A SURVEY OF FRESHWATER SNAILS OF VETERINARY AND MEDICAL IMPORTANCE IN ZARIA AREA, NIGERIA

BY

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DECLARARATION

The work presented in this thesis is original and was carried out by me under the supervision of Dr. V. C. Ogbogu, Prof. R.I.S. Agbede and Dr. S. Ebele of the Department of Veterinary Parasitology and Entomology, Ahmadu Bello University, Zaria.

Reference is made to the work of other investigators and duly acknowledged. No part of this thesis has previously been submitted for a degree or diploma.

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DEDICATION

To my parents (Hosea Shadoro and Zibiya Shadoro)

and my beloved wife

CERTIFICATION

This thesis entitled "A SURVEY OF FRESHWATER SNAILS OF VETERINARY AND MEDICAL IMPORTANCE IN ZARIA AREA, KADUNA STATE OF NIGERIA" by Zakki Yula HOSEA, meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

The survey of freshwater snails carried out in Zaria area, Nigeria, from July 1990 to June 1991, using 10 to 15 minutes man sampling method, revealed five species of snails, thus, Bulinus globosus, Morelet; Biomphalaria pfeifferi, Krauss; Lymnaea natalensis, Krauss; Bulinus forskali,Ehrenberg; which are pulmonates, and a species of prosobranch, Melanoides tuberculata, Miller. The distribution of these snails varied because the differ in tolerance of pH, temperature, vegetation and habitats. Temperature and pH ranges observed during the study, fall within the ranges required for snails survival and development.

The mean values of the measurement of furcocercous cercariae shedded by L. natalensis, B. globosus and B. Pfeifferi correspond to cercariae of Schistosoma bovis, S. haematobium and S. mansoni respectively. B. forskali under laboratory conditions was not susceptible to Schistosoma haematobium miracidia infection.

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CHAPTER ONE

INTRODUCTION

Snails belong to the phylum: Mollusca; Class Gastropoda; Order Pulmonata. They possess a structure called the mantle which envelops the internal organs and secrete a shell of calcium carbonate which is spirally coiled. Snails had been recognised to be of great medical and veterinary importance as they serve as intermediate hosts for various species of helminths (Sodeman, 1979; Mutani et al 1983). For these diseases their occurrence depend on the presence of biotypes suitable for the development of the molluscan intermediate hosts and as such associated with specific ecological nitches.

The economic losses resulting from these diseases are enormous (Oakley 1965; Bida and Schillhorn, 1977; Soulsby 1986) and the increasing frequency of the diseases appear to be associated with intensive agricultural development which necessitates development of irrigation resources which in turn provides adequate environment for the development of the snail hosts. Knowledge of the distribution patterns of snails, differences in ecological preferences and types/species of snails present is therefore necessary.

The objectives of this project are:

a) To collect and identify freshwater snails found in Zaria area.

b) To determine under laboratory conditions if Bulinus forskali can act as intermediate host of Schistosoma haematobium.

CHAPTER TWO

2 LITERATURE REVIEW

Many freshwater and amphibious snails have been identified as intermediate hosts of digetic trematodes of medical and veterinary importance and have a high degree of specificity among the helminths in general (Wright, 1973; Malek and Cheng, 1974). Because of differences in ecological preferences by snails, their distribution worldwide depends on the presence of ecological factors suitable for their survival and development (Christensen et al., 1983) found in the habitat.

2.1. Diseases Transmitted by Snails

Helminthic diseases that are disseminated by snails are many. The diseases transmitted include Fascioliasis, caused by Fasciola hepatica/gigantica species, Fascioliopsiasis caused by Fascioliopses species, Fascioloidiasis caused by Fascioloides species, Paramphistomiasis by Paramphistomum species, Schistosomiasis (Bilharziasis) by Schistosoma species, dicrocoeliasis by Dicrocoelium species, Opisthochiasis by Opisthochis species, Eurytremiasis by Eurytrema species, gastrodisciasis by Gastrodiscus species, Paragonimiasis by Paragonimus species.

Others include platynosomiasis, pseudamphistomiasis, parafasciolopsiasis, catatropiasis, prosthogonimiasis, alaniasis, etc. (Cowper 1973; Brown, 1980; Soulsby 1986).

2.2. Role of Snails as Intermediate Hosts of Helminths

Snails act as intermediate hosts of pathogenic helminths of man and animals worldwide. This is so because development of larval stages of helminths take place in snails. The larval stages that develop in snails are miracidia, sporocyst I and II, radiae as Fasciola species and cercariae stage (Soulsby 1986).

2.3. Snails Host of Medical and Veterinary Helminths

In Western Kenya, Bulinus globosus is an intermediate host of Schistosoma haematobium. S. bovis develops in B. africanus, B. forskali and and B. truncatus (Southgate and Knowles, 1977). B. truncatus was susceptible to experimental infection with miracidia of S. haematobium (Southgate and Knowles 1977).

In Tanzania, B. africanus is the most important snail host for S. bovis, B. forskali at least locally may contribute significantly to the transmission of S. bovis (Southgate and Knowles, 1975; Mutani et al., 1983; Christensen et al., 1983).

Odei (1961) suggested that, B. forskali is a snail host of S. haematobium in Nigeria and in Congo (Akouala et al., 1988). B. forskali is widespread in West African countries and is an intermediate host of S. bovis in Ghana, and S. intercalatum in Cameroon (Wright et al., 1972).

In Nigeria, B. globosus is an intermediate host of S. haematobium (Hira, 1968), Biomphalaria pfefferi is the snail host of S. mansoni (Odei, 1961; Smith, 1982). Bulinus truncatus rohlfsi is also found in Nigeria as in other parts of the tropical world (Betterton, 1984). B. truncatus rohlfsi in Ghana as reported by Ansari (1973) is an intermediate host of S. haematobium. S. haematobium develops in Bulinus senegalensis in Senegal and in B. camerounensis in Cameroun (Hira, 1968; Appleton, 1978).

Lymnaea truncatula is snail intermediate host of Fasciola hepatica in Ethiopia (Goll and Scott, 1978). Lymnaea natalensis is for Fasciola gigantica which is present in Nigeria. L. columella had been suggested as a potential intermediate host of F. hepatica in South Africa and other countries in Europe (Brown et al., 1981).

Prosobranch snails among which are Semisulcospira libertina and Thiara granifera serves as important intermediate hosts of Paragonimus westermani, in Asia (Brown, 1980). In Nigeria,

Potadoma africanus is the snail intermediate host of P. westermani (Brown, 1980). Potadoma freethi P. africanus, P. sanctipaudi (= liberiensis) and Afropomus balanoidea serve as snail intermediate hosts of Paragonimus uterobilateralis in Liberia (Voelker and Vogel, 1973). Melanoides tuberculata serve as intermediate host of Paragonimus kellicoti in Asia (Brown, 1980).

Bulinus tropicus, B. truncatus, B. natalensis serve as snail intermediate hosts of Paramphistomum microbothrium and P. daubneyi in South Africa. B. truncatus, B. africanus, B. nasutus and Biophalaria pfeifferi are snail hosts of P. sukari (Garaber and Daynes 1974). B. forskali and B. globosus are snail hosts of P. togolense in Togo and Zambia respectively (Dinnik 1965; Alberet et al., 1978). Achatina felica (the giant African land snail) is the snail intermediate host of Angiostrongylus cantonensis and is the source of human infection (Mead, 1961).

Cleopatra bulimoides, and Lymnaea natalensis in Egypt serve as intermediate hosts of Gastrodiscus aegyptiacus (Brown, 1980). Other snail vectors, Biomphalaria sp., B. forskali and B. senegalensis were observed to have proved susceptible to G. aegyptiacus (Le Roux, 1958).

2.4. Generalized Life Cycle of Digenetic Trematodes

Eggs pass out with the faeces or urine of the definitive hosts. The eggs laid are operculated. Within the eggs larvae develop before the eggs are laid. When the eggs are in contact with water, they hatch to the first stage larva which is the miracidium. Hatching depends on environmental conditions like pH, Temp., etc. the development of larva (miracidium) in water is because, miracidia cannot withstand dessication (Ansari, 1973; Soulsby 1986). The miracidia are cilliated which aid them in swimming when looking for the intermediate host. The intermediate hosts are snails of the phylum Mollusca. Miracidia penetrate the molluscs using its spines. In the molluscs, development to sporocyst(s) takes place. Inside the molluscs, miracidia losses the cillia. Sporocyst(s) develop to radia(e). There could be two generations of radia.

The last larval stage in the intermediate host is the cercariae. They have tails, adapted to water environment, used for swimming. Cercariae shedded, loose the tail, encyst and become metacercariae(e) which is the infective stage in many species of trematodes, while in others it is cercariae which is the infective stage.

Definitive host become infected by ingesting of the metacercariae or in contact with the cercariae.

After ingestion there is excystation, and a young fluke emerge, penetrate the intestinal mucosa and migrate until they reach the predilection site where they mature to adult worms. Not all species of trematodes have the whole stages of the life cycle (Blood et al., 1979; Soulby, 1986).

2.4.1. Factors relating to release of Cercariae and infection of Man and Animals

Age of snail: Young snails are more susceptible to miracidia infection than the adult snails. Light is the stimulus for release of cercariae by snails. Snails can emit 1500 to 2000 cercariae daily for about 200 days (Wilcocks and Manson-Bahr, 1974), and infected snails become susceptible to adverse conditions than uninfected ones (Soulsby 1986). Active transmission of snail-borne diseases in East Africa takes place for 4 to 5 months, i.e. at the end of the main rainy season (April to August). Less transmission takes place during wet season (Cowper, 1971; Christensen et al., 1983).

High rate of infection of snail-borne diseases of man and animals occur at a velocity of range 15-60 cm/s in experimental animals. Optimum rate is 30 cm/s, below the range, few cercariae make contact with animals or man and above the range, cercariae which make contact with definitive hosts

tend to be swept away.

2.5. Ecology of Freshwater Snails

There are many factors which function as ecological factors. These are, climate, temperature, pH, oxygen tension, etc. Hardly, you see a habitat having the optimum conditions for snails survival. Tolerance to these cological factors differ with species of snails. As reported by Ndifon and Ukoli,(1989), snails are found in habitats having ecological factors that are suitable for their survival. They further explained that, the distribution of snails in the habitats is also a function of tolerance of ecological factors which corresponds to the finding of WHO, (1957); Watson, (1958); and Hira, (1966).

