphidiocercariae, megalurous, and parapleurolophocercous from *Melanoides tuberculata*, *Filopaludina martensi*, *F. polygramma*, *F. siamensis*, and *B. siamensis*, examined in Central Thailand. Elijah and Chessed (2025) reported a cercaria infection rate of 3.96% and 10.7% in *Pila ovata* and *Lanistes ovum* respectively, from Lake Njoboliyo, Adamawa State. Of the eight freshwater snail species investigated; *Bulinus globosus*, *B. truncatus*, *Lanistes ovum*, *Melanoides tuberculata*, *Cleopatra bulimoides*, *Pila ovata*, and *Bellamya unicolor*, only *L. ovum* and *P. ovata* were infected.

Nevertheless, in contrast to the report in this study, Edo-Taiwo (2005) recorded a lower overall infection prevalence of 0.74% in *P. ovata* from Edo State, the recovered larval stages were radiae, sporocysts and cercariae. The cercariae were identified as amphistome cercariae with an overall infection rate of 65.9%, radiae 20.1% and sporocysts 14.0%. Joseph (2019) also reported lower prevalence of 1.14% in *P. ovata* from Ugbekoko River in Delta State, where an unidentified nematode larva was detected.

However, Ajijola-Alabua *et al*. (2024) found no trematode parasite infection in the freshwater snails (*Bulinus truncatus*, *B. senegalensis*, *Biomphalaria pffeiferi*, *Lymnaea natalensis*, *Segmentorbis kanisaenis*, and *P. ovata,*) they examined from Ojo area of Lagos State.

Previous studies (Awharitoma and Ehigiator, 2012; Awharitoma and Enabulele, 2018; Laidemitt *et al*., 2019; Outa *et al*., 2020) have shown that xiphidiocercariae and echinostome cercariae were the cercariae harboured by *Pila ovata.* However, Outa *et al.* (2020) isolated eight digenean trematodes from *Pila ovata* from Lake Victoria namely *Haplorchis pumilio*, *Thapariella* *prudhoei, Nudacotyle* sp., *Renicola* sp., *Bolbophorus* sp., *Echinostoma* sp. and an unknown cercaria belonging to the genus *Haematoloechus* identified as xiphidiocercaria but possessed a long sword-shaped stylet with an overall prevalence of 15.4%. Although, xiphidiocercariae and echinostome cercariae were among the trematode cercariae recovered from the study, other trematode were also found indicating that xiphidiocercariae and echinostome cercariae might not be the only cercariae found in *Pila ovata.* Similarly, Laidemitt *et al.* (2019) reported the presence of echinostomatid *Petasiger* sp. infecting *Pila ovata* from Dunga Beach, Kenya.

The findings from Iguobo Community, Ovia North-East LGA, Edo State investigated in this study revealed that *P. ovata* is not only infected with xiphidiocercariae and echinostome cercariae, as previously stated, but it also harboured gymnocephalous and cercariaeum cercariae. Moreover, from available literatures, there is no previous report of these cercariae (gymnocephalous and cercariaeum) infection in *P. ovata* from Nigeria generally and Edo State in particular.

Ibrahim and Ahmed (2019) documented the occurrence of gymnocephalous and cercariaeum cercariae in *Lymnaea natalensis* from Egypt. Chantima *et al.* (2018) reported the presence of gymnocephalous cercariae in *Bithynia siamensis siamensis* from Chiang Rai, Thailand. Haruay and Piratae (2018) reported the occurrence of cercariaeum cercariae in *Bithynia siamensis goniomphalos* from Ubon Ratchathani Province, Thailand. In the study, the authors recorded an overall trematode cercariae infection of 1.69% and cercariaeum, virgulate, cotylomicrocercous, and furcocercous cercariae were isolated from six snail species: *Bithynia siamensis goniomphalos, Anentomebelena, Filopaludina sumatrensis spiciosa, F. martensi martensi, F. martensi munensis,* and *Pomacea canaliculata.* It is worthy of note that cercariaeum cercaria is a known parasite of the intestines of fish and the respiratory tract of birds (Ibrahim and Ahmed, 2019). The cercaria uses different intermediate hosts including snails, fish and birds to enable its transmission to get to the definitive host. It doesn't use fish or bird as host, snail is also among.