2.5.1. Snails habitats

Biomphalaria pfeifferi and B. sudanica are confined to lakes in Southern Rift Valley in Ethiopia. B. pfeifferi usually is found amongst vegetation in streams and also lives in stoney water courses in Upper Basin of Awash river (Maffi, 1960). Most population of B. pfeifferi can also be found in irrigation canals. Bulinus abyssinicus occur in southern Somalia Juba and Webi river

valleys, while B. truncatus can be found in dried irrigation canals, while is vice versa in Ethiopia. Frandsen (1979) reported that B. forskali is normally found in small pools and irrigation canals in Ethiopia, and was supported by Brown (1980). Ndifon and Ukoli (1989) found a widespread distribution and high frequency of B. globosus in all the habitats samples, which was attributable to the ability of the species to tolerate wide ranges of ecological factors (Brown, 1980). B. forskali was also widespread too (Ndifon and Ukoli, 1989). They also found that, B. pfeifferi was selfom recorded from temporary habitats, thus suggesting that habitat permanence may be an important factor in its occurrence. This apparent restriction to permanent habitats may be due to its poor aestivative ability (Brown, 1980). According to Brown (1980), B. pfeifferi is excluded from large areas of East and West Africa, because of its narrow ecological tolerance.

Lymnaea natalensis is also known to be widespread throughout Africa and is found in streams, canals, dams and rivers (Brown, 1980). Melanoides tuberculata is restricted to dams only (Smith, 1982, Ndifon and Ukoli 1989). M. tuberculata is not known to occur in habitats which frequently dry out and although it occurs in most parts of

Africa, it is known to be infrequently encountered in West Africa and absent from the Zaire basin (Brown, 1980).

2.5.2. Vegetation and Flood of Snail Habitats

Aquatic vegetation provides snails with a firm footing, a place for egg clusters deposition, and resting places, this provide opportunities for large populations to grow from only one or two floating snails caught up in it (Pike, 1987; Ndifon and Ukoli, 1989). Vegetation of snail habitats as reported by Brown (1980); Pike (1987) and Ndifon and Ukoli, (1989) are, algae, species of the families: Lamnaceae, Lentubulariaceae, Avaceae, Salvinaceae, Nymphaceae, Gramineae, Commelinaceae, Polygonaceae, Amaranthceae and Onograceae. They further stressed that, the percentage frequency of occurrence of the vegetation differs with habitats. Water level fluctuations can sometimes prevent snail breeding by affecting the adults or snail eggs attached to the vegetation (Wilcocks and Manson-Bahr 1974).

Floods resulting in river flows, of high volume and velocity can wash snails down stream resulting in the temporary disappearance of snails from some areas and sudden increase in numbers of snails in some areas. If these snails are shedding

cercariae, they continue to shed until death and so can set up infections in people and domestic animals (Cowper, 1973; Pike, 1987). Miracidia and cercariae can travel long distances with the river flow and still be capable of infecting snails and people respectively.

2.5.3. Temperature of Snail Habitats

All known snail intermediate hosts of helminths show tolerance to a considerable range of temperature fluctuations (Cowper, 1971). The threshold range is between 18^{o} to $32^{o}C$ with an optimum of 22^{o} to $26^{o}C$. Higher and lower temperatures can be tolerated for limited periods (Cowper, 1959; Wilcocks and Manson-Bahr, 1974).

In a recent study on B. *globosus*, it was found that mutation, fecundity and egg production increased with rising temperature, but that longevity was greater at lower temperatures thus balancing the reduced fecundity (Schiff, 1964; Pitchford and Du Toit, 1976; Christensen et al, 1983).

Temperature is a factor in the infection of snails by miracidia and subsequent development (Boray, 1963; Kendall, 1965; Appleton, 1978; Soulsby, 1986). In laboratory experiment, Pitchford (1981) found that cercaria positive rate in exposed

B. truncatus was highest between 20° and 30°C (Pitchford, 1981).

According to Brown (1980), water temperature probably also plays an important role in the distribution of snail species, since even in permanent but small fish ponds, mass mortalities of snail populations were often observed at the peak of the dry season when the ponds probably attained higher temperatures owing to small amount of water left in them.

2.5.4. Shade and Light Tolerance by Snails

Shaded and fast flowing areas are not suitable for snail establishment which explains the absence of snail-borne disease in forest areas (Wilcocks and Manson-Bahr, 1974), although it is not yet supported because B. truncatus was bred experimentally in total darkness in Iraq (Cowper, 1971; Brown, 1989), but population growth was restricted. Infected Biomphalaria species have been recovered from bottom of Lake Victoria at a depth of 12m (Cowper, 1971). Australorbis glabratus also had been bred in total darkness, therefore, light tolerance depends on snail species (Bony 1963; Prah and James, 1987).

Cercariae are photopositive while the snails are photonegative. After absorbing sufficient

sunlight enough to stimulate release of cercariae, snails sink down and the cercariae shedded swim to the surface of the water ready to penetrate definitive hosts.

Calcium: The element is necessary to form nacreous shell substance of any mollusc but as the vegetable food eating supplies most or all of the calcium requirement, the dissolved Ca in water is of little importance and it is not a practical factor in control. Aquatic snails can exist in water with a line content of less than 10ppm (Boray 1963; Cowper, 1971).

2.5.5. Hydrogen-Ion Concentration and Oxygen tension

Great fluctuations almost certainly occur in the pH of natural bodies of water often within 24 hours and the tolerance range of snails is a wide one as reported by WHO (1957), Kendall (1965) and Cowper (1971). In the laboratory, B. truncatus, Biomphalaria pfeifferi ruppellii and Australorbis glabratus can be bred between pH 4 and pH 10 (Watson, 1958).

If the oxygen tension is high, snails pseudobranch of a planorbid snail extract enough O_2 to enable the snail to live at a depth of 10m if food and protection from predators are satisfactory.

Oxygen tension is the chief limiting factor in snail ecology. Importance of O_2 tension was stressed by Cowper (1971) in a study of microhabitats in African molluscs, which explains the common preference of snails for undersurface of water lilly leaves by providing a high oxygen tension in a layer below it, due to photosynthesis, and temperature is a little cooler. Absence of snails in an area could be due to low oxygen tension (Smith 1982). Snail eggs and perhaps the young snails are more vulnerable than adult snails to low oxygen concentration (Cowper, 1971; Smith, 1982) and therefore absence of snails from polluted water-bodies.

2.5.6. Pollution of Waterbodies

Warm, still and shallow water with plenty of decomposing organic matter in it provides ideal conditions for snail habitats provided oxygen content of the water is not low. Three factors cause pollution in snail infected waters (Pike, 1987).

i) Pollution by decaying organic matter of either animal or vegetable origin.

ii) Pollution by human excreta or animal faeces and

iii) Pollution by industrial waste.

(i) and (ii) are favourable to snails as reported by Cowper (1971) and Smith (1982). (iii) is deliterous to snails as reported by Pike (1987).

2.5.7. Natural Predators of Snails

Mammalia like water voles, musk rats and mink may eat aquatic snails. So also with some pisces like, Tilapia and Gambusia species. Reports on Arthropoda as predators shows that, in the class. Insecta, Orders: Coleoptera, Odonata, Arachnida, Crustacea and some Annelida prey on fresh water snails (Cowper, 1971; Madsen, 1986). Some bacteria, fungi and rolifers are known to parasitize snails.

Certain species of Marisa, Ampullaria, Physa and Lymnaea may destroy egg nets. The ampullarid snail, Marisa cornuarietis may prey upon the eggs of or on young Biomphalaria alexandrina and on adult B. truncatus and Australorbis glabratus.

So far, keeping ducks on a circumscribed areas of water is the only method of biological control which has shown practical result (Cowper, 1971).

2.6. Control of Freshwater Snails

All methods used to prevent or eradicate snail-borne diseases depend upon interrupting the life-cycle of the parasite in such a way as to break transmission. Evidence indicates that snail control is the most effective single measure of control of snail-borne diseases as the snails represent the weakest link in the life-cycle of the parasites (WHO, 1960; Boray, 1963; Soulsby, 1986; WHO, 1989). The aim of snail control is to achieve a reduction in transmission of snail-borne diseases (Madsen, 1986). A complete eradication of snails in an area is an unrealistic goal. Snail control can be divided into three categories, i.e. chemical control by application of snail toxins (Molluscicides); environmental manipulations to render snail habitats unfavourable to snails and biological control by introduction of snail parasites, predators or competitors.

2.6.1. Chemical Snail Control

A great number of chemicals have been used as molluscicides in the past, but at present very few molluscicides are used in routine snail control, and virtually only one, namely niclosamide, (Bayluscide or Mollotox) is commercially available.

So some of the earlier used molluscicides still are used on a limited scale. Some of the most important of these are reviewed below.

Bayluscide EC 250 is an emulsifiable concentrate containing 25% (W/W and W/V) niclosamide. It is thermally stable and is quite stable to storage under tropical conditions (Andrews et al., 1983). Niclosamide is toxic to snail eggs as well as miracidia and cercariae of snail-borne diseases. Niclosamide is apparently not irritating to snails. From the available data, it is clear that it exerts most of its effect on respiration and carbohydrate metabolism.

Trifemorph (Frescon) has been formulated as an emulsifiable concentrate (e.c.) with various percentages of active ingredient. When distributed in water, the active ingredient becomes dispersed as five particles and the size of these particles infleunces the toxicity to snails. The lack of toxicity of Frescon to snail eggs is obviously a disadvantage.

Sodium pentachlorophenate (NaPCP) was used in Zimbabwe and during the first year of snail control in the Egypt-49 project. It is toxic to snail eggs as well as cercariae. Its activity may be lost due to absorption to mud.

Copper sulphate ($CuSO_4$) has been used extensively in snail control in the past. In the lab, it is very toxic to snails but under field conditions higher concentrations are needed, i.e. 30ppm. It also kills fish and imposes severe effect on the aquatic vegetation and invertebrate fauna.

Other compounds used as molluscides are: Copper Carbonate act as stomach poison when ingested by snails; Organotin compounds, nicotinanilide, Sodium 2,5-dichloro-4-bromophenol, named B2 acts on Oncomelania nosophora.

Many plant species have been reported to exert molluscicidal activity (Adewunmi and Sofowora, 1980) and of these, the most thoroughly studied is Phytolaca dodecandra also called Endod (Madsen, 1986). Unfortunately, this plant has a high toxicity to snail eggs. Kela et al (1989) found that young snails (Lymnaea natalensis) are less susceptible to plant extracts as plant molluscides than adults.

2.6.2. Environmental Snail Control

There exists several measures that may be taken to render habitats (ponds, pits, marshes, swamps, streams, irrigation schemes, rivers, lakes, valleys, dams, etc) unfavourable for the snails.

Some of these measures require drastic alterations of the environment (Cowper, 1971). These include:

a) Complete removal of all water inhabited by snails.
b) Rendering water sources unsuitable for snail breeding.
c) Enclosure of water to prevent contamination with excreta.
d) Periodic drying out of irrigation channels.
e) Weed clearance from the shorelines of the habitats.
f) Fluctuation of water level in storage ponds in order to strand snails.
g) Burying snails by ditch reconstruction (Madsen, 1986).

2.6.3. Biological Control of Freshwater Snails

Biological control is based on the introduction of natural enemies (i.e. predators of parasites) or competitors of the undesired species. Predators and parasites are organisms which kill the prey species, or in the case of snail parasites, cause sterilization, i.e. reproductive death (Madsen, 1983, 1985, 1986). A competitor will reduce the amount of one or more resources available for another species, the competitor will harm the

other species during the process of obtaining the resource which both species are trying to gain (i.e. interference competition).

Bacteria: There are some reports of Bacillus pinoti causing high mortality among Biomphalaria glabrata populations. Larvae or adults of many species of insects have been reported as snail predators. Waterbug, Limnogeton fieberi was reported to kill large numbers of snail in Egypt. Flies belonging to the family Sciomyzidae have been proved exclusively to be snail predator. The larvae prey on snails. A number of the larger freshwater crustaceans (Astacus fluviatilis, Cambarus sp., Potamon, sp.) are reported to eat snails but their use in biological control is limited as their diet is so varied (Madsen, 1986).

Marisa cornaurietis is an ampullarid snail which has been extensively studied in the lab and under field conditions in Puerto Rico. It destroys egg masses and juveniles of the intermediate host snail and it may prey on adult snail as well, because Marisa is a voracious consumer of aquatic plants and in this way, modifies the environment to the disadvantage of the snail intermediate host sp. In one study in Puerto Rico, Marisa reduced the Biomphalaria glabrata populations almost to extinction over 81 week observation period

(Radke, et al., 1961; Jobin, 1977). In Tanzania, Marisa was apparently eliminating thriving populations of Biomphalaria pfeifferi, Bulinus tropicus and Lymnaea natalensis, in an established small dam.

Helisoma duryi a planorbid snail, is a competitor of snail intermediate hosts. H. duryi controls Biomphalaria pfeifferi populations when the two species are left in the same waterbody. H. duryi also eliminated B. glabrata in simulated field trials in five artificial "banana drains" (Madsen, 1983 & 1985).

In several habitats, the ovoviviparous and pathogenetic thiarid snail, Thiara granifera eliminated Biomphalaria glabrata, in South East Asia. The same result was obtained in four field trials on St. Lucia. Unfortunately T. granifera can act as the molluscan host of the lung fluke Paragonimus westermani.

One drawback in the use of biological control, in reducing snail population is that, they have been mostly based on the results of laboratory experiments. Under laboratory conditions however, the biological balance is disturbed to to the disadvantage of the snail and therefore in nature where this imbalance does not occur, it seems unlikely that these parasites and predators will

be effective in exterminating the snails. Therefore a reduction in the snail population density may be observed. (Madsen and Thiongo, 1983).

One major problem in the control of snail-borne diseases that, different species of snails vary in susceptibility to different molluscides and techniques used for the control of one snail host may not be effective for another, even for snails of the same genus (Kela 1987; Kela et al, 1989).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Description of the study area

Zaria is located on a plateau at a height of about 2200 feet above sea level in the centre of North-Nigeria and is more than 400 miles away from the sea. Zaria which lies between 11°3'N, 7° 42'E latitude and longitude, possess a tropical continental climate (Mortimore, 1970). The man daily maximum temperature shows a major peak in April and a minor one in October. The daily maximum temperature rises gradually from January and attains its highest value in April, then drops rapidly to its lowest value in August as 2° lower peak. It rises again to its secondary peak in October. The mean minimum temperature rises from its lowest value in December to January, to its highest value in July to August. Zaria lies within a region which has a tropical guinea savana climate with distinct wet and dry season. The mean annual rainfall is 43.0 inches.

Vegetation of the area assumes various shades of green in the wet season and turns brown, pale or yellow in the dry season. The vegetation of

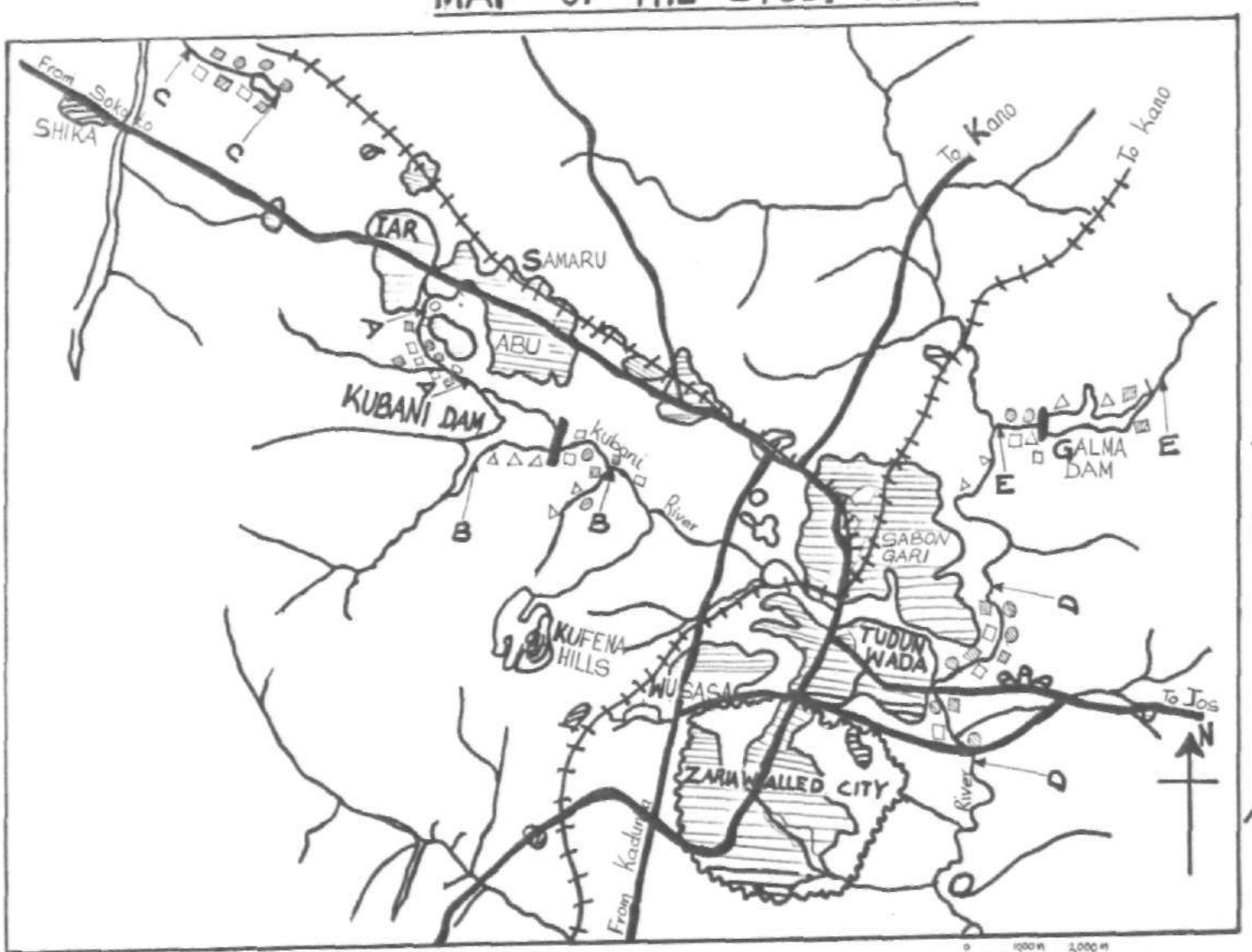
Zaria area is just that of a tropical guinea savana vegetation.

The culture of Zaria people as per agriculture is farming, cattle rearing and fishing. They practice both dry and wet season farming. In dry season, they do irrigation system of farming concentrating at rivers and dams. Cattle rearing and fishing also, is practised by Zaria people throughout the year. The major dams found in Zaria are: Zaria dam (Galma dam); University dam (Kubani dam); Shika dam and I.A.R. dam (Institute of Agricultural Research dam). (Fig 3).

3.2. Collection of snails

Water bodies sampled include those in Samaru stream (AA); University dam (BB); IAR dam (CC); Jos road river (DD) and Zaria dam (EE) (Fig. 3). All the areas were visited once monthly for a period of one year (July 90 to June 91). A 10 minutes man snail sampling method, for snail search was carried out in each location as described by Sodeman (1979). This was done by using long handled snail net. Where the net could not be used as in the case of shallow or stony water bodies, a careful visual examination of debris and aquatic vegetation was conducted. Every attempt was made

MAP OF THE STUDY AREA



KEY=:

$\overrightarrow{AA}$ = Samaru Stream

$\overrightarrow{BB}$ = University Dam

$\overrightarrow{CC}$ = IAR Dam

$\overrightarrow{DD}$ = Jos-road River

$\overrightarrow{EE}$ = Zaria Dam

= Settlement.

= Dam

Fig 3

Snail species key:

- ▨ = B. globosus
- □ = B. pfeifferi
- ○ = B. forskali
- ◍ = L. natalensis
- Δ = M. tuberculata

= Rail line

= River or stream

= Road

to examine as many freshwater bodies as possible throughout the area and the snails found were collected and transferred to plastic beakers for later visual morphological examination, and identification in the laboratory. Identification was based on snails' shell orientation and appearance. They were then taken to Dr. G. T. Ndifon and Prof. V. N. Okwuosa for identification.

To check whether the snails were infected, the snails were individually placed in petridishes, containing distilled water and left overnight under a 60w bulb light. The petri dishes were later examined for cercariae. Record of the type(s) of cercariae shedded were noted. Those snails not shedding cercariae were later crushed to see if they contain sprocyst I or II.

The cercariae shed were left in the refrigerator for one hour to relax and equilibrate. They were then picked one at a time using pasteur pipette and placed on glass slides, and then straightened using glycerine latex. Measurement of the body, ramus and furcus were made using a callibrated microscope. Only furcocercous cercariae were measured, because furcocercous cercariae are of medical and veterinary importance.

The scoring of type of vegetation was recorded based on the relative occurrence of the type of vegetation species found in all, few and none in the water bodies sampled in all the sites of the study area.

3.3. Measurement of pH and Temperature

The pH of the water bodies sampled in each site was measured using pH meter.

The average pH of the water bodies of each site/area sampled was recorded every month. A thermometer was used to measure the temperature of the waterbodies, in each site sampled. The average temperature of the water bodies sampled of each site was recorded every month of the study period. The regression and correlation coefficients were calculated and graphs representing the necessary tables were plotted.

3.4. Culture of Snails

Egg masses of *Bulinus forskali* and *B. globosus* were collected and kept in glass beakers set up as described by Shonekan (1961) for hatching. Glass beakers were observed at 3 days intervals for emergence of young snails, which took 20 days. Newly hatched snails were transferred into glass aquaria containing loosely packed mixture of washed pebbles, gravel and mud free sand at the bottom to a depth of about 15mm. *Elidea* weed, *Pistia stratiotes* and young aquatic sedge were introduced as shelter and resting places for young snails. Petioles of lettuce and ground dried pawpaw leaves were added as food. Water was changed at 24 hours

interval. Water from the stream was filtered using fine sieve before adding it to the glass aquaria.