The ecology of the snail host is vital to the type of parasites species recovered from it; this is evident from the findings of Mbah *et al*. (2022) who conducted parasitological study on five species of terrestrial snails (*Achatina achatina*, *A. belteata*, *A, fulica*, *A. marginata*, and *A. degneri*) in Cross River State, Nigeria. The investigation revealed the presence of both nematodes and trematodes, including the ova of *Ascaris lumbricoides*, larvae of *Strongyloides stercoralis*, *Angiostrongylus cantonensis*, *Fasciola gigantica*, *Dicrocoelium dendriticum*, and *Schistosoma mansoni*. The authors reported a prevalence rate of 41.97% from these terrestrial snails.

RECOMMENDATIONS

Findings from this study have revealed the possibility of *Pila ovata* harbouring other types of cercariae contrary to earlier reports of xiphidiocercariae and echinostome cercariae infection. Therefore, further investigation should be conducted on *Pila ovata* to ascertain the species status of trematode cercariae infecting this snail. Such studies would help to identify the parasites of both veterinary and economic significance with respect to the study location. Understanding the diversity and prevalence of these parasites will provide valuable insights in producing effective control measures and safeguarding public health.

CONCLUSION

Pila ovata (Family, Ampullariidae) is a popular edible delicacy, widely consumed in various parts of the world as a source of protein due to its high protein content. This edible apple snail is not only valued for its nutritional benefits but also serves as an intermediate host for trematode infections. This study reports Cercariaeum and gymnocephalous cercariae in *P. ovata* from Nigeria for the first time.

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APPENDIX

Morphometric of *Pila ovata* from Iguobo Community, Ovia North-East LGA

Serial number	Length (cm)	Diameter (cm)	Serial number	Length (cm)	Diameter (cm)
1	3.8	3.2	**34**	3.4	2.6
2	3.5	3.3	**35**	4.75	3.6
3	3.8	3.6	**36**	3.2	2.55
4	3.5	3.0	**37**	3.0	2.2

5	3.6	3.0	**38**	2.8	2.3
6	2.5	2.1	**39**	3.0	2.4
7	3.1	2.4	**40**	3.15	2.5
8	2.3	1.9	**41**	3.7	3.1
9	3.0	2.55	**42**	4.0	3.7
10	3.1	2.7	**43**	4.9	4.0
11	3.85	2.9	**44**	4.4	3.6
12	3.3	2.6	**45**	4.4	3.6
13	3.35	2.7	**46**	3.9	3.4
14	3.05	2.3	**47**	4.15	3.8
15	3.0	2.5	**48**	4.2	3.7
16	3.0	2.45	**49**	4.6	3.8
17	1.9	1.7	**50**	3.9	3.1
18	1.5	1.3	**51**	4.0	3.5
19	4.6	4.6	**52**	3.5	2.8
20	2.1	1.7	**53**	3.5	3.0
21	3.3	2.8	**54**	3.4	2.9
22	2.2	1.9	**55**	3.5	2.9
23	2.8	2.5	**56**	3.8	3.0
24	3.0	2.8	**57**	3.55	2.9
25	2.9	2.6	**58**	3.6	3.0
26	3.4	3.1	**59**	3.9	3.3
27	3.75	3.0	**60**	3.45	2.9
28	3.55	2.7	**61**	4.6	3.4
29	2.3	1.9	**62**	4.0	3.45
30	2.9	2.35	**63**	3.9	3.3
31	2.4	2.1	**64**	4.9	3.85
32	2.9	2.3	**65**	3.55	2.7
33	2.4	2.0	**66**	3.8	3.0