3.5. Isolation of S. haematobium eggs

Urine of patients infected with Schistosoma haematobium was collected from Ahmadu Bello University Teaching Hospital (ABUTH) Zaria. Tap water was added to it in a beaker, and was left to sediment, after which the supernatant was decanted. Repeated exercise was done until blood in urine was completely washed off. The last sediment was filtered using a fine sieve. The supernatant with S. haematobium eggs in a petri dish was left for hatching in an incubator at 28°C in 0.9% normal saline.

3.6. Infection of Snails with Miracidia of S. haematobium

The laboratory-reared B. forskali and B. globosus were infected at 3 weeks of age with miracidia of S. haematobium. Infection was carried out on group basis. Each species group (B. forskali and B. globosus) were kept in glass beakers containing water at about 3mm depth. Each species group was made up of 10 snails. Forty miracidia counted under stereo-microscope were drawn out using a pasteur pipette,

into the glass beakers. The set up was allowed to stand for 3 hours after which the snails were taken out from the beakers and put back into the aquaria. The snails were continually observed for cercariae shedding up to 35 days post infection. Thereafter, they were crushed to see if they contain any developmental stages.

CHAPTER FOUR

RESULTS

4.1. Vegetation of Individual Sites

Vegetation of the individual sites of the study area which snails were seen attached to, is shown in Table I. The table shows the relative abundance of the vegetation type species of each site sampled for snails. The type of vegetation observed include green algae, brown red and blue green algae. Others observed are: Pristia stratiotes, Salvinia nymphellula, Nymphea lotus Ipomea aquatica, Echinochloa stagnina, Leersia luxandra, and species of the family Cyperaceae. N. lotus, I. aquatica, P. stratioles, E. stagnina and L. luxandria were collected inside water bodies. Species of the family Cyperaceae were observed at the edges of the waterbodies and cannals. The rest, i.e. algae species were observed right incide and edges of waterbodies of the sites sampled.

TABLE I : VEGETATION OF THE SITES SAMPLED DURING THE STUDY PERIOD

TYPE OF VEGETATION	SAMARU STREAM	UNIVERSITY DAM	I. A. R. DAM	ZARIA DAM	JOS ROAD RIVER
Green algae	++	+++	+	+	++
Brown algae	+	+++	-	-	+++
Red algae	+	++	+	-	+
Blue green algae	+	+	++	+	+
Pistia stratiotes	+	+	-	-	++
Salvinia nymphellula	+	+	++	+	+
Nymphea lotus	++	++	+++	+	+++
Ipomea aquatica	+++	+++	+++	++	++
Echinochloa stagnina	++	+	+++	-	++
Leersia luxandra	+	+++	++	+++	++
Species of Cyperaceae	++	++	+++	+++	+

KEY: +++ = Plenty in abundance
++ = Moderate in abundance
+ = Few in abundance
- = Not present

4.2. Snail of the Study Area

Five different species of snails were collected from the study area. The snails identified were Bulinus globosus, Bulinus forskali, Lymnaea natalensis Melanoides tuberculata and Biomphalaria pfeifferi.

All together, 852 snails were collected in Zaria area, out of which 252 (29.7%) were positive for cercariae shedding. Oout of the 852 snails collected, 380 (44.6%) snails were Bulinus globosus out of which 154 (40.5%) were positive; 146 (17.1%) were Lymnaea natalensis, out of which 28 (19.2%) were positive; 165 (19.4%) were Biomphalaria pfeifferi out of which 55 (33.3%) were positive for cercariae shedding; 49 (5.8%) were Bulinus forskali; 3 (6.1%) were positive and 112 (13.1%) were collected from Samaru stream, 315 (37.0) were from the University dam; 41(4.8%) were collected from I.A.R. dam; 152 (17.8%) were collected from Jos road river and 45 (5.3%) were from Zaria dam (see Tables 2-7). Total number of snails collected from each site of the study area, species of snails and their percentage positivity for cercariae shedding are shown in Tables 3 to 7. Different species of snails collected, number positive and % positivity for all the months samples of the study area is shown in Table 8.

TABLE 2 : TOTAL NUMBER OF SNAILS COLLECTED FROM THE STUDY AREA

SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE
Bulinus globosus	380 (44.6)*	154	40.5
Lymnaea natalensis	146 (17.1)	28	19.2
Biomphalaria pfeifferi	165 (19.4)	55	33.3
Bulinus forskali	49 (5.8)	3	6.1
Melanoides tuberculata	112 (13.1)	12	10.7
TOTAL	852	252	29.6

*Numbers in paranthesis represent percentage of total number of snails collected.

TABLE 3 : TOTAL NUMBER OF SNAILS COLLECTED FROM SAMARU STREAM

SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE
B. globosus	153	53	34.6
L. natalensis	44	8	18.2
Biomphalaria pfeifferi	53	17	32.1
Bulinus forskali	49	3	6.1
TOTAL	299 (35.1%)	81	27.1

TABLE 4 : TOTAL NUMBER OF SNAILS COLLECTED FROM THE UNIVERSITY DAM

SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE
B. globosus	116	50	43.1
L. natalensis	37	8	21.6
Biomphalaria pfeifferi	50	16	32.0
Melanoides tuberculata	112	12	10.7
TOTAL	315 (37.0%)	86	27.3

TABLE 5 : TOTAL NUMBER OF SNAILS COLLECTED FROM I.A.R. DAM

SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE
B. globosus	17	9	52.9
L. natalensis	12	3	25.0
B. pfeifferi	12	2	16.7
TOTAL	41 (4.8%)	14	34.1

TABLE 6 : TOTAL NUMBER OF SNAILS COLLECTED FROM JOS ROAD RIVER

SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE
B. globosus	73	32	43.8
L. natalensis	40	6	15.0
B. pfeifferi	39	18	46.2
TOTAL	152 (17.8%)	56	36.8

TABLE 7 : TOTAL NUMBER OF SNAILS COLLECTED FROM ZARIA DAM

SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE
B. globosus	21	10	47.6
L. natalensis	13	3	23.1
B. pfeifferi	11	2	18.2
TOTAL	45 (5.3%)	15	33.3

TABLE 8 : SNAIL SPECIES COLLECTED AT EACH MONTH SAMPLED FROM JULY 1990 TO JUNE 1991 IN ZARIA AREA.

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	MEAN TEMP. IN °C	pH MEAN
JULY '90	B. globosus	27	8	29.6	22.2°	6.0
	L. natalensis	12	3	25.0		
	B. pfeifferi	11	2	18.1		
AUGUST '90	B. globosus	21	7	33.3		
	L. natalensis	7	1	14.3	22.2°	6.0
	B. pfeifferi	4	1	25.0		
SEPTEMBER '90	0	0	0	0	22.2°	5.8
	B. globosus	52	17	32.7		
OCTOBER '90	L. natalensis	9	1	11.1		
	B. pfeifferi	23	10	43.5	22.4°	6.0
	B. forskali	3	0	00.0		
	M. tuberculata	8	0	00.0		
	B. globosus	59	27	45.8		
NOVEMBER '90	L. natalensis	10	1	10.0		
	B. pfeifferi	27	16	59.3	22.3°	6.2
	B. forskali	3	0	00.0		
	M. tuberculata	12	0	00.0		

TABLE 8 CONT'D. : SNAIL SPECIES COLLECTED AT EACH MONTH SAMPLED FROM JULY 1990 TO JUNE 1991 IN ZARIA AREA

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	MEAN TEMP. IN ^{o}C	pH MEAN
DECEMBER '90	B. globosus	54	26	48.1	22.3°	5.9
	L. natalensis	12	2	16.7		
	B. pfeifferi	19	8	42.1		
	B. forskali	9	2	22.2		
	M. tuberculata	10	2	20.0		
JANUARY '91	B. globosus	27	7	25.9	19.0°	5.8
	L. natalensis	11	1	9.1		
	B. pfeifferi	6	1	16.7		
	M. tuberculata	23	3	13.0		
FEBRUARY '91	B. globosus	33	12	36.4	21.6°	5.7
	L. natalensis	18	5	27.8		
	B. pfeifferi	18	6	33.3		
	M. tuberculata	20	5	25.0		
MARCH '91	B. globosus	25	9	36.0	20.2°	5.9
	L. natalensis	15	2	13.3		
	B. pfeifferi	10	0	00.0		
	M. tuberculata	8	2	25.0		

TABLE 8 CONT'D. : SNAIL SPECIES COLLECTED AT EACH MONTH SAMPLED FROM JULY 1990 TO JUNE 1991 IN ZARIA AREA

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	MEAN TEMP. IN °C	pH MEAN
	B. globosus	32	18	56.3		
	L. natalensis	19	5	26.3		
APRIL '91	B. pfeifferi	19	7	36.8	**28.0°**	6.0
	B. forskali	4	1	25.0		
	M. tuberculata	10	0	00.0		
	B. globosus	27	13	48.0		
	L. natalensis	19	5	26.3		
MAY '91	B. pfeifferi	13	3	23.1	**24.5°**	6.0
	B. forskali	10	0	00.0		
	M. tuberculata	9	0	00.0		
	B. globosus	23	10	43.5		
	L. natalensis	14	2	14.3		
	B. pfeifferi	15	2	13.3	**22.9°**	6.0
	B. forskali	20	0	00.0		
	M. tuberculata	12	0	00.0		

4.3. Snail Collected from Individual Sites and Types of Cercariae being Shed

Snails that were collected from individual sites of the study area differ in abundance, distribution and cercariae shedding. The number of different species of snails collected from each site, percentage infectivity and number positive of each species collected at each month of the study period are shown in Tables 9-13. From the tables, it is seen that Bulinus globosus was the species most abundant, followed by Biomphalaria pfeifferi, Lymnaea natalensis, Melanoides tuberculata and Bulinus forskali.

B. globosus from the individual sites sampled was shedding furcocercous cercariae, gymnocephalous cercariae and lipodermal cercariae. Lymnaea natalensis was shedding gymnocephalous cercariae and furcocercous cercariae. Biomphalaria pfeifferi from Samaru stream was shedding gymnocephalous and furcocercous cercariae while Biomphalaria pfeifferi from I.A.R., Zaria and University dams were shedding furcocercous cercariae and from Jos road river, was shedding as that of Samaru stream. B. forskali was collected only from stream, and was shedding only furcocercous cercariae. Melanoides tuberculata was found in University dam and was shedding only lipodermal cercariae. (Fig 4).

Measurements of the cercariae's body, ramus and furcus, shed by B. globosus, L. natalensis and Biomphalaria pfeifferi are shown in Tables 14-16.

Types of cercariae shedded by snails sampled from the study area.

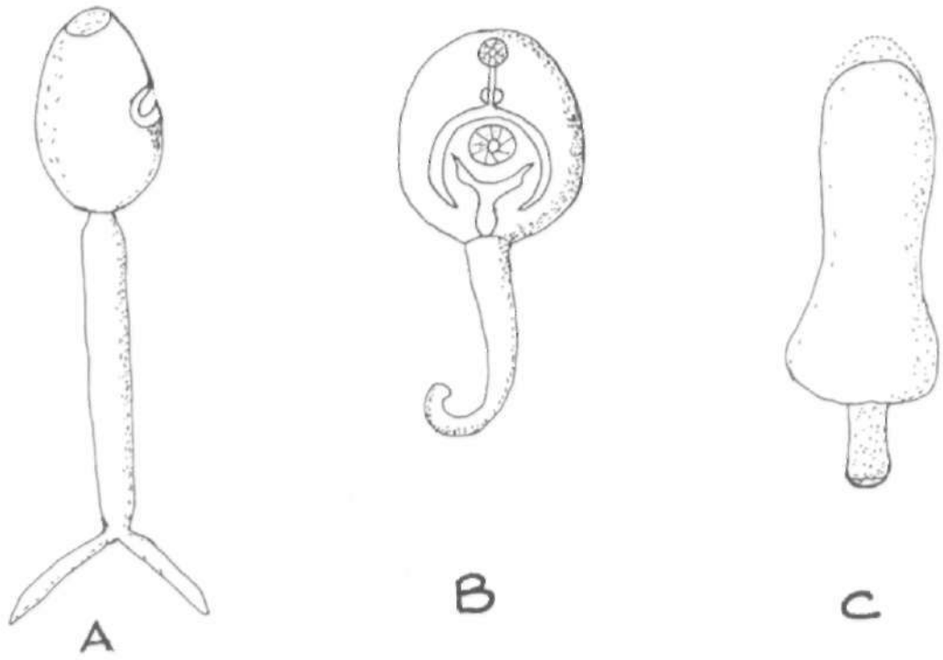


Fig. 4. A- Furcocercous cercariae, B- Gymnocephalous cercariae and C- Lipodermal cercariae

TABLE 9 : SPECIES OF SNAILS COLLECTED FROM SAMARU STREAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
JULY '90	B. globosus	15	4	28.8	22.5°C	5.5
	L. natalensis	4	1	25.0		
	B. pfeifferi	6	2	33.3		
AUGUST 90	B. globosus	10	3	30.0	22.0°	6.0
	L. natalensis	2	0	00.0		
	B. pfeifferi	1	0	00.0		
SEPTEMBER 90	0	0	0	0	22.0°	6.0
OCTOBER '90	B. globosus	24	7	29.1	22.0°	5.5
	L. natalensis	1	0	00.0		
	B. pfeifferi	10	3	30.0		
	B. forskali	3	0	00.0		
NOVEMBER '90	B. globosus	21	5	23.8	21.5°C	6.0
	L. natalensis	1	0	00.0		
	B. pfeifferi	8	4	50.0		
	B. forskali	23	0	00.0		

TABLE 9 CONT'D. : SPECIES OF SNAILS COLLECTED FROM SAMARU STREAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE PH
DECEMBER 90	B. globosus	23	13	56.5	22.0°	6.0
	L. natalensis	5	1	20.0		
	B. pfeifferi	4	2	50.0		
	B. forskali	9	2	55.2		
	B. globosus	13	3	23.1		
JANUARY '91	L. natalensis	1	1	100.0	19.0°	6.0
	B. pfeifferi	1	0	00.0		
FEBRUARY '91	B. globosus	10	4	40.0		
	L. natalensis	5	1	20.0	22.0°	5.5
	B. pfeifferi	3	1	33.3		
	B. globosus	11	4	36.4		
MARCH '91	L. natalensis	3	1	33.3	20.0°	6.0
	B. pfeifferi	2	0	00.0		
	B. globosus	13	5	38.7		
APRIL '91	L. natalensis	8	2	25.0	28.0°	6.0
	B. pfeifferi	10	3	30.0		
	B. forskali	4	1	25.0		

TABLE 9 CONT'D. : SPECIES OF SNAILS COLLECTED FROM SAMARU STREAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
MAY '91	B. globosus	8	3	37.5	25.0°	6.0
	L. natalensis	8	1	12.5		
	B. pfeifferi	4	1	25.0		
	B. forskali	10	0	00.0		
JUNE '91	B. globosus	5	2	40.0	23.0°	6.0
	L. natalensis	6	0	00.0		
	P. pfeifferi	4	1	25.0		
	B. forskali	20	0	00.0		

TABLE 10 : SPECIES OF SNAILS COLLECTED FROM UNIVERSITY DAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP IN °C	AVERAGE pH
	B. globosus	10	3	30.0		
JULY '90	L. natalensis	4	1	25.0	22.0°	6.0
	B. pfeifferi	2	0	00.0		
AUGUST	B. globosus	6	2	33.3		
	L. natalensis	2	0	00.0	21.5°	5.5
	E. pfeifferi	1	0	00.0		
SEPTEMBER '90	0	0	0	21.5°	21.5°	5.5
	B. globosus	20	7	35.0		
OCTOBER '90	L. natalensis	4	1	25.0	21.5°	5.5
	B. pfeifferi	8	3	37.0		
	M. tuberculata	8	0	00.0		
	B. globosus	28	17	60.0		
NOVEMBER '90	L. natalensis	5	0	00.0	21.5°	6.5
	B. pfeifferi	11	6	54.0		
	M. tuberculata	12	0	00.0		
DECEMBER '90	B. globosus	25	10	40.0		
	L. natalensis	4	1	25.0	22.2°	6.0
	B. pfeifferi	10	3	30.0		
	M. tuberculata	10	2	20.0		

TABLE 10 CONT'D. : SPECIES OF SNAILS COLLECTED FROM UNIVERSITY DAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
JANUARY '91	M. tuberculata	23	3	13.0	18.5°	6.5
FEBRUARY '91	B. globosus	5	1	20.0	22.0°	6.0
	L. natalensis	3	1	33.3		
	B. pfeifferi	8	2	25.0		
	M. tuberculata	20	5	25.0		
MARCH '91	B. globosus	3	1	33.3	20.0°	6.0
	L. natalensis	4	0	00.0		
	B. pfeifferi	2	0	00.0		
	M. tuberculata	8	2	25.0		
APRIL '91	B. globosus	8	5	62.5	28.0°	6.0
	L. natalensis	4	1	20.0		
	B. pfeifferi	4	2	50.0		
	M. tuberculata	10	0	00.0		
MAY '91	B. globosus	6	2	33.3	24.0°	6.0
	L. natalensis	4	2	50.0		
	B. pfeifferi	2	0	00.0		
	M. tuberculata	9	0	00.0		

TABLE 10 CONT'D. : SPECIES OF SNAILS COLLECTED FROM UNIVERSITY DAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE PSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
	B. globosus	5	2	40.0		
JUNE '91	L. natalensis	3	1	33.3	23.0°	6.0
	B. pfeifferi	2	0	00.0		
	M. tuberculata	12	0	00.0		

TABLE 11 : SNAIL SPECIES COLLECTED FROM I.A.R. DAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN ^{o}C	AVERAGE pH
JULY '90	0	0	0	0	22.0°	6.0
AUGUST '90	0	0	0	0	22.0°	6.0
SEPTEMBER '90	0	0	0	0	22.5°	6.0
OCTOBER '90	0	0	0	0	23.0°	6.5
NOVEMBER '90	0	0	0	0	23.0°	6.5
DECEMBER '90	0	0	0	0	22.5°C	6.0
JANUARY '91	B. globosus	2	1	50.0	19.0°	6.0
	L. natalensis	2	0	00.0		
	B. pfeifferi	3	1	33.3		
FEBRUARY '91	B. globosus	3	2	66.7	21.0°	5.5
	L. natalensis	3	1	33.3		
	B. pfeifferi	2	1	50.0		
MARCH '91	B. globosus	2	1	50.0	20.0°	6.0
	L. natalensis	1	0	00.0		
	B. pfeifferi	2	0	00.0		

TABLE 11 CONT'D. : SNAIL SPECIES COLLECTED FROM I.A.R. DAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
APRIL '91	B. globosus	3	2	66.7	28.0°	6.0
	L. natalensis	2	0	00.0		
	B. pfeifferi	1	0	00.0		
MAY '91	B. globosus	2	1	50.0	24.0°	6.0
	L. natalensis	2	1	50.0		
	B. pfeifferi	1	0	00.0		
JUNE '91	B. globosus	5	2	40.0	23.0°	6.0
	L. natalensis	2	1	50.0		
	B. pfeifferi	3	0	00.0		

TABLE 12 : DIFFERENT SPECIES OF SNAILS COLLECTED FROM ZARIA DAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
JULY '90	0	0	0	0	22.0°	6.0
AUGUST '90	0	0	0	0	22.0°	6.0
SEPTEMBER '90	0	0	0	0	23.0°	5.5
OCTOBER '90	0	0	0	0	22.5°	6.5
NOVEMBER '90	0	0	0	0	23.0°	6.0
DECEMBER '90	0	0	0	0	22.0°	6.0
	B. globosus	4	1	25.0		
JANUARY 91	L. natalensis	2	0	00.0	19.5°	5.5
	B. pfeifferi	1	0	00.0		
	B. globosus	5	2	40.0		
FEBRUARY '91	L. natalensis	3	1	33.0	21.5°	6.0
	B. pfeifferi	2	1	50.0		
	B. globosus	3	1	33.3		
MARCH '91	L. natalensis	4	1	25.0	20.5°	6.0
	B. pfeifferi	2	0	00.0		

TABLE 12 CONT'D. : DIFFERENT SPECIES OF SNAIL COLLECTED FROM ZARIA DAM (JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
APRIL '91	B. globosus	4	3	75.0		
	L. natalensis	2	1	50.0	28.0°	6.0
	B. pfeifferi	2	1	50.0		
	B. globosus	3	2	66.7		
MAY '91	L. natalensis	1	0	00.0	25.0°	6.0
	B. pfeifferi	2	0	00.0		
JUNE '91	B. globosus	2	1	50.0		
	L. natalensis	1	0	00.0	23.0°	6.0
	B. pfeifferi	2	0	00.0		

TABLE 13 : SNAIL SPECIES COLLECTED FROM JOS SIDE ROAD RIVER
(JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
JULY '90	B. globosus	2	1	50.0		
	L. natalensis	4	1	25.0	22.5°	6.5
	B. pfeifferi	3	0	00.0		
AUGUST '90	B. globosus	5	2	40.0		
	L. natalensis	3	1	33.3	22.5°	6.5
	B. pfeifferi	2	1	50.0		
SEPTEMBER '90	0	0	0	0	22.0°	6.0
	B. globosus	8	3	37.5		
OCTOBER '90	L. natalensis	4	0	00.0	23.0°	6.0
	B. pfeifferi	5	3	60.0		
	B. globosus	10	5	50.0		
NOVEMBER '90	L. natalensis	4	1	25.0	22.5°	6.0
	B. pfeifferi	8	6	75.0		
	B. globosus	6	3	50.0		
DECEMBER '90	L. natalensis	3	0	00.0	23.0°	5.5
	B. pfeifferi	5	3	60.0		
	B. globosus	8	2	25.0		
JANUARY '91	L. natalensis	6	0	00.0	19.0°	5.0
	B. pfeifferi	1	0	00.0		

TABLE 13 CONT'D. : SNAIL SPECIES COLLECTED FROM JOS SIDE ROAD RIVER
(JULY 1990 TO JUNE 1991)

MONTH	SNAIL SPECIES	NUMBER EXAMINED	NUMBER POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP. IN °C	AVERAGE pH
	B. globosus	10	3	30.0		
FEBRUARY '91	L. natalensis	4	1	25.0	21.5°	5.5
	B. pfeifferi	3	1	33.3		
	B. globosus	6	2	33.3		
MARCH '91	L. natalensis	3	0	00.0	20.5°	5.5
	B. pfeifferi	2	0	00.0		
	B. globosus	4	3	75.0		
APRIL '91	L. natalensis	3	1	33.3	27.5°	6.0
	B. pfeifferi	2	1	50.0		
	B. globosus	8	5	62.5		
MAY '91	L. natalensis	4	1	25.0	24.5°	6.0
	B. pfeifferi	4	2	50.0		
	B. globosus	6	3	50.0		
JUNE '91	L. natalensis	2	0	00.0	22.5°	6.0
	B. pfeifferi	4	1	25.0		

TABLE 14 : MEASUREMENT OF CERCARIAE (IN MICRONS) SHEDDED BY B. GLOBOSUS

BODY LENGTH (μ)	BODY BREADTH (μ)	RAMUS LENGTH (μ)	RAMUS BREADTH (μ)	FURCUS LENGTH (μ)	FURCUS BREADTH (μ)
160	56	214	30	76	14
168	60	216	28	72	16
164	58	212	34	70	10
152	54	216	36	76	14
154	58	210	34	72	10
154	60	216	34	70	16
160	56	212	38	76	10
158.57 ± 6.19	57.43 ± 2.23	213.71 ± 2.43	33.43 ± 3.41	73.14 ± 2.79	12.86 ± 2.79

Correspond to cercariae of ≤ haematobium

TABLE 15 : MEASUREMENT OF CERCARIAE (IN MICRONS)

by L. NATALENSIS

BODY LENGTH (μ)	BODY BREADTH (μ)	RAMUS LENGTH (μ)	RAMUS BREADTH (μ)	FURCUS LENGTH (μ)	FURCUS BREADTH (μ)
158	54	212	30	78	10
160	56	210	32	74	12
156	58	212	34	78	10
168	52	210	32	76	8
154	50	208	36	78	14
160	56	210	36	74	12
158	52	210	32	74	12
159.14 ± 4.45	54.00 ± 2.83	210.29 ± 1.38	33.14 ± 2.27	76.00 ± 2.00	11.14 ± 1.95

= Corresponds to cercariae of S. bovis

TABLE 16 : MEASUREMENT OF CERCARIAE (IN MICRONS)

SHEDDED BY B. PFEIFFERI

BODY LENGTH (μ)	BODY BREADTH (μ)	RAMUS LENGTH (μ)	RAMUS BREADTH (μ)	FUROUS LENGTH (μ)	FUROUS BREADTH (μ)
160	60	212	36	78	10
168	58	208	34	76	14
168	54	210	36	74	12
164	60	206	30	76	10
162	58	214	28	72	14
166	58	216	30	78	12
164.67 ± 3.27	58.00 ± 2.19	211.00 ± 3.74	32.33 ± 3.44	75.67 ± 2.34	12.00 ± 1.79

Corresponds to cercariae of S. mansoni

4.4. Overall monthly collection of snails and snail infectivity

The overall monthly collection of snails and their infectivity during the study period is shown in Table 17. In September, 1990, nothing was collected from either of the sites. The highest monthly collection and infectivity was in November 90 and December 90 (Table 17). Percentage infectivity was highest in November, December 90 and April 91.

The monthly collection of snails from individual sites and their infectivity is shown in Tables 18-22. Samaru stream, University dam and Jos road river, snails were constantly collected every month except the month of September, 1990. (See Tables 18-22).

4.5. Variations of pH and Temperature of sampled sites

pH and temperature variations of the individual sites sampled were recorded as the average pH and temperature of the waterbodies sampled in the sites and are shown in Tables 9 to 13. There was not much variation in pH compared to that of the temperature. Highest average pH encountered during the study period was pH 6.5 in all the sites except Samaru stream. The least value for average pH was pH 5.5 in all the

TABLE 17 : TOTAL NUMBER OF SNAILS COLLECTED AT EACH MONTH FROM ZARIA AREA (JULY 1990 TO JUNE 1991)

MONTH	TOTAL NO. EXAMINED	TOTAL NO. POSITIVE	PERCENTAGE POSITIVE	MEAN TEMP IN ^{o}C	MEAN pH
JULY '90	50	13	26.0	22.2°	6.0
AUGUST '90	32	9	28.1	22.0°	6.0
SEPTEMBER '90	0	0	0	22.0°	5.8
OCTOBER '90	95	28	29.5	22.4°	6.0
NOVEMBER '90	111	44	39.6	22.3°	6.2
DECEMBER '90	104	40	38.5	22.3°	5.9
JANUARY '91	67	12	17.9	19.0°	5.8
FEBRUARY '91	89	28	31.5	21.6°	5.7
MARCH '91	58	13	22.4	20.2°	5.9
APRIL '91	84	31	36.9	28.0°	6.0
MAY '91	78	21	26.9	24.5°	6.0
JUNE '91	84	14	16.7	22.9°	6.0

TABLE 18 : TOTAL NUMBER OF SNAILS COLLECTED AT EACH MONTH FROM ZARIA DAM

MONTH	TOTAL NO. EXAMINED	TOTAL NO. POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP IN °C	AVERAGE pH
JULY 90	0	0	0	22.0°	6.0
AUG. 90	0	0	0	22.0°	6.0
SEPT. 90	0	0	0	23.0°	5.5
OCT. 90	0	0	0	22.5°	6.5
NOV. 90	0	0	0	23.0°	6.0
DEC. 90	0	0	0	22.0°	6.0
JAN. 91	7	1	14.3	19.5°	5.5
FEB. 91	10	4	40.0	21.5°	6.0
MAR. 91	9	2	22.2	20.5°	6.0
APRIL 91	8	5	62.5	28.5°	6.0
MAY 91	6	2	33.3	25.0°	6.0
JUNE 91	5	1	20.0	23.0°	6.0

TABLE 19 : TOTAL NUMBER OS SNAILS COLLECTED AT EACH MONTH FROM I.A.R. DAM

MONTH	TOTAL NO. EXAMINED	TOTAL NO. POSITIVE	PERCENTAGE POSITIVE	AVERAGE	
				TEMP IN °C	pH
JUL. 90	0	0	0	22.0°	6.0
AUG. 90	0	0	0	22.5°	6.0
SEPT. 90	0	0	0	22.5°	6.0
OCT. 90	0	0	0	23.0°	6.5
NOV. 90	0	0	0	23.0°	6.5
DEC. 90	0	0	0	22.5°	6.0
JAN. 91	7	2	28.6	19.0°	6.0
FEB, 91	8	4	50.0	21.0°	5.5
MARCH 91	5	1	20.0	20.0°	6.1
APRIL 91	6	2	33.3	28.0°	6.0
MAY 91	5	2	40.0	24.0°	6.0
JUNE 91	10	3	30.0	23.0°	6.0

TABLE 20 : TOTAL NUMBER OS SNAILS COLLECTED FROM UNIVERSITY DAM AT EACH MONTH

MONTH	TOTAL NO. EXAMINED	TOTAL NO. POSITIVE	PERCENTAGE POSITIVE	AVERAGE TEMP IN °C	AVERAGE pH
JULY 90	16	4	25.0	22.0°	6.0
AUG. 90	2	22.2	21.5°	21.5°	5.0
SEPT. 90	0	0	0	21.5°	5.5
OCT. 90	40	11	27.5	21.5°	5.5
NOV. 90	56	23	41.1	21.5°	6.5
DEC. 49	16	32.7	22.7	22.0°	6.0
JAN. 91	23	3	13.0	18.5°	6.5
FEB. 91	36	9	25.0	22.0°	6.0
MARCH 91	17	3	17.6	20.0°	6.0
APRIL 91	26	8	30.8	28.0°	6.0
MAY 91	21	4	19.0	24.0°	6.0
JUNE 91	22	3	13.6	23.0°	6.0

TABLE 21 : Total number of snails collected at each month from Samaru Stream

MONTH	TOTAL NO. EXAMINED	TOTAL NO. POSITIVE	PERCENTAGE POSITIVE	AVERAGE	
				TEMP. IN ^{o}C	pH
JUL. 90	25	7	28.0	22.5^{o}	5.5
AUG. 90	13	3	23.1	22.0^{o}	6.0
SEPT. 90	-	-	-	22.0^{o}	6.0
OCT. 90	38	10	26.3	22.0^{o}	5.5
NOV. 90	33	9	27.3	21.5^{o}	6.0
DEC. 90	41	18	43.9	22.0^{o}	6.0
JAN. 91	15	4	26.7	19.0^{o}	6.0
FEB. 91	18	6	33.3	22.0^{o}	5.5
MARCH 91	16	5	31.3	20.0^{o}	6.0
APRIL 91	35	11	31.4	28.0^{o}	6.0
MAY 91	30	5	16.7	25.0^{o}	6.0
JUNE 91	35	3	8.6	23.0^{o}	6.0

TABLE 22 : Total number of snails collected at each month from Jos road river

MONTH	TOTAL NO. EXAMINED	TOTAL NO. POSITIVE	PERCENTAGE POSITIVE	AVERAGE	
				TEMP.IN ^{o}C	pH
JUL. 90	9	2	22.2	22.5^{o}	6.5
AUG. 90	10	4	40.0	22.5^{o}	6.5
SEPT. 90	-	-	-	22.0^{o}C	6.0
OCT. 90	17	6	35.3	23.0^{o}	6.0
NOV. 90	22	12	54.5	22.5^{o}	6.0
DEC. 90	14	6	42.9	23.0^{o}	5.1
JAN. 91	15	2	13.3	19.0^{o}	5.0
FEB. 91	17	5	29.4	21.5^{o}	5.5
MARCH 91	11	2	18.2	20.5^{o}	5.5
APRIL 91	9	5	55.6	27.5^{o}	6.0
MAY 91	16	8	50.0	24.5^{o}	6.0
JUNE 91	12	4	33.3	22.5^{o}	6.0

sites sampled. Highest average pH value recorded in Samary strea was pH 6.0.

Temperature was changing throughout the study period. The highest average temp value was 28.5°C in Zaria dam and the least average value was 18.5°C in University dam. The least value in other sites varies up to 19.5°C, so also the highest value differs, i.e. 27.5°C, and 28.0°C in others.

The highest mean value for pH of the study area was pH 6.0. The least mean value was pH 5.7 and highest mean value for temperature of the study area was 28.0°C while the least value recorded was 19.0°C in April and January respectively.

Snails species were observed to show differences in length of days for shedding cercariae. Some species shed for 3 days and die. Some for one week, others for one month, before dying.

pH and temperature below pH4 and 18°C were not favourable for snail survival.

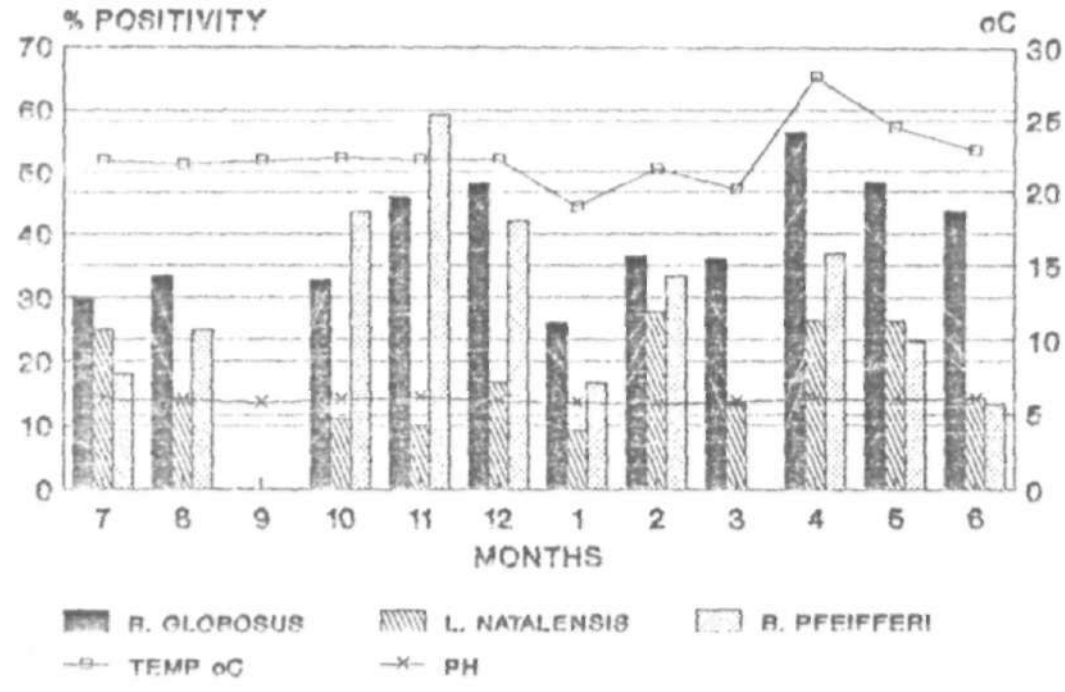
4.6. Percentage infection, Temperature, and PH Variations

Percentage positivity for 3 abundant snails can be seen in Fig. 4.1. In September no sample was sampled because, collection was done immediately after a heavy down-pour of rainfall in Zaria area. Temperature variation, attains its highest peak in April, lowest in January (Fig. 4.3). Monthly variation of the snails that were shedding cercariea in seen in Fig. 4.2. PH variation in the months of sampling period is seen in fig. 4.4. Highest pH recorded was in November.

4.7. Laboratory experiments

Laboratory reared snails (*B. globosus* and *B. forskali*) infected with *Schistosoma haematobium* miracidia under laboratory conditions, were observed up to day 35 post infection, at a temperature of 26°C. *B. globosus* as control was found shedding furcocercous cercariae at day 25 post infection with miracidia of *S* haematobium while *B.* forskali as the experimental snail under laboratory conditions was not susceptible to *S. haematobium* miracidia infection. Up to day 35, *B. forskali* was not shedding furcocercous cercariae.

FIG. 4.1 PERCENTAGE POSITIVITY FOR
3 ABUNDANT SPECIES OF SNAILS.



67

FIG 4.2 MONTHLY VARIATION IN POSITIVE SNAILS

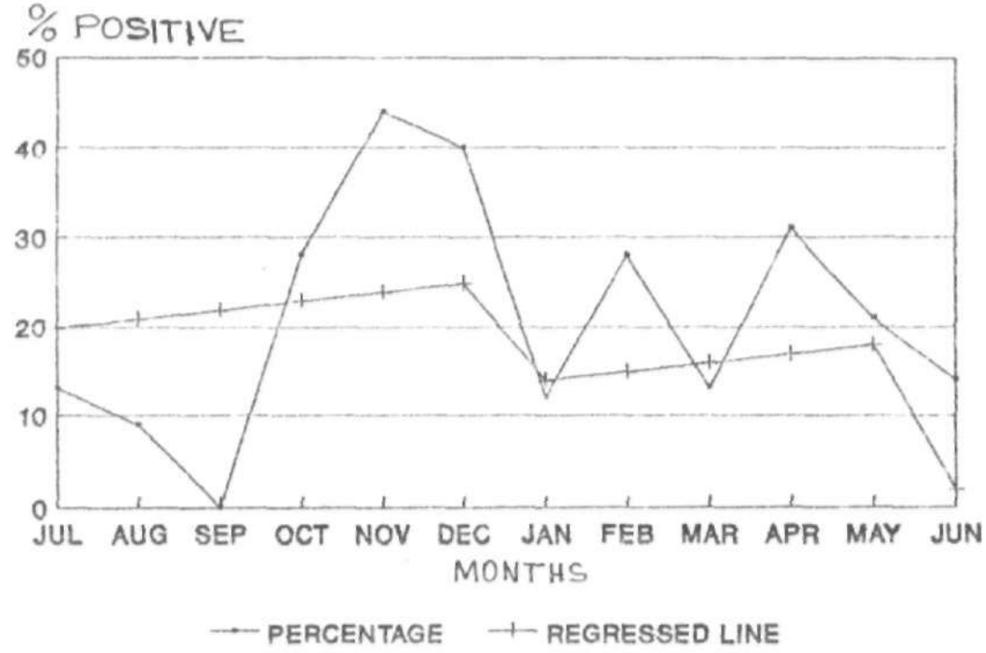


FIG 4.3 MONTHLY VARIATIONS IN TEMPERATURE

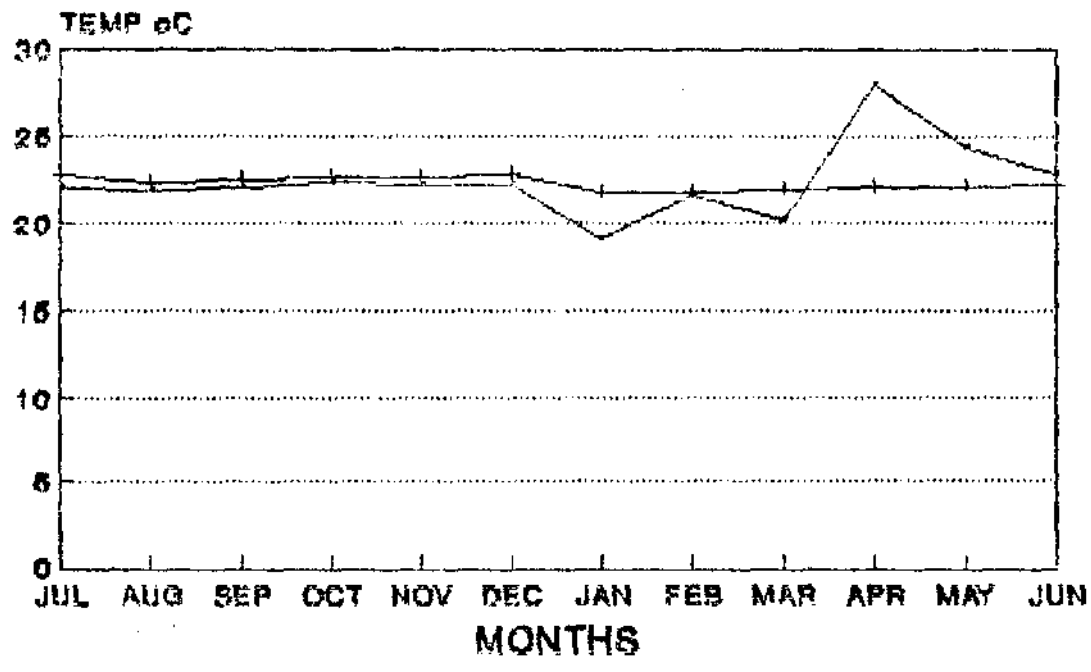
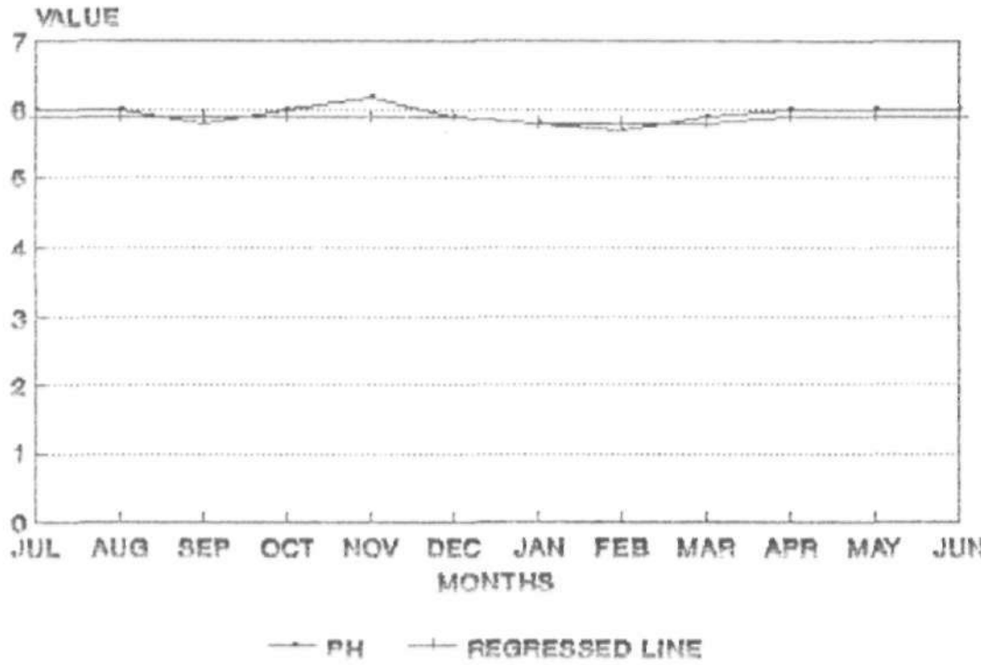


FIG 4.4 MONTHLY VARIATIONS IN PH



CHAPTER FIVE

DISCUSSION

Identified snail species from the study area are Bulinus forskali, B. globosus, Lymnaea natalensis Biomphalaria pfeifferi and Melanoides tuberculata. Their presence in the area signifies that ecological factors favourable for their survival were available in the sites sampled. Snails collected from the sites were mostly found attached to the vegetation of the waterbodies because vegetation provide surfaces for resting, egg deposition and protection (Pike, 1987; Ndifon and Ukoli, 1989). Not only that, species of vegetation like, Nymphea species, are extensively used by snails for egg deposition and resting in order to get oxygen from the plants photosynthetic process (Cowper, 1971, Ndifon and Ukoli, 1989). Algae seen are used as food as reported by Cowper (1971) and Brown (1980). Species of snails differ to tolerance to pollution, which B. globosus had the highest tolerance (Smith 1982). Pollution is also a factor in the distribution of fresh water snails. This is because the snails mantles varies in their vascularization (Ndifon and Ukoli, 1989).

Bulunus globosus was widespread throughout the study area because it has a wide range of tolerance to ecological factors. In each site sampled, B. globosus was in abundance which corresponds to the finding of Ndifon and Ukoli (1989). This also explains the reason why B. globosus had the highest positivity for cercariae shedding.

Mix infection was observed in snails collected during the study. Lymnaea natalensis was shedding gymnocephalous cercariae and furocercus cercariae. B. globosus shed gymnocephalous, furcocercous, and lipodermal cercariae. Biomphalaria preifferi was shedding gymnocephalous and furcocercous cercariae. Lipodermal cercariae are for Paramphis tomum species, gymnocephalous cercariae are for Fasciola species and furocercous cercariae are for Schistosoma species. Therefore since the snails collected were shedding those cercariae, means the diseases caused by these trematodes are present here in Zaria area because the snails found in Zaria were susceptible to miracidia infection of these diseases. Cercariae measurements shows the mean values of cercaroae as those of S. haematobium, S. mansoni and S. bovis which correspond to values given by Cowper (1971).

High number of positive snails for cercariae shedding was observed in November, 1990, December 1990 and April 1991. These are the months that activities of humans are closer to the waterbodies, and there is frequest contacts between animals, humans and the waterbodies. Other facts could be

due to clearing of farms for irrigation system of farming and preparing for rainy season farming which corresponds to the finding of Christensen et al., (1983) and Madsen (1986). This synchronizes to infection and transmission of trematode diseases of which snails are the intermediate hosts (Brown, 1980; Christensen et al., 1983) and obey the criteria in assessing vector effectiveness in transmission of water-borne diseases.

Since tolerance to ecological factors like vegetation cover, pollution, temperature, water current, flood, wave action, etc, play vital role for presence of snails in waterbodies in a habitat, and tolerance to these factors differs with snail species living in individual sites, (Ndifon and Ukoli, 1989; Okwuosa, perso. com.) could explain the reason why some months sampled records nothing. Activities of humans and animals alter the ecological factors of the waterbodies of the sites sampled, and could render the habitat unsuitable for snail survival (Boycott, 1936, Christensen et al., 1983). Irrigation system of farming practised at University dam, Samaru stream and Jos road river, create more channels, canals for snail establishment, however contribute to the fact that large number of freshwater snails were sampled, which agrees with the finding of Brown, (1980): Christensen et al (1983), Pike (1987) and Ndifon and Ukoli (1989): that irrigation canals and dam construction for sgricultural practices increase snail populations.

Temperature and pH values were fluctuating as months were changing. The range of average pH value observed during the study period (pH 5.5 to pH 6.5) and average temperature range (18.5°C to 28.5°C) fall within the ranges of pH and temperature suitable for snail survival (Cowper, 1971; Wilcocks and Manson, Bahr 1974; Soulsby, 1986).

Some waterbodies were encountered with pH below 4.0 and temperature below 18.0°C. Only dead snails were seen due to the fact that, the parasitaemia of miracidia infecting the snails was high and overcrowd the pseudobranch hence destroyed or damaged the pseudobranch which results to the death of snail (Kela, pers. comm.).

Temperature and pH varies in individual sites due to some certain reasons which include climatic conditions of the sites and activaties of the fauna and flora inside the waterbodies. The average temperature recorded i.e. the highest and lower value corresponds to the figures given by Mortimore (1970). The regression and correlation coefficients signify no significant statistical linear and correlated relationships of Temperature, number positive, months and pH. Each of the two factors studied (pH and Temp.) was not dependent on the other nor the two factors function as one (appendices I & II). This explains why the absence of snails for some months sampled in some sites can not be explained on the concept of one or two ecological factors but multiple factors which act independent of each other (Christensen et al. 1983).

Report by Odei (1961), Hira (1968) Soulsby (1986) suggest that, Bulinus forskali is an intermediate host of Schistosoma haematobium; Akuoala et al. (1968) doubts their postulations by saying "Can B forskali act as intermediate s haematobium?". In the present study carried out in the laboratory, B. forskali under laboratory conditions was not susceptible to S. haematobium miracidia infection. B. globosus miracidia infection. B. globosus a known snail host of S. haematobium was susceptible to the infection of S. haematobium miracidia, under laboratory conditions. The present work tends to agree with the report by Akuoala et al (1988);

SUMMARY AND CONCLUSION

Five species of freshwater snails were identified thus: B. globosus, B. forskali, Biomphalaria preifferi Lymnaea natalensis (Pulmonates) and one prosobranch Melanoides tuberculata, Distribution and abundance of these snails was different because they differ in tolerance to ecological factors like pH, temp., pollution, vegetation, shades, etc, which were not the same in all the waterbodies. pH and Temperature studied were fluctuating throughout the study period. The fluctuation was within the ranges of temp and pH described by Cowper,(1971) and Christensen et al, (1983). The absence of snails in some waterbodies cannot be explained on the grounds of one or two ecological factors but multiple factors. Bulinus forskali reared in the laboratory under laboratory conditions, was not susceptible to S. haematobium miracidia infection.

In conclusion, tolerance to ecological factors is the chief factor for snails distribution patterns in the study area, this is because snails differ in tolerance to ecological factors and hence B. globosus had highest tolerance degree to ecological factors and therefore widely distributed in number and infectivity, followed by Biomphalaria preifferi and Lymnaea natalensis.

CHAPTER SIX

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APPENDIX

Regression Coefficient and Correlation Coefficient

Results of Regression coefficient is shown in APPENDIX II.

APPENDIX IIa - IIe show the regressed y of all the variables compared with.

APPENDIX I

Correlation coefficient of the variable

(temperature and pH (X_2 and X_1)

METHOD	X_1	X_2	α	df(n-2)	CV	γ	1 t 1
1	pH	Temp.	0.05	10	2.228	0.36	1.299
2	pH	Temp.	0.05	10	0.676	0.36	-

Hypothesis:

Ho = 1 t 1 = 0 no slope

H_A = There is a linear relationship between the two variables.

Condition:

(1) Reject Ho if our 1t1 $\geq t\alpha$, n-2.

(2) Reject Ho if our r $\geq \gamma\alpha$, n-2.

$$r = \frac{x_1 \; x_2}{\sqrt{[(Ex_1^{\,2})\,(Ex_2^{\,2})]}}$$ where X_1 and X_2 are the two variables considered.

From the table $1t1 = \frac{r\sqrt{n-2}}{\sqrt{1-2^2}}$ substituted from,

$$1t1 = \frac{r}{Sr} \quad \text{where } Sr = \frac{\sqrt{1-r^2}}{\sqrt{n-2}}$$

From Appendix I, since 1t1 & r $\angle$ CV, therefore we accept Ho and reject H_A.

APPENDIX II This table shows the value of regression coefficient of the variables (see X and Y) considered during the study

X	y	b	α	df	CV	SB	Sy.x	t	95% CI OF POPULATION SLOPE	STANDARD ERROR OF ESTIMATE Se
Months	No. +ve	1.00	0.05	10	2.228	0.98	13.12273	1.122	$-1.18344 \leq B \leq 3.18344$	12.201970
Months	Temp.	0.10	0.05	10	2.228	0.31	2.29350	0.323	$-0.59068 \leq B \leq 0.79068$	2.298712
Months	pH	0.01	0.05	10	2.228	0.01	0.13848	1.000	$-0.01228 \leq B \leq 0.03228$	0.138480
Temp.	No. +ve	1.90	0.05	10	2.228	1.80	13.18252	1.056	$-2.11040 \leq B \leq 5.91040$	13.182522
pH	No. +ve	35.50	0.05	10	2.228	28.20	12.90977	1.259	$-27.32960 \leq B \leq 98.32960$	12.909773

H_o = There is no significant linea relationship between the two or sample slope is zero.

H_A = There is significant linear relationship between the two values.

Conditions: Reject H_o when $|t| \geq t_{\alpha, n-2}$.

$t = \frac{b}{Sb}$ Sb = sample standard deviation of regression co-efficient.

$Sb = \frac{Sy.x}{\sqrt{Sx^2}}$ Sy.x = Sample standard devoatompm frp, regression.

$SE = \sqrt{\frac{\Sigma(y-\hat{y})^2}{n-2}}$ The larger the Se (Standard Error of Estimate, the greater the scattering of points around the regression line.

If the Se = 0, the estimating equation is a perfect estimator of independent variable i.e. all the data should lie on the regression line.

APPENDIX IIa

X	y	$\hat{y}$
7	13	19.9
8	9	20.9
9	0	21.9
10	28	22.9
11	44	23.9
12	40	24.9
1	12	13.9
2	28	14.9
3	13	15.9
4	31	16.9
5	21	17.9
6	14	18.9

X = Months (July to June 1991)

y = Number of snails positive for cercariae shedding.

$\hat{y}$ = Regressed y.

APPENDIX IIb

X	y	$\hat{y}$
7	22.2	22.38
8	22.0	22.48
9	22.2	22.58
10	22.4	22.68
11	22.3	22.78
12	22.3	22.88
1	19.0	21.78
2	21.6	21.88
3	20.2	21.98
4	28.0	22.08
5	24.5	22.18
6	22.9	22.28

x = Months (July 1990 to June 1991)

y = Temperature.

$\hat{y}$ = Regressed y.

Appendix IIc

X	y	$\hat{y}$
7	6.0	5.888
8	6.0	5.898
9	5.8	5.908
10	6.0	5.918
11	6.2	5.928
12	5.9	5.938
1	5.8	5.828
2	5.7	5.838
3	5.9	5.848
4	6.0	5.858
5	6.0	5.868
6	6.0	5.878

X = Months (July 1990 to June 1991)

y = pH at each month

$\hat{y}$ = regressed y.

Appendix IId

X	y	$\hat{y}$
22.2	13	20.53
22.0	9	20.15
22.2	0	20.53
22.4	28	20.91
22.3	44	20.72
22.3	40	20.72
19.0	12	14.45
21.6	28	19.39
20.2	13	16.73
28.0	31	31.55
24.5	21	24.90
22.9	14	21.86

X = Temperature at each month

y = Number of snails positive for cercariae shdding at each month

$\hat{y}$ = regressed y